Question Box Revision

FROM 1902 TO 1909

National Electric Light Association

New York
1911

Preface.

If there are any—and there probably will be many,—who detect shortcomings in this book and are inclined to criticise, we ask them to read this Preface.

The idea of getting out the book originated some years ago with one of the editors of the Question Box, who felt that much valuable information was being lost to ready use by being scattered through many volumes. He knew, further, that there was no electrical handbook designed to meet the needs of operators, although there were several covering the engineering side. It seemed to him that both deficiencies might be supplied at the same time by gathering the information scattered throughout the Question Box into one volume as the nucleus of a Central Station Operator's Handbook. It was with this end in view that the present work was undertaken.

The field was divided into twenty-five subjects and assigned to twenty-six associate editors, each one an authority on his subject, and they were asked to compile and condense the information to be found in past issues of the Question Box under their respective assignments.

The work has been done by them gratis and in addition to their regular work. If, therefore, it has taken time to gather together material from the twenty-six men, it is simply evidence of the fact that the electrical industry is growing and thriving and that the men connected with it are busy to the limit of their time and capacity.

As the first step, each associate editor was asked to draw up a comprehensive skeleton form or set of headings for his subject, and later, to fill in under these headings as much as he could with the material available in the past issues of the Question Box.

It was soon apparent that many of the subjects were very scantily covered and that to make a comprehensive work much more information and material would have to be supplied.

No attempt to fill in these omissions has been made in the present issue. It is simply a revision and compilation of existing material, and the extent to which it is incomplete is the measure of what remains to be done to round out the complete handbook which the editors have always had in mind as the final goal. They themselves never expected to reach it in this issue, but have only hoped that the publication of this work would form the starting-point for a more comprehensive volume. These facts should be borne in mind in justice to the associate editors, who have acted merely as compilers and have not been requested or allowed to insert original matter, and who realize the lack of completeness better than anyone else. They should not be held responsible for any defects or shortcomings.

The material herein includes the Question Box up to July, 1909, only, and therefore is not quite up to date. This is greatly to be regretted, because during the last two years the Question Box has contained a large amount of most excellent material that would have proved valuable. Nevertheless, it was necessary to make a stopping point somewhere and July, 1909, was fixed upon when the preliminary work of compilation began in the fall of that year.

The industry, and the National Electric Light Association representing it, have been growing at such a pace that there has been a duplication of publications, and this volume is quite open to the charge of covering in part ground already covered by other of the Association's handbooks or committee reports. What the editors hope, however, is that a consolidation can be effected and that all of the Association's information of this general character can be gotten out uniform in style, either in one volume or a series of volumes.

The thanks of the editors and of the Association are due to the associate editors who have so willingly and capably compiled the material found herein.

THE EDITORS.

Editors.

SECTION I.

Buildings.

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Buildings.

GENERAL LAYOUT.

Typical Layout.—A good design for a generating station in a town of 6,500 people in an eastern coal mining state, is as follows:

The station building to consist of operating-room and boiler-room side by side, with fireproof division wall between.

Engine-Room.—Two 200-kw. horizontal engine-driven units with two-phase, 60-cycle, 2,300-volt generators; one 200-kw. horizontal engine-driven unit, 550-volt direct-current generator.

Additional space for two 200-kw. alternating-current units; one 200-kw. direct-current unit.

Boiler-Room.—Four B & W water-tube boilers, 125-hp. each, set in batteries of two. Additional space for four more of same type. Arrangement as shown in diagram. This arrangement permits a growth of 100 per cent., and if the limit of the building is reached in three or four years the plant can easily be duplicated at either end.

The stack is shown at the center of the completed boiler-room, the flues from the boilers entering it from both sides, and the feed-pumps to be located in the stack bay. The main steam header should be supported by brackets on the division wall on the boiler-room side, with leads either overhead or in trenches to the engines.

The condensers are set in pits between the engines and the division wall, with suction and discharge pipes below leading to the river. Jet condensers could best be used with combination circulating and air-pumps; such units being very well adapted for small plants.

The entrance and superintendent's or chief's office are located on the street side of the operating-room, as shown, and along the same side are the alternating-current and direct-current switchboards.

The coal would be stored in bunkers along the outside wall of the boiler-room, into which it could be run either by cars or trucks, flowing from the bunkers into the side of the firing aisle through suitable chutes. The ashes could be handled either by being washed away by hydraulic conveyor below the ash-hoppers, if a convenient place of deposit is available, or by hand with a small track and car along the firing aisle and thence to carts. (Geo. L. Knight, Brooklyn Edison Co., 1908.)

MATERIALS.

All-Concrete Work.—An all-concrete construction for power house buildings should be acceptable if the necessary material is available and cheap. It is largely a question of the expense of this construction as compared with other fireproof methods. (The Colorado Springs Elec. Co., 1906.)

Reinforced Concrete Construction.—A concrete construction with suitable steel reinforcements should make a stronger building. (H. A. Strauss, Allis-Chalmers Co., 1906; I. O. Westchester Lighting Co., 1906.)

Brick Construction.—In many localities, however, especially for small low buildings, 9-in. brick walls with pilasters will probably be cheaper. An all concrete building is apt to be homely unless some special treatment is given the exterior. (Fred W. C. Bailey, 1906.)

Concrete Block Construction.—A moderate sized power plant, one story high, constructed wholly of concrete blocks making a 10-in. wall has proved satisfactory, easily heated and not unduly damp. (Wm. B. Jackson, 1906.)

Concrete Substations.—Concrete may be considered a practical material for substation construction. It makes a very substantial building. (F. C. Sargent, Malden Elec. Co., 1907; Walter Flint, The Jacob Tome Institute, 1907.)

The advisability of its use depends upon the conditions and the design of the station. (H. B. Gunnison, Peninsular Elec. Lt. Co., 1907.)

One objection to this use is the large size of columns and beams necessary, requiring additional room and making wiring layout more difficult. (J. T. Whittlesey, Public Service Corporation of New Jersey, 1907.)

Large Concrete Buildings.—Concrete construction for buildings of considerable size, especially if they are of considerable height, will probably cost more than brick so far as the walls are concerned, if the walls are built by the use of moulds. Concrete floors are generally cheaper than fire-proof steel-supported floors. If in a locality subjected to earthquakes, it is advisable to reinforce the concrete with steel.

Another type of construction which gives a pleasing appearance is to build a steel reinforced concrete frame, filled in with brick curtain-walls. Concrete, however, should be cheaper than brick construction for warehouses and shops where the wall height is comparatively low. (J. T. Whittlesey, Public Service Corporation of New Jersey, 1907; G. L. Bennett, 1907.)

Concrete Work in Freezing Weather.—Concrete construction in freezing weather is something of a gamble, even with the best of care and material. Cold affects concrete made with Portland cement much less seriously than that made with natural-cement. If fresh concrete is frozen and stays in that condition for weeks, there will probably be no injury if it has plenty of time after thawing to harden before it is again subjected to cold. Alternate freezing and thawing daily will produce poor concrete cracked on the outside and with no cohesion within. Even in this state it will do for great masses, employed to obtain weight such as a backing for stone-masonry, but it will not do where the construction requires uniform strength throughout. To prevent damage from frost it is necessary to keep fresh work warm. When it is in large masses it may be roofed over and warmed with steam pipes. For building construction close all window openings with curtains; cover floors as soon as prepared, with planks, panels raised 6 in. above top of floor. Heat with salamanders. Steam is used to heat sand and stone and also to heat and moisten the air in the enclosed space. Use quick-setting cement, warm sand and stone and sometimes salted water. (*Engineering Record,* December 22, 1906.—Ed.)

In Wisconsin a concrete flume was partly built in zero weather. The sand and gravel were heated and hot water was used. The walls were carefully protected by a foot of manure. The part put in during cold weather is as good as that put in earlier in the season. The flume is now more than three years old. (P. H. Korst, Janesville Elec. Co., 1907.)

Sometimes concrete is mixed with salt water for winter use, the ingredients being heated before mixing. Concrete must be handled quickly and kept covered with salt hay or horse manure if the surface is to be exposed for any length of time. By these methods, good concrete work can be done in cold weather. (Geo. Ross Green, The Philadelphia Elec. Co., 1907.)

Where the situation will permit and extreme cold weather is expected, the site of the work can be enclosed with a cheap temporary light board structure, the temperature inside the structure being kept above the freezing point by means of fire, steam, etc. If the temperature is liable to fall below the freezing-point before concrete has set, some protection must be provided. (G. L. Bennett, 1907; Walter Flint, The Jacob Tome Institute, 1907.)

FOUNDATIONS.

Amount of Water to be Used in Concrete.—The proper amount of water to be used in mixing concrete is something for which no definite rule can be given; it varies considerably with the conditions. Concrete with too much water is a safer mixture to use than concrete with too little, as it is not certain the latter will set. Concrete has been put in large foundations so wet as to shake like jelly, yet when set it was as hard as stone, and of the best quality. A large amount of water in concrete increases the difficulty of tamping. The concrete reaches its ultimate strength after about one year if mixed wet, but this ultimate strength is somewhat greater than would be attained by a dry mixture. A dry mixture reaches its maximum strength earlier. Less water should be used in cold weather than in hot weather. If the water has a chance to freeze before the initial set has taken place, the concrete is absolutely worthless. (I. O. Westchester Lighting Co.; Geo. B. Springer, Chicago Edison Co., 1906.)

Tamping.—A great deal of stress is often laid on the amount of water in concrete and not enough on the tamping. As a matter of fact, it is the tamping that gives the strength provided the cement is good and the proportions right. Concrete well tamped is about one-third to one-half stronger than concrete with little or no tamping. These remarks are true only for concrete properly mixed and made of reliable material. (I. O. Westchester Lighting Co.; Geo. B. Springer, Chicago Edison Co., 1906.)

So far as has been discovered excess water has no bad effect on the cement, but it may make the concrete porous, and thereby seriously affect its strength. (Wm. B. Jackson; Chas. W. Comstock, Denver, Colo., 1906.)

Time Required to Reach Normal Strength.—A concrete structure should never be loaded to its estimated practical limit (350 to 500 pounds per square inch with good, rich concrete) before it is seven days old. (I. O. Westchester Lighting Co.; Geo. B. Springer, Chicago Edison Co., 1906.)

Cinder Concrete.—Cinder concrete in foundation work, where much dead weight is to be expected is not advisable. Cinders and clinkers make a light porous concrete suitable for self-supporting floors and other places, where there is no liability to absorption of moisture and where dead weight is undesirable. (Chas. W. Comstock, 1906.)

In using cinders or clinkers in concrete care must be taken to use only those which are solid and not easily broken, otherwise, the concrete will be weak. (F. Tobey, Jr., Kingston Gas & Elec. Co., 1906.)

The amount of sulphur in the clinker is something that must be carefully considered before clinkers or cinders are used. For that reason, cinder concrete is not to be recommended where it will come in contact with iron or steel. The following table gives the comparative strength and weight of cinder, gravel and stone concrete:

WEIGHT.

Cinder concrete	105 lb. per cu. ft.
Stone concrete	140 lb. per cu. ft.
Gravel concrete	150 lb. per cu. ft.

STRENGTH (ULTIMATE).

Cinder Concrete	1,600 lb. per sq. in.
Stone concrete	2,750 lb. per sq. in.

(I. O. Westchester Lighting Co., 1906.)

Concrete Piles.—Concrete piles have been used quite extensively in recent years. They are constructed both with and without steel reinforcement. They have comparatively greater carrying capacity, possibly more durability than wooden piles, and they may be used above the water level whereas wooden piles must be cut off at such a point that they will always be in water or wet ground. Thus where the water level is considerably below the basement floor, quite a saving can be made in the excavation and foundations by the use of concrete piles. The relative cost of wooden and concrete piles depends largely upon the locality where they are to be used. (S. C. Foster, Supt. Rappahannock Elec. Light and Power Co.; J. T. Whittlesey, Public Service Corporation of New Jersey, 1907.)

Further information on this subject may be obtained from Volume 27, April 10, 1907, of Engineering and Contracting; also in the Feb. 13th issue of same paper. (H. B. Gunnison, Peninsular Elec. Lt. Co., 1907.)

Imperviousness of Concrete.—The imperviousness of concrete to the passage of water depends not so much upon the ingredients as it does upon the thoroughness and care with which the concrete is mixed, placed and tamped. A very good paper, entitled, "Experiments on Steel-Concrete Pipes on a Working Scale," by John H. Quinton, treats this subject in detail. This article appears in Bulletin No. 143 of the Geological Survey, entitled "Water Supply and Irrigation," which may be obtained by applying to the Director of the United States Geological Survey, Washington, D. C. (F. J. Howes, 1910.)

FLOORS.

Fireproof Floors.—All generating stations and sub-stations should be constructed with fireproof floors, built of brick arches, terra cotta arches or reinforced concrete arches, carried by either reinforced concrete girders or steel beams. If the latter are used they should be fireproof as well as the columns supporting them.

Floor Finish.—The floor finish may be granolithic, tile or the terrazzo surface commonly used in corridors and halls of office buildings. If the granolithic finish is employed it should be colored or tinted by the use of lampblack or coloring matter mixed into the cement giving a more pleasing appearance and a surface that will not stain so readily from oil. If a tile floor is desired the smaller sized tile should be used. They stay in place better and lay up to a truer surface. (W. F. Sims, Chicago Edison Co.; W. W. Titzell, Public Service Corporation of New Jersey; United Elec. Light Co.; W. E. Moore, Lewiston-Clarkston Co.; H. N. Crandall, Baker Gas & Elec. Co.; I. E. Moultrop, Edison Elec. Ill. Co. of Boston; Augusta Railway & Elec. Co.; E. F. McCabe, Lewistown Electric Light Co., 1905.)

Opening in Floors.—The proper treatment of floor construction to permit the use of overhead traveling cranes on apparatus in the basement depends largely on the design of the station and the arrangement of the apparatus. Where possible it is better to leave permanent openings in the floor as they provide light and ventilation to the basement and enable the watch engineer to observe conveniently the operation of the machinery in the basement without going down stairs. (I. E. Moultrop, Edison Elec. Ill. Co. of Boston; W. W. Titzell, Supt. United Elec. Co. of New Jersey, 1906.)

Small panels of reinforced concrete with steel edges or grooved iron sections of floor with lead surface insertions may be employed where permanent openings are objectionable. The latter is considered preferable. (Fred W. C. Bailey, 1906.)

A cheaper construction is obtained by flag stones laid in channel iron supports. (H. A. Strauss, Allis-Chalmers Co., 1906.)

Floor Insulation.—It is unsafe to handle electrical apparatus of any dangerous voltage when standing upon plain concrete floor, for although when the concrete is dry it may be an excellent insulator, yet when wet this is not the case. People have been seriously burned by coming in contact with 500 volts and standing upon a damp concrete floor. (Wm. B. Jackson, 1906.)

Proper insulation, such as a hardwood platform, rubber or cork mattings, et cetera, should be provided for the protection of those handling 2,300-volt apparatus installed on cement floors. For very high voltages the mat should be supported on light frames of wood. (W. W. Fuller, C. C. Railway Gas & Elec. Co., 1906.)

Dust from Cement.—Cement floors are objectionable because they give off considerable dust, show oil stains and are not apt to be waterproof. They are also liable to become rough when subjected to much wear. A paint manufactured by Toch Bros. of Long Island City has proved efficacious in eliminating these objections. It consists first, of an application of a resinous liquid which seems to permeate the cement. A second coat of similar material is then applied containing a pigment which gives a pleasing finish. This makes the floor practically oil and waterproof as long as the paint lasts. (William Esty, Lehigh University; Geo. W. Stone, The Development and Funding Co., 1907.)

A treatment of paraffin applied to the surface will reduce the amount of dust from the floor. (Wm. M. Lewis, 1907.)

Another treatment consists of applying a couple of coats of sizing (a cheap grade of varnish), and then two coats of lead and oil paint of a desired color. (H. B. Gunnison, Peninsular Elec. Lt. Co., 1907.)

ROOFS.

Shingle Roof.—A good pine shingle roof should give a life ranging from fifteen to twenty-eight years. A twenty-four inch shingle will last longer than an eighteen inch size. Old fashioned galvanized iron cut nails are preferable to wire nails and copper nails are still better. The quality of pine shingles has deteriorated in the last few years and Washington red cedar shingles are replacing them with good results. (Wm. R. Gardener; H. A. C., New York Edison Co., 1904.)

Flashing.—The valley between two pitched roofs should be lined with metal if a durable tight job is desired. Sheet copper with long laps and no solder is recommended by the Augusta Ry. & Elec. Co., (Augusta, Ga., 1904) or similar construction soldered at the joints in the usual way may also be used. (Wm. R. Gardener, 1904.)

A cheaper and less permanent construction is to use tin painted on both sides extending well under the shingles. (H. A. C., New York Edison Co., 1904.)

Fireproof Roofs.—For a fireproof building some form of a concrete or tile roof should be used with suitable waterproof covering on top.

Spans of reinforced concrete can be satisfactorily made up to ten or twelve feet. (J. T. Whittlesey, Public Service Corporation of New Jersey; Walter Flint, The Jacob Tome Institute; H. B. Gunnison, Peninsular Elec. Lt. Co., 1907.)

Furthermore, roofs for fireproof buildings should be flat especially if the building is of any considerable size. A good construction consists of book tile carried on light steel trusses without intermediate supports. The top of the book tile should be covered with a thin layer of concrete to give a smooth surface and true pitch. Waterproofing is obtained by five thicknesses of tarred paper, mopped on with hot tar and finished on top with building gravel spread over hot tar. The under side of the book tile should be plastered if a smooth appearance is desired. If it is essential to eliminate all condensation the plastering should be applied to expanded metal, suspended a few inches below the book tile. If monitors or skylights are required for light or ventilation, condensation will collect on them, and this can be collected by gutters arranged to discharge back onto the roof. (I. E. Moultrop, Edison Elec. Ill. Co. of Boston; W. F. Sims, Chicago Edison Co.; F. L. Williamson & Co., 1905.)

Provided suitable pitch is given to the roof, slate roofing may be used in place of tarred paper and gravel. This is more durable and likewise more expensive. (W. B. Rolland, Supt., Cape May Light & Power Co., 1905.)

A cheaper construction is obtained by using reworked corrugated iron for roofing with a layer of heavy roofing paper supported by galvanized iron netting, two inch mesh, suspended a couple of inches below the corrugated iron. (W. E. Moore, Lewiston-Clarkston Co., 1905.)

Another cheaper construction consists of two thicknesses of corrugated galvanized iron supported by light steel trusses. (Wm. M. Lewis, 1907.)

Asbestos lumber shield may also be used for roofing material. (Augusta Ry. & Elec. Co., 1905.)

Slow-Burning Roof.—A slow-burning roof of considerable cheaper first cost is a so-called mill construction, consisting of 3-in. southern pine plank, supported by 3 in x 12 in. southern pine purlins, and covered on the outside by slag roofing which consists of 5-ply felt treated with all the pitch it will hold. (E. F. McCabe, Lewiston Elec. Light Co., 1905.)

Rusting of Tin Roofs.—A tin roof may rust or pit under or near a hot water storage tank while the rest of the roof remains in good condition, because of the sweating due to want of air circulation. (Chas. N. Shaw, Newburgh Light, Heat & Power Co.; C. E. Bowe, The Elec. Co., 1905.)

Its action may be intensified by the water absorbing sulphuric acid from the atmosphere forming a dilute sulphuric acid. (W. W. Titzell, Public Service Corporation of New Jersey; Augusta Ry. & Elec. Co., 1905.)

Dividing Line Between All-Concrete and Steel Truss Roofs.—The width of span where a short span all-concrete roof exceeds in cost long span steel truss roof, is problematical and depends on type of construction, general detail of design, etc. This might come anywhere between 25-ft. and 60-ft. spans. (Chas. W. Comstock; Fred W. C. Bailey, 1906.)

Slate Roofs.—Slate roofs with copper valleys and gutters should be so constructed that each valley has sufficient slope. One over-lapping free joint should be provided between every two anchorages, all, of course, should be properly spaced. A loose drip trough should be provided with swing supports at all points except at the down spout where the trough should be anchored. Gutters built onto the roof must be thoroughly soldered. (I. Lundegaard, Rochester Railway & Light Co., 1909.)

If trouble is experienced with the joints in sheet copper, it would seem to indicate poor soldering. This may be overcome by fastening with tinned copper rivets, then soldering with pure tin and a flux made up of a saturated solution of zinc chloride more than neutralized by sal ammoniac. The solution should turn red litmus paper blue. (H. F. Frasse, Edison Elec. Illg. Co., Brooklyn, 1909.)

CHIMNEYS.

Steel Stacks.—Steel stacks unlined have a life which depends on the care given them and temperature of escaping gases. (W. B. Bloxham, Georgia Ry. & Lt. Co., 1903.)

A stack built of 3/16-in. iron at the base and ⅛-in. iron at the top, erected in central Pennsylvania failed in 8 years by rusting through in one of the top sections. Two similar stacks having ¼-in. stock at the top showed a reduction of ⅛ in. in 6 years. (Jas. E. Pile, Edison Electric Illuminating Co., West Chester, Pa., 1903.)

The use of steel stacks where exposed to salt atmosphere is not recommended as they are liable to fail suddenly, even where close examination shows no evidence of weakness. (Alex. J. Campbell, Norwich Gas & Elec. Co., 1903.)

Protective Paints.—Central Station men do not agree as to the best paint for steel stacks and breechings nor as to the methods of application. The following paints have been tried and are recommended: Graphite paint. (W. B. Bloxham, Georgia Ry. & Lt. Co., 1903.) Oil tar, the by-product of water gas manufacture. (Peoria Gas & Electric Co., 1903.) The Woodbury hot iron paint. (Edison Electric Ill. Co., Boston, 1903.) A paint consisting of asphaltum, tar and graphite manufactured by Robert Watt, of Denver, Colo. (W. T. Baker, Denver Gas & Elec. Co., 1903.) A paint consisting of four parts fine graphite, four parts powdered charcoal, two parts oxide iron mixed with boiled linseed oil. (N. H. Ledford, Proprietor, Bowling Green Elec. Plant, 1903.)

Method of Applying Paint.—It would seem, however, that with steel stacks removed from the influence of salt atmosphere, there is very little choice between any of the leading graphite coal-tar paints, or similar paints, provided they are properly applied. Rust spots should be removed and joints thoroughly cemented and caulked before painting. The paint should be well rubbed in and care taken to obtain a uniform body throughout the entire surface. The stack should neither be cold nor very hot when painted. Many of the paints which give good results in the interior will prove unsatisfactory on stacks adjacent to the sea-coast. Raney's enamel iron paint has given good satisfaction, but along the sea-coast the stacks must be painted very frequently. (L. W. Byers, Supt., Atlantic City Elec. Lt. & Power Co., 1903.)

Reinforced Concrete Chimneys.—A reinforced concrete chimney may have its strength seriously impaired by horizontal cracks, if they are deep enough to admit moisture or corrosive gases to the reinforcement. The steel will rust, and the absorption of the rust by the concrete will accelerate rather than retard oxidation. This action is liable to so weaken the longitudinal reinforcement that a high wind will break it. However, if a chimney is well designed it will probably take a good many years to reduce the section of the steel to the danger limit. (F. J. Howes, 1909.)

WATER CONDUITS OR TUNNELS.

Life of Steel in Salt Water.—Structural iron exposed to salt water would have a length of life which is hard to fix with any certainty. A 10-in. iron beam exposed on one side to salt water might last 20 to 25 years if the water was clean. Contaminated salt water would materially shorten the length of life. (Clemens Herschel, 1907.)

Concrete Tunnel.—A concrete tunnel with 12-in. walls, roof 12 inches thick with a 5-foot span, reinforced with expanded metal 2 inches from bottom of roofing and the entire structure designed to stand 4,000 lb. pressure to the sq. ft., should be built with a mixture of 1 part cement, 2 parts sand and 4 parts 1-in. broken stone. (Geo. Ross Green, The Philadelphia Elec. Co., 1907.)

Gate in Tunnel.—When a gate has to be installed in a conduit or tunnel, conveying salt water, all metal used in the construction should be of bronze. (Clemens Herschel, 1907.)

Keeping Tunnel Dry During Construction.—In building a concrete tunnel through a water-bearing stratum of sand, freezing the ground is a method which will keep the tunnel fairly dry during construction. (L. H. Conklin, West Pennsylvania Elec. Co., 1908.)

Maintain Tunnel Dry.—With an 80-ft. head of water a most practical way to maintain the tunnel dry, is to waterproof it on the outside. It is doubtful if any compound could be applied to the interior that would be satisfactory or remain permanent for any length of time. (I. E. Moultrop, Edison Elec. Ill. Co. of Boston, 1908.)

MACHINERY FOUNDATIONS.

Materials.—The materials best adapted for dynamo, engine and turbine foundations are brick and concrete. The considerations governing the choice of either are principally the cost of materials and labor, and sometimes the appearance of the finished work. If the foundation is to be large, and is at all unsymmetrical or cut up, concrete should be adopted without question. If solid piers can be used, brickwork is easily constructed and usually cheaper. If the foundation is exposed above the engine-room floor-level, brick is usually adopted, and in any case it would be used for the outside course of exposed surfaces, and would preferably be enameled brick.

Concrete Work.—The appearance of concrete work can be very greatly improved, and the cost of forms considerably lessened by using rough instead of planed lumber and tacking thin, black sheet-iron (about 24-gauge) over the entire inside surface of the form. A coat of liquid grout applied with a whitewash brush over the exposed surfaces of the foundation, after the forms are removed, gives the job a very smooth and neat appearance. In large horizontal turbines, where the only foundations are comparatively small piers, and where the height of the pier is great, we have used concrete with 0.75-inch twisted-steel reinforcing rods placed vertically 6 in. from surface of pier, the rods extending into the concrete sub-foundation 18 in. On the generator piers where the shape used was a hollow rectangle, the rods were placed on 3-in. centers in rows 6 in. from both inside and outside surfaces. (G. L. Knight, The Brooklyn Edison Co., 1906.)

CONVEYORS FOR COAL AND ASHES.

A station of about 1,200 hp. may make use of hoppers and an industrial railway as a simple and cheap arrangement for taking ashes from under the boilers to cars or carts for removal from station. (W. S. Barstow, 1903.) But it is doubtful if a station of this size could afford to use anything but carts or barrows. (The Edison Electric Illuminating Co. of Boston, 1903.)

WINDOWS.

Metal window frames and wired glass should be used where a fireproof building is required and especially in cases where a fire hazard from adjacent buildings is great. (N. A. Rollins, Chicago Edison Co.; F. C. Sargent, Malden Elec. Co.; H. B. Gunnison, Peninsular Elec. Lt. Co.; J. T. Whittlesey, Public Service Corporation of New Jersey, 1907.)

All sky-lights in power houses should be made of wired glass. In case of breakage the glass will then not fall to the floor below. (Geo. Ross Green, The Philadelphia Elec. Co., 1907.)

VENTILATION.

Choice of System.—A pressure system is usually preferable to a vacuum system for forced ventilation of buildings, but this depends on the building and its uses. The vacuum system usually causes draughts at points where air may leak in. In the pressure system with an outward leakage, large quantities of air may be moved without causing draughts, provided the system is properly constructed, and care exercised in locating the inlets and outlets. The pressure system necessitates the use of heating coils for warming the incoming air. (B. J. Denman, 1909.)

The best method of forced ventilation of buildings depends on the conditions of that particular installation, such as the relation between the amount of heat and ventilation required, the use the building is put to, whether there is an unusual amount of moisture or obnoxious gases in any portion of the building, etc. An exhaust system may prove unsuccessful on account of the difficulty of controlling admission of cold air to the various rooms, the condensation of moisture in the cold air and the presence of draughts in the vicinity of windows. (S. P. Cobb, 1909.)

Combined Pressure and Exhaust System.—Better results are obtained by a combined pressure and exhaust system, so run that the intake fan supplies about a third more air than that removed by the exhaust fan. This prevents draughts from loose fitting windows and exterior doors. (N. A. Rollins, 1909.)

CRANES.

Substations.—The installation of hand-power cranes for substations containing rotary converters or motor-generators must be determined by a study of the local conditions. Under conditions most frequently met, it is doubtful if they will be used enough to warrant the expense, especially since rotaries and motor-generators are now being built so that most of the repairs can be readily and cheaply made with the machine in place. (H. Bottomley, Fall River Elec. Light Co.; The Edison Illuminating Co. of Detroit; I. E. Moultrop, Edison Elec. Illg. Co. of Boston, 1905.)

Crane for Erection of New Apparatus.—If the situation is such that much apparatus has to be shifted or new apparatus moved past existing installations, a traveling crane may be warranted. (A. S. Kibbe, American Railways Co., 1905.)

New apparatus especially of the larger sizes can be erected more cheaply with the use of a traveling crane, and this, together with a possible saving of time, when emergencies occur may justify the extra expense. A portion of this extra cost may be considered an investment for insurance purposes. (H. T. Hartman, Electric Company of America, 1905.)

COSTS.

Brick Buildings.—A brick central-station building with no basement, and with walls 18 ft. high from floor to bottom of roof trusses, can be built for from $1.50 to $2.00 per sq. ft. This includes granolithic floor, iron-truss roof framing, and slate roof with Monitor ventilators. (H. T. Hartman, Electric Co. of America, 1906.)

(1) A power station designed for crane, and 1,600 kw. in generators, 1,000 kw. in rotaries, 1,600 hp. in boilers, slate and steel roof, no basement, concrete footings up to water table, concrete floors, steel roof trusses, no steel columns, brick walls, total floor area, 8,118 sq. ft., cubical contents, 260,460 cu. ft., cost of building per cu. ft., $0.063.

(2) A power station designed for crane and 1,500 kw. in generators, 400 kw. in rotaries, 800 hp. in boilers, steel and timber roof, concrete basement floor, concrete footings up to water table, concrete floors, steel columns and trusses, brick walls, total floor area, 15,180 sq. ft., cubical contents, 355,740 cu. ft., cost of building per cu. ft., $0.05.

(3) A power station designed for crane and 1,200 kw. in generators, 900 kw. in rotaries, 1,200 hp. in boilers, brick walls, concrete footings up to water table, concrete and steel roof, concrete floors, steel columns and trusses, total floor area, 16,544 sq. ft., cubical contents, 431,826 cu. ft., cost of building per cu. ft., $0.061.

NOTE.—Estimates of building costs based on cubical contents have very little value, as variations in contents are frequently very great without materially affecting cost, principally due to differences in roof construction. A better rule for making a rough determination of current building costs is the following: 50 cents per sq. ft. of floor area; 50 cents per sq. ft. of roof area; 60 cents per sq. ft. of wall area. Figuring on one side of party wall but including basement wall. This will cover a first-class building having, selected ordinary brick walls, concrete footings, roof and floors, steel columns and steel trusses and designed to support crane. (H. A. Strass, Allis-Chalmers Co., 1906.)

DEPRECIATION.

Substations.—A fireproof building devoted exclusively to rotary converters and storage batteries, if constructed so it could be used for nothing else, should have a depreciation of about 4 per cent.; if the building is of a commercial type, the depreciation should be 3 per cent. (B. G. Jamieson, 1909.)

However, such a building built for that specific purpose would undoubtedly, through the natural evolution of the art, become obsolete long before the building would show much depreciation. An amortization charge of 10 per cent. to cover this would be good accounting. (T. H. Yawger, 1909.)

MISCELLANEOUS.

Fireproof Substations for Mines and Smelters.—It pays to build stone or some other standard form of fire-proof construction for substation buildings for mines and smelters, as the fire risk is practically eliminated; but the installation must be of sufficient importance to warrant the increased first cost, and also, the requirements for a station in the given locality must be of sufficient duration to justify the increased expenditure. (C. W. Koiner, Pres., Madison County Gas & Elec. Co.; The Colorado Springs Elec. Co.; H. N. Crandall, Baker Gas & Elec. Co.; W. E. Moore, Lewiston-Clarkston Co., 1905.)

A water tank exposed to freezing weather may be saved from damage due to the formation of ice by standing one or more sticks perpendicular in the tank and near the center. The capillary attraction of the water on the sticks causes the ice to bulge or heave at this point, which results in preventing an excess of pressure of the ice on the sides of the tank. (Geo. Ross Green, The Philadelphia Elec. Co.; Herbert A. Fife, Commonwealth Edison Co.; J. C. G., 1909.)

SECTION II.

Water Power Plants.

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Water Power Plants.

DAM.

Power House Part of Dam.—Where dams are comparatively low there seems to be no valid objection to incorporating the power house building as a part of the dam. It is advisable to construct such a dam of reinforced concrete. (A. E. Walden, 1905.) Such construction may be used for heads up to 40 or 50 ft. (James B. Foote, 1905.) It saves cost of long flumes or penstocks (W. W. Titzell, 1905), also wheel pit excavation and allows depth of river to be utilized as a tail-race. (A. R. MacKinnon, 1905.) Provision must be made for flood water to pass without injuring power house, which should be built high enough to be above any possible flood. (F. L. Williamson & Co., 1905.)

With this form of construction care must be used to thoroughly protect the breast wall against leakage and to see that the river below the dam has sufficient cross section to prevent backing up of tail water to a dangerous point. (Augusta Railway & Electric Co., 1905.)

This construction has been carried to the point of locating the power house inside the dam, which was in this case of reinforced concrete. (W. N. Ryerson, 1909.)

ICE PROTECTION.

Slush or Anchor Ice.—The best means for preventing these forms of ice from clogging racks or screens is to provide a body of comparatively still water immediately above the screens which will freeze over on the surface. (Edward Peterson; W. J. Trott, 1904; Union Electric Light & Power Co.; L. E. Watson; E. H. Mather; Easton Power Co.; F. B. Hubbell; C. H. Hollingsworth; Little Falls Water Power Co. of Minnesota; E. S. King, 1905; James B. Foote; L. E. Watson; George M. Pierce, 1906.)

If the portion of the racks projecting above the water level be kept at a temperature above the freezing point by enclosing them in a building which can be heated there will be less likelihood of ice adhering to them, as the heat absorbed by the exposed portion will be conducted down the metal of the screens into the parts under water. (W. N. Ryerson, 1909.)

Booms or diverters may be constructed in some cases to throw the ice off to one side of the racks, either allowing it to be swept over the spillway, or providing a sluice-gate in the dam for flushing it out of the way. (C. W. Rice; C. H. Hollingsworth; Augusta Railway & Electric Co.; F. B. Hubbell; Franz Koester; L. E. Watson; E. H. Mather, 1904; H. D. Pope; G. F. Willard, 1905.)

In many cases the racks or screens may be removed partially or entirely, allowing the ice to pass through the turbines or water wheels (G. B. Lander, 1903; Union Electric Light & Power Co.; Little Falls Water Power Co. of Minnesota; Easton Power Co., 1904). This, however is liable to clog the wheels or gates. (G. B. Lander, 1903; C. H. Hollingsworth, Union Electric Light & Power Co.; Easton Power Co., 1904; H. D. Pope, 1905.)

If it becomes necessary to pass this form of ice through the wheels, clogging may be prevented by introducing a steam jet into the wheel case, or by heating the casings by fires or by providing extra casings or locating the wheels in a comparatively warm place. (W. J. Trott, 1903; C. L. Hoon; Easton Power Co., 1904; H. D. Pope; W. W. Titzell, 1905.)

Cause of Anchor Ice.—Forms at the bottom of swift shallow streams usually at night, when sky is clear and heat is radiated from rocks, etc., on the bottom, thus cooling them to the freezing-point. (W. L. Bird; A. A. Mace; F. J. Howes, 1909.)

PENSTOCK, FLUME AND CANAL.

Prevention of Pressure Rises.—Open standpipes, connected to the penstocks as near the Power House as possible, offer the best solution of this problem. (R. R. Laxton, H. J. Gille, F. B. Sharpe, A. Balsley, 1905.) Relief valves of air chambers are also used. (L. O. Veser; Augusta Ry. & Elec. Co.; A. Balsley, 1905.)

Where head is too great to permit use of standpipe, impulse wheels with deflecting nozzles should be used. (R. R. Laxton; A. Balsley, 1905.)

Danger from Lightning Striking Penstocks.—A wood-stave, iron-bound penstock always filled with water and resting on the surface of the earth, partly uncovered, is in no danger from lightning. (C. H. Hollingsworth; E. H. Mather; Augusta Ry. & Elec. Co., 1904.)

RACKS OR SCREENS.

Cleaning:—A long handled rake either of wood or metal is the best implement. (Union Elec. Lt. & Pr. Co.; L. E. Watson; C. H. Hollingsworth; E. H. Mather; Augusta Ry. & Elec. Co.; Franz Koester, 1904.) Material collecting on the screens should be brought to the surface and removed. (Geo. B. Lander; E. H. Mather; C. H. Hollingsworth, 1904.) Sluiceways may be used for running off the debris after it has been dislodged from the screens. (Geo. B. Lander; E. H. Mather, 1904.) Racks may be made in two or more sections overlapping each other and so arranged that one section at a time may be removed entirely for cleaning, allowing the remaining ones to protect the intake. (Franz Koester, 1904.)

It is preferable to have the face of the screens at an acute angle with the direction of flow of the stream, as there is then less tendency for trash to collect on them. (E. D. Blackwell, 1904.)

WATER MEASUREMENT.

Measurement of Head and Tail Water Levels.—In the event of head and tail water levels fluctuating and measuring points being separated by a considerable distance, the readings may be obtained by floats above and below dam with pointers in power house sliding over gauge boards. (A. E. Walden, 1905.)

Various mechanical and electrical recording instruments may be utilized to better advantage. (United Elec. Lt. Co.; J. F. Dostal; H. Bottomley; Augusta Ry. & Elec. Co., 1905.)

In cases where load is comparatively steady, a recording pressure gauge on the penstock in the power house will show changes in pressure head, the draft head being determined from water gauge, (either indicating or recording) as above. (W. N. Ryerson, 1910.)

STEAM AUXILIARY.

Supplying Fluctuating Load.—With load fluctuations of more than 50 per cent. good results were obtained by using a storage battery floating on the d-c. side of motor generator sets, the generators being shunt wound. It was found that the generator load was practically constant, the battery taking the fluctuations without the aid of boosters, and the water wheels operated at constant gate opening without governors. A voltage regulator was used on the a-c. generators. With the d-c. generators compounded, there was slight variation in the generator load, causing a variation in alternating voltage not exceeding 2 per cent. (Easton Power Co., 1904.)

No difficulty has been experienced in operating steam plants in parallel with water driven units under severe conditions as to variation in load. (T. B. Whitted; E. W. Crawford; W. F. Kingan, 1904.) It is necessary to adjust the governors so that the steam plant takes the variable load, when lighting service is also being supplied from the same source. (Geo. S. Carson, 1904.)

Length of Time an Auxiliary can be Economically Used.—This depends upon size of installation, cost and selling price of current, size and character of steam plant and its operating cost, load conditions, danger of shutdowns from shortage of water supply and their cost. (A. E. Walden; Augusta Ry. & Elec. Co.; H. T. Hartman, 1905.) Water supply sufficient for 8 months' operation must be assured to warrant installation of hydraulic plant. (D. C. Jackson, 1905.)

COST OF HYDRAULIC ENERGY.

Mechanical Energy.—The price paid for energy generated by wheels furnished by the owner of the water power varies from $5.50 to $60 per hp-year depending upon local conditions, plant cost, hours use per day, etc. (Union Elec. Lt. & Pr. Co.; C. H. Hollingsworth; E. H. Mather; Augusta Ry. & Elec. Co., 1904.)

Operating Expenses.—An old plant having an installation rated at 830 hp. and an annual output of 1,700,000 kw-hr. was operated for 0.515 cents per kw-hr., not including depreciation, superintendent, taxes or general expenses. (H. McNulta, 1904.)

A modern plant of 1,500-hp. rating can be operated for from $3.00 to $4.00 per hp-year, including only labor and material. (E. H. Mather, 1904.)

INFLUENCE OF HEAD ON TYPE OF WHEEL.

Turbines.—Operate best under heads of from 18 to 20 ft. (W. W. Titzell, 1905.) Can be operated without limit as to head if equipped with efficient water cushion as a substitute for step or thrust bearings. (E. T. Copeland, 1905.) Modern reaction turbines are successfully operating on heads as high as 500 ft. with oil pressure thrust bearings. (W. N. Ryerson, 1910.)

Impulse Wheels.—Are best for heads exceeding 200 ft. (E. T. Copeland, 1905.)

Size of Wheels for Given Head and Power.—To develop a maximum of 150 hp. and an average of 75 hp. under 75 ft. effective head, two turbine wheels of 75 hp. each would be preferable. (W. W. Titzell; United Elec. Lt. Co.; Augusta Ry. & Elec. Co., 1905.) These wheels may be mounted as a pair on the same shaft, the gates being separately operated for partial loads. The unbalanced thrust must be provided against. (E. T. Copeland, 1905.)

Multiple Wheels on Same Shaft for Low Heads.—Two or more pairs of wheels may be thus connected and operated successfully. (R. R. Laxton; A. R. MacKinnon, 1905.) The governing problem must be carefully worked out and the wheels must be submerged at all times to prevent loss of head. (Augusta Ry. & Elec. Co., 1905.)

RUNNER.

Pitting.—When occurring on back side of iron blades away from water pressure is probably due to electrolysis. This may be determined by taking voltmeter readings between wheels and ground. May possibly be remedied by fastening blocks of zinc to side of wheel casing near the runners. (P. H. Kemble; R. J. C. Wood, 1908.)

This is often caused by grit in the water where the guide vanes and runners are improperly designed. (W. N. Ryerson, 1910.)

BEARINGS.

Wood for Step Bearings.—This material has been used with success when the bearings run under water and ordinary lubricating methods are not feasible. (W. W. Titzell; Geo. B. Lander; J. D. Saunders; Augusta Ry. & Elec. Co., 1905.) Graphite is a good lubricant. (A. E. Walden; W. W. Titzell, 1905.) Also soaking the step in oil or beef tallow. (W. W. Titzell, 1905.) Also plain water. (Geo. B. Lander; J. D. Saunders, 1905.) Lignum-vitae bearings are self-oiling. (Augusta Ry. & Elec. Co., 1905.)

GOVERNOR.

Hydraulic and Steam Plants in Parallel.—When the load fluctuations amount to 50 per cent. or more, operate water wheels at constant gate opening, allowing steam engine governors to do the regulating. A storage battery is a useful auxiliary. (E. W. Crawford, 1904.)

Set the water wheel governors to operate less sensitively than the steam engine governors. (W. F. Kingan, 1904.)

SPEED REGULATION.

Good regulation is dependent on efficient governors and fly-wheel capacity. (E. W. Crawford, 1904.) Should be nearly as good as with steam engine governors where Lombard governors are employed. Is limited by mechanical considerations such as wear and tear on gate operating mechanism inertia of moving parts. (W. F. Kingan, 1904.)

With railway load and Lombard governors 3 per cent. (C. N. Shaw, 1905); from 2 per cent. to 3 per cent. depending upon back-water conditions, momentum of moving parts and relation between capacities of wheels and generators (A. E. Walden, 1905); from 5 per cent. to 6 per cent. (United Elec. Lt. Co., 1905); two per cent. (P. H. Korst; Augusta Ry. & Elec. Co., 1905.) This is dependent upon ratio between head and penstock length and to sine of angle of hydraulic slope. Minimum closing time of gates may be reduced by suitable standpipe and automatic pressure relief valves. Balance of gate rigging must be as near perfect as possible. (W. N. Ryerson, 1910.)

EFFICIENCY.

Operation of Multiple Wheels to Conserve Water.—Arrange individual gates so as to be separately operated, shutting off wheels as load decreases. (Geo. B. Lander; J. B. Foote; C. H. Hollingsworth, 1904.) Improve load factor by reducing rates for off-peak load. (C. W. Rice; Augusta Ry. & Elec. Co., 1904.) Install a smaller wheel. (E. H. Mather, 1904.) Use storage batteries. (Augusta Ry. & Elec. Co., 1904.)

Efficiency at Low Heads.—From 75 per cent. to 80 per cent. (United Elec. Lt. Co., 1905); from 50 per cent. to 60 per cent. (Augusta Ry. & Elec. Co., 1905.) For turbine only—80 per cent. (E. T. Copeland, 1905.)

DRIVING MECHANISM.

Substitutes for Bevel Gears.—Mount generator directly on vertical wheel shaft. (Geo. B. Lander; H. T. Hartman, 1905.) Rope drive. (Augusta Ry. & Elec. Co.; E. W. Furbush, 1905.) Twisted belt. (H. T. Hartman, 1905.)

Losses in Bevel Gears.—From 8 per cent. to 12 per cent. for large gears when well made and aligned. This will usually increase with use. (D. C. Jackson, 1905.)

Successful Use of Bevel Gears for Large Capacities with Governors.—A unit of 135 hp. has been in use for 8 years without trouble with gear teeth. Wooden teeth should be covered with glue before being driven into mortises. Keys should be held in place by wooden screws at an angle so as to go into the teeth. Maple teeth and keys used. (B. E. Noyes, 1909.)

Belting Versus Gearing.—Rope drive preferable and more reliable than belt, and less noisy and more efficient than gearing. (R. R. Laxton, 1905.) Belting in most cases. (Augusta Ry. & Elec. Co., 1905.) Belting has a higher efficiency, makes less noise and costs less for repairs than gearing. (H. T. Hartman, 1905.)

DEPRECIATION.

Depends largely upon style of installation. With modern direct-connected horizontal water-wheel units and generators, with dams, buildings, etc., of concrete and steel on good rock foundation, it should not exceed 5 per cent. This covers building and machinery. In modern plants, well operated, depreciation on buildings and dams should not exceed 3 per cent., water-wheels 6 per cent., revolving field alternators 5 per cent., governor and electrical apparatus 10 per cent. (W. F. Kingan, 1904.)

SECTION III.

Feed Water Heaters, Purifiers, Condensers, Pumps, Piping, Etc.

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Venturi Meters, Feed Water Measurement.—The Venturi meter may be used to measure hot feed water to within 1 per cent. of absolute accuracy if used with a duplex pump or if so located that it will not be subject to surging. (J. D. A., New York Edison Co., 1904.)

We have a 4-in. Venturi meter connected in a feed line carrying water at a temperature of from 200 deg. to 210 deg. fahr., and a pressure of about 90 lb. gauge. On account of the varying demands for steam, the velocity in the line (controlled by a pump governor) varies through quite a wide range. The meter is equipped with the usual registering mechanism, and, beyond an occasional inspection and adjustment of that device, it has required no attention for several years. Checking against scale weights shows it to be very accurate. (The Edison Electric Illuminating Company of Boston, 1904.)

Rotating Disk Meters.—After four months' service 16 hot-water meters of the rotating disk type were tested for accuracy, with the following average results:—

Per cent. of full rating	66	100	133
Slow	10.2	5.7	4

The average of all readings showed the meters to be 6.6 per cent. slow. Under small loads the meters cannot be depended upon, but if run steadily at the full evaporative rate of the boiler, they give good results. As the feed varies constantly from nothing to maximum, the indications of the meters as a whole are probably about 10 per cent. slow. This cannot be determined exactly from the tests. These meters are built in two sizes: 1.5-in. on 500-hp. boilers and 2-in. on 800-hp. boilers. (Robert Lindsay, 1904.)

The life of a hot water meter used continuously at full load is but eight months. (O. H. Young, 1905.) Such a meter will have an error of about 5 per cent. within ten days. (Edison Illuminating Co. of Detroit.) Experience with impulse meters shows that some makes of these meters will run continuously for several months and retain their accuracy. Some trouble has been experienced on account of pivot bearings, and particularly the counters wearing out. (W. L. Abbott, Com. Edison Co., 1904.)

The concensus of opinion seems to be that meters can be found which when used with hot feed water will be accurate enough for a check on the regular operation of the plant, (The Philadelphia Electric Co., 1905) or for boiler efficiency tests when well taken care of, if calibrated before and after the tests. (A. A. Fielmetzer and A. S. Kibbe, 1905.)

FEED WATER IMPURITIES.

Boiler Compound.—The following formula is recommended for a boiler compound for use with feed waters containing moderate quantities of lime: 40 lb. caustic soda, 40 lb. soda ash, 35 lb. liquid hemlock, 15 lb. gambier. Dissolve in hot water. This will make one barrel of good dissolvent. Where water contains much lime, add 20 lb. tri-sodium phosphate. (Wm. Wiatte, 1905.)

The following method of keeping a boiler free of scale is described: Place within a 100-hp. boiler 1 bucketful of washing soda, put in 2 gal. of kerosene oil (after closing the blow-off cocks) and fill the boiler with water. Feed in at least 1 qt. of kerosene oil every day through a sight-feed oil cup attached to the feed pipe near the boiler; that is, between the heater and boiler, so that the oil is not entrapped within the heater. If it is inconvenient to open the boiler, dissolve the washing soda in hot water and feed it in with the feed pump or through a tallow cock (attached between the injector and the valve in the suction pipe) when the injector is working.

This method was successfully used with feed water having the following analysis. (W. W. Titzell, 1905) :—

ANALYSIS OF SCALE.

	Per cent.
Organic and volatile	7.3
Calcium carbonate	39.9
Lime	10.1
Calcium sulphate	5.3
Magnesia	18.1
Silica	10.9
Iron oxide and alumina	8.4

With feed water having impurities as follows: 65 per cent. calcium sulphate, 13 per cent. calcium carbonate, 22 per cent. other substances, a boiler compound of following formula is recommended: A mixture of soda ash with a small amount of caustic soda, together with a considerable amount of tannic acid in the form of catechu; quantity and proportion to be determined by experiment. (The Philadelphia Electric Co., 1906.)

To use water having impurities of the kind and amount as described by Philadelphia Electric Co. requires a water-softening plant. (W. W. Titzell Co., 1906.)

The presence of soda in a boiler, either introduced as a boiler purge or existing as an alkali in the feed water, tends to produce foaming when the boiler is working hard, it is destructive to gum gaskets, and necessitates an increased amount of oil for cylinder lubrication. (D. Kennedy, Steubenville Traction & Light Co.; W. Bloxham; E. S. Aspnes; G. R. W. Halden Electric Co., 1904.)

HEATERS.

Open Heater Advantages.—The advantages of the open type of feed water heater are:—

1. Safety—operated under atmospheric pressure.
2. Higher temperature of feed water when exhaust steam is used.
3. Reliability and uniformity of operation.
4. Less care and consequently less cost of maintenance. (G. Wilbur Hubley, 1905.)

An open heater has the advantage of being more easily cleaned (J. T. Gowling, 1905), also of giving hotter water, because the water mixes with the exhaust steam; but, to offset this, the pump will need more attention; also, oil is liable to get into the boilers (Edison Electric Illuminating Co. of Brockton, 1905); and last, the pump must be flooded. (H. C. Hall, 1905.)

Closed Heater Advantage.—The advantages of the closed heater are:—

1. Where city water is used the pump will have the benefit of city water pressure.

2. The cylinder oil that the exhaust steam contains will not get into the feed water.

3. The pump will have to handle cold water only,—therefore will be more easily cared for. (H. C. Hall, 1905.)

Location of Heater.—Heaters may be installed between engine and condenser and give good satisfaction and increase the economy of the plant, as the feed water will take up some of the heat from the exhaust steam, and, at the same time, reduce the work in the condenser and thus increase its capacity. (G. B. Leland, 1905.)

If the plant is equipped with an economizer, the gain in heat from a heater placed between engine and condenser would not be sufficient to justify the cost of its installation. (W. H. Mills, 1905.)

In plants equipped with steam-driven auxiliaries, sufficient exhaust steam for heating feed water is usually derived from this source to render the use of an intermediate heater inadvisable. (The Edison Electric Illuminating Co. of Westchester, Pa., 1905.)

Cleaning Heaters.—To loosen scale from incrustated heaters, boil out for twenty-four hours with a strong solution of soda ash, then drain out the solution, put in three or four gallons of kerosene oil and slowly fill and drain the heater repeatedly, until the coating is thoroughly saturated by the oil, after which it will be found that the scale can be readily removed. (H. B. Johnson, 1906.)

PURIFIERS AND PURIFYING COMPOUNDS.

Sea Water.—Sea water in a boiler is corrosive and very injurious. Pure salt, however, is not injurious, but has the beneficial effect of increasing the solubility of lime sulphate and tends to prevent its deposit as a hard scale. The use of salt with soda ash is not recommended. (Hartford Steam Boiler Inspection and Insurance Co., 1905; W. A. Converse, 1905.)

Zinc is sometimes suspended in the boilers of ocean-going vessels, with the object of arresting the corrosive action of the saline or other active agents in the water, by making the zinc the negative element and the steel of the boiler the positive element of a galvanic battery. According to the law of primary batteries, the greatest action takes place at the negative element, which in this case would be the zinc. (Louis I. Porter, 1904; C. H. Peters; D. Kennedy, 1904.)

CONDENSERS.

Choice of Condenser.—Under similar conditions, the efficiency of the surface and of the jet condenser in producing a vacuum is the same, but the jet condenser, because of its lower first cost and maintenance cost and because less power is required for its auxiliaries, is preferable when, because of the presence of oil or for other reasons, it is rendered undesirable to return the condensation to the boilers. (The Edison Electric Illuminating Co. of Boston, 1905; Geo. Ross Green, 1907.) But when it is desired to use the condensation over again for boiler feed, surface condensers are necessary. They also have the advantage of returning to the boilers in the feed water more of the heat of the exhaust steam than is possible with jet condensers. (I. E. Moultrop, 1905.)

References.—References to literature on the subject of the barometric condenser are given by B. J. Denman, 1907: Articles in "Power," January, 1907, p. 1, and February, 1907, p. 91. Geo. Ross Green (1907) gives a list of patents covering the Weiss counter-current condenser, which illustrate plainly its operation. Patents Nos. 496,716, 511,519, 577,996, 771,515, 588,585, and 588,586.

Pressure Drop in Surface Condenser.—In a surface condenser, the difference in vapor pressure between the point where the steam enters the condenser and the point where the dry air is removed, due to the resistance of the nest of tubes, should be less than 0.1 inch in a well-designed condenser when operated at rated load. (J. T. Whittlesey, 1907.)

Value of Dry Vacuum Pump.—The benefits to be derived from the use of a dry vacuum pump in connection with a barometric jet condenser are: less water will be required for a given vacuum; the amount of water can be adjusted to the load on the engine instead of pumping maximum amount at all times; air pump can be speeded up and ordinary air leakage taken care of without lowering the vacuum; it will remove the air and other non-condensable vapors, which the condenser will not take care of, and thereby increase the vacuum. (Fred W. C. Bailey, 1906.)

Causes of Poor Vacuum.—The failure to secure guaranteed or expected vacuum in the every-day operation of surface condenser plants, either with turbines or with steam engines, is caused by:

1. Designing the condensing plant too small for the work,—that is, making either the entire installation or one of the pieces of the apparatus too small.
2. Air leaks in that portion of the condenser and its appurtenances where the pressure is below that of the atmosphere.
3. By the temperature of the cooling water running higher than anticipated, thereby warming up during the summer months.
4. Leakage through the pump used to remove the water of condensation and through the pump removing the vapor of condensation, if there be such a pump in use.

The above list covers most of the causes of failure in condensing apparatus, but there may be other causes brought about by the peculiar conditions of an individual installation, which would require special investigation. (I. E. Moultrop, 1905.)

Counter vs. Parallel Flow.—The most efficient design for a surface condenser is the counter-current flow. (C. W. Koiner, 1905, and H. C. Hall, 1905.) I. E. Moultrop, (1905) holds that the parallel flow gives results equal to the counter-current flow.

Exhaust of Auxiliaries.—Without economizers, all the units of the surface condensing outfits should be operated by steam, as the steam will be needed to heat the feed water. (Geo. Ross Green, 1907.)

Authorities differ as to the proper disposition of the exhaust steam from the dry air pump; if the feed water is heated up to 200 deg. fahr., it should go into the condenser.

FEED PUMPS.

Choice of Pumps.—The ordinary steam-driven duplex boiler feed pump requires from 100 to 200 lb. of steam per hp-hr., and in non-condensing plants, where there is an excess of exhaust steam for feed water heating, the motor-driven feed pump is preferable, although it is not as reliable and requires more space. (J. H. Vail, 1904; A. D. Williams, Jr., 1907.)

Because of the difficulties of pumping hot water, due to the liability of the water to boil in the suction pipe and cause the pump to hammer, hot water should be delivered to the pump suction under a slight head. (Edison Electric Illuminating Co. of Boston, 1904.)

Valves.—As hot water tends to soften ordinary pump valves, specially designed valves should be used for this purpose. (W. F. Sims, 1904.)

The life of a rubber valve seat in the marine type of boiler feed pumps is shorter than the metallic, and not as reliable when pumping hot water. (Geo. W. Richardson, 1905.) A pump with ball valves will operate satisfactorily at slow speed, although the only advantage over the flat valve is that gritty or viscous liquids containing more or less solids can be handled; in high-speed pumps the ball valves would be liable to batter the seats out of shape, owing to the quick and frequent reversals. (The Knowles Steam Pump Works, 1904.)

Packing.—Metallic packing should be used on plungers of outside-packed feed pumps, since it keeps them reasonably tight without causing undue wear, scoring, etc., on the plungers, thus saving a lot of expense that would be incurred by having to renew soft packing frequently, and in case of horizontal plungers it maintains the plunger in proper alignment; whereas with soft packing the weight of the plunger causes it to wear away the packing on the underside. (I. E. Moultrop, 1905.)

Air Chamber.—An air chamber on the discharge side of a feed pump produces an even flow of water in the feed pipe and prevents or reduces shocks to both pump and piping. (W. W. Titzell, 1905.) Where the suction lift is considerable, an air chamber should be placed on the suction pipe as well. (The Edison Electric Illuminating Co. of Westchester, Pa., 1905; O. H. Young, 1905.) With duplex pumps working at slow speed an air chamber is of little or no value. (G. Wilbur Hubley, 1905, and G. F. Willard, 1905.)

Injector vs. Feed Pump.—An injector is preferable to a pump for feeding a boiler if the feed water is cold and no heater is used. Under such conditions the efficiency of an injector is very high and it works quite satisfactorily, but as a rule a feed pump is preferable, because its speed is better controlled, it can handle hot water, and effects a great saving of waste heat when used in connection with a heater and exhaust steam. (Snow Steam Pump Works, 1904; E. W. Furbush, 1905; B. F. Goodrich Co., 1904; Augusta Railway & Electric Co., 1904; I. E. Moultrop, 1905.)

COOLING TOWERS.

Value.—While an ample supply of condensing water is preferable, the fact that many cooling tower installations have been made and are being used is an evidence of their value, particularly where water for condensing purposes is not otherwise available, where the cost of fuel is high, where the character of the feed water is unsatisfactory for boiler feed, or where there is a considerable amount of long-hour business. (P. Junkersfeld, 1904, and H. T. Hartman, 1904.)

Natural Draft vs. Fan.—A natural draft cooling tower is larger than a fan cooling tower and costs from 50 per cent. to 100 per cent. more, but when the cost of the fan is added, the total costs of the two kinds of towers are about the same, and the natural draft tower will have the lower operating cost. (P. Junkersfeld, and G. W. Humphrey, 1904.) The power required to run the fans and pumps of a cooling tower amounts to about 6 per cent. of the generated output of the plant. (A. C. Bach, Los Angeles, Cal., 1907.)

Cooling Ponds.—Cooling ponds or lakes have been successfully used instead of cooling towers, although when artificially constructed the first cost is usually high. (J. F. Dostal, 1907.) An area of 5 sq. ft. per lb. of steam condensed per hour will give results as good as can be obtained with a tower, and will entail less loss of power in pumping. (B J. Denman, 1907.) A smaller area of pond surface will suffice if the water is delivered to the pond under pressure and through spraying jets. (C. J. Embree, 1907.)

SEPARATORS.

Oil.—Oil may be removed from exhaust steam by enlarging the exhaust pipe and using a separator having plenty of baffling surface and at least twice the cubical contents of the low-pressure cylinder. (C. F. Hewitt, 1905.)

PIPING.

Steam Velocity in Pipes.—General practice accepts a standard of 6,000 ft. per min. for velocity of high pressure steam and 4,000 ft. per min. for velocity of low pressure steam. (W. B. Roland; F. M. Former, and M. C. T., 1904.) Although in Germany pipes are designed for a velocity of steam of two miles per minute. (Franz Koester, 1904.)

Pipe Location.—The header should be placed in the engine-room to secure better inspection. (Augusta Railway Company, 1905.) The boiler-room is the place for the steam header except in plants of very large capacity. (H. T. Hartman, 1905.)

Pipe Covering.—In covering steam lines carrying superheated steam, use plastic or sectional covering arranged in layers. (W. Bloxham; W. J. G., of New York Edison Co., 1904.) Covering without air space will stand up better if it is firmly put on so that it cannot work loose with vibration. The air space also acts as a flue to circulate air and carry away heat if the joints are not tight. (E. E. Lee, 1904.) Magnesia covering is considered the best material to-day for high-pressure steam piping. This is used either in the sectional form or the plastic form, and where a first-class job is required better results are obtained by applying two layers of sectional blocks next to the pipe and then covering the whole with a thin layer of plastic material. In any case, the pipe covering should be protected by heavy cotton duck sewed tightly in place, and painted. (I. E. Moultrop, 1904.) For outside service pipes should be covered with a layer of felt, and then placed in a box filled with sawdust to prevent freezing. The box should be painted to render it moisture-proof. (John O. Magnani, 1904.)

Color Scheme.—The painting of pipes for different services in different colors may be of use when the piping system is complicated. Canvas covering should be saturated with a standard filler and a double coat of paint applied, so that it may be kept clean. (John McFeeley and Geo. Ross Green, 1907.)

Radiation Loss.—The radiation loss from uncovered pipes may be expressed as 1/420 lb. of steam condensation per hour on each square foot of exposed surface for each deg. fahr. difference in temperature. (D. Kennedy, 1904.)

Pipe Joints.—For joints in oil piping, rawhide gaskets between flanges may be used, screw joints being made tight without the aid of solder. (John McFeeley, 1904.) A paste made of litharge and glycerine may be used for screw joints. (J. F. Dostal, 1907.)

The following gaskets are recommended for steam headers carrying superheated steam at high pressures. Corrugated copper disks. (J. F. Dostal, 1907; Fred W. C. Bailey; B. J. Denman, 1906.) McKim double-jacketed, with asbestos center. (B. E. Morrow, 1907.) Soft iron or steel; asbestos board saturated with boiled linseed oil, and both sides covered with Dixon's Flake Graphite. (W. W. Titzell, 1905.) A metal core surrounded by flexible composition. (H. A. Strauss, 1906.) The joint in any case must be drawn up true and square and water kept out of the line as much as possible. Where there is much vibration, large flanges with thin gaskets give best results. (W. C. Anderson, 1907.)

Pipe Expansion.—Expansion in steam pipes is best taken care of by inserting a "U" bend of either copper or steel. The steel bend is the better, but it takes more space than the copper. The stuffing-box type is not reliable. Short lengths of pipe up to 50 ft. generally do not need expansion joints.

Drips.—The Holly system of handling drips is somewhat more expensive to install than the automatic tank and pump system, but, including operating expenses, it is the cheapest system at the end of a period of three or four years. (Edison Electric Illuminating Co. of Boston, 1904; G. B. Leland; I. E. Moultrop; H. C. Hall; and W. P. Hancock, 1905.) All lines should be dripped, even though superheated steam is used. In low-pressure lines any first-class trap returning drips and condensation to feed water heaters gives good service. (B. F. Goodrich Co., 1904.)

Valves.—Authorities differ as to the best type. Different types of atmospheric exhaust relief valve for use in condensing plants are recommended: The Lunkenheimer regrinding metallic seat valve. (D. Kennedy, 1904.) Plain weight-loaded globe valve similar to those built by Edward P. Allis Company for the 96th Street engines of the Metropolitan Street Railway, New York City. (J. D. A., New York Edison Co., 1904.) Vertical atmospheric exhaust valve with water-seal. (B. F. Goodrich Co., 1904). The Worthington spring type. (Augusta Ry. & Elect. Co., 1904.) Single-seated, piston balanced, water-sealed valve provided with dash-pot to prevent chattering. (E. E. Lee, 1904.) A simple valve with metal disk and groove in which may be inserted a soft rubber ring when used in connection with turbines. (Francis Hodgkinson, 1904.)

A globe valve should be placed so that it closes against the pressure, in order that the stem may be packed with the valve closed. It will be much easier to open a valve with the pressure on if so placed. The valve stem should be placed horizontally or with the stem up, to prevent a water pocket at the stuffing-box. In a boiler feed line the stop valve should always be placed between the check valve and the boiler, so that the check may be taken out at any time without shutting down the boiler. A still better arrangement is to have a stop valve on each side of the check valve. (G. W. Richardson, 1904; G. W. Koiner, 1905.)

For use in superheated steam work, the seat and disk of valves should be made of bronze and the body should be made of steel. (Franz Koester, 1904.)

Gate valves with removable brass seats and disks have given good satisfaction for feed water regulation. (E. W. Furbush and W. Bloxham, 1904.) Globe valves are preferable for this work. (John A. Wilson, B. F. Goodrich Co., 1904.)

SECTION IV.

Fuel.

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Fuel.

GAS.

The Mond process of generating gas is used for large power plants, the suction producer for small plants, and the pressure producer for intermediate sized plants. (R. D. Wood & Co., 1907.)

Natural gas may be burned under boilers and attain an efficiency of from 60 per cent. to 70 per cent. (Wm. Kent, 1905; W. C. Bailey, 1906), and at a cost of 10 cents per 1,000 cu. ft. it is as economical as coal at $2.00 per ton. (Ludwig Kemper, 1906.)

OIL.

A comparison of oil, wood and coal for fuel purposes is as follows: Taking oil as 100 per cent., wood is 11 per cent. and coal 63 per cent. (B. J. Denman, 1907.)

The better grades of coal have a calorific value of from 14,500 to 15,500 B. t. u., while crude oil has values varying from 18,500 to 20,000 B. t. u. In burning oil under a boiler more economy may be had than in burning coal, because it may be burned with more nearly perfect combustion. When an oil fire is properly handled, no smoke will be emitted from the stack, and carbon monoxide (CO) is rarely found in the flue gases. (Samuel Kahn, 1906.)

On the authority of the Standard Oil Co., the commercial value of a ton of coal for burning is about three times that of a barrel of petroleum oil. (Paul Lupke, 1906.)

Some advantages of burning oil as fuel are the elimination of all coal and ash handling apparatus, a reduction of cost of building and stack, and a decided reduction in boiler-room labor. (H. A. Strauss, 1906.)

COAL TAR.

Coal tar was used as fuel under one of seven boilers for about a year. (David W. Beaman, 1904.)

COKE BREEZE.

Coke breeze has been successfully burned in return-tubular boilers with large furnaces (W. W. Titzell, 1906) at gas works, by using a fan giving from 0.3 to 0.5 in. air pressure under the grates, getting an evaporation of 5.9 to 6.1 lb. of water per pound of fuel. By increasing the pressure under the grates to 0.8 in. the boilers were over-loaded 100 per cent. (M. R. Bump, 1906.) Gas house coke may be burned with the same success as coal. (J. R. Cox, 1906.)

COAL.

Low Grade Coal.—The cheapest grade of fuel when burned in well-designed and well-set boilers having brickwork in good condition, using forced draft and mechanical stokers gave an efficiency of 81 per cent. Allowance was made for the steam used by the stokers, etc. With hand-firing an efficiency of from 45 to 65 per cent. was obtained. (James Milne, 1904.) Slack from a high-grade fuel for use with mechanical stokers is more economical than washed screenings from a low grade fuel. (W. W. Titzell; G. Wilbur Hubley, 1905.) With limited boiler capacity and intelligent hand-firing, run-of-mine coal is the cheapest fuel. (G. N. Shaw, 1904.) Washed screenings are cheaper as fuel than either run-of-mine or lump. (Geo. W. Robinson, 1904.)

Value of Coal.—The value of coal may be judged as follows:—

1. By its heating value, as determined by an evaporation test made under same conditions as to furnace and type of boiler where used. (E. A. Beckstein, 1905.)

2. By considering the percentage of ash which, if excessive, might reduce the value of coal by increasing the cost of handling and maintenance of the furnace. (Walter Flint, 1905.)

3. By its size, the very small sizes as a rule not being as efficient as the larger. (J. A. Maloney, 1905.)

The relative evaporative value of run-of-mine, bituminous, and No. 3 buckwheat anthracite coal are equal, with proper care and intelligent firing. No. 2 buckwheat is 10 per cent. better and No. 1 buckwheat is 15 per cent. better. (Geo. L. Colgate; W. F. W., New York Edison Co., 1904.)

Spontaneous Combustion in Storage.—The liability to spontaneous combustion in storage coal may be determined by chemical analysis, it being related to the percentage of volatile matter. (R. H. Hadfield; Geo. M. Tidd, 1906.) In storage coal an excess of sulphur makes it liable to spontaneous combustion. (Wm. Kent and R. N. Kimball, 1906.) Spontaneous combustion is sometimes caused by moisture in the coal. (Geo. W. Richardson, 1906.)

To prevent spontaneous combustion in storage coal, the coal should be perfectly dry when put in storage (D. Kennedy; Edison Electric Illuminating Co. of Boston, 1904) and a ventilation system of perforated pipes should also be provided. (G. W. Koiner, 1905.) The pipes should be 2 in. in diameter and placed in vertical position in the coal pile at different depths, the ends being allowed to project above the pile in order to carry away gas as well as acting as ventilators. (Samuel Kahn, 1904.) The height to which coal may be piled for storage depends on the quality of the coal, varying from 8 ft. to 30 ft. (Ludwig Kemper; R. N. Kimball; Fred W. C. Bailey, 1906.)

Putting Out Fires.—The best method of putting out storage coal fires is to move the coal as soon as possible. (H. T. Hartman, 1905.) A coal fire may be put out by driving a pipe into the pile to get beyond the layer of coke which forms over the fire, then forcing water through the pipe, flooding the fire. Water thrown on top of the pile simply runs off over the layer of coke.

Weathering of Coal.—The weathering of bituminous coal causes a loss of ½ per cent. in heating value. (Wm. Kent, 1906.) Reaches perhaps 6 per cent. in six months. (H. T. Hartman, 1906.) Its steaming qualities are not impaired, the deterioration being physical, not chemical. (W. L. Abbott, 1904.) There is no appreciable loss with Illinois third vein lump stored three months. (Ludwig Kemper, 1904.) There is no deterioration of Iowa coal stored eleven months. (R. H. Hadfield, 1904.) Deterioration is rapid at first, but lessens after the first month or so. (D. Kennedy, 1904.)

From experience of Western Electric Company with coal stored under water at Hawthorne, Illinois, the following deductions are made:

1. Storage of coal under water appears to offer economic and other advantages over storage with exposure to air, whether wholly in the open or under shed.

2. The saving in calorific value and gain in working power is probably due to the retention more completely by the coal of its original chemical and physical properties lost in storage in air by: (*a*) dissipation of

natural volatile constituents, (*b*) oxidation, and (*c*) the weathering effect of sun, wind, rain and frost. (Paul Lupke, 1907.)

Coal Handling Apparatus.—The most economical way to handle coal in stations of 100 kw. rating or less is by means of chutes delivering coal from cars direct to boiler-room floor in front of furnaces, or by industrial trackage carried parallel with the furnace fronts, upon which charging cars are run. (H. T. Hartman, 1906.) For stations over the above size, and where the extra cost of building to carry overhead bunkers is not objectionable, the most desirable arrangement is, of course, mechanical stokers supplied by chutes connected to overhead coal bunker, forming part of the building proper and carrying a considerable storage of coal.

Bunkers.—For these stations, the use of mechanical stokers and overhead bunkers undoubtedly results in a considerable reduction of labor item. An arrangement somewhat less elaborate than the last described, which does away with the frequently objectionable large cost of building construction, is to provide a traveling coal bunker, which may be moved along and parallel to the fronts of the boilers. This traveling bunker gathers up its coal from a self-contained conveyor and is moved along electrically to charge the several stokers. (H. A. Strauss, 1906.)

Handling Coal.—Most authorities agree that it is easier for a fireman to handle coal from a charging car, (S. B. Richey, 1904), the floor of which is about 17 in. high, than from the boiler-room floor, using a shovel with the standard length handle. (Geo. Colgate; D. Kennedy; C. W. Hunt Co., 1904.) One fireman can handle about 10 tons in an 8-hour day (F. Ellwood Smith, 1904), and the passer can handle from 40 to 50 tons in the same time. (W. L. Abbott; Geo. B. Tripp, 1904.)

Cost of Handling Coal.—The cost per ton, exclusive of fixed charges on equipment, of handling coal from car to boiler-room bins, with modern coal and ash conveying machinery, assuming an annual coal consumption of 6,000 to 10,000 tons, is 6 cents a ton. (G. Wilbur Hubley and G. H. Hollingsworth, 1904.) D. Kennedy gives 3 cents a ton as the cost of handling coal and ashes under the above conditions. The Philadelphia Electric Co. gives 1½ cents per ton as the cost of handling coal where coal is dumped from cars into hoppers. Other authorities give from 3 to 5 cents per ton as the cost on handling coal in modern plants.

B. t. u. Contracts.—Buying coal in accordance with contracts based on the analysis for B. t. u. has given good results. (M. L. Sperry, 1907; Albert Lea Light & Power Co., 1906; Illinois Maintenance Co., 1905.)

SECTION V.

Boilers.

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Boilers.

TYPES.

Choice of Type.—Properly proportioned return-tubular boilers, well set and carefully fired, will show as high evaporative results as any other type of boiler operating under the same conditions. (W. Bloxham; G. R. W., Malden Electric Co., 1904.) For Indiana and Illinois coals, internally fired boilers are not satisfactory on account of limited furnace room and grate area. (R. N. Kimball, 1906.) If supplied with Morrison furnace, they are satisfactory for steam pressures above 125 lb. per sq. in. For a small electric light station of say 250 hp., three return tubular boilers should be used in preference to two water-tube, as they are easier to take care of, operate and repair. (Steubenville Traction & Lighting Co., 1904.)

The Heine open water-leg allows the free and unrestricted circulation of water through all the tubes. (D. Kennedy and S. B. Richey, 1904.) The Babcock and Wilcox separate header restricts the flow through the 7, 8, or 12 tubes, because of its small cross section. The circulation through the upper tubes is also retarded, because the water from the lower tubes has a higher velocity, due to head and more intense heat. Hence the advantage of the Heine over the Babcock and Wilcox arrangement. (E. E. Lee, 1904.)

A boiler using the horizontal or Heine pass was changed so as to have the cross or Babcock and Wilcox pass, and by actual test there was an increase in economy of between 10 and 11 per cent. when running under exactly similar conditions. (Reginald Constable, 1904.) Another point in favor of the cross pass is that any soot that lodges on top of the tubes falls down into the combustion chamber when the boiler is being cleaned. With the horizontal pass the soot that is blown from the tubes simply falls to the bottom row of tile, lodges there, and keeps increasing each time the boiler is blown.

The Heine parallel pass known as horizontal is preferable to the cross pass, because experiments have shown that it is from 6 to 10 per cent. more efficient in the absorption of heat. (A. Bement, 1907.) Besides, the baffles are close fitting, and when broken or burned out can be easily renewed, the latter being impossible with some cross-pass settings. (H. M. Lyman, 1904.) Provided both types of boilers are operated under similar conditions, there is no difference in the economy in the two types. (James Milne, 1904.)

MATERIAL.

Charcoal iron is preferable to steel for boiler tubes for both the return tubular and water-tube boilers on account of less liability to cracking and splitting (W. W. Titzell, 1906), and can be re-rolled in case of leaks at the headers; also they are longer lived and thus more economical, considering first cost, service and maintenance. (G. Wilbur Hubley and Edgar B. Green.) Charcoal iron tubes, such as were used 20 years ago, cannot be bought, and therefore the steel tubes of to-day are more reliable than the so-called charcoal iron tubes. (H. M. Lyman.)

SETTINGS.

The front end of the drums of all boilers should be supported stationary and independent of the brick setting, and the rear end supported on rollers to allow for expansion. (A. E. Walden, 1906; W. Bloxham; S. S. Ingman, 1904.) The side walls of the setting of a 60-in. x 18-ft. tubular boiler should be 20 in. thick. (L. W. Greene, 1906.) The rear arch should be self-supporting and no material but fire-brick used in it. (W. H. Banes, 1904.)

The Hartford Steam Boiler Inspection and Insurance Company recommend a rear arch whose axis is parallel to that of the boiler itself and in which the arch brick is supported on cast iron ribbed clamps which rest on the side walls. (H. T. Hartman, 1904.) Wrought iron "T" beams or 2-in. pipe may be used to support the fire-brick of the rear arch, and the whole covered with common brick laid in asbestos. (S. B. Richey; S. Ingman, 1904.)

Boiler setting should be built with an air space between inner and outer walls to permit of expansion and contraction of the fire-brick. (J. D. A., New York Edison Co.; Reginald Constable; H. M. Lyman, 1904.) An objection to such an air space is that it renders it difficult to prevent air leakage through the setting; the air space affording a communication between cracks in the outer and the inner walls. (D. Kennedy; Geo. L. Colgate, 1904.) Boiler settings may be tested for air leakage by building a smoky fire with oily waste and then closing the damper and observing where the smoke escapes through the walls. (H. T. Hartman; S. S. Ingman, 1904.)

FURNACES.

Choice of Type.—The best design for a furnace using coals high in volatile matter is of the "Dutch oven" type, or a construction using the same principle, which brings the gases in contact with incandescent arches. (Reginald Constable, 1904.)

To burn Iowa block coal the only special furnace feature required is to place the boiler at an ample height above the grate bars (about 3 ft. 6 in. in the case of a horizontal tubular boiler) and to provide for an ample supply of air through the grate bars. (H. T. Hartman, 1905.)

The fire-brick coking arch above the grate of an ordinary hand-fired boiler has been used with good results. The arch brick were set up with very little fire-clay in the joints, the bricks being merely dipped in a solution of fire-clay and laid brick to brick. Most authorities agree that it would be best to set furnace, with brick arch as above, in front of the boiler instead of under; the height of the arch being from 18 to 27 in. above the grate. (E. P. Coleman, 1904.)

STOKERS.

It is generally conceded that with chain grates or other mechanical stokers, a lower grade of fuel can be successfully burned than is possible with hand-firing. (Toledo Railway & Light Co.; C. W. Koiner, 1905.) Although there is a difference of opinion as to whether hand or stoker firing will give the greater boiler capacity, all agree that mechanical stokers effect no net saving in plants lower in capacity than a certain minimum, which is fixed by various authorities at 5,000 kw. (J. B. Denman, 1904), and between 2,000 kw. and 400 kw. according to conditions. (H. Bottomley; I. E. Moultrop; E. F. McCabe, 1905.) To burn hard coal on a chain grate is wasteful, and for the same work a larger grate surface is required for hard coal than for soft coal. (W. W. Titzell, 1906.)

BANKING FIRES

In a plant having three boilers for peak load all authorities would advise banking one fire when the load falls within the capacity of two boilers. (G. W. Richardson; G. W. Koiner; G. Wilbur Hubley; W. P. Hancock, 1905.)

OIL BURNERS.

To obtain the best combustion in oil burning in a brick arch furnace the oil should be atomized by steam and burned. The brick arch serves as a protection to the boiler. (G. H. Chapman, 1905.) Another method is to use a brick checker-work and then remove the bridge wall, and brick over about two-thirds of the grate surface. (E. A. Walden, 1905.) The cheapest method of holding steam on boilers kept as a reserve against breakdowns is to burn fuel oil or gas. (J. T. Whittlesey, 1907.)

SMOKE PREVENTION.

With a tile roof furnace and a properly selected and arranged stoker, it is possible to produce a smoke-proof apparatus, as illustrated and described in the December, 1906, issue of the Journal of the Western Society of Engineers. A hand-fired furnace, constructed on the principle referred to, can be made practically smokeless. (A. Bement, 1907.)

The Engineering Record of March 23, 1907, describes the "Ganz" smoke preventing device, which consists essentially of automatic damper and furnace steam jet control actuated by the opening of the furnace door. A boiler trial is described, in which the device increased the boiler efficiency from 74.4 per cent. to 81.8 per cent. with a practical suppression of smoke. (Paul Lupke, 1907.)

Successful instances of smoke prevention with Jones underfeed, Murphy, and other stokers are described. (H. H. Rice, 1907; United Electric Light Co.; I. E. Moultrop; A. Bement, 1905.)

A hand-fired plain grate, set under a fire-brick arch and supplied with air above the fire, can, with proper firing, be run smokeless. (Peninsular Electric Light Co., 1904.) The Kent wing wall furnace, with proper firing, can be run smokeless. (H. T. Hartman, 1906). Another method of smoke abatement, which can be used with either hand or mechanically fired furnaces, is to mix with the soft coal from 15 to 25 per cent. of the smaller sizes of hard coal. (W. W. Titzell, 1905.)

SUPERHEATERS.

The tendency in this country and in Europe is to use superheated steam, ranging from 100 deg. to 150 deg. fahr. above the temperature, due to the pressure. Out of 40 plants investigated, ranging from 2,000 kw. to 4,000 kw., 34 used superheat. From the results of various tests, a gain of from 10 to 11 per cent. per 100 deg. fahr. superheat was observed in the steam consumption of the turbine, the gain being practically the same at all loads.

Although the superheating boilers are efficient and economical, modern practice tends to place superheating coils in the boilers. (W. K. Alger,' 1906; Dudley McFarland, 1905.)

DRAFT PRODUCTION.

Methods of Producing Draft.—A simple means of increasing the draft is to blow steam through an expansion cone in the base of the stack. (Reginald Constable, 1904.) Another method is to use a steam blower, discharging into a tight ash pit. (E. E. Lee, 1905.) A steam blower requires for its operation from 5 to 15 per cent. of the steam generated by the boiler which it supplies (H. T. Hartman, 1905; M. E. Oliphant, 1907), whereas a fan blower, driven by a direct-connected engine, requires but 1½ per cent. of the steam its boilers generate, and the engine exhaust is available for feed water heating. (Carl S. Dow, 1907.) The use of steam blowers is warranted in some cases. (H. T. Hartman, M. E. Oliphant, 1907.)

In a plant of 600 kw. rating it would be better practice to have a good chimney than to have forced draft and economizers. (G. W. Hubley; G. W. Richardson; W. B. Roland, 1905.)

The capacity of the boilers at the Hudson River Electric Power Co. was increased and a saving of 20 per cent. in the cost of coal effected by using the McLean balanced draft system of the Engineering Co. of New York. (C. E. Parsons, 1907.)

Forced vs. Induced Draft.—With forced draft air is forced through the fire, the pressure above the atmosphere being maintained either in the closed ash-pit or in the closed fire-room. The latter arrangement is practical only in marine service. (E. E. Lee, 1905.) With the induced or suction method the products of combustion are exhausted from the furnace, a partial vacuum is produced therein and air thereby caused to flow through the fuel. Both systems, however, operate to produce a pressure difference between the ash-pit and the combustion chamber, and, other things being equal, there is no conclusive evidence that one method is superior to the other; the one to be adopted must depend upon conditions, and the advantages as compared with chimney draft are common to both. (C. C. Cortland, 1905.)

Forced draft is more economical than the induced draft system for the following reasons: Less power to operate, because of smaller volume of gas; less maintenance and depreciation, because gases are cool and free from sulphur compounds; less leakage in boiler settings, because of less difference of air pressure between gas passages in boiler and atmosphere, with a given difference of pressure below and above the grate. (W. W. Titzell; G. Wilbur Hubley; C. F. Heywood; G. F. Willard, 1905.)

FLUE GAS ANALYSIS AND TEMPERATURE.

Temperature Measurement.—For determining chimney temperatures a mercury column pyrometer is the most reliable instrument, and can be obtained to read up to 900 deg. Barring actual breakage, a mercury thermometer will always read fairly accurate. A Siemens pyrometer is reliable, but involves labor and some skill and judgment. A thermostat pyrometer with mechanical connections to a gauge is too liable to get out of order. (G. Wilbur Hubley; J. W. Brassington, 1904.)

Proper Flue Temperature.—Most authorities advocate a flue temperature of from 500 to 550 deg. fahr. (B. F. Goodrich; G. Wilbur Hubley. 1904.) Actual tests have shown as much as 15 per cent. more water evaporated with the flue temperature ranging from 350 to 400 deg. fahr. than with the flue temperature ranging from 500 to 600 deg. (James E. Pyle, 1904.)

CO_2 Determinations.—For determining the percentage of CO_2 in the waste gases of boilers, the econometer, gas composimeter, and Ados apparatus are all automatic and continuously-indicating instruments. The chemical econometer and Orsat apparatus are simple chemical instruments, but require personal manipulation. All of these devices are good and efficient. The Orsat apparatus is much the lowest in cost and is to be recommended in the very large majority of cases, because the other instruments require a little care and attention, and in a plant where condition of combustion and furnace performance has only occasional attention, they suffer neglect and so get out of proper condition through no fault of the instrument. (A. Bement, 1905.)

REPAIRS.

Extent of Repairs with Different Types of Boiler.—The percentage of repairs on a return tubular boiler is higher than that of a water-tube boiler operated under similar conditions and with the same care; but if interest and the investment is taken into account, there is very little difference between the two types. As far as the brick work is concerned there is no difference in the two types. (J. H. Vail, 1904.)

Inserting Fire Tubes.—A tube of a boiler may be expanded with the boiler full as well as empty, but no hammering or calking should be done when the boiler is full, as the concussion will cause leaks in other parts of the boiler. (C. N. Shaw; W. W. Titzell, 1905.) A tube should be removed if it leaks or if it is badly pitted on the inside or outside, or if it is blistered or tends to pull out of shape. (Reginald Constable, 1904.)

Patches.—A boiler head or shell, if patched where exposed to the products of combustion, should have a hard patch, namely, a steel plate, riveted over the injured part and caulked. In other places, (unexposed), a soft patch may be used; that is, a steel plate bolted over the injured part, with white lead and iron filings between the patch and the original plate. The patch plate should be crimped at least an eighth of an inch. (Reginald Constable, 1904.) Defective heads must be renewed. Patches on the bottom plates of the shell should be put on the inside. Elsewhere on the shell it does not matter whether the patch is outside or inside. (D. Kennedy, 1904.)

COST OF OPERATION.

Labor.—A fair figure for boiler-room labor for non-condensing stations having an annual output ranging from 1,500,000 to 2,500,000 kw-hr. is 0.2 cent per kw-hr. (A. L. Lansberg, Philadelphia Electric Co., and H. T. Hartman, 1905.)

Cleaning.—With the same horse-power rating in boilers, using the same kind of water and with similar hours of service, the cost of cleaning the water-tube boilers will be at least 40 per cent. in excess of that for the horizontal tubular. (J. H. Vail, 1904.)

The cost of clearing scale from drums of water-tube boilers, using rounded nosed chisels operated by compressed air, as compared with hand chipping is 50 per cent. less with the mechanical cleaners. (J. D. A., New York Edison Co.; W. Bloxham.)

CARE.

Parts Out of Service.—The best way to preserve a boiler out of service is to empty the boiler (A. F. Hall, 1905), dry it out thoroughly with a charcoal fire, and then place quicklime on the inside to take up any moisture. (Edison Electric Illuminating Co. of Westchester; C. N. Shaw; G. W. Richardson, 1905.) Another method is to keep the boilers full of water and steam them about once a month. (G. W. Hubley; G. W. Koiner; Wm. Wiatte, 1905.) Still another method is to put in 2 or 3 gal. of crude petroleum when the boilers are full and then blow them down, leaving a coating of oil over the entire internal surface. (W. W. Titzell, 1905.)

Tube-Hole Gasket.—Tube-hole cover should be on the inside and the joint made with a rubber or lead gasket, soft enough so that one man with a short wrench can pull it tight when cold. It will always hold when warmed up with pressure on it and will relieve the bolt of strain.

The outside cap needs to be pulled up with a long wrench and generally by two men, and it needs tightening again when warmed up; and the higher the pressure, the greater the strain under which the bolt and plate must be placed to resist a leak. (H. M. Lyman, 1904.) A composite gasket of copper wire, lead or zinc alloy will give good service. (W. H. Banes, 1904.)

From the standpoint of the convenience in taking off and replacing them, it is preferable to have the hand-hole plates on the outside. (Reginald Constable; J. D. A., New York Edison Co., 1904.) The plates should be numbered in order that they may be put back in the original location, thereby lessening the chance for leakage. (Augusta Railway & Electric Co., 1904.) The oval hand-hole cover is better than the round. (D. Kennedy; Edison Electric Illuminating Co. of Boston; Augusta Railway & Electric Co., 1904.)

RATING.

The standard code for steam boiler trials adopted by the American Society of Mechanical Engineers a few years ago provides two efficiencies that are recognized standards:

$$(1)\quad \text{Efficiency of boiler} = \frac{\text{Heat absorbed per lb. of combustible}}{\text{Calorific value of 1 lb. of combustible}}.$$

$$(2)\quad \text{Efficiency of boiler and grates} = \frac{\text{Heat absorbed per lb. of coal}}{\text{Calorific value per lb. of coal}}.$$

PIPING CONNECTIONS.

Blow-off.—The blow-off pipe of a boiler should be protected from the furnace gases by an asbestos covering, fire-brick, or piece of cast iron pipe large enough to leave an air space around the pipe. (Fred Hubbell; G. H. Cushman; E. E. Lee, 1904.) It is sometimes recommended to keep a circulation of water in the blow-off pipe, but scale is liable to accumulate and the pipe burn out if not otherwise protected. (S. S. Ingman, 19...)

Feed Water.—Feed water should be introduced in a boiler at some point where the feed pipe will not be affected by expansion and contraction of the boiler, and the pipe should extend some distance through the water in the boiler, thus preventing the very cold water (when such is used) from striking any part of the heated metal. (Augusta Railway & Electric Co., 1904.) The practice of feeding through the blow-off to protect the blow-off pipe, is not to be recommended. (S. B. Richey, 1904.)

STACKS.

Choice of Section.—A round stack has 2 per cent. less gas friction and 2 per cent. less radiation than a square stack, and offers 43 per cent. less resistance to the wind. (John Cyrus Distler, 1904.)

Steel Stack Construction.—A riveted steel stack should be composed of slightly conical sections with the large ends down. (F. W. C. Bailey, 1906.) If placed the other way, the upper edges of the plates form little shelves on which dirt and moisture accumulate and cause the plates to rust. On the inside this accumulation of moisture is not to be feared. (H. T. Hartman; R. H. Hadfield; Chas. W. Comstock, 1906.) Smaller stacks are made of straight sections, every alternate section fitting inside of the section above and below, which are made slightly larger. (Fred C. Bailey, 1906.)

Life of Steel Stacks.—The life of a steel stack depends upon the thickness of the metal used, the care which is taken of it, the part of the country in which it is located, and the kind of fuel used. (H. T. Hartman, 1905.)

Lining.—In the middle or western states stacks 60 in. in diameter and 120 ft. high should be lined, as the coal contains so much sulphur that the life of an unlined stack is quite short. (H. T. Hartman, 1906.) For self-supporting steel stacks, not less than 5 ft. in diameter, one-third of the height seems to be the minimum limit for lining. (G. W. Hubley, 1905.)

Paint for Steel Stacks—The composition of a good paint for steel stacks and breechings is as follows:—4 parts fine graphite; 4 parts powdered charcoal; 2 parts oxide iron. Mix with boiled linseed oil and apply with paint brush. (N. H. Ledford, 1903.)

Cost of Constructions of Various Kinds of Stacks.—The comparative cost of concrete, brick, and steel stacks is as follows.—

For a 100-ft. stack with 84-inch flue—

Concrete	$2,475.00
Radial brick	$2,750.00
Red brick	$3,050.00
Steel	$2,800.00

For a 200-ft. stack with 96-inch flue—

Concrete	$7,650.00
Radial brick	$8,500.00
Red brick	$9,500.00
Steel	$5,700.00

(P. C. Oscanyan, 1907.)

At the time of writing, a steel stack properly designed, with an 8-in. brick lining and foundations on good bottom, is about 10 per cent. cheaper than any of the radial brick stacks and will be about 50 per cent. as heavy. The bulk of the saving is in the cost of the foundation. Where rock bottom can be secured, the stacks would be approximately equal in price. The item of freight is a very heavy one for brick stacks, and the above is based on the net price of the erected stack exclusive of freight. A well-designed common brick stack is at least 20 per cent. more costly than a radial brick stack. (G. A. O., New York Edison Co., 1904.)

The approximate cost of a brick stack about 200 ft. high above foundations, with 18 ft. core, will be about $22,000.00; a Custodis stack of the same size, about $17,000.00; a similar steel stack, $20,000.00. (C. G. Y. King, 1904.)

A concrete stack has no advantage over a brick stack except in price, but it will have a longer life and a lesser maintenance cost than a steel stack. (H. A. Strauss, 1906.)

SECTION VI.

Steam Engines.

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DESIGN.

Metallic Packing.—Metallic packing for Corliss valve stems has given good satisfaction; one requirement seems to be the use of a soft metal like "Babbetts" for the stem contact. (D. Kennedy; W. Blockham; J. D. A., New York Edison Co.; C. S. Davidson; The B. T. Goodrich Company, 1904.)

Piston Packing Rings.—Bronze rings have been used for steam pressures of 500 pounds and over by Perkins on Steamer Anthracite. (W. W. Titzell, 1905.) Bronze rings have been used without lubrication for high temperatures. With temperatures ordinarily used the cast iron ring is generally used with satisfactory results. (J. P. Sparrow, 1910.)

Clearance in Cylinders.—The accepted meaning of the term clearance is the proportion of space in the cylinder and the associated passages that may be occupied by steam but over which the piston does not sweep. (D. C. Jackson; G. W. Richardson; W. P. Hancock, 1905.) Clearances in high-speed engines, vary from 7 to 14 per cent. and in Corliss engines from 0.5 to 3.0 per cent. (G. W. Richardson; S. C. Foster; G. W. Hubley; Edison Electric Illuminating Co. of West Chester, Pa.; C. W. Koiner, 1905.)

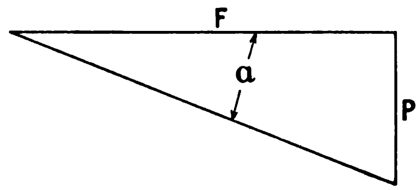
Four-Valve Engines.—Four-valve engines with separate eccentrics for admission and exhaust are accepted as of standard design. With shaft governors grid-iron admission valves are more commonly used. (W. B. Roland; G. W. Hubley; W. W. Titzell, 1905.)

Separate Eccentrics for Steam and Exhaust Valves.—The advantage of separate eccentrics for admission and exhaust valves on the Corliss type of releasing valve gear lies in the ability to obtain longer range of steam admission without affecting release or compression. The range of cut-off with the single eccentric and wrist pin motion lies between zero and three-tenths stroke. With separate eccentrics this can be increased to 75 per cent. of stroke. (A. E. Walden; G. H. Cushman; Edison Electric Illuminating Company of Brockton; H. C. Hall; E. T. McCabe, 1905.)

Over Versus Under-Running Engines.—The advisability of running horizontal engines under instead of over as is the common practice is governed solely by design. Upper guides must be of ample surface and heavy enough to resist thrust, adjustments must also be close to avoid pounding of cross-head: (W. H. Thompson, Jr.; F. D. Sampson; H. D. Larrabee; F. R. Spiller; W. Flint, 1906.)

To Calculate Pressure on Guides.—Indicate the engine and note the effective pressure for the given position of cross-head. This pressure per square inch times the effective piston area in square inches gives the total horizontal pressure in pounds. Knowing the position of the cross-head we know the position of the crank, which determines the angle made by the connecting rod with the horizontal. Then: P = pressure per square inch for given position of cross-head. A = effective area of piston in square inches. F = the total horizontal force is then = PA.

Let F in diagram represent the horizontal force and *a* the angle made by the connecting rod with the horizontal. Then, P, the pressure on the



guide is equal to F tangent *a*. (H. D. Larrabee, 1906.) This solution neglects the weight of the cross-head and connecting rod. (J. P. Sparrow, 1910.)

Allowable Pressures on Engine Bearings.—The usual practice is to allow 125 to 150 lb. per sq. in. of projected area, though this varies with the type and make of engine. (A. E. Walden; 1906.) There are great differences of opinion among designers regarding dimensions of engine bearings, variations in pressure being observed in the case of the cross-head bearings of from 40 to 500 lb. per sq. in., in the case of crank pins from 100 to 500 lb. per sq. in. of projected area. In general it may be said that conditions of operation and surroundings affect the design and that bearings should be designed with areas sufficient to assure proper lubrication. (J. P. Sparrow, 1910.)

Best Type of Engine for Direct-Connected Dynamo 100-kw.—This is dependent on the personal preference of the purchaser. A moderately high-speed engine is indicated, and engines of the Harrisburg, Ideal, Ames and McEwen type have given good satisfaction. (M. C. Turpin, 1907.)

Repairing Loosened Foundation Cap Stone.—Provided the stone is large enough and on good foundation a repair may be effected by cutting out enough of the old joint to permit driving wedges to hold the stone in place. then remove all of old joint and if stone is dry and free from oil, a sulphur joint may be poured by building clay or cement dam around stone and pouring melted stick sulphur. The only precaution to be taken lies in properly melting the sulphur over a slow fire; it should be as liquid as water. Should there be trouble with oil or moisture a rust joint should be driven, this however, needs experience to assure success. It is also suggested to drill through the capstone into foundation, if possible, and insert foundation bolts which should be split for about 6 in. at the bottom, insert a wedge in the split, heat to white heat and drive bolt home. When cold fill around bolt with sulphur. (A. T. Lloyd; D. Kennedy; B. J. Denman, 1907.)

Computing Horse-Power of Compound Engines from Size of Cylinders and Speed.—Consider each cylinder as a simple engine, assume or find from indicator cards, the mean effective pressure in each cylinder. Then work out the horse-power of each cylinder and add the results for the total, or, consider all the steam to be expanded in one cylinder, preferably the low-pressure, find the m.e.p. of each cylinder and add to the m.e.p. of the low-pressure cylinder, the m.e.p. of the high-pressure cylinder divided by the ratio of the cylinder areas, which will give the combined m.e.p. where the steam is considered to be expanded in the low-pressure cylinder only.

Insert this value of m.e.p. in the formula hp. $= \frac{Plan}{33{,}000}$ for the total engine horse-power. (E. W. Furbush; G. W. Hubley; E. W. Lloyd; W. J. C., New York Edison Co., 1904.) The above method may be formulated as follows:

Let P_h = m.e.p. of high-pressure cylinder
P_1 = m.e.p. of low-pressure cylinder
P = m.e.p. when expansion is considered as taking place in the low-pressure cylinder only
A_h = area of high-pressure cylinder
A_1 = area of low-pressure cylinder
r = ratio of cylinder areas $= \frac{A_1}{A_h}$,

then $\left(P = P_1 + \frac{P_h}{r}\right)$ which gives the value of P in the formula Hp. $= \frac{Plan}{33{,}000}$. A being taken as the area of the low-pressure cylinder. (J. P. Sparrow, 1910).

Cylinder Ratios Required for Superheated and Saturated Steam.—The accepted opinion is that superheated steam does not require a different cylinder ratio from that of saturated steam. In American practice no difference is usually made, while European practice uses a higher ratio for superheated steam than for saturated. (C. L. Davidson; Franz Koester, 1904.) It is claimed by some authorities that the efficiency of superheated steam is from 10 to 15 per cent. greater than saturated and there is no reason why a higher ratio could not be used with economical results. (Wm. R. Gardener, 1904.)

To Prevent the Vibration of Engine Governors Under Varying Loads.—If there is a dash pot on the governor and the fluctuation of the load is very great use a thin oil, if the fluctuation is not so great use a thicker oil in the dash pot and see that the dash pot is in good order, full of oil, and holes in the piston clean. It has also been suggested that a larger dash pot be used and that the engine should be indicated to ascertain if the trouble is in the valve chest. The valves should be set correctly by taking several sets of cards and be sure that the valve stem is not binding and that the lubrication is good. (Geo. W. Richardson; Edison Electric Illuminating Co. of Brockton, 1905.) With inertia governors the governor weights and eccentrics are usually keyed to a pin in the spoke of the flywheel. Care should be taken that this pin is free to oscillate or revolve in its bearing. (W. H. Thompson, Jr., 1905.)

Governing of Engines Affected by Variations of Steam Pressure.—Regulation with a varying steam pressure is much more difficult than with a varying load. This is especially true of well designed non-condensing engines with sufficient flywheel capacity. (F. D. Sampson; H. D. Larrabee; T. W. Greene; F. R. Spiller, 1906.) Variation in steam pressure is often caused by the small capacity of the steam pipe, the volume of which is not sufficient to supply the sudden demand when admission takes place. Good practice recommends the placing of a receiver or receiver separator near the steam chest having a capacity of 3 or 4 times that of the high-pressure cylinder. This will provide a reservoir for the sudden demand made by the engine at each stroke and deliver a more uniform steam pressure at the throttle. (J. P. Sparrow, 1910.)

Steam Actuated Dash Pots Versus the Vacuum Type.—Steam actuated dash pots have proved satisfactory on Corliss engines up to 164 rev. per min. The advantage over the vacuum type is in the positive action and faster closing valves. This applies to Corliss gears with direct positive connection between wrist-plate and valve stem rocker. (Wm. R. Gardener; S. S. Smith; G. R. W., Malden Electric Co., 1904.)

Maximum Speed of Poppet Valves, with Detaching Valve Gear on a 2,000 Hp. Engine.—A speed of 100 rev. per min. is practically as fast as it should be run. (W. Bloxham, 1904.)

Relative Economies and Maintenance Costs of Corliss and Poppet Valve Systems.—There is no appreciable difference. (J. P. Sparrow, 1910.)

Adjustable Piston Valve Compared with the Solid Piston Valve.—Adjustable piston valves of proper design have been found superior to the solid piston valve, as the latter soon wear and allow steam leakage. (G. W. Hubley; C. W. Koiner, 1905.)

Installation Cost of Engines per Kw.—The estimated cost of a 2,750-kw. lighting plant complete was $91.00 per kw. with a guaranteed overload capacity of 25 per cent., 37.5 per cent. load factor for 24 hours and high grade construction. The same estimate gives a price of $89.00 per kw. on a 5,000-kw. railway plant with 66 per cent. load factor. (See paper on Power Plant Economics A.I.E.E., Jan., 1906, abstracts of which appeared in the Elect. Journal, February, 1906, p. 106 and Elect. World, Feb., 1906, p. 144.) (J. R. Bibbins; S. S. Ingman; B. J. Denman, 1906.)

OPERATION.

Loss from Engine to Switchboard, Generator Belt Driven.—As a rule it is safe to figure that 100 kw. at the switchboard will equal 150 hp. at the engine, full load.

The efficiency of a moderately large unit should be from 75 to 80 per cent., that of the dynamo 85 per cent. at half load and 92 or 93 per cent. at full load; this makes the total loss 44 per cent. at half load and 26 per cent. at full load. (Geo. W. Richardson; G. W. Hubley, 1905.) The above results show a variation in efficiency of the system of from 74 to 90 per cent. at full load and from 56 to 75 per cent. at half load. A more correct method would be to find the efficiency of each unit in the system (from specification or test) and multiply these together for the total efficiency of the system. i. e., $E = E_E \times E_B \times E_G$, etc., where E total efficiency, $E_E =$ efficiency of engine, $E_B =$ efficiency of belt and jack shaft, and $E_G =$ efficiency of the generator. (J. P. Sparrow, 1910).

Steam Consumption of Various Types of Engines.—This will vary according to conditions from 14.5 to 27 lb. per hp-hr. for Corliss type, as high as 30 to 35 lb. for automatic high-speed engines, and 45 lb. per hp-hr. for simple slide valve engines. (D. Kennedy; S. S. Smith, 1904.)

Coal Consumption for Non-condensing Engines.—This varies according to local conditions, anywhere from 3.75 lb. to 18 or 20 lb. of coal per hp-hr. for non-condensing engines. (G. W. Hubley; D. Kennedy; E. H. Mather; S. S. Smith, 1906.)

Many Small Units vs. Fewer Large Ones.—A number of small units instead of two or three larger ones makes a more flexible station to operate and will in a number of cases make a more economical layout, but will tend to increase rather than lessen the liability of disablement and repairs. (Geo. W. Richardson; G. W. Hubley; C. F. Haywood; Edison Electric Illuminating Co. of Brockton, 1905.)

Installation of Larger Engines than the Present Load Warrants.—It is not unusual in small plants, in growing towns or cities to install larger engines than required. This is done to provide for the future needs of the city and the increase of the power load. However, it can hardly be recommended. It is far better to make ample provision in building and add boilers and engines as required. (Chas H. Peters; P. Junkersfeld; G. H. Cushman, 1905.)

The Minimum Coal Consumption Reputed.—Steam engine plants rarely get below 3.5 lb. of good coal per kw-hr., even in railway plants with high load factors at the switchboard. (J. R. Bibbins, 1906.)

Handling Light Loads.—The simple Corliss gives better economy when the load factor is small than does a compound non-condensing engine. Reduce the boiler pressure to a point that will give the most economical point of cut-off for varying loads and increase as the load increases. (W. B. Boxham; Geo. L. Colgate; G. B. Leland, 1903.)

Reducing Boiler Pressure During Light Loads.—It pays without doubt to reduce the pressure on a non-condensing engine when the load becomes so light as to cause excessive cylinder condensation due to early cut-off. Indicate the engine and if the expansion curve extends below the atmospheric line the pressure should be reduced, as this 'negative loop' indicates wasted power. (G. W. Richardson; G. W. Hubley; C. W. Koiner; W. W. Titzell; G. H. Cushman, 1905.)

The Most Economical Engine for Varying Night Loads.—An automatic high-speed Corliss will be the most economical for an all night lighting load where the load factor is high. If the load gradually increases until the maximum is reached after the first hour, continues for two or three hours and then falls off rapidly to a minimum for the rest of the night, the best results might be obtained by having two engines, one for the light load and one for the heavy. But as other things besides fuel are to be considered, cost of installation, repairs, etc., the conclusion is that the Corliss or automatic cut off engine of ample capacity will be most economical to install, all things considered. (Brush-Swan Electric Light Co.; S. S. Ingman; Guy C. Ginn, 1903.)

Compound Non-condensing Engines vs. Single Expansion Engines.—If the compound non-condensing engine can be run at full load there will be a saving of from 10 to 15 per cent. over the single expansion engine. However, if the peak load is only one-third the time and the load factor low the simple or single medium speed engine would show the best economy. The compound non-condensing engine at 100 lb. pressure is more efficient than the single expansion engine only at full or nearly full load, as under light load the consumption increases more rapidly with the compound than with the simple engine. (D. Kennedy; W. Bloxham; E. S. Aldrich, 1904.) It seems extremely doubtful whether there would be any saving in economy by using the compound engine at low pressure, when the initial cost, the greater number of wearing parts, the oil and repairs and the variable load that may be expected are considered. (J. P. Sparrow, 1910.) Compound engines are more economical than simple engines on half load, *only* when run *condensing.* (S. C. Foster; G. W. Hubley; W. H. Whitton, 1905.)

Economy of Belted and Direct-Connected Units for Small Stations.—The efficiency of a belt connected unit is not as great as with a direct connected unit if the engines are of the same type, because of belt slip, etc. to consider. (J. P. Sparrow, 1910.)

Low-Speed Belted Corliss vs. High-Speed Direct-Connected Engines.—The concensus of opinion is in favor of the simple low-speed Corliss belted to the generator. This is based on conditions usually found in small plants and on the better economy of the low-speed Corliss. Tests taken on direct-connected high-speed engine shows a high steam consumption per kw-hr. at the switchboard, with an average load of 35 per cent. of the maximum. A Corliss low-speed shows better efficiency under the same conditions. (W. H. Banes; D. Kennedy; W. Bloxham; J. D. A., New York Edison Co., 1904.)

High-Speed Corliss vs. Low-Speed Corliss Engines.—Just as good economy is obtained with a high-speed Corliss as with a low-speed Corliss, all conditions being equal. (S. S. Smith, 1904.)

Economy of High and Low-Speed Engines.—There is no question but that the low-speed or Corliss type is more economical than the automatic or high-speed engine. If high and low-speed engines of the same type are considered, the high-speed is more economical only on account of fixed charges as represented by the lower investment. Otherwise there is little difference. (H. A. Strauss; H. B. Johnson; C. D. W., New York Edison Co.; Andrew F. Hall, 1906.)

Medium-Speed Four-Valve Engines vs. High-Speed Compound Engines.—Medium speed four-valve engines, other than the Corliss type, are more economical than high-speed compound engines at low pressure. 125 lb. is about as low a pressure as should be used with compound engines, and this is higher than should be used, to get the best results, with four-valve engines. (H. T. Hartman, 1905.) Many instances show that medium speed four-valve engines use about 10 to 15 per cent. less steam than high-speed engines. (W. H. Whitton, 1905.) This is dependent largely on initial steam pressure. (J. P. Sparrow, 1910.)

Medium-Speed Belted Corliss vs. High-Speed Direct-Connected Automatic Engines.—The medium-speed belted Corliss is more economical provided the belt is of proper size, the jack shaft not excessive in length, and the engine is run at or near full load. (G. W. Hubley; Geo. W. Richardson; W. W. Titzell; C. W. Koiner; E. F. McCabe, 1905.)

Receiver Pressure.—The receiver pressure should be maintained as near as possible to the terminal pressure in the high-pressure cylinder. The most economical drop being dependent to a great extent on the cylinder ratio. An approximate balance of work done between the two cylinders is desirable and fixes the drop. This point should be determined by the indicator. (G. W. Hubley; G. H. Cushman; C. F. Haywood; H. C. Hall; W. H. Mills, 1905.)

Simple Condensing vs. Compound Condensing Engines.—All conditions being favorable the compound condensing is most economical. (Q. H. I., 1908.) (J. P. Sparrow, 1910.)

Superheated Steam, Its Advantages and Disadvantages.—The advantages are in economy of steam consumption, and absence of partial condensation when the steam enters the cylinder. The thermodynamic efficiency of an engine depends on the difference between the initial and final temperature of the working fluid. Since the condenser limits the final temperature of exhaust it becomes clear that the efficiency can only be increased by increasing the initial temperature. Superheating therefore increases the efficiency by raising the initial temperature of the steam. The disadvantages are, additional quality of pipe covering, a better grade of valves and pipe fittings capable of standing the action of superheated steam and the liability to increased leakage. (W. S. Barstow; Edison Electric Illuminating Co. of Boston; W. F. Durand; W. B. Bloxham, 1903.)

Superheated Steam and Its Effect on Valve Lubrication.—The greatest difficulty in the way of using high superheat is the lubrication of the engine valves. 160 deg. fahr. can probably be used. (H. G. Stott, 1903.)

Superheated Steam and Valve Leakage.—The valve leakage with superheated steam is greater than with saturated steam. (W. W. Titzell, 1905.) This is partially due to the fact that the condensation of the saturated steam acts as a valve packing. (J. P. Sparrow, 1910.)

Piston Speeds of 1,000 to 1,200 hp. Engines.—There should be no difficulty in operating well designed engines of 1,000 to 1,200 hp. at a piston speed of 800 to 1,000 ft. per min. (W. P. Hazeltine; G. H. Cushman; I. E. Moultrop, 1905.)

Revolutions per Minute of Corliss Type Engines.—Corliss engines of releasing gear type have been run at 150 rev. per min. However, it is recommended that 90 rev. per min. is far better speed since the valves work more satisfactorily and the engine is more economical. (G. W. Richardson; S. C. Foster; G. W. Hubley; G. B. Leland, 1905.)

Adjustment of Corliss Valve Gear with Double Eccentric to Secure More Compression.—Advance exhaust eccentric and re-adjust reach rods. (G. H. Cushman; E. W. Furbush; J. H. Robinson; Philadelphia Electric Co., 1905.)

Lubrication of Engine Bearings.—Too much attention cannot be given to engine bearings, that they are of proper size, in alignment, oil cups and grooves clean and that the oil is of a good grade and free from grit, etc. Ring bearings often run hot because the rings do not turn, or the oil is low in the well. The grooves are liable to become stopped up with grit and foreign matter. If an overflow gauge is not used on the self oiling bearing, the worn out oil should be removed every 30 days. Otherwise, a little oil can be added occasionally and the well cleaned out about every three months. Oiling devices should be looked after before starting up and closely watched during operation. (W. S. Barstow; Henry E. Longwell, 1903.)

Mechanical Lubricators Compared with the Ordinary Hydrostatic Type.—The mechanical feed lubricator is superior to the ordinary type in every respect except first cost. It has greater economy, better regulation and is much more reliable. (D. Kennedy; G. W. Hubley, 1904.)

Mechanical Feed Lubricators.—Any reciprocating motion, such as cross head or valve rods will drive the mechanical lubricator. Best results are obtained when the oil is piped to enter between the throttle valve and cylinder. This pipe should be extended within the steam pipe to about the center, in order to cause the spraying effect, which will give a uniform distribution of oil. (G. W. Hubley, 1906.)

Graphite Mixed with Cylinder Oil as a Lubricant.—Graphite mixed with cylinder oil has given good satisfaction in economy and operating conditions, decreasing the maintenance cost and increasing the life of the cylinder. However, it has a tendency to collect in the exhaust pipes and drips. If the condensed steam is returned to the boilers, careful experiments should be made to ascertain the results on the feed piping and boilers. (The Edison Electric Illuminating, Westchester, Pa.; G. W. Hubley, 1904.)

Fire Test for Cylinder Oil.—Good cylinder oil should stand a fire test of 600 to 650 deg. fahr. for steam at 125 lb. per sq. in. pressure. (C. W. Koiner; Chas. H. Peters, 1905.)

Animal Fats in Cylinder Oil.—High-grade cylinder oil should be principally a mineral oil and contain only little if any animal fats. (C. W. Koiner; O. H. Young; Madison Light & Railway Co.; Chas. H. Peters, 1905.)

Cost of Good Cylinder Oil.—Cylinder oil varies in price from 28 to 55 cents per gal. (B. J. Denman; A. Peters; F. D. Sampson, 1906.)

Prices for good cylinder oils vary from 19 to 40 cents per gal. (J. P. Sparrow, 1910.)

Crank Case Oil.—There are several crank case oils on the market any one of which is good provided it contains no vegetable oil. The crank case method of oiling is considered very economical. (Geo. W. Richardson, 1906.)

Cost of Cylinder Oil.—With an output of 50 kw. one pint runs 10 hours. A station of 90,000 kw-hr. per month uses 50 gal. per month. A 1,500-kw. station with 75 per cent. load factor, 12-hr. days expended for cylinder oil 0.02 cents per kw-hr. In large central stations with reciprocating engines the cost of cylinder oil is from 12 to 24 cents per 1,000 kw-hr. (W. W. Fuller; H. A. Strauss; Dudley Farrand; Philadelphia Electric Co.; T. D. Sampson, 1906.)

Cost of Machine Oil.—A station of 90,000 kw-hr. per month expended 5 cents per 1,000 kw-hr. = 1/200 cents per kw-hr.

For a 1,500-kw. station 75 per cent. load factor and 12-hr. days, machine oil costs 1/100 cents per kw-hr. (The Philadelphia Electric Co.; F. D. Sampson, 1906.)

The Properties of Good Engine Oils and Their Tests.—A good oil should have the following characteristics for either engine bearings or cylinder:

1—Viscosity or body enough to prevent the contact of the surfaces to which it is applied.

2—Freedom from corrosive acids.

3—As fluid as possible with required viscosity.

4—Minimum coefficient of friction.

5—High flash and burning points.

6—Freedom from elements liable to produce oxidation or gumming.

Tests Without the Aid of an Extensive Laboratory.—1—Viscosity—the simplest test for viscosity of any oil is to compare its time of flow through an orifice with the time of flow of a known oil, or water, through the same orifice. Using the same quantity of each, and test at the same temperature (if possible the temperature at which the oil is to be subjected). A cylindrical vessel (copper or glass) with a 1/16-in. diameter of orifice in the bottom, should be used. Record the time that each requires to flow through this orifice.

The viscosity of oils compared with water as determined by accurate test are as follows.

Prime lard oil, 3.6; sperm oil, 2.2; castor oil, 2.6 and rapeseed, 4.2; temperature during test 68 deg. fahr.

2—To identify an animal oil or vegetable oil; Chlorine turns animal oil brown and vegetable oil white.

3—Flash and burning tests: Place sample of oil in a small dish having a tight cover through which a thermometer can be inserted.

Make a small hole in cover to allow vapors to escape as the oil is heated. Heat the vessel slowly through a layer of sand, gently increasing the heat. When the oil is hot pass a flame over the hole in the cover, observing the temperature. The temperature at which the oil flashes (and then goes out) is the flash point. The burning point is obtained by continuing the heating process and the last temperature observed at the time the oil takes fire is the burning point.

4—Test for gumming. Compare the time required for a small amount of the sample to flow down a smooth inclined plane with the time required for a like amount of good oil to flow down the same plane.

5—Test for density: Take any small object of a known weight. Note the loss of weight when weighed in oil and when weighed in pure water. The ratio of the losses will be the density of the oil as compared with water.

The following densities have been determined by experiment:

Kind of Oil.	Density compared with water.
Animal	0.62 to 0.89
Sperm at 39 deg. fahr.	0.88
Rapeseed	0.91
Cotton seed	0.92

(K. W. Alger, 1907.)

Lubrication with Superheated Steam.—The oil must be of the best grade and able to stand up under the temperature to which it is exposed. From 40 to 50 per cent. more oil will be required than with wet steam. (The Edison Electric Illuminating Co. of Boston, 1904; W. P. Hancock, 1905.)

The oil for superheated steam use should be of high flash test and in some cases should be compounded with a fixed oil. (Thomas R. Baxter, 1906.) This appiles only when closed heaters are used and the exhaust steam does not return to the boilers. (J. P. Sparrow, 1910.)

Vacuum at the Engines with a Central Condensing System.—Stations equipped with central condensers regularly maintain a vacuum at the engine of 26 or 27 in.

This is only under favorable conditions. (S. D. S. New York Edison Co.; The Edison Electric Illuminating Co. of Boston; J. H. Vail, 1904.)

Steam Conditions for a Combined Turbine and Engine Plant.—Twenty-seven inches of vacuum, 150 lb. per sq. in. steam pressure and no superheat. (James E. Davidson, 1908.)

MAINTENANCE.

Effect of Speed on Maintenance of Corliss Engines.—There seems to be very little difference in maintenance cost between Corliss engines at 100 rev. per min. and others running at 120 to 130 rev. per min. The oil consumption and repairs would be slightly greater for the latter. (D. Kennedy; E. H. Mather, 1904.)

Maintenance of Four-Valve High and Moderate Speed Engines.—Tests show an economy in a Corliss medium speed 750-hp. at 150 rev. per min. after one year service, of 13.2 lb. of steam per hp-hr., at 26-in. vacuum and 150 lb. initial steam pressure. Also other engines of same capacity and conditions in another plant, show 300 watts developed per pound of buckwheat anthracite coal, month in and month out, with a mixed load of incandescent, arc and railway service. The repairs on these engines show an exceedingly small percentage of first cost and the engines show little wear after seven years of service. These results in economy illustrate how well this type of engine maintains its high efficiency after years of service, and places these engines in the same class as the best low-speed Corliss. (S. S. Smith, 1904.)

SECTION VII.

Steam Turbines.

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DESIGN.

Object of Increasing Number of Stages in the Curtis Turbines.—One of the objects of increasing the number of stages in the Curtis turbine, is greater steam economy due to smaller temperature ranges in the different stages, thus decreasing the heat loss due to radiation. The Curtis turbine is of the impulse type, hence the velocity of the buckets is determined by the velocity of the steam. The bucket velocity is limited by the strength of materials and desirability of lower speed of rotating parts. In order to decrease the speed of rotating parts it is necessary to have a lower drop between the pressure of steam entering the nozzles and that leaving the buckets, hence the larger number of stages with the total pressure drop (entering to exhaust) divided up into four or five stages. With the decrease in pressure between stages there is a corresponding decrease in peripheral velocity of the rotating parts, hence greater ease of construction, less liability to accident and slower speed of the generator. (C. J. Embree; John C. Distler, 1907.)

The Vertical Turbine vs. the Horizontal Turbine.—The vertical turbine has some advantage in net floor space, but usually requires more actual floor space on account of the extra area required for numerous auxiliaries.

HORIZONTAL (PARSONS) TYPE.

Name of Plant.	Sq. ft. per kw. Station.	Sq. ft. per kw. Operating Room.*
Metropolitan Dist Ry., London	1.31	0.563
P. N. Y & L. I. R. R.	1.37	0.595
Phila. Rapid Transit	1.19	0.506
Brooklyn Rapid Transit	.817	0.326
Average	1.169	0.497

VERTICAL (CURTIS) TYPE.

Name of Station.	Sq. ft. per kw. Station.	Sq. ft. per kw. Operating Room.*
Chicago Edison	1.88	0.77
Boston Edison	2.64	1.04
Average	2.26	0.905
Difference in favor of Horizontal type..	1.091	0.408
Difference in percentage of Horizontal type	93 per cent.	82 per cent.

* "Operating room" includes ground floor area of switch room.

The greater compactness of horizontal turbine plants is mostly due to the more effective location of auxiliaries in the basement, so that no extra floor space is required. (J. R. Bibbins, 1906.)

Structural Foundations for Turbines.—Several stations are operating horizontal turbines on structural steel foundations. One station is now building in which the turbines are on the second floor above the boilers.

Their weight being carried by the building frame-work. (J. R. Bibbins, 1906.)

The Prevention of Air Leakage Around Shaft of Steam Turbine.—The only way absolutely to prevent leakage through packing glands is in the use of some form of fluid packing gland. (Francis Hodgkinson, 1906.)

Indicated Horse-Power of a Steam Turbine.—There is no method of getting the i.h.p. of a steam turbine. (The Edison Electric Illuminating Co. of Boston, 1904.) The expression, indicated horse-power, of a steam turbine undoubtedly means the amount of work done by the steam in the turbine wheels. (J. P. Sparrow, 1910.)

Ratio of Boiler Horse-Power to Generator Kw. Rating.—There can be no fixed ratio of boiler horse-power to generator rating. In power station design this depends entirely on conditions under which the station is to be operated. (J. P. Sparrow, 1910.)

Steam Driven Auxiliaries and Motor Driven Auxiliaries.—In a turbine plant enough of the auxiliaries should be steam driven to heat the feed water to the proper degree. Steam driven auxiliaries are more economical up to the point where all the exhaust steam can be condensed in heating the feed water. Beyond this point motor driven auxiliaries can be used with economical results. No fixed rule, however, can be given as it all depends on operating conditions. (G. B. Leland; I. E. Moultrop; J. T. Cowling, 1905.) In stations generating electric energy for lighting and industrial power auxiliaries exclusively motor driven are undesirable. In time of system disturbance troubles are increased when drop in voltage results in drop in speed in auxiliaries. In starting up it is necessary to have some steam driven auxiliaries unless storage batteries or outside source of supply is available. (J. P. Sparrow, 1910.)

Condensing Equipment of Turbines and Engines Compared.—The steam turbine does not necessarily require a special condensing equipment or one essentially more expensive than required by the reciprocating engine. However it is recommended as a paying investment to furnish an equipment of the highest grade obtainable, since the turbine can avail itself of a higher ratio of expansion than is found practical or expedient with the reciprocating engine. It has been found that every inch of vacuum above 25 inches obtainable in the exhaust outlet will improve the efficiency three or four per cent. The extra cost of installing a high vacuum 28-in. condenser varies from $1.50 to $2.65 per kw. over a 26-in. vacuum condenser. The only real item of cost besides that of initial investment in higher grade condensing apparatus lies in the handling of the greater amount of cooling water necessitated by the decreased temperature range in the condenser. (Calvin W. Rice; A. R. Dodge; G. A. O., New York Edison Co.; The Edison Electric Illuminating Co. of Boston; W. S. Kingan; P. Junkersfeld, 1904.)

Installation of Surface Condensers Directly Beneath the Turbine.—This is the usual construction with the horizontal type of turbine. For the vertical type it is necessary to elevate the turbine the depth of the condenser. The condenser shell is necessarily made strong enough to bear the entire weight of the turbine unit and is in two compartments to provide access to step-bearing, thus increasing the cost. (Francis Hodgkinson, 1906.)

OPERATION.

Steam Consumption of Back Pressure Turbine.—A prominent manufacturer has recently given the consumption, of a turbine operating with

150 lb. steam pressure and 5 lb. back pressure, as betwen 34 and 36 pounds per brake horse-power.

Steam turbines can hardly be expected to show economical results when working against a back pressure, since the best efficiency is obtained with a high vacuum. (J. P. Sparrow; Henry E. Longwell, 1903.)

The steam consumption of a Curtis turbine working down to the atmosphere will generally be about twice as much as that which it requires with a good vacuum. With saturated steam the consumption will range from about 32 to 40 lb. per kw-hr. with turbines of different sizes and speeds. The non-condensing steam economy of the best turbines is probably inferior to that of the best compound reciprocating engine at full load. Since the turbine costs much less to operate and maintain, and since steam economy is generally not important where steam is used for heating, it will never be advantageous to use the reciprocating engine instead of the turbine for this purpose. A turbine especially designed for non-condensing work will show a much lower water rate than one designed for high vacuum.

Such a turbine has shown as low a water rate as 23 pounds per kw.-hour at full load with atmospheric back pressure. However steam turbines cannot be operated with the same *steam* economy on back pressure as a reciprocating engine. (W. L. R. Emmett; C. D. Chaseney; Francis Hodgkinson, 1906.)

Experiments with Westinghouse-Parsons turbines show that a turbine designed for high vacuum with an economy of 16 lb. per effective hp-hr. under vacuum, will show a corresponding consumption of about 34 lb. per effective hp-hr. running non-condensing. However, if it is designed for operating non-condensing, much better results will be obtained. For instance, a 150-kw. turbine shows a steam consumption of 30 lb. per brake hp-hr., and a 600-kw. turbine about 25 lb. per brake hp-hr., both run non-condensing.

A turbine designed to operate condensing, requires about twice as much steam per hp-hr., when operated non-condensing, as when run with 95 per cent. vacuum. (W. Bloxham; A. R. Dodge; Francis Hodgkinson; 1904.)

Consumption of Condensing Steam Turbines, Compared with Compound Condensing Engines.—The best result on a 100-kw. steam turbine, using superheated steam, running condensing, is about 19 lb. per kw-hr. The best result published—Sulzer triple expansion condensing engine—is equivalent to 13.2 lb. per kw-hr. under the same conditions. (H. G. Stott, 1903.)

Degree of Superheat for Turbine Use.—On the continent of Europe temperatures of superheat up to 300 deg. fahr. and more are commonly used, while in this country and in England 150 deg. of superheat is considered the maximum for favorable operation. European experiments have proved that for every 9 deg. fahr. of superheat supplied to the turbine, a decrease of 1 per cent. in steam consumption is obtained. (Franz Koester; I. E. Moultrop, 1905.)

Boiler Pressure for Turbine Use.—Average conditions are 175 lb. steam pressure and 150 deg. superheat. (I. E. Moultrop, 1905.)

Economy of Steam Turbo-Generators.—Refer to report of C. F. Hewitt, to Committee on steam turbines. (C. F. Hewitt, 1905.) This varies according to operating conditions of station and quality of coal used. (J. P. Sparrow, 1910.)

Method of Testing Steam Turbines.—The water consumption from input to boilers can be used for turbine tests if valves are so arranged in header that boiler feeding apparatus to be tested can be isolated so as not to feed any other apparatus. Also, the feed pumps must be supplied with water that is weighed, so of course they must be isolated from feed to other boilers.

A test for leakage of boilers and piping system should be made by keeping up steam in them at the same pressure as during the test and for the same length of time, immediately before or after the test, but without supplying steam for anything except leakage. The quantity of feed water required to keep the same water level in boilers during this leakage test should be deducted from the quantity fed during the test of the turbine as well as the average percentage of moisture in the steam measured at the turbine throttle during test. Care must be taken that boilers do not blow off during either turbine or leakage test.

A test may also be made by placing a steam flow meter in the steam pipe leading to throttle and installing ammeters and wattmeters to check the generator output. (Komono, Marion and Western Tract Co.; Poughkeepsie Light, Heat and Power Co., 1908.)

Efficiency of Steam Turbines Compared with that of Steam Engines.—Steam engine plants rarely get below 3.5 lb. of good coal per kw-hr. generated, even in plants with high load factors. Steam turbine plants are considerably more economical, running down to a minimum of 2.5 lb. of good coal per kw-hr. (J. R. Bibbins, 1906.)

Steam Consumption of Turbines and Engines Compared.—With 175 lb. steam pressure, 150 deg. superheat and 27-in. vacuum a steam turbine will show a lower steam consumption than a Corliss compound engine. The guarantee for the 7,500 hp. Allis-Chalmers Corliss engines for the Interborough Rapid Transit and Manhattan power plants in New York are, respectively, 12.25 and 13.0 lb. per indicated hp-hr., while that for the 5,500-kw. Westinghouse-Parsons turbine for the London Underground road, at full load is 13.2 lb. per effective hp-hr.; or assuming an efficiency of 85 per cent., 11.2 lb. per indicated hp-hr.

For the 5,000-kw. Brown-Boveri-Parsons turbine for the Paris Underground road the guarantee is 9.5 lb. per indicated hp-hr. The vacuum and pressure in the two latter are the same, while the superheat in the latter is approximately double that used in the former. (Franz Koester, 1905.)

As there is no method of obtaining a steam diagram of the turbine the only means of comparing the consumption per indicated hp-hr. is by estimate.

The output of the turbine is of interest wholly from an electrical point of view and it seems more equitable that comparisons and guarantees on prime movers for electrical stations be made on the basis of the relation that input bears to output. The input measured in pounds of steam and the output in watts. Results from a test on a reciprocating engine and a Curtis turbine operating at the same load, boiler pressure, superheat and vacuum, show the turbine economy as 18 per cent. better than that of the engine. However good engineering practice does not recommend operating turbines and engines under the same conditions, as a reciprocating engine operates most economically at 26-inch. vacuum and the steam turbine at 28-in. vacuum, 30-in. barometer.

Assuming an average figure of 90 per cent. efficiency, a medium size turbine should give a water rate of 11.9 lb. per indicated hp-hr. on saturated steam and 10.5 lb. per indicated hp-hr. on moderate superheat. (Chas. B. Burleigh; H. A. Strauss; J. R. Bibbins, 1906.)

A good design of Corliss engine operating under favorable conditions is on an equal basis with small steam turbines, up to 1,500-kw. rating, working under the same conditions. (J. P. Sparrow, 1910.)

Economy of Small Turbines and Engines Compared.—The steam turbine should have from 6 to 10 per cent. greater economy than the engine running with 26-in. vacuum, depending somewhat on the price of fuel. If the coal is low in price and other conditions not normal, the engine may show a better economy. (The Philadelphia Electric Co.; P. Junkersfeld, 1905.)

Economy of the DeLaval Turbine Compared with Corliss Engines.—The DeLaval steam turbines with proper pressure, claim to, and actually do compete with Corliss compound engines in their economies and general performances. (C. K. N., New York Edison Co.; C. D. Chasteney, 1906.)

Economy of Allis Type Engine and Curtis Turbine Compared.—The results of a test conducted under the supervision of Mr. W. P. Hancock, Superintendent of generation of the Edison Electric Illuminating Company of Boston, on a three-phase, revolving field, 6,600-volt, 5,000-kw. Curtis turbine, are as follows:

Load	Load kw.	Gauge lb. per sq. in.	Superheat deg. Fah.	Barometer in.	Vacuum in.	Water rate lb. per kw-hr.
Full load ..	5195	173.7	142	30.48	29.30	13.57
Half load ..	2575	174.6	146.1	30.11	28.96	14.99

Numerous other tests substantiate the fact that the one and one-half load rate increased the water rate 0.6 lb. over the full load rate. Tests have not shown any decided difference in economy betwen the Curtis 5,000 kw. turbine and the Allis engine driven unit of same size. It seems that the turbine makes up in economy at light load what is lost at the point of maximum efficiency, or full load, of the reciprocating engine. (Chas. B. Burleigh; Geo. R. Green, 1907.)

Difference in Steam Consumption of New Turbines and Old Ones.—The Columbus Railway & Light Company of Columbus, Ohio, has a 500-kw. Curtis turbine which had been in service between 6,000 and 7,000 hr. before it was tested by Prof. E. A. Hitchcock, with the following results:

Data	Test	Guarante
Average gauge pressure dry saturated steam lb.......	158	150
Average vacuum—in.	28	28
Average load—kw.	519	500
Average water rate per kw-hr. lb.	20.5	21.5

This test would indicate that it had not fallen off in efficiency to any great extent. A record of performance of this turbine, some five months later, is as follows:

Time	8-9 A.M.	9-10 A.M.	10-11 A.M.	11-12 A.M.	12-1 M.	1-2 P.M.	2-3 P.M.
Ave. steam pressure lb.	150	149	155	153	154	154	154
Ave. back pressure lb...	2.2	2.2	2.2	2.2	2.	2.	1.9
Ave. load in kw.	128	120	121	85	279	327	445
Ave. lb. of steam per kw-hr.	30.4	30.19	30.92	34.27	22.44	21.22	20.17

This test was made while working on regular commercial lighting load without any special preparation whatsoever, and shows the actual results which were obtained under extreme varying load conditions. (Chas. B. Burleigh, 1907.) The back pressure in the latter test is evidently the pressure above absolute, and not above gauge pressure, or the steam consumption would have been much greater. (J. P. Sparrow, 1910.)

Superheaters and Their Effect on Fuel Consumption.—Operating results show decrease in full consumption per unit generated when superheated steam is used. A net gain of 5 per cent. can be effected by placing superheaters in the boilers. This does not necessarily apply to separately fired superheaters. Turbine builders will give a guarantee of 1 per cent. saving for every 10 deg. fahr. superheat over the economy guaranteed on saturated steam. (A. D. Williams, Jr.; P. C. Oscanyan; J. F. Dostal, 1907.)

Best Degree of Superheat for Curtis Turbines.—Curtis turbines have been operated sucessfully with as much as 250 deg. of superheat and with the later types of valve mechanism there will be no trouble caused by superheat at this high degree. Recent investigations show that a steam pressure of 175 lb. and 100 deg. superheat carries from 4 to 5 per cent. more heat units than saturated steam of same pressure. The Curtis turbine gains in economy from superheat, of as high a temperature as can be obtained, to the point where the fuel necessary to produce it, does not represent a cost in excess of the saving effected. (W. L. R. Emmet; Chas. B. Burleigh, 1906.)

The Effect of High and Low Vacuum on Water Rates.—The following is from a test of a 500-kw. Westinghouse-Parsons turbine, run at about full load with high and low vacua and saturated steam:

Vacuum in in.	Pounds of water per brake hp-hr.	Pounds of water per kw-hr.
28	13.68	19.3
26	14.91	21.
24	15.86	22.

(J. R. Bibbins, 1906.)

Reasons for High Superheat and High Vacuum.—With high steam velocities employed in superheated steam the losses from fluid friction can be largely reduced by evaporating the moisture in the steam and working the low pressure stages in the most rarefied atmosphere possible. (J. R. Bibbins, 1906.)

Economy Increase Due to Degree of Vacuum and Superheat.—European experiments have proved that for every 9 deg. fahr. superheat supplied to the turbine, a decrease of 1 per cent. in steam consumption is obtained. The first 100 deg. of superheat reduce the steam consumption 7.5 per cent. and the first 150 deg. 10 per cent. Every inch of vacuum above 25 in. obtained in the exhaust pipe will improve the efficiency from 3 to 4 per cent. (Franz Koester; C. F. Hewitt, 1905; Francis Hodgkinson, 1904.)

Degree of Vacumm to Secure the Highest Economy.—As turbine connections present less opportunity for air leaks, it is possible to maintain a higher vacuum than with reciprocating engines and the turbine benefits from it in economy. From 27 to 29 in. and not less than 26 in., referred to 30-in. barometer, should be maintained. (Chas. B. Burleigh; J. R. Bibbins; H. A. Strauss, 1906.)

High Vacuum vs. Superheat for Parsons Turbines.—Neither high vacuum nor superheat are absolutely necessary on account of the low steam velocity employed in this type of turbine. However a fairly high vacuum is recommended as a paying investment and costs less to obtain and control than does high superheat. (Francis Hodgkinson, 1906.)

Overload Capacity of Steam Turbines, without Opening the By-Pass.—The Curtis turbine will automatically take care of from 90 to 100 per cent. momentary overload without adjustment, and 25 per cent. overload will be taken care of by the Westinghouse-Parsons turbine.

The overload capacity depends entirely upon the design of the individual machine and upon its rating determined by the character of the load that must be sustained. If a steady load is to be sustained by the generator, the turbine can naturally be rated much higher than if a widely fluctuating load is to be provided for. Turbines may be designed so as to carry continuous overloads far beyond the capacity of the generator, still maintaining close control by the governor. However, as a turbine shows its highest economy when operating normally at its maximum load, it is somewhat more advantageous to employ an auxiliary or secondary valve on widely fluctuating loads, thus providing large overload capacity and still maintaining its best economy at or near the point of rated load. (A. R. Dodge; The B. F. Goodrich Co.; Francis Hodgkinson, 1904.)

Centrifugal Governor vs. Inertia Type.—The centrifugal governor is the accepted type for turbine work. (J. P. Sparrow, 1910.)

Control of Steam Turbines and Synchronizing.—There should be no difficulty experienced in turbine control due to racing when adjusting speed preparatory to synchronizing. The governor will prevent any tendency to race before synchronizing, and when once in step the other machines will tend to keep it in step. (J. P. Sparrow, 1910.)

Means of Bringing Turbines to Rest.—The Curtis vertical shaft turbine was originally designed with a mechanical brake for the purpose of bringing the machine to rest. However, it has been abandoned, as it has proved satisfactory to shut off the steam, leave the fields excited, and break the vacuum on removal of the load. (Chas. B. Burleigh, 1906.)

Temperature of Step Bearing Oil.—If a filtering tank with large radiating surface is used, so that the temperature is never above 160 deg. fahr., other means of cooling will not be necessary. The normal temperature of the oil should never be above 120 to 160 deg. on leaving the step bearing.

Oil or water is supplied to bearing surfaces for two reasons; first to reduce the friction and second to conduct away the heat occasioned by friction. An oil that answers the second purpose should be kept at such a temperature as will best serve its purpose in the bearing.

As the oil increases in heat it loses viscosity and consequently the safety factor is greater at 100 deg. than at higher temperatures. (Florus R. Baxter, 1906.) (The Philadelphia Electric Co., 1905.)

Oil vs. Water for Use in Step Bearing.—Water has in many cases been adopted in connection with step bearing and lower steady bearings of vertical shaft Curtis turbines, on account of the inconvenience in handling oil and maintaining a vacuum packing, which is necessary where oil is used. The operation in most cases is as good with water as with oil. However, the thickness of the step bearing film is less, the cushioning effect of the steady bearing is less, and consequently a less margin for imperfections of balance and alignment. All machines are so constructed that oil can be used if for any reason water is found undesirable. The best oil lubricant is a good grade of mineral oil, which should not be too heavy in viscosity. If too light it will approach the defects of the low viscosity of water. Water in the event of excessive friction, will vaporize and leave the bearing surface perfectly clean, while under the same conditions oil will carbonize, become extremely hard and result in excessive cutting. There have been a number of cases where the two blocks in the step bearings have come together due to a failure in the water pressure, with little or no bad effects. In fact the step blocks are surfaced in position by running at low speed without a lubricant. (Florus R. Baxter; W. L. R. Emmet; Chas. B. Burleigh; I. E. Moultrop, 1906.)

Oil Cooler, with Oil in Tubes vs. Oil Outside of Tubes.—With the oil circulating in the tubes, the average distance through which the heat must pass to the cooling medium, which would be the surface of the tube, is comparatively short. With the oil in the shell, this distance is much greater. A larger supply of oil is necessary to fill the shell than the tubes. Also the oil has a less gumming effect when flowing through brass than through iron. Hence it is recommended that the oil be circulated in the tubes or coils and the cooling water in the jacket. (A. D. Williams, Jr.; John McFeeley; J. F. Dostal, 1907.)

Oil for Bearings of Horizontal Turbines.—A good engine oil with sufficient viscosity to stand the imposed load is recommended for horizontal turbine bearings. Little if any difference has been noticed between good engine oil and special turbine oil. (J. F. Dostal, 1907.)

Oil for Primary Valve of Parsons Turbine Using Superheated Steam, also Method of Feeding.—The best oil for use on the primary valve, with superheated steam, is a pure mineral oil with a high flash point and sufficient viscosity to prevent excessive wearing of the bearing surfaces. The most approved method of feed is the "direct feed," that is, the oil should be forced in and not vaporized. (J. P. Sparrow, 1910.)

Steam Turbines in Power Plant Operation.—Up to date the troubles and defects encountered in the use of steam turbines appear to be remarkably small and of no great moment. Every fully developed machine represents the gradual elimination of defects arising in its predecessors. The only points where the turbine has not met the reciprocating engine are extremely low speeds and belted units. Both of these are characteristic of passing rather than present engineering practice. (The B. F. Goodrich Co., 1904; I. E. Moultrop; S. C. Foster, 1905.)

Exhaust Steam from Turbines for Heating Purposes.—The steam turbine has been found altogether unsuited for operating against any back pressure whatsoever. However the turbine can be run against a back pressure but only at the expense of the coal pile. (C. F. Hewitt; 1905.) (H. B. Johnson; F. W. C. Bailey; H. A. Strauss, 1906.) See heading "Steam Consumption of Back Pressure Turbines." (J. P. Sparrow, 1910.)

Behavior of Blades in the Curtis Turbine, Under Heavy Load Fluctuations.—The stock from which the blades are milled is of greater width than the blades when complete, and the blades and disks holding the blades, are amply stiff, therefore under no conditions can the blades come in contact with anything other than the actuating fluid. It is a physical impossibility. (Chas. B. Burleigh; The Philadelphia Electric Co.; Ralph R. Laxton; T. H. T. & L. Co., 1906.)

Time Required to Erect a Turbine Unit.—A 1,200-kw. Westinghouse-Parsons turbine unit was erected in two days and was in service within seven days from the beginning of erection. The delay being caused by non-completion of station piping. (J. R. Bibbins, 1906.)

Time Required for Dismantling a Turbine to Remove Rotor.—With crane facilities, a Westinghouse-Parsons turbine of moderate size has been shut down, dismantled, and the rotor removed for inspection, in less than one hour. The machine was again assembled and put into operation in about an hour and three quarters. (Francis Hodgkinson, 1906.)

Overload Capacity of Turbines Compared with Engines.—The turbine will stand 50 per cent. momentary and sustained overload. The momentary and sustained overload capacity of the turbine is much greater than those of the Corliss engine. Regulation under both conditions is far superior to engine results. (United Electric Light Co.; The Philadelphia Electric Co., 1905.)

Coal Consumption of Westinghouse-Parsons Turbine.—The coal consumption of a station running idle is so largely affected by methods of handling fires, and station losses outside of the turbines, that any data along this line would be worthless. The 1,000 kw. Westinghouse-Parsons turbine tested by the National Electric Light Association at Hartford, required 2,684 lb. of water per hour running light and 20,000 lb. per hour at a little over full load. (J. R. Bibbins, 1906.)

A 2,000-kw. Westinghouse-Parsons railway turbine plant in Ohio, shows 2.99 lb. of Ohio slack per kw-hr. on turbine plant alone; about 4 lb. with 50 per cent. additional plant capacity in reciprocating engines. (J. R. Bibbins, 1906.)

A Long Continued Run for a Turbine Plant.—A 600-hp. Parsons type turbine has a record of 17,200 hours, practically a continuous run under official seal, with no deterioration noticeable when seals were removed. (J. R. Bibbins, 1906.)

Coal Consumption of Parsons Turbines.—Four Parsons turbines varying in load from three-quarters to full load, averaged 3 lb. of coal per kw-hr. at the switchboard. Three turbines were 1,000 kw. rating and one 2,500-kw. rating. (United Electric Light Co., Springfield, Mass., 1909.)

Energy Losses in Windage and Friction in Turbo-Generators.—The windage of high-speed generators is very largely governed by the movements of the air required for ventilation. In turbine generators a large amount of such air must be taken through confined spaces and under certain conditions this movement may involve very heavy losses while in other cases the removal of heat may be acomplished with relatively small loss. In machines of about 1,000-kw. rating the windage loss is in some cases as high as 4 per cent. while in other cases with the same speed it may be below 2 per cent. In smaller machines the windage is relatively greater than in large machines. In a 300-kw. machine it might be as great as 6 per cent. and would seldom be less than 3 per cent. whereas in a 14,000-kw. machine it should never amount to 1 per cent. and might be much less. The possibilities are so variable that no rule can be given. (W. L. R. Emmet, 1910.)

Energy Losses in Modern Steam Turbines.—Steam turbines are being sold with efficiency varying over very wide ranges, and the fact that a machine is modern is no guarantee of quality. There are few departments of engineering in which quality is so much obscured and misrepresented. Generally speaking, large turbines are more efficient than small ones, but the relation of size to efficiency is largely governed by speed. The efficiency of turbines is also largely governed by the range of steam pressure and vacuum under which they operate. Increases of vacuum add greatly to the available energy but most turbines cannot realize so large a proportion of this increase as they do of the available energy in other pressure ranges. The ability to use high vacuum with good efficiency is a very valuable quality in a turbine but no turbine can show as high an efficiency with very high vacuum as it can with lower vacuum. Increases of steam pressure also give large increase of available energy but many turbines cannot be so proportioned as to make this increase fully available. If high station economy is desired, high vacuum and high pressure should be provided for. The best existing large turbines give in electric energy about 67 per cent. of the total available energy of the steam, working from 200 lb. gauge pressure to a 28-in. vacuum. This corresponds to a shaft efficiency of about 69.5 per cent. Some turbines may give higher efficiency than this but not under such conditions as those stated. Turbines of various sizes are being sold which have an efficiency ranging all the way from this limit down to 30 per cent. (W. L. R. Emmet, 1910.)

Advisability of Small Steam Turbines for Small Stations.—If steam consumption alone is to be considered it is a question if turbines of any size would receive the preference over reciprocating engines. However in the matter of space, simplicity, attendance, supplies and perhaps repairs, the turbine appears to have the advantage. It would hardly seem advisable to install turbine units of less than 200 hp. rating and larger sizes only when superheated steam and condensers are to be used. (W. H. Whitton.)

Advantages of a 500-kw. Turbine Over the 500-kw. Engine.—The most important advantages of a 500-kw. turbine over a reciprocating engine in cases where floor space is not important, are that the installation, equipment, foundations, attendance, oil and repairs will involve much less expense and give greater flexibility and simplicity of operation. The efficiency at light load and overload will, under favorable conditions, be decidedly better. The efficiency of reciprocating engines falls rapidly with overloads, while that of a 500-kw. turbine will generally be maintained or will improve to a point of high overload. This affords better economy and greater overload capacity with a given steam supply. In fact, there is no item of either first cost or operation that should be greater with a properly selected and properly installed steam turbine than with the same selection and installation of reciprocating engine. There is every reason to expect a saving on most items and a strong possibility of saving on every item of cost connected with the purchase, installation and operation. (W. L. R. Emmett; Chas. B. Burleigh; C. K. N., New York Edison Co., 1906.)

Arguments for and Against Steam Turbines as Compared with Reciprocating Engines, Both Operated Non-Condensing.—The first cost, attendance and space occupied, of the steam turbine versus the reciprocating engine, when both are non-condensing, are all in favor of the turbine. However, since the steam turbine is most economical in steam consumption when run condensing, it is doubtful if the turbine run non-condensing, all things considered, is to any marked degree actually more economical than the reciprocating engine. (I. E. Moultrop, W. H. Whitton and Geo. Howe, 1905.)

Exhaust and Mixed Steam Turbines.—The Philadelphia Rapid Transit Company has two 800-kw. single-stage Curtis turbines utilizing the exhaust from five 1,500-kw. engine driven units. Surface condensers and cooling towers are used. With one engine in operation one turbine can develop from 60 to 70 per cent. of its rating and with three engines both turbines can develop their rated load.

For three months with the turbines generating 20.9, 23.8 and 23.4 per cent. of the total output, the coal consumption in pounds per kw-hr. was 3.88, 3.77 and 3.5 respectively. Average for twelve months of the engines without the turbines was 4.48 pounds of coal per kw-hr. With sufficient turbines to utilize all the exhaust, the coal consumption could be cut down to 3 lb. per kw-hr. (B. J. Denman, 1907.) (For an exhaustive test on a 15,000-kw. steam engine turbine unit, see American Society Mechanical Engineers Journal, March, 1910.)

SECTION VIII.

Gas Engines and Producer Plants.

Gas Engines and Producer Plants.

FUEL.

Use of Lignite Coals in Producers.—The Westinghouse Machine Co. has successfully burned Texas, Colorado and South American lignites in its producer plant at East Pittsburgh, and has obtained very good results under ordinary operating conditions, getting a brake-horsepower at the engine on from 1.5 to 2 lb., depending upon the quality of the lignite. That is, it ran about 2 lb. on the Texas lignite and about 1.5 lb. on the Colorado lignite. The Western Chemical Manufacturing Company, Denver, Colorado, has had two producers operating on Colorado lignite coal since September 1, 1908, and is erecting a third at this date (Feb., 1909). (Edwin D. Dreyfus, 1909.)

Experience with a 300-hp. lignite producer and gas engine shows that with everything new and in good order; reasonable economy may be attained. Such apparatus is, however, in too much of an experimental state, and mechanical difficulties, such as handling ash and clinker and removing tar, render the process, on the whole, uneconomical. (Wenatchee Electric Co., 1909.)

Lignite fuels are now being successfully handled in several types of producers in Texas and in some of the far western states. Peat has been experimented with and successfully gasified under certain conditions. (J. B. Klumpp, 1909.)

COST OF INSTALLATION.

Comparison of Cost of Installation with that of Steam.—A recent competitive estimate on a producer-gas engine, a steam-turbine plant and steam engine plant, complete, having 2,750 kw. rating, with 25 per cent. overload capacity of units, 37.5 per cent. load factor, 24-hour service and high-grade construction throughout, totaled $122 per kw. for gas; $88 for turbine and $91 for reciprocating engine. On a 5,000-kw. railway plant, with 66 per cent. load factor, the gas-power plant totaled $118 per kw., and the steam-engine plant about $89. With $3.50 coal, the net saving per year, including all fixed charges, amounted in the former case to 16 per cent. over steam, and in the latter considerably more, owing to higher load factor. The excess cost of the gas plant is thus wiped out in the latter case in about three years. (J. R. Bibbins.)

See paper on "Power Plant Economics" (by Henry G. Stott, Superintendent of Motive Power, Interborough Rapid Transit Company), read before the American Institute of Electrical Engineers, January, 1906. Abstracts of this paper appeared in "Electrical Journal," February, 1906, P. 106, and "Electrical World," February, 1906, P. 144 (B. J. Denman) —in brief, as follows:

Steam plant, reciprocating engine delivered 10.3 per cent. of energy as electric power. Losses which could be avoided would bring this up to 14.44 per cent.

Gas engine and producer gives efficiency of 24 per cent.

The Investment Cost (relative):

Reciprocating Steam Engines	100.00
Steam Turbines	82.50
Reciprocating Engines and Steam Turbines	77.00
Gas Engines	100.00
Gas Engines and Steam Turbines	91.20

An internal combustion engine, in combination with turbines, offers the most reliable and efficient proposition to-day, with possibility of reducing cost of generation to less than half.

Life of Plant.—Fifteen years. The small gas engine will run from four to five years under ordinary conditions without having the cylinder rebored, and the cylinder can be rebored three or four times. If the engine is run in places where grit, dirt or cement dust are likely to be drawn into the cylinder the engine should be enclosed; otherwise, the cylinder will need reboring in a much shorter time. (P. S. Young.)

Gas engines have been in operation in many plants from ten to fifteen years, with repairs not exceeding those of steam engines, and such improvements have been made in design and construction that there is no reason to believe that the life of a modern gas engine should not equal that of the reciprocating steam engine. (J. B. Klumpp, 1910.)

Reliability of Service.—A 650-hp. Westinghouse engine of the vertical, 3-cylinder, single-acting type has a record of 40 days (24 hrs.) uninterrupted run, under a load of gas compressors, with absolutely no mishap or evidence or undue deterioration. A small engine of the same type has run 1,157 hours, or over 48 days, without stopping, and a total of 8,230 hours with but 0.6 per cent. shut down.

In a 500-hp. pumping plant on the Allegheny River each gas engine unit regularly operates from 96 to 98 per cent. of the elapsed time. (J R. Bibbins, 1906.)

Gas engine compressors in the natural gas districts have been in operation from 60 to 90 days without a shut down. A known installation of three (3) engines has been operating eleven (11) years without interruption. (J. B. Klumpp, 1910.)

DESIGN OF GAS ENGINE.

Horizontal vs. Vertical Engines.—For larger sizes, horizontal engines are more desirable than vertical engines, owing to accessibility of valve and working parts, and to improved methods of lubrication. (S. S. Ingman, 1906.)

Strictly speaking, there has been no reversion to horizontal gas engines, as vertical engines are widely used, mostly of the single-acting type. The horizontal design presents many good features leading to greater stability, rigidity of structure, lower cost of construction. More especially is it adapted to the tandem-cylinder arrangement that has proved desirable in large double-acting engines where two power strokes per revolution are desired, such as is the case in driving alternating-current generators for parallel working. (J. R. Bibbins.)

ECONOMICS.

Why Gas Engines have not been Extensively Used.—Gas engines have not been more generally installed because many operators have been afraid to put them in. (Chas. N. Shaw); because first cost is considerably greater; because fuel is only in rare cases so high in this country as to warrant the additional investment; because high-grade gas engines have only recently (in this country) been placed on the market. (H. A. Strauss, 1906.)

Popular prejudice and cheap fuel are largely responsible for the comparatively slow advancement of the gas engine art. High cost of fuel is forcing the adoption of gas power. (J. R. Bibbins, 1906.)

That the efficiency falls off on light loads, and because the producer is in an experimental stage, has deferred more general installation. (W. L. K., 1905.)

Because some makers have failed in making guarantees, has deferred installations. (Norman McCarty.) This has been true in some instances, but the most flagrant failures have been in general design and construction. (J. B. Klumpp, 1910.)

The builders of large gas engines (1,000 hp. and up) have demonstrated conclusively that their guarantees in fuel consumption and regulation are within reason. But the question of maintenance and its increased cost over steam, which in some cases exceeds the saving in fuel, robs the proposition, as a whole, of its golden hue. But, notwithstanding this condition, gas producers in connection with gas engines are possessed of real merit, and before the proposition is thrown to one side it deserves a thorough investigation. (H. M. Beardsley, 1906.)

Producers and Engines from Same Company.—Producers and gas engines should be bought from the same company, so that there will be no shifting of loads and responsibilities in case of failure to get guaranteed results. (R. N. Kimball, 1905.)

Relative Efficiency of Gas and Steam.—The actual running efficiencies, considering the load for which the station operates, are approximately the same between producer gas engines and compound condensing steam engines, and not quite so good as with a turbine plant using superheated steam. Operated under full load conditions, the gas producer plant is superior to either of the steam plants. The cost of a producer is larger per horse-power than that of either steam engine or steam turbine plant. (W. L. K.)

Fuel Consumption.—Gas engine builders to-day are making guarantees for large size units that are approximately as follows:

For full load	10,000	to	12,000	B. t. u.	per brake hp.
¾ "	17,000	"	13,000		"
½ "	13,000	"	15,000		"
¼ "	15,000	"	20,000		"

These figures are substantiated by various correspondents, although they vary somewhat in detail.

The average gas consumption per hp.-hr. at quarter, half, three-quarters, and full load on a few of the engines under test was as follows:

Size of engine hp.	B. t. u. in gas	Gas consumption at per cent. of full load 25	50	75	100
2	560.0	60.4	46.2	38.0	31.0
8	560.0	46.0	30.6	31.2	25.5
16	560.0	44.1	35.0	29.0	23.1
165	597.0	41.2	34.3	24.0	18.3
165	129.44	148.10	110.0	97.2	93.0
165	123.85	155.4	141.5	115.7	97.2
165	128.15	150.3	131.0	105.3	94.8

This shows that the gas consumption per hp.-hr. in the very small engines was very much in excess of that which was to be found in the larger engines.

If the composition of a gas is known, the air consumption necessary for explosion must necessarily be known. From this fact the B. t. u. available per explosion at full load is determined readily from the size of the cylinder. Now, if the composition of the gas that was used when the engine was tested is known, the performance of the engine with the gas at hand will be found to be very nearly in proportion to the ratio of the B. t. u. in the two equal portions of mixture at full load.

Efficiency.—Actual tests made on gas engines of various types gave efficiencies of engines running on half, three-quarters, and full load as follows:

Per cent. Full Load	Mech. Efficiency	Thermal Efficiency
50	65	12.7
75	70	20.5
100	78	23.7

These efficiencies were found while making runs at constant brake loads for periods of two hours. The engines showed an average heat value given up to jacket water and lost through exhaust, as follows:

Per cent. Of Load	Per cent. Heat Given Up to Jacket	Per cent. Heat Given To Exhaust and Radiation
50	21.75	58.68
75	29.1	44.7
100	38.7	28.3

Repairs.—The repairs on the gas engine plant during the year 1904 amounted to $0.00219 per kw.-hr. generated.

The repairs on steam plant during year 1904 amounted to $0.004451 per kw.-hr. generated.

Cost of Fuel.—The cost of fuel for gas engine plant per kw.-hr. was 0.679 of the cost of fuel per kw.-hr. with steam. (Philip F. Ballinger, 1905.)

Heating Value of Gases.—The several gases mentioned have approximately the following heating values: Natural gas, 1,000 B. t. u. per cu. ft.; manufactured coal gas, 625 B. t. u. per cu. ft.; producer gas 125 B. t. u. per cu. ft. With a gas engine requiring 12,500 B. t. u. per brake hp.-hr., the following quantities of gas would be required per hp.-hr.: With natural gas, 12.5 cu. ft.; with manufactured gas, 20 cu. ft.; with producer gas, 80 cu. ft., from which the cost per hp.-hr. for the first two kinds can be easily determined when the cost per thousand feet for gas is known. The manufacturers of producer gas apparatus claim to be able to furnish one brake horse-power per pound of coal used in the producer. Probably a safer estimate for plants of medium to large size would be 1.5 lb. of coal per hp.-hr. With this information one can easily determine the cost per hp.-hr. when the cost of coal is known. To the cost of producer gas power, as shown above, there should be added the cost of operating labor and maintenance of plant, which, however, would be comparatively small items. (S. J. Glass, 1907.)

Operation Cost.—Gas engines for producer gas will be more economical in operating expenses than the steam engine is likely to be within the next five years. The total expense, viz., operating expenses plus fixed charges, will depend upon how much energy is produced with a given engine, and as a gas engine costs more than a steam engine, fixed charges will be more per horse-power. (Henry L. Doherty, 1903.)

Efficiency.—A high-grade gas engine will show from 24 to 25 per cent. efficiency at full load; a steam engine of a similar character from 15 to 18 per cent.

A 450-kw. producer plant, using bituminous coal and Westinghouse engine, gives an average net plant efficiency of 13 per cent. at 2/3 load factor, and has given 15 per cent. efficiency under heavier load. The average steam plant operates under 10 per cent., probably from 7 to 8 per cent. A 40,000-kw. railway plant, in New York City, operating on 66 per cent. load factor, has given 10.3 per cent. efficiency.

"Vide" reports below on largest gas power plant in London compared with steam plants in vicinity doing same service.

OPERATING COSTS—1904.

LONDON METROPOLITAN BOROUGHS.

	Plant rating Kw.	Output sold Kw.-hr.	Ratio sold gen. per cent.	Load fac. per cent.
Average of 11 steam plants	2,799	2,991,500	83.9	17.25
Walthamstow	810	1,019,326	80.0	15.45
Saving per cent. (in favor of gas)	—	—	—	—
Operating expense items–per cent. of works cost (steam plants)	—	—	—	—
Operating expense items–per cent. of works cost (gas plants)	—	—	—	—

	Operating cost-cents per kw.-hr. generator					
	Fuel	Oil waste water	Labor	Total re-pairs	Works or operat-ing	Total inc. manage-ment
Average of 11 steam plants	0.597	0.059	0.214	0.218	1.088	1.41
Walthamstow	0.368	0.152	0.288	0.048	0.856	1.05
Saving per cent. (in favor of gas)	38.4+	++	−13.5	78.	21.5	25.
Operating expense items–per cent. of works cost (steam plants)	55	5.4	19.6	20	100	129
Operating expense items–per cent of works cost (gas plants)	43	17.8	33.6	5.6	100	123

Coal—anthracite; costs $6.75 per ton. (J. R. Bibbins, 1906).

Economy of Gas Plant Compared with Steam.—An approximate comparison of the relative efficiencies of steam and internal combustion-engines may be obtained from the table on page 119 of the "Preliminary Report on the Operations of the World's Fair Coal Testing Plant of the United States Geological Survey," which describes fourteen (14) tests, made on different kinds of coal, portions of each of the samples being used in a steam plant and portions of each in a gas plant, and showing an average fuel consumption in the steam plant of 4.27 lb. of dry coal per electrical hp.-hr., and in the gas plant 1.7 lb. of dry coal per electrical hp.-hr.

Gas vs. Gasoline.—Gas engines are preferable to gasoline engines, but it is a question of economy in fuel.

Gas vs. Oil.—Oil engines are probably more economical, due to price of fuel. However, in large plants producer gas and gas engines are the cheapest to operate and also the most satisfactory. (W. W. Fuller, 1906.)

Indicator Cards.—The way to determine whether a gas engine is doing its best duty is to indicate it as would be done in steam engine practice. Indicator cards will detect any variation in power obtained, and show time of ignition and relative compression and initial pressures. (J. B. Klumpp, 1910.)

Rough Test for Mixture.—Many gas engines have a small cock on cylinder head, which when opened will show the relative force of the explosion of the charge, and from this may be determined the best mixture. Some operators can tell by the sound of the suction when the proper mixture has been obtained. (J. R. Bibbins, 1905.)

REPAIRS AND MAINTENANCE.

Cost of Maintenance.—While there is no question as to the economy of the producer engine being far in excess of that of a reciprocating engine, we do not consider it possible at the present time to figure closely on the difference of maintenance, these items being such variable factors in either case. (R. D. Wood & Co., 1907.)

Relative Cost of Maintenance and Operation:

Reciprocating Engines	100.00
Steam Turbines	79.64
Reciprocating Engines and Steam Turbines	75.72
Producer-gas Engine Plant	50.67
Gas Engine and Steam Turbine	46.32

Extract from Stott: "Power Plant Economics"—American Institute of Electrical Engineers, January, 1906.

Owing to the recent development of the gas engine, and the consequent mistakes made in its design and construction, repairs have naturally been excessive, when compared with the well established reciprocating steam engine. The relatively high piston pressures and temperatures obtained in a gas engine were subjects that necessitated great detail study, and it was only through the experimental stage that these pressures and temperatures have been successfully handled. The modern gas engine may be well considered comparable in general maintenance costs with the steam engine of equal capacity. One of the reasons for this has been the precaution many manufacturers have taken to make their engines of such weight and strength as to be sure of their giving reliable service. (J. B. Klumpp, 1910.)

PARALLEL OPERATION.

Feasibility of Parallel Running.—Thorough investigation of the question indicates that parallel operation could be successfully secured by direct-connection of the generator and engine by means of a flexible coupling. (Henry L. Doherty, 1903.)

No trouble with parallel running. (W. B. Bloxham.)

Guarantees have been made by gas engine builders specifying no payments until successful parallel operation was accomplished. (A. L. Kimball, 1905.)

Two 500-hp. Westinghouse heavy duty gas engines of the horizontal, double-acting type are operating the entire urban and interurban system between Warren, Pa., and Jamestown, N. Y. Owing to the small number (3) of heavy (35-ton) interurban cars in service at any one time, the heavy grades and sharp curves, the variation of load on the engines is extremely violent, yet they are handling this load without any troubles from alternating-current parallel operation or other causes. The average expense for fuel is about 7 cents per car-hour. A dozen or more plants of from two to five units of the vertical, single-acting type are operating successfully in parallel on various classes of power service. (J. R. Bibbins.)

Results may be obtained equal to steam engines of different makes working in parallel. (A. E. Walden.)

The parallel operation of gas engines at this day is a certainty, either working in conjunction with each other, or with steam or water power.

This has been accomplished for both 25 and 60-cycle operation, and has been obtained through general improvement in design of engine, flywheel weights and diameters. (J. B. Klumpp, 1910.)

The regulation of a Diesel engine is such as to parallel with steam power. (Norman McCarty.)

Flywheels.—The function of a flywheel is to equalize the motion whenever the power communicated or the resistance to be overcome is variable. In one case where the flywheel is used to overcome a variable resistance. it may be considered a conservator of energy; in the other case the flywheel may be said to be a distributer of energy; consequently, as a regulator of motion for the gas or steam engines the weight and diameter of flywheel must depend upon the work and character of the machinery it is intended for, so that in proportioning a flywheel to a given engine, attention must be paid to many particular circumstances, rather than to any given rule. The effectiveness of the flywheel in steadying the motion of the engine depends upon the distance of the metal from the centre. For this reason the material of which the flywheel is composed should be concentrated as much as possible in the rim. The steadying action varies also as the square of the speed of the rim. Hence, within certain limits increasing the diameter saves weight. Considering the safe rim-feet per second, use following rule for finding the weight of a flywheel, having the size of cylinder, the diameter of the wheel and the revolutions per minute: First, multiply area of the piston by the length of stroke in feet. Multiply this product by the constant 12,000,000. Second, square the number of revolutions, multiply this by the diameter of the wheel in feet. Divide the first by the second and the quotient is the proper weight for the flywheel in pounds. (C. C. Gartland, 1906.)

AUXILIARY STANDBY.

Suction Plant.—A 100-hp. suction producer and gas engine plant could hardly be considered a quick starter, as it takes time to start up producer before gas is rich enough to operate the engine. (W. L. K., 1905.)

Combination Suction and Pressure Plant.—Combined suction and pressure plants give best results. (A. E. Walden.)

Plants with Gas Storage.—In power plants of all kinds, where there is sufficient gas storage, or an immediate gas supply, such as natural or city gas, gas engines are excellent for emergency units, as they can be gotten in operation in a few minutes. Where producers are used for gas generation it takes from ten minutes to half an hour to start from cold generators, while if they are banked gas can be made in a very few minutes. In several known cases where gas engines were installed as emergency units they have been used daily over the peak loads, or in continual operation, due to their ability to generate at such low operating costs (J. B. Klumpp, 1910.)

Points in favor of the gas engine are its quick starting from cold conditions, thereby being very efficient as a standby unit, and its efficiency as to fuel costs; but against these points will have to be balanced the increased first cost of the gas installation, building, and so forth. (T. H. Yawger, 1909.)

LUBRICATION AND OILS.

Cylinder Oil.—A good grade of engine oil (not valve oil) is found an excellent lubricant for gas engine cylinders. (C. C. Gartland, 1906.)

Flash Test:—A few years ago an oil of too high flash test could not be furnished to the manufacturers of gas engines, but very many of the oils on the market at present have a flash test not better than 380 deg. fahr., and these oils of low flash point deposit less carbon in the combustion chambers than did the heavier oils of a few years ago. Most of the gas engine oils on the market to-day are pure mineral, though large quantities of compounded gas engine oils are sold for use on stationary water cooled gas engines, generating as high as 250 hp.

These points are given to show that the question of writing the specifications for gas engine oil that will give just the oil that is needed for lubrication, to the exclusion of all others, is just as difficult as it is to write the specifications for a good steam cylinder oil. A pure mineral and well refined oil, having at from 380 to 400 deg. fahr. the same viscosity as neatsfoot oil at the temperature of steam will lubricate 9 out of every 10, and possibly a larger percentage of water cooled engines from 5 to 2,000 hp.

The question of lubrication is not dependent on the color, though a filtered oil would show any floating impurities quicker than black oil. (Florus R. Baxter, 1906.)

UTILIZATION OF WASTE HEAT.

Uses.—The jacket water of gas engines may be used for boiler feed water for boilers of producer plant or steam power plant (W. R. Collins, 1905), or for hot water heating systems, the water being further heated in specially constructed heaters, utilizing the exhaust of the gas engine for this purpose. (F. N. Jewett, 1905.)

Gain in Efficiency.—This has been successfully accomplished in several known instances, bringing the thermal efficiency of the installation up to above 50 per cent. (J. B. Klumpp, 1910.)

DIESEL OIL ENGINES.

Characteristics.—Diesel engines are internal combustion engines, using oil as a fuel, and compressing to such a pressure that combustion results from the high temperature obtained. These are used in many small electric light plants through the country—notably Jewett City, Conn., Mansfield, Mass., Provincetown, Mass. (Norman McCarty, 1905) South Norwalk, Conn.—see description, "Electrical Age," March, 1907. Diesel engine operating costs seem to compare favorably with high-grade Corliss engine figures. However, the cost of repairs, poor regulation, depreciation and unreliability fully offset any advantages gained. (G. H.—New York Edison Co., 1905.)

Cost of Operation.—Due to the very high thermal efficiency of the Diesel engine, as well as to the crude quality of the oil that can be used to operate it, the actual cost of the fuel per hp.-hr. when operating with this style of engine will be much less than any other form of power generation; but the cost of the Diesel engine (both first cost and cost of maintenance), the difficulty of getting started, the unreliability of its operation and its lack of the high-grade speed regulation of the steam engine, have prevented its general adoption. (Geo. Howe, 1906.)

Disadvantages.—The probable reasons why Diesel engines are not in more general use are:

(1) High initial cost.

(2) Greater complication than engines of the more familiar types.

(3) Trouble experienced on account of the unreliability of gas engines in general has probably prejudiced many engineers against internal-combustion engines of any type. (H. T. Hartman, 1906.)

SECTION IX.

District Steam Heating.

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SUCCESSFUL SYSTEMS.

Necessary Conditions.—A profitable heating business depends upon local conditions, such as climate, rate charged, amount of business, cost of coal, and last but not least on the amount of exhaust steam available. (Albert Lea Light & Power Co., 1901.) (F. N. Jewett; H. T. Hartman; N. Wallace; C. R. Maunsell; R. N. Kimball; H. C. Eddy; The Edison Electric Illuminating Co. of West Chester, Pa.; G. Wilbur Hubley; F. N. Jewett; American District Steam Co., 1905.)

Use of Live Steam.—How far district steam heating pays when you go beyond the amount of exhaust steam available, is governed entirely by local conditions. Great caution should be taken and the situation carefully studied before taking on new business to that extent. (F. N. Jewett; American District Steam Co.; N. Wallace; R. N. Kimball, 1905.)

Small Towns.—Whether the installation of the heating system in small towns having no day electric load would be a profitable investment is exceedingly doubtful, (H. T. Hartman, 1905), but under the most favorable local conditions, it might be. (F. N. Jewett; E. F. McCabe; American District Steam Co., 1905.)

Large Towns.—In any large city a system properly installed and properly managed should be a success. (J. B. Lukes; G. O. House; J. S. Lewis; G. W. Bryne; R. E. Richardson, 1906.)

Records.—To make a district heating plant a success, carefully compiled data and records should be kept, which fully set forth and bring out the important factors of operation, financial results, etc. This, plus a well designed system of mains and proper rates, will assure a profitable business. (American District Steam Co.; E. S. Kelly; C. R. Maunsell; J. A. Bendure; W. J. Green, 1906.)

HEATING SYSTEMS.

Steam vs. Hot Water.—Steam is favored by some for business districts and hot water for residence heating, (Home Light, Heat & Power Co., 1907), but the initial cost of a steam system is less than that of a hot water system, and the operation is much more satisfactory. Buildings piped for hot water system can use steam, while those piped for steam cannot use hot water without considerable expense. (L. R. Crawford; 1907.) Steam can be furnished to a very wide field of usages, not open to district hot water systems, such as swimming pools, and heating hot water supplies, (L. R. Crawford; G. N. Tidd; R. P. Bache; Walter Flint; the Edison Electric Illuminating Co., West Chester, Pa.; Home Light, Heat & Power Co.; H. C. Eddy, 1907), and can also be used in heaters to heat water for consumers hot water systems. (L. R. Crawford; G. N. Tidd; R. B. Bache; Walter Flint; Edison Electric Illuminating Co., West Chester, Pa.; Home Light, Heat & Power Co., 1907.)

Where there is a small heating load and plenty of available exhaust steam, a hot water system is best as it does away with back pressure on the engines, (G. N. Tidd, 1907), but whether a hot water system would prove successful where there is not enough exhaust steam to take care of the load, depends on local conditions and rates charged for service. (R. N. Kimball; B. J. Denman; F. N. Jewett; H. T. Hartman; American District Steam Co.; Fred W. C. Bailey; R. S. Wallace; R. H. Hadfield; G. N. Tidd, 1906.)

Steam vs. Hot Water Rates.—An advantage of a district steam system over a hot water system is that steam service can be measured by condensation meters, thus doing away with flat rates and making the consumers careful of its use. Hot water cannot be measured and flat rates must be charged, greatly increasing the cost of operation, as there is no incentive for economy by the consumer. There is also a greater loss of heat from the mains and depreciation of the system is greater. The necessary pumps increase the cost of operation. (H. C. Eddy, 1907.) Hot water systems are strongly defended by (D. F. McGee, 1904)..

Air Heating Systems.—All district steam consumers should be strongly urged to install in their buildings atmospheric heating systems, as the service is so much more satisfactory and economical than heat distribution by any other means. (Home Light, Heat & Power Co.; H. C. Eddy; Edison Electric Illuminating Co., West Chester, Pa.; N. A. Rollins; R. B. Bache, 1907.)

Competition of an electric district steam plant with a hydro-electric plant is possible providing the city is large enough. (H. T. Hartman, 1907.)

CONSTRUCTION.

Distance Limit.—The economical limit of distance for the transmission of steam depends altogether on the distribution and heating business. If the pipes are of sufficient size, the loss of pressure between the plant and the point where the first customers are supplied will be very slight even if the distance be several thousand feet. (Colorado Springs Electric Co.; American District Steam Co.; M. Wallace, 1905.)

Expansion.—Expansion joints and variators both serve their purpose equally well. The expansion joint in the long run will have a higher maintenance but as they take care of the expansion and contraction of a considerably longer section of pipe than a variator, fewer have to be installed. For this reason they are not suitable for a section of a system where frequent services are taken off. (Colorado Springs Electric Co.; American District Steam Co., 1905.) The number and location of traps on steam mains depends entirely on the local characteristics of each individual system. (American District Steam Co.; N. Wallace, 1905.)

Cost.—The cost per foot of different sizes of completed mains for district heating is impossible to estimate even approximately. In congested business districts with heavy street traffic and with a large number of conduits, pipes, and sewers already in the streets, the cost would be much heavier than in residence districts. (American District Steam Heating Co., 1908.)

Return of Condensation.—An installation for the return of condensation of a district steam system to the plant, is a most attractive proposition theoretically, but very seldom practicable, as the cost of the equipment is far too high for the benefit obtained in economy of operation. (H. T. Hartman, 1904.)

OPERATION.

Cost.—The operating costs of a combination electric light and heat system compare very favorably with the cost of operating either one as a separate business. (Albert Lea Light & Power Co.; Home Light, Heat & Power Co.; H. C. Eddy; L. R. Crawford; G. N. Tidd, 1907.)

Success of Exhaust Steam System.—The successful operation of a district heating system depends on the utilization of as much exhaust steam as possible. In a steam system exhaust steam gives much better operating results and better circulation due to its delivery into the mains in pulsating waves by the reciprocating engines. (L. R. Crawford; G. N. Tidd; R. P. Bache; Fred Leslie; Walter Flint; H. C. Eddy; Albert Lea Light & Power Co.; Home Light & Power Co.; H. C. Eddy; L. R. Crawford; G. N. Tidd, 1907.)

Exhaust vs. Live Steam.—The extent to which it is economical to supply exhaust steam for heating is determined very largely by the style of engines used. So long as the operating conditions do not make the cost of furnishing the exhaust steam exceed the cost of furnishing the same amount of live steam, everything being considered, it is advisable to use exhaust in preference to live steam. (American District Steam Co., 1905.)

Exhaust Between High- and Low-Pressure Cylinders.—It is entirely feasible to take exhaust steam for heating from betwen the high and low-pressure cylinders of a compound engine. (A. E. Walden, 1908.)

Back Pressure Turbines.—The turbines are being used by some plants exhausting against back pressure into a heating system. (H. E. Longwell, 1903.) (H. C. Eddy, 1906.)

Back Pressure and Steam Consumption.—The relation of the back pressure carried on engines to the steam consumption per hp-hr. varies according to the different makes of engine used. (H. C. Eddy; G. N. Tidd, 1907.)

Pressure Regulation.—The regulation of pressure at the plant should be taken care of by a pressure reducing valve in the direct steam connection. (American District Steam Co.; E. S. Kelly; C. R. Maunsell; J. A. Bendure; L. R. Crawford; W. J. Green; R. S. Wallace; R. H. Hadfield, 1906.) It is impossible to work out rules for certain pressures to be carried at certain temperatures due to the variations that will always exist in wind and humidity; demand is what determines the pressure. (E. S. Kelly; American District Steam Co.; C. R. Maunsell; J. A. Bendure; L. R. Crawford; W. J. Green; R. S. Wallace; R. H. Hadfield, 1906.) Some tests have been made to ascertain the relation of the average season demand to the maximum demand and some interesting daily load curves have been plotted in connection with this subject. (B. J. Denman, 1907.)

Heat in Steam.—Interesting statistics are the comparison of the heat units in one pound of steam generated and delivered from boilers, one pound reduced from one hundred pounds by a reducing valve and one pound of exhaust steam. (Geo. W. Richardson; Edison Electric Illuminating Co., West Chester, Pa.; G. Wilbur Hubley; F. N. Jewett; Geo. Howe; H. C. Hall; American District Steam Co., 1905.)

Operation of Vacuum System.—The successful operation of a vacuum district steam system depends on the elimination of all air leaks. This is accomplished best by having the air valves of each consumer's system frequently inspected to see that they have not been tampered with by the occupants of the building. (H. C. Hall; American District Steam Co.; H. T. Hartman; C. R. Maunsell, 1905.)

All Year Heating.—Some heating plants in a northern climate find it profitable to keep steam on all the year around. A neat business may be kept up during the summer supplying steam for hot water supplies for various purposes. It is also better for the mains, lessening the rust and preventing decay of the wood casing. (Emil W. Erick, 1909.)

Operation Charges.—Where exhaust steam is used certain portions of the power house expenses should be charged to the heating system. This should amount to all extra expenses for increased wages, fuel, supplies, etc., over and above what would be necessary for operating the electric end of the business separately. (B. J. Denman; Albert Lea Light & Power Co.; H. C. Eddy, 1907.)

RATES.

Determination of Rates.—Rates should be governed by the cost of producing and delivering steam to the consumers, and great care should be taken in calculating the amount of live steam, as the cost of producing it is much greater than that of exhaust (B. J. Denman, Edison Electric Illg. Co., West Chester, Pa.; H. C. Eddy, 1907). The amount consumers are willing to pay per year for Central Station heat, over the cost of running their own plants depends on the individual conditions and the personal characteristics of the customers served. (American District Steam Co.; H. T. Hartman; C. R. Maunsell, 1905.) The cost of fuel to the individual user should be taken into consideration in forming rates, and a sliding scale of rates is favored by some companies adopted to apply to various size consumers (American District Steam Co.; E. S. Kelly; C. R. Maunsell; J. A. Bendure; L. R. Crawford; W. J. Green; R. S. Wallace; R. H. Hadfield, 1906).

Choice of System of Charging.—The average opinion on methods of charging for steam favors the meter system. A comparison between that and flat rates is a hard matter to work out in general cases. (L. R. Crawford; G. N. Tidd; Home Light, Heat & Power Co.; H. C. Eddy; Edison Electric Illuminating Co. of West Chester, Pa., 1907.) Many steam heating companies have suffered greatly from the absence of any accurate means of measuring the consumption of customers. It has been found that no two customers will use the same amount of steam even under similar conditions. Heat is more easily wasted than any other commodity furnished by Public Service Corporations. The only equitable method of charging for heat is by condensation meters (American District Steam Co., 1905; H. C. Eddy; A. W. Zahm, 1906).

Some companies favor a readiness to serve charge system based on a combination of meter, and flat rate on square feet of radiation required by customer. (R. M. Kimball; Edison Electric Illuminating Co. of West Chester, Pa.; F. N. Jewett, 1905.)

METERS.

There is no steam meter both practical and satisfactory for measuring steam supplied to the consumers. The St. John or Sargent meters would do this work but their complicated construction and high cost prohibits their use. Meters for measuring the condensation of a consumer's system arrive at the same results and are satisfactory. (G. W. Richardson; The Edison Electric Illuminating Co. of West Chester, Pa.; C. F. Jewett; Colorado Springs Electric Co.; American District Steam Co.; R. N. Kimball; C. R. Maunsell, 1905; H. C. Eddy, A. W. Zahm, 1906.)

The condensation meter is the ideal method of charging for steam, but their use should be supplemented by frequent and careful inspection. (C. R. Maunsell, 1905.)

The amount of live steam put into steam mains to supplement the exhaust steam may be determined by a Venturi tube or by any one of the several makes of duplicating steam meters now on the market (A. Bement. American District Steam Co., 1905).

SECTION X.

Rotating Electrical Machinery.

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ALTERNATORS.

125-Cycle vs. 133-Cycle Machines, Line Drop.—Assuming that the 125 and 133-cycle machines are generating precisely the same voltage, there will be a greater loss in transmission at 133 cycles both in line and transformer loss than in the case of 125 cycles. Consequently the line drop in this case will be greater than that at 125 cycles. (E. P. Dillon; E. M. Tingley; E. P. Coles, 1904.)

125-Cycle Alternator Operating at 60 Cycles.—If it is possible to change the armature connections from a parallel to a series connection a 2,200-volt, 125-cycle alternator may be used as a 2,200-volt, 60-cycle machine by properly reducing the speed. Running at this reduced speed, however, the field current necessary to obtain 2,200 volts would possibly overheat the field and, in any event, the rating of the machine would have to be greatly reduced. If it were possible to rewind the armature with a little over twice the number of turns per coil as at present, the wire being of one-half the cross-section of the present winding, a 60-cycle, 2,200-volt machine of one-half the former rating would be obtained. (Wm. B. Jackson; M. C. Turpin; A. Peters, 1906.)

The Power Rating of a Three-Phase Alternator, Current and Voltage Being Given.—The power rating of a three-phase machine, whether the armature is connected Y or Δ, is found by taking the product of (*a*) the volts between the mains, (*b*) the current in one main and (*c*) the square root of 3. This assumes that the load of a generator is entirely non-inductive, in other words, that the power factor is unity, which is rarely the case in actual practice. The correction for this is made by multiplying the above result by the power factor of the load, which is generally expressed as cosine ϕ, ϕ being the angle of lag of current behind the voltage. In other words, if

$P =$ watts
$E =$ volts between lines
$I =$ amperes in any line, then
$P = E \times I \times \sqrt{3} \times \cos\phi$.

It is assumed, of course, that the load is balanced. (F. M. Farmer; M. C. Turpin, 1904.)

Maximum Station Load and Generator Rating.—In an extensive system, to insure continuity of service and at the same time not to make any unreasonable investment charge, the ratio between the rating of the generating equipment and the actual maximum demand will vary somewhat with conditions, such as the length of peak, the type of machines, the manner in which the machines have been loaded just before the peak, etc. If the machines are of different size, sufficient equipment should be provided to carry the maximum load with the largest unit out of service.

In most modern power plants with four or more units loaded with full load on the peak, it is not necessary to provide reserve equipment, as the overload capacity of machines will easily take care of the load in case of accident to one. As the number of units increases, the ratio may be reduced to less than unity, working all generators beyond rating on peaks. In large stations it will probably be necessary to carry load at times with two or more machines out of commission. At such times it is only necessary to have sufficient equipment to keep the temperature of the running machines within a safe limit, which is dependent primarily on the shape of the station load curve. (H. H. Barnes, Jr.; George Ross Green; B. J. Denman, 1907.)

Air Gaps, Change Under Running Conditions.—As a rule, the air gaps of modern alternators are practically constant throughout the range of load. In the largest type of machines it is, of course, necessary that the armature frame be exceedingly strong in order that the gap may be kept uniform. With a weak frame it is possible, and has actually happened, that the frame be drawn in against the revolving field. This is, of course, an inherent weakness in the frame. Under such conditions changes in the bearings or possibly heavy short circuit might bring the armature against the field even though the air gap was uniform all around the machine while standing. With loose bearings, the effort on the crank pin might be sufficient to throw the revolving field over towards the armature and, under certain conditions, the shortened air gap might allow the frame to spring over until the fields and frame came into contact.

Armature Slots and Insulation of 2,300-Volt, Three-Phase Machines.—The choice as to which type of armature slot is preferable for alternating-current machines lies between the partially closed slot and the open slot. The former gives higher efficiency and better regulation and the latter gives greater ease of repair. It is a question, therefore, of better performance on the one side as against ease of repair on the other. In open slots, coils may be insulated and dropped into place, while on the partially closed slots the coils must either be wound in place or else wound and insulated and then shoved through the slot and connected at each end. The open slot has, therefore, many advantages when quick repairs are considered. With regard to insulation for armatures of this type, formed coils, protected by oil cambric and protected from the iron of the armature frame by press-board slot insulation, are extremely serviceable. Formed coils, of course, demand the open slot. Inside, and next to the copper, is generally a double cotton covering treated with proper insulating compound. (George Ross Green; P. M. Lincoln, 1907.)

Two and Three-Phase Current from Combination of Single-Phase Machines.—It would seem to be entirely practicable to take two single-phase alternators, couple the shafts together and use them as a two-phase machine. Certain precautions with regard to wiring, connections and excitation must, of course, be observed. The arrangement, however, is cumbersome and therefore undesirable. (D. C. Jackson; H. A. Strauss; M. C. Turpin, 1906.)

The same, of course, applies to three-phase machines. It is possible that there would be, on account of the probable presence of third harmonics, a considerable circulating current throughout the winding which would cause heating and limit the capacity. The external power factor would be unaffected by such an arrangement, however. (W. F. Cox; John C. Parker, 1909.)

Regulation Test, Three-Phase Generator.—The regulation of a machine is the comparative variation in voltage, assuming constant speed and constant excitation, when full non-inductive load is taken off the machine.

The matter of making a regulation test for a three-phase generator, using the ordinary station instruments, is a very important one. It is necessary, of course, that the instruments be carefully calibrated and that careful attention be paid while reading them. The result is greatly affected by change in power factor of the load or by any unbalancing.

A simple method of calculating regulation is by plotting the curves, first of the open-circuit saturation characteristic of the machine and, secondly the short-circuit characteristic, in both cases using as abscissas the field excitation in amperes. It is absolutely important that the speed be carefully adjusted in making the saturation curve, but with regard to short-circuit curve a considerable variation in speed makes no appreciable error. Using the method given by the American Institute of Electrical Engineers, the regulation is then calculated by composition of vectors of the magnetomotive forces. (E. M. Tingley; F. M. Farmer; C. F. Haywood, 1904.)

Small Polyphase Generators and Unbalanced Load.—The question of installing single-phase or polyphase circuits in small stations depends somewhat upon whether there is any prospect of motor load. Three-phase generators are capable of being operated at 75 to 80 per cent. of their full rating as single-phase machines. It might, therefore, be advisable to operate the circuits single-phase. If, however, polyphase circuits are required, balance can be obtained by means of doubling the switches on each circuit, a careful use of which will keep the station fairly well balanced. It is frequently the regular practice in three-phase systems having a power load, to run all lighting circuits from one-phase and install automatic feed regulators on that phase. The problem necessarily varies with the size of the system and the type of load. It is sometimes found advisable to operate the incandescent lighting load from one-phase, and the arc load, made up of series alternating constant current arcs, from another phase, the motors, of course, making use of all three phases. Regulators on the incandescent circuit will give practically all the potential regulation necessary. Absolute load balance is not necessary. There seems to be a difference in opinion, some people having single-phase installation entirely in such cases and others insisting on the polyphase generator, with regard to future business.

There are systems in use which are operated separately. The problem of unbalancing, then, becomes of considerably more importance. For instance, one plant has two 200-kw. three-phase machines connected to one wheel shaft, one alternator supplying energy at 11,000 volts, for a distance of 12 miles to a single-phase load, only two legs being in use, the other alternator transmitting energy 10 miles at the same voltage as a part of a three-phase system. It would seem that, with the installation of proper regulating apparatus, it would be perfectly possible to operate both circuits on one machine at times of light load, the only difficulty being in obtaining satisfactory voltage regulation at the end of the three-phase line.

It would, therefore, probably be a good policy under most conditions where a new machine is necessary, to purchase a three-phase alternator and use it for single-phase lighting and whatever other load can be obtained. (Wagner Elec. Co.; C. F. Haywood; A. Peters; E. J. Bechtel; Seattle Elec. Co.; F. G. Proutt; E. F. McCabe, 1905.)

Gas Engines for Central Station Work.—The problem of operating 60-cycle alternators, direct connected to gas engines of large size is still an open question in many minds. As a matter of fact, however, there are numerous installations of such design in which the operation is reported to be very successful. Particularly is this so in plants of lower frequency, such as 25 cycles. Alternators in parallel driven by belt from gas engines are running satisfactorily, and it is thought that by means of a flexible coupling, any trouble due to variation in angular velocity will be practically eliminated. For latest advice on this important subject, see report of Gas Engine Committee for 1908 and 1909, N. E. L. A. (Henry L. Doherty, 1903.)

Direct-Connected Machines, A-C. and D-C., vs. Belted Units.—Assuming compound-condensing Corliss, or equally economical engine, and dynamo units of from 200 to 300-kw. rating, the question is, will the annual operating economy with direct-connected dynamos be sufficient to overcome the additional fixed charges over direct-belted units, the hours of service being 7,000 annually and the average load factor 40 per cent.

It is necessary to take into account economy in fuel, economy in size of building, etc. In the matter of fuel economy belted units may have the advantage, as the Corliss engine is extremely economical. Of course, when space is the limiting factor the direct-connected unit is to be preferred.

In units of over 300-kw. rating, belts should not be considered. The advantages of the belt-driven set are that it is cheaper, more flexible, can be moved and used elsewhere if necessary, the generator may be used as a motor if desired, and, also, in case the plant is changed, the belt-driven machine will probably be more saleable. The direct-connected machine has the advantage of less floor space, higher efficiency in larger sizes, and absence of belts, which are always a source of danger both to life and apparatus as well as a source of care on the part of the attendants. The low-speed generator is usually a better machine than the very high-speed machine of equal rating. (Edison Electric Illuminating Co. of West Chester Pa.; M. C. Turpin, 1904.)

With regard to precautions necessary in coupling and operating two direct-belted machines of the same design and make in multiple, assuming that alternators are somewhere near the same rating and are driven by units of proportionate size, there should be little trouble in paralleling the generators, care, of course, being taken to have the synchronizing devices properly connected. If each alternator has its own exciter it might be well to run the exciters in parallel, although this should not always be necessary. The engine must receive careful attention and the governing apparatus the same. If both alternators should be couoled to the same prime mover, good operation depends essentially upon exact adjustment of pulleys, belts and belt tension. Even where the pulleys are of exactly the same dimensions, a slight difference in belt thickness may cause heavy cross-currents. If machines are run from a jack shaft, energized by two or more engines, attention should be paid to correct design of flywheels. In case of light flywheels it may be well to resort to the European practice of synchronizing the engines themselves, so that the impulses may come together. As a general thing, high-speed engines will operate in parallel more successfully than low-speed engines will, on account of the larger angles between the poles.

In the case of belt or rope driven machines operating with direct-connected units with fluctuating railway load, certain conditions might throw the whole load on direct-connected set, especially if the belt should slip. A short circuit on the system would also, if it hung on for any length of time, make it necessary to open the switches on one or both of the generators on account of the possibility of throwing off the belt or burning up the direct-connected machine through overload. However, installations of a combined lighting and railway load, belted and direct-connected, have been operating in parallel for years with entire satisfaction. (C. W. Higgins; P. J. O'Neill, 1909.)

Paralleling with Overloaded Machines Running Below Speed.—It is entirely practicable to overload an incoming generator on a water rheostat, thus lowering its frequency, in order to synchronize it properly with a generator that is already overloaded and running below speed. In Germany, when the question of paralleling with overloaded machine first came up, water rheostats were commonly used, it being the belief at that time that the facility with which machines could be thrown together was increased by loading up the incoming generator in this way, the rheostat load also being used more or less for obtaining the proper speed. This expedient, however, should not be necessary. It would seem a better way out of the trouble to take care of speed by means of hand control of governor or throttle. (H. H. Barnes, Jr.; L. O. Veser; Ralph R. Laxton, 1905.)

Single-Phase Machine in Parallel with a Three-Phase Revolving Field Alternator.—If it is desired to operate single-phase alternators of the revolving armature, compound-wound type, in parallel with three-phase machine for supplying current to a single-phase of a three-phase load, the machines would without doubt operate together, although the compound winding on the single-phase machine had best be cut out in order that they may properly divide the load. This manner of operating, however, is of doubtful advantage in practice. (R. M. Stevenson, 1909.)

Resultant Armature Currents; Alternators in Parallel.—When two alternators are running in parallel and one is taken off the line, the current of the one remaining will generally be less than the sum of the amperes before cutting apart, even though the machines are properly designed for running together. Two alternators very seldom run in parallel with the exact excitation necessary to avoid small cross currents.

Alternators in Parallel, Effect of Automatically or Otherwise Shutting Off Steam on One of the Units.—Assuming two or more alternating-current generators feeding into a common busbar without automatic circuit opening devices, both machines being fully loaded, the effect of shutting off the steam from one unit for any reason would be a serious overload on the remaining unit. This would undoubtedly result in a drop in voltage and speed. The unit with its steam shut off would continue to revolve as a synchronous motor. There would also probably result an interchange of cross-current, the amount of which would depend upon the load and field excitation of the machine running as a motor. (R. F. Schuchardt; P. M. Lincoln, 1907.)

Speed Regulation of Prime Movers.—In order to obtain the best results in parallel driven units, it is necessary that the speed regulation, meaning the drop in speed from no load to full load, of both sets of prime movers be nearly alike in order that both machines may share their loads properly. It is not desirable, however, that the regulation be made too close for the same reason. In such case it would actually prohibit the satisfactory operation of machines. It will, therefore, be found that a closer regulation than four per cent. is generally undesirable. (P. M. Lincoln; M. C. Turpin; George Ross Green, 1907.)

Turbines and Reciprocating Sets in Parallel, Division of Load.—The division of load which fluctuates to a considerable extent between turbines and reciprocating units will be principally a question of the flywheel characteristics of the two units, in case the generators have similar characteristics as to governor regulation. Turbo-generators very frequently have large flywheel capacity and do not quickly follow the change in the low-speed engine conditions, due to the great inertia of the turbine field, etc. Also in many instances the speed regulation of the reciprocating engine is considerably lower than that of a turbine. In consequence it may happen that a turbo-unit with great inertia and good speed regulation may be operated in parallel with reciprocating units having a smaller inertia and with much poorer speed regulation. In such a case, the turbine will take the fluctuations of the load to a considerable extent. If, however, the turbine unit were replaced by a reciprocating unit having similar inertia and speed characteristics, the latter should also take the fluctuations in a similar manner.

With regard to heavy cross-currents between turbine and reciprocating units at times of overload or open circuit, it might be mentioned that in case of two large plants operating in parallel, one engine, the other turbine driven, no serious troubles due to cross-currents between turbines and reciprocating units have been noticed. (H. H. Barnes, Jr.; Westinghouse Elec. & Mfg. Co.; Charlestown Consolidated Railways, Gas and Electric Co., 1905.)

Alternators in Parallel in Small Stations.—The problem frequently comes up to operators of a small station, are not the advantages of parallel operation of units more than offset by the increased care and attention required. A divergence of views is here noted, but on the whole the advantages of parallel operation seem to be fully appreciated and adopted by most small stations. If the alternators are direct-coupled, or each belted to an independent engine, parallel operation makes it possible to get very much more economical engine performance, as the load can then be shifted and divided equally, requiring less generating capacity for a given load on the station. In the large majority of properly designed small and medium sized plants, parallel operation of a limited number of units requires no additional care, and is highly desirable from the standpoint of economic operation, reliability of service, and investment required for a given load. (Charles G. Bell; H. A. Hampton; P. Junkersfeld; Edison Electric Illuminating Co. of Boston, 1903.)

Paralleling Plants Over Long Transmission Lines.—For an example under this heading, the reference may be had to an article on "The Influence of the Line on the Parallel Operation of Synchronous Motors," in the "Electrical World," June, 1904. Another excellent article is "Some Practical Experiences in the Operation of Many Power Plants in Parallel," by R. F. Hayward, See Transactions of the International Electric Congress, at St. Louis, in 1904, volume II, page 443. (C. W. Higgins; A. R. Cheyney, 1909.)

Alternators in Parallel, Open Field Circuit.—If the field circuit of an alternating-current generator, operating in parallel with a number of generators, were to be opened accidentally it is necessary for operator to open main switch on that particular generator immediately. The armature under this condition is practically short-circuited across the bus and the current is only limited by the impedance of the armature itself. If this current were allowed to exist for any length of time the armature would be seriously damaged through overheating. (D. W. Roper; George D. Barnard; A. Herz, 1909.)

Breaking the Field Circuits of Alternators.—In taking a generator out of service, the question has arisen as to how low it is customary to reduce the voltage before opening the field circuit. Field break switches are generally equipped with discharge resistances. It is, of course, advisable to lower the voltage the full extent of the rheostat before opening the field circuit. The arrangement of the main field rheostat is not entirely designed with a view to caring for this particular piece of operation. Most rheostats, however, will probably give a voltage of from 15 to 20 per cent. below normal with maximum resistance in circuit. With the discharge resistance the increase in voltage across the field terminals, due to inductive discharge, is reduced to a minimum. (F. C. Sargent; B. E. Morrows; P. M. Lincoln; George Ross Green, 1907.)

Inductor-Type Generators vs. Revolving Field Type.—If both machines are built for the same inherent regulation, there should be no particular advantage of one over the other. On inductive load, however, the inductor type of generator seems to be frequently unable to maintain voltage. In the inductor generator the armature magnetism does not reverse, and the armature coil is subject to about one-half the variation in magnetism that is usual with the rotating field type. Therefore, for equal weight of active material, the machine should have twice as many armature conductors as the rotating field type, or, if the number of armature conductors is made the same, the induction must be practically doubled in the inductor-type, consequently with a great increase in the amount of material. In order to keep the weight of the inductor-type down to a reasonable figure, it has been the practice of some makers to adopt the middle course in design. Machines built on such lines would have relatively more armature conductors than the rotating field type and would have somewhat poorer inherent regulation on both non-inductive and inductive loads. Also, to lessen the weight, the inductor machines are frequently worked much nearer to saturation than are the rotating field type, and therefore in many cases have not the margin for holding up voltage on severe inductive loads.

Tirrill Regulator and Inductive Load.—With generating units of 1,000-kw. rating, Tirrill regulators and ample copper in feeders, it is asked how large sizes of single-phase squirrel cage motors can be used without seriously affecting the lighting regulation. The load on the generators is mixed lighting and power, but no lamps are installed on the power feeders. The installations of large single-phase motors in any system, or, in fact, polyphase motors of capacity at all comparable in size to that of the generating unit, is a source at times of considerable annoyance to the lighting customers. The installation of Tirrill regulators will help considerably in providing a uniform voltage although it is impossible to avoid the flickering of the lights whenever these large motors are thrown on. In many large installations a five horse-power single-phase motor, or possibly a seven and a half horse-power, is the largest that is allowed, although this is possibly as much on account of unbalance in the circuits as on account of interfering with the quality of the light. Under certain conditions, however, large size single-phase motors can be used. (Edward Peterson; M. C. Turpin; R. H. Garrison; John J. Gaffney; Wagner Electric & Mfg. Co., 1907.)

Allowable Voltage Variation.—With 60-cycle, three-phase, three-wire generators, delivering current to arc lamps and motors to an amount not exceeding one-half the total output, the balance, consisting of straight incandescent lighting, the maximum allowable voltage variation would depend on conditions. The voltage variation on lighting circuits is not of such importance in the day time as it is after dark. Gradual variation of voltage, therefore, if it does not exceed, say, 5 per cent., and if precautions are taken against frequent variations of voltage during the hours of darkness, may be allowed. After dark 2 per cent. is the maximum allowable limit. The practice of the largest stations and of the smaller stations with regard to this matter is naturally somewhat different. (H. W. Peck; W. G. Clayton, 1909.)

Limits of Voltage Controlling Main Field Rheostat.—It is occasionally necessary to have a field rheostat installed so that the normal voltage may be reduced to one-half if required. This may be for several reasons, in order to perfect the adjustment of the voltage regulators, to assist in drying out coils after installation, or for evaporating moisture in connection with coils which have been exposed to dampness. It is also desirable to have sufficient range in case the prime mover should suddenly speed up beyond normal limits. Under such conditions, unless the voltage were held down, considerable damage would be possible. (H. H. Barnes, Jr.; B. E. Morrow, 1907.)

Installation of a Small Unit to Care for Periods of Low Load.—Whether or not it is advisable to install a small generator to care for the long hours of operation at light load would depend upon circumstances in every case. It will probably result in a large saving of fuel and wear and tear in many installations if a small unit is installed. It is good practice in any station to have two or three units, and in most cases it is desirable to have units of one size. Under this plan the station can operate at a fair economy under light load, and in case of breakdown all or most of the load can be cared for by the balance of equipment. In this connection it will be remembered that a Corliss condensing engine of medium size will consume about 18 pounds of steam per horse-power at full load, while at quarter load the consumption will be between 45 and 50 pounds. If a small engine were to carry the light loads the steam consumption would be in the neighborhood of about 22 pounds per hp-hr. (Toledo Railway & Lighting Co.; B. F. Goodrich Co.; C. W. Humphrey, 1904.)

Grounding the Frames of Generators.—It is considered the best practice to ground the frame of any generator of a potential sufficiently high to be dangerous to life. The same applies to other high voltage apparatus such as transformers, etc. The matter of whether or not a special ground wire is necessary in case of large alternators whose frames are heavily bolted down to massive concrete foundations has not been touched upon at length. (United Electric Light Co.; J. F. Whittlesey; C. E. Skinner, 1907.)

Repairs to Alternators.—In case of a damaged coil in the armature of an alternating-current generator, the question sometimes arises whether it is necessary to remove the defective coil entirely, or whether the machine can be operated for a short length of time by cutting it out and bridging the adjoining coils. As a rule there is very little choice in the matter. The damaged coil would be liable to heat and injure the good coils adjacent to it. Of course, if the damaged coil has merely been damaged by grounding and its windings are free from short-circuited turns, it might be left in the machine for a short length of time. As a rule, however, it is necessary first to remove the coil entirely and then replace by a new coil before satisfactory operation can be accomplished. (George B. Lander; L. E. Watson; B. A. Schak, 1904.)

New Machine Does not Generate—Location of Defective Coils.—The locating of a defective coil, in case a new machine does not generate properly may be accomplished in several ways. Run the machine with a low field and feel the various coils from time to time. The defective coil will soon begin to heat up under such treatment. If not assured that the field circuit is all right it may be well to take the drop of potential across each one of the field spools and see if they are practically alike. It is possible that some of the fields are short-circuited and are producing no magnetism. Ring out the armature connections at the three terminals and see if there is a circuit between each pair. Test the polarity of the field by means of a compass and see if it is alternately north and south. As a rule the locating of such trouble is not very difficult. (P. M. Lincoln; M. C. Turpin, 1907.)

Arcing Between Segments of Commutator on Alternating-Current Generator.—Arcing between segments of commutator on an alternating-current compounded generator can arise from several causes, dust and dirt, small particles of copper, poor excitation in compound windings, improper adjustment of brushes, loose brushes, overloaded generator, sudden changes in load and also variations in power factor. (A. Peters; B. A. Schak; C. W. Higgins; F. W. C. Bailey, 1906.)

DIRECT CURRENT GENERATORS.

Flat Commutators.—The causes of flat commutators are several in number, each having its own remedy. (1) Poor material, causing unequal wear on the commutator. Remedy:—Turn down commutator as trouble develops or replace with new commutator. (2) Commutator imperfectly baked in building causing it to soften as it heats up under load. Centrifugal force may then further injure the commutator. Remedy:—Take off commutator, bake it, tighten up thoroughly and turn in lathe. (3) High or low segments in commutator, due to injuries in handling, imperfect workmanship or inferior material. Remedy:—File down high bar or turn up commutator in place. If segments are loose the commutator will have to be removed and repaired. Other causes are vibration, open circuit in armature, high mica, soft copper, short-circuited coil in armature. An open circuit is easily detected by the burned bars. The cause of vibration if it is excessive should be removed. Flat spots due to high mica or soft copper may be corrected by turning down the commutator or grinding same. Still other causes are uneven brush tension, bent shaft, worn bearings, continuous sparking, etc. Remedy:—Keep brushes even, bearings lined up, turn off commutator if necessary and go over it occasionally with sandpaper to keep it smooth. (John O. Montignani; Robert L. Stewart; G. D. Gratton, 1909.)

Life of Commutator.—The working life of a 125-volt, 300-kw., moderate speed, direct-current commutator depends almost entirely upon the care and attention given it. Presuming that the machine is of first-class make and proper care is given to commutator the life should be at least 10 years. A set of carbon brushes should last from 6 months to 1 year. Machines of moderate size have frequently operated for years without being turned down and a new set of brushes occasionally lasts for two or three years. As above, the commutators must be well cared for and occasionally slightly lubricated. (Charlestown Consolidated Railway, Gas & Electric Co.; Augusta Railway & Electric Co.; Fred M. Lege, Jr., 1905.)

Commutator Lubricants.—The matter of the proper lubricant for a commutator is very frequently brought to the attention of those in charge of machines. It is important that whatever is used be used in moderation and that immediately after lubricating the commutator should be carefully wiped down to remove any excess of lubricant and whatever carbon dust may have been loosened up by its application. A dirty commutator is cleaned while out of service with a very light application of coal oil on rag, care being taken to wipe dry immediately after applying. There are several commutator compounds manufactured, consisting probably in main of graphite and paraffin wax. A light engine oil occasionally applied with a raw silk wiper or a strong piece of ticking gives good results if not used in too large quantities. Sperm oil is an excellent commutator lubricant which should be used frequently but in small quantities. Vaseline is probably the most universally used of all commutator compounds. If this is applied carefully and regularly excellent results can be obtained and the commutator be given the proper bronze finish of which careful dynamo men are so proud. Very little lubrication is necessary in any case unless the brushes become noisy. (L. E. Watson; E. P. Dillon; A. Peters; George L. Colgate; M. C. Turpin, 1904.)

Maximum Safe Unbalancing on a Three-Wire Dynamo.—Machines of this class should be balanced exactly whenever possible. They have, however, frequently been observed to operate at 25 per cent. unbalance without any trouble. (George L. Colgate; W. F. Kingan, 1904.)

550-Volt Generator Operated at 250-Volts.—The experiment of operating a 550-volt, compound-wound machine on an Edison 125-250-volt, three-wire system has been tried several times with entire success. It is necessary to completely short-circuit or cut out the compound winding and it is also necessary that sufficient rheostat be supplied to control the machine at lower voltage. It may also be necessary under certain conditions to have the machine operated at less than normal speed. In case of emergency almost anything has to be done in order to insure continuity of service. Under these conditions the above machine might be run temporarily as a 250-volt generator, but it would be inefficient and its capacity would be greatly reduced. Excessive armature reaction would probably result in considerable sparking. It may be necessary to connect the shunt field coils in parallel and separately excite the machine from the 250-volt bus. Under this latter condition, it is reported that a machine was satisfactorily operated at 140 per cent. over its ampere rating. (H. D. Larrabee; W. F. Oviatt; Edison Electric Illuminating Co. of West Chester; L. L. Elden; Wm. B. Jackson; M. C. Turpin, 1906.)

Compound vs. Shunt Generators, Water-Power Installation, No Governor.—As to which would be most satisfactory under the above conditions, the shunt or the compound machine, experience with any machine running from an ungoverned water wheel would lead to the conclusion that a shunt-wound machine would give about as good regulation as a compound. If machines were operated in parallel it would probably be safer. However, a compound dynamo should have some advantage over a shunt machine under conditions where an increase of load would cause a drop in speed. If, however, the several machines are operating in parallel and the various wheels driving them will not regulate together serious difficulties will possibly result if compound machines are used. (George B. Lander; W. S. Barstow; Edison Electric Illuminating Co. of Boston, 1903.)

Shunt vs. Compound Dynamo for the Edison Three-Wire System.—The reasons for adopting the shunt dynamo as the standard for use in connection with Edison three-wire-systems is primarily on account of the greater simplicity in switching arrangements necessary for throwing machines in multiple. Compound wound generators are usually employed in plants having wide and frequent fluctuations and in small installations having but occasional switchboard attendance. In central lighting stations of the Edison three-wire systems the load is generally steady, increasing and decreasing gradually and evenly. Loads of this character are easily taken care of by the operator who is in constant attendance. For such work the shunt-wound machine is more desirable than the compound-wound dynamo with the accompanying equalizing cables and buses, the equipment of which adds to the first cost of the plant and is unnecessary in handling usual Edison loads. Compound-wound generators bring in the factor of load distribution when paralleling and in some instances have been known to interchange load to such an extent that another machine connected to the same bus has been caused to run as a series motor and has then run away. (A. Peters; Louis I. Porter; George L. Colgate; David A. Beaman, 1904.)

Compound Machines vs. Shunt for Substation Work.—In both railway and power work compound-wound generators are of advantage in maintaining the proper potential on the system when the load fluctuates considerably. Shunt-wound generators are preferable for lighting, as the instantaneous changes in load are small and the machines are simpler to manage in case of short circuits, etc. (H. A. Strauss; Chas. W. Stone, 1906.)

125-Volt vs. 250-Volt Machines in the Edison Three-Wire System.—With regard to the practice of using 125-volt sets exclusively, or 250-volt single units, operated in connection with balancer sets, either two or three units, modern practice in large stations is to use 250-volt machines connected to the outside of the system with two or more 125-volt machines and possibly a battery to care for the greatest unbalance that may occur. Before the use of batteries became general one objection to a 250-volt unit was that in case of heavy short-circuits between the positive and neutral conductors the 125-volt balancer sets might burn out and thus allow the potential of the 250-volt machine to exist between the negative and neutral. With 125-volt units this is impossible. (J. H. Hallberg; J. Manley; A. Peters; Wm. R. Gardner, 1904.)

Compound Machines of Widely Different Ratings in Multiple.—The operation of compound machines in multiple depends altogether upon the prime mover and the compounding curve of the machine itself, and should cause no trouble once the machines have been adjusted by means of properly shunting the series coils of the machines the voltage of which tends to rise with increased load. A sufficient approach to uniformity of compounding may be reached which will enable machines to divide the load automatically under any reasonable variation of station output. Machines of 1,000 and 500-kw. rating have been operated in parallel with perfect success, one being a Siemens and Halske and another a General Electric machine.

In order that compound machines of different size may properly divide their load when connected to a common bus bar, it is necessary, after adjusting all machines to the same degree of compounding when driven at proper speed, to adjust the resistance of each series field circuit (by inserting cable in series if necessary) inversely as the rating of the machine, *i.e.*, with one machine as a standard and requiring no change, another machine with half the rating should have twice as much resistance in its series circuit. In every case an equalizer should be used.

If machines are thrown in parallel without first closing the equalizer switch the result depends largely upon the difference in regulation. Any change in load or speed conditions with machines operating without an equalizer offers a chance of one machine feeding back through the series field of the other and thus reversing the second machine, causing a very severe short circuit. (G. B. Leland, 1903; Wm. R. Gardener; A. Peters; F. W. Bullock; John A. Wilson; J. Manley; F. M. Farmer, 1904; A. M. Wilson; P. M. Lincoln; M. C. Turpin; F. D. Sampson; Geo. M. Tidd; E. F. Smith; D. C. Jackson, 1906.)

Equalizing Connections on the Negative for Railway Purposes.—It has been customary in the past to put the series winding of compound-wound direct-current railway generators on the line side. The reason for this practice has usually been traceable to the protection from lightning that the series coil gives, being as it is in this case between the armature winding and the line. How much protection from lightning this arrangement gives is problematical. Many modern stations are now equalizing in the negative, which makes it possible to run the equalizing bus at low potential from ground, and makes it safe to work around machines when equalizing switch is closed. In these systems equalizing switches are always kept closed. A simple switchboard arrangement is thus made possible. (P. M. Lincoln, 1907; A. R. Cheyney, 1910.)

Reversal of Polarity in Direct-Current Machines.—Direct-current machines may be reversed in polarity from a number of causes. Short circuit, open circuit, suddenly discharging field, and an abnormal armature reaction. due to short circuit or suddenly interrupted circuit may cause this condition. Reversal may also be caused by lightning discharge, mistakes in switching, imperfect equalizing connections, or failure to close equalizing switch. Mistakes in connecting up a machine after having it apart for repairs may also cause this trouble. (George B. Lander; Wm. R. Gardener; Geo. L. Colgate; F. W. Bullock; Edison Electric Illuminating Co. of West Chester, Pa., 1904.)

Loss of Magnetism.—Magnetism may be lost through open circuit in field coils, lightning, reversed connections, the earth's magnetism or proximity to another machine. The generators sometimes appear to lose their fields when such is not the case, the trouble being found in loose connections, etc. Residual magnetism when weak may be destroyed by vibration. A heavy short circuit when the brushes are given a forward lead may also have a similar effect. Allowing a machine to stand idle for a long time will sometimes result in a similar loss of magnetism. The same occurrence has also been noticed on suddenly switching off a heavy load and simultaneously opening the field circuit when the machine is hot from long run. (Wm. R. Gardener; L. E. Watson; Edison Electric Illuminating Co. of West Chester, Pa.; George L. Colgate; F. W. Bullock; C. F. Haywood, 1904.)

Grounds and Short Circuits on Direct-Current Machinery.—In a small plant which cannot afford a laboratory equipment it is frequently desired to know what is the best method to locate short circuits or grounds in armatures or fields of direct-current motors. Very many tests can be conducted, providing a source of current is available with a single voltmeter. A magneto may also be used. In bar-to-bar test on armatures for open or short-circuit, a galvanometer or low reading voltmeter is desirable but if this is not at hand the test may be performed very satisfactorily by using a telephone receiver in place of the galvanometer. A lamp cord with two free terminals which allows the lamp to light up under closed circuit is extremely useful. A ground can thus be indicated by the lamp.

One of the simplest ways to locate short circuits in the armature of a generator or motor is to drive machine as a generator, separately exciting the fields, beginning with a low excitation and increasing until you can smell the burning insulation and then shutting down and ascertaining by feeling the coils where the short circuits are. If the short circuit is in the commutator it may be necessary to disconnect entirely the commutator from the armature winding. The drop of potential method is applicable to short-circuited fields, and, in a measure, can be used to locate short circuit in armature winding. (New York Edison Co.; W. F. Kingan; L. J. Lisberger; G. W. Hubley; Louis I. Porter; J. Manley; E. P. Coles, 1904.)

Ring Armature, Defective Coil, Remedy.—In case a ring armature contains a defective coil and it is necessary to make temporary repairs, these may be accomplished by open-circuiting the defective coil and putting a jumper around it, or the coil may be disconnected from the commutator and taped up securely and the commutator bars to which the damaged coil was connected short-circuited. (J. A. Lane; P. M. Lincoln; George Ross Green, 1907.)

ARC MACHINERY.

Motor-Driven Arc Machines: Economy.—For plants of 200 lamps and under a series alternating arc system is cheaper than motor-driven arc machines and also for larger plants it furnishes an alternative worthy of consideration. Special conditions, however, have much to do with this matter. (Sherbrooke Gas and Water Company, 1903.)

Under certain conditions the use of motor-driven arc machines is advisable. Assuming that direct-current series arc lighting is required, then the cost per kw-hr. at the arc lamp switchboard from motor-driven arc machines must be enough lower than when driven from small engines or line shafting to allow ample margin for interest and depreciation on extra investment required. In general, with long time contracts stipulating direct current and with arc load less than from 30 to 35 per cent. of the total load of the station, motor-driven arc machines may prove an economical arrangement. (P. Junkersfeld, 1903.)

There is no advantage in the motor-driven set where arc machines are directly driven by the engines without the intervention of countershafts. With the introduction of countershafts for driving a number of machines, motor-driven sets become preferable and in many cases more economical. From the standpoint of insurance of service the motor-driven sets are the most reliable. There is no question that the motor-driven set entails higher first cost, but the results obtained more than offset this, assuming long service. (The Edison Electric Illuminating Co. of Boston, 1903.)

The efficiency of drive of motor-generator sets is approximately 95 per cent. The efficiency of drive of the belt-driven arc machine including countershaft will not exceed 85 per cent. The first cost of the motor drive is much higher than that of the belt drive. The great advantage, however, lies in the great saving of floor space and in the fact that the arc machine can be located in substations at such a point as will give the most economical distribution of conduits and cables. (H. G. Stott, 1903.)

Very frequently the replacement of belt-driven arc machinery by motor-generator sets means the operation of the arc lighting system from a central station of high efficiency and the possible dismantlement of a high-pressure station should be given proper credit.

Wood Arc-Dynamo Regulator.—The current of a Wood (Fort Wayne) series arc light machine is maintained at a constant value by means of an electro-mechanical regulator consisting of a magnet, friction wheels and a brush-shifting device, all of which are mounted on the frame of the machine on commutator end. The machine is equipped with two sets of brushes which are placed so that they incline at a slight angle toward each other, and can be moved to or from each other. The main current of the machine passes through the magnet and attracts the armature, which attraction is opposed by a spring. Upon being raised, the armature moves a lever, which in turn engages the friction wheels which actuate by means of a belted pulley, the brush-shifting device moving brushes to or from each other as the armature is raised or lowered. If the current exceeds its normal value, the lever is moved upward and the brushes are nearer together and in a nearly vertical position, thus decreasing the voltage, while if the current decreases, the lever is lowered and the brushes are moved from each other, and in a nearly horizontal position when the voltage is increased. (M. C. Turpin; J. Manley, 1904.)

EXCITERS.

Shunt- and Compound-Wound Exciters.—If a Tirrill regulator is used, shunt-wound exciters are much to be preferred. Shunt-wound exciters have also some advantages when the exciting system is backed up by a storage battery as it is possible for compound-wound machines to reverse under certain conditions. On the other hand compound exciters are frequently desirable on account of their better regulation.

Exciter Rating.—The ratio of exciter rating to that of alternator depends upon conditions. For large-size, low-frequency high-speed alternators such as turbines, ½ per cent. of the rating of the alternator is ample for excitation. In other cases the exciting power may be as high as 2 or 3 per cent. of the alternator rating. (P. M. Lincoln, 1906.)

The size of exciter required depends in every case on the size and characteristics of the alternator to be excited, and upon the power-factor of the load. In a 1,000-kw., 60-cycle unit operated at 100 rev. per min., the exciting current exceeded 3 per cent. at unity power-factor, full load. In a 2,000-kw. machine of somewhat closer regulation the excitation amounted to less than 2.5 per cent., while in steam turbines owing to their high speed, the excitation is less than 1 per cent. of the total output of the alternator. (Philadelphia Electric Company, 1906.)

Motor-Driven vs. Engine-Driven Exciters.—An induction motor-driven exciter is very advisable for exciting alternating-current generators. Should it be used, however, either an engine-driven exciter set or a small exciter battery should also be installed, as otherwise it would be impossible to start up after a shut-down. (F. G. Proutt, 1905.)

The cost of operating a motor-driven exciter is practically one-half the cost of operating an engine-driven exciter, and the maintenance cost of the motor-driven set is also less than that of the engine-driven set. Therefore, it would seem advisable in many cases to use induction motor-driven sets. Practically the only exception would be in cases where the lines outside of the station are subject to very frequent and heavy short circuits which would be liable to cause a shut down of the exciter and therefore of the system. (J. B. Whitaker, 1905.)

If a station has a motor-driven exciter equipment without a storage battery as an auxiliary, an induction motor-generator for excitation would have some advantage over a synchronous motor-generator, as in the case of severe disturbances to the system, induction-motors would be less likely to drop out of step and shut down the station. (Edison Electric Illuminating Co. of Boston, 1905.)

Under average conditions the motor-driven exciter is more economical than the engine-driven exciter even although the best possible use is made of the exhaust from the engine-driven unit. The electric-driven set is also more convenient and requires less attention and repairs. As the entire operation of the station, however, depends directly upon the continuity of excitation, a large number of very important stations use either steam-driven or water-wheel-driven exciters as they are entirely independent of the main generator and are more reliable in case of trouble on the alternating-current lines.

Speed Variation and Loss of Motor-Driven Exciters.—If an alternator is excited from a motor-driven exciter operated with current from the alternator there is a frequency below which the machine will lose its excitation. This speed may, however, be much below the normal speed of operation. If the speed of the alternator is maintained at normal but an excessively heavy alternating-current load is thrown on it, there may occur a drop in alternating-current voltage sufficient to allow the motor-driven exciter to fall out of step, in which case the alternator will also lose its excitation without dropping far below normal speed. (Stone and Webster Engineering Corporation; Sydney Hosmer, 1908.)

SYNCHRONOUS CONVERTERS.

Relative Efficiency and Cost of Synchronous Converters, and Induction and Synchronous Motor Sets.—The cost is affected to a certain extent by the frequency. At 25 cycles, for instance, the converter, for a given cost, should have at least as great an output as a generator of the motor-generator set. The efficiency of the converter would be probably 2 per cent. greater than that of the generator at full load, and from 2 to 4 per cent. at one-half load. It then remains to compare the cost and efficiency of a high-voltage synchronous or an induction motor with that of the lowering transformers. Assuming the cost of the synchronous and induction motors and likewise the efficiency as practically the same, the cost of the motors will be considerably higher than that of the lowering transformers, perhaps even two or three times as great. Therefore, the combined cost of the motor-generator set should be considerably greater than that of the converter set with equally good operating machines. Efficiencies of the synchronous or induction motor will usually be from 3 to 5 per cent. lower than that of the lowering transformers. Therefore, the efficiency of the motor-generator unit should be from 5 to 7 per cent. lower than that of the converter with lowering transformers, and the difference may be even greater in small units. In the case of 60-cycle synchronous converters the differences will not be so great. The efficiency of a 60-cycle converter will be possibly equal to or even lower than that of the direct-current generator of the motor-generator set. On the other hand, the efficiency of the 60-cycle synchronous or induction motor may be slightly lower than in the case of a 25-cycle unit. As the transformer efficiency will not be reduced the same amount, the combined efficiency of the 60-cycle motor-generator will be slightly lower than that of the 25-cycle motor generator set and will be from 3 to 6 per cent. lower than that of the 60-cycle converter set. (Westinghouse Electric and Manufacturing Co., 1905.)

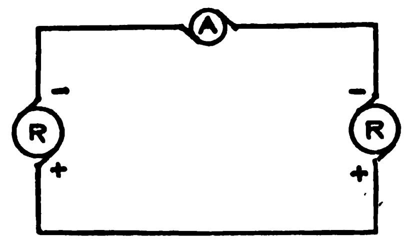
Induction Motor Sets, Synchronous Motor Sets, or Synchronous Converters in Connection with Short Circuits on the Direct-Current Mains of Edison System.—In connection with a 60-cycle alternating-current system supplying direct-current to an underground Edison three-wire system through substations, the question has arisen as to what type of machine will cause the least trouble in the case of a short-circuit on the direct-current system.

The converter, on account of its liability to flash over and because it furnishes a direct connection between the alternating-current station and the direct-current system, in case of the above short-circuit, has no advantage over the motor-generator sets, in fact, is considerably at a disadvantage in comparison with them. The question is, then, between the synchronous motor and the induction motor. The induction motor-driven sets are probably preferable for the larger systems while the induction motor generator would sometimes be advantageously used in the smaller stations. (W. A. Rollins, 1905.)

Induction motor-generators could furnish current longer under severe short-circuit conditions; that is, they would not be affected by a drop in voltage to such an extent as would synchronous motor-generators or converters which would almost immediately drop out of step under severe conditions. (The Edison Electric Illuminating Co. of Boston, 1905.)

Induction motor-generator sets are preferable under these conditions. (Edison Electric Illuminating Co. of Brooklyn, 1905.)

Testing of Synchronous Converters.—In regard to the practicability of using a Hopkinson, Kapp, or other similar test, on two six-phase rotaries in a substation, connected to run normally in multiple on the same busbars, current to be supplied by a three-phase line, a separate engine being available at the generating station; if induction regulators are available for varying the direct-current voltage, one rotary can be run inverted by adjusting the regulators and a full load placed on such converter. If induction regulators are not available the test can be made by means of an auxiliary machine of ampere rating equal to that of one of the converters and rating in kilowatts equal to the copper-loss in the two converter outfits. The two converters should be started and direct voltage equalized at the desired value for the test. Then the auxiliary machine should be connected as shown in diagram and the



field of this machine should be adjusted to secure the desired current in the armatures of the rotaries. (D. W. Roper, 1905.)

Commutation of Three-Phase vs. Six-Phase Converters.—The addition of extra collector rings to a three-phase rotary may be beneficial if there are no cross connections or balancing rings on the converter armature. If there are already three or more balancing rings on the armature, changing from three-phase to six-phase would make no appreciable change in the commutation. This assumes that the commutation is not influenced by pumping or other conditions. that would be modified by the six-phase connection. (E. M. Tingley, 1904.)

The improvement of commutator due to changing a three-phase to a six-phase converter, would not justify the expense incurred, but the three-phase converter, if connected six-phase will give a 45 per cent. greater output for the same internal losses. (A. D. Gilmore, 1905.)

The Westinghouse Electric and Manufacturing Company have built converters for both three-phase and six-phase circuits. So far as they have been able to determine, the commutation and general operation of the three-phase converters was in every respect equally satisfactory to that of the six-phase converters. The additional expense and complication of the six-phase converter is therefore not warranted as far as converters themselves are concerned. In some cases, however, where large units are employed, the subdivision of cables and switches will, in any case, be made so that they are practically no more complicated for six-phase than for three-phase. (Clarence Renshaw, 1904.)

60-Cycle Synchronous Converters and Hunting.—The difficulty of running certain 60-cycle converters in parallel on the direct-current end when they were operated from the same engine-driven generator, may be due to several causes. The tendency to "hunt" varies directly with the frequency. Sometimes the characteristic of two converters of the same make, type and construction differ greatly. This being the case, the machine having the steeper characteristic will carry the most load. Should the load fluctuate very greatly this machine will start to "hunt" and may fall out of synchronism. (C. F. Haywood, 1904.)

With properly designed converters there should be no difficulty in operating under these conditions unless it is attempted to run the converters with alternating-current terminals in parallel; that is, unless it is attempted to run two or more converters on the same transformer secondaries or from the same alternating-current busbars. The difficulty that is experienced in running converters with alternating-current terminals and direct-current terminals both in parallel is not due to 60-cycle current, but is due to the fact that unless the characteristics of the machine are exactly identical at all loads, there will be large cross currents through the a-c. and d-c. connections. The same difficulty would be experienced with converters operating on any frequency. (Clarence Renshaw, 1904.)

60-Cycle Synchronous Converters a Success.—We have been operating a double-current 200-kw., 60-cycle converter for about two years and have found the same to be very satisfactory, running both direct and inverted. The machines are practically in constant use. At times they are floated on the line as synchronous motors for power-factor correction. (F. Leslie, 1908.)

Converters from 125 to 250-kw. rating on 60-cycle circuits are entirely successful and numbers of them are in operation all over the country. It is necessary, however, to give them careful attention, especially the commutators which must be kept clean. (M. C. Turpin, 1908.)

We have been using, with success, three converters of 200-kw. rating on 60-cycle circuits. (A. F. Nelson, 1908.)

Advisability of Connecting in Multiple the A-C. and D-C. Sides of Converters in Substations.—It is not generally advisable to connect both the alternating-current and direct-current ends of converters operating in parallel, on account of the liability of currents between them. The alternating-current end should be fed from separate transformers. (E. M. Tingley, 1904.)

It is seldom good policy to put all your eggs in one basket. A substation consisting of a number of units should be sectionalized on the alternating end and fed by two or perhaps three transmission lines, depending upon the number of units in the substation and the importance of the substation. Each line should feed a group of units and the switching arrangement should be made flexible so that any or all of the units can be operated from any of the lines entering the substation. On the direct-current side the converters generally feed into a common system and are thus in parallel with each other. (R. F. Schuchardt, 1904.)

There can be no objection to operating two converters in a substation in multiple on both alternating-current and direct-current buses. As a matter of insurance, however, it would be preferable to subdivide the converters into groups in a station, operating the groups from separate sources of supply as much as possible, as in this way troubles with individual lines on machines would not effect such a large part of the substation equipment. (Edison Electric and Illuminating Co. of Boston, 1904.)

Under certain conditions it may be advisable to operate converters with both alternating and direct-current sides in parallel. (R. W. Rollins; E. P. Coles; S. O. Swenson, 1904.)

Balance of a Polyphase System Supplying Synchronous Converters and Synchronous Motors Only.—A three-phase system supplying converters and synchronous motors operating at a reasonably high power-factor should be in practically perfect balance. In case the converters and synchronous motors should be run at extremely low power-factor there might be considerable unbalancing, due to the magnifying of the very slight variations in the magnetic and electric circuits of generators and motors. (Wm. B. Jackson, 1906.)

Starting Synchronous Converters from the Direct-Current Side.—In starting from the direct-current side a double delta or a diametrically connected converter that has transformers and regulators permanently connected to the low-tension side, the windings of the transformers and regulators act as a short circuit. In order to reduce the starting current it is recommended that switches be installed in the secondary alternating-current conductors between the converter and the transformers and regulators. These switches should be left open until the converter is up to speed. This means synchronizing on the low-tension side, which is the standard practice of some manufacturers. (Toledo Railways and Lighting Co., 1904.)

Circuit Breakers and Series Field Winding of Synchronous Converters.—As a protection against internal short circuits due to accidental grounding of large generator windings, it is customary to place the circuit breaker on the negative or grounded side. This breaker is mounted on the generator panel and with it the ammeter. In order to avoid complications, the series winding of the generator is connected on the positive side. With converters the opposite practice is usually followed, both with regard to location of the circuit breaker and of the series winding, as converters are considered to be sufficiently protected against internal "shorts" to ground by the automatic switch features on the alternating-current end, even though the direct-current breaker is on the positive. (H. H. Barnes, 1907.)

Compound-Wound Converters and Series Reactances.—By the use of choke coils and properly proportioned series coils it is not difficult to obtain 10 per cent. compounding in converters. It is customary to operate so that the power-factor at full load is practically unity. At less than full load the power-factor will be lagging and at greater than full load the power-factor will be slightly leading. (P. M. Lincoln, 1907.)

Compound Converters in Lighting and Power Substations.—It is usually unnecessary to compound converters in lighting and power substations, because the load usually comes on and off gradually and gives the switchboard attendant time to regulate the voltage by other means. (M. C. Turpin, 1907.)

Synchronous Converters:—Insulation Strains on Starting and Synchronizing.—When a converter is started from the alternating-current side by applying full or fractional voltage to the armature, a high voltage is induced in the shunt field-windings. It is customary to decrease the strain on the insulation from this cause by providing switches for breaking up the shunt field-windings into several sections. These strains do not occur when the converter is started from the direct-current side or the alternating-current side by means of an induction starting motor. (Stone and Webster Engineering Corporation, 1908.)

Commutators and Collector Rings: Grinding and Turning Down, Obtaining Proper Speed, Etc.—We have used both the grinding stone and turning tools on commutators. On collector rings that have been turned, we use a flat file with good results. We happen to have a three-unit, 120-hp. motor-generator set. The alternating-current motor is cut loose from the line. One direct-current end of the set is operated from the 125-volt bus as a motor; the other end is self excited. The machine to be turned is given full field from the bus and low armature current from the generator end of this 120-hp. motor-generator set operating at low excitation. A regular turning tool is used which is insulated and used as in any ordinary turning job. This has been used successfully on several 500-kw. motor-generator sets and on one 1,500-kw. converter. (B. E. Noyes, 1909.)

The slow speed required for turning commutators and collector rings can be obtained in several ways, one of which is by means of a properly connected booster. (Brooklyn Edison Co.; B. H. C., 1909.)

Inverted Converters.—Inverted converters are operated successfully in a great number of cases. One very common use of this form of machine is in connection with interurban railways in which the power is all generated at 550 volts direct-current. The alternating-current for a suburban line from 10 to 20 miles length is obtained by running a converter inverted and stepping up the voltage to about 15,000 volts. (A. M. Wilson, 1906.)

The inverted converter has also been used in certain instances to reduce the alternating-current station peak load, being used at other times to supply direct-current to the direct-current Edison system. On account of the sensitiveness of the converter thus operated it is necessary that a reliable speed limit device be installed in all such installations.

Speed Control of Inverted Converters.—With inductive loads it is sometimes difficult to control the frequency of the inverted converter in a polyphase system satisfactorily. Operation within certain limits, however, can be obtained by using shunt-wound converters and exciting the fields by means of small direct-current generators coupled to the converter shaft, or driven by induction motors actuated by a current from the alternating-current side. (C. W. Miller, 1909.)

Soaking Carbon Brushes in Oil.—Opinions with regard to this matter are very divergent, some thinking it unnecessary and unsatisfactory and others strongly advise same. With our modern machines, however, this practice is, to say the least, not generally necessary.

End Play Devices on Converters.—The use of end play devices in connection with commutating machines wherever possible is exceedingly beneficial in the matter of obtaining a good commutator surface. It is practically impossible to keep a good commutator surface for any length of time without a certain amount of end play. (Philadelphia Electric Company, 1906.)

Ridges which form on commutators of 1,000-kw. converters operated without end play devices for about five months soon disappeared after the end play devices were installed. (Brooklyn Edison Co.; T. N. Hicks, 1906.)

Commutator Lubrication.—Any lubricant on commutators should be used very sparingly. Every time the machine is shut down, wipe off and clean both the armature and brushes very carefully.

DOUBLE-CURRENT GENERATORS.

60-Cycle, Double-Current Generators.—Opinions as to the use of 60-cycle, double-current generators for lighting service where the load is reasonably uniform seem to differ. Properly designed 60-cycle, double-current generators having good inherent regulation should be commercially satisfactory under the above conditions. With machines with weak field and poor inherent regulations, it will probably not be satisfactory. (Clarence Renshaw, 1904.)

For 60-cycle service the high speed and large number of poles are such that it results in a very undesirable machine. (P. Junkersfeld, 1904.)

We have been using 60-cycle, double-current generators for 7 years and have obtained very satisfactory results for lighting and power work from the direct-current side. The motor service on the alternating-current side has been operating under a fairly steady load. (Edison Electric Illuminating Co. of West Chester, 1904.)

MOTOR-GENERATOR SETS.

Average Power-Factor of Motor-Generator System.—The average power-factor of large systems supplying synchronous motor-generators and synchronous converters is in practice 98 or 99 per cent. The average power-factor for somewhat smaller systems operating exclusively induction motor-generator sets would be about 75 or 80 per cent. (J. Junkersfeld, 1906.)

The average power-factor of an induction motor-generator system transforming from a central station current to low-tension Edison mains is about 80 per cent. Synchronous motor generator sets give in practice a power factor of 96 to 100 per cent. (Philadelphia Electric Company, 1906.)

SYNCHRONOUS MOTORS.

Balance of Polyphase Motors.—The average induction or synchronous polyphase motor has generally been found to take power practically equally on each phase. This, of course, means that the voltage and phase balance at the motor must be preserved. There are, of course, due to various causes, instances where the balance is poor. (N. Y. Edison Co., 1905.)

Induction vs. Synchronous Motors: Motor Generator Sets.—In small or moderate sizes the induction motor would probably have the advantage, in first cost, over the synchronous, as it has fewer accessories and requires less care in operation, particularly at starting. It is also free from "hunting." In larger sizes, however, there is considerable difference of opinion as to which type is preferable, the low power-factor of the induction motor offsetting to a certain extent the advantages inherent in the induction machine. (Ralph R. Laxton, 1905.) The induction motor has the advantage of a certain increase in stability in the case of momentary troubles on the system. In the case where voltages are apt to be unbalanced, the induction motor also has the advantage over the synchronous machine. The absence of moving contacts, the low cost of necessary switchboard connections and the fact that no external exciting current is necessary are also in favor of the induction motor. In efficiency neither type of motor has any great advantage over the other. The attendance in the case of an induction motor is not necessarily of as high a class as that required where synchronous machines are used. Another advantage of the induction motor is that on short-circuit conditions the motor sets do not feed back into the line in the same way as the synchronous machines, and if the main station breaker opens the short circuit, conditions are relieved at once as the induction motor is thereby unable to act as a generator. The main advantage of the synchronous machine is the fact that it is extremely beneficial in assisting in the case of low power-factors, thereby saving considerable line loss and increasing station efficiency. This is an important item. The choice between the induction and the synchronous machine, therefore, depends largely upon the local conditions. (H. J. Gille; H. J. Meyer; W. R. Collier; Phila. Elec. Co.; M. Carrington; Edison Elec. Ill'g. Co. of Boston; Westinghouse Elec. & Mfg. Co.; New York Edison Co.; M. P. R., 1905.)

Transferring 200-kw. Synchronous Motor from One Generator to Another.—If a synchronous motor of this size is to be transferred from one generator to another, it is preferable that the generators be synchronized before the transfer takes place. If one generator is running on one bus and the other on another bus, the machines may be paralleled by connecting the buses together at the proper time and if the motor has two independent switches, one on each bus, both of these switches may be closed at once, and, by opening the original bus switch of the motor and tie switch between the buses, the motor will be properly transferred to the second machine. It is questionable whether it is possible deliberately to switch a synchronous motor from one machine to another, as, for instance, by double throw switch, with entire satisfaction, especially if the motor be loaded.

Balance of a Polyphase System Supplying Converters and Synchronous Motors Only.—A three-phase system supplying converters and synchronous motors operating at a reasonably high power-factor should practically be in perfect balance. In case the machines are operating at extremely low power-factor there might be considerable unbalancing owing to the magnifying of the very slight variations in the magnetic and electric circuits of the generators and motors. (William B. Jackson, 1906.)

Synchronous Motors and Power-Factor Correction.—The synchronous motor, when its field is excited beyond that which will give normal operating voltage, takes leading current from the system to which it is connected. This leading current neutralizes lagging current, such as is taken by induction motors and similar apparatus. Underloaded synchronous motors will probably be more effective in neutralizing these lagging currents than those with load, depending upon the inherent regulation of the motors. (P. M. Lincoln, 1907.)

The possible range of over-excitation of a motor is, of course, greatest at no load. The limit in this regard is the ampere rating of the motor itself. (C. R. Wylie, 1907.)

As an example of power-factor correction, the following is taken: A synchronous motor-generator set of 300-kw. rating carrying 75 per cent. of rated load, running in parallel with a circuit of 500-kw. and with 72 per cent. lagging power-factor, will give, assuming that the synchronous motor is operated at full load amperes, the following results:—

A 500-kw. load of 72 per cent. power-factor has a lagging wattless component equal to 480-kw. A synchronous motor operating with a total load (power component) of 225-kw. and 300 kv-amp. input, has a leading wattless component of 198-kw. The corrected power-factor then equals:

$725 \div \sqrt{(500 + 225)^2 + (480 - 198)^2} = 93$ per. cent. lagging. (H. Hollis, Lebanon, Pa., 1909.)

ALTERNATING CURRENT MOTORS.

Fuses for Induction Motors.—When the starting current of an induction motor is so far in excess of the running current that a fuse which will carry the starting current will not protect the motor, there are several ways out of the difficulty. Use a fuse or circuit breaker heavy enough to carry the starting current. Use a double throw switch and two sets of fuses, using a heavy fuse for starting current and proper sized fuses to carry the running current. Use time limit devices on circuit breaker. Use double throw switch that will allow the motor to be started and attain full speed without fuses and then throw the motor to the running position with fuse protection.

Starting 50 to 150-hp. Induction Motors Without Compensator.—There are several ways of starting induction motors without the aid of starting compensators; for instance, a half voltage tap may be taken from the transformers and this by means of a double throw switch would permit the motors being started on half voltage, and when it had attained full speed it would be thrown to the running point. (M. C. Turpin, 1906.)

Another satisfactory method of starting such motors is by the use of variable resistances in the secondary element. (W. B. Jackson, 1906.)

It is hardly practicable to start large motors of the squirrel cage type from rest without compensator even with no load without producing severe disturbances of the voltage regulation. (R. R. Laxton, 1906.)

Size of Wire Required in Starting up Polyphase Motors, Using Compensator.—The installation of wiring sufficiently heavy to carry continuously the starting current of induction motors without exceeding the Underwriters' safe carrying capacity, would mean a considerable increase in expense for no plausible reason. The rush of current lasts only a short time and any excessive drop can be easily taken up by changing connections on the compensator. (M. C. Turpin; H. D. Larrabee, 1906.)

Effect of Three-Phase System of Induction Motors Operated at 15 Per Cent. Below Normal Voltage.—The torque of an induction motor varies as the square of the voltage, and if the motors are operated near the point of maximum power-factor the efficiency and reduction in voltage would be disastrous. A reduction of 15 per cent. in voltage would mean that the motors would be developing only about 73 per cent. of their rating. (M. C. Turpin; Ralph R. Laxton, 1906.)

Relative Cost of Two-Phase and Single-Phase Motors.—Polyphase motors of a given output should as a rule be somewhat cheaper than single-phase motors of equal rating.

2,300-Volt, Three-Phase Induction Motors.—The installation of 2,300-volt induction motors should be confined to units of large output, for instance, 50 hp. and over. (H. C. Stoddard, 1907.)

This type of motor should not be installed except under special conditions and those where an experienced electrician is in charge. Such an installation, to be in accord with the Underwriters' requirements, is governed by stringent rules. (M. C. Turpin, 1907.)

Single-Phase Motors of Both the Split-Phase and the Repulsion Type; Testing Current, Torque, Reliability, Etc.—Our Company has 350 hp. in Wagner single-phase motors on its circuits in all sizes up to 40 hp. and has no trouble whatever. Some of the larger motors of 15 and 20 hp. start with non-inductive resistances, others of 30 to 40 hp. start on half voltage taps from the transformers. The split-phase type of motor has not been entirely satisfactory. (A. E. Walden, 1908.)

Two-Phase Motors on Three-Phase Circuits.—Two-phase motors may be satisfactorily operated from three-phase circuits by using the "T" connection or Scott system of three-phase to two-phase transformation. (E. B. Rannells, 1909.)

Alternating-Current Motor-Driven Pump for Individual Water Works.—Probably the most satisfactory outfit to meet the above conditions will be a centrifugal pump direct-connected to an a-c. squirrel cage, two or three-phase motor. (A. E. Hibner, 1909.)

Locating Short-Circuited Coil in Stator Winding of Motor.—If the motor is installed, the quickest way to locate defective coil is to run the machine under load until it begins to smoke. Then, by shutting down the motor, the short-circuited coil can be located by the excessive heat shown by the short-circuited coil. (R. H. Tillman, Rochester, N. Y., 1909.)

Another method is to remove the rotor and connect the stator winding to an alternating-current circuit. The short-circuited coil will act as a secondary of the transformer, generating in itself sufficient current to become heated. In factories short-circuited coils are sometimes located by means of a two-pole, alternating-current electro-magnet. By placing this magnet in proximity to the short-circuited coil a current will be generated in the coil causing a rise in temperature. (F. L. Leitner, 1909.)

Short-Circuited Coil Acting as a Brake.—The reason why a short-circuited coil in an alternating-current induction motor acts as a brake on the rotor is as follows:—The phase in which the short-circuited coil is located may be considered as an auto-transformer of which the short-circuited coil is the secondary. The secondary current in this automatic transformer is opposite in phase to the primary current, and therefore produces a negative torque and for the same load decreases the speed. (A. E. Hibner, 1909.)

Relative Maintenance Cost of Induction Motors and Direct-Current Motors.—It is generally conceded that the maintenance cost of the squirrel cage induction motor is considerably lower than that of the direct-current motor of equal capacity.

Efficiency of Induction-Motor Speed Control vs. Direct-Current Speed Control.—A variation of speed in the induction motor may be obtained by changing the number of poles of the motor. The efficiency in this case is practically the same at reduced speed as at full speed.

For constant speed work, the efficiency of control during the starting and acceleration of the induction motor is practically the same as that of the direct-current shunt motor. For variable speed work the direct-current shunt motor speed control can be regulated by varying the field current, and in this way the shunt motor control is more economical than the speed control of the induction motor. Speed control of the induction motor during starting and acceleration is less economical than that of the direct-current series motor. In general the speed control of an induction motor is similar in efficiency to the speed control of a direct-current shunt motor by means of resistance in its armature circuit. ((C. Renshaw, 1904.)

Single-Phase Alternating-Current Series Commutator Type Motor for Elevator Service.—It would not be advisable to use this motor for elevator work as the conditions of this service demand a constant speed for different loads, which could not be attained with this type of motor. (A. E. Hibner, 1909.)

Maintenance: Single-Phase Motors vs Direct-Current Motors.—With regard to the relative maintenance of single-phase vs. direct-current motors of the same size, there seems to be a difference of opinion. Out of fourteen answers to this question two writers state that the replacement in connection with the single-phase motor is considerably greater than in connection with the direct-current motor. The remaining twelve are of the opinion that the modern single-phase motor causes less trouble than the direct-current motor of same rating. (1905.)

DIRECT-CURRENT MOTORS.

Speed Variation of Compound Motors Under Variable Load.—The speed variation of a compound-wound motor under a load varying from 10 per cent. of load to 20 per cent. overload, the supply voltage remaining constant, would depend upon the design of the motor and whether or not the series coil were differentially or cumulatively connected. The method of connection of the series windings would depend upon the use to which the motor was put. If the motor is differentially wound and the series coils are properly proportioned to the shunt characteristics, the motor should run at nearly constant speed throughout wide range of load. (F. M. Farmer, 1904.)

If a motor has a 20 per cent. series and an 80 per cent. shunt winding, the ratio generally used on standard compound-wound motors, the change of speed from 10 per cent. of load to 20 per cent. overload would be 12 to 15 per cent., assuming constant line potential. In this assumption the coils are supposed to be connected cumulatively. (H. B. Emerson; E. P. Coles, 1904.)

Shunt Motor Operating with Open-Field Circuit.—The effect of armature reaction on a shunt-wound motor with open-field circuit is well illustrated by the following example: A small direct-current shunt motor was found to be throwing fire at the brushes and on several occasions the current leaped from brush to brush. Examination showed the armature in perfect condition. The field circuit was found to be open. The magnetism induced in the fields by armature reaction, while fairly weak compared with the normal field, was still strong enough to operate the motor even under load, although on account of low counter e.m.f. the current was necessarily large, causing bad sparking. The speed also fell off considerably due to the same cause. (A. Peters, 1904.)

Sparking at Commutator: 500-Volt Motor.—In a certain instance a commutator sparked considerably at the brushes, even though they even set at the neutral point. Reversing the holders, and still keeping the brush on the neutral point stopped the sparking. The trouble in this case was evidently due to vibration or chattering of the brushes and to the fact that in the first instance carbon was continuously being deposited from the brush upon the commutator.

TESTING AND GENERAL OPERATION.

Installation Tests of Electrical Apparatus.—The following tests should be made, if possible, whenever a central station purchases a piece of apparatus as, for example, a generator:

(1) Insulation resistances, including puncture tests.

(2) Full load and overload heat runs.

(3) Regulation.

(4) Test insulation to ground and between phases with double the working voltage using a small step up transformer. The machine being tested should be protected from excess voltage by a spark gap between needle points.

Machines should be run at approximately full load for 10 hours. If the system is alternating-current the load should be near unity power-factor. If the power-factor of the load is low, do not exceed full load current of machine. The machine should operate at about rated voltage and speed. At the end of run insert thermometers on the various windings and commutator. If direct-current, protect the bulbs from the air by putty or waste. Read thermometers frequently and note the highest temperature attained. Also note temperature of air in engine-room near machine. Compare temperature rises with guarantees, making corrections outlined in section 269, A. I. E. E. Standardization Rules if necessary. Then follow with overload run for prescribed time and read thermometers again.

Regulation: Note voltage E^1 at full load with given excitation and speed also voltage E at no load with the same excitation and speed.

Regulation $= \frac{E - E^1}{E} =$ per cent. rise of voltage from full load to no load in terms of full load voltage. Complete data on testing of machines can be found in the Electric Journal, 1904. (H. L. Wallau, 1908.)

Grounding of the Neutral of a High-Tension, Three-Phase, Star-Connected Generator.—The main objections of grounding the neutral of a three-phase, star-connected generator is that any ground on the system means a short-circuit. Another objection is the liability of damage from lightning. (E. H. Mather, 1904.) We operate our 4,000 and 2,300-volt, four-wire, three-phase system with ground on neutral at the station. (Toledo Railways and Lighting Co., 1904.) A certain 2,800-kw. 11,000-volt, Y-connected, 6,600-volt to neutral transmission system operating over approximately 40 miles of underground cable is grounded through a resistance, the advantages being that the neutral point is practically fixed so that a ground on the cable trips the switch and clears the system; and that arcing ground on a cable might continue for considerable length of time unnoticed, possibly causing surges and destruction of insulation in other parts of the system if the system were not artificially grounded. (H. L. Wallau, 1909.)

A 15,000-kw. system is grounded: Reasons, decreased strain on insulation of line and apparatus; decreased lightning troubles, and also there is an advantage in the fact that in a three-phase, four-wire system considerable lighting and power work can be done with only one of the primaries by grounding the neutral. (T. H. Yawger, 1909.)

Current in Neutral of Three-Phase, Star-Connected Machines.—Two star-connected, three-phase generators, of the same rating, running in parallel with neutral solidly grounded have shown a neutral current proportional to the difference in load on the two machines. This current does not appear on the ammeters on the main wires of the machines. The current is probably caused by a deterioration of the wave form and the appearance of harmonics. It is a short-circuit current through the windings of the two machines, and is frequently excessive. It will probably have little or no effect on operating conditions other than increasing the heating of the machines. The current can be done away with by using a generator that gives a perfect sine wave and one which remains undisturbed throughout normal operation, something very hard to obtain. (1904.)

A simple remedy is, of course, to have but one neutral grounded at a time, instead of grounding each machine. The ground is frequently made through a low resistance of large current carrying capacity, the resistance being usually made of heavy cast iron grids mounted in suitable frames, the whole being supported on insulators suitable for the required voltage. (Bertram Rowe, 1905.) Practical experience in several plants shows that it is not advisable to ground the neutral of more than one of a group of three-phase generators when operating in parallel. (P. M. Lincoln, 1905.)

Reactance in Generator Leads in Case of Large Three-Phase, Star-Connected Alternators with Neutral Point Grounded Through a Resistance.—Ohmic resistances in the neutral limit only the ground current in case of a ground in one of the outer wires. A double ground or one on each of two phases would result in a short-circuit and there would be a resultant current from phase to phase without passing through the limiting resistances. The use of reactance in the generator leads will limit the initial current in such cases and reduce the mechanical strains on the generators. See short-circuits on Alternators, General Electric Review, Feb., 1909; also Electric Age, June, 1909. (H. L. Wallau, 1907.) See also paper and discussion on the use of choke coils, by A. S. Loizeaux, of Baltimore and discussion by P. Junkersfeld, Chicago; Dr. Steinmetz, etc., Proceedings of the N. E. L. A., Atlantic City, N. J., 1909.

Reactive coils are desirable in the generator leads of an alternator having a low armature reactance (such as is found in modern low-frequency turbo-generator sets) to limit destructive torque due to short-circuit on generator. (H. Hollis.)

Delta- or Star-Connection.—In a central station for electric light and power generating at 60-cycles, 2,300-volts, by means of three-phase generators, the question is asked which is preferable, delta- or star-connection and why? The distribution is partly three-phase and partly single-phase with motor load a considerable portion of the total. Either star- or delta-connection will be equally well adapted for three-phase power for substation supply. But when the load is wholly or partly single-phase, the delta-connected generator is preferable for the following reasons: Referring to Fig. 1 showing a delta-connected generator, we know that the current in "A" is $\sqrt{3} \times$ the current in "a" or "b." Referring to Fig. 2 or the star-connected generator, we know the current in "A" is equal to the current in "a." Therefore, it is clear that in the case of an overload on "A" in the delta-connected generator, Fig. 1, the winding, "a" will have to bear $\frac{1}{\sqrt{3}}$ of the overload, or 57.7 per cent. of it, while the winding, "a" in the star-connection, Fig. 2, would have to take the entire overload alone. The heating effect in the two windings would be proportional to the current[2] in each. (Chas. G. Buckmaster, 1908.) Lest a wrong impression should have been given as to the heating of two generators connected delta and star respectively, it should be stated that

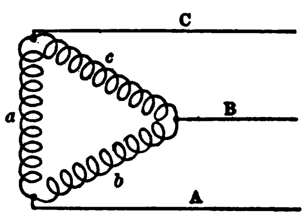


FIG. 1—DELTA CONNECTION

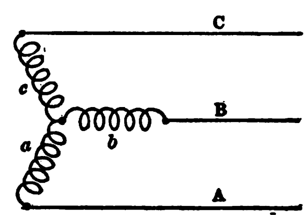


FIG. 2—STAR CONNECTION

this answer refers to generators that have facilities for being run either star or delta. (1908-1909.) The three-phase, four-wire distribution is suggested, the phase voltage to be 2,300, voltage of lines 4,000. The voltage between any line and neutral would then be 2,300, allowing the use of standard transformers while retaining the advantage of the 4,000-volt distribution. (R. M. Stevenson, 1908.)

Edison Three-Wire System.—Maximum Allowable Unbalance.—The operation of the system is not interfered with by unbalancing so long as the neutral conductors are of sufficient size to properly carry the current equivalent to the amount of unbalancing.

Voltage Regulation: Large Fluctuating Power Load.—Where very large fluctuating power load is being run from the same motor-generator sets as the lighting load in order to keep the pressure steady, a Tirrill regulator should be installed on the generator. This will handle any reasonable variation in pressure. (F. R. Spiller; M. C. Turpin; P. Junkersfeld, 1906.)

Compressed Air for Cleaning.—The advantage of using compressed air for cleaning purposes in central stations is readily seen in the case of armatures of considerable size where with a nozzle of some length dust can be blown from coils and leads that are entirely inaccessible to a bellows or cleaning by hand. (Lee Boyer, 1905.) The use of air for cleaning electrical machinery shortens the time required to do the work and enables the operator to do a much more thorough job. It is possible, thus, to clean out recesses that cannot be reached by other means. (I. E. Moultrop, 1905.)

Air Suction vs. Air Blast.—Air suction has a maximum possible pressure (or suction) of less than 15 lb. which is not sufficient to dislodge dirt from deep crevices. It is also impossible and would be dangerous to have the suction nozzle reach into crevices around electrical apparatus and unless the nozzle comes into very close contact with dirt and grease it will not remove it by suction. A high pressure air blast of 60 to 80 lb. is much more effective in dislodging dirt and grease. (C. R. Meston; A. V. Thompson; C. A. Keller, 1907.)

I do not see any objection to using air suction, and think it would be preferable to air-blast. (F. C. Sargent, 1907.)

Cleaning 120-Kw., 2,000-Volt Alternators as a Prevention of Burning Out of Coils.—Such a machine should be cleaned out about once a week, although this depends upon surroundings, and whether there is much dirt or dust in the air or whether the air is always clean. 50 lb. under these conditions seems very satisfactory air pressure. Thorough cleaning while absolutely necessary will not prevent the armature coils from burning out, although by keeping the air ducts clear it will greatly assist in this regard, (James W. Bishop, 1909.)

Circuit Breakers on Generators or Exciters.—The use of circuit breakers on generators seems to be somewhat dependent upon conditions such as the size of the system, whether or not generators are operated in parallel, etc., whether or not the station attendant is always within reach of the board, etc. Very many of our larger stations have no automatic circuit breakers on the generators. There are, however, exceptions to this rule. In the smaller stations, judging by the trend of answers to the above question, automatic circuit breakers are generally advisable in connection with the alternators. Circuit breakers on exciters if they are installed should be set very high and possibly provided with a reverse current attachment. (1905.)

SECTION XI.

Switchboards.

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HIGH TENSION BOARDS.

Location and Arrangement.—High-tension current should be controlled high-tension switching apparatus in separate masonry compartments, the switches being controlled from a distance on a control board, where are situated the instruments and controlling apparatus.

Both switch and bus compartments and control boards should be laid out so as to be accessible for cleaning, repairs and general maintenance while in constant operation. The following points should be emphasized.

Thorough insulation of all exposed parts carrying current.

Length and number of high-tension conductors reduced to a minimum.

Careful arrangement of all conductors with reference to each other, and with proper barriers and clearances.

Rheostats mounted at a distance, as in the basement.

Sub-division of the board into sections using the double busbar system and duplicate switches for all feeders and generators. (Peoria Gas & Electric Co.; Edison Electric Illuminating Co. of Boston; P. Junkersfeld; W. S. Barstow; H. G. Stott; C. C. Poole.)

Switch and Bus Compartments.—For high-voltage and large power, high-tension switch and bus compartments should be constructed of brick or concrete with concrete or soapstone barriers between phases and between adjacent generators and feeders. (Malden Electric Co.; Harry M. Hope; Edison Electric Illuminating Co. of Boston.)

The relative cost of brick and concrete for the purpose of switch compartments is about two to one in favor of concrete if pressed brick is used, and if rough brick is used the cost is about equal. (B. Jamieson; G. L. Knight.)

Local conditions should determine whether large clearances are preferable to barriers in individual cases, the large clearances being preferable because cheaper in plants located where real estate and buildings are cheaper, barriers being used in large stations where real estate is at a premium. (H. G. Stoddard.)

Oil Switches and Circuit Breakers.—In oil switches and circuit breakers the following precautions should be taken to insure reliability.

Oil should be free from moisture and the oil pots filled to the proper level. Contacts should be so designed as to give the maximum amount of spring contact with slight rubbing action tending to keep the surface in good condition. When the switch opens the arc should be taken on a projection from the main contact not a part of the rubbing surface and care should be exercised in lining up accurately when installed. Means should be provided for opening the switch by hand in case of the failure of the control circuit from any cause. (M. Carrington.)

If switches are interrupting large currents once or twice daily, the oil should be changed at least monthly, but if interrupting small currents, once in six months would be good practice. In general, after a switch has opened 5,000-kw. or more under short-circuit conditions it should be inspected and the condition of the oil should govern a decision as to the need of changing the oil. (Edison Electric Illuminating Co. of Boston.)

A moisture test is sufficient to determine when oil should be changed under normal conditions, a sample of oil should be taken from switch and heated in a vessel covered with a glass plate, raising the temperature to boiling, if a perceptible amount of water condenses on the glass cover, the oil should be changed. (G. N. Eastman.)

Oil switches located between generators and busbars are made non-automatic because an automatic device is not always to be relied on and will sometimes operate for no apparent reason. Automatic switches should be located in the feeder lines, so that a short-circuit will open the feeder line where the trouble is, but will not trip generator switch; as when several generators are operating in parallel tripping a circuit breaker on one, would throw more load on the other generators and would probably cause other switches to go out also, if they were automatic. (H. C. Stoddard; F. C. Clark; P. M. Lincoln; George Ross Green; M. C. Turpin; Chas. B. Burleigh; F. C. Sargent.)

If cable from the generator is carefully inspected and tested before installation and run in suitable conduit there is very little danger of trouble between the generator and the busbars. (Jno. McFeeley.)

In all large installations of oil switches it is usual to provide each switch with disconnecting switches so that the oil switch can be cut out of circuit and repaired at any time. (B. E Morrow; M. C. Turpin; George Ross Green.)

When taking oil switches out for cleaning, oiling, etc, precaution should be taken to place a card or tag on the control switch, warning operators that the switch is out of service and under repair and to disconnect the oil switch operating motor from its control circuit. (P. R. Farrell.)

Control Boards.—Control boards should be laid out upon as simple a plan as possible, the generally accepted design being in the panel form, instruments being on a vertical section and the controlling switches on a benchboard slightly inclined to the horizontal. Control wiring should be simple and easily traced out, the wire used mechanically strong and the insulation tested for not less than 3,000 volts and preferably 5,000 volts, as the reliability of the control board is worth insurance at considerable cost, the operator being dependent upon this board for the operation of the entire station. (G. L. Knight.)

Some companies go to the extent of diagrammatically indicating the high-tension connections on the face of the control board. (W. H. Greenslit; B. Jamieson; Malden Electric Co.; Edison Electric Illuminating Co. of Brockton.)

The value of diagrammatic connections lies chiefly in the information it furnishes new operators. (Edison Electric Illuminating Co. of Boston.)

It is in any case desirable to have a diagram showing connections of control board and all high-tension cabling framed and kept near the switchboard. (J. T. Cowling; G. L. Knight.)

Reliability.—There are two opinions on the question of the position of the operating gallery with reference to the operating-room. The one side advocating a gallery in full view, and the other insisting on keeping it isolated. The advocates of the first method maintain that in case of a failure of signals or in case of trouble it is often extremely important for the operator not only to get a full view of the operating-room, but to shout to the engineer. The advocates of the isolated switch house maintain that the operator should be free from all disturbances and noise from the operating-room, especially in case of trouble, and say that the operator is much more likely to keep his head if his instruments are the only indicators of trouble.

A compromise between these two extremes seems best, and the advocates of both systems can be satisfied with an operating gallery in such a position that the operator can obtain a full view of the operating room by opening a door giving access to a balcony, but when the door is closed all noise and all danger of escaping steam or other disturbance is cut off. (G. L. Knight.)

DISTRIBUTING BOARDS.

Alternating-Current (2,300 Volts).—Wood skeleton switchboards have been used successfully where the wood was treated with fireproofing material, and where the wiring is suitably mounted on porcelain or equally good insulators. (J. F. Dostal; E. W. Gough; W. H. Greenslit; E. W. Crocker; Fred. Sharpe; C. H. Cushman; A. R. MacKinnon; Colorado Springs Electric Co.; C. W. Higgins.)

Most companies prefer marble or soapstone panels for the above voltage, especially where the cost of apparatus and the character of the station make appearances a factor as against cost. (G. L. Knight.)

Oil circuit breakers should be used on alternating-current distributing boards, the switches being automatic and equipped with time limit relay. (W. A. Carter; H. Clyde Parrish; J. S. Reesman; F. C. Sargent; F. C. Clark; M. C. Turpin.)

If the switch controlling the circuit is the last of a series beginning at the generating station no time element relay should be used. (George Ross Green.)

Where the feeders are overhead it is especially desirable to have time element oil circuit breakers as in windy days, in wet weather, the striking of the wire together may cause instantaneous breakers to operate (Albert Robinson.)

Potential Regulators.—Proper voltage regulation on alternating-current distributing feeders may be maintained by the use of induction or step by step regulators. When automatic these regulators are operated by a motor controlled by a relay switch, which is in turn actuated by an instrument variously termed a contact making voltmeter, primary relay, etc. This device is used in connection with a line drop compensator, which has resistance and inductive reactance, cut in or cut out by means of a small rheostat arm and in connection with current and potential transformers. The regulator is thus automatic in operation and is usually designed to boost or buck the line voltage from 7 to 10 per cent. These regulators are designed for either single or polyphase circuits, and are very satisfactory in operation, maintaining the voltage at a given point of distribution within one or two per cent. even with rapidly fluctuating motor loads.

The regulators and controlling apparatus are manufactured by at least two of the large manufacturing companies, each of whom have many successful installations. (L. L. Elden; Douglas P. Morrison; Fred W. C. Bailey; E. F. Smith; J. J. Gaffney; J. R. Cox.)

Phase Balance.—On a three-phase system it is not uncommon to use one phase for lighting and the other two phases for arc lighting circuits, where the three phases are used for power. With a careful combination of the load it is frequently unnecessary to have a regulator even on the lighting phase, the regulation being done on this phase through the generator field. (W. B. Jackson.)

Where more than one circuit is operated from the station it is advisable to arrange the various circuits so that the lighting phase of each circuit comes on different phases of the system so that it remains at all times approximately balanced. (L. L. Elden.)

A lighting circuit can be taken from one phase of a three-phase machine and a regulator placed on this phase, while polyphase power could be taken from all three phases of the generator and not from the other two phases. The best way, however, would be to place a Tirrill regulator on the machine, keeping its voltage constant irrespective of the load or power factor, placing compounding coil of the regulator (by means of series transformers) on the lighting circuit above mentioned. This would insure the voltage being automatically compounded according to the load on the single-phase lighting circuit. (M. C. Turpin.)

In a four-wire three-phase circuit the regulator may be installed in the phase wire or in the neutral, preferably the latter, if the lighting load is to be confined to one phase only. (E. F. Smith.)

One phase of a three-phase system can be used for single-phase lighting and three-phase motors operated by the same system. In this way the voltage can be regulated only for the phase carrying the lighting load, where single-phase current is to be used on the three-phase system. (E. M. Mather.)

Single-phase energy cannot be taken from polyphase system without unbalancing the polyphase system. The only way to balance a single-phase load is to divide it equally among the phases of the polyphase system. (P. M. Lincoln.)

Considerable unbalancing may be indulged in without causing serious trouble. (H. A. Strauss; M. C. Turpin.)

No transformation is necessary to obtain single-phase current from a three-phase system. Any well designed three-phase machine should give about three-quarters of its output single-phase. (M. C. Turpin.)

Direct-Current.—Direct-current switchboards have become so standardized that, except for the larger systems, they may be purchased from the manufacturing companies like supplies, the customer specifying little more than the voltage and size of the machines and feeders to be controlled and the instruments desired.

Each of the larger companies has adopted its own standard of unit panels, the arrangement in which is standard for a given company, that is, a machine or feeder panel, in any substation is a duplicate of that used for the same purpose in any other substation.

The latest design of switchboards developed for large Edison systems and with a number of buses, has an arrangement of horizontal buses composed of copper 8 in. in width and in multiples of ¼ in. in thickness, the whole system of buses and connections extending not more than 15 in. behind the switchboard panels. The positive and negative sides are separate, the positive being above and the negative below, the leads being taken out over head for the positive and below the floor for the negative, thus allowing ample space for access behind the board when the panels are set 5 ft. from the walls.

The development of vertical edgewise instruments of excellent accuracy has made this arrangement possible. (G. L. Knight.)

Fuses and Circuit Breakers.—Where direct-current feeders feed into a network, circuit breakers and fuses have been practically everywhere eliminated, the practice being to burn off the feeder in case of a short-circuit as the best means of stopping the trouble. In smaller systems, where the feeders are isolated, the use of circuit breakers is recommended. (G. L. Knight.)

On direct-current generators circuit breakers are placed on the negative side because the series field and equalizer are usually on the positive side, and under certain conditions current may traverse the armature instead of the breakers. (A. Peters.)

Fuses on direct-current circuits should not be used excepting on distributing panels of small capacity. (G. L. Knight.)

INSTRUMENTS.

Indicating Instruments.—Hot-wire instruments have been superseded by more satisfactory and reliable types. (E. P. Dillon; Edison Electric Illuminating Co. of Boston.)

General practice on generator panels in the larger systems is not to economize in the matter of instruments. It is usual to find a direct-current voltmeter and field ammeter for the excitation and an indicating wattmeter, alternating-current voltmeter, alternating-current ammeter, power-factor meter and indicating wattmeter on each generator panel with sometimes a frequency meter. On the other hand on the feeders an indicating wattmeter and power-factor meter are usually all that are necessary. A small pocket type alternating-current ammeter sometimes being added as an indicator of current in the circuit between the current transformer and the relay coil.

Opinions differ as to the relative value of the indicating wattmeter and alternating-current ammeter in generating stations to tell the operator the conditions, the general opinion being that both are desirable on the generator panel to enable the attendant to tell whether the machines are suitably dividing the external load, and are not burdening each other with excessive cross currents where several generators are running in parallel.

On the feeder panel, if the load is balanced, as is usual on transmission lines to substations, a wattmeter in connection with a power-factor meter gives the most reliable information, and it reduces the amount of figuring necessary to obtain actual loads if the ammeter is used.

In the substations on the alternating-current distributing panels an alternating-current voltmeter and an alternating-current ammeter are usually sufficient for each single-phase circuit.

On direct-current switchboards for rotaries, a power-factor meter, alternating-current ammeter or wattmeter and direct-current voltmeter, and on the direct-current feeders simply an ammeter, or two ammeters, where the system is three-wire. (Edison Electric Illuminating Co. of Boston.)

In a small station of 600-kw. capacity for three-phase mixed power and lighting load, the use of three ammeters on generator panels instead of one is worth the addition in cost as it is the only method of accurately telling whether or not the load is balanced. On the power feeder panels one ammeter may be used. (F. C. Sargent; M. C. Turpin.)

If the strictest economy is to be observed one ammeter may be used with ammeter jack so that the same ammeter may be put in any phase. (P. M. Lincoln.)

It is not satisfactory to use the power-factor meter in place of an indicating wattmeter to determine the amount of power delivered over any circuit for the reason that this necessitates a calculation by the operator, which, of course, is not desirable, as he should be able to read at a glance. (M. C. Turpin.)

A polyphase wattmeter correctly measures power in either two-phase or three-phase circuits as indicated in the following explanation:—

Considering a polyphase meter as two single-phase meters (which it is in reality) operating the same indicating mechanism on a two-phase circuit, suppose the voltage to be 220, the current 10 amperes and the power-factor unity and the load balanced, then the watts equal $220 \times 10 \times 2$ or 4,400 watts. If one of the single-phase units is connected with one leg of a phase through series coil or potential across the same leg to the other side of the same phase, and the other unit is similarly connected on the other phase and potential pressure through shunt coil is in phase with the current through series, then the watts measured by each unit are equal to 10×220 or 2,200 and the sum of the two units is 4,400, the true watts.

On a three-phase circuit with 10 amperes, 220 volts, the load balanced and the power-factor unity the watts equal $10 \times 220 \times \sqrt{3}$ or 3,806 watts. One of the units is connected with an outside leg through the series coil with potential across from same leg to center leg, and the other unit is similarly connected on the outside leg. Under these conditions the potential pressure through the shunt coil is not in phase with the current through the series coil, but at an angle, leading the current in series coil in one unit and lagging in the other, exactly the same way.

This difference in phase in each unit is such as would be represented by a power-factor of 0.865, therefore, each unit would measure 10 amperes × 220 volts × 0.865 or 1,903 watts, the sum of the two units will then be 3,806, the true watts. (B. E. Gerchell.)

Energy Meters.—The best method of determining at power houses the total energy in kilowatt-hours generated at 11,000 volts is to put in a watt-hour meter on each generator panel, using potential and current transformers of suitable rating. These meters are guaranteed with a certain percentage of error, no greater than for direct reading instruments of the same class. (F. D. Sampson; C. W. Stone.)

In registering the total energy output of a station the general practice is to place the watt-hour meters on the generator panels rather than on the feeder panels, for the reason that fewer instruments need be purchased and that as watt-hour meters are more inaccurate at light loads, greater accuracy would be assured on the generators than on the feeders, many of which would be lightly loaded at times. (F. C. Ripley; R. J. Clark; Alex. Dow.)

Watt-hour meters on both generators and feeders will be a check one against the other. (J. B. Moore.)

Current and Potential Transformers.—Ammeters and time-limit relays on alternating-current feeders can be operated satisfactorily through one current transformer. (C. O. Vesser; H. M. Hope; M. P. R., New York Edison Co.; H. J. Meyer.)

If proper constants are chosen for current transformers, ammeters and time-limit relays, but one current transformer is necessary to operate an ammeter and time-limit relay, it being possible to add two or three more instruments to the circuit without affecting the accuracy of the readings, if the current transformer is properly chosen in the first place. (H. H. Barnes, Jr.)

The secondary side of all current transformers should be grounded, the usual way being to run one ground wire the length of the compartments and tap the secondaries into this. (M. C. Turpin; Nashua (N. H.) Light, Heat & Power Co.)

The fuses by which station voltmeter and wattmeters are protected should be so proportioned that their resistance and consequent drop in voltage would be negligible, especially in the potential circuit of instruments where the current would not ordinarily exceed 25 or 30 milliamperes and where the protection desired is against currents enormously greater than normal. (A. M., New York Edison Co.)

It is standard practice to fuse the primary connections of potential transformers supplying switchboard voltmeters, wattmeters, etc. (E. W. Gough; G. W. Hubley; C. A. Keeler; Louis I. Porter; Fred B. Sharpe; C. H. Cushman; Harry M. Hope; A. R. MacKinnon; J. T. Dostal; H. S. Russell; C. F. Haywood; A. M. Cover; Augusta Railway & Electric Light Co.; Edison Electric Illuminating Co. of Brockton.)

Relays.—The type of time-limit device or relay for oil circuit breakers which has given the most reliable service is the bellows type time-limit relay, manufactured by at least two of the large electrical manufacturing companies. (G. L. Knight.)

Bellows type time-limit relays need not be recalibrated so long as the service conditions remain the same, they should, however, be inspected, cleaned and operated by hand at frequent intervals, and to keep the leather pliable it should be oiled occasionally with Neatsfoot oil. (E. M. Hewlett.)

The reverse-current relay for alternating-current service has been fully developed and has been in successful operation since 1907. (P. MacGahan.)

A time-limit relay using alternating-current for its trip coils is not as positive and reliable in its action as one using direct-current, for the following reasons:

An alternating-current relay whose coil is energized by the secondary of a current transformer that is part of the circuit controlled by the oil switch, with the relay contact normally closed a slight vibration of contact will permit particles of dust to accumulate, also, any tendency toward oxidization of contacts, will have the effect of cutting the trip coil into circuit, and impairing if not wholly removing the time-limit features. (O. H. Hutchings, H. W. Peck.) A relay using direct-current for the tripping circuit is preferable for the reasons that when using alternating-current, as the armature of the solenoid moves toward the tripping position it produces an increasing choking effect on the current, which decreases the torque. With the direct-current there would be no choking effect, producing a more nearly uniform torque throughout the range. (Nashua (N. H.) Light, Heat & Power Co.)

Ground Detectors.—A simple form of ground detector for use on Edison three-wire systems is as follows:

Ground positive wire through two 110-volt lamps in series and ground neutral through one 110-volt lamp. The three lamps should be of equal candle-power and voltage. If the positive becomes grounded there will be current through one lamp to the neutral, causing it to glow at full candle-power. If the neutral becomes grounded there will be current through the two lamps in series to the positive, causing the two lamps to glow dull red. Should the negative become grounded there will be current through the two lamps in series to the positive, causing them to glow at full candle-power, also through one lamp to the neutral, causing it to glow at full candle-power. Thus the indication will read—no ground on the system, a dull red on all lamps; one lamp burning brightly, positive ground; two lamps burning dimly, neutral ground; three lamps burning to candle-power, negative ground. (Edison Electric Illuminating Co., West Chester, Pa.)

A very simple ground detector may be made by connecting three incandescent lamps in series between the positive and neutral conductors of an Edison system, and making a ground connection between the second and third lamps. If the system is clear all lamps burn at one-third voltage.

If the positive conductor becomes grounded, lamps Nos. 1 and 2 are extinguished and No. 3 glows at full voltage.

If the negative conductor becomes grounded, all lamps glow at full voltage.

If the neutral conductor becomes grounded, lamps Nos. 1 and 2 burn at half voltage and No. 3 is extinguished. (W. F. W., New York Edison Co.)

Electrostatic ground detectors to indicate grounds on polyphase systems have been in successful use for a number of years. The three-phase ground detector consists of three single-phase instruments symmetrically arranged and enclosed in a common cylindrical case.

Pointers are used to indicate on three separate scales marked on a common scale plate. The ground detector is connected through external graphite resistance directly to the high-tension bus, there being as many ground detectors as there are buses.

On some of the larger systems where a multiplicity of feeders makes it difficult to ascertain on what feeder a ground has developed, and where a process of elimination to locate the trouble has been found impracticable, a selective ground detector has been developed. This consists of a pair of small series transformers clamped around the lead sheath of the incoming feeder, the leads of which are brought up to the control board and connected to a series of drops similar to those on a telephone switchboard. When a drop falls it shows up the number of the feeder on which the ground has developed, thus giving instant indication to the operator. The drops are restored by the throwing of a small switch. (G. L. Knight.)

Testing.—A central station supplying direct-current for arc lamps and alternating-current for incandescent lamps should have a testing outfit consisting of ammeters, voltmeters and indicating wattmeters of suitable ranges to suit the various generators and feeders in the station, the cost should be under $50.00. (Edison Electric Illuminating Co. of Boston; A. O. Fretz.)

Switchboard instruments such as ammeters and wattmeters, to insure reasonable accuracy should be tested when they are installed and any troubles developing from shipment or handling should be remedied. After this recalibration once a year should suffice. They should be checked monthly unless very favorably situated with respect to vibration, careless treatment, etc. A good plan is to take checks quite frequently for some time, keeping a record of the errors found, if any, and from this determine the necessity of checking. (C. W. Higgins; M. C., New York Edison Co.; G. H. Cushman.)

Switchboard instruments should be checked every time they receive any severe overload, and should be tested once a week. (W. S. Howell; C. H. Sharpe; F. M. Farmer.)

In determining the correctness of the watt-hour meters it is necessary to check the ratio of series and shunt transformers, as these, if properly constructed, should remain unchanged unless the transformers have been damaged. If any accident has occurred or there is reason to believe that some of the turns may have become burned out it is desirable to check the ratio for the purpose of learning whether or not the transformer is still in satisfactory condition. (Dugald C. Jackson; R. C. Lanphier; Bertrand Rowe.)

Switchboard instruments are more easily and accurately checked up by removing them from the board and checking them against instruments of known accuracy. Where considerable refinement is required they should be checked against standards on alternating-current, but the standards themselves should be accurate either on direct or alternating-current so that they (the standards) may be checked up on direct-current against absolute standards of current and e.m.f.

For example, an alternating-current voltmeter of any type could be checked against a Weston voltmeter of moving coil type, which is accurate on either direct or alternating-current, and this standard Weston voltmeter could be maintained accurately against absolute standards. The ratio of current and potential transformers, however, should be known under their working conditions. The current transformer may or may not have an exact ratio, depending upon the characteristics of the winding of the ammeter that is connected with it, and its ratio in connection with this ammeter should be determined. (E. W. Gough.)

Means should be provided for the insertion of temporary standardized instruments and transformers in series with each group of switchboard instruments. This not only provides means for checking the permanent instruments and transformers, but also the connections, which are liable to be erroneous or to have become unintentionally deranged. (C. R. Brown.)

The following method we find to be a rapid and sufficiently accurate method of checking our switchboard instruments. We short-circuit the secondary coil of our current transformer and then cut a standard ammeter and indicating wattmeter in series with the switchboard ammeter and indicating wattmeter tapping the potential circuits of the wattmeters across the same points and arranging the connection so that no instrument indicates the losses in any other. Then by means of a variable non-inductive resistance (viz., a lamp bank) we vary the current through the current coils of the instruments and compare the readings. If they check up, this completes the test, if not, the instruments are removed from the board and adjusted in the meter department.

By a slight modification this test can be arranged to check up the ratios of the current and potential transformers if desired. (S. R. Inch.)

Alternating-current switchboard instruments used in connection with transformers can best be checked by testing them in connection with their transformers. This is not always feasible since instruments using transformers are generally connected to high-tension conductors. For example, a wattmeter on a high-tension circuit can be checked by putting a standard wattmeter into the circuit with its voltage coil directly on the high-tension side of the potential transformer and a large amount of non-inductive resistance in series with it. It is much simpler to connect the series coils on the secondary of the current transformer for making a check of the instrument in position. The ratio of transformation of the current transformer must, in this case, be determined by a separate experiment in the laboratory after disconnecting the transformer from the high-tension circuit. It is perfectly feasible to determine, also, the ratio of transformation of the potential transformer in the laboratory. If this is done, the indicating instrument alone may be given a separate laboratory check. To determine the ratio of transformation of the current transformer, an accurate alternating-current ammeter, such as for example, a Kelvin balance, can be used to measure the current on the primary side, while another ammeter measures the current on the secondary side. The way in which a check of this kind is made will depend largely upon local conditions, so that no general rule can be followed. Obviously, it is necessary in making checks on the instruments on the high-tension circuits to insulate thoroughly all instruments and multipliers employed. (Electrical Testing Laboratory; R. C. Lanphier.)

A current dynamometer or the Kelvin balance is the most reliable instrument for use in standardizing alternating-current ammeters. A properly constructed electrodynamometer is a most reliable transfer instrument. (Electrical Testing Laboratories; E. W. Gough; R. C. Lanphier; C. R. Brown.)

The best instruments for standardizing alternating-current voltmeters is a Weston standard alternating-current voltmeter of the moving coil type. (E. W. Gough; Augusta Railway & Electric Co.; Electrical Testing Laboratories.)

The best method of obtaining the work constant of a watt dynamometer, if properly constructed, so that it is free from error due to capacity, inductance and eddy currents is by direct-current standardization. If the dynamometer does not fulfill these conditions, its constant can be determined by comparing it on an alternating-current circuit of the required frequency with a standard wattmeter that does fulfill the above conditions. (Electrical Testing Laboratories.)

Calibrate as a direct-current meter in the following manner:—level up instrument on a stand that can be swung through an angle of 180 degrees, apply direct-current pressure to the pressure coil of dynamometer with no current through the current coil. If meter is affected by stray fields dynamometer will swing, rotate dynamometer on stand until no deflection is obtained. The meter is then in position where it is not affected by external fields and can be accurately calibrated by using direct-current voltmeter and ammeter.

STATION WIRING.

Conductors.—Wire or cable having suitable insulation for the pressure at which it is to be used and in turn covered by a substantial flame proof and slow burning braid is the proper wire to use for station wiring. Insulation should contain at least 30 per cent. pure Para with no reclaimed rubber. Use lead covering where deterioration from dampness or fumes is feared. (H. A. Strauss; A. T. Beauregard; W. H. Greenslit; Warren Partridge.)

Have been using varnished cambric cable for several years insulated and tested for double the voltage for which it is used, and covered with either double flameproof braid or lead armor where exposed to dampness. Have had no trouble whatever and find it vastly superior to rubber. (G. L. Knight.)

High-tension wiring should be thoroughly insulated for at least double the voltage and with flameproof covering, or if bare, such as busbars and interconnections of switches should be absolutely protected from contact by barriers, preferably masonry, so that attendants cannot accidently touch them. In wiring from generator to switchboard for polyphase current it is better to use one conduit for each phase unless iron is used, in which case all wires must be in single duct, and should be multiple conductor cable. (H. Clyde Parrish; F. C. Sargent; M. C. Turpin, G. L. Knight.)

With 2,300-volt, three-phase, 60-cycle generators, the best practice for connecting the generator with the switchboard is to use three-conductor, lead covered cables, tested to 5,000 volts. Ample carrying capacity in the cable should be provided, there should be bells at each end, and the bells filled with insulating compound. (F. C. Sargent; W. C. Stoddard; George Ross Green.)

Insulation.—The discharge resistance leads from the generator field switch need not be insulated for a higher voltage than the field leads. (Bertrand Rowe; H. H. Barnes, Jr.; M. P. R., New York Edison Co.; Clayton Geirger.)

It is advisable to insulate a switchboard gallery, particularly in a station constructed of steel and concrete. However, it is impossible to be sure that the gallery can be kept free from grounds. It is certainly much safer to have all structural work about the power station thoroughly grounded and all apparatus grounded also, such as frames of generators, transformers and other devices. (J. T. Whittlesey.)

Control Wiring.—See control boards.

Grounding.—The best practice for ground plates is to sink a tinned copper plate in permanently damp earth and embed it in crushed coke or charcoal, preferably pea size. In a water-power station connection should also be made to the iron flume. Connect all ground circuits and the frame of the building as well as all apparatus to be grounded to the same circuits. (Bertrand Rowe; R. D. Laxton.)

A 1-in. galvanized pipe 8 ft. long driven in the ground shows good results on lightning arresters. All parts should be insulated for safe protection. (Augusta Railway & Electric Co.)

Conduit.—High-tension conductors inside the station, if cable should be run in either fiber conduit surrounded by concrete or in iron pipe. Single-phase alternating-current cables may not be run in iron pipe as hysterisis heats the pipe and losses result.

Control wiring should always be run in iron pipe, care being taken as above on alternating-current circuits.

If necessary to run single-phase high-tension conductors, where the concrete construction and fiber duct may not be used, brass pipes should be used. (G. L. Knight.)

SECTION XII.

Overhead Lines.

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Overhead Lines.

Setting.—With a derrick on wheels, using horse for power, it takes about ten minutes to erect a 60-ft. pole from the time they take hold of it until they let go. (1903.)

The best way to erect a large pole is to use rope blocks and gin pole, pulling by hand, windlass or horse-power, having necessary guy lines for steadying pole. (1903.)

Cost of Dead Man.—A first-class anchorage for guying poles can be installed for about $4.00 per anchorage where there is no blasting, the service being entirely satisfactory. (1904.)

Blasting Pole Holes.—An inexperienced person should never be trusted to use material necessary for blasting pole holes, as it is highly dangerous work and the best results can be obtained by those who have had experience in mining operations. The materials used are nitro-glycerin of the 40 per cent. variety with the usual cap and fuse for exploding, ignition by magnet or battery being instantaneous and much less dangerous than a match lighted fuse. Hole should be about 1⅛-in. in diameter, drilled on a slant to a depth of about 3 ft. 6 in. for a 5-ft. hole. In localities where flying pieces of rock are objectionable heavy timbers, such as old railroad ties, chained together, should be placed over the hole before the blast is set off. Materials may be brought at most hardware stores. (1904.)

Length of Pole.—Under average conditions the best size of pole is a well proportioned 35-ft. pole when there are no trees to be considered. When trees interfere it is best to go over them up to a point where poles exceed 50 ft., in which case it is better to use short poles and go under the trees or through the lower branches if proper trimming privileges can be obtained. (1908.)

Treating Poles—After the poles have become air dried the following treatment is recommended:

The butts of the poles are placed in an open iron tank, containing a sufficient amount of creosote (dead oil of coal tar) to cover them about 1 ft. above the ground level. The tank should be equipped with steam coils, or so arranged that fire can be placed underneath. The temperature of the oil should then be raised to from 212 deg. to 225 deg. fahrenheit and for most species this temperature should be maintained for about 6 hours. The heat should then be shut off and the poles allowed to stand for several hours in the cooling oil. The process can be somewhat hastened by allowing the hot oil to run out and letting in the cold oil simultaneously. The practicability of this method has been fully demonstrated by the experiments of the Forest Service. Many details, however, yet remain to be worked out in order to arrive at the quickest and most economical method. A cheaper but less effective treatment can be given by painting the butts of the poles with two coats of creosote or of carbolineum applied at about 175 deg. fahrenheit. The results of the open tank process, however, are much more desirable in proportion to the first cost. The open tank process has been found particularly well adapted for such species as southern yellow pine, chestnut, cedar, the so-called white pine or bird's-eye pine of the Rocky Mountains and western yellow pine. One of its principal advantages is that it avoids the necessity of creosoting the entire pole, as in some situations only that portion at or near the ground line is subject to rapid decay. In very damp, warm situations, however, such as are found along the Gulf Coast, it is often necessary to creosote the entire pole.

Just what increase in length of service will be brought about by the open tank or brush treatment cannot be definitely stated, as all the work under American conditions has been too recent to permit the decay of the poles. It is well known that a thorough impregnation with a good grade of creosote will render wood immune from decay for a long term of years, and judging from the condition of the butts of the poles after treatment by the open tank process, and from our knowledge of the antiseptic qualities of the preservative, there can be little doubt as to the securing of a decided increase in life. It can be said without hesitation that this increase will be more than sufficient to repay the cost of the treatment. (1905.)

Creosoted poles have not been used to any extent for electric work for although the length of life is greater, it is believed the strength of the pole is somewhat impaired. The telephone companies once used creosoted poles for distribution work, but it is not now their general practice. (1907.)

Life.—As a rule poles have the longest life in service when they are of wood indigenous to the section of the country in which they are to be used. (1906.)

Average age of chestnut trees (Maryland) from which can be cut poles of the dimensions given in these specifications. (1905.)

	Minimum circumference		Corresponding ages	
Length over all in feet	6 ft. from base inches	top inches	Trees from seed years	Coppice years
30	37	22	53	43
35	41	22	58	48
40	44	22	63	54
45	47	22	68	59
50	50	22	73	65
55	53	22	78	72
60	57	22	84	79

The relative life of chestnut and white-cedar poles is about 30 per cent. in favor of the former. (1904.) Native Western poles should be cut when sap is down. Cypress poles as a rule last about three or four years, Gulf Zone cypress being better than any other. They fail without warning, are very brittle, and are not recommended by anybody who has ever used them.

Pole Specifications.—The following is a fair specification for cedar poles:

All poles must be cut from line growing cedar timbers, peeled, knots trimmed close, and butts and tops sawed square; tops must be sound and must measure as follows in circumference:

Butt measurement inches	Top measurement inches	Butt measurement inches	Top measurement inches
13	4	25	8
15	5	28	9
18.5	6	31	10
22	7		

Idaho Cedar tapers approximately 1 in. every 8 ft. of length.

No pole shall have more than one crook and this crook shall be one way only, the sweep not to exceed 1 in. to every 6 ft. in length, to be determined in the following manner:

Place a tape at the center of the top and stretch to the center of the butt; the distance from the tape to the nearest side of the pole at widest point shall determine the amount of sweep.

Butt rot in center including ring-rot, shall not exceed 10 per cent. of the area of the butt. Butt rot of a character that impairs the strength of the pole above ground is a defect. Neither a large knot, if sound and trimmed smooth, nor a perfectly sound dead or dry streak shall be considered a defect when not materially impairing the strength of the pole. (1907.)

Guys.—On pole lines through wet swampy sections, guys are used in preference to braces for taking up side strains. (1908.)

Life of Iron Poles.—The apparent life of iron poles is from 20 to 40 years, dependent chiefly upon construction of the pole. (1904.)

CROSSARMS.

Seasoning.—Checking of crossarms cannot be prevented, but the probability of checking is greatly lessened by piling the crossarms loosely, placing thin strips of wood between each layer in the pile, thus allowing a free circulation of air about the crossarms. (1906.)

Life of Crossarms.—Yellow pine heart wood has an average life of 10 years, yellow pine sap wood 5 years and cypress about 5 years. White pine is not used as it is too expensive and too soft.

Oregon fir is best material to be used for untreated crossarms, for the reason that it is large growth timber and on this account can be obtained free from knots and of straight grain, clear stock. Hard yellow pine makes a good crossarm but is not as strong, does not last as well as Oregon fir and is more difficult to obtain. Maine spruce used to be a fair material when large growth timber was obtainable, but in recent years this has become impossible. (1906.)

Short leaf yellow pine properly creosoted will give practically an indeterminate life. (1906.)

PINS.

Mounting.—Crossarms should be fitted with pins before leaving the storeroom, pins being painted or treated before they are placed in the arms. (1905.) A coating of paraffin or white lead answers all purposes.

Material.—Locust wood makes the best wood pin, all other wood being decidedly inferior, on account of early rot or brittleness.

When locust pins cannot be obtained steel or iron pins are usually used, with wooden bushings to take the thread of the insulator. Birch and oak pins are also substitutes, but they give very unsatisfactory service. (1907.)

POLE HARDWARE.

Guy Anchors.—The general practice is to use a dead man, but on light lines where conditions are favorable the use of patent screw anchors has given satisfaction. The line and soil conditions will govern the size of patent anchor to be used and thereby its comparative cost, (1907.)

Galvanizing.—The hot galvanized or dipping process is preferable as by this process only is it possible for the finished product to meet what is called the "four immersion," or engineering standard test. (1907.)

CONDUCTORS.

Protection from Trees.—For protection from trees for circuits of the ordinary 2,000-volt class, tree wire with wooden moulding gives the most satisfactory results. (1903.)

Telephone Wires on Same Line with Power.—Telephone lines on the same poles carrying wires of 2,400-volt potential and less may be sufficiently protected by placing the higher voltage wires above the telephone wires using standard construction, and placing the highest telephone wire at least 4 ft. below the lowest lighting or power wire.

Telephone wires for public uses should not be carried on the same poles with wire of a constant potential exceeding 5,000 volts. Conflicting lines should not be put up. The highest potential wires should be in the topmost position. For ordinary 2,400-volt primary voltages, one standard 24-in. gain space is sufficient; for higher voltages the spacing of arms should be sufficient to meet the exigencies of the voltage effects. (1903.)

It has always been and is at present considered undesirable to run public telephone wires on the poles which carry lighting or power wires of a voltage exceeding 5,000 constant potential. When public telephone wires are run on the same poles with lighting or power wires of a potential less than 5,000 volts the lighting or power wires should be above the telephone wires.

Private telephone wires, such as are used between substations and for patrolmen, may be run on the same poles with transmission lines of any voltage, but they should be below the transmission wires, and have pin spacing and arm spacing sufficient to care for the induction effects and probabilities of contact with the transmission wires. Special instructions are necessary for the handling of such telephone circuits. (1904.)

To prevent danger to linemen and troubles from induction the minimum vertical distance between the high-tension wires (1,000-2,000 volts) of two different companies occupying the same side of the street or crossing at right angles should be 4 ft. (1903.)

Cable Ducts.—It is not desirable to run more than one cable in one duct, such a cable to carry as many conductors as may be required by the distribution system, and of such size as to be properly enclosed in one case or sheath. The standard size of duct is approximately 3 in. (1904.)

Wire Through Trees.—It is not desirable nor economical to put up sections of lead covered insulated wires through trees, as the benefits desired are not obtainable thereby. A suitable rubber covered tree wire protected by a wooden moulding is a good method for such construction and is not expensive. (1904.)

Grounding Direct-Current Three-Wire System.—Grounding the neutral of secondary circuits reduces the life hazard to a minimum at the consumer's premises. The best ground obtainable is an active water pipe system, though driven pipes, or plate grounds may be made where water pipe grounds are not available. The grounding of the neutral wire outside should occur approximately every 500 ft. (1905.)

Spacing on 2,400-Volt System.—The normal pin spacing for 2,400-volt work is 14½ inches, and the arm spacing is 24 inches, with poles from 100 to 125 feet apart. (1905.)

Telephone and Power Wires.—Induction effects from 11,000-volt line on telephone systems may be avoided by placing the telephone wires 8 ft. below transmission wires, insulating them thoroughly from ground and transposing every 6 sections. (1905.)

Joint Use of Poles.—When two lighting companies are required to make joint use of certain poles, each having 2,200-volt primary alternating-current lines and 220-volt secondary lines, a zone should be allotted to each company, with a separation of two gains or 48 in. between the zones. The primary wires should be on top position in each zone with their secondary wires immediately underneath, thus following standard construction methods and making it possible easily to distinguish the construction of each company. A climbing space of 40 in. should be provided between the pole pins on each arm on the pole. (1905.)

High-Tension Crossings.—A positive method where possible is to have the crossing poles of sufficient height to make it impossible for a wire in the span, if it should fail, to touch a wire of the line below. Where such construction is not possible, crossing wires should be put up with such factors of safety in wires, insulators, pins, crossarms, ties, etc., that there is little probability of failure, and metal arms, grounded, are recommended. The cost will depend entirely on number and size of wires and local construction conditions. (1905.)

Joints.—All joints in soft drawn covered wires should be soldered and taped. Hard drawn wires should be spliced by means of mechanical connectors or sleeves. (1907.)

Arrangement of Two Two-phase Circuits.—A good arrangement of two two-phase circuits is to use two four-pin arms with one phase on each of the arms and both phases on one side of the pole. The effects of self induction will thus be at a minimum and also one side of the pole on one circuit can be killed for working on it and leave the other side alive and safely out of the way of the linemen. By having the complete two-phase circuit on one side of the pole a better arrangement of two-phase service leads is possible. (1907.)

Spacing High-Tension Wires.—If pin insulators are used, 14½ in. spacing up to 6,600 volts with an increase of not less than ¾ in. for each additional 1,000 volts will be safe. If suspension insulators are used, conductors swinging 45 deg. shall not come closer to any part of the supporting structure or to other conductors than 30 in. for 60,000 volts, with an increase of not less than ½ in. for each additional 1,000 volts. Suspension insulators are seldom used for voltages lower than 60,000. (1908.)

Light and Power in Same Circuits.—There should be no difficulty in operating light and power from the same circuits, if separate transformers are provided for light and motors, under the conditions described. Any of the standard forms of hand controlled regulators will give reasonably good satisfaction if the power load does not fluctuate rapidly. If considerable fluctuation is noticeable it would be more satisfactory to use automatic regulators. The circuits may be equipped with line drop compensators which can be set to compensate both for resistance and inductive drop and which indicate to the station operator at all times the feeder end pressure. This method of operation is in use in a number of cities of 80,000 inhabitants and over. (1909.)

Services.—Rubber covered and braided duplex service loops are the best method of construction for service into residences. Its life is yet to be determined.

COPPER.

Wire Sizes.—For 2,000-volt work No. 4/0 B. & S. gauge is the largest wire that can be run overhead comfortably and look well; if larger copper is required to meet the load conditions it is better to add circuits and operate them in parallel, rather than to increase the size of the copper in any one circuit. The minimum size of wire should be No. 6 B. & S. gauge, as smaller wire than No. 6 has not sufficient mechanical strength to make its use desirable. (1903.)

Life of Rubber-Covered Wire.—Ten years is the average life of rubber insulation under average conditions, though longer life is attained under favorable conditions. (1903.)

Use of Insulated Wire.—Triple braid weatherproof insulation is desirable on wire carrying voltages up to and including 6,600 volts, both for the sake of appearance and the protection afforded linemen, and it is beneficial in case of high resistance crosses. All wires, whether insulated or bare, should be treated as if alive by the men handling same, and no dependence should be placed upon the insulation. (1906.)

ALUMINUM.

Feeders.—Aluminum feeders have given satisfactory service. The price of aluminum very closely follows the price of copper and the saving in the purchase of aluminum is usually from 5 to 10 per cent. (1904.)

Long Distance Lines.—For heavy high-tension long distance transmission lines the use of aluminum is somewhat cheaper as it can be put up for less money, and also as it is lighter it lessens the strain on the poles or towers. There is no difficulty in making satisfactory joints and the expense of making joints is not appreciable. (1906.)

Sleet.—The accumulation of sleet on aluminum as compared to copper will vary in direct proportion to the difference in cross sectional area of the conductors used.

GROUNDED WIRE PROTECTION.

Grounded Wire.—A grounded wire stretched above the circuits on a high-tension transmission line does afford some protection against effects of lightning. On voltages below 15,000 the benefits hardly warrant the expense. See N. E. L. A. reports of Committee on Protection from Lightning Disturbances. (1908-1909 and 1910.)

Ordinary barbed wire such as is used for fence work has not sufficient mechanical strength to be safe for such work. (1907.)

Carry ground wire in a solid insulating conduit from crossarm to ground. A half wooden moulding properly banded or strapped to the pole is often used. On private right of way ground wires from transmission lines are often of bare conductor and strapped to the pole without covering of any kind. (1906.)

LIGHTNING ARRESTERS, JUNCTION BOXES, FUSES, POT HEADS, ETC.

Arresters in Secondary Circuits.—Lightning arresters should not be used on secondary circuits. Ground the secondaries. (1904.)

Cut-Outs on Primary Lines.—The least interruption of service will result if cut-outs are used on all branch lines of any importance. (1904.)

Protection of Long Lines.—The best and most efficient lightning protection for a high-voltage transmission line not exceeding 10 miles in length is given by electrolytic arresters at each end of the line and if line varies greatly in altitude throughout its route, multi-gap arresters installed at one or two of the high points would add to the protection. (1904.)

It is desirable to place arresters between phases as well as between each phase and ground. (1904.)

Fusing of Transformers.—When transformers are connected in parallel, fuse the secondaries to 50 per cent. overload of each transformer so fused.

Lightning Arrester Ground.—The best ground usually obtainable in paved streets is an active water pipe system. Where such is not available driven pipes inter-connected give fair results and a coil of wire placed in bottom of pole-hole when pole is set will give fair results also.

Static charge may be removed from arc and primary circuits by using lightning arresters at station end of lines and at junction points with the underground. Ground the sheath of all underground cables. (1905.)

Spacing of Line Anchors.—Under average conditions there should be about four arrester installations per mile. Special conditions require special and careful study as to lightning arrester requirements. (1906.)

Connecting Underground to Overhead Circuits.—A porcelain pot head with metal disconnecting parts, the whole having a weatherproof hood, is the best type of device for connecting underground services at 2,300 volts to overhead lines. (1907.)

Tests of Fuses.—The rating to which open-link fuses must conform is given in Section B of Article 53 of the Electrical Code of the National Board of Fire Underwriters. The rating for enclosed fuses is much more explicit and is given in Section H of Article 53. Fuses made by reliable companies easily meet these specifications.

The tests are best made on a storage battery, because it is easy to maintain a large steady current at low voltage. A constant air temperature of 24 deg. cent. should be maintained around the fuse. This temperature regulation is often difficult to obtain. The ammeter used should be calibrated if very precise results are desired, and allowance made for error in scale readings.

The time it takes the fuse to blow under various overloads is easily measured with a stop-watch. The true rise in temperature of the caps and shell (of enclosed fuses) is hard to estimate accurately, because check results are almost impossible. Readings taken from a thermometer bound to the fuse, vary, often widely, from those obtained by using a thermal junction and galvanometer. A large number of fuses of a kind should be tested in order to determine whether the heating of the fuse is injurious to the caps and shell or to the fuse block.

MISCELLANEOUS CONSTRUCTION AND OVERHEAD OPERATION

Open Circuit or Ground.—Where a transmission line is sectionalized, a cross, an open circuit or a ground can be located very quickly by switching out the various sections. If not and the line is polyphase and the cross is between two of the phase wires, it can be located from the generator end by the loop method in connection with a Wheatstone bridge, both ground and open circuit being found in the same manner.

The best and most convenient device, in the hands of workmen, for detecting whether high-tension cables are alive or not is a coil and telephone receiver.

For ordinary line poles without special side guys, etc., transformers not larger than 15-kw. can be safely placed, but with special construction, transformers as large as 100-kw. can be erected.

Line Maintenance.—In order to divert public sentiment against the unsightliness of overhead lines, build and keep the lines in the best possible condition, erect the poles as nearly as possible on property lines, keep the wires from damaging trees, and avoid unnecessary trimming.

Adopt a system (such as a railroad wrecking train) to take care of interruptions to service. A transformer of sufficient size already connected to flexible wires of sufficient current capacity and insulation and so arranged as to be readily placed on a wagon or automobile, speedily transported to point of demand and temporarily connected into circuit, is the practice in England. The transformer remains in the wagon and a man remains on duty as watchman until daylight when the regular gang arrives and makes permanent repairs. It is not, however, practiced in this country, although it is thought by central station men to be a good scheme and worthy of careful consideration.

Agreements have been made by member companies with telephone and telegraph companies covering joint ownership or occupancy of pole lines; in some instances rental is paid by the company for attachments made to another company's pole. As the erecting of two pole lines on the same street is now prohibited in most municipalities it has become quite common practice for the various companies to jointly build the pole lines, each company interested bearing its share of the expense and each reserving a position for its construction, the maintenance being borne jointly by the companies.

RECORDS, COSTS, ETC.

Stenciling Paint.—A durable paint for stenciling names and numbers on poles can be made from lampblack and turpentine and will last one year in Western climates, while ordinary "Stencil Paint" will last three years in Eastern climates.

Stencil 2-in. black numbers on pole after shaving surface of pole with a draw knife to give firm base and clear back ground for letters and numbers. Use initial or symbol to indicate municipality in which poles are located and also the initial of the company to whom the pole belongs.

The best method of keeping records of location, size, etc., of overhead lines is a map; feeders, primary and secondary may be designated by different colors and different classes of rulings, and the sizes of wire may be plainly marked. This, with a card system giving a complete history of the pole and showing all attachments, makes a very complete record and is most valuable if properly kept as it does away with the possibility of a Superintendent or Company being left in an embarrassing position by having the employee who has it all in his head leave suddenly and take this information with him. It is also valuable as circuits can be traced and checked by the man in charge without its being necessary for him to leave his office.

Annual Inspection.—It is customary for all large companies to make an annual inspection of their pole lines, this work being usually allotted to a competent lineman who reports the conditions as found on a regular form, recommending any action necessary, and when such recommendations have been carried out it is noted upon the form and filed. The cost of repairs per annum per kw-hr. sold runs from 0.09 to 0.50 but will vary greatly on different systems, being usually about 30 per cent. of the total cost of distribution.

SECTION XIII.

Underground Lines.

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COST OF CONDUIT LINES.

The cost of conduit construction varies according to kind of duct, number of ducts installed, kind of paving, character of soil to be excavated and manner of laying duct. The average cost varies from 15 to 30 cents per duct foot. (C. W. Rice, 1904.) Vitrified clay duct in macadam streets; 2-duct, 80 cents; 4-duct, 98 cents; 6-duct, $1.20 per trench foot. (W. R. Gardener, 1904.) Cost with 3-in. envelope of concrete, 15 to 30 cents per duct foot, not including manholes. (W. E. Carleton, 1904.) Average cost of from 9 to 12 ducts in cedar block paving 30 to 33 cents per duct foot including manholes; granite pavement 33 to 35 cents per duct foot, asphalt pavement 50 to 60 cents per duct foot (G. B. Springer, 1904), 6-duct conduit in macadam pavement with 3-in. envelope of concrete. Mixture 1 : 3 : 6 may be installed in easy digging, for approximately $1.00 per foot, including resurfacing trench. (United Electric Light Co., 1909.)

Manholes cost from $75 to $150 according to size, method of construction and pavement. (W. R. Gardener; W. E. Carleton, 1904.)

Whenever possible conduit lines should be built by the regular employees of a company. After a conduit system has once been put in operation, the extensions to it are continuous and it would be a poor proposition to have to hire a regular conduit contractor to put in the extensions as they are required. However, it would be much better to make the first installation by contract than to educate the regular employees at the Company's expense to do such work. (F. G. Proutt, 1905.)

Conduit work can be done cheaper by contract than by Company employees. (United Electric Light Co., 1905.) Conduit work done by Company's employees six years previous to 1905, was done 25 per cent. cheaper and better than by contract. Since that time work has been done by contract. (L. Carspecken, 1905.)

Cost of Maintenance as Compared with Overhead Lines.—The comparative cost of underground and overhead systems depends upon local conditions, the density of the load, the arrangement of streets and system of lighting used. (W. E. Carlton, 1904.) As the load density diminishes, cost of underground lines increases until it becomes prohibitive. With a compact load in a small area, the relative cost of underground lines diminishes, while the relative cost of overhead lines on the same area increases on account of increased accident risk, more frequent renewals, safeguards, etc. (F. S. Chandler, 1904.) There are few places where it is advisable to put residence lighting underground, where the population is less than 50,000, although it is frequently possible to do so in the business sections of such cities. (W. E. Carlton, 1904.) Cities of 20,000 inhabitants or less should not have an underground system. Local conditions and the nature of the system have much to do with the question of underground lines in cities over 20,000 and there is always more or less underground in the business center of those over 100,000. (E. C. Teal, 1908.) A company can not determine accurately from a financial standpoint whether or not putting lines underground would be a paying proposition, although in certain cases it would pay to put wires underground in the business section of almost any city of 10,000 or more inhabitants. (F. G. Proutt, 1905.)

In general the cost of maintaining underground lines will be less than that of maintaining overhead lines. (W. E. Carlton, 1904; W. G. Carlton, 1905.) This would depend on whether high- or low-tension system was in use, and in case manhole transformers were used, whether good drainage could be obtained for the manholes. (W. E. Carlton, 1904.) In case of a bad burnout, the repairs will be much higher than on overhead work. Depreciation on well installed conduit is small being about 5 per cent. Deterioration on cables would be from 8 per cent. to 10 per cent. (W. G. Carlton, 1905.) The cost of maintaining underground system is so much less than that of an overhead system that the matter of putting lines underground should not be considered purely from a financial standpoint. (F. G. Proutt, 1905.) Overhead lines used in conjunction with a limited amount of underground lines are more difficult to maintain, owing to the difficulty of protecting from the weather, the joints between cables and overhead wires, the difficulty of properly guying and supporting terminal poles, and to the presence of the grounded cable sheaths creating dangerous conditions for linemen. (H. B. Gear, 1904.)

Overhead lines used in conjunction with a limited amount of underground cable are no more difficult to maintain than complete overhead lines. (E. H. Mather, Edison Electric Illuminating Co. of Boston; W. R. Gardener, 1904.) There is, however, more liability to damage from lightning. (E. H. Mather; W. R. Gardener, 1904.)

Cheapest and Best Underground Systems for Small Towns.—Vitrified clay conduits are the best; creosoted wood conduits are the cheapest. (W. S. Barstow, 1903.)

Choice of System for Best Distribution.—The system to be chosen would depend upon the nature of the town. With customers close together, a low-tension system using the Edison tube system would be cheapest and best. (H. L. Bragdon; W. E. Carlton; Edison Elec. Ill. Co. of Boston, 1903.) With a more extended territory, the conduit and cable system, using high-tension distribution and manhole transformers would be very much cheaper. Individual services should be run from the regular manholes at the street corners. (Edison Elec. Ill. Co. of Boston, 1903.) In the majority of cases, a conduit and cable system built of tile duct for both trunk and distributing lines, with manholes at street intersections can be used. Handholes on distributing lines can be built where house connections are installed, by breaking out tile ducts and building the walls of brick or concrete which can be brought to the surface with castings, or the mason work can be covered with an iron plate and paved over.

Paper insulated cable with lead armor is cheapest for mains and feeders. Rubber insulated cable with lead armor should be used for house service connections, as when paper insulated cable is used for this work the house ends require considerable attention. (H. S., New York Edison Co., 1903.) The best plan of distribution for a direct-current system is to run two three-wire cable mains, one on each side of the street, as close to the curb as possible. From these mains laterals may be run to buildings, the connections to mains being made in small handholes. The mains should receive their supply of current from junction boxes in sewered manholes, at points to give uniform pressure and even distribution of load on the feeders supplying the system. This same system can be used for alternating-current distribution by replacing the junction boxes with transformers. (R. W. Rollins, 1902.)

Trenching.—In trenching in asphalt, cut the asphalt into squares which can be replaced when work is done, until permanent repairs can be made. (G. B. Springer, 1904.) Asphalt may be cut into squares by cutting incisions ½ to ¾ in. deep, filling these cracks with kerosene oil and setting fire to the oil. This causes the asphalt to lose its brittleness so that it can be cut readily. (B. E. Strohm, 1904.) It is cheaper to have the city replace asphalt. This plan eliminates all chance for argument as to whether or not pavement is right when finished. (H. L. Bragdon, 1904.)

Duct.—The following different kinds of duct are recommended for use in conduit systems:

Vitrified clay tile on account of low cost, durability and ease of laying. (G. B. Springer, 1905; L. L. Elden, B. E. Strohm, 1906; P. C. Oscanyan, 1907; S. Hosmer, 1908.) Fiber conduit, (F B. Sharpe, 1905) especially where insulating qualities are desired. (L. H. Conklin, 1908; P. C. Oscanyan, 1907.)

Creosoted pump-log, for small lines. (F. M. Vander Voort, 1906.) Multiple terra-cotta duct, on account of durability. (L. Carspecken, 1905.) Iron pipe, where good foundations are impossible, or to span gaps. (L. H. Conklin, 1908.)

The reasons for the use of any particular kind of duct will be subject to the conditions to be met. Where difficult obstructions are encountered, in crowded streets where groups of pipes have to be crossed, or where it is necessary to go between pipes, the single clay duct is most available and easy to handle, (G. B. Springer, 1905), and if not subject to mechanical interference will probably be most durable. (L. H. Conklin, 1908.) Multiple conduit of 2, 3, 4, 6 or 9-duct sections, 3 ft. long, may be used in streets free from obstructions. The duct most commonly used is the single round and single square tile about 3½ in. in diameter and 1½ ft. long. This duct gives the additional advantage of two walls separating any 2 cables. (G. B. Springer, 1905.)

Ducts for conduit lines should be practically indestructible, not subject to disintegration by the elements, water, acids, alkalies or electrolysis. They should have a smooth inside surface, be reasonable in cost and economical to install. (G. B. Springer, 1905.) A tile which will absorb water is not fit for conduit construction. (Edison Electric Illuminating Co. of Detroit, 1905.)

Installation of Duct Lines.—Conduit lines should not be laid too near the surface, as frost is liable to throw them out of line. (Edison Electric Illuminating Co. of Detroit, 1905.)

Conduit should be surrounded with three inches of concrete for protection against digging by other companies, and to render conduit more nearly water-tight at joints. (L. Carspecken, 1905.) In laying several single ducts in a conduit, all joints should be staggered to give protection to adjacent cables in case of a burnout in any one duct. (G. B. Springer, 1905.) The number of ducts to be installed should be considerably more than the immediate requirements to provide for future increase of the system. (B. E. Strohm, 1906.)

Manholes.—Manholes should be located at street intersections, and should be large enough to accommodate transformers. Small manholes can be built at intervals of 500 ft. from which laterals may branch off to reach customers on both sides of the street. (B. E. Strohm, 1906.) Transformer manholes should be fairly dry, preferably with sewer connection. (W. G. Carlton, 1903.)

Construction of Manholes.—Manholes may be built with concrete floor and sidewalls, reinforced concrete, or iron and brick coverings, with iron openings and cover. (Toledo Railways & Light Co., 1905.) Probably the best roof for manholes is concrete, as it is practically water-proof. (W. G. Carlton; G. B. Springer, 1905.) Cracks are likely to develop in manhole walls, particularly in the corner between the walls and the roof. These should be kept cemented up. (W. G. Carlton, 1905.) In laying concrete roofs, spread about one inch of cement mortar on the temporary boards for supporting roof during construction; on this place concrete 8 or 9 in. thick and tamp well; on top of concrete place another inch of fairly rich cement mortar; if deemed necessary, cover with a coating of tar; this method will make a practically water-tight roof. (G. B. Springer, 1905.) In building a waterproof brick manhole, bricks should be laid with flush joints and no space left without mortar. About ½ in. of mortar should be plastered on the outside of brick wall, as well as on roof. Tar paper and gravel may be used on the roof. There are several preparations said to be water-tight which may be applied to the back of walls and to the bottom, inside of manholes. Waterproof manholes are too expensive to use except where absolutely necessary, (G. B. Springer, 1906) and it is almost impossible to build an absolutely waterproof hole. (Toledo Railway & Light Co., 1906.)

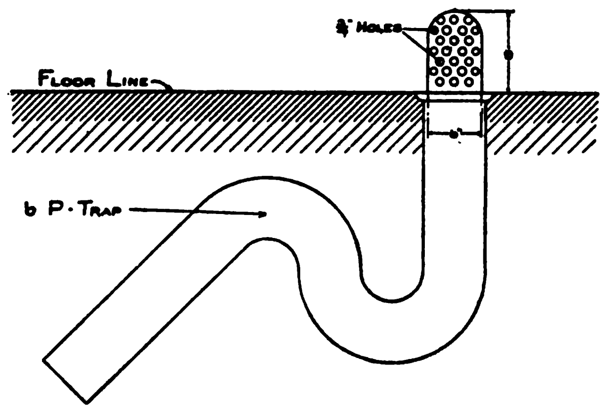
Ventilation of Manholes.—The most common method of ventilating manholes is by the use of perforated covers. (Edison Elec. Ill. Co. of Boston; J. B. N., New York Edison Co., 1903; H. E. Bragdon; W. G. Carlton; L. Carspecken, 1905; Rochester Railway & Light Co., 1908.) A shield may be used under the perforated cover to keep dirt from falling into the manhole. (H. G. Stott, 1903.) Connections to smoke stacks help to ventilate manholes. (Edison Elec. Ill. Co. of Boston, 1904.) Transformer manholes may be ventilated by tubes run under the street surface to sidewalk and brought up through the sidewalk in the shape of a small cast iron post. (F. G. Proutt, 1905; H. L. Wallace, 1908.) Two tubes should be installed, one from top and one from bottom of the manhole, to provide good circulation. (Edison Elec. Ill. Co. of Boston, 1905.) Installation of ventilating tubes would depend upon amount of heat given off by transformers. Good ventilation should be provided for large heavily loaded transformers. Perforated cover on manhole would probably be more satisfactory than a tube. (W. G. Carlton, 1905.)

Transformer vaults in customer's premises are ventilated by means of gratings at top and bottom of vault walls. In some cases, pipes are let in at top with elbows and a short standpipe projecting outside, protected by a rain shield. (H. L. Wallace, 1908.)

Prevention of Gas Explosions, Etc.—Ventilate the manholes by use of perforated cover. (W. S. Barstow; W. G. Carlton; Edison Elec. Ill. Co. of Boston; H. G. Stott; J. B. N., New York Edison Company, 1903; H. E. Bragdon; W. G. Carlton; G. B. Springer; F. G. Proutt; L. Carspecken, 1905; Rochester Railway & Light Co., 1908.) Connect manholes to sewer through a trap. (H. E. Bragdon, 1905; J. B. N., New York Edison Co., 1903.) Leave covers off of holes near gas mains as long as necessary before allowing men to enter holes. (W. G. Carlton; G. B. Springer, 1905.) Notify the gas company whenever traces of gas are found, that they may repair their pipes. (G. B. Springer; W. G. Carlton, 1905.) Take all possible precautions against sparks or flames from cable burnouts. (W. G. Carlton; J. B. N., New York Edison Co., 1903.) Keep gas mains in good repair, and as far away from conduits as possible and protect conduits and cables from mechanical injury caused by other excavations. (New York Edison Co., 1903.)

When a fire occurs in a manhole from burning gas, shut off the gas supply if it can be reached. This is usually impossible unless it is coming in through the ducts, when it is sometimes possible to stop it by plugging the ducts in the next manhole. Sand or some extinguishing powder will sometimes smother the flames. (B. E. Strohm, 1907.)

Sewer Connections.—Sewer connections using an ordinary bell trap, or



flat grating on P-trap often clog in heavy rains. A cast iron inlet as shown in sketch obviates clogging. (L. Carspecken, 1905.)

Conduit for Service Connections, and for Connections from Underground to Overhead Lines.—In connecting underground to overhead lines, iron pipe risers should be run to top of pole. This form of construction may be used to cross streets, on which construction is required to be placed underground, and dispense with manholes. (B. E. Strohm, 1906.)

Charges for Installing Underground Services.—A charge of $1.25 per foot from property line through cellar wall, company furnishing main switch and cut-out. No charge for business blocks setting on street line. (W. E. Holmes, 1907)

A charge of $0.25 per foot for conduit from curb line into house. Cable is property of Company and is installed by Company. (United Electric Light Co., 1907.)

Cut-out located at most convenient place to subway entrance and customer runs wiring to meet it. (M. C. Turpin, 1907.)

In changing from overhead to underground systems, it is impossible to charge customers for installing the underground connection, without arousing antagonism, which will cost more in the end than the cost of connections. If possible to do so, charge for all material and labor; if not, make an average charge per foot of service line. (Editor Question Box, 1903.) No charge is made for new connections of this kind. (Edison Electric Illuminating Co. of Boston, 1903.)

Types of Cable for Different Classes of Service.—Underground transmission line at 25,000 volts, using one paper and one rubber insulated cable is in successful operation at St. Paul, Minn. (H. L. Doherty, 1902.) Difficulty in securing thoroughly reliable insulation retards the introduction of high-tension underground cables above 13,000 volts. (R. R. Laxton, 1905.)

Lead covered cable can be used for transmission of 25-cycle or 60-cycle energy up to 13,200 volts. (H. L. W., Clev. Elec. Ill. Co.; J. J. Gaffney; P. C. Oscanyan, 1907.) These installations are on systems of the Cleveland Electric Illuminating Co. and Public Service Corporation of New Jersey. 2,000 kw. at 13,200 volts is successfully transmitted over three-conductor submarine cable. (F. C. Sargent, 1907.)

Lead covered, paper or rubber insulated, cable should be used on 2,200-volt primary circuits. (P. C. Oscanyan, 1907.)

Single-conductor lead-covered cables should not be used on alternating-current systems, on account of induced currents in the lead sheath. (P. M. Lincoln; P. C. Oscanyan, 1907.) The lead loss thus incurred increases with frequency and amount of current carried. (P. M. Lincoln, 1907.)

Lead-covered, rubber-insulated cables may be used on single-phase service with entire satisfaction, (H. L. Bragdon, 1904) provided the two conductors are in the same lead sheath; or, two single-conductor cables are placed together in the same duct. (C. W. Rice, 1904.) Lead covered cable may be used with entire success on alternating-current lines up to 2,000 volts, even where the ducts are more or less filled with water. (W. L. Mulligan; F. Vander Voort; Edison Electric Illuminating Co. of Boston, 1903; Edison Electric Illuminating Co. of Boston, 1905.)

Leads Between Generator and Switchboard, and Between Switchboard and Step-Up Transformers.—Use single-conductor cables without lead covering with extra insulation suitably waterproofed. (L. L. Elden, 1906.) Single-conductor cables give less liability of trouble and greater flexibility, at greater first cost. (H. A. Strauss, 1906.) Single-conductor cambric insulation. (B. Jamieson, 1906.) Single-conductor cables give less chance of damage to any pair of conductors. (Philadelphia Electric Co., 1906.) Single-conductor cables in separate clay conduits make it practically impossible for lightning or static discharge to cause a short circuit by puncturing insulation. (R. R. Laxton, 1906.)

Use three-conductor lead-covered cables,(E. F. Smith, 1906) as single-conductor lead-covered cables induce current in lead sheath causing voltage drop and heating of sheath. (W. T. Oviatt, 1906.) If lead-covered cables must be used and size of cable is not too great use three-conductor cable. (B. Jamieson, 1906.)

Current-Carrying Capacity of Cables.—Safe current-carrying capacity of underground feeders is about 1 ampere per 1,000 circular mils, (H. J. Myers, 1905) for intermittent load; for continuous duty 0.75 ampere is safer. (Edison Electric Illuminating Co. of Boston, 1905.) Current-carrying capacity of feeders should be such that maximum load would not cause excessive rise in temperature, but would stand large overload for a short time.

Allowing maximum temperature rise of 50 deg. cent., amperage per 1,000 cir. mils. would be.

Sizes of feeders cir. mils	Amp. per 1,000 cir. mils
1,500,000	0.9
1,000,000	1.0
750,000	1.1
500,000	1.2
350,000	1.5

On concentric feeders the current should be about 5 per cent. less. (G. M. Armbrust, 1905.)

Bare Neutral Conductors.—On three-wire direct-current 110-220-volt systems bare stranded cable may be used for the neutral conductor, (D. Burnett; N. T Wilcox; F. G. Proutt; W. G. Carlton; M. A. Hogan, 1905) unless railroad return currents are encountered, when insulated cable should be used. (Edison Electric Illuminating Co. of Boston; M. Carrington, 1905.) It is not good practice to install the bare copper cable in the same duct with lead-covered cable, as the lead covering will carry neutral current and be damaged. (W. C. Carlton, 1905.)

Use of Unsheathed Cable.—It is not advisable to install unsheathed cable under any condition, (H. L. Bragdon; B. E. Strohm; H. S., New York Edison Co.; G. W. Hubley, 1904) as the unsheathed cable is liable to mechanical injury in drawing into the ducts. (H. L. Bragdon, 1904.) Heating and cooling of conductors, by varying current values passing, cause rubber insulation to become partially vulcanized, causing cracks; gases cause deterioration of rubber insulation (H. L. Bragdon; H. S., New York Edison Co., 1904), insulation of fibrous material such as paper or hemp, will stand moisture but a short time. (H. S., New York Edison Co., 1904.) With lead sheathing these troubles are obviated and the life of cable greatly prolonged. Lead sheathing also enables cable to be removed from the ducts at any time, which is often impossible when the braid on an unsheathed cable becomes rotted and strips off from the cable in the attempt to pull it out. (H. S., New York Edison Co., 1904.)

It is unwise to use bare cables even for the neutral, with live current-carrying legs sheathed, because any current on the neutral, caused by an unbalance of the system, will go to ground where it is in contact with the lead sheath of the other cables; should this current be heavy enough, the lead sheath would be destroyed at all points of contact. (B. E. Strohm, 1904.)

Arc Circuit Cable.—Paper insulated lead covered cable may be used with good results on series arc circuits up to 8,000 volts. (H. L. Bragdon; H. J. Meyer; Edison Electric Illuminating Co. of Boston, 1905.)

With 7/32-in. insulation frequent punctures occur after from 7 to 9 years' service. Some of the trouble is due to electrolysis, and there is almost no trouble with the sections running up the lamp posts. (Edison Electric Illuminating Co. of Boston, 1905.)

Advantages and Disadvantages of Various Kinds of Insulation.—Varnished cambric is cheaper than paper or rubber, has a longer life than rubber, is not affected by gases or oils, is easier to install than lead covered paper cable and does not need a pothead. (S. O. Swenson, 1904.) The principal advantage of paper insulated cable over rubber insulated cable is that it is cheaper. (United Electric Light Co.; G. W. Hubley, 1905.) Its disadvantage is its liability to crack and break during installation, although this trouble is more liable to occur in the smaller sizes. (G. W. Hubley, 1905.)

Specifications for Insulation.—It is generally better to leave specifications for cable for both low and high-tension work to the manufacturers. Comparison should be made between the specifications of different manufacturers. (W. G. Carlton, 1905.) Thickness of lead insulation would vary with size of cable required, but the purchaser should lean rather to both heavy lead and heavy insulation. (F. G. Proutt, 1905.)

The average life of rubber insulation should be at least 10 years under ordinary conditions. (G. W. Hubley; Edison Electric Illuminating Co. of Boston, 1904.) The manufacturer should guarantee the cable to stand a reasonable test pressure, depending on the service to which cable is to be put, on all cable installed; also a guarantee that the cable will stand service for 5 years from date of test. (F. G. Proutt, 1905.) High-tension feeder cable which will not stand a test of double voltage for one minute is not safe. (R. D. Laxton; H. J. Gille; N. T. Wilcox; A. Balsley, 1905.) A test of 50 per cent. above normal voltage for one minute when the cable is installed is used on a system operating at 9,000 volts. This test is repeated semi-annually. During a period covering 2 years no cables have been broken down on the semi-annual tests, although occasionally a new cable fails on the preliminary test. It should not be necessary to test cables on large high-tension systems at double the normal voltage. (W. G. Carlton, 1905.)

Periodical Insulation Tests of Working Lines.—It is a question whether or not it is worth while to make such test, as it is usually very difficult to get lines out of service for such a purpose. One Company operating twenty-three 9,000-volt feeders made weekly insulation tests with galvanometer for over a year, without locating any trouble, although several burnouts occurred during this time. Such tests on lines operating at 5,000 volts or under can be made with an ordinary voltmeter and 100-volt battery, and are of some value in keeping track of the general condition of cables. The same kind of tests should be made on feeders and tie lines which can be isolated from other wiring, at reasonable intervals. Tests can not be made on low-tension mains to which house services are connected, as the test would include the insulation of the house wiring. (W. G. Carlton, 1905.) Periodical insulation tests are unnecessary and possibly prejudicial. (C. Olcott, 1909.)

Apparatus for Making Potential Tests on Cables.—The best apparatus for making potential tests will depend very largely on local conditions, such as available apparatus, connections, etc. It may be advisable in some cases to use some of the existing apparatus in conjunction with a special step-up transformer. A separate testing set consisting of a motor generator, or an induction regulator, together with a step-up transformer makes a very convenient arrangement. For a three-phase system, a three-phase testing transformer greatly lessens the time necessary for a test over that required with a single-phase transformer, but the rating of the latter need not be so large, the kilovolt-amperes for a single-phase test being about 45 per cent. of the kilovolt-amperes of a three-phase test. (R. F. Schuchardt, 1907.)

Installation of Cables.—Paper-insulated lead-covered cable must be handled very carefully during installation to avoid puncturing the sheath, thus admitting moisture and destroying the insulation. (H. J. Meyer, 1905.)

To prevent grounded circuits, great care should be used in installing cables, sharp bends and corners should be avoided, care used in splicing, and ends of cable should be kept sealed to keep out moisture. (P. C. Oscanyan, 1907.)

Installation of Cables in Sloping Duct Lines.—Cables may be installed in clay conduit lines having a grade even as high as 100 per cent. if the cable, or cables, in case there are several in one duct, approximately fill the duct. In such cases the friction of the cable on the duct is sufficient to hold it. Split tile placed around the cables, in the bend which connects the vertical conduit with the horizontal conduit will prevent the cable from slipping. Where it is necessary to install a conduit on a steep grade, it will probably be sufficient to have the conduit extend for a short distance further with a grade of only a few per cent. (D. W. Roper, 1907.) No precaution was deemed necessary to prevent slipping, and no creeping was observed after 3 years on cables of from 70 to 180-ft. sections on a slope of 30 deg. (J. W. McNamara, 1907.) A clamp using lead bushing between cable and clamp may be used to prevent slipping of cables in ducts. (P. M. Oscanyan, 1907.)

Number of Cables Installed in One Duct.—Six No. 6, Six No. 4, or 4 No. 4/0 B·& S gauge wires, can be pulled into a 3-in. conduit. (P. E. Strohm, 1904.) Three duplex cables may be run in a single-duct, but it is advisable to place each in a single-duct if possible, as it is necessary to draw out all the cables in one duct, to repair the damage occurring to any one cable, thereby causing interruption to service and much labor and expense. (H. L. Bragdon, 1904.)

Splicing Large Cables.—In splicing large cables use a sleeve, (E. W. Lloyd, 1904) or a special conical brass coupling with a union joint like a hose coupling. The ends of cable are placed in coupling, and then wedged out to the conical surfaces, sweated with solder and carefully filed to true surfaces on end. The ends are butted together and secured by screwing to the nut. A soft copper disk should be inserted between ends before joint is tightened and set. (G. W. Hubley, 1904.)

Prevention of Leakage of Compound from Cable Ends.—The only method of stopping compound from leaking out of the end of paper and lead cables, where the end of cable sweated into a lug is the lowest point in the cable, is to use a cable of which the paper insulation is saturated, but has no excess of oil. This cable would not be good for general use, but might be used for station terminals where this trouble occurs. (Edison Electric Illuminating Co. of Detroit, 1905.)

PROTECTION OF CABLES.

Burnouts.—Burnouts are caused by bad joints, but very little damage done, never more than two feet of cable destroyed. (H. G. Stott, 1903.) Practically impossible to state how burnouts were caused. One or two manholes were completely burned out, but this is the exception, as the damage is usually limited to two or more adjacent cables. (Edison Electric Illuminating Co. of Boston, 1903.) Cables in manholes may be protected against fire and from burnouts in adjacent cables as follows: by wrapping with asbestos sheet or bands of asbestos tape, bound on with galvanized steel tape. (H. G. Stott, 1903; Edison Electric Illuminating Co. of Boston; H. S., New York Edison Co., 1904; L. L. Elden; J. J. Gaffney, 1906), by building shelves on the walls of manholes of the same material as the manhole. (Edison Electric Illuminating Co. of Boston, 1904; L. L. Elden, 1906), by placing split tile around cable and then cementing the tile. (G. B. Springer; B. E. Strohm, 1904), by installing light sheet iron shelves to hold the cable thus encased in split tile, each shelf being large enough to hold several cables (B. E. Strohm, 1906); by means of a grounded metallic covering. (C. W. Rice, 1904.)

Electrolysis, Protection Against.—Alternating-current does not have any electrolytic effect upon underground metallic structures, (H. L. Bragdon; G. W. Hubley, 1904) as it has not the property of causing electro-deposition of metals, which depends solely on direct-current. (C. H. Peters, 1904.)

Electrolytic action may take place with a very low difference of potential between cable sheath, or pipe, and the ground circuit. On the other hand there may be a considerable difference of potential without electrolysis taking place. (R. H. Pierce, 1902.) The amount of electrolytic action taking place on lead cables, or pipes, depends on the amount of current from the cables, or pipes and, to a large extent, upon conditions surrounding them. The best way to remedy the trouble is to connect the cables, pipes, etc., to the negative busbars in the power station, with a conductor of large size and low resistance. (H. L. Doherty; Captain Brophy; Mr. Cahoon, 1902.)

Electrolytic action on cable sheaths and pipes is due to the fact that a portion of the current in the rails of the street railway system leaves the rails and passes through the ground to the cable sheath or pipe. If the current encounters high resistance in its path along the cable or pipe and passes from the cable or pipe, an electrolytic action takes place at this point. In case the conditions are such as to limit the exit surface to a small area the damage at this point will be serious. (W. R. Gardener, 1904.) The following remedies have been suggested to remedy electrolytic action:

Secure adequate return for the street railway system. (C. W. Rice; W. E. Carlton; W. R. Gardener, 1904.) Bond all sheaths together and ground in each manhole. (1904.) Bond all sheaths together and run a heavy return to street railway system, (H. L. Bragdon, 1904) connecting to some point always negative to cables. (D.

W. Roper, 1904.) Make tests on cables with a low reading voltmeter often enough to determine whether there is an appreciable difference in potential to ground. Where this is found, break sheaths on cables. (W. E. Carlton, 1904.) Where such a difference is found between cable and track, a copper wire of sufficient size, connecting cable and track and carried back to generator, has to a great extent eliminated the trouble. (W. R. Gardener, 1904.) Lay cables in vitrified ducts, breaking the lead frequently and insert joints at all such breaks. Any means that will interrupt the continuity of the lead sheath will accomplish the desired results, except when cables are under water at all times. Under the latter conditions, the installation of a large bare conductor bonded to all cable sheaths at each end of the wet section will materially aid in protecting cables. (Edison Electric Illuminating Co. of Boston, 1905.)

Stray Currents in Sheath.—Inductive currents on lead cable sheaths may be prevented by placing both conductors of a circuit in one sheath. (C. W. Rice; Augusta Railway & Electric Co., 1904.) When this is not possible, put the single-conductor cables in the same duct. (C. W. Rice, 1904.)

Cable sheaths may be protected against stray ground currents by bonding sheaths together and connecting to ground (H. E. Bragdon; G. W. Hubley, 1905); insulating sheath from ground in manholes and breaking sheaths frequently and inserting insulating joints at such breaks, (Edison Electric Illuminating Co. of Boston; W. G. Carlton, 1905); using tile ducts, not using iron supports in manholes and by covering high-voltage cables with tile where passing through manholes. (W. G. Carlton, 1904.)

Identification of Lines, Testing of Live Lines, Location of Trouble, Etc. —Tag all cables and keep careful records of the same open at all times to employees of the company. A very satisfactory material for tags is ⅛-in. sheet lead secured to the cable with wire solder. The cable number, voltage, et cetera, are stamped on the lead tags. Detailed drawings should show duct numbers, cable lengths and sizes, etc. One way is to tag all cables at least every block. Tag them all consecutively as they are drawn in on each street. If a cable is ever drawn out, this number disappears. This means there are no two kinds or makes of cable numbered the same on the same street. When feeders are cut up, destroy old records and make new ones. In addition to tagging, safeguard by using a small transformer connected to a telephone receiver, and laid on the cable. If the cable is alive, a noise due to the reversal of current will be heard. In another case, on 13,000-volt, three-phase cables, a telephone receiver in circuit with about 300 turns of No. 24 wire, wound on a wood core, is used. If voltage is on the conductors of the cable, a hum will be heard in the receiver when the coil is laid on the lead sheath of the cable. A compass is misleading on a direct-current cable, because of the ground currents in the sheath. Another way is to strip off the lead carefully and saw the copper in two, using care by standing on dry board and wearing gloves. The action of the spark when cutting the copper will show whether the cable is alive or dead. Block switches at station. A block of wood painted red and stenciled "Wireman on lines," placed in the slot of the switchboard and held in place with a rubber band, is suggested. Also, short-circuit cable ends and ground them. (Dec., 1907.) Coil and telephone for locating grounds. (Edison Electric Illuminating Co. of Boston, 1904.) The slide wire bridge can be used with good accuracy to locate faults on three-conductor lead-covered cables, providing there are two continuous conductors, one grounded and one clear. (G. W. Lunn, 1909.)

Location of Grounds on Low-Tension Cable Feeders and Mains.—Grounds may be located in same manner as described in section on Edison tube system. In addition to these methods, grounds are successfully located by the use of a bank of lamps controlled by a reversing switch connected to bad conductor and ground, and by then following along cables in manholes with a compass, which will show deflections according to direction of current, until ground is reached, when deflections will cease. (H. S., New York Edison Co., 1903.)

Low-Tension Service Connections.—Cable services from low-tension cable mains may be tapped direct to the mains through a wiped joint. Such cables should be fused where they enter customers' premises, before connecting to service switches. Very large services, where the energy comes from more than one direction, may be taken off the mains through junction boxes provided with fuses on positive and negative polarities and cables connected to same through protecting fuses. Ordinarily neutral cables may be tied together without entering the junction boxes. (F. S. Chandler, 1907.)

High-Tension Service Connection.—Cable services from 2,300-volt cable mains should be tapped to the main cables in the service box or manhole, with a lead sleeve, with wiped joints over the connection, the sleeve being filled with compound. This method can be used with single, two or three-conductor cables. The service cables should be run through iron pipe directly to customers' switchboard and there ended in a cable head of cast iron with porcelain bushings, through which the conductors project. This head should be filled with compound. (1904.)

Service Switches and Cutouts.—Service switches and cutouts supplied by the company secures uniformity and reduces liability incurred by promiscuous installation of various types of switches by incompetent persons. (L. L. Elden; G. R. Radley, 1906.) An iron box switch with "lobster claws" in cover combines the function of switch and cutout, takes up less room than required for two pieces of apparatus, offers less temptation for theft of current than an open switch, and can be sealed when required. (G. R. Radley, 1906.) A discontinued customer can be prevented from jumping the fuses and getting current, by placing all exposed terminals under the Company's seal, (F. W. Smith, 1909) or by removing the meter cover, taking the wires out of the binding posts in the meter, taping the wires and sealing up the meter. (J. W. Bishop, 1909.) See also article on Rochester Railway & Light Co.'s standard meter installation in the Electrical World and Engineer for January 21, 1909, page 221. (C. G. Durfee, 1909.)

Connection from Underground to Overhead Lines.—In making connections from underground to overhead lines on circuits of 1,000 volts and over, it is best to use multiple-conductor to the manhole at the base of the cable pole, and there splice on to single-conductor cables run in iron pipe up the pole. These single-conductor cables should be equipped with pot heads, preferably of porcelain with a weatherproof cap and arranged with metal parts which can be pulled apart, virtually making a disconnecting switch. Opposite polarities are thus kept apart on the pole and a cumbersome multiple conductor pothead avoided. (H. B. Gear, 1906.) Ordinary joints well taped and painted have never given any trouble on 2,200-volt circuits, or on 8,000-volt series arc circuits. Potheads are not deemed necessary. (United Electric Light Co., 1906.)

High-Tension Terminal Bells.—Bubbles rising in the compound in terminal bells on 13,000-volt lines are caused in some cases by hydrostatic head in a considerable length of the cable at a higher elevation than the terminal bell. In other cases, the explanation has been offered that the bubbles were caused by heating of cable expelling air. (P. Junkersfeld, 1905.)

Protection Devices on High-Tension Lines, at Connection of Overhead Lines to Underground Lines.—On transmission lines carrying 10,000 volts or over, lightning arresters and line dischargers, located in suitable houses, should be provided in every case where change from overhead to underground occurs. (D. Farrand, 1906.) Resistances between discharge gaps and ground should be sufficiently high to prevent maintenance of arc at line potential. (R. D. Laxton, 1905.)

General Electric non-arcing lightning arresters may be used as line dischargers to relieve abnormal rises of potential in large cable installations. They may be installed in a similar manner as installed on tub transformer circuits to prevent resonance. (F. M. Vander Voort, 1905.)

Installation of Transformers in Manholes.—Transformers for feeding underground mains should be placed in manholes. It is necessary that transformers for such installation be made with water-tight cases, and that the top be put on over a rubber gasket. The manholes should have sewer connections. The transformer should be placed so the top is above the level of the ducts. In this way water can never reach the inside of transformer, as it will flow out through the ducts, if the sewer connection happens to be stopped up. By placing transformers in manholes, all high-voltage wires are kept off of the customers' premises, and also a larger range is obtained for service taps from a single transformer. Transformers should be fused on the primary side, and if there are several connected to the same secondary mains they should be fused on the secondary side also, so they may be cut off the line in case of trouble. (W. G. Carlton; Edison Electric Illuminating Co. of Boston, 1903; C. W. Rice; Geo. L. Colgate; H. L. Bragdon; G. B. Springer; B. E. Strohm; W. J. C., New York Edison Co.; Robert Lindsay; Edison Electric Illuminating Co. of Boston, 1904; P. C. Oscanyan, 1907.)

Switches, Fuse Boxes, Etc. for Underground Use.—It is not advisable to use fuse boxes on high-voltage (over 1,000 volts) in manholes. (1904.) The best fuse box will gather dampness and corrode, which will in time cause trouble, while no particular advantage is gained as the main and service are protected by a cutout where service enters customer's premises from shorts on customer's wiring. (B. E. Strohm, 1904.) There is no satisfactory fuse box for 2,300 volts or over, for use in manholes. (Edison Electric Illuminating Co. of Boston, 1904.) Single-pole "Noark" boxes have been used with success for this work. (United Electric Light Co., 1906.) A cast iron fuse box with gasket under cover, and rubber expansion rings around cables has also been used in manholes occasionally filled with water. (P. C. Oscanyan, 1907.) A weatherproof oil switch has been used on 2,300-volt lines in manholes. This switch is weatherproof from water coming down on top of it, and could probably be made entirely waterproof if desired. (W. E. Holmes, 1907.)

Location of Grounds on Edison Tube System.—Subdivide system into sections, keeping each section on separate feeder, and locate ground in one particular section. Transfer mains from this section to the rest of the system, until ground is located on the main or feeder. After having located ground on main or feeder, divide the line in middle and test both ways, subdividing until the fault is located. (W. S. Barstow, 1903.)

Burn off the ground and then locate the point where the main is open, by testing at services along the line. In case ground can not be burned off, the trouble may frequently be located by digging where other work has recently been done in the street, or by opening main at point where service connection is made for important customers and testing either way. (H. E. Niesz, 1903.)

Tube Feeders.—Trouble is first located by the effect it has on feeder ammeters in station. Cut out the bad section, by removing connections in junction boxes and locate trouble by "cut and try method."

Tube Mains.—Trouble on mains is first indicated by station instruments, complaints from customers, or when junction boxes are opened for inspection. House connections on the grounded or open main are then tested. and the trouble is located as nearly as possible in this way, when the "cut and try method" is used. Loop services are a great advantage in locating main trouble. The slide wire bridge and telephone and interrupter system meet with little success on Edison tube, owing to the number of joints and low insulation resistance. The above methods may be used on cable feeders and mains. (H. S., New York Edison Co., 1903.)

SECTION XIV.

Storage Batteries.

SECTION XIV.

Storage Batteries.

POLICY AND UTILIZATION.

Order of Importance.—The order of importance of the functions of the storage battery in central station practice are considered as follows: First, emergency reserve; second, taking peak load; third, regulation. (Edison Electric Illuminating Co. of Boston; A. L. Landsberg; Chas. Blizard, 1905.)

First, emergency reserve; second, regulation; third, peak load. (H. T. Hartman, 1905.)

Peak Load Work.—A storage battery to take care of peak loads and carry the light loads in an alternating-current plant would require motor-generator equipment installed for that purpose. Generally speaking it is not a good commercial proposition. (L. L. Elden; L. D. Nordstrum; Louis J. Porter; J. Lester Woodbridge; H. A. Strauss, 1906.)

Batteries installed for emergency insurance may sometimes be used to advantage on peak work instead of increasing the generating equipment. (Chas. Blizard; Ernest Lunn; A. Peters; N. H. Greenslit; G. Wilbur Hubley; W. H. Wolvekamp, 1905.) The advantages of Storage Batteries in either class of service are established by local conditions.

Continuity of service is the most important requirement of light and power companies and large private plants. It is, therefore, of the utmost importance to keep the batteries that are depended upon for this purpose fully charged at all times to insure against interruption. Discharging them temporarily suspends the insurance.

Modern generating equipment is higher in efficiency and lower in depreciation than the storage battery, hence the use of the latter in peak work must have its advantage in special cases, as for instance, where the peak discharges are of too short duration to warrant installing additional apparatus, or a saving is effected to offset the difference of efficiency and depreciation, etc. (Wm. Yeager, 1911.)

Ratio of Battery Rating to Load.—No universal rule can be prescribed for determining the ratio that storage battery rating should bear to total connected load. The local engineering staff must decide for itself, taking into consideration the duties the batteries may be called upon to perform, the quality of service they must deliver in emergencies, and the investment they are willing to make for the insurance. Some companies install sufficient battery rating to carry entire peak for from 20 to 30 minutes. (Edison Electric Illuminating Co. of Boston; Charles Blizard; W. H. Wolvekamp; George E. McKana, 1905.)

Batteries for Exciter Systems.—The value and utility of storage batteries for exciter systems are mainly to float on the exciter bus, to insure against interruption of the exciting current in case of breakdown of the supplying units, and to reduce fluctuations of the exciter current thereby affording a steadier output for the generators. In addition they may be utilized in connection with the lighting circuit to prevent the station from being put in darkness in the event of accident. (Edison Electric Illuminating Co. of Boston; J. Lester Woodbridge; H. Bottomley; G. Wilbur Hubley; A. Peters; W. H. Greenslit; Harry Hollis; W. H. Wolvekamp; C. C. Gartland, 1905.)

Generally speaking stations of fair proportion should be equipped with storage battery to protect exciter circuits. In large modern stations they are practically considered a necessity. The need is least where the exciter units are separately steam driven. (Charles Blizard; L. L. Elden; Ernest Lunn; Clayton F. Geiger; A. Peters; J. Lester Woodbridge; Philadelphia Electric Co., 1904; P. Junkersfeld, 1906.)

Batteries for Small Plants.—Whether it pays or is good policy to install storage batteries in small plants to take peak loads, or for other ideas of economy depends entirely on local conditions and requirements without a knowledge of which the question cannot be answered satisfactorily. In many instances it pays, in some not. (Chas. Blizard; E. Lunn; A. Peters; G. W. Hubley, 1905.)

Protection of Apparatus.—Boosters and other apparatus operating in series with batteries should be protected against dangerous overloads and kindred troubles by means of circuit breakers and speed-limit devices. (R. N. Pierce; S. C. Harris, 1902; Electric Storage Battery Co.; Edison Electric Illuminating Co. of Boston, 1904.)

ENGINEERING.

Battery Sizes.—The matter of determining the proper sizes and other requirements of storage batteries for peak load work is one that is governed entirely by local conditions. If merely to take care of a peak of given amount and duration, a battery having a corresponding ampere and time rating is all that is required. Ratings are furnished by the battery manufacturers. (Hugh Rodman; J. Lester Woodbridge, 1907.)

In addition load fluctuations, future increase in the peak load, etc., should be considered, and furthermore when installing it is well to debate whether it is not advisable to provide a battery sufficiently large to insure against interruption of service in emergency cases. This is now considered of prime importance in large electric companies. (Wm. Yeager, 1911.)

Costs.—Changes in market prices and the various conditions under which batteries are operated or are subjected to, make it impossible to give figures as to the cost of installing, maintaining and operating that will be reliable or hold good for any length of time. (J. Lester Woodbridge; Hugh Rodman, 1907.)

Ventilation.—Suitable battery room ventilation can be provided by the use of exhaust fans. The air-handling capacity of the fan and outlet should be such as to insure a positive steady movement of air toward the latter effectively to carry off the rising spray during battery charge. The outlet should be located above the height of the tanks and one or more inlets provided at opposite end of the room at the base. In the outlet opening four or five screens, made up of thin sheets of lead with numerous perforations about 1/32-in. diameter, are placed fairly close together, through which the air is drawn. This removes the acid and prevents a deleterious effect on the fans and other surroundings, that might otherwise result. The room temperature, probably in most cases, can be regulated in conjunction with the ventilating system, taking the air from places where it is normally heated in cool weather, and from a cool place in warm weather. Heating apparatus, when necessary to be located in the battery room, should consist of steam pipes or coils that readily admit of cleaning, painting, and repairs, or removal when not in use. (Ernest Lunn; Hugh Lesley; I. E. Moultrop, 1905; Wm. Yeager, 1911.)

Floor Construction.—Asphalt laid on concrete foundation has given satisfaction. (Edison Electric Illuminating Co. of Detroit, 1905.)

Vitrified brick or tile, grouted with asphalt compound or pitch make the most satisfactory battery room floors under general conditions. (Carroll Hodge; I. E. Moultrop; A. Peters, 1906.)

Concrete floors with finishing coat containing only the necessary proportion of cement, properly graded to rapidly carry off drippings, are quite as satisfactory as brick floors. (A. S. Kibbe, 1903.)

Opinions as to the best kinds of floor construction are largely the result of personal experience, and, therefore, differ considerably. There are cases in which a certain type of floor has given good satisfaction in one place, and has proven worthless in other places. When the ventilation is good and the floor always dry any of the materials will endure for a long time.

Generally speaking, floors of cement construction are attacked readily by the acid and should be avoided. Asphalt floors have been known to crack considerably, and may also contain foreign material that is not acid resisting. The cracks may occur under the tanks where they are hard to repair. On account of the softness of this material the tanks would have to rest on concrete or other substantial base.

The requisites for good floor construction are mainly two: First, the material should be acid proof; second, it should not settle in spots, as for instance, from the weight of the tanks where they rest.

A type of floor that has given good satisfaction consists of vitrified paving bricks having four small projections or feet on one face. The projections rest on the top of a concrete finished floor and a grouting of special grade asphalt compound melted thin, is used, which runs under the bricks forming a thoroughly protecting coating over the concrete; at the same time the bricks cannot settle. (Wm. Yeager, 1911.)

Boosters—Requirements.—The selection of a booster as to its rating for a battery installation is determined by the charging rate of the battery, unless it is intended to be used also in series with the battery on discharge, in which case its ampere rating will have to be about that of the likely maximum discharge.

Its voltage boosting range must extend from the floating voltage of the battery to the maximum charge voltage with all cells in circuit. (Hugh Rodman; J. Lester Woodbridge, 1907.)

Booster vs. End Cells.—Batteries operating on large light and power systems, should preferably be provided with end cells rather than with booster regulation. Batteries never break down without ample warning, while this is not true of boosters. All equipment in the circuit should be equally reliable. (Chas. Blizard, 1905.)

Also if boosters were used in place of end cells their rating would have to be that of the maximum discharge likely to occur, which in the case of emergency batteries in large systems would be impracticable construction. (Wm. Yeager, 1910.)

Booster vs. High-Voltage Rotaries.—The comparative advantages of high-voltage rotaries and boosters for charging batteries are mainly as follows:—Such rotaries have advantages when their voltage range is such as not to prohibit their use as a part of the station generating equipment and may be used in such connection and not for charging alone.

Boosters can be used conveniently to charge end cells and individual cells independently, which is not true of ordinary rotaries and in the majority of the distributing stations boosters are of utility for other purposes as well, such as for boosting feeders, etc. (J. Lester Woodbridge, 1905; Wm. Yeager, 1911.)

Meters and Instruments.—Recording voltmeters are useful in connection with battery operation, giving fairly accurate graphic indications of the discharge, charge and floating. (Hugh Lesley; Ernest Lunn; W. H. Greenslit; W. H. Wolvekamp; A. Peters, 1905.)

They are very helpful to the operators because of the convenience of observation, and they also furnish records for reference.

Recording ammeters have not been of any utility in this connection. Integrating ampere-hour meters of the mercury-motor type, having indicating dials for recording trains, can be had that will give quite accurate light load readings; such meters are especially valuable in that they enable close regulation of floating and thereby prevent excessive charging and discharging. (Wm. Yeager, 1911.)

OPERATION.

Charging.—A storage cell is fully charged when the specific gravity of the electrolyte has reached its maximum (temperature correction allowed for), and when the voltage with constant charging current ceases to rise; under these conditions the cell will be gassing freely. (Ernest Lunn; S. C. Harris; Elec. Storage Battery Co.; Ed. Elec. Illg. Co. of Boston; F. M. Farmer; B. A. Shak; A. Peters, 1904.)

Discharging.—No serious harm follows as a result of high rates of discharge, such as may occur in emergency cases, providing the discharge is not carried too far and the conductors and connections have ample current-carrying capacity to prevent overheating. (Hugh Lesley; A. Peters, 1906.)

Maximum Discharge Permissible.—When occasions occur in emergencies where batteries are called upon to over-discharge because interrupted service from generating equipment cannot be restored in time, the question arises as to how far the discharge may be permitted to continue before cutting out the battery. Sufficient capacity should be retained to start up the system where rotaries or motor-generator equipment are used. In high rates of discharge (say one hour or higher) it is safe to hold on while the battery continues to give serviceable pressure, which means down to about one volt per cell in the usual 75-cell equipment. At low rates the plates are likely to over-sulphate if discharged that far.

They should not be left in the discharged state any longer than can be helped; recharge should follow as soon thereafter as possible. If completely discharged and it is impossible to recharge for several days, the electrolyte should be drawn off and replaced with water to check continued sulphating. (S. C. Harris; Edison Elec. Illg. Co. of Boston, 1904; Wm. Yeager, 1911.)

Floating.—A storage battery connected to the station bus at a balanced voltage *i.e.* floating, acts automatically as a partial regulator. Whenever the voltage of the bus drops due to an increase in the load of the generator, the battery will discharge, relieving the generator of a part of its load, thus preventing as great a drop in voltage as would otherwise result. Likewise when the load lightens and the pressure rises, the battery charges, supplying, so to speak, a counter balancing load that checks the rise in voltage. To check wide fluctuations, automatic regulating devices are used in addition, as for instance the well-known carbon regulator.

In the event of interruption of service from the generator supply, a floating battery automatically assumes the load, merely requiring additional end cells to be added to the circuit to maintain the voltage. (J. Lester Woodbridge, 1907; Wm. Yeager, 1911.)

Records.—The keeping of records is of use mainly as a matter of statistics and history, rather than as a guide for handling and maintenance, and they should include those of total charge and discharge. As an aid to the proper handling of batteries, records of specific gravity readings of the electrolyte are most useful, and should be taken in all cells weekly, and in a representative cell designated as pilot cell (one on each side in the three-wire system) daily.

They should be supplemented by voltage readings in specific cases where unsatisfactory conditions are suspected. (Edison Electric Illuminating Co. of Boston; Electric Storage Battery Co. of Philadelphia; Ernest Lunn; A. Peters, 1904.)

Systematic inspections, especially gassing inspection at each charge, and capacity tests, taken say once in from 3 to 6 months in normal batteries, are the best means of determining the condition and needs of the batteries.

The combined use of recording voltmeters and ampere-hour meters affords the best guide for proper operation. They are simplest and most convenient for observation by the operators and engineers and accurate in their essentials.

The present suitable type ampere-hour meter is of the mercury-motor type and may have either indicating dials or recording trains or both. (Wm. Yeager, 1911.)

MAINTENANCE.

Separators.—Properly prepared wooden separators give better all-around results than any other kind. In some cases they have served to prolong the useful life of plates that otherwise would have had to be renewed. (Hugh Lesley; Ernest Lunn, 1905.)

Tanks, Leaks.—Leaks in lead-lined wooden battery tanks occur chiefly from electrolysis caused by insufficient insulation between tanks and ground. The insulators should be of glass, kept free from coating of acid spray and dirt, and all cracked or broken ones replaced.

Usually the lining repairs require but a patch or two or a new bottom lining at the most. Before putting in new bottom lining the wood should be well washed with a strong bicarbonate of soda solution and painted with asphalt paint. If convenient it is well to lift the whole lining out to clean and paint more effectively. (Hugh Lesley; Ernest Lunn; Harry Hollis, 1905.)

A recent and promising development in tank insulation is an improved oil insulator—a glass insulator designed to contain a well of oil in the electrical path, and provided with an acid-resisting cover to exclude dirt and moisture from the well. (Wm. Yeager, 1911.)

Electrolyte, Renewing.—The electrolyte in the storage cells never requires changing unless detrimental impurities are present. Acid must be added at long intervals to replace that lost in spray or otherwise, to keep the electrolyte up to standard specific gravity.

Water only is needed to replace evaporation and care should be taken to have the water pure. (S. C. Harris; Elect. Storage Battery Co. of Phila.; Edison Electric Illuminating Co. of Boston; A. Peters; Edgar Switzer, 1904.)

Tests of Electrolyte.—Chemical tests of electrolyte to determine absolutely its purity for battery purposes are so unreliable except when made by an experienced chemist that the publishing of a list of tests here is not warranted. Cases can be cited where such tests have given reactions indicating certain impurities when actually such impurities were not present. Most electrolyte that has been used for some time will show presence of impurities though not in sufficient quantity to be harmful; therefore quantitative as well as qualitative tests are essential. Whenever the presence of impurities is suspected a quart sample should be sent to the battery manufacturers who usually make the tests without charge. (Wm. Yeager, 1911.)

Care of End Cells.—End cells which are used only occasionally can be kept in good condition by giving them a charge at weekly intervals until maximum specific gravity and voltage is reached, the cells at the same time gassing freely. (Hugh Lesley; A. Peters, 1906.)

Tank Painting.—The most suitable paint for the outer wooden cases of storage battery cells is one that has a high grade of asphalt as a base. Before applying, the surfaces to be painted should be washed with a strong solution of bicarbonate of soda to neutralize the acid and then flushed off with clean water. An occasional oiling of well painted tanks with linseed oil answers quite well for a time as a preservative and to improve appearances. (Ernest Lunn; Hugh Lesley, 1905; Wm. Yeager, 1911.)

Metal Painting.—For painting exposed iron surfaces and copper conductors in battery room a special grade of heavy asphalt paint is most serviceable. (Carroll Hodge; A. Peters, 1906.)

While lead paint seems to be fully as good as asphalt paint and brightens up the battery room. A good coating of heavy oil or grease applied to the copper work as needed has proven in many cases to be quite as satisfactory as paint and is cheaply and easily applied. Before painting all traces of acid should be removed with a neutralizing solution of bicarbonate of soda. (Wm. Yeager, 1911.)

Labor.—The labor or attention that storage batteries require entails a competent knowledge on the part of the person performing or directing the work. Ignorance in that respect has been the cause of much of the high maintenance cost of the past. In companies having quite a number of batteries, the proper method is to have a regular battery staff under special supervision. (Ernest Lunn, 1904; Wm. Yeager, 1911.)

Removing Sulphate from Plates.—Plates that have become abnormally sulphated usually may be di-sulphated by charging, which should be continued until there is no further rise in the specific gravity of the electrolyte. In severe cases it is advisable to charge alternately until gassing is reached, and rest for an hour or two, repeating the operation until a point is reached where the cell starts to gas immediately on resuming the charge after such rest. (Hugh Lesley, 1905; Wm. Yeager, 1911.)

Sediment.—There are several methods of removing sediment from battery tanks. In small size tanks it may be done readily by means of a suitably constructed L-shaped wooden scoop having sufficient sweep to draw the sediment to the ends of the tank.

Another way is to draw off the electrolyte and introduce water having necessary force to stir up the sediment, unless paddles are used for this purpose. The sediment is then pumped out or siphoned where sufficient gravity force can be had. Tanks must be refilled with acid immediately upon finishing. (Ernest Lunn; W. C. L. Eglin, 1903; Hugh Lesley; W. H. Wolvekamp; A. Peters, 1905.)

With the scoop method, usually a few plates at the ends of the cell need to be cut out, but the cell does not necessarily have to be taken out of service while cleaning. Aluminum scoops are now made, taking the place of wooden scoops for use in lead lined tanks.

The water flushing method necessitates special provision for shunting the cell out of circuit for the time being where uninterrupted service is important.

Another method highly satisfactory as to its convenience, and as being cleaner and more rapid, is the one that may be termed "Electrolyte Circulating Method." Two small centrifugal pumps of acid-resisting alloy composition are used. One pumps out the sediment, stirred up in the electrolyte, through a heavy 1½-in. suction hose, into a series of three or four settling tanks located at any convenient place. The tanks are arranged to overflow one into another during which process the sediment has a chance to settle. The other pump draws the cleared electrolyte from the last settling tank of the series and returns it to the cell preferably through two branched 1-in. hoses having on their ends bronze pipes with L bends. The L bends direct the returned electrolyte along the cell bottom driving the sediment toward the suction, and the pipes have reduced nozzles to increase the force for stirring up the sediment. The two pumps are operated in unison so as to maintain the level of electrolyte in the cell.

In some cases the settling tanks can be located to give enough gravity force in the return electrolyte to stir up the sediment as required. (Wm. Yeager, 1911.)

THEORY AND CHARACTERISTICS.

Plate Life and Battery Depreciation.—The life and depreciation of storage batteries are influenced by the class of service they perform, the attention they receive, and the character of their surroundings.

The life of the positive plates (without reference to improper care) is measured in terms of ampere-hours discharged and hence depreciate quite in proportion to the work they perform. Loss of rating, however, is not evidenced materially until the plates have reached nearly their theoretical ampere-hour life. Bulk of active material (or its fundamental constituent pure lead in the Planté type) is of course the chief factor of plate life, but the character of construction is also an important one. Owing to the latter, plates may vary considerably in life even though they may be equal as to the former and therefore should be rated according to their characteristics of construction.

Negative plates, while they do not lose their active material out of the plate, diminish in capacity through the material becoming more or less inactive; for this reason they are usually constructed with an excess rating of about 50 per cent. over the positives with a view to making them last the life of two or more sets of the latter.

As to batteries in purely emergency service, sufficient experience has not accrued to determine definitely what the depreciation will be but the indications are that it can be kept exceedingly low for a long period of years.

Batteries depreciate rapidly through neglect and improper care.

The surroundings, except as to high temperature which may effect the positive plates somewhat, have more to do with the depreciation of tanks. Good ventilation, dry atmosphere, best tank insulation, proper cleaning and painting, all prolong their life. (Wm. Yeager, 1911.)

Efficiency.—The watt efficiency of storage batteries ranges from 60 to 75 per cent. and the ampere efficiency from about 80 to 90 per cent. (Hugh Lesley; W. H. Wolvekamp, 1905; L. I. Porter, 1906.)

The term "efficiency" in many cases is misapplied. It is practically the ratio of the discharge of a battery and the recharge back to exactly the same condition or state of the battery as just prior to the discharge.

Efficiency of battery operation, which is quite another thing, depends (assuming that the battery is in good condition) upon the handling; this largely accounts for the wide variations in efficiency for which batteries are sometimes credited. (Wm. Yeager, 1911.)

A storage battery that is properly handled and cared for should not change in efficiency during several years of service. (W. S. Barstow; W. C. L. Eglin; W. I. D., New York Edison Co.; Lamar Lyndon, 1903.)

Rating.—The ratings of batteries of similar construction are practically in proportion to their bulk. (Bruce Ford; Hugh Rodman, 1907.)

The rating of plates at high rates of discharge depends upon the kind and condition of plates. The one-hour rate is usually about 4 times the 8-hr. rate and the 20-min. rate about twice the 1-hr. rate. (Ernest Lunn; Hugh Lesley, 1905.)

Battery Rating.—Ampere rating for storage batteries is preferable to kilowatt rating in the respect that it is more comprehensible to switch board operators in battery operation, both as to charging and discharging. It holds good also for one or any number of cells, and gives more concise idea of plate area.

Kilowatt rating refers to a battery as a whole, and is more convenient for engineering or office use for the purpose of general calculations and comparisons, since generating equipment is universally rated in similar terms. (Wm. Yeager, 1911.)

Effects of Temperature on the Storage Cell.—The available capacity of a storage battery increases and decreases with the rise and fall of temperature, respectively. The percentage change in capacity is fairly proportional to that of the temperature. The density of the electrolyte increases with lowering temperature, and vice versa; the variation is about 0.001 specific gravity to 3 deg. fahr. During the charge and discharge of a battery the temperature normally will rise, hence the drop in specific gravity during the discharge will be accelerated and the rise on charge retarded. The electromotive force of a cell throughout a charge is lower the higher the temperature. (Wm. Yeager; Gerhard Goettling; C. D. Hibler, 1910.)

Corrosion.—The corrosive effect that is noted at the positive pole of a storage battery and not at the negative is due to the fact that when current is passed into a battery oxygen is generated at the positive pole and hydrogen at the negative. The former in the presence of acidulated water has a corrosive effect, and the latter a reducing (non-corrosive) effect. This can be checked or prevented by suitably protecting the terminals from the acid. Lead or lead antimony alloy are very slightly affected while copper or brass are quite susceptible to this action. (Electric Storage Battery Co., 1909.)

VEHICLE STORAGE BATTERIES

Charging.—For charging vehicle batteries, where only alternating-current is available, the mercury rectifier is the most suitable medium to be used, having superior advantages in most respects to motor-generators. (The Philadelphia Elect. Co.; Percy H. Thomas, 1905; W. R. Collier, 1910.)

The mercury arc is much preferable to the motor-generator set for charging vehicle batteries on alternating-current mains. The points of advantage are as follows:

First—Costs about 50 per cent. less.

Second—Great saving in space—an important item in the case of a small private garage.

Third—Much more economical in operation.

The full-load efficiency of the mercury arc is about 85 per cent., as against about 67 per cent. for a small motor-generator set. The efficiency of the mercury arc is about the same at low loads, whereas that of the motor-generator is extremely small at low loads. (George H. Jones, 1909.)

Milage.—Data as to milage and milage costs of electric vehicles is usually most available from the vehicle manufacturers. (M. C. Turpin, 1908.)

In view of the active interest that Central Station Companies are now taking in electric vehicle promotion more reliable data as to above, possibly can be had from them or from the Electric Vehicle Associations. (Wm. Yeager, 1911.)

SECTION XV.

Transformers.

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SELECTION OF TRANSFORMER.

Size for Residence Lighting.—For small residences, flats and apartments, a transformer rating equivalent to 50 per cent. of the connected load is considered safe, but for single residences, or where the flat rate is used, 75 or even 100 per cent. may be advisable. (L. W. Byers, 1903; United Electric Light Co.; F. D. Sampson; L. W. Greene; H. D. Larabee; Beacon Light Co., 1906.)

Where electricity is sold by meter and several houses are connected to the same transformer, it has been found sufficient to install transformer rating that is from 15 to 20 per cent. of the load connected, although in some localities 25 to 50 per cent. is used for the same service. (H. B. Gear; F. Van der Voort; F. Ellwood Smith, 1903; B. C. Adams, 1906.) A Wright demand ammeter in service several months on the primary of a 300-lamp transformer, about ten residences, registered about 25 per cent. of the connected load. (D. L. Ott, 1906.)

In all cases it is well to ascertain the maximum load of the largest residence connected and install a transformer large enough to take care of this maximum, with about 8 lamps per residence for the remainder connected. This will answer for the average residence districts. (Paul F. Williams, 1906.)

Size for Commercial Lighting.—In business districts the transformer rating is usually about 75 per cent. of the connected load, but where arc lamps are used extensively, 100 per cent. or more may be necessary to provide sufficient current carrying capacity for the lagging current of the arc lamps. On the other hand, some business houses on a single transformer may require 50 per cent. or less. (H. B. Gear; F. Van der Voort; L. W. Byers, 1905; L. W. Greene, 1906.)

Size for Motor Service.—For ordinary polyphase motor service it is customary to allow transformer rating of 1 kw. per hp. connected. For elevator and other variable speed motors it is generally advisable to install larger transformers having a rating equivalent to the kilovolt-amperes required by the motors. (Edison Electric Illuminating Co. of Brockton; Edison Electric Illuminating Co. of Boston; M. P. R., New York Edison Co.; Alex. J. Campbell; F. C. S., Malden Electric Co.; D. Clifton Shain; H. J. Myer; A. R. MacKinnon; G. Wilbur Hubley; Douglass Burnett, 1905.) The transformer rating referred to above is of course the total rating of the bank.

For single-phase motors which start as repulsion motors and operate at full load as induction motors, the transformer rating can be selected on the same basis as polyphase motors for the same service. Single-phase motors with split-phase windings for starting, require extra transformer rating for the heavy starting currents. (Warren Partridge, 1905.)

Where several motors are connected to the same transformer with only a small possibility of all motors being started at the same time, the starting current need not be taken into account if the transformers are selected with sufficient rating for starting the largest motor.

Size for Mixed Lighting and Power.—For lighting service where electric flat-irons and small heating or power apparatus is used, transformer rating selected for the lighting duty will usually be sufficient. (Peninsular Electric Light Co.; L. L. Elden; Central Gas & Electric Co.; R. J. C. Wood; St. Clair Ed. Co., 1908.) In some cases where the ratio of transformer rating to connected load is small, or for small transformers, it has been found necessary to use larger transformers when power load is added. (H. A. Holdredge; W. M. Bell, 1908.)

If the load consists chiefly of motors, the transformers can be chosen to operate at their rated load provided the motor load is fairly steady and the starting duty does not interfere with the regulation. For factory and shop work, regulation is usually not important. (Edison Electric Illuminating Co. of Brockton; Edison Electric Illuminating Co. of Boston; M. P. R., New York Edison Co.; Alex. J. Campbell; F. C. S., Malden Electric Co.; D. Clifton Shain; H. J. Meyer; A. R. MacKinnon; G. Wilbur Hubley; Douglass Burnett, 1905.)

In general, if the lighting and power loads do not come at the same time, the transformer rating is determined by the larger load. The safest method is by actual tests for each particular case.

Size With Respect to Economy and Nature of Load.—It is in almost all cases better to overload a transformer at peak than to allow it to stand a heavy core loss all day. The saving by the use of smaller transformers will more than offset the injury by short periods of overload. There is, however, one objection; the regulation of the transformer, increasing almost directly with the load may result in inferior illumination and reduce meter readings. The standard transformer should not be subjected to an every day peak of more than 25 per cent. overload.

In regard to the amount of peak overload which will give the best all day efficiency and at the same time ensure safety the concensus of opinion seems to favor from 25 per cent. to 50 per cent. depending upon the length of time and the season of the year.

Size for Pole Service.—Size of transformers and mains should be determined by the density of load. As few sizes should be used as possible. One size wire, either No. 6 or No. 4 can be used for practically all resident districts, and two or three sizes, say No. 2 and No. 0 and No. 0000 for business districts. The size of transformer should be in proportion to the size of wire, say 3 to 5 kw., No. 6 and 25 to 50 kw. No. 0000, the size of transformers depending upon the density of the load. (The Seattle Electric Co.)

Large Transformers vs. Groups of Smaller Ones.—In estimating fixed charges or expenses of a transformer we figure interest 5 per cent., depreciation 10 per cent., maintenance 50 cents per year on 0.5-kw. and 1-kw. sizes and $1.00 per year on larger sizes, and allow 3 cents per kw-hr. for core-loss current. This makes the annual fixed charge for a 0.5-kw. transformer $9.45; 1 kw. $12.15; 1.5 kw. $14.47; 2 kw. $17.15; 3 kw. $21.71; 4 kw. $26.09; 5 kw. $28.11; 7.5 kw. $40.06; 10 kw. $46.03. For these figures the saving that can be made by substituting larger transformers for groups of small units can be readily figured. As long as the station is not overloaded the cost price of the electric energy should be considered in figuring core-loss charge. Where the point is reached that the extra equipment would be required, then the selling price should govern; the reason being that where ample equipment is available the fixed charges have to be carried by the paying load and the core-loss entails only the expense due to actual operating; but where special equipment would have to be provided the core-loss would have to carry operating, fixed and profit charges, the same as any paying load, and should be classed accordingly.

Annual Cost of Operation.—The annual cost of operation, at least certain phases of it, is probably given more detailed study by transformer purchasers than any other phase of the transformer problem.

Of first importance is the core-loss of the transformer, which continues for 24 hours of the day and 365 days of the year. The second is copper-loss, which varies as the square of the load, is zero at no load, and has its maximum value at full load. The equivalent full load copper-loss under varying conditions averages from 3 to 24 hours per day. Probably for an average central station the equivalent for 4 hr. at full load copper-loss per day is about correct.

The third item of importance is the interest and depreciation account. This has to be considered under the head of interest and depreciation on the transformer, and, in some cases, interest and depreciation on a portion of the central station building and its equipment. In other cases, to be exact, it may be necessary to consider the cost of such a portion of the transmission losses as are caused by the transformer losses, and also to charge up a portion of the interest and depreciation on transmission lines to the transformer, where any additional expense in installing the transmission system is incurred solely on account of transformer losses. The question of transmission losses due to transformer losses, and interest and depreciation on the transmission system because of these losses, can nearly always be neglected.

As a specific example under annual cost of operation, suppose we take the following transformers:

Core-loss, 80 watts, (0.080 kw.)

Copper-loss, 150 watts, (0.150 kw.).

Price $81.00.

Interest and depreciation, 10 per cent.

Cost of station and equipment, $150.00 per kw.

The annual cost of operation at 2 cents per kw-hr., on the basis of 24 hours per day for core-loss and equivalent full load copper-loss of four hours per day, would be as follows:

Core-loss = 0.080 × 24 × 365 × 0.02 .... =	$14.02
Copper-loss = 0.150 × 4 × 365 × 0.02.......... =	4.38
Interest and depreciation on transformer $81.00 × 0.10 .... =	8.10
Interest and depreciation on station equipment chargeable to transformer = 0.230 (total full load losses in kilowatts × 150 × 0.10	3.45
Total	$29.95

The selection of 4-hr. equivalent full load copper-loss in the above example was arbitrary, as also was the cost of energy. In determining the equivalent full load copper-loss, it must be born in mind that copper-loss varies as the square of the load, for example, at half load we have one-quarter full load copper-loss. As a further example, 2 hr. at full load and 4 hr. at half load, give the equivalent copper loss of 3 hr. at full load. The interest and depreciation charge on station equipment should not be charged against the annual cost of operation of the transformer, if surplus station capacity exists or would be installed independent of any consideration of transformer losses. Again, a uniform rate of 2 cents per kw-hr. for any hour of the day would not be correct if the transformer losses constituted a real check on the sale of energy. That is, if there is a market for more energy than is generated, so that the transformer losses cut out the sale of an equal amount of energy, the cost of losses should be computed on the basis of a light-load period of say, 20 hr. per day at 2 cents per kw-hr., and on some other value, such as 4, 5 or possibly 6 cents per kw-hr. during the peak of the load, say 4 hr.; the peak load value determined by what the central station manager feels the energy at peak load is really worth. The above reasoning applies to both core and copper losses. (M. O. Troy, 1909.)

Cost of High Efficiency.—A transformer of high efficiency costs more than one of low efficiency, and the question as to what efficiency for a given service will be the most economical is an important one.

At a bare production cost of 1.5 cents per kw-hr., a charge of 1 per cent. in the loss of a 1,000-watt transformer amounts to $1.31 per annum, which at a 15 per cent. interest and a depreciation charge is equivalent to an investment of $8.74. In other words, for every 0.1 per cent. gain in transformer efficiency we can afford to pay an additional cost of $0.874 per kw-hr. (Warren Partridge.)

Efficiency of Constant-Current Transformers.—The average efficiency of a constant-current transformer is about 95 per cent. and its power-factor at full load is approximately 80 per cent. As the load is decreased the power-factor of the primary decreases and becomes very small at no load.

Transformers for Single-Phase Service.—For single-phase load, the single-phase transformer is undoubtedly the best. It has the advantage in compactness, weight, cost and efficiency, when compared with a polyphase transformer of the same capacity. If a small part of the load consists of polyphase motors, the single-phase transformer has the additional advantage that stock transformers may be utilized for either incandescent lighting or motors. This simplifies the system and reduces the cost of spare units. (D. L. Ott; D. C. Jackson, 1906.)

Transformers for Two-Phase Service.—For two-phase motor service, a two-phase transformer is practical but unsatisfactory, as it requires special transformers, which, at present, are used very little. (P. C. Oscanyan.) The advantages of two-phase transformers over single-phase are the same at three-phase, but to a smaller degree.

Transformers for Three-Phase Service.—Comparing a three-phase transformer with a bank of three single-phase units of the same total capacity, the advantage of compactness, weight, cost and efficiency is in favor of the three-phase transformer. The individual single-phase units are, however, smaller and have the further advantage of being interchangeable for single-phase service, in case the three-phase service is discontinued. (D. C. Jackson, 1906; A. E. Walden, 1908.) If the installation is liable to be permanent and the motors well loaded, polyphase transformers are sometimes preferred, especially in the larger sizes. (W. H. Wolvekamp, 1906; H. A. Holdredge, 1908.)

In most installations a bank of three single-phase units is preferred to a polyphase transformer, because of the fact that service need not be discontinued in case one transformer burns out. The injured transformer can be removed and the other two transformers operated on open delta, pending repairs. The load capacity of the transformer bank will, of course, be reduced one-third, but it is still possible to operate part of the equipment, or, in some cases, the entire equipment, provided the motors are not over-loaded. (A. Peters, 1906; R. J. C. Wood; A. E. Walden; L. L. Elden, 1908.) The same advantage applies to star-connected transformers in case the neutral is grounded. Two transformers can then be operated with "open-star" connections.

INSTALLATION.

Methods of Drying Transformers.—The installation of small and low voltage transformers is a comparatively simple operation. It is with large, high-voltage transformers that much precaution must be taken to ensure that the transformer is free from moisture before it is placed in service.

No unconditional limits can be fixed as to size and voltage at which drying and other precautions may be dispensed with.

There are several standard methods of drying in use at the present time. Generally speaking, these may be divided into two classes, viz.:

(1) Those in which the oil and transformer are dried simultaneously.

(2) Those in which the oil and transformer are dried separately.

Under the first class, probably the most common method is that of applying heat to the transformer. This can be done by building a fire around the base of the transformer or by passing a sufficient current through the windings to produce the required heating.

Another method consists in passing the oil through a bath of sand and lime instead of using vacuum.

The time required to dry a transformer by any of these methods under favorable conditions varies from one to three days depending upon the size.

Chemical Drying.—The use of chemicals for drying oil is not considered practical on an extensive scale, since their action is too slow and furthermore there is an element of danger in their use. Some of the chemicals employed as driers combine with water to give acids which affect insulation, or gases which might become ignited by excessive heating within the transformers. A third danger is the lowering of the dielectric strength which may arise from suspended particles of salt as a result of chemical reaction.

Calcium chloride and calcium oxide are the substances most commonly employed.

Mechanical Drying.—In addition to chemical driers, mechanical methods have been employed for removing moisture from large quantities of oil. One of these consists of a hot air furnace and a blower. By means, of which hot air is forced through the oil.

Another excellent means of drying and filtering oil has just been placed on the market, which depends upon the fact that blotting paper will absorb moisture in preference to oil. In this filter the oil is forced through a number of layers of dry blotting paper; by which the oil is not only cleaned but effectively dried. This promises to be most convenient and effective means for stations to keep transformer oil in good condition, if they have any quantity to handle.

Handling of Oil.—That the extreme importance of the oil in relation to the rest of the transformer is appreciated is shown by the extraordinary precautions taken to insure its being pure and free from moisture.

Oil is usually shipped in barrels or drums unless the quantity is so large as to warrant shipment in bulk.

In addition to removing the moisture as described above, oil must be very carefully strained before being put into the transformer.

There are two kinds of oil much used by the larger electrical manufacturing companies, one a heavy petroleum oil, which on account of its high flashing and burning points is particularly useful where the higher oil temperatures are frequent.

The other is a light, mineral seal oil and is useful only in transformers in which the oil never exceeds moderate temperatures.

Neither oil has any marked advantage over the other in regard to dielectric strength.

Deposits in Oil.—It sometimes occurs that a brownish or black deposit is formed in the oil. Careful experiment has shown this deposit is a phenomenon of temperature alone. This deposit is formed from the oil and from the insulating materials, such as varnishes, etc., which are used on the solid insulation of the transformer. This deposit is itself a good insulator, and the only harm done by such deposit is to imperil the cooling of the transformer by lodging in ventilating spaces and on the cooling coils of a water-cooled transformer. In the very high-tension transformers there is also a tendency for this deposit, when it does occur, to line up at points where the stress is greatest. Such a deposit does not necessarily mean a deterioration in the insulation of the oil, or of the transformer. An occasional cleaning of the parts in which the deposit occurs is all that is necessary to keep the transformer in good condition.

When coils and insulating materials are treated with varnish that is properly oxidized, the varnish is practically insoluble in transformer oil. Where coils are treated with waterproofing materials having an asphaltum base, a considerable amount of inconvenience may be expected, as such compounds are sometimes dissolved by the oil, giving it a black appearance and often forming a heavy, sticky "dope," which is apt to clog the ventilating ducts.

Methods of Hanging Transformers on Poles.—The following is a method used for hanging two 30-kw. transformers: See that the pole is physically able to carry the transformer, then bolt a pin crossarm to the pole 20 ft. from the ground and another arm 3½ ft. above the first arm. Take a pair of blocks and falls and fasten to the top of the pole and raise the transformer by aid of a team of horses until it reaches the top of the crossarm and before removing the block and fall, place a ⅝-in. eye-bolt upon the pole 4 ft. above the top crossarm and use a Brooklyn strain insulator and some seven-strand guy wire to guy the strain and strain insulator and some seven-strand guy wire to guy the transformer to the eye-bolt. This guy will hold the transformer if anything were to happen to the crossarm. Then remove block and fall and all is ready to connect the transformer to the line. (J. J. Gaffney, 1906.)

Sizes up to 50-kw. can be readily mounted on poles if regular hanging irons are provided by the manufacturer; they can be hung to suitable crossarms in the regular way. In one case which is given as a good example of hanging a 50-kw. transformer, a Georgia pine crossarm 4-in. thick and 8-in. wide was used. This was secured to the pole with ordinary standard ⅝-in bolts. (N. B. Neth, 1906.)

If no hangers are provided, they must be placed on platforms which makes the mounting more difficult. A 50-kw. transformer can be supported in this way by taking two pieces of 3 x 8-in. oak plank, bolted to both sides of the pole with four angle-iron braces to support the ends of the two planks. Over this is placed a flooring which should be large enough for a lineman to stand upon while connecting up and working around the transformer. (D. Boyle; W. H. Fellows, 1906.)

A successful method of mounting two 50-kw. transformers on one pole employs a platform supported by two pieces of 4 × 6-in. hard pine placed horizontally, one piece on each side of the poles, fastened together by two bolts passing through the pole. The length of these pieces is sufficient to support the platform upon which transformers can be placed one on each side of the pole. This platform is strengthened from the bottom by heavy iron braces. (F. C. S., Malden Electric Co., 1906.)

Advantages of Multiple Connections.—The principal advantage of interconnecting the secondaries of several transformers is the fact that larger units of smaller total rating can be used. If the transformers divide their load properly and can be operated near their rated load, there will be a saving in cost and an improvement in efficiency. (W. A. Carter; M. C. Turpin, 1907.)

Transformers of Different Size and Make in Parallel.—Transformers having the same ratio, but different ratings can usually be operated successfully in parallel providing their impedances are nearly alike. Transformers of different make can also be connected in parallel, provided their impedance is the same at the power-factor of the load. They need not have the same voltage, provided their ratio is the same. (L. L. Elden; W. H. Fellows; F. D. Sampson; W. H. Greenslit; A. Peters; Geo. N. Tidd; F. C. S., Malden Electric Co.; M. C. Turpin; W. T. Oviatt, 1906.)

Where the transformers are located some distance apart, the line resistance tends to equalize the impedance of the transformers and, under such conditions, it has been found satisfactory to operate in parallel, transformers of different size and make. (Geo. B. Lander; C. C. Giles; Guy C. Gum, 1903.) Greater precautions must be taken, however, than if transformers connected in parallel are the same size and make, and it is considered by some to be poor practice, unless there is some means of distributing the load by means of pressure regulator, or choke coils. (W. S. Barstow; Edison Electric Illuminating Co.; W. T. M., New York Edison Co., 1903.)

Division of Load in Parallel Operation.—Parallel connected transformers of the same ratio will divide their load in proportion to their kilowatt rating and inversely proportional to their impedance drop in per cent. (not the per cent. regulation.) In other words, the proportional factor would be: Kilowatt rating divided by corresponding per cent. impedance. For illustration, a 5-kw. transformer with 4 per cent. impedance and a 10-kw. transformer with the same percentage impedance would each be fully loaded with a total load of 15-kw.

The best method of determining division of load in parallel connected transformers in actual service is by actual test with an ammeter. This can be a maximum demand ammeter or, more conveniently, a splitring current transformer with ammeter. In this way, the division of load for each individual transformer in the network can be determined and then adjusted by means of external impedance. (E. C. Deal; J. S. Codman; W. H. Greenslit; Paul F. Williams; L. L. Elden, 1906.)

To determine the division of load between three or more transformers, a very simple procedure is as follows:

(*a*) Determine first the "relative impedance" of each transformer in the group. This "relative impedance" is the rated kw. of that transformer, divided by the per cent. of its actual impedance.

(*b*) Then determine the relative impedance of the entire group of transformers. This will be the sum of the "relative impedance" of the individual transformers in the group.

(*c*) The load carried by any one of the transformers may be then derived from the following formula:

$$\left.\begin{array}{l}\text{The load carried by one of}\\ \text{the several transformers}\\ \text{connected in parallel}\end{array}\right\} = \frac{\text{Rated kw. of that transformer}}{\text{Per cent. impedance of transformer}}$$

$$\times \frac{\text{Total kw. capacity of all the transformers grouped together}}{\text{Total ``relative impedance'' of entire group of transformers}}.$$

For example, assume one each of 2, 4 and 10 kw. transformer operating in parallel with a total load on the circuit of 16-kw. Assume per cent. impedance for the individual transformers as indicated by load; the division of load will work out as indicated:

	Capacity in kw.	Per cent. impedance		Relative impedance	Kw. carried by each transformer with total load of 16 kw.
	2	2.8		0.715	2.36
	4	3.2		1.25	4.16
	10	3.5		2.86	9.46
Total kw. load....	16		Total relative imped.	4.825	16.00

Danger of Overloading Transformers in Parallel.—Special precautions must be taken for fusing parallel connected transformers for protection against overload. The best way is to fuse each transformer individually on the primary side and put light fuses in the secondary network between each pair of transformers. It is not advisable to have too many transformers banked together, unless they are properly fused. Cut-outs should be placed where the primary branch leaves the main line, but the secondary circuit should be cut into sections with light fuses between each section. (Alex. J. Campbell, 1907.) In this way, the overloaded transformer will be cut out, but if the primary fuses do not blow, some means should be adopted for determining whether the secondaries are disconnected from the multiple network.

For three-wire secondary distribution, the conditions for parallel operation would be the same as for two-wire distribution. (B. C. Adams; W. H. Wolvekamp, 1906; R. H. Garrison, 1907.)

The same is also true for two-phase and three-phase transformers. (H. Clyde Parrish; J. S. Reesman; W. A. Carter; W. M. Scott; M. C. Turpin, 1907.)

In case of two-phase transformers, it must be remembered that the secondaries cannot be connected in parallel for single-phase distribution. (H. L. W., C. E. I. Co.; E. A. Wagner; J. S. Reesman; M. C. Turpin; W. A. Carter, 1907.)

Life.—The average life of a lighting transformer is from 10 to 15 years when operated under normal conditions. The life of a transformer depends for the most part upon the temperature at which it is operated; high temperature causes deterioration of the insulation.

Transformers in service should be inspected at least once a year for the purpose of noting their condition, especially the oil. A record of burned out transformers covering two seasons showed that the oil was below the top of the coils in nearly every instance. The lines were well protected by lightning arresters, but in some cases, transformers of recent and well-known makes burned out without any apparent cause other than the lack of sufficient oil. (H. B. Gear, 1906.)

Water in Oil.—In making yearly inspection of transformers of the pole type, it is advisable for the inspector to be provided with a glass tube by which he can take a sample of oil from the bottom of the case, and see if any water has gotten into the oil. It is only necessary to close one end of the tube with the finger, lower the other end of the tube to the bottom of the case, remove the finger and give the oil a chance to rise in the tube; then after closing the end again with the finger, raise the tube. If an appreciable amount of water is in the oil, it will have collected in the bottom, and thus by the above method we have a ready means of obtaining that part of the oil in the transformer liable to contain the greatest amount of moisture. (M. O. Troy, 1906.)

There are a number of tests by which the presence of moisture in oil can be detected. If the water is present in considerable quantities, it can be gathered from the bottom of the tank as suggested above. Smaller quantities may be detected by heating a sample of the oil to the boiling-point of water and holding over the surface of a cold glass. Moisture will be indicated by the condensation on the glass. (H. H. Barnes, 1907.)

Perhaps one of the most simple and at the same time most positive methods of determining whether there is water in the oil is to test a sample of the oil with a small piece of metallic sodium. If there is moisture in the oil, this is converted to sodium oxide and is precipitated to the bottom as a residue. If there is no moisture present, this metallic sodium simply drops to the bottom of the container as a soft putty-like material, but otherwise is a heavy powder precipitate. (W. A. Layman, 1911.)

Reasons for Grounding.—The concensus of opinion at present seems to favor strongly the grounded secondary system. In the two-wire system grounding one side seems to be advantageous while in the case of a three-wire or three-phase system the neutral should be grounded. Several of the advantages to be gained are:—

(*a*) The neutral point is practically fixed.
(*b*) Decreased stress on insulation of line and apparatus.
(*c*) Decreased lightning troubles.
(*d*) An arcing ground with resultant surges eliminated.
(*e*) Consequent protection to life and property.

In case the primary is properly protected by arresters, there should be no break-down of transformers by lightning due to a grounded secondary. On the other hand, while the grounding of one side of a secondary system will take care of a cross and of lightning to a certain extent, it is not sufficient to rely upon as a safeguard and lightning arresters should not be displaced.

Trouble may be occasioned to telephone fire or police alarm systems, by grounded secondaries, in case an accidental partial ground occurs on the other side of the line. This occurred in the lines of one company and attention was first drawn to it by a telephone company. Their instruments were being operated with one ground wire condenser in series. It was reported that all bells in this territory were continuously ringing. (D. L. Ott, 1906.)

In the majority of such cases trouble would probably result in the blowing of the fuses, in the transformer primaries. Sectional fuses in the secondary net work and fuses in the transformer primaries would probably minimize the possibilities of such accidents. (M. O. Troy, 1906.)

Method of Grounding.—The usual method of grounding is to connect the secondary to a water pipe, caution being exercised to make the connection between the meter and the source of supply. In case there is no water pipe convenient, a copper plate may be planted at some point where the earth will be permanently wet.

The most satisfactory method of making ground connection to a water pipe is to attach a special clamp to the pipe and make connection with the secondary through a No. 4 wire soldered to the clamp.

The practice of grounding to a water pipe does not seem detrimental to the pipe in any way if a good connection is made and water companies, as a rule offer no objection to it. It is not good practice, to use gas-pipes for this purpose, however. It is good policy to ground the frames of high-potential transformers. All grounds should be tested as the resistance should be as low as possible.

Lightning Protection.—Well designed primary and secondary lightning arresters will assist very materially in reducing the blowing of fuses, but a choke coil seems to have no tendency to remedy this trouble.

The report of failures from many central stations seems to indicate that transformers placed on the end of a line will break down sooner under lightning strains than those placed elsewhere on the line. This is probably due to the fact that the surge naturally piles up at the end of the line. An effective remedy for such failures is to extend the line for some distance beyond the last transformer and install a lightning arrester at the end of the line.

It is very essential that good grounds be made in connection with lightning arresters.

If secondaries are not grounded, transformer windings will, in themselves, act as efficient kicking coils. In cases of severe electric storms such as we experience in the mountains, it has often been found that the kick of these windings is so strong that heavy insulator type primary fuse blocks would be shattered into fragments and the metal fused together, leaving transformer windings apparently uninjured. (Chas. H. Peters, 1905.)

Emergency Operation.—Several companies have adopted a system to take care of interruptions to service of having a transformer of a certain size already connected to flexible wires of sufficient capacity and insulation and so arranged so as to be readily placed on a wagon or automobile and speedily transported to a point of demand where it may be temporarily connected into circuit. The transformer is allowed to remain in the wagon until such time as permanent repairs may be made. It has been used for some time very successfully and seems to be a wise precaution.

Remedies for Overheating.—Place cooling pipes in the oil surrounding the transformer core and coils and connect them to a water supply. (Jas. B. Foote; J. S. Peck; C. F. Haywood.)

Place the entire transformer, including the iron tank in a large galvanized tank, containing water. Circulation of the water is maintained by forcing in cold water at the bottom and allowing the heated water to discharge at the top. (A. O. Whitmore; G. Wilbur Hubley.)

Transformers may be cooled by air blown upon the surface of the transformer tank by ordinary desk fans. (R. H. Thurston; E. A. Wagoner.)

The transformer oil may be circulated through a pipe or coil immersed in cool running water.

Compressed Air Cooling.—Compressed air has been suggested as a possibility for cooling air-blast transformers. The air would be passed through an injector and the low temperature resulting from the expansion of air would be utilized to cool the transformer. This scheme has never found favor among engineers on account of the large volume of air necessary to carry off a given amount of heat. This volume is somewhat decreased by expanding immediately before sending into the transformer, but there is not sufficient gain by this method to compensate for compressing the cooling air. (P. M. Lincoln, 1907.)

Varnished Cambric.—The insulation resistance of varnished cambric decreases quite rapidly with increasing temperature until a minimum resistance is reached. Then it increases slowly with further increase of temperature. A number of recent tests indicate that insulating material when exposed to 110 deg. Cent. or higher temperatures gradually carbonizes and ultimately is destroyed, principally on account of mechanical breakage due to its brittleness. (R. D. De Wolf, 1909.)

Strains Due to Connection of a Loaded Circuit.—The actual phenomena taking place in a transformer when connected to or disconnected from a loaded circuit is very complex. The initial rush of current may be great or small depending upon the state of magnetism in which the transformer was left when last disconnected from the circuit and also upon just at what point of the wave the connection is made. In addition to this, individual turns, carry different amounts of current, since a large proportion is shunted by the capacity against adjacent metal and ground. Since the voltage across individual turns depends upon the current, it also follows that the voltage across end turns must be greater than across the others.

No serious trouble has been reported as resulting from this cause. It has been demonstrated by oscillograph records, and otherwise, that a transformer is subjected to unusual mechanical and electrical strains at this time and must be properly designed to withstand them. (M. O. Troy.)

Maximum Voltage for Pole Service.—It is possible to install transformers on poles to operate at e.m. forces up to 15,000 volts, although above 6,000 volts, such installations are not common. Special precautions to secure proper weather protection should be used for such voltages, unless the transformer has been especially designed for out of door service. A safe and convenient method of doing this is to bring the leads out of the sides of the case and have a roof projecting out over the bushings.

Pumping of Constant Current Transformers.—Trouble is sometimes experienced with constant current transformers, "pumping" or "churning" violently at uneven intervals. This may be due to variable frequency on transformers operated from inverted rotary converter driven by railway generator. Trouble from this cause must of course be corrected at the generating end of the line.

Pumping due to line capacity might be remedied by installation of static dischargers on secondary line. Systems operating at a moderate power-factor are rather more stable than those where the designers strive for too much in this direction. (R. D. Laxton, 1905.)

Swinging grounds or sluggish lamps will produce this condition; if regulator is overloaded or the oil is too heavy the same results will follow. (G. E. Palmer.)

TESTING.

Tests in Service.—Our transformers are tested in service once a year, at least, at the time they are carrying their maximum load for the longest period—namely, during the months of November, December and January—and more often if required. We have about 80 transformers. The tests are conducted as follows: 24-hr. load is made with a Bristol recording ammeter having a 5-amp. winding and supplied with two charts which have a full scale reading of 5 amp. and 15 amp. which work in conjunction with two series transformers having a ratio of 1:1, 5 amp. to 5 amp., and 3:1, 15 amp. to 5 amp., so that the instrument is direct reading for the primary current. The series transformers are so connected that the ammeter may be thrown across the secondary of either one, the rating of the transformer under test determining which one is used. The series transformer is connected in shunt with one of the primary fuse boxes, the plug of which is removed when all other connections have been made. This still leaves one fuse to protect the transformer under test. In removing the ammeter the fuse plug is first inserted and then the other connections are broken. See diagram for wiring box. The ammeter and series transformers are enclosed in a waterproof box made of one-inch pine and painted black. The box has a lug at the top for hanging on the pole or in other convenient locations. It is kept in a vertical position by means of hinged braces which are fastened to the pole by short wood screws.

A 24-hr. secondary voltage test is made by a Bristol recording voltmeter mounted in a weather-proof box, equipped in the same manner as the ammeter box for mounting on the pole. A 16-cp. lamp is left burning in the box in very cold weather to prevent the ink from freezing.

The oil test is as follows: When a transformer is provided with a tap at the bottom of the case, this is opened and a little oil drawn off. In cases where no tap is provided, the top is removed and a little oil is pumped out, care being taken to see that the suction hose is down to the bottom of the case. The oil is taken to the laboratory, where it is tested for moisture, quality, etc.

Ground tests on the secondaries are made by the voltmeter method. It is seldom found necessary to test for a ground on primary, because if there is one it is manifested by the blowing of fuses, flashing, and burning that occur. If it is necessary to test the primary it can be done by using a portable potential transformer or voltmeter in the same manner as the secondary voltage test.

The instrument boxes are connected by means of heavily insulated No. 10 flexible cables, 30 ft. long, provided with a "T" connector at one end and a pin at the other. The reason for the long cables is that it is not always convenient to have the box close to the transformer under test. (G. D. Gratton.)

Insulation Test.—Too great stress cannot be placed on the proper insulation of transformers, for upon it depends the safety of the customer; this is especially true in distributing transformers.

Safety results from the quality of the insulation, its permanency, ability to exclude moisture and the freedom of the transformer from local or general abnormal heating.

The insulation of transformers is tested by applying an electromotive force, first between primary and all the parts, and second between secondary and all other parts. The voltage to be applied depends upon the line voltage on which the transformer is to operate.

In general, twice the normal line voltage is considered an ample test for the insulation: although for small voltages, much higher than double line voltage is very often given in order to insure sufficient durability. For example the 200-volt secondary is generally tested for 2,500 volts.

For distributing transformers, where special precaution is taken to insure safety more than double normal protective test is generally given. For example in 2,000-volt lighting transformers 6,000 volts is at least specified; and sometimes the transformer is subjected to a 10,000-volt test.

Heat Tests.—The heat test on a transformer is a most important one, for the life of a transformer under normal conditions depends upon the working temperature.

It is essential that the test be conducted to approximate as nearly as possible the working conditions of the transformer, *i.e.*, the transformer must be excited to normal voltage and at the same time have full-load current in the windings.

There are two methods of accomplishing this:

(1) The primary of the transformer may be connected to a circuit of the proper voltage and frequency and the secondary loaded with lamps or a water rheostat until full-load current is obtained.

(2) If two transformers of the same voltage and rating are available, a heat test may be run on them by the so-called "motor-generator" method.

The secondaries are connected in parallel and excited at the proper voltage and frequency while the primaries are connected in series but in such a way as to oppose each other.

Full-load current may then be produced in the two transformers by impressing a voltage across the primary terminals equal to twice the impedence voltage of either transformer.

In view of the greater amount of power required in the first case, the second method is preferable.

The determination of temperature may be made by thermometer or by measurement of resistance. As insulation is a poor conductor of heat, during a heat test the temperature of the coils will increase rapidly from the exterior to the interior so that the latter method of taking temperature is the more accurate.

Readings of temperature are usually taken every hour and the run should be continued until several constant readings are obtained, showing that the transformer has reached its ultimate temperature.

Core-Loss.—An accurate knowledge of the core-loss taking place in transformers in service is essential for all well regulated central stations. This loss takes place all day long whether the transformer is operating or not, and it may easily be that the total cost of core-loss throughout the year is considerably more than necessary.

This is especially true for distributing transformers situated at the ends of distributing lines or feeders; for then the loss means an additional load on the entire system.

The core-loss may be found by impressing upon any coil of the transformer the normal voltage and frequency for which the coil was designed, all other coils being on open circuit. This test requires the use of a voltmeter and wattmeter. The true loss is obtained by subtracting the losses in the instruments from the wattmeter reading.

The core loss is dependent upon the wave shape of the generator and the temperature of the core. The core loss should always be measured on the sine wave generator or due correction made for the wave form. As the core loss decreases with increasing temperature, a correction for core loss should be made if the temperature of the core varies considerable from 25 deg. C.

Exciting Current.—It is customary to measure the exciting current or no load current simultaneously with the core-loss by observing the current in the coil when rated voltage is impressed upon it.

The exciting current should not exceed 10 per cent. of full-load current.

Wave Shape.—The shape of the e.m.f. wave exerts a considerable influence upon the core-loss of a transformer, a peaked wave usually causing somewhat lower core-losses than a flat wave. It is not uncommon to find alternators having such a peaked wave form that the core-loss of the transformer when tested from them, will be 5 per cent. or 10 per cent. less than that obtained when the transformer is tested from a generator giving a sine wave.

It is customary for electrical manufacturing company's to give core-loss results on a sine wave basis in order that there may be a basis of comparison.

The wave form of the testing generator must also be taken into account in determining the dielectric strength of any material, since it is the peak of the wave that produces rupture. It is for this reason that the spark gap gives more accurate results in this class of testing.

Balancing of Load.—For ascertaining the maximum load on transformers or the balancing of the secondaries, maximum demand indicators are very useful. The same may be said of accurately adjusted recording voltmeters installed at the points of lightest and heaviest loads.

In case portable instruments cannot be conveniently used, pressure wires may be run back to the station and a voltmeter used on each side of the system.

SECTION XVI.

Lamps.

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Lamps.

ARC LAMPS.

Suspension Chains.—For the installation of arc lamps for street lighting, the use of galvanized chain for suspending arc lamps has proven very satisfactory. (F. C. Sargent.)

To prevent meddlers from releasing the lamps where they are suspended on cutter pulleys, a lock has been used with the Philbrook mast arms which has proven very satisfactory. (F. E. Smith; J. W. Cowles; Edison Electric Illuminating Co. of Boston.)

Automatic Cut-Outs.—The automatic cut-out switches that cut the lamp out of the arc circuit and close the circuit when the lamp is lowered have not been extensively used until recently; the earlier types were not thought practical on account of cutting out of circuit and cost of maintenance. (F. C. Sargent; Malden Electric Co.)

The question of cut-out switches has recently been taken up by a number of manufacturers and in connection with both series and multiple arc lamp work. Sufficient time has not elapsed to obtain definite figures as to cost of maintenance, etc., in the suspension of lamps in streets. The breaking of swinging lead wires from crossarms to arc lamps has been a source of trouble which can be avoided to a great extent by the use of stranded cable of approximately 48 strands for these lead wires; the same results also being obtained by splicing a short section of stranded cable to each end of the swing lead wires. (C. W. Humphrey.)

Reflectors.—The development of reflectors for both interior and exterior work has received considerable attention and it is desirable to use some sort of reflector for arc lamps in street fixtures. (J. W. Cowles; Edison Electric Illuminating Co. of Boston.)

Closed vs. Open Base Lamps.—The relative costs of series enclosed arc lamps as equipped with closed base enclosing globes and similar lamps equipped with open base enclosing globes is a matter depending upon method of handling. If lamps are equipped with removable lower holders the cost of maintenance should be in favor of the open base type of enclosing globes and the cost of globes themselves is somewhat less as against the closed base type. (R. Fleming; General Electric Co.)

Various schemes have been tried for preventing the rusting of the iron gas caps on enclosed arc lamps, none have been eminently satisfactory. (J. W. Cowles; Edison Electric Illuminating Co. of Boston.)

Humming.—For interior work the alternating-current enclosed arc lamp is subject to considerable humming, especially noticeable on low frequency circuits. This is inherent in the arc, but in well built lamps operated under favorable conditions the humming will be reduced to such an extent as to be unobjectionable. In most cases of commercial service the hum of the arc itself is often less than the noise due to the vibration of the lamp mechanism and the latter evil may be overcome by proper design and construction of the regulator. Elastic supports should be provided for the lamp and when the arc is suitably enclosed a diminution of the noise is obtained; no satisfactory method has yet been devised to entirely eliminate this objection. (Lewis B. Marks.)

Globes.—The question of globes, especially as to the amount of absorption, diffusion, etc., has been the subject of considerable study recently. There has not as yet been developed a globe that is more decorative and within reason, as to cost and weight, than the plain white or clear glass that is commonly used and at the same time not absorbing any more light than an opalescent globe. (Edison Ill. Co.)

Usefulness of Arc Lamps.—The commercial arc lamp is now and will probably always be a commanding factor in the illuminating field, even in face of the recent development of a high efficiency metallic filament incandescent lamp. The flexibility and convenience in size of the incandescent lamp will always make it a factor in decorative and artistic effects for window illumination, illuminated signs and in places where the color value is not of any importance.

In locations where the color of the light enters into consideration the arc lamp will always retain its hold; notwithstanding the increase in window illumination and the wide spread introduction of high efficiency incandescent lamps there is a continued growth in the use of the arc lamp, relatively smaller, however, than the increase in use of incandescent lamps. (E. W. Phillips: Brooklyn Edison Co.)

Note:—The comparatively recent introduction of the so-called daylight or intensified arc lamps, that is, those using the 5 or 7 mm. electrodes will prove a further incentive to the adoption of arc lamps, the efficiency of these lamps having been increased by the small electrodes at no excessive sacrifice in life. (R. S. Hale.)

Flaming Arc.—The flaming arc lamp has not been extensively used for interior work owing to the excessive first cost of the lamp itself as well as of the electrodes and to the short life, in addition to the fact that insurance authorities have been slow in giving it their sanction for interior installations. The high intrinsic brilliancy of the lamp has made it undesirable to install it for interior work. (E. A. N., New York Edison Co.) A number, however, have been installed in foundries, armories and in other locations where they can be placed at sufficient height to reduce the eye fatigue. The fumes given off by the lamps are due entirely to the material used in the core of the carbons. There is a lamp being manufactured which in its construction eliminates the fumes almost entirely. (G. H. Rettew.)

The general policy that has been adopted in regard to flaming arc lamps has been for the customer to buy them and furnish his own electrodes. In districts covered by the regular arc lamp trimmers they will be trimmed by the company. (J. W. Cowles; Edison Electric Illuminating Co.)

INCANDESCENT LAMPS—(Carbon Filament).

Renewals.—It is the practice almost universally to furnish free renewals of carbon lamps and in a great many cases the first installation of incandescent lamps is furnished by the electric companies. A certain number of extra lamps are provided for the customer and he is held responsible for them; these extra, or spare lamps are not only a convenience in replacing a burnt out lamp but serve as an agent of continuity in revenue of the company. (Percy Ingalls.)

On the renewal of lamps no restriction should be placed on customers, the company protecting itself by rephotometering, cleaning and reissuing into service all lamps that are good. (F. W. Wilcox; General Electric Co.)

The renewal of lamps is a good investment, in that it results in a closer relation between the company and the consumer. Should no free renewals be granted the customer would use his lamps until they had depreciated beyond the useful life and then complaints in regard to poor service and high bills would be frequent. The small stations can afford the expense of inspection and renewals of incandescent lamps as well as the larger stations. (Wm. R. Gardner.)

The sizes of lamps which are given on the free renewal basis differ in various localities, in some places all lamps under 8 c-p. are charged, on account of the excessive cost of lamps and number of candle-power-hours used. (LaCrosse Gas & Electric Co.) In other localities the 4-c-p. lamp is given free for interior work and the 2-c-p. for signs. (Edison Electric Illuminating Co.)

The general practice is to renew only those lamps obtained from the companies and some method of identifying lamps furnished by the company has been used. This has mainly been accomplished by etching the initials of the company on the lamp, during process of manufacture. (J. J. Cagney.) This has to a great extent at the present time, been discontinued.

Coloring of Lamps.—The policy of coloring lamps for temporary or holiday decoration or for sign work is one that is admirable; the cost being so slight that it is considered good policy to do this as an accommodation to the customer, bringing before his mind the desire on the part of the company to furnish him service.

Considerable trouble has been encountered in the coloring of lamps owing to the fact that the colors are not weatherproof. Of course, the natural colored lamps can be used but their expense precludes free renewals. There are available coloring materials for lamps but it is not possible to guarantee them to stand indefinite exposure to snow and rain. (F. W. Willcox; General Electric Co.)

Turned Down Lamps.—The supplying of the so-called "turned down" incandescent lamps to customers, by whatever arrangement desired, is advisable for the reason that the use of the turned down lamp is a step in the way of convenience which tends to popularize the use of electricity.

Instances have been found (S. S. Ingman) whereby the use of the turned down lamp customers has been so impressed with the convenience of electricity as to adopt electric lighting for their residences, etc.

There are some companies that check up lamp manufacturers' guaranteed life and general efficiency but the practice is to depend upon the Edison Lamp Bureau. (Edison Electric Illuminating Co. of Boston.)

Minimum Frequency.—The lowest frequency in which incandescent lamps can be still used on commercial circuits at the present time is probably 25 cycles per second; with this low frequency the flickering is not actually noticeable. With high-voltage lamps and lamps of lower candle-power, that is, those having a finer filament, the flickering is more noticeble than with the higher candle-power lower voltage lamps in which the thermal sluggishness is considerably greater. (Clayton H. Sharp.)

Series Street Lighting.—In relation to series incandescent lamps for street lighting there has recently been considerable attention devoted to the redesigning of fixtures along the lines of a more artistic appearance and several neat and strong fixtures have been placed on the market. (Beacon Light Co.)

Street Lamps Renewal.—The incandescent lamps in street illumination should be considered in the same light as for interior work, in that the lamps should not be left in the sockets until burnt out, but replaced when they become sufficiently blackened to attract attention. (J. W. Cowles.)

Size of Lamps for Street Lighting.—There are various conditions which determine size of incandescent lamps for street lighting, the spacing of lamps and the foliage of trees have important bearing on determining which lamps to use. A 32-c-p. lamp is recommended where arc lamps are not wanted as it is considered that the 16-c-p. is too small to give satisfactory street lighting. (Ludwick Kemper.)

INCANDESCENT LAMPS (Metallic Filament).

Encourage Use of High Efficiency Lamps.—From both the central station and consumers' view point it is believed best to urge customers to use high efficiency units, not reducing the meter rate, inasmuch as the customer would get more light for the same consumption. (Bennington Electric Co.)

There is, however, a tendency to replace the carbon filament lamp with the metallized filament lamp; the latter costs more but is doing much to popularize the use of electricity. It's sustained candle-power is a feature; and although there is a small increased renewal cost on a kw-hr. basis to the station, the gain in efficiency and life tend to popularize electricity and lead to the installation of additional larger lamps with a resultant increased revenue to the central station. (James E. Davidson; L. W. Layman, 1910.)

Tungsten C-P. Variation.—The tungsten lamps of 100 to 120 volts will show, on commercial a-c. frequencies a larger variation in light than a carbon filament lamp of corresponding candle-power and voltage; this is due in a great extent to the diameter of the filament; however, as frequency of variation becomes so much smaller a point is reached where the variations are so slow that temperature conditions throughout the filament of either lamp have time to adjust themselves and the tungsten lamp must then show smaller variations then the carbon filament lamp on account of positive temperature coefficient of the tungsten. (H. C. Marquardt, 1909; Clayton H. Sharpe; John W. Howe, 1910.)

Current Consumption of Tungsten Lamps.—The current consumption and useful life of a 25-watt tungsten lamp on 110-volt circuit is largely based on the claim of manufacturers that this lamp takes from 0.18 to 0.31 amperes and has a life of 800-hr.; voltage variations, however, affect the useful life. (H. C. Marquardt, 1910.)

Life of Tungsten Lamps.—Various data have been obtained on individual cases of life which will exceed 800-hr. The 25-watt tungsten lamp has been pushed in a number of cases for burglar protection in the rear of residences; owing to its small wattage consumption it has been advanced as an inexpensive method of protection, the lamp, however, being installed sufficiently far from the ground so that it cannot be removed or broken under ordinary conditions. (James C. Hutchins, 1910.)

Free Renewals.—The general practice in regard to furnishing tungsten lamps to customers has been that all lamps are tested in customer's presence. If broken while being carried home the lamps are not replaced free of charge; a printed notice is enclosed in each cardboard carton which encloses the lamp explaining the fragility of the filament and the necessary care to be exercised in handling the lamp. In cases where complaint is entered on the breakage of the lamp, an investigation is made and should the lamp be found to have burnt out or carbonized after two or three days use it will be replaced free of charge. Every case is considered on its own merits and no definite length of time is stated in which to replace lamps free of charge. (C. C. Paver, 1909; Edison Electric Illuminating Co. of Boston, 1910.)

Two C-P. Tungstens.—The use of small tungsten lamps (about 1 c-p. per volt operated by dry batteries) has been made in a number of cases on motor boats and for emergency and temporary lighting. (N. C. Cotabish.)

This, however, becomes a problem of charging cost plus interest on depreciation against the prices obtainable for service for such installations. (E. St. Clair, Clayton.)

Multiple Street Lighting.—Multiple tungsten lamps have been used to some extent for street lighting in place of 32-c-p. carbon lamps, these being suspended over the middle of streets on a guy wire arranged in an approved manner so that they may be lowered or raised from the poles as desired. Assume that the same rate of interest is obtained on the investment for street lighting for the operation and maintenance of a 60-watt tungsten that is now obtained from a 32-c-p. carbon lamp and about a 10 per cent. increase for a 100-watt lamp. (William Wallace.)

Multiple tungsten lamps left turned on, when connected to the secondary of an a-c. service, are often burnt out when the primary switch is turned on at the station; this is due to the sudden surge caused by throwing on the current with the voltage considerably above normal; this overshoots the filament of the lamp to the breaking point. If the station is a small one and the load is not carried in daylight, starting the generator with the line switch closed and letting the primary voltage build up on the line as the machine speeds up would prevent this trouble; if the station is operated and the circuit in question is to be thrown in from a high-voltage busbar, placing a few more lightning arresters on the line might neutralize the surging. (E. St. Clair, Clayton, 1910.) It is also possible to overcome this difficulty very largely, by lowering the voltage a little below normal before closing the circuit switch and then closing it gradually. (R. O. Bentley.)

NERNST LAMPS.

Street Lighting.—The Nernst lamp has been used to considerable extent in street lighting in country towns because it gives frequent units where they are wanted underneath trees, etc., while on account of these trees an arc lamp would not cover the ground that it should cover. (Union Electric Light & Power Co.)

In other localities in suburban districts the series tungsten incandescent lamp is used with considerable success for street lighting. Edison Electric Illg. Co. of Boston, 1910.)

The charges for energy as used by Nernst lamps are the same as for other forms of lighting. (C. W. Rice.)

The Nernst lamp in a certain sense is regarded as a constant efficiency lamp inasmuch as after a decrease in c-p. of about 15 per cent. which takes place within 300 hours, the candle-power remains practically constant owing to the fact that the addition of new glower just about makes up for the deterioration. (E. R. Roberts.)

Where the lighting company has enough Nernst lamps on its circuits to warrant it, the most satisfactory method is to have the maintenance in the hands of the lighting company; small users have found it more satisfactory to contract with the Nernst Lamp Co. for service. (George R. Colgate.)

In other localities the lamps are either maintained by the customer, in arrangement with the Nernst Lamp Co., or under certain conditions on a small rental charge per glower, by the lighting company. (E. E. I. Co., 1910.)

MISCELLANEOUS LAMPS.

The Cooper-Hewitt lamp as compared with incandescent arc lighting, lamp for lamp, consumes about equal current. The cost of Cooper-Hewitt renewals, however, places the operating cost at a somewhat high figure (Percy H. Thomas), although recent developments in the tube have brought the figure of maintenance to a lower point. (R. S. Hale, 1910.)

SECTION XVII.

Illuminating Engineering Problems.

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FOREWORD.

Illuminating Engineering has not been defined by an authoritative body, nor has its practice been standardized. Indeed it is questionable if it will ever be possible to define or standardize the practice rigorously.

The engineering of illumination admits of a wide range of activity. Broadly speaking, every phase of lighting, beginning with the production of light, lies within its scope. The design of light sources and accessories; the selection of the most suitable form of illuminant and reflecting or diffusing devices; the design or selection of fixtures on which they are to be used; the location of the illuminants; the decoration of interiors; the maintenance of illuminants; the photometric tests of illuminants and illuminating effects; the study of the hygienic and physiological features of the problem—these and other ramifications in a broad sense are within the scope of illuminating engineering.

Some of these subjects are considered in other Sections of the Question Box, as for example, all discussions pertaining directly to "Lamps." The classification adopted restricts the discussion in this Section to certain subjects which are embraced in the following sub-divisions:—

Illuminating Engineering.
Lighting of Interiors.
Street Lighting.
Special Lighting Problems.
Photometry.
Specifications.

Illuminating Engineering is a rather recent development in central station practice and consequently has received but little attention in the Question Box. Moreover, there is some reason to believe that Illuminating Engineering may never receive the attention in the Question Box which its importance would warrant, due to the individuality which characterizes the nature of its problems. The variables which enter into the conditions of lighting problems are so many and varied as to forbid extensive treatment along general lines. There is no panacea for lighting ills!

The dearth of Question Box discussion which results from these causes makes it seem advisable to include in the following review brief references to pertinent discussions elsewhere in the Transactions.

ILLUMINATING ENGINEERING.

Illuminating Engineering in Central Station Practice.—Oehlmann points out usefulness of lighting specialties in securing new business. (Trans., 1907.) Lansingh notes growing appreciation by Central Station men of importance of illuminating engineering and cites results which may be, and which have been attained. (Trans., 1908.) Sawin describes organization and operation of a Central Station Illuminating Engineering Department. (Trans., 1909.) Marks discusses place of Illuminating Engineering in Central Station Practice (Bulletin, Vol. I., Page 57) and its value in obtaining new business (Bulletin, Vol. I., Page 106).

Illuminating Engineering as a Specialty.—Ryan shows that one important function of the illuminating engineer is the design of lighting appliances with intelligent regard to the requirements of good lighting. He then describes certain appliances designed with this in view. (Trans., 1908.)

LIGHTING OF INTERIORS.

Design of Installations.—Ryan in paper entitled "Light and Illuminating Engineering" recommends enclosed arc lamps for lighting mercantile establishments because of superior quality, volume and economy of light. Considers 80-volt arc better than 100-volt arc. (Trans., 1903.)

In lighting offices, draughting rooms, etc., concensus of opinion favors small rather than large light sources (1907, S39) while insisting unanimously upon avoidance of exposed glaring illuminants (1907, S40). Considerable difference of opinion is developed as to choice of illuminants (1907, S4). General discussion 1909, 17-1). Norman describes two installations. (Trans., 1907.)

Trend of discussion on Bedroom Lighting points to need for central lamp for general illumination and two lamps for lighting of dresser, with reading lamp for bed where desired (1908, S8).

For Meeting-Room Lighting, use of chandeliers is condemned, individual units being preferred.

In Kitchen Lighting contributors favor use of one central lamp for general illumination and one lamp located over sink.

Illumination Intensity Required.—Ryan in paper entitled "Light and Illuminating Engineering" states watts per sq. ft. required for good lighting with enclosed arc lamps in mercantile establishments. (Trans., 1903.)

Lansingh (1905, Z17) generalizes as follows:

Churches—Minimum	1 ft-candle
Libraries—General—Minimum	1 ft-candle
Local—Maximum	3 ft-candle
Bedrooms—General	½ ft-candle
Local	2 ft-candle
Ballrooms—Minimum	2 ft-candle

Norman finds 13½ ft.-candles in well lighted draughting room. (Trans., 1907.)

Various methods of computing lamps necessary to produce given illumination are discussed as "c-p. per sq. ft.," "c-p. per cu. ft.," and "watts per sq. ft." (1907, S42). For approved method see Transactions Illuminating Engineering Society, Vol. II., Page 414 and Vol. III., Page 518. (Ed.)

Color of Light.—For matching colored goods enclosed arc lamps are superior to so-called gas arcs (1906, S27). Bauder discusses quality of daylight and artificial light and submits data obtained by Ives colorimeter. Describes unique application of color photography to the investigation of color of light. (Trans., 1909.) Opinion favors use of a number of rooms illuminated by different kinds of lamps in Department Stores, thus enabling customers to examine goods under the light under which they are to be used. (1908, S7.)

Flicker.—Discussion of relative flicker of carbon and tungsten lamps on alternating-current indicates that no general conclusion can be reached. (1909, 16-4.) Kennelly and Whiting investigate general subject of flicker using photometers under exoerimental conditions. They analyze variables which enter into the problem but draw no conclusions which have significant bearing upon lighting practice. (Trans., 1907.)

Maintenance.—Eustice reports tests showing loss of light due to dust and emphasizes need for systematic cleaning of lamps and glassware. (Trans., 1909.)

STREET LIGHTING.

Street Lighting Systems.—Wagoner reviews developments of incandescent series systems and discusses tungsten series lighting from viewpoints of illumination and costs. (Trans., 1908.)

Description of Installations.—Cowles under title "Developments in Street and Park Lighting" discusses requirements for various kinds of street lighting and describes application of some new lamps (Trans., 1909.)

Equipment of Lamps.—There is considerable difference of opinion as to best glassware to be used with enclosed arc lamps. Some favor clear inner with clear outer globes while others recommend opalescent inner with clear outer globes. (197, S4.) Reflectors are of value in improving the illumination only when alternating-current is used, or when the lamps are placed unusually high. Under other conditions, the chief value of reflectors lies in the protection which they afford the globes. (1907, S3.)

Location of Lamps.—There is marked difference of opinion as to the height at which lamps should be placed when streets have shade trees. Heights ranging from 12 to 22 ft. are suggested, with an average height of about 16 ft. indicated by the mean of all replies. (1906, S15.)

Lamp Posts.—Need for satisfactory decorative or artistic posts for incandescent lamps is stated (1906, S16 and 1908, S9). Some suggestions offered (1907, S2).

SPECIAL LIGHTING PROBLEMS.

Decorative and Sign Lighting.—Williams (Arthur W.) submits profusely illustrated reports on this subject and discusses some phases of the problems involved. (Appendices of Trans., 1903 and 1904.)

Miscellaneous.—Billiard Table Lighting is covered by expertly prepared specifications submitted by Lansingh, Marks and Hall (1908, S15).

The lighting of a store with GEM lamps so as to provide good illumination and at the same time attract attention to a store by means of the lighting is a problem which brings out a number of suggestions (1908, S17). Norman describes manner in which this is accomplished in the Harlem Office of the New York Edison Company. (Trans., 1907.)

Suggestions as to the best way to light a bowling alley are offered by Lansingh and White (1909, S12).

PHOTOMETRY.

A universal rotator for simplifying the determining of the distribution of light about incandescent electric lamps is described by Bailey. (Trans., 1902.)

Clifford under the title "Some Fundamentals of Photometry" discusses the characteristics of various photometers, considers the physiological elements involved and reports experiments in photometry of differently colored lights. (Trans., 1903.)

Lawrence describes arc lamp photometer installed in the Massachusetts Institute of Technology. (App. C., 1903.)

Kennelly and Whiting report experiments to determine photometric precision, employing a number of photometers and observers, comparing similarly and dissimilarly colored lights. (Trans., 1908.)

SPECIFICATIONS.

Street Lighting.—Elliott rehearses difficulties growing out of the 2,000-c-p. and the 450-watt ratings of arc lamps. Opines that street lighting specifications should be based upon illumination produced. (Trans., 1907.)

Report of "Committee to Consider Specifications for Street Lighting" discusses various methods of rating and recommends desirable form of specifications. After much discussion, pro and con, Committee is continued with understanding that final report is to be submitted during following year. (Trans., 1907.) Committee delegates some of its functions to Ryan who carries out extensive experimental work and submits report for Committee. Report classifies illuminants with regard to street lighting value, and is adopted by Association. (Trans., 1908.)

Gilmour suggests form of Agreement for Municipal Street Lighting (Bulletin, Vol. I., Page 80).

SECTION XVIII.

Electric Heating and Cooking.

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Advantages of Electric Heating.—There can be no doubt of the desirability of the load afforded by heating appliances. The current required, however, is so very small and so intermittent that it is doubtful whether the comparatively limited amount of heating appliances in use really affects the load of any central station. But even if it had no effect at all it would still be most desirable for the central stations to extend the use of heating appliances, as anything that tends to make electricity convenient and popular will undoubtedly increase its general application. (H. T. Hartman.)

Heating devices take a steady current and mostly at the non-peak hours. (New York Edison Co.)

The addition of heating appliances means the addition of small amounts of energy consumed at a time. What is of equal if not greater importance—it multiplies the use to which electricity is put by the consumer, and the more varied uses to which electricity can be put by a customer the more satisfied is he and the more certain to continue. (J. D. Israel; Jas. I. Ayer.)

To your customers it is more cleanly, safer, more flexible, and except in case of radiators, does not heat the room. Present developed business in domestic application is largely confined to small household conveniences that operate at little cost. In manufacturing and commercial establishments the safer fire risk, cooler workrooms, increased output, and frequently lower cost for heat can be claimed. In some cases very effective and efficient applications can only be made with the electric method. (Jas. I. Ayer; J. D. Israel.)

Advertising.—Large companies issue monthly bulletins advertising heating devices, supplemented occasionally with loose-leaf dodgers and booklets, distributed by mail with bills.

Use return postal cards. (New York Edison Co.; John F. Gilchrist; Brooklyn Edison Co.)

Daily newspaper advertising followed by personal letters with illustrated literature.

Street car advertising has been found efficient. (The Edison Co., Altoona, Pa.; A. T. Lloyd; Wm. Rawson Collier.)

DOMESTIC APPLIANCES.

Ovens.—Ovens have been used to some extent. Practical cooks state they give satisfaction.

Also used for dental work.

Sanitary conditions a strong feature. (C. J. Herrick.)

Electric ovens are in use for cooking, and are beyond question superior for such purposes to all others. At lighting rates they are not cheap to operate, though at from 2 to 5 cents per kw-hr. they are much used. There is no more satisfactory electric cooking device.

Flat Irons.—Objection to flexible cord overcome by using gooseneck stand or a coil spring to take care of slack in cord. Special devices are manufactured to take care of slack in cords.

Generally there is no objection when operators and demonstrators know how to use the irons.

Servants' objections are overcome by the arguments of work turned out more speedily with less exertion and better results; also more comfort.

It is important that you connect up and demonstrate to the servant the correct utility of the iron, which incidentally shows them that there is no danger connected with it, and it is of much importance that you use every means by practical example to show that it is perfectly harmless. (J. D. Israel; Jas. I. Ayer.)

Repairs and Maintenance.—One company maintains without charge, all flat-irons installed. When a customer reports an iron out of commission a boy is immediately sent with a renewal. When repairs are made the iron is returned and the one substituted is placed in stock. We find that the renewals on flat-irons represent a small item, and the elimination of repair costs is a great benefit in that the customer, having no repair bills to pay, is greatly impressed with the reliability of the heating devices.

If the repair department keeps repair parts in stock there is hardly any need of loaning the customer an iron during repairs as the repair work should be handled very promptly. (L. D. Mathes; Wm. Rawson Collier.)

INDUSTRIAL APPLIANCES.

Flat Irons.—In industrial installations where the irons are continually in use it is essential that a good arrangement of cord suspension be provided, and that operators be cautioned against allowing the cord to become twisted or kinked. This is the most fruitful cause of broken cords. (J. D. Israel; Jas. I. Ayer.)

Heating Greenhouses.—Electric heating for greenhouses is practical for the consumer only when used strictly as an auxiliary heat for extreme cold conditions, or breakdown of regular heating. It may be used successfully in small window greenhouses of private residences. (A. E. Hatchfield; R. H. Tillman.)

DISPLAY.

The general concensus of opinion is that it is advantageous to establish Display and Showrooms, centrally located, in the business sections, in conjunction with existing central offices where practical, and if the general offices are not centrally located it has been deemed feasible to establish a separate Display and Salesroom in the business section of the City, covering heating apparatus and other small electrical appliances. (J. D. Israel; Jas. I. Ayer.)

Efficiency and Practicability.—The rate per kw-hr. at which electric energy for heating purposes will compete favorably with gas, is 2½ to 3 cents. For intermittent use, on account of the cleanliness and convenience, a rate varying from 5 to 10 cents per kw-hr. will always be found satisfactory.

For large installations it works to advantage to consider heating appliances on a power basis at power rates. (H. D. Larrabee; New York Edison Co.; J. C. Shade.)

Electric heaters vary in efficiency, roughly, from 50 to 90 per cent. In short operations, low values—while operations of an hour or more —will approach the higher values. This applies to the miscellaneous use of apparatus for domestic requirements.

Gas apparatus for similar uses has an average efficiency of not more than 10 to 20 per cent., and while the B. t. u. of electricity does cost many times the B. t. u. of gas, the efficiency in the electric apparatus justifies the statement as to comparative economy in electric devices.

Electric air radiators are not practical for house heating, but they have their applications.

Electric air heaters are not sold for general heating purposes but for uses as auxiliary heaters for bathrooms, corners of rooms, etc., where the total cost of operation is not material because of short periods of use.

The cleanliness, convenience, freedom from odor, etc., are of more importance than the cost of operation.

LOANS AND DEMONSTRATIONS.

We have given free trials of flat-irons to a large extent with considerable success. We give free trials of other apparatus to a very small extent. Our policy is that when we can give a short free trial without making the apparatus into secondhand apparatus, we shall be quite liberal with free trials, but not otherwise. (R. S. Hale.)

The policy of loans and demonstrations proves profitable, putting such articles as flat-irons and toasters with consumers for a period of thirty days or longer, as conditions warrant, and having female demonstrators follow to instruct consumers in the proper use of the articles. (Jas. I. Ayer; J. D. Israel.)

RATES AND MINIMUMS.

Small appliances do not require special rates and can be installed on existing circuits whether they be light or power, and if the installation is somewhat large it can be treated as a power proposition under power rates.

Special cooking rates are made in some communities for electric kitchenette installations.

Under all conditions energy should be sold by meter.

The question of the use of separate meters for cooking and lighting for domestic requirements is proposed in some instances, but not generally. (Jas. I. Ayer; J. D. Israel.)

Complete Cooking Devices.—Current sold for heating and cooking must be sold as low as you can afford to sell it per kilowatt-hour. One house that we know of cooks entirely by electricity, and used 150 kw-hr. in one month. At 3 cents per kw-hr. this would just about equal gas at $1.40 per 1,000 cu. ft.

A separate meter should be used. (J. W. Cartwright, Jr.)

Ranges to do all cooking in the home, and to a very large extent meet the requirements of clubs, cafes, hospitals, etc., usually give excellent results. In domestic use, rates must range from 2 to 5 per kw-hr. where all cooking is electric. (Jas. I. Ayer.)

REVENUE.

For electric irons a large number of central stations range the estimated consumption at from 30 kw-hr. to 150 kw-hr. per year. About 75 kw-hr. per year is a fair average. (Jas. I. Ayer; J. D. Israel.)

SALES.

Exhibition rooms should be salesrooms as well, rather than display rooms only. In all cases reported much greater success has followed where salesrooms have been maintained or substituted in place of display rooms only. (Jas. I. Ayer; J. D. Israel.)

Selling Price.—In large cities where department stores and supply houses sell electrical appliances, it has been found advisable for central stations to sell at list price, in order to foster profitable coöperation, rather than invite unpleasant competition. The policy of selling at cost was found to result in deterring such establishments from handling electrical devices, thereby restricting the number of outlets for these goods. Another undesirable consequence was the arousing of a feeling of irritation or resentment on the part of department stores, who are either large customers or possible customers, and on the part of our natural allies, the contractors, many of whom sell supplies.

In referring to "list," this is understood to apply where list provides only the usual retailers' profit; but is not intended to apply where discounts are in effect.

The general tendency throughout the country is to sell heating appliances, with the exception of one or two leading articles, at a fair profit. This has been brought about by the establishment of substantial dealers carrying electrical goods, and by department and other stores taking up these lines, thereby materially increasing the opportunity for purchase on the part of the public.

The earlier practice of selling at cost is being changed, because of the above reasons. However, the general statement still holds, that the more appliances introduced the more energy will be sold, and the lower the price of any article, the greater the quantity sold; and possibly because it has been the practice of gas companies to sell heating appliances at cost, our practice began that way and still continues to an extent. There is some argument for this practice, as applied to one or two small articles—flat irons being the most conspicuous. (James I. Ayer; Joseph D. Israel, 1911.)

UNDERWRITERS' AND COMPANIES RULES AND REGULATIONS.

Flat-Irons.—The desirability of some visible indication of current being on or off is to be recommended. A desirable method is to connect a lamp in multiple with the iron, which proves useful to the consumer in avoiding waste and is a measure of protection against neglect.

The failure of the lamp burning means the signal is not an absolute protection and in that sense does not meet with the approval of the Underwriters' generally. They want something which will always indicate the exact condition. (J. D. Israel; Jas. I. Ayer.)

SECTION XIX.

Electric Power.

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MOTOR APPLICATIONS.

Hoist and Elevator Work.—Induction motors can be used for elevator and other intermittent service if the proper type be installed, and will cause practically no more disturbance on lighting feeders than would be caused by corresponding direct-current shunt motors for the same service. On lighting feeders, carrying ordinary loads in residence territory, it is somewhat difficult to prevent interference with the lighting service if elevator motors larger than 7½ hp. on single-phase circuits are used. Alternating-current elevators are preferably operated on the two or three-phase system, as these types of motors are best adapted to this class of service and produce less disturbance to the lighting system. (1902.)

The consumption of electric energy per car-mile would necessarily depend not only on the efficiency of the motors but on the efficiency of the pump and apparatus driven. An average figure would be about 6 kw-hr. per car-mile. (1904.)

Single-phase commutator motors with repulsion characteristics, have been used for a large variety of service requiring adjustable speed. A motor of this type has characteristics similar to those of direct-current series wound motor, and is applicable, therefore, to the driving of such apparatus as fans, blowers, printing presses, and such other apparatus as requires certain fixed speeds at certain fixed loads. This speed adjustment is more economically obtained by the use of an auto-transformer, since under these conditions, as the speed is decreased, lower voltage is applied to the motor, and, therefore, its constant losses decrease. With a resistance type of controller a large part of the total energy is used up in heat in controller resistance. The auto-transformer method of control has not been, to our knowledge, used for controlling single-phase elevator motors on account of the high cost of controlling apparatus of this type for the service in question, and the large number of makes and breaks which would be necessary in going from step to step of the auto-transformer, unless some form of shunt is used across the various controller steps. This would, however, make the controlling apparatus exceedingly expensive. (1909.)

Single-phase elevator motors are being installed to-day by the largest elevator manufacturers in the country, and are giving thoroughly satisfactory results, both from a practical and engineering standpoint. (1907.)

Multiple Stage Pumps.—The general experience with motor-driven two or three-stage centrifugal pumps in connection with electric-hydraulic elevators has been satisfactory. This has been the case at the 116th Street Station of the 9th Avenue Elevated R. R. Co. of New York City. There should be no particular difference in the use of direct-current motors as against alternating-current motors. Ordinary centrifugal pumps are not quite as efficient as plunger pumps, but the recent improvements in this type of pump have been great, and it would be a question of guarantee by the manufacturers as to which pump is the more efficient. (1906.)

Brake for Hoists.—The type of brake best suited to electric hoists depends on the size of the apparatus. On small hoists solenoid brakes are very satisfactory, and also mechanically operated brakes. For large hoists a motor operated brake is the best practice at the present time.

City Pumping.—Electrically driven pumps for city water works in small towns have proven very satisfactory, both to the central station and to the town, particularly by making arrangements so that the pumps shall not be operated during the peak of the lighting load, excepting for fire service. The electric company can afford to sell the electric energy at a rate that will effect a considerable saving to the town as well as being profitable to the lighting company.

Type of Pump.—Turbine pumps are preferred by electric company on account of the load being steadier; deep well pumps and duplex pumps cause troublesome fluctuations in line voltage, unless equipped with heavy flywheels, on account of the load on pumps not being the same at different periods of pump stroke. Triplex pumps should be used instead of duplex pumps, and as a rule a centrifugal pump is preferable to either a duplex or triplex pump. Where suction lift on pump is less than 25 ft. a single-pump, preferably a centrifugal pump direct connected to a motor would be installed to pump direct into mains and stand pipe. Where water has to be lifted from 25 to 125 ft. out of the ground, and the amount of water per well does not exceed 150 gal. per minute, a double-acting deep well plunger pump would be installed to raise water out of the ground into a surface reservoir and a direct-connected centrifugal pump would deliver water from the surface reservoir into mains and stand pipe. If the amount of water required per well exceeds 150 gal. per min. a turbine type of deep well pump would take the place of the plunger type pump.

It requires about 1 kw-hr. per 1,000 gal. pumped in the average small pumping plant and the net rate earned on electrical energy should not exceed 3½ to 4 cents per kw-hr.

It has been found to be good practice to use motor-driven pumps for city pumping with a stand-pipe system in a town of from 3,000 to 5,000 people.

Motor-Driven Air Compressors.—Air compressors can be driven by variable speed three-phase motors of the wound rotor type, using a remote control magnetically operated switch with an air operated contact arm for cutting resistance in and out of the rotor circuit. This mechanism is controlled by a pressure gauge which makes and breaks the circuit of the remote controlled switch. This contact maker depends for its operation upon the increase or decrease of air pressure on the tank starting the motor when the pressure reaches the minimum and stopping it when the pressure reaches the maximum. The saving on an installation of this kind over steam drive depends somewhat on the character of the service. (1908.)

INSTALLATION OF MOTORS.

The inside wiring for polyphase motors should be large enough to prevent excessive drop in voltage; otherwise the motor will not have sufficient torque to pick up its load. It is not necessary that the wiring be large enough in all cases to prevent the starting current from exceeding the safe carrying capacity of the wire as specified in the Underwriters' rules, as the starting current lasts only a few seconds and there is no danger of overheating the conductors on this account. The Underwriters' rules require that the wire be large enough to carry 50 per cent. more than the rated full load of the motor, and this is ample to take care of the starting current. Wherever possible, circuit breakers should be used on such an installation. (1906.)

The installation of 2,300-volt motors is prohibited in many localities, and such an installation should not be made under any condition unless under the care of an experienced electrician. The Underwriters will not approve such an installation excepting under very stringent rules.

MOTOR OPERATION.

Types and Efficiencies.—For general power purposes the induction motor is preferable because it does not require direct-current for excitation. For larger power purposes, such as motor-generators or other purposes where machines are installed in a place where they have continuous attention, synchronous motors are often preferable because of the ability to control the power-factor of the current taken by the motor. Generally speaking, the induction motor will stand more rough usage than the synchronous motor, and when used in places where there is a great deal of dirt, it is far preferable to the synchronous motor on account of the absence of sliding contacts and the high starting torque, which permits the induction motors to be installed in an out of the way place where little attention is required. (1905.)

Efficiency.—Generally speaking, the higher the efficiency of a motor the better for all concerned. For some classes of service, such as very heavy duty in rolling mills, efficiency is frequently sacrificed for reliability. In all applications of power for general service from central station lines, a high efficiency motor would certainly be preferable. (1906.)

Polyphase vs Single-Phase Motors.—Two or three-phase motors are cheaper to build than the single-phase type, partly due to mechanical and partly to electrical reasons. Pound for pound and speed for speed, a single-phase motor would have an output of about two-thirds of that of a polyphase motor. If a single-phase motor is to have sufficiently high starting torque to meet commercial requirements, the rotor must have several times the ohmic resistance of the rotor of a polyphase motor; a larger frame is also necessary due to the fact that one component of the flux, called the quadrature component, falls off in approximately direct proportion to drop in rotor speed, making it necessary to have a heavy initial flux to aid in accelerating the rotor and also to prevent same dropping out of step due to decrease in torque with decrease in speed. The starting torque of any induction motor is proportional to the product of the main fields by the quadrature fields, hence to the product of the main electromotive force by the quadrature electromotive force. It is therefore necessary to employ a larger frame to obtain the same output than with a polyphase motor where the quadrature flux is independent of the speed. The polyphase motor is cheaper than certain types of single-phase motor where accessories are required in the way of external or internal phase-splitting devices, clutches or similar mechanical devices in pulleys or armature, etc. When a commutator type single-phase motor is used, there is naturally the additional cost of providing brushes, brush rigging, extra connections, etc. (1906.)

Single-phase motors in sizes up to 25 hp. have given very satisfactory service in many cases. This type of motor being usually provided with a commutator is somewhat more subject to trouble than polyphase motors of the squirrel cage type. They are fully as satisfactory to the power user as the polyphase motors of the internal resistance or collector ring type. (1906.)

Single-phase motors up to a certain size, varying from 1 to 10 hp. depending upon the size of the plant and lines may be used on the three-phase four-wire system. Single-phase motors are somewhat lower in efficiency than the two-phase motors. In cases where the service connection is not too expensive on account of more material and work involved in the two-phase connection, the two-phase motor would be the better selection. Generally speaking, the power-factor of a two-phase motor is better than that of a single-phase motor, depending somewhat upon the design of the motor. (1907.)

The high price of single-phase motors in comparison with three-phase motors is probably the reason that some central station companies have difficulty in selling this type of motor. (1907.)

The single-phase motor for light service is very satisfactory, and it is generally convenient to connect them to single-phase lighting circuits. Polyphase motors require more wires and the hanging of more transformers, and a more expensive meter increasing the transformer loss and also the central station company's investment. (1907.)

Cost of Installing Single-Phase Motor.—As far as the interior wiring is concerned it is cheaper to install a single-phase motor than a three phase motor. Taking into consideration the cost of the motor and wiring, it is no doubt true that the polyphase motor makes the cheaper installation in the average case. (1907.)

Speed Adjustment of Machine-Tool Motors.—For the usual commercial requirements on machine tools and where polyphase current is available, constant speed motors and the use of mechanical speed changing devices (usually incorporated into the driven machine) or the use of multi-speed motors, *i.e.*, motors with changeable pole groupings giving a definite number of speeds are alike satisfactory. As machine tool work demands almost invariably constant horse-power rather than constant torque, multi-speed motors are of necessity larger and more expensive than the constant speed type. Where multi-speed motors are used, the many well known advantages of individual drive are secured, and as provision may be made for intermediate speeds by mechanical gear change to fill in the gaps between the speeds at fixed polar groupings, this system is entirely feasible. The single-phase induction commutator type motor may have its speed diminished within certain limits by the use of ohmic resistance or by employing a compensator. By the latter method, a speed change may be secured, which is adjustable and unvarying, irrespective of change of load within the capacity of the motor. Within certain horse-power limitations and where a variation of 50 per cent. from synchronous speed will prove satisfactory, practically the same operating results may be secured as by the use of a direct-current motor with shunt field control. (1907.)

Self-Starting Single-Phase Motors.—Both the split-phase and repulsion starting type of single-phase motors are reliable. The repulsion type of motor will no doubt start under heavier loads than the split-phase type. Up to the present time, the repulsion type of motor seems to be the most popular seller. (1908.)

Reliability.—Generally speaking, a three-phase motor will not give better service to a consumer than a single-phase motor. A repulsion type single-phase motor is equipped with a commutator, used in starting the motor, and such a device may possibly get out of order quicker than any part of a three-phase motor; the only friction parts of which are two bearings.

The cost of maintenance of induction motors, generally speaking, is considerably less than d-c. motors. There is considerable difference of opinion as to exactly what this difference is varying from 25 to 75 per cent. less in favor of the induction motor. In general it may be stated that where proper care is taken of the motor practically the only cost of maintenance in induction motors is the renewal of bearings. With induction motors having resistance in their armature for starting, the renewal of contact pieces would somewhat increase the cost of maintenance. With a direct-current motor the brushes and commutator are in constant use, and are subject to considerable depreciation. The brushes and commutator have a tendency to collect dirt and transmit troubles to the armature windings. (1904.) The average single-phase motor is no more expensive to maintain than the average direct-current motor. This depends somewhat upon the type of motor used, but the latter developments in single-phase motors have been such that it is safe to say there is very little to choose between these types of motors in the matter of maintenance (1905.)

The best method of starting induction motors by means of starting compensator and protected by fuses is to use a three-pole single-throw fuse extension front connected switch with studs brought through the slate from the hinge blocks. The method of connecting this switch is to bring the energy to the clips of the switch, the starting leads of a compensator being carried to the rear connected studs of the switch and the running leads to the bottom contact block of the fuses. By the use of this switch the motor is started from the service fuses and when it has attained full speed by throwing the compensator to the running position, the motor receives its energy from a set of running fuses rated at 25 per cent. in excess of the normal rated capacity of the motor. This method allows the motor to start on fuses large enough to care for the starting current and run on a fuse of proper size to protect the motor from an abnormal rush of current. In case no compensator is used, a double-throw switch that will allow the motor to be started and attain full speed through large fuses, and then thrown to the running position, with fuses protecting the motor, will accomplish the result.

Where three-phase motors are operated continuously without an attendant, large starting fuses can be installed by the use of a throw-over switch, with fuse capacity on the running side of the switch sufficient to carry the motor at normal load. The blowing of one fuse would then result in throwing an excess amount of current on the remaining two, which would open either one or both and shut the motor down. (1904.)

Comparing the efficiency of a multi-speed induction motor employing resistance in rotor versus a direct-current motor with resistance in the armature circuit, the efficiency of either system will be comparatively the same, assuming equally good a-c. or d-c. design. The losses by resistance in a-c. rotor or d-c. armature are principally I^2R and practically the same loss will occur whether the I^2R loss is occasioned by the use of resistance in series with a d-c. armature or with the phases or an a-c. rotor. In comparing the efficiency of an induction motor using resistance in rotor versus a direct-current motor with resistance in the shunt field, the efficiency of the latter combination will be very much higher since the d-c. armature remains under all conditions of load directly connected across the source of supply and the losses will simply be I^2R in the field regulating rheostats plus such comparatively negligible losses as are produced by magnetic distortions under weakened field, etc.

An efficient method of control is found in a well known commercial type of direct-current motor where 40 per cent. variation in working speed is obtained by the use of resistors in the field circuit, the "make-ready" or starting speeds being obtained by armature resistance. The point may be illustrated by reference to the following comparative test of figures on an a-c. or d-c. motor each rated 7½ hp. The a-c. unit makes use of rotor resistance for speed variations from "make-ready" to minimum and maximum working speeds. The d-c. motor uses field resistance from 100 per cent. to 60 per cent. speed and from this point down through the range of requisite "make-ready" speeds rheostatic control in armature circuit is employed.

Speed variation	Arm control	Field control
100 per cent. speed	85	83
90 per cent. speed	77	83
80 per cent. speed	69	82.5
70 per cent. speed	60	81.5
60 per cent. speed	50	80.0

Speed variation may also be obtained with induction motors by the use of resistance in primary, or by employing a sliding or high resistance low resistance rotor, which consists essentially of a combination of two squirrel cage rotors, one having high and the other low resistance. In this arrangement the rotor may be mechanically shifted in relation to the field, thereby allowing a certain range of speed variation. Control, either by resistance or reactance inserted in primary of the motor circuit may be employed where the service corresponds to that of a fan load, in other words, where the torque and load curves are identical. Where resistance in primary is used and the secondary resistance of rotor is made comparatively high a motor operating under these conditions has somewhat similar characteristics to those of a series d-c. motor, as previously discussed. (1909.)

Fusing Motor Leads.—It is considered good engineering to design the mains for the total capacity of all motors connected to the installing fuses of such capacity as to protect the mains from dangerous rises in temperature: the tap circuits for individual motors to have a capacity of 50 per cent. in excess of the normal rating of the motor; fuses protecting these tap circuits to be of sufficient size to protect the wires from a dangerous rise in temperature, and the fuses protecting the motor to have a capacity of 25 per cent. in excess of the normal rating of the motor. (1905.)

Throwing of Oil.—If the bearing is properly designed, and there is not too much oil placed in same, it should not throw oil. In one case an explanation of the cause has seemed to be that it is due to air currents which draw the oil out as it is passing the openings while it is in a finely divided state as thrown from the oil grooves of the shaft. With enclosed type of motors it is often possible to use on the outside a cap packed with felt which rubs on the shaft and removes all oil which tends to creep along the shaft, but this usually transfers the difficulty to the inside, fills up the machine with oil and in a short time causes trouble. Trouble of this kind may be due to a too light grade of oil or too small rings. (1905.)

Large synchronous motor units may be switched into the supply mains by having the motor wound with two windings which can be connected in series for starting and in parallel for running after the machine has attained, synchronous speed. This would reduce the starting current, but the additional expense for the winding and the complicated switching required would more than off-set the cost of the starting compensator. (1905.)

The best method of starting induction motors without the use of compensator is to use the half taps of the service transformer, thereby getting half pressure for starting, using a double-throw switch for throwing the motor from the starting leads to the running leads. (1906.)

Reversing Single-Phase Motors.—Motors of the Wagner type can be wound for reversing by means of a switch, and any one of them can have its direction of rotation reversed by shifting the brushes. An ordinary split-phase induction motor could be reversed while running. It can, however, be easily connected to start and operate in whichever direction is desired by reversing the connections of the phases or starting coil. (Note—This answer will not apply to all forms of single-phase motors, but only to those which have their main and starting coils in shunt with each other, in which case the change in connection for reversing is similar to the change in an ordinary direct-current shunt motor. (1907.)

Fuse Rating.—If the load is started frequently, a d-c. motor should be fused at 20 per cent. in excess of the full load rating of the motor. Where the motor is in continuous service, it should be fused about 10 per cent. above the normal rating of the motor. Single-phase motors of the Wagner type should be fused for about 50 per cent. above the full load rating of the motor. Owing to the excessive rush of current in the starting of the polyphase motor under load, throw-over switches should be used in starting. On the starting side of the switch the capacity of the fuses should be large enough to take care of the starting current, while on the running side the switch should be equipped with fuses not to exceed 25 per cent. in excess of the normal rating of the motor. (1907.)

Single-phase a-c. commutator type motors with repulsion characteristics have been used for a large variety of service requiring variable speed. A motor of this type has characteristics similar to those of d-c. series wound motor, and is applicable, therefore, to the driving of such apparatus as fans, blowers, printing presses, and such other apparatus, as requires certain fixed speeds at certain fixed loads. This speed regulation is more economically obtained by the use of an auto-transformer, as under these conditions, as the speed is decreased, lower voltage is applied to the motor, and, therefore, its constant losses decrease. With a resistance type of controller, a large part of the total energy is used up in heat in controller resistance. The auto transformer method of control has not to our knowledge, been used for controlling single-phase elevators on account of the high cost of controlling apparatus of this type for the service in question and the large number of breaks which would be necessary in going from step to step of the auto transformer, unless some form of shunt is used across the various controller steps. This would, however, make the controlling apparatus exceedingly expensive.

Two Induction Motors on Same Shaft.—It is not considered good practice to drive one shaft by two three-phase motors. It can be done but if the speed of one motor drops only 3 per cent. at full load while that of the other drops 5 per cent. the motor on 3 per cent. speed regulation will be overloaded before the other carries its full load. For a temporary job you can jockey two motors having different slip into approximately dividing the load by running the belt of one slacker than the other or by slightly changing the ratio between the driving and the driven pulleys. (1909.)

EFFECT OF MOTOR OPERATIONS ON OTHER FORMS OF SERVICE.

Single-phase motors are being operated on lighting circuits with good success in sizes from ½ to 20 hp. where separate transformers are installed for motors and lamps and where the use of the motor is not intermittent as in elevator service. The size of the single-phase motor is limited by the length of the feeder, size of the generator and manner of operation.

With the motor operated continuously, single-phase motors have been used with good success on medium sized plants up to 35 hp. where the length of the circuit does not exceed two miles, and the size of the generator is 150 kw. or more. Generally speaking, it is not desirable to go above 15 or 20 hp. On intermittent service, such as elevators, where the motor is started frequently, it is difficult to prevent interference with the lighting service if motors larger than 7½ hp. are used. Of course, where the distributing system is heavy enough in concentrated districts, this type of motor could be operated very satisfactorily, even using sizes larger than 35 hp. The Missouri Edison Electric Co. are operating on lighting circuits a connected load of over 1,000 hp. in alternating-current single-phase 60-cycle motors. The motors run as high as 30 hp. rating, and results have been satisfactory. It was found necessary to limit the starting current by starting the large motors on one-half voltage or on a rheostat. In the underground district motors are connected direct to a secondary service. (1902.)

The three-phase elevator motor has been developed to such a point in the past few years that there is no question about the feasibility of operating such a device from an alternating-current system having a line of reasonable current carrying capacity. (1904.)

Elevator Motors.—Up to within a comparatively short time the effect of elevator motors on a small system has been troublesome. With the very great development, however, in this type of apparatus, it now seems possible to operate a-c. elevators on lines of small current carrying capacity without serious trouble. Of course, the better way is to run separate power circuits for such a load. (1905.)

The inside wiring for polyphase motors should be large enough to prevent excessive drop in voltage; otherwise the motor will not have sufficient torque to pick up its load. It is not necessary that the wiring be large enough in all cases to prevent the starting current from exceeding the safe current carrying capacity of the wire as specified in the Underwriters' rules, as the starting current lasts only a few seconds and there is no danger of overheating the conductors on this account. The Underwriters' rules require that the wire be large enough to carry 50 per cent. more than the rated full load of the motor, and this is ample to take care of the starting current. Wherever possible, circuit breakers should be installed on such an installation. (1906.)

Effect of E.m.f. Drop in Induction Motors.—It would be bad practice to run induction motors at 15 per cent. below their rated pressure. The motors would not pull to exceed 75 per cent. of their normal rating. The torque of the induction motor varies as the square of the voltage, and if the motors are loaded anywhere near the point of maximum power-factor and efficiency the reduction in voltage will be disastrous. (1906.)

Welding transformers, on account of the intermittent character of the load, will interfere with lighting service if the line is long enough to cause more than 2 or 3 per cent. drop when the transformer is in use at its full load. If supplied by a generator of 100-kw. or less there may be 2 or 3 per cent. additional drop due to the generator regulation, which may cause a total drop of 4 or 5 per cent. and considerable interference with the lighting service. On power circuits the voltage fluctuation caused by welding would not cause serious trouble unless the generating apparatus were small. On large power systems there would be no more disturbance than caused by large motor installations being taken on and off the system. (1906.)

REFRIGERATION.

Power and Energy Consumption.—A 1-ton machine requires 2 tons 3½ hp., 3 tons 5 hp., 4 tons 6 hp., 5 tons 7½ hp., 6 tons 9 hp., 7 tons 10 hp., 8 tons 12 hp., 9 tons 13½ hp., 10 tons 15 hp., 15 tons 25 hp. In the latitude of Chicago the kw-hr. consumption per ton of ice is approximately 55, for refrigeration about one-half of this. (1904.)

Individually driven refrigeration machines are giving good satisfaction in apartment houses, drug stores, saloons, dairies, butcher shops, grocery stores, florist shops, etc. There are a number of machines made which are very satisfactory in their operation. The cost of operation of motors for the above class of business from central station service is proving very satisfactory to consumers, and the rapid growth in the development of this class of business in many large cities indicates that these devices can be recommended and pushed by central station companies with profit to them and to their customers. The load is very desirable from the fact that it uses the electricity for long hours per day, generally in the summer time when the load is most welcome. (1905.)

With ice at $6.00 per ton and electric energy at 5 cents per kw-hr., the motor-driven machine will save the consumer money. There are a steadily increasing number of machines, of small sizes, being placed on the market whose efficiency is constantly increasing, and it seems as if the time is at hand when such machines can be recommended by central station companies without fear of criticism. (1905.)

TESTING.

In a small community, where a company is attempting to build up a motor business, it is well to spend considerable time in inspecting the customers apparatus, testing it when necessary in order to show customers any waste that may exist. In a very large city this would obviously be impracticable owing to the large amount of business usually connected to a central station company's lines. The cost of making tests in such cases would be prohibitive. Special cases coming to the attention of the Commercial Department should be given attention, and where customers are making serious complaint as to the cost of operation from your service, it would be well to make tests to determine whether or not the apparatus is operating at the highest efficiency. A record of the more important motor installations should be kept by the company so that in cases of trouble reference could be made to this data for intelligent discussion. (1906.)

Electrically Driven Grain Elevators.—Companies in Minneapolis, Buffalo and Chicago have been successful in securing large grain elevators by making a careful analysis of their power requirements. A great many of the grain elevators in this country are equipped with the old-fashioned belt or rope drive, and any one familiar with the friction loss of such installations can appreciate the large saving in energy by the removal of all belts, ropes and shafting and the installation of individual motors. The removal of such transmission devices reduces the amount of energy required from one-third to one-half, which, in itself, is a first-class argument for motor drive. The installation of individual drive also greatly facilitates the handling and cleaning of grain. At times of a dull market grain elevators in many cities often shut-down for days at a time. Such elevators may be called upon at any moment to handle certain quantities of grain, and in order to do so must keep their plants in condition to start quickly. This is one good reason why central station service is economical for this class of business. On a quick market it is necessary to move the grain rapidly and continuously. In such cases these elevators are required to run night and day. If such is the case it is necessary to have a night shift, and such night shifts necessarily cost considerably more money. Grain elevators also require practically no steam for heating purposes, and this is another argument in favor of central station service. The longer hour use of the energy the lower the cost for handling a bushel of grain; this being still another argument for central station service. Induction motors are the ideal prime movers for grain elevators. Their installation reduces to the minimum the amount of room required for the machinery when service is supplied from the central station. A grain elevator operated with such motors is working under the most efficient conditions. (1907.)

MISCELLANEOUS.

The power required to drive a blower varies as the cube of the speed, therefore, if a fan requires 5 hp. to drive it 1,200 rev. per min., it will require x hp. to drive it at 1,800 rev. per min., thus:

$$5 : x :: (1{,}200)^3 : (1{,}800)^3,$$

or the blower running at 1,800 rev. per min. would require approximately 16.8 hp.

Regenerative Effect.—A motor driven above synchronous speed by the counter-balanced elevator will act as a generator and will furnish a small part of the power consumed by the other motors.

Two-Phase Motors May be Operated from a Single-Phase Line.—Take two wires from the main switch of an incoming single-phase current to one pair of wires carrying one-phase to your two-phase motor. Take two more wires from the same part from your incoming single-phase switch and pass through the winding of a two-phase motor, and after leaving the motor carry them to a pair of wires carrying the second phase of your motors. Operation: Use a small single-phase motor belted to a two-phase motor, to get this motor up to speed. When up to speed close your incoming single-phase switch. The belt on the small single-phase motor may then be thrown off. The size of the two-phase motor used in splitting the phase is determined by the size of the installation. In this operation economy is a secondary consideration. (1909.)

In every day practice it would not be economy to operate as above indicated.

Two-Phase and Three-Phase Motors from Same Transformers.—In order to make the use of the three-phase and two-phase motors and the same set of transformers practicable, one transformer should be purchased with an 86.6 per cent. tap out of the secondary, in which case the transformers can be Scott-connected for balanced three-phase voltage; and by utilizing all the secondary winding of the one transformer, a balanced two-phase voltage can be obtained. (1909.)

LOAD FACTORS.

Horse-Power Year.—There is considerable difference of opinion as to what the term "horse-power year" means. In the large majority of cases it is accepted as being based on 24 hours per day and 365 days per year or 8,760 horsepower-hours. This would also be construed in such a case as being 100 per cent. load factor, and the use of power for less hours per year would make the load factor of the consumer something less than 100 per cent. (1907.)

The simplest definition of the term "load factor" is that it is the ratio of the average load to the maximum load. The period over which the average is taken on the monthly basis is 720 hours, or, on a yearly basis,

8,760 hours. In arriving at the monthly load factor in any particular installation the average kilowatt load is, therefore, obtained by dividing by 720 the total kilowatt-hours used in the month. The load factor may also be expressed as being the ratio of the actual number of kilowatt-hours used in any one month to the maximum possible use; that is, the actual kilowatt-hour consumption divided by the product of the maximum demand in kilowatts by 720. It is obvious that this latter ratio will have the same numerical value as the ratio of the average load to the maximum load. These values are shown in the following:
expression:

$$\text{Load factor on 30-day basis} = \frac{\text{Average load over 720 hours}}{\text{Maximum load}} = \frac{\text{Actual kilowatt hours}}{\text{Maximum kilowatts} \times 720.}$$

Throughout the country to-day different engineers and commercial men have many different definitions of the term load factor. The American Institute of Electrical Engineers' Standardization Rules say "load factor is the ratio of the average load to the maximum load." This term ought to be more closely defined. The term maximum load factor might mean the ratio of average kilowatts to maximum kilowatts. The term capacity load factor might mean the ratio of average load to capacity of the plant; the connected load factor the ratio of average kilowatts delivered to connected kilowatts. It might also be stated that there is some misunderstanding as to the term maximum demand—whether the load factor is figured on momentary, one minute, fifteen minute or one hour peaks; whether the absolute or momentary maximum or the average maximum be used in determining the load factor. By applying these different conditions you might have many different kinds of load factors; such as momentary or absolute maximum load factor; average maximum load factor, to be made up of the average of momentary peak load; five minute load factors; half hour maximum load factors.

It is no doubt inevitable that different companies will put a different construction on the term load factor. However, in the writer's opinion, the first paragraphs of this discussion cover the proper explanation of the term. For business and practical reasons it may be necessary instead of using the absolute maximum demand of the customer to modify this by lengthening the time of the reading of this maximum. On water-power plants five minutes may be a sufficient length of time; on steam plants this time may be lengthened to as high as one hour, depending on the conditions. On ordinary commercial business I do not think this period of time should exceed half an hour, because if it does the customer using a large quantity of light could take undue advantage of the central station company.

As stated before, for commercial reasons it may be unwise to adopt the absolute momentary maximum in making a contract, because any isolated steam plant is enabled to carry an overload of, say, 25 per cent. without undue strain on the apparatus, and the central station company should be in a position to meet this condition in drawing contracts.

Load Factor in Planing Mills.—A large and busy planing mill, operating 54 hours per week, would average the actual maximum demand between six and seven hours per day or a load factor of from 25 per cent to 30 per cent. This load factor would be based on 24 hours per day for 30 days, or in other words in case the actual maximum was 200 kw., the consumption of energy on a 25 per cent. load factor would be the use of 36,000, kw-hr. per month. In compiling information on 64 woodworking establishments having group drive installations, it was found that the percentage of average load to connected motor load was 33-⅓ per cent. The total installation of motors for these 64 establishments was 2,532 hp. or an average of 39½ hp. connected for each customer. The number of motors installed was 234, and the total kw-hr. per month was 147,620. These figures, however, are an average, and the individual cases varied widely. In smaller establishments the tendency is towards a lower load factor than in the larger and busier establishments. (1909.)

SECTION XX.

Meters.

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ACCURACY.

Accuracy After Period of Service.—The opinion is expressed by the members that after meters have been in service for a year the following percentage of all the meters tested will be within 5 per cent. of correct: Direct-current meters 75 to 85 per cent. at full load and 40 to 50 per cent. at light load; alternating-current meters 95 to 98 per cent. at full load and 80 to 90 per cent. at light load.

Allowable Limits in Calibrating.—The allowable accuracy limits in calibrating are 1 per cent. plus or minus at full load and 1 per cent. fast to 2 per cent. slow at light load. These are the limits at the time of the test and under the testing conditions.

NOTE. It is, of course, not intended that these figures represent the percentage from absolute accuracy. Errors of observation and errors of the testing apparatus always exist and should be added algebraically to these limits in order to obtain the real variation from absolute accuracy.

Determination of Accuracy.—If the accuracy of a meter at several points is determined, there are a number of methods given for figuring the combined accuracy, as follows:—

1. Find the accuracy at the maximum load that the consumer uses, the accuracy at the lightest load, and the accuracy at the average load, then average the three.

2. Find the accuracy at full load, the accuracy at one-tenth load and the accuracy at a normal load, which is specified according to the nature of the installation; multiply the normal load accuracy by three, add to this the accuracy at full load and the accuracy at light load, then divide by five. This method is used by the Public Service Commission in the First District of New York.

3. Plot a curve so as to show the accuracy of the meter at every point, divide the total kw-hr. consumption by the estimated hours use; the result will be the average kw. consumption. From the curve find the accuracv corresponding with this consumption.

Normal Curve.—The normal curve of a meter should not depart from 100 per cent. accuracy beyond the limits following:

Direct-current meters should run at 2 per cent. of rated load; should be within plus or minus 7½ per cent. at 5 per cent. of load; should be within plus or minus 2 per cent. from 10 per cent. of load to 50 per cent. over-load.

Alternating-current meters should run at 2 per cent. of rated load; should be within plus or minus 3 per cent. at 5 per cent. of load; should be within plus or minus 2 per cent. from 10 per cent. of load to full load, and should be within plus or minus 3 per cent at 50 per cent. over-load.

If a meter is correct at light load, it will not necessarily be correct at one-half and full load, within the limits given above. The full load accuracy is controlled mainly by permanent magnets and the light load more especially by the friction compensator. Both adjustments may get out of order and have opposite effects so that, for example, the meter may be correct at light load and fast at full load.

CLERICAL RECORDS AND FORMS.

Records of Individual Meters.—Many companies consider it desirable to keep a complete card index record of each meter from the date of its purchase until it is finally discarded. The meters should be numbered serially, and the cards filed according to these numbers. Upon the card should be entered the serial number; the manufacturer's number; name, type, form and catalogue number of the meter, rating in amperes, volts, and wire; various constants, the date purchased or received, and any other information that may be of value. The card should also give the name and address of the consumer, purpose for which the building is occupied, location of the meter, load on the meter, information regarding the circuit, as a-c. or d-c., voltage, wire, etc., date the meter was installed and removed, information regarding tests, as reason for test, accuracy of the meter as found and left, adjustments necessary, and any other information which the company may desire to keep. (See 1909 Meter Committee Report.)

Meter Record—Meters in Service and in Stock.—Many companies keep a record of the meters in service and in stock on two card indexes—First, an alphabetical index upon which are entered the name and address of the consumer and the serial number of the meters installed in his premises: Second, a numerical index in which a separate card is filled out for each meter, giving serial and manufacturer's numbers of the meter, name, form and type of the meter, its rating in amperes and volts, the constants and other information of this description. Upon this card is also entered the name and address of the consumer in whose premises the meter is installed, the date of the installation and removal, and similar information. Cards for meters on order, meters in service and for meters in stock, are filed in separate compartments. By the use of these indexes, it is possible to determine at any time the number of meters in each division.

Also, given the name of the consumer, the meters in his premises can be determined, and, given the number of a meter, it is easily ascertained in whose premises it is installed.

The cards in the alphabetical index are filed alphabetically according to the name of the consumer, and those in the numerical index according to the serial number of the meters. A numerical card is filled out at once for each meter when received. (See 1909 Meter Committee Report.)

COMPLAINTS.

Correct Meters—How to Satisfy Consumers in this Respect.—

1. Teach the consumer how to read the meter and calculate his bill; explain to him what each division of the fastest moving dial means in hours burning of a lamp of certain wattage, and show him how to make a trial test on his meter with a certain number of lamps burning for a certain period. With this information the consumer himself can roughly check his meter at any time.

2. In explaining the operation of a meter to a consumer, turn on one or more lamps and show him the disk speed increases or decreases in proportion to the lamps burning. Often good results may be obtained by allowing a consumer to turn on an unknown number of lamps and from the disk speed tell him how many lamps are burning.

3. Explain to the consumer the principle of the meter, clearly point out that there is no mystery or secrecy about it. Let him thoroughly under-

stand that jewel wear or commutator wear, etc., will tend to make the meter run slower.

4. If the consumer knows enough about electricity, test the meter in his presence and allow him to see all the operations and follow the calculations.

5. As a last resort, have the meter tested or test verified, by a reliable and impartial outside expert.

. As a means of settling complaints, a curve drawing instrument, which will show the time the consumer was using energy, and how much, has proven valuable.

Where the consumer felt that his bill was too high, good results have been obtained and the consumer satisfied, by sending a competent man to instruct him regarding the economical use of his light and to advise regarding the candle-power of lamps to use to secure proper illumination. He should also suggest the rearranging of wiring and changes in power installations to reduce the losses and to otherwise effect economy.

One opinion expressed is that if the consumer feels his bill is too high, the company should allow a rebate, not on the basis of incorrect meters, but on the policy of "give and take" to insure a satisfied consumer. (A. J. Campbell.)

Creeping Meters—Allowing Rebate.—If the meter is creeping the amount of registration due to creep should be determined by test and rebate should be made to the consumer accordingly.

Treatment of Complaints.—The office force should listen with the utmost courtesy and attention to all complaints; should ascertain how much energy is used and how long.

If a reasonable explanation cannot then be found which will satisfy the consumer, the meter should be tested by the Meter Department and an examination and test made on the installation for grounds, leaks, etc. The commercial office should discuss the matter with the consumer openly; should show him all data and conceal nothing. (See Report of the Meter Committee, 1909.)

If a meter is fast beyond the limits of commercial accuracy, it is customary to rebate the entire amount fast, and not merely the excess over the established commercial limits.

CONSTANTS AND FORMULAS.

Determining the Correctness of Constants.—To determine if the constants and the registering train are correct, one method is to maintain a steady known load on the meter for several hours, carefully noting the exact time, and compare with the watt-hours registered. The two, of course, should agree.

A second and more accurate method is to count the teeth in the registering train and thus determine the ratio between the revolutions of the moving element and the revolutions of the first dial hand. (See Report of Meter Committee, 1909.)

COSTS AND MAINTENANCE.

Cost of Maintenance of Meters.—Data on the annual cost of the maintenance of meters is meagre. One company states that this cost for direct-current meters is $1.33 and for alternating-current meters $0.40. Another company states that direct-current meters cost $1.00 to $1.50, and alternating-current meters $0.50 to $0.75. Still another company states that for 3,000 meters the cost is $4,000 per year. The above presumably includes only the cost of testing and repairing.

Regarding the percentage of the total investment in meters which would be considered a reasonable meter department expenditure in a plant with about 1,000 meters, the estimates are from 5 per cent. to 10 per cent. One company with 900 meters of all kinds states 6½ per cent.

The data given is not clear and comparisons are of little value for the reason that the different companies do not distinctly state what items are included in meter expense.

DEMAND INDICATORS AND RECORDERS.

Demand Indicators—Time Limit.—The normal curve of the Wright demand indicator shows 95 per cent. registration in 4 to 5 minutes and full registration in 20 to 30 minutes, which is satisfactory for the majority of purposes. The opinion, however, seems to be that the 95 per cent. registration should occur after a longer period.

Demand Indicators—Reliability and Accuracy.—The Wright Demand Indicators are reliable and commercially accurate for direct-current loads and for alternating-current non-inductive loads. For alternating-current inductive loads, however, the opinion is general that these indicators can be used only with fair results because the power-factor of the circuit is an unknown variable. A fear is expressed by some that the reading would increase under a steady load because of a siphon action, but this is not borne out by practice. According to the opinions expressed, the indicators should not be exposed to excessive temperatures, such as a boiler room, as errors would result.

FINANCIAL.

Deposits, Reasons for and Where Required.—In general, if a consumer is a property holder, or if his credit is found to be satisfactory, no deposit is required; otherwise a deposit is required. Guarantees are seldom asked or accepted. Reasons given for deposits are, that as the company cannot collect until sometime subsequent to delivery, the deposit is a security for the payment of the bill. This is simply a sound business policy. Another reason given is, that the deposit is an estimated payment in advance for one month. The money deposited is practically always on interest, so the consumer loses nothing.

In general, the members do not require a deposit from a single consumer for each meter installed, it being the practice to base the amount upon an estimate of the total bill. If, however, a consumer requires separate meters for his own benefit, it is customary to charge him a rental varying from $3.00 to $6.00 per meter per year for each extra meter.

If electricity is supplied to independent premises under control of one consumer, it is customary to require a deposit for each location.

Insurance of Meters.—In general it is not the practice to insure meters in service, or to charge a consumer for damage to a meter resulting from fire. If, however, the damage is due to willful misuse or neglect on the part of the consumer, the company charges him for the damage.

One company insures its meters against fire, but no results are given. (R. J. Clark.)

One company endeavored to oblige consumers to cover the meters by insurance, but after considerable trouble, this practice was dropped. (F. C. Sargent.)

Some companies insure meters in stock.

Minimum Charge on Prepayment Meters.—Where prepayment meters are used, two member companies require a minimum charge and if electricity to this amount is not used in any month, the collector is required to collect the balance of money due.

One company omits the minimum charge preferring to let the consumer benefit.

One company charges a trifle higher rate per kw-hr. and omits the minimum charge.

GENERAL.

Slow Meters—Charging for Test.—It is the unanimous opinion that if a consumer requests a test and the meter is found slow, that no charge should be made for the test. It is the company's duty to keep its meters accurate at all times, therefore, a charge for testing work done for this purpose by the company itself should never be made.

Tests of Meters—Information to Give Consumers.—It is the general opinion that the meter tester should give no information to the consumer; he should politely refer his questioner to the office. The reason given should be that the information to be official should come from the office and the meter man has no official authority. An exception, of course, should be made where a special test has been arranged with the consumer in his presence, in which case the consumer should have access to all information at the time of the test.

One member suggests that the meterman give the consumer the information, if the latter desires it, and write on his test card the information which he has given.

Changing Type of Meter at Consumer's Request.—If a consumer requests a different type of meter from the standards of the company to be installed in his premises, it is the general opinion that this should be done without charge, provided the meter which the consumer requests is equally reliable as the standard meter. In all cases, however, an attempt should be made to satisfy the consumer that the standard meter is as good as any meter on the market.

A minority opinion is expressed that if the company is using the best types of meter it can obtain, the above change should not be made, as it might be construed as an admission that there is a better meter to be had.

Printed Booklets on Electric Meters.—It is the unanimous opinion that printed matter or booklets explaining electric meters could be distributed to advantage among the consumers; the reasons given are that the more the consumer knows about meters, the less mystery surrounds them, therefore there is less chance for complaints. The information given, however, should not be too technical, as it would be liable to confuse the consumer and do more harm than good. The opinion is expressed by some that such printed matter should be furnished by a manufacturing or some advertising company.

Free Installation of Watt Hour Meters.—It is the general opinion that central stations should own and furnish free the watt-hour meters used on the consumer's premises. It is more to the advantage of the central station to have watt-hour meters installed, therefore, they should own them. This is the only way that the central station can be sure that the watt-hour meters used are the best obtainable. The general opinion is usually modified by stating that a minimum or similar charge should be made where such services are rendered.

One member reports that he attempted to collect rent for watt-hour meters, but so much opposition was encountered that the practice was abandoned.

Reading Meters—Operating Versus Commercial Department.—The general opinion is that it is more advantageous to have the meters read by the meter department than by the commercial department of a company. This puts the entire handling of the meters under one head, and means that all men entering the consumer's premises in any way connected with meters are under one authority. It insures better attention to the meters. In many cases, the determining factor as to when to test the meter is based on the meter readings, and it is therefore well to have these readings in the meter department.

A minority opinion is expressed that if the meters were all read by the meter department at the end of the month it would cripple its work. To avoid this condition, continuous reading is suggested.

Reading Meters—Elimination of Complaints.—The suggestion is made that a duplicate reading be left with the consumer as a means of eliminating complaints, but the general opinion seems to be that while this might be of slight advantage, it is not of sufficient advantage, to warrant the expense.

Prepayment Meters.—Assuming prepayment meters to be satisfactory in all respects, it is the opinion of many companies that they should be freely installed for all consumers desiring them.

INSTALLATION.

Meter Location.—The general requirements are that the location shall be dry, free from dust and vibration, not in close proximity to gas pipes, water pipes or heaters, nor subjected to extremes of temperature. The location should also admit of the installation of the meter on a firm support, accessible at all times. The meter should be installed some 5 or 6 ft. from the floor with sufficient clear space around it to admit of easy inspection.

Many companies require meters to be installed only in cellars or on the first floors of buildings, as the operations of testing and reading cause less trouble both to company's employees and to the consumer.

Wires from an overhead circuit are run in a suitable conduit to the cellar or first floor. (See 1909 Meter Report.)

Size of Meter to Install.—No rigid rule can be advanced to cover all conditions. In residences it is customary to install a meter having a rating of from 25 per cent. to 50 per cent. of the connected load. In small stores, saloons and the like, where all the lamps connected are burned at one time, a meter should be installed having a rating about equal to the connected load. Under certain conditions, as when some of the lamps are lighted during the entire night, a smaller meter may be found desirable. For signs and other sources of constant load, a meter having a rating equal to the load should be installed, and this also applies to motor circuits in general. Some companies, however, prefer to install a meter of larger current capacity on motor loads depending on the starting current and the duty of the motor. For theatres, churches, and buildings requiring similar services, it is generally impossible to install a single meter sufficiently large size to measure the maximum load and effectively register the minimum load. In such cases the circuits should be divided and several meters installed. (See Meter Report, 1909.)

Size of Fuses.—The fuses on the service side of the meter should have a rating equal to the connected load, irrespective of the rating of the meter, as most meters will stand an overload of 100 per cent. for a short time. In some instances, however, it is customary to use a smaller meter than the connected load and place fuses to protect the meter, in such cases informing the consumer to notify the company in the event of possible abnormal use of energy, in order that the entire installation may be gone over, fuses increased, and other precautions taken to prevent any trouble or interruption of service occurring when the abnormal amount of energy is being used.

It is sometimes advisable for the company to have a competent trouble man on the consumer's premises during special events and when there is to be an abnormal use of the energy. He should have an ample supply of fuses of the proper rating to replace any which might blow.

Lightning Protection.—To protect direct-current meters from lightning when connected to a three-wire, overhead net-work, with grounded neutral, it has been found advisable to place a sufficient number of lightning arresters on the overhead system, and it is particularly necessary that arresters should be placed at the end of each branch running any distance from the main net-work. If lightning shows partiality for a meter in any particular location, the meter should be protected by choke coils on the service wires, and lightning arrester should be connected to each of the outside wires of the three-wire system. Choke coils for this purpose can be made of weatherproof wire of the same size as the service wire. Coils 12-in. internal diameter, 5 layers and 5 wires in each layer, making a total of 25 turns have proven effective.

For the protection of meters installed on 500-volt direct-current, two-wire, power circuits, reactive coils on both lines placed between the arresters and the meters have proved effective.

Number of Meters Installed in One Building.—In general companies install a sufficient number of meters to efficiently measure the energy used; the number depending upon the conditions. (See 1909 Meter Report.)

Location of Meter Loops by Contractors.—The most effective way for a lighting company to secure the proper location of meter loops is to issue to each wiring contractor a set of rules and regulations and compel him to live up to them. Many companies refuse to connect their meters unless the wiring contractor has fully complied with their rules.

METER DEPARTMENT.

Investigation by Tester—Counting Connected Load.—The tester should examine the meter and the installation to see that the wires are in proper condition and that the seals are intact. Any defect may have caused an error in the registration of the meter and may account for the difference between previous and subsequent bills. It is also desirable to take the statement of the meter.

Some of the smaller companies require the tester to count the connected load, while most of the larger companies do not. The counting of the load does not usually require a man of the same caliber as does the testing of the meter.

In complaint investigations it is necessary for the tester to make a thorough investigation and the counting of the load is desirable. (See 1909 Meter Report.)

Advisability of Small Company Employing Experienced Meter Tester.—It is advisable for a company to employ an experienced meter man to take entire charge of all meter work. (See 1909 Meter Report.)

METERING.

Use of Multipliers.—In general, if a resistance is used as a multiplier in series with an indicating instrument, the reading on the instrument must be multiplied by a factor which is equal to the total resistance of the instrument plus that of the multiplier divided by the resistance of the instrument only. Ordinarily a multiplier will be arranged to have a resistance exactly equal to the resistance of the instrument with which it is to be used, in which case the multiplier is two.

One member asks if he may use a 150-volt Weston indicating wattmeter having a Y box for a 220-volt delta system, for measuring the input to a three-phase, four-wire, 440-volt meter. Of course the instrument with the Y box cannot be used in the usual manner since the voltage of the motor is too high. Since in the ordinary Y box each leg of the Y has a resistance equal to that of the instrument, one or both legs may be connected in series with the instrument as a multiplier. If one leg is used, the reading of the instrument should be multiplied by two; if both legs are in series, the reading should be multiplied by 3.

The use of non-inductive resistance in series with induction meters as a multiplier will produce incorrect readings and should never be used. A multiplier could be made by using a reactance of the proper value, but this is impracticable and it is better in this case to use a potential transformer.

Measurements of Power-Factor.—For determining the power-factor on a single-phase circuit, it is necessary to measure the wattage, amperage and voltage, the power-factor will then be equal to the watts divided by the volts times the amperes.

In a polyphase circuit, unless the circuit is exactly balanced, the power-factor on the different phases will be different, so that the circuit will have as many power-factors as phases.

To determine the power-factor of a two-phase circuit, measure each phase separately, as if it were a single-phase circuit.

To determine the power-factor of a three-phase circuit, which is unbalanced, the power-factor of each branch from the line to the neutral should be measured separately as if it were a single-phase circuit. If a three-phase circuit is balanced, the power-factor can be obtained by the use of two wattmeters connected in the usual way and the power-factor will be found by the following formula:

$$PF = \frac{W_1 + W_2}{2\sqrt{W_1^2 - W_1 W_2 + W_2^2}}$$

Where W_1 equals the reading of one wattmeter and W_2 the reading of the other wattmeter.

Ampere-Hour Meters.—It is the unanimous opinion of the members answering that ampere-hour meters should never be used to measure the energy supplied to a consumer. On direct-current circuits, ampere-hour meters do not take care of voltage variations, and on alternating-current circuits they not only neglect voltage variations, but also have large errors introduced when used on inductive loads.

Flat Rates.—It is almost the unanimous opinion that meters are preferable to flat rates, even if the amount of current is limited on the flat rate system by an automatic controller.

One member expressed the opinion that in all places having less than five lamps, a flat rate charge should be made, and for all places having more than five lamps, a meter be used. (F. B. Sharp.) For the opinions of other members on flat rates, see the report of the Meter Committee, 1909.

Use of Three-Wire Meters.—The usual three-wire meter is arranged so that the current in one of the outside wires passes through one current coil and the current in the other outside wire passes through the other current coil, both these coils being arranged to act upon the armature which is energized by the potential across the two outside wires or in some cases across one side of the three-wire circuit. This method of metering will give correct results for all values of unbalanced current, provided the voltage is balanced. If the voltage is not balanced, the meter will not register the true power. For all ordinary commercial circuits, the voltages are sufficiently balanced so that this method of metering is commercially accurate.

A three-wire meter should never be used to measure a polyphase circuit, as it will give incorrect results.

A 220-volt, two-wire meter should not be used in place of a three-wire meter. While a two-wire meter will give correct results, provided the circuit is at all times perfectly balanced with reference to the current, yet this condition exists so seldom in practice that the method should not be used.

Polyphase Meters vs. Single-Phase Meters.—It is the general opinion of the members that a polyphase meter is preferable to two single-phase meters for measuring either two-phase or three-phase energy. As far as accuracy is concerned, the polyphase meter is two single-phase meters contained in one case, therefore, the accuracy is practically the same as would be obtained by two meters. The advantage of a polyphase meter is that the reading is on one dial, thus simplifying reading and billing. The main advantage of two single-phase meters is that it is not possible for one meter to stop, due to potential troubles, without detection.

Arc Circuits.—It is the usual practice by the members to obtain the energy in a series arc circuit by multiplying the hours burned by the number of lamps and by the average energy per lamp. The result will be reasonably correct, as the energy per lamp is a matter of adjustment. This energy should be checked, however, about once a year.

Balanced Three-Phase Meters.—A balanced three-phase meter, as its name implies, will measure the energy correctly only when the circuit is absolutely balanced. As this condition seldom exists in practice, it is the opinion of the members, that polyphase meters or two single-phase meters are preferable to the balanced three-phase meters.

Demand Indicators.—Wright demand indicators measure the maximum demand in amperes and the readings are ordinarily reduced to watts by multiplying by an assumed average voltage. For finding the current demand of a three-phase system one demand indicator is ordinarily sufficient unless the circuit is badly unbalanced. For reducing the current demand so obtained to watts, however, multiply by the assumed voltage and also 1.73.

Measurement of Power in Two-Phase Circuits.—For measuring the power of a two-phase circuit, a polyphase meter or two single-phase meters may be used. If a three-wire system is employed, care should be taken to connect so that the common return does not pass through the current coil of either meter. When using two meters, they will read alike only when the circuit is exactly balanced. Ordinarily, slight differences of reading will be found.

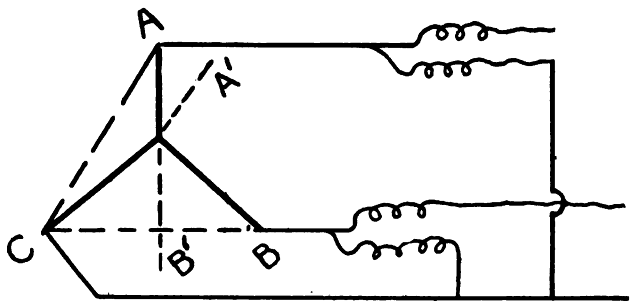
When measuring two-phase circuits by two meters, neither meter should ordinarily run backward, no matter what the power-factor of the circuit. Occasionally one of the two-phase meters may be found running backward, but this will be found only on extremely light loads and is due to inequalities in the motor windings.

Measurement of Power in Three-Phase Circuits.—For measuring the power in a three-phase circuit, a polyphase meter is preferable. Two single-phase meters, however, will measure the power correctly provided the current coils of the meters are connected independently in two of the three-phase wires, and the potential circuits of both meters connected to the third wire. In this case the algebraic sum of the dials of the two meters will give the total energy used. If the power-factor falls below 50 per cent., one of the meters will run backward. This is correct, however, and no attempt should be made to change it.

Balanced three-phase meters may be used provided the circuit is balanced, as has been explained elsewhere.

A single-phase meter may be used to measure a three-phase circuit, provided it is absolutely balanced by connecting the current coil in one leg and the potential coil from that same leg to the middle point of a potential transformer connected across the other two phases. This meter will measure one-half the total power of the circuit. This same connection will measure one-half the power of a three-phase Scott connection. It should be remembered, however, that this is correct only when a circuit is absolutely balanced.

In the two meter method of measuring power, one current coil is connected in phase A (See diagram) and operates with the potential from that phase to phase C. The current coil of the other meter should be



connected in phase B, and operates with the potential from that phase to phase C. As may be seen from the diagram, at non-inductive load there is a difference of 30 degrees in phase between the current in A of the potential A C with which it works. The same is true of current B and the potential B C with which it works.

If we assume lag to be in a clock-wise direction it will be seen from the diagram that as current A lags to A′ for example, it will become nearer in phase with its potential A C, whereas if current B lags, to B′ for example, it very quickly reaches a position where it is 90 degrees from its potential B C which is the condition of no power. If the current B lags still further, the meter through which it passes must of course run backward. The total power of a three-phase circuit, assuming balanced conditions, for the sake of simplicity, is $E\,I\,\sqrt{3}\,\mathrm{Cos}\,A$. In the two-meter method, the first meter will measure $E\,I\,\mathrm{Cos}\,(30^\circ - A)$ and the second meter will measure $E\,I\,\mathrm{Cos}\,(30^\circ + A)$. The sum of the two readings, which would equal the true power, therefore, is $E\,I\,\mathrm{Cos}\,(30^\circ - A) + E\,I\,\mathrm{Cos}\,(30^\circ + A) = E\,I\,(\mathrm{Cos}\,30^\circ\,\mathrm{Cos}\,A + \mathrm{Sin}\,30^\circ\,\mathrm{Sin}\,A + \mathrm{Cos}\,30^\circ\,\mathrm{Cos}\,A - \mathrm{Sin}\,30^\circ\,\mathrm{Sin}\,A) = 2\,E\,I\,\mathrm{Cos}\,30^\circ\,\mathrm{Cos}\,A = 2\,E\,I\,\tfrac{1}{2}\sqrt{3}\,\mathrm{Cos}\,A = E\,I\,\sqrt{3}\,\mathrm{Cos}\,A$.

Where E equals voltage between any two wires, I equals the current in any one wire and A represents the angle of lag.

Measuring Current from a D-C. Machine.—In measuring current from a d-c. machine, it makes no difference whether the ammeter is connected to the positive or negative lead wire. It is, of course, assumed that the ammeter will be connected into the circuit beyond the point where the equalizer wires connect.

METER OPERATION AND TROUBLES.

Effect of Polarity.—If a direct-current commutating meter is connected contrary to the polarity markings on the current leads, it is liable to show several per cent. error at 5 per cent. load. Direct-current meters, therefore, should be calibrated in position very soon after they are installed to eliminate any polarity errors or errors due to fixed external fields.

Creeping.—If a meter creeps on no load, it will register the creep at all loads; thus, when figuring the registration, a 24-hour period per day should be taken. However, in rebating for creeping, the accuracy of the meter throughout its range will materially affect the amount to be rebated and should be taken into consideration.

Vibration.—Vibration on a meter, either intermittent or continuous, will eventually cause a meter too run slow. This is due to the fact that the hammering or rubbing of the pivot over the jewel produced by the vibration, wears the jewel very rapidly. Relief may be had by using a diamond jewel. In addition, on commutating meters, vibration is very liable to cause sparking at the brushes, which quickly roughens and burns the commutator and causes the meter to run slow. The best practice in such cases is to move the meter to some solid support or to some place which is free from vibration. If this is impossible, relief may often be effected by mounting the meter board on large spiral springs made of No. 10 or 12 spring steel wire. If the meter is of the commutated type, the brushes should be given more tension to reduce the sparking.

Grounds.—When a two-wire installation is connected to a three-wire system having a grounded neutral, the service being connected to an outside wire and to the neutral, if an accidental ground occurs on the house side of the meter on the outside wire, the leakage current will be recorded by the meter. If, however, the accidental ground occurs on the service side of the meter, either on the wire connected with the neutral or on the outside wire, there will be no effect on the meter registration.

Short Circuits.—If a short circuit occurs on the meter, the tendency is to weaken the magnets and to make the meter run fast. No member has reported where the meter ran slow because a short circuit strengthened the magnets. If a meter is found running slow after a short circuit, it has probably been due, either to a number of turns in the current coil becoming short circuited or to the damaging of the armature, commutator, moving element or bearings.

Effect of Change in Frequency.—If the frequency of an alternating-current changes 10 per cent., it will cause very little error on induction type meters, especially on non-inductive loads. The errors on inductive loads at low power-factor would be more noticeable, but for all variation in frequency met in practice, combined with power-factors above 75 per cent., the errors thus produced are well within the commercial limits of accuracy.

Effect of Change in Voltage.—A 10 per cent. change in voltage on induction type meters will not cause errors of any magnitude.

Effect of Over-Loads.—All the modern meters will stand 100 per cent. over-load for a reasonably long period without burning out. It is not the best practice to subject the meters to such over-loads, however, as they will run slow, especially induction type meters.

Commutating Meters—Used on Alternating-Current and Direct-Current Circuits.—Since the generally used type of commutating meter has no iron in the field coils or armature, it will usually register very nearly the same on direct-current and on non-inductive alternating-current loads. A meter may, therefore, be calibrated on an alternating-current circuit and used on a direct-current circuit or vice versa. It is preferable to calibrate the meter on the current with which it is to be used, since large errors have been found under certain conditions.

The commutated type meter when used on alternating-current, inductive loads, will register in error, unless it is especially calibrated for inductive loads by placing a non-inductive resistance of proper value in shunt with the current coils.

Effect of Temperature Variations and Weather Conditions.—Changes in temperature over a wide range will not produce errors in the accuracy of meters beyond commercial limits. If the meters are installed out of doors, however, they are liable to become damp inside, which will cause the parts to rust, especially the pivot, and make the meter run slow. This effect has been noticed, even in some types of the so-called "hermetically sealed meters." It is, therefore, the general opinion of the members that it is better not to install meter out of doors.

Effect of Change in Power-Factor.—Modern induction meters, which are calibrated for inductive loads, will register correctly on any power-factor.

Armature Troubles.—The operation of a commutated type meter having a short circuit in the commutator, in comparison with a short circuit in the armature, will depend entirely upon the number of turns of the armature, which are cut out of circuit. If the number of turns cut out are nearly equal to the whole armature coil, the operation of the meter will be the same as a short circuit in the commutator, but if the number of turns cut out are few, the operation will be entirely different.

Cause and Remedy of Noisy Meters.—The humming or rattling in a meter may be due to three causes:

1.—Rattling in the top bearing.

2.—Hum from the laminations.

3.—Vibration of the moving element.

The first may be corrected by using a flexible top bearing; temporary relief can be obtained by using a little watch oil at the top bearing, but this should not be made a permanent practice.

The second may be corrected by tightening all screws holding the laminations.

The third, which is the least common trouble, can be changed conveniently, only by using a new moving element.

METERS AND METER PARTS.

Prepayment Meters—Advisability of Using.—There is no unanimity of opinion regarding the use of prepayment meters. Some companies seem to use them with success, while others are unable to obtain satisfactory results.

Some companies have used the prepayment meter as a means of collecting back bills; if the nominal rate were 10 cents per kw-hr., with the consent of the consumer, the meter would be set to register at a rate of 15 cents per kw-hr.—10 cents of which is to apply for the current being used, and 5 cents toward the back bills. When the back bills have been satisfied, the meter is reset to register at the 10 cents per kw-hr. rate.

Two-Rate Meters.—The two-rate meters which have been placed upon the market have not proved entirely satisfactory. Some companies prefer to install two independent meters and change from one to the other at different times by means of a time switch. One meter registering the current to be billed at one rate and the other meter registering the current to be billed at the other rate. This system seems to have proven more satisfactory then the two-rate meter.

Commutator Types vs. Induction Types.—Commutator meters should be considered as direct-current meters, and should not be used on alternating-current circuits except under special conditions.

The advantages claimed for the induction type of wattmeter on alternating-current circuits are:

The induction meter will generally maintain its accuracy for longer periods.

Brush and commutator troubles are eliminated.

Lighter moving element, resulting in a longer life of the jewel and pivot.

Generally occupies less space.

Shunt losses are less.

First cost generally less.

Maintenance cost generally less.

More accurate on inductive loads.

Permanently Sealed Meters.—It is generally conceded that the permanent sealing of meters by the manufacturers is an undesirable practice as some of the smaller companies are apt to use the fact that the meters are so sealed as an argument to convince the consumer of the meters' accuracy. Meters may be damaged in transportation, during erection, and in other ways, and all meters should therefore be tested in the company's shop before being placed in service; this requires that the seal of the meters be broken, and it is, therefore, preferable to purchase meters that are not permanently sealed.

Jewels—Repolishing.—Some companies maintain that sapphire jewels, when repolished, give as good results as new jewels, since the repolished jewel must be passed through the same process as when first manufactured. Other companies maintain that sapphire jewels should not be repolished.

Regarding diamond jewels, it is claimed that they cannot be repolished to advantage on account of the thinness of the stone and for the reason that the labor required, owing to the amount of stone to be removed, and the extreme hardness of the diamond, is greater than the labor necessary to make a new jewel.

Peephole in Cover.—There is a diversity of opinion regarding the advisability of providing a peephole in the cover in order to observe the revolutions of the moving element of the meter. Some companies strongly recommend the peephole, while others as strongly object to it and close the hole, provided in some makes of meters. Some companies equip their meters with glass covers thus permitting their consumers to see the entire workings of the meter.

Magnets, Flux Density.—It is not customary to determine quantitatively the flux density of the magnets used in meters. It is customary, however, to rate magnets according to the strength of some magnet arbitrarily used as a standard. Many of the larger companies purchase from the manufacturers, magnet testing machines for the purpose of determining the relative strength of magnets. A simple method is to use an ordinary meter and compare the effect of a magnet of unknown strength with the effect of one of known strength by alternately substituting them in the meter.

The deterioration of permanent magnets in meters consists of loss in magnetism. This loss may be gradual, or sometimes the magnets are affected by large overloads on the meters, and short-circuits, which under certain conditions will materially affect the magnets, depending upon their position and the strength of the current.

Make and Type of Meter to Purchase.—The chief requirements of an electric meter are essential accuracy and the ability to remain accurate. The detailed requirements of an electric meter will be found in the 1909 report of the Meter Committee.

Dials.—The diameter of meter dials should be as large as possible, consistent with the size of the meter. The hand or pointer, should be sharp pointed, and it is generally conceded that it should be plain and straight, without an arrow head.

Torque.—The chief advantage of a high torque meter is that it will operate under conditions that might stop a low torque meter.

The torque or driving force depends essentially upon the electrical design of the motor element of the meter. A high torque may be obtained at the expense of large losses in the current and potential circuits or by changes in the design of the moving element, such as increasing the cross section and conductivity of the rotor in induction meters or by increasing the number of turns of the armature in commutated type meters, etc.

In general it is desirable that the electrical losses of a meter should be low, the weight of the moving element small, the torque high and the friction small. It is evident, however, that these factors are so interdependent that they must not only be considered independently, but also collectively.

The weight of the moving element determines, to a large extent, the life of the jewel, therefore, it is desirable to obtain as light a moving element as possible, consistent with strength, torque and other features. In addition, the ratio of the torque to the weight of the moving element should be high.

METER SHOP.

Equipments.—The proper equipment for shop and laboratory work depends largely upon the geographical location and upon the number and types of meters installed. (See Report of Meter Committee for 1909.)

As each case should be considered separately, it is practically impossible to give a complete answer to this question. It is suggested that any companies desiring this information shall write directly to the Chairman of the Committee.

READING.

Time of Reading Meters.—It is the general opinion that it is better to read the meters continuously, that is, read and bill every day, than to read at a certain period of the month, usually the end of the month. The advantages in reading continuously are, that the meter readers are better trained, that the billing can be done by a smaller force, and that the receipts are continuous. The consumer should know that the reading is continuous, but should understand that his meter will be read on approximately the same day of each month. One suggestion made, is that the city be divided into districts and each district read at a certain part of each month; for example, if the city was divided into three districts, they could be read approximately at the 10th, 20th and 30th of each month.

Errors in Reading.—It is the general opinion that the errors in reading should be a very small fraction of a per cent., for example, one error in 1,000 readings. To eleminate errors, competent men thoroughly instructed in meter reading should be employed. All meters should read directly in kw-hr., without the use of constants other than 10, 100, etc., and, as far as possible, only one style of dial should be used. All meter readings should pass through the hands of a competent man whose duty it is to question any apparent increase or decrease in the consumption.

The opinion is expressed that the reader should have before him the readings for several months past, so that he can compare the present month with those past and immediately investigate the cause of any unusual change.

Number of Meters Read Per Day.—The number of meters it is possible to read per day varies according to the territory covered; the location of the meter, as in attic or cellar; the number of meters in the same premises, etc. The figures given are 100 minimum, 400 maximum with about 150 average.

Method of Reading.—In reading meters, it is the unanimous opinion that the reading routes should be laid out in such a manner that the reader may cover the route in the least possible time. This means that the routes should be laid out arbitrarily and not follow the feeders blindly. Every reader should have a binder with the reading sheets inside, arranged according to the order in which the meters may be read with the most ease; a loose leaf system is found most advantageous.

It is the general opinion that in reading meters, it is more accurate and quicker for the reader to transcribe the statement directly, rather than to mark the position of the hands on a facsimile of the meter dial to be transcribed later. Experience has shown that there are two chances of error in the latter method against one in the former.

One member company follows the practice of marking the position of the hands on a facsimile of the dials and having the same man also enter the readings on the same card; this is later transcribed and the two readings checked by another man.

Where difficulty is experienced in reading because the occupants are absent, these suggestions are made:

1.—That a time for reading be arranged with the consumer, either by letter, telephone or return postal card.

2.—That, in certain cases; a key be obtained and kept in the meter department, in which case the key should be numbered only, so that the consumer's name and address does not appear upon it. This will prevent trouble in case the key is lost.

3.—That the minimum charge be billed month by month against such meters until the reading can be obtained, and a balance made at that time.

4.—That a prepayment meter would be of advantage in such cases.

Elimination of Complaints.—The suggestion is made that a duplicate reading be left with the consumer as a means of eliminating complaints, but the general opinion seems to be that while this might be of slight advantage, the extra expense would not be warranted.

TAMPERING.

The most effective means of providing against tampering with the meter installation is to enclose all wires and cutouts from the service to the house cutout in iron pipe and iron boxes, and use meters of the latest design, which are generally supposed to be dust, moisture and tamper proof.

TESTING AND CALIBRATING.

Primary Meters—Testing Of.—In testing meters used with transformers, it is not necessary to test the transformers and meter as a unit, since testing without the transformers, as secondary meters will give accurate results. However, the transformers with the meters should be checked periodically to make sure that the ratio or ratios are correct.

Installation Test.—The opinion is equally divided as to whether it is better to test a meter soon after it is installed or not. It might be inferred from the answers, however, that if the meters are installed by apprentices or by a different department, other than the meter department, they should be tested as soon as possible after the installation. On the other hand, if the same department does the installing and testing, the meter need only be inspected; except commutated type meters which should be tested soon after installation in all cases.

Method of Testing Meters—Whether in Place or at the Station.—It is the general opinion that it is better to test the meters in place rather than remove them to the central station.

The advantages of testing in position are:—that they are then calibrated for the exact conditions under which they operate, there is no change in calibration due to transportation, the cost per test is less, and the testing in position tends to create more confidence in the mind of the consumer. Of course, if extensive repairs are needed, the meter should be removed to the shop.

Polyphase Meters—Testing on Inductive Load.—It is not correct to test a polyphase meter at non-inductive load and assume that the meter is correct. Polyphase meters, especially three-phase meters operate at inductive load much more frequently than non-inductive load; therefore, a test on low power-factor is essential. In making this test, each motor element should be excited separately, but both potential coils should be in service at all times.

Testing Loads.—In general, calibration at full load and light load is all that is necessary to insure accuracy of a meter throughout its range.

Period of Testing.—The general opinion is expressed that induction meters should be tested every twelve (12) months and commutator meters should be tested every six (6) months. (For induction meters, 68 per cent. of the answers specify a period of 12 months, 16 per cent. specify 6 months, 13 per cent. specify from 12 to 18 months, and 3 per cent. specify 2 years as the correct period. For the commutating meters, 56 per cent. of the answers specify 6 months, 24 per cent. specify 3 or 4 months, 18 per cent. specify 12 months, and 6 per cent. specify one month, as the correct period.)

The general opinion also is that meters of high current capacity and meters from which a large income is derived should be tested more often; in general, from one to three months. Meters subject to unfavorable conditions, such as vibration, dust, fumes, etc., should be tested often enough to insure accuracy. One company endeavors to test its meters when they have made approximately 1,000,000 revolutions of the moving element. (See 1909 Meter Report.)

Methods of Testing on the Lines.—There are in general use three methods of testing meters in service.

The first method is, by use of indicating instruments consisting of an ammeter and a voltmeter on direct-current circuits and a wattmeter on alternating-current circuits. The instruments indicate the wattage in the circuit, and by timing the revolutions of the meter with a stop-watch, the watts passing through the meter are obtained, and the two results are compared to obtain the percentage of accuracy of the meter. With this method the load must be practically steady during the test, as it may be difficult to estimate the average of a load which is fluctuating.

In this method, in some cases, a number of instruments are required to cover the range of all meters tested, since no instruments should be used at low points on its scale. In direct-current service, a millivolt meter with shunts is often used, and is preferable, since with this combination a greater range can be covered with less equipment.

The second method of testing is, by the use of calibrated sets of resistance coils with a voltmeter and a stop-watch. Since the resistances are calibrated, if the voltage across a set is known, the current and therefore the watts are also known. This apparatus may also be used on alternating-current providing the resistances are wound non-inductively. It is very important that the resistances have a zero temperature coefficient, and that they be perfectly constant in value. The watts passing through the meter are obtained by timing the revolutions as in the first case.

The third method of testing is, by the use of a rotating watt-hour standard.

The rotating standard method is the most satisfactory, at least for testing induction watt-hour meters. The portable test meter is wound with a number of current coils and usually two potential coils, so that one instrument covers a wide range. With a rotating standard, a man can do the testing correctly, and it is the opinion of the members that he can test from 10 per cent. to 15 per cent. more meters per day. Two advantages making this possible are that the stop-watch may be eliminated and fluctuations in the load will be altogether taken care of by the test meter, and hence will not bother the tester, and the calculations are simple. Further advantage possessed by the test meter is that it can be transported with less danger of injury.

The meter tester should carry with him some artificial load as it is not always convenient to use the consumer's load. A convenient form of this load is a set of resistance coils or load box arranged to be connected in the circuit by means of switches. A number of load boxes are now on the market and it will ordinarily be found better to buy these boxes. A load box which will give from 40 to 1,500 watts will weigh about 9 lb.

New Meters.—It is the unanimous opinion that new meters received from the factories should be tested before they are placed on the lines. This eliminates errors due to transportation, checks the manufacturer's calibration and satisfies the operating company that its meters are correct when first installed. A number of the larger companies always count the dial gearing to be sure that the dials have the proper gear ratio.

Current Transformers.—The use of a current transformer for reducing the current through the meter in order to measure it with a low current capacity instrument or test meter is good practice, and there can be no errors, provided the current transformer is so designed that the ratio of the primary current to the secondary current is known for the conditions under which the transformer is used and provided the transformer has no appreciable error due to phase displacement between primary and secondary.

Polyphase Indicating Wattmeters.—The use of a polyphase indicating wattmeter for testing three-wire meters will give correct results if the current elements are connected in outside legs of the three-wire system and the potentials connected from each leg to the neutral.

THEORY.

Relative Position of Magnets and Fields of a Meter.—The magnets in a meter should be so arranged that their plane is perpendicular to the plane of the fields of the meter. By this arrangement the stray magnetic flux from the fields would cut across the permanent magnet instead of passing through the magnet from tip to back and in such cases will have considerably less demagnetizing effect.

Theory of the Commutating Meter as Illustrated by the Thomson Watt-Hour Meter.—The commutating meter may be considered as a meter having a field due to the current coils, in which is placed a drum wound armature. The torque will be proportional to the strength of the magnetic field, the current in the armature, and the number of turns on the armature. The strength of the magnetic field, is due to the current in the field coils, and when constructed without magnetic material, such as iron, is proportional to the current in the coils. The armature is connected across the circuit with a high resistance in series, so that when the meter is not running, the current in the armature is proportional to the voltage of the circuit. When the armature is rotating, however, the current which passes through it will be proportional to the circuit voltage minus the counter e.m.f. set up in the armature by its rotation. The counter e.m.f. is proportional to the field strength, to the spread and to the number of turns on the armature; for example, in the Thomson watt-hour meter the speed is low, the magnetic field strength, since in most types there is no iron and since the ampere-turns of the field coils are small, is very low, and the number of the turns on the armature is low; therefore, the counter e.m.f. is practically zero in the commutating meter. In fact it has been measured and found to be a small fraction of a per cent. of the voltage of the line; therefore, the counter e.m.f., in such cases, may be neglected and the armature current may be considered as exactly proportional to the voltage of the line. Therefore, as the magnetic field is proportional to the current in the line, and the armature current to the voltage across the line; the torque must be proportional to the energy or watts of the circuit.

The damping mechanism of the meter consists of a metallic disk rotating between jaws of permanent magnets. Since the magnets are constant in strength the damping or counter torque of the meter is proportional to the speed only; hence, the speed is proportional to the torque, and if the number of revolutions are counted by means of a register, this register reading can be readily reduced to kw-hr.

A commutating meter is similar to a shunt wound motor in connections, but in a shunt wound motor the field strength, armature turns, and speed are many times greater than in a commutating meter; hence, the counter e.m.f. in a shunt wound motor is many times greater than in a meter; in fact, the counter e.m.f. in a motor is the controlling feature in its operation, whereas it is a negligible feature in a meter. Therefore, the meter and the shunt motor behave differently under change of field strength. (See 1909 Meter Report.)

SECTION XXI.

New Business.

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New Business.

GENERAL.

The effect of a good commercial department on the value of stocks and bonds of the company having such a department is hard to judge, but if the department is good the business will be good—the earnings greater and values of securities should be increased.

A bad commercial department would at least affect values to the extent of its being a non-productive expense. (W. H. Gardiner, Jr.; John Craig Hammond, 1906.)

New business appropriations for advertising and soliciting should be divided between the two at the rate of sixty per cent. for soliciting and the balance in advertising to assist the solicitors. (John Craig Ham mond, 1906.)

The commercial department should bear the same relation to the electric company that the selling force does to any manufacturing plant. A good commercial department therefore means more and better-pleased customers, and the additional load means better operating costs. (W. H. Gardiner, Jr.; John Craig Hammond, 1906.) The commercial department should have in charge all departments and employes with which the public comes in contact, such as solicitors, meter readers, complaint clerks, cashiers, and even the ledger bookkeepers. These last two would seem to be purely in the accounting department but writer's experience would tend to show that the best results can be obtained by including them under the commercial department. ("X," 1906.)

The amount an electric company is justified in spending for new business per dollar of business thus obtained would vary with local conditions. An average of ten per cent. of the annual revenue from such business would seem reasonable. Provided the business is reasonably permanent in character even fifty per cent. might not be too high a figure. (John Craig Hammond; W. W. Freeman, 1906.)

Where the new business requires an increase in capacity of station or lines or both, the estimated net earnings should show in general from 10 to 25 per cent., depending greatly on local conditions. (P. Junkersfeld; E. H. Mather, 1904.)

Credit of a Customer.—The credit department will give best judgment in the matter of deciding the credit of a prospective customer; the contracting department is apt to be influenced by the desire to do business. (George E. Burns; Ralph R. Laxton; Brooklyn Edison Co., 1906.) The prospective customers' credit should be passed both by contracting or sales department and the auditor. (P. S. Young; Birmingham Railway, Light & Power Co., 1906.)

Encouraging wiring of new buildings for light and power is best done by following up building permits and mailing printed matter to parties interested, followed by calls from solicitors. Company should also offer to get up specifications and if desired obtain bids on wiring. Keep local architects on mailing list and have solicitors call on them regularly and often. (Douglass Burnett; Fred M. Liege; D. O'Connell, 1905.) No "inducements" to architects or engineers should be made. (P. H. Korst;

Percy Ingalls, 1906.) **We allow builders 10 per cent. of the wiring job.** (C. R. Price, 1907.)

Inducing Owners to Wire Old Houses.—Careful following up good prospects (good prospects being considered according to neighborhood and class of buildings) as well as offers to prepare plans and obtain bids, showing added revenue to be derived from properties so equipped will usually obtain results. (Douglass Burnett; D. O'Connell, 1905.) Also a plan for the company to pay the contractors and let owners pay back in installments. (F. G. Proutt, 1905.)

ADVERTISING.

The best method of advertising is undoubtedly good service. Use an electric sign and advertise in the newspapers. No matter how small a town is, newspaper advertising will pay the electric company. While the smaller towns will not afford such great returns, the rates will be in proportion. A selected mailing list should be prepared from knowledge of the town and solicitor's reports, and personally-addressed letters should be sent out. How often, local conditions must decide.

Specialize in your mailing matter. Power prospects should receive information on that subject and the circulars for the store lighting prospect should be different from those for the residence. (R. Louis Lloyd, 1905.)

Good monthly bulletins each on a specific subject and giving detailed information and views of local installations and if possible testimonial letters from your customers. Have a liberal policy with customers. (Douglass Burnett, 1905.)

Local conditions and size of the appropriation will have to govern but it would seem advisable to take up advertising in the following order.

1. Circular letters addressed to selected lists.
2. Mailing cards, folders, etc., interspersed between such letters.
3. Newspaper advertising, except for power.
4. Display room.
5. Street-car cards.
6. Billboards and other similar methods of general publicity.
7. Programs and similar petty advertising grafts should not be charged to advertising, but to charity. (Frank B. Rae, Jr., 1906.)

The percentage of direct replies to advertising will vary greatly and is somewhat dependent upon the quality of the matter sent out. We find that returns vary from nothing to 5 per cent. on circulars with an average of probably 1 per cent. Letters produce from nothing to 20 per cent. with an average of about 3 per cent. (Frank C. Farrar, 1907.) The replies are few; indeed practically negligible. (A. J. Campbell, 1907.)

A central exchange for advertising matter would undoubtedly be of benefit to all the members of the Association, providing as it would an efficient and constant contact and discussion of various schemes for promoting business. The most effective manner in which to carry on this work would be for every member to send to headquarters copies of all advertising matter as it appears and this could be reprinted in booklet form or sheets and sent out to all members. There is no reason why an advertisement or illustration that has proved its worth in one locality should not be equally as good in another if judiciously used and if not too local in flavor. A certain amount of discrimination would necessarily have to be used in adopting the methods of others but if properly done an exchange of this kind would be invaluable. (W. R. Gardiner; La Rue Vredenburgh; S. S. Ingman; F. C. S., Augusta Railway &

Electric Co.; C. B., New York Edison Co., 1904; J. J. Cagney; F. C. S.; L. W. Emerick; W. H. Gardiner, Jr.; John Craig Hammond; Philadelphia Electric Co.; J. J. Cagney, 1906.)

If a public service corporation can secure the exclusive services of an advertising man of equipment, experience and ability; by hiring such a man, organizing its own advertising department and conducting its own advertising campaign out of its own office, the corporation is, in my judgment, far more likely to achieve profitable and satisfactory results.

Such an organization is certain to be more in touch with the business, to grow closer to it, in comprehension and expression, than can an essentially foreign agency, the primary allegiance of which is due not to the public-service corporation, but to the outside advertising concern. The situation is not different from what it would be if it affected the highest executive offices of the corporation. To conduct the general management or the operating superintendency of the company, we should not consider for a moment the proposition of hiring an outside agency, however expert, whose energies and responsibilities were scattered over a number of enterprises. The advertising department of a highly organized and well regulated public-service corporation should be one of the most important factors in its business existence, for the function of such a department should be not only to sell energy, to inform and educate the public, and to popularize the service by demonstrating its superiority and familiarizing people with its various uses, but it should also have largely in charge through its newspaper connection, the public-opinion relations of the corporation to its constituency; that subtle, close and delicately-poised relationship, the immense significance of which is but now beginning to be fully realized. In other words the advertising manager should be not only a star salesman, but, in co-operation with the executive officials, he must be the custodian of the company's reputation and of that real asset, the public good-will.

This function, in the nature of things, no outsider can adequately administer. It requires a man of discretion, understanding and constructive imagination, with mind and purpose singly devoted to the service of the company. The central station that can afford an A 1 advertising man has no business with syndicate services and advertising agencies. (The Brooklyn Edison; M. S. Seelman, Jr., 1906.) Outside advertising experts should be employed only in an advisory capacity. The policy of putting the execution of an advertising campaign into their hands is open to question. (J. J. Cagney; "X"; John Craig Hammond, 1906.)

Amount of Expenditure.—As a general rule about 2 per cent. of the gross receipts should be spent for advertising. (John Craig Hammond; P. H. Korst; H. E. Ryder, 1908.) Where the company is prepared to back up the advertising by solicitation and carefully and conscientiously take care of the customers secured—promptly and efficiently—the expenditure should not be based on a percentage of the gross receipts, but every cent the central station can get should be put into this vehicle for expanding its business. This applies even more strongly to the small cities because a city of 10,000 or 12,000 inhabitants can get a more profitable return on money expended on advertising than larger cities, since the customer in the smaller towns can have more effect produced on his mind by a small expenditure of money, than his busier brother in the larger city.

No two cases are the same and no rules nor fixed percentages of gross receipts can be set down to be followed in individual cases, where local receipts and conditions may vary widely. There is no manufacturing business in the world in which the percentage of fixed charges and general expenses so rapidly decreases as in the production of electricity. Consequently, every effort should be bent and every cent possible should be expended toward increasing the number of profitable customers. (Converse D. Marsh, 1906.) If the business has not been developed spend every cent that can possibly be obtained. Every new customer increases the earning value of the property by $100. (Birmingham Railway, Light & Power Co., 1906.) It is impossible to put advertising expenditure on a percentage basis, local conditions must govern. (C. C. Gartland; Percy Ingalls, 1907.) Our expenditure per capita for advertising during 1906 was 10 cents. (Frank C. Farrer, 1907.) Our expenditure as above was 8 cents. (Percy Ingalls, 1907.)

Advertising for manufacturers seems to make its best appeal when well worded and well displayed in the technical and trade papers and followed up with good mail matter. Of the two, persistent circularizing to carefully-selected lists seems best. (Converse D. Marsh; La Rue Vredenburgh, 1905.)

The bulletin and catalog are the best advertising for the manufacturer, and where competition is brisk use the technical papers. (D. H. Howard; 1905.) The technical papers for large or small advertising are best. (Augusta Railway & Electric Co.; G. Wilbur Hubley, 1905.)

Reading of Advertisements.—The public can easily be induced to regularly read the electric advertising, circular letters and newspaper advertisements if they are made interesting and attractive to them. Not necessarily by the use of fantastic designs or vivid colors, but by their homeliness, timeliness or pertinency. Base your articles on truth, build up with simple Anglo-Saxon words and sentences, salt with attractive illustrations. Let them appeal to the fundamental attributes and qualities of human nature, and they will be read. The best plan is to have your advertising written by someone with a knowledge of your business and a sympathetic understanding. (M. S. Seelman, Jr.; J. J. Cagney; Frank B. Rae, Jr.; John Craig Hammond, 1906.)

By keeping at it persistently and by making the advertising distinctive as well as attractive and of a high grade. (H. A. Strauss; E. A. M., New York Edison Co.; W. H. Gardiner, Jr., 1906.)

Articles of general news interest concerning central-station service, heating appliances, new type of lamps or power may easily be gotten into the local newspapers by means of a personal acquaintance with the editor and frequent heart-to-heart talks. Write them up in interesting style and supply the articles ready for printing. The editor is glad to use the matter and the public is interested. (J. J. Cagney; Frank B. Rae, Jr.; F. Ellwood Smith; John Craig Hammond; H. A. Strauss; "X"; F. D. Sampson; R. N. Kimball, 1906.)

Newspaper advertising for the central station would seem to pay better in its indirect returns rather than in obtaining customers. Through the good will of the editors, better public feeling is fostered and this is a very valuable asset. (La Rue Vredenburgh; F. Ellwood Smith, 1905; R. N. Kimball; Ralph R. Laxton; F. C. S.; Malden Electric Co.; "X," 1906; M. C. Turpin; R. N. Kimball; J. H. Enright, 1907.)

Properly worded and displayed newspaper advertising will pay in any size town. While in a smaller town you do not reach as great a number of people with the same advertisement, as in a larger town, the price in the smaller town for the newspaper space will be in proportion. (M. S. Seelman, Jr.; Frank B. Rae, Jr.; John Craig Hammond, 1906; Frank C. Farrer; E. C. Stahl, Jr., 1907.)

Newspaper publicity, if the advertisements are carefully written, is always valuable, but the trouble is that results can not be checked as readily as follow-up advertising through a campaign of direct-mail solicitation. The money spent in newspaper publicity will not bring as direct or renumerative results as in direct mail advertising. (Converse

D. Marsh; Philadelphia Electric Co., 1906.) However, when newspaper advertising is used as an aid to a mailing system the results are more profitable than either system used alone. (Converse D. Marsh, 1906.)

Newspaper advertising in towns of 5,000 inhabitants or less will pay an electric light company if the matter is bright and well written and while not so many prospects are reached as in the larger towns the rates are proportionately lower. Besides keeping the electric company before the public the good-will of the paper is secured. (D. H. Howard; Converse D. Marsh; F. Ellwood Smith; L. E. Watson; R. Louis Lloyd; La Rue Vredenburgh, 1905.)

Newspaper advertising copy should be changed as often as possible and should never appear more than twice and if possible only once. Never use the same copy twice unless you cannot improve it; then have somebody else do so. A 6-in. double column every other day is much more effective than a 6-in. single column every day. Constant hammering brings the results.

Page and half-page advertisements are good only for making some startling announcement of events lasting for a short time. Good location is especially important and should be obtained by all means. (Frank B. Rae, Jr.; J. J. Cagney; L. W. Emerick; W. H. Gardiner, Jr.; John Craig Hammond; F. D. Sampson, 1906.)

Printed matter and letters mailed to the prospective customer are good in cities of any size but should be followed up by the solicitors as soon as any lead is brought out.

Compile your mailing lists from your solicitor's cards and revise frequently. Include such of your customers as you think will be interested and induced to use more energy.

Send out communications of good workmanship at least every month. If it is necessary to cut down expense reduce the number of addresses but keep the quality and frequency as high as possible. (Converse D. Marsh, 1905; H. T. Hartman; Frank C. Farrar; P. H. Korst; Percy Ingalls; M. C. Turpin.)

The syndicated electric bulletin might be employed to advantage by the smaller central stations provided but part of each local issue of the bulletin be syndicated. The items of local interest are of great importance in bulletins. (W. H. Gardiner, Jr., 1906.)

The small central stations that are not able to afford a bulletin can doubtless use a syndicated electric bulletin to advantage, at a price. But the price must be low, and the bulletin especially well conducted, otherwise the money can be better expended in purely local advertising. (The Brooklyn Edison; M. S. Seelman, Jr., 1906.) For small stations the syndicated bulletin would seem to pay, but it must naturally be very much broader than the usual bulletin and the quality of the syndicated articles must be good. (John Craig Hammond; Frank B. Rae, Jr.; F. Ellwood Smith, 1906; Converse D. Marsh; D. H. Howard, 1905.) Local conditions vary to such an extent that a syndicated bulletin would be manifestly a "patent sheet" and again the syndicate plan would preclude your presenting the pertinent points most helpful to you. (J. J. Cagney, 1906.)

Advertising in theatre programmes does not usually pay an electric light company. Many reasons contribute to this, some of which are that the same people are reached through other channels, while some do not care to think about business when at the theatre. (J. J. Cagney; W. H. Gardiner, 1906.)

The Brooklyn Edison Co. selects the high-class play houses within its territory, and advertises to a limited extent in their programmes, feeling that the kind of people it is desirable to reach and influence attend these theatres. This is done, however, for the same reason that a "now-and-then" advertisement is placed in the newspapers with little expectation of direct, immediate returns. (M. S. Seelman, Jr., 1906.)

Pasters on bills or enclosures with same when well prepared are efficient and economical advertising and productive of good results. It is important that the printed matter be prepared to meet local conditions although some manufacturers furnish attractive matter which can be used very successfully. (John Craig Hammond; J. J. Cagney; Frank B. Rae; Ralph R. Laxton; R. N. Kimball, 1906.)

Stickers or enclosures with customers bills do not pay. It is bad psychology to ask a man to use more service at the time when you are asking him to pay you for what he has used. If stickers or enclosures are used, have local ones unless those supplied by the manufacturer exactly fit local conditions. (W. H. Gardiner, Jr., 1906.)

Street-car advertising for central station is of doubtful value and should be used only as part of a very extensive advertising campaign. (F. B. Rae, Jr.; Philadelphia Electric Co.; W. H. Gardiner, Jr.; John Craig Hammond, 1906.) For advertising heating and cooking appliances and other household helps, street-car advertising will pay the central station. (Altoona Edison Co.; Wm. Rawson Collier, 1908.) But not unless electric light and power are advertised on the same card. (A. T. Lloyd, 1908.)

Billboard and poster advertising will not bring in the same returns for the money spent as other forms of advertising. However, this advertising might be made more effective if the signs were illuminated at night because it would help to induce other advertisers to follow suit and use electricity for the same purpose.

This class of advertising for a central station is a good publicity method although not a directly remunerative one and the results are not easily checked up. (Philadelphia Electric Co.; John Craig Hammond; Frank B. Rae, Jr.; W. H. Gardiner, Jr., 1906.)

No electric company should use billboard or poster advertising as it will hurt the sale of electric signs. (J. J. Cagney, 1906.)

If this class of advertising is used it would be better to spend the money on a few permanent, painted signs properly illuminated and located at transfer stations along the street-car lines. (W. H. Gardiner, Jr., 1906.) The design and reading matter on large permanent, painted signs should be changed every fall and spring. (J. J. Cagney, 1906.) Change matter at least every 3 months, or, better yet, every 6 weeks. (W. H. Gardiner, Jr., 1906.)

Souvenirs as advertising aids may pay an electric light company if the souvenirs are suitable and well distributed and of a grade corresponding with the class of business sought. Much, of course, depends on the souvenir. Supplemented with a regular campaign they may create talk and perhaps win friends but they do not create business. (W. H. Gardiner, Jr.; J. J. Cagney; John Craig Hammond; Frank B. Rae, Jr., 1906.)

Old customers should be educated to increase their use of electricity. If they have been treated right they should be the easiest to reach. This class of service is of course the most profitable as practically no new equipment is necessary to supply the extra energy. A differential rate is perhaps the greatest aid to gaining increased consumption as under such a system the old customers can be relied upon to increase their use of energy as this automatically decreases the rate per unit. Pains should be taken to cultivate this class of business by the use of stickers on bills, follow-up letters on various appliances and as his premises are already wired, he will be under less expense to install these appliances and is therefore more easily induced to do so. (W. H.

Gardiner, Jr.; M. S. Seelman; Philadelphia Electric Co.; John Craig Hammond, 1906.)

In fighting municipal ownership the best weapon is publicity. Municipal ownership rests with the public and advertising skillfully done in a fair and honest manner should have a very important part in moulding public opinion. Local conditions must govern the matter entirely. If the agitation for public ownership is a circulation scheme of a newspaper pandering to that part of the public which loves to gloat over attacks on public utilities companies, statements to the public both in the news and advertising sections of the local newspapers made in a dignified, fair and honest manner will do much good. Most municipal-ownership campaigns are due to a misconception of facts and the presentation of but one side of the case. Conservative people who have studied the question thoroughly agree that municipal ownership is a fallacy and a burden on the tax payers. This should be brought out prominently.

The real effects of municipal ownership have shown it to be such a dismal failure that the more publicity given them, the better, especially when contrasted with the results of private ownership and management. (J. J. Cagney; Frank B. Rae, Jr.; C. A. L., New York Edison Co.; John Craig Hammond; The Brooklyn Edison; W. H. Gardiner, Jr., 1906.)

SOLICITING.

The contract department should be in the hands of a contract agent whose business shall be exclusively the matter of getting load for the station. The lighting company in a town of 50,000 or more cannot afford to be without such a man. In a small place he can himself see all customers and keep the necessary records for the department. In the larger places, he must have solicitors in regular districts for covering the territory, and a chief clerk who shall talk with the general run of customers in the office, attend to the details of putting through contracts and seeing that they are properly executed, and keeping complete records of the business done, reports of solicitors, card systems of people on whom solicitors are calling for the purpose of following up, and so forth. (John F. Gilchrist, 1905.)

The soliciting department should be divided into three branches. The lighting bureau, which in addition to lighting business, also has sale of small motors (less than 1 hp.) that are connected on lighting rates, and domestic heating appliances, but makes no special effort in the latter case. The heating bureau solicits strictly heating goods, both domestic and industrial. The power bureau solicits for power business only. (E. R. Davenport, 1907.)

There is only one satisfactory plan for co-operation between the lighting solicitors and the power department, namely, to consolidate the two departments, and thereafter to require that the lighting solicitors should know enough to close a small power deal and that the power men should not despise lighting business. (Peninsular Electric Light Co., 1909.)

Solicitors should visit their customers continually, whether they buy or not, so as to show an interest in them.

The most propitious time to show interest in any customer is when he is not in the market for your goods. If he is in the market and you visit him, he feels that you are not so much interested in his success as you are in his pocketbook and if you sell him and drop him, he has evidence that this is the case. He has no incentive for gratifying your interest in his pocketbook and if his necessity has obliged him to do so, he has derived no pleasure from it. A pleased customer is the salesman's best advertisement. (Chas. B. Burleigh; R. T. Bump; E. W.

Lloyd; C. C. Gartland; M. C. Turpin; William M. Lewis; United Electric Light Co.; C. R. Price; J. H. Enright; P. H. Korst; F. Ellwood Smith, 1907.)

In cities it is best to divide the territory so that each solicitor has a section in which he constantly works. In this way, the peculiarities of the locality become known to him, and his frequent visits cause him to become known to the people of his section. (E. R. Davenport; Percy Ingalls; F. Ellwood Smith; E. W. Lloyd, 1907.) We divide our territory but solicitors may bring in business from other sections if satisfactory to the solicitor in charge. (P. H. Korst, 1907.) When a solicitor has worked his own section thoroughly—and you can decide this by the reports—switch another solicitor on to this section. There will be a certain number of people who have given the other man no business and the ways of the new man may appeal to them. (Wm. M. Lewis, 197.)

In a city of 75,000 population there should be four solicitors, or in other words one solicitor for every 18,000 people. (W. R. Collier, 1909.) Two good canvassers should suffice for 75,000 people if there are skilled men behind them ready to handle every possibility promptly. (R. M. Searle, 1909.)

Our solicitors meet every morning for about 15 minutes; make their reports on the previous day's business, and ask questions of the head of the department about particular cases they have in hand for the day. We also have a monthly meeting, at which any agent has the privilege of asking questions on any subject pertaining to the business. We also have papers and discussions on new business subjects. The subjects are, generally speaking, open to a free discussion. (E. W. Lloyd, 1907.) We have our solicitors meet every morning from 8:15 to 8:45, for general conference and one evening a week for educational purposes. Existing conditions are very thoroughly and freely discussed. (S. A. Sewall, 1907.)

When solicitors have no other duties, about one good man per thousand customers would be about right. (The Pueblo & Suburban Traction & Lighting Co.; E. W. Lloyd, 1907.) We employ two solicitors per thousand customers but these men also read meters and collect. (P. H. Korst, 1907.) A good live solicitor weighted with encouraging salary and commission condition should handle about 5,000 customers. (C. C. Gartland, 1907.)

Educating solicitors is best accomplished by having meetings at which lecturers can be given on business-getting methods and at which the men can be asked to give their experiences in looking out for business. Instructions and general information sheets should frequently be issued to the men and afterwards kept in binders where readily accessible. Hold daily meetings at which the little points of the day's business can be brought out. (J. J. Cagney; E. A. M., New York Edison Co.; John Craig Hammond, 1906.)

In combination gas and electric companies solicitors must be carefully selected in order that they may be able to guard their company's interests from a gas as well as electric point of view. (J. H. Enright, 1906.) Have solicitors handle both gas and electric business. Leave residence lighting for gas and sell electricity for decorative and commercial lighting and power. (R. N. Kimball, 1906.) Advocate gas for heating and cooking and electricity for light and power. This, we believe admits maximum increase in both services. (J. J. Cagney, 1906.)

Specialty salesmen such as power and sign experts are necessary in the larger cities when given sufficient scope. By devoting his attention to one field entirely, the solicitor becomes expert and thoroughly conversant with all things pertaining to his line. (E. A. M., New York Edison Co.; J. J. Cagney; W. H. Gardiner, Jr., 1906.)

Male vs. Female Solicitors.—We find that men excel in flat-iron soliciting on account of being able to go into the kitchen or laundry and repair sockets, replace fuses and otherwise make the installation right mechanically and electrically, thus insuring satisfactory operation. We have in mind a man who followed up a professional woman solicitor sent out by a leading manufacturing concern, and not only placed more irons but had fewer comebacks on a thirty day trial plan, due undoubtedly to ingenuity in installing the irons. For other household appliances, the woman solicitor has a natural advantage, and her best work is for example at women's clubs, church socials, and in homes. (Indiana & Michigan Electric Co., 1908.)

We think women the better solicitors for heating appliances, when properly selected and trained. This is because of the fact that most of the soliciting is done at the residences where women solicitors are able to meet and talk to the housekeeper to better advantage. (The Edison Co. of Altoona, Pa.; Wm. Rawson Collier, 1908.)

Women solicitors for special canvassing, particularly in the residence districts, can get a hearing far quicker than men. (C. A. Hutchings, 1907.) We employed one woman solicitor with success, after having taught her the business. (Pueblo & Suburban Traction & Lighting Co., 1907.) Women are the best demonstrators for heating appliances and may also be employed successfully in soliciting residence lighting. (Percy Ingalls, 1907.) We believe in women solicitors for the sale of flat-irons only. (F. Ellwood Smith, 1907.) We do not employ women as solicitors. Ordinarily, I believe the prospective customer does not have as much confidence in the ability of a women solicitor as in a man, and they can not be promoted so rapidly or advantageously. (D. R. Pierson, 1907.)

Solicitors on Salary or Commission.—Argument can be advanced in favor of either plan, but experience has proved to our satisfaction that the best results are obtained from a combination of salary and commission. The salary gives the company the right to control the work of the solicitor and to have him devote such time and effort as is necessary to hold business in his territory, which is even more important to the company than obtaining new business, and the additional commission affords the necessary impetus to put forth every possible effort in obtaining new business. The successful electric lighting solicitor must be willing to work during all hours and under all conditions, and it is not within human probability that any man will continuously put forth unusual effort unless the compensation is commensurate to the effort. The commission basis, when adopted solely, however, restricts the company in the control of the solicitor to an undesirable extent, and we therefore believe that the salary should be based on the fair value of the solicitor's services up to a certain accomplishment in new business in each month and commission allowed on the excess of such figure. This plan has been in operation with us for two years, and the results are exceedingly gratifying. (W. W. Freeman, 1904.)

Small salary and commission on all business above a certain amount, is the best plan. (George L. Colgate; William R. Gardener, 1904.) We make a rate of 25 cents per 16-c-p. lamp. At some seasons of the year a good solicitor makes more money by this method than by a salary plan. We do not keep a solicitor all the year around but only during certain seasons of the year. (Little Falls Water Power Co. of Minnesota, 1904.) We pay solicitors on a straight basis and think this method the cheapest way of producing new business per 16-c-p. lamp connected.

Our cost last year on salary basis was 5.647 cents per 16-c-p. equivalent. (Frank W. Smith, 1904.)

Avoid all premium offers for new business. Pay a fixed nominal salary and a guaranteed commission on all business written in excess of what you would be entitled to expect if no commission were attached. (J. J. Cagney, 1906.) Premiums are good for bringing forward the best men. Encouragement is better than extra fees, if the encouragement is in the shape of advancement to the men who show results. (John Craig Hammond, 1906.)

The average yearly salary of our solicitors (not including heads of departments) is $1,200. (E. R. Davenport, 1907.) $1,020. (Edison Electric Illuminating Co., West Chester, Pa., 1907.) We pay solicitors $60.00 per month all the year around. This seems to appeal to local men better than a percentage basis on which their pay varies. (R. N. Kimball, 1907.)

Checking work of solicitors is best accomplished by having them make out report of daily calls either on prospect card or on report sheet from which prospect cards in the office files may be compiled. (Philadelphia Electric Co.; R. N. Kimball; Douglass Burnett; Charles D. Penniston; Frank W. Frueauff, 1905; R. N. Kimball; J. J. Cagney; E. A. M., New York Edison Co., 1906; E. R. Davenport; The Pueblo and Suburban Traction and Lighting Co.; E. W. Lloyd, 1907.)

DISPLAY ROOMS.

Display rooms would seem to make their greatest return in the form of advertising, to which account they should be charged. We find a display room as effective in the electric-light business as it would be in any other line, although perhaps the direct pecuniary benefit is not so great.

A properly arranged display room should show a few of the more popular household appliances such as flat-irons, sewing-machine motors hair dryers, fans, water heaters, washing machines and vacuum cleaners. The newest lighting appliances should be demonstrated mainly by being used for the illumination.

In an industrial town a few direct-connected motor-driven machines suitable to the general manufacturing carried on. (John F. Gilchrist; La Rue Vredenburgh; A. W., New York Edison Co.; H. M. Bengler, 1903.)

Display rooms undoubtedly pay for themselves and even central stations should have some such display. (Converse D. Marsh; G. W. Hubley; A. R. MacKinnon; J. W. Cartwright; Augusta Railway & Electric Co.; D. H. Howard; Douglass Burnett; John F. Gilchrist, 1905.)

LIGHTING.

Residence business is best obtained by the use of follow-up letters in conjunction with personal solicitation. A book for the solicitor to carry containing pictures of fixtures and interior views of electrically-equipped houses is good ammunition. (W. H. Gardiner; E. W. Phillips, 1906.)

Light for Color Matching.—To demonstrate the superiority of the electric arc light in matching and selecting colors, an instrument called the lumichromoscope is used in such a way that the light from various sources, say the arc, Nernst, Welsbach, and tungsten and carbon filament incandescent lamps fall simultaneously onto a piece of colored material each light forming a square patch with a black border separating the squares to produce simultaneous contrast and gradation. The colors that should be used for the most striking contrasts between the electric and gas arcs are violets, blues and yellows containing rather a small percentage of green. The general color value of the electric arc is best illustrated by showing all the principal colors; namely, red, orange, yellow, green, blue, indigo and violet. (W. D. A. Ryan, 1903.)

SIGN AND DISPLAY LIGHTING.

To Develop the Sign Business.—The first step is for the central station to erect a sign of its own and follow this up with general advertising and personal solicitation. (United Electric Light Co.; John Craig Hammond, 1906.)

Joliet (Ill.) a city of 35,000 inhabitants after taking up with the free-sign proposition, within ten months contracted for about 30 signs having 2,889 2-c-p. lamps burning on patrol from dusk till midnight daily, and producing an annual gross income of $4,649.64.

Advertisements were carried in the three daily papers and about half of the space devoted to sign talks. We also used a follow-up system of mailing cards furnished by the sign manufacturers. The follow-up system was apparently very effective. (Edward Currey, 1908.)

A city of 30,000 inhabitants had two electric signs, both of which were condemned by the insurance companies who would not allow them to be operated. Within two years after beginning a free-sign campaign, this city has 31 signs and 10 flaming-arc lamps on a flat-rate basis. A connected load of 2,078 2-c-p. lamps and 196 4-c-p. lamps or about 25-kw., consuming approximately 37,500-kw-hrs. per year. For this service, the revenue is $4,100 per year of which 20 per cent. is charged against rental of signs and balance for energy consumed, making about $125.00 per year per kilowatt connected.

Sign expenditure was $3,170. divided as follows:

Cost of 29 signs, $2,200; installation, $650.00; lamps, $320. (John S. Bleecker, 1908.)

Boston employs a man to look after the sign business but furnishes no signs and gives no special rates, believing that while more business can undoubtedly be obtained by free signs, the extra expense involved is considerable in proportion to the returns. A proper rate that will allow discounts for long-hour business seems to them the best way of encouraging the use of signs and display lighting. (R. S. Hale, 1908.)

Offering customers signs on 12 monthly payments seems a good way of avoiding free signs and arrangements can probably be made with some sign manufacturers to do this. (D. Thomson, 1908.)

Free signs with flat rates controlled by time switches will materially aid the sign business. (E. A. M., New York Edison Co., 1906.)

Free signs and flat rates with fixed hours of burning should pay an electric company as the customer is more easily induced to use the sign when he knows in advance just what the cost will be. (Converse D. Marsh, 1906.)

Special holiday lighting seems to be good business if the central station is able to care for the demand. While not a highly renumerative load it is as much an advertisement for electricity as for the user and serves to strongly impress the public with the safety, beauty, cleanliness and adaptability of electric light. (W. W. Freeman; Geo. B. Tripp; E. E. Larrabee; Geo. L. Colgate; S. S. Ingman; John Gilchrist; F. E. Baker; Edgar B. Greene; W. R. Gardener; W. R. B., New York Edison Co.)

A plan for soliciting for outline lighting suggested by the Electrical World (1908) is to have a dark print made of the building and with a fine needle prick holes at points where it is proposed to put lamps. The photo is then mounted as a transparency in the front of a box containing lamps.

GENERAL POWER.

When displacing steam engines by electric motors the steam plant should be inspected and if necessary the engine indicated and the motor drives decided upon. After going over with the prospect the cost of the steam installation, figures should be presented showing cost of operating by electricity. The disadvantages of the steam plant in having to maintain steam and employ labor all day long for a varying load as against the ease with which motors may be stopped when not required, with attendant savings in power, should be brought out. Figures should be presented showing what other customers in the same line of business pay for their electric service. If objections are made to signing a long-time contract and buying motors for "an experiment," the central station should make an offer to install all or a certain amount of power, furnishing motors and wiring with the understanding that after a one or two-months' trial if the power is not satisfactory the central station will remove its motors and lines from the premises and the customer need only pay for the cost of wiring and setting motors used in trial and for the energy consumed. Such a trial, however, should only be made when the solicitor is reasonably sure that some saving will be made either by reducing labor, increasing output or insuring safety and continuity of service. (Geo. B. Lauder; John F. Gilchrist; E. H. Mather; Augusta Railway & Electric Co., 1904; Alex. J. Campbell; D. O'Connell; E. Peterson; John Gilchrist, 1905.)

A woodworking plant running at full load all of the time and burning shavings and waste for fuel may under certain conditions be profitably operated by electricity. The arguments best quoted would be the following: 1. Some shavings, such as pine, can be sold at a profit to be chemically treated. 2. The engineer and fireman are likely to be of a lower class of labor and less reliable. 3. Variation in steam pressures from wood fires means decreased output and lumber worked by slow-running knives. 4. Superintendent's time devoted to plant purchase and operation could be devoted to mill work. 5. Rearrangements of machines, allowing lumber to be worked with minimum handling. 6. Large sticks readily handled by motor-driven cranes or hoists. 7. Less fire risk; reduced insurance. 8. No overtime work required on furnaces as is necessary with wood fires. 9. Machines can be stopped and started quicker and without belt trouble. 10. The item of power is about 25 per cent. and labor about 60 per cent. of the total cost. An increase of even 20 per cent. in power cost will increase the total expense approximately 5 per cent., but this increase will be compensated for by the increased speed of the machinery and an increased output due to uniform speed of the machinery and ability to start quicker. (C. A. Graves, 1908.) Shavings and kindlings usually command a good price and it should be easily proved that it will pay a planing mill to sell its waste and buy energy from the central station. (Wm. Rawson Collier, 1908.)

Large steam laundries usually have an efficient system for the utilization of exhaust steam and unless some exceptional condition prevails can ordinarily make their own energy cheaper than they can buy at a figure satisfactory to the central station.

Many laundries, however, buy electric energy for electric flat-irons and this sometimes proves to be the entering wedge as a result of which all of the energy is bought from the central station. However, it is the usual case for laundries to generate their own energy for irons and mangles. (Wm. Rawson Collier; B. W. Mendenhall, 1908.)

In combination companies the best satisfaction will be obtained by pushing the sale of motors for power in place of gas engines. (R. N. Kimball; J. J. Cagney; Ludwig Kemper; R. R. Laxton, 1906.)

Displacing gas engines with electric motors is best accomplished by a trial installation of motors. After motors have once been used the gas engines will never again be operated.

If it is not thought best to make a trial installation, figures should be presented to show what other customers pay for electric energy. When the unsteadiness, noise, dirt, attention required and rapid depreciation of the gas engine are brought into comparison with the silent, steady, reliable and efficient electric motor there should be no difficulty in making the change; provided a reasonable rate is made. (W. W. Freeman; E. W. Lloyd; C. K., New York Edison Co., 1904; E. W. Lloyd, C. C. Gartland; F. C. Stahl, Jr., 1907.)

Free wiring for motors should be unnecessary in ordinary cases. Conditions might arise wherein this would be necessary but these would be special and have to be considered individually. (Ludwig Kemper; R. N. Kimball, 1906.)

Free wiring for motors and changing hydraulic elevators to electric by the electric company do not pay. In the first case the consumer has to provide a power equipment of some kind and in any event the installation of a motor with necessary wiring will cost him less than the same capacity steam plant or gas engine. In regard to hydraulic elevators the revenue derived from this hardly desirable class of business would not warrant the expense. Some plan of easy payments might, however, be a good inducement when competition is strong. (Ludwig Kemper; J. H. Enright; R. N. Kimball; The Pueblo & Suburban Traction & Lighting Co.; P. H. Korst; E. W. Lloyd, 1907.)

SMALL MOTORS, FANS, ETC.

The readiest means of selling and inducing the use of desk fans would seem to be by means of enclosures with bills. Circulars and booklets should be sent out early in the season not later than April 1st and the work kept up until the July bills are sent out. When the warm weather arrives advertisements of suitable size should be printed in all the newspapers going to the best class of residences and even by advertising in street cars that serve that same class of residences.

Whether the central station or the contractor should sell fans is of course a local question but in any case a suitable stock should be kept on hand.

The above is taken from the reports of many electric companies. (T. M. Weston, 1906.) We find it is best to co-operate with manufacturers and to set a reasonably-low, fixed rate for service. (J. J. Cagney, 1906.)

Electric washing machines and sewing machine motors do not consume enough energy to justify any but the largest central stations employing a man to give his entire time to their introduction. However, from the viewpoint of making and keeping pleased customers they are valuable and the solicitor should have information about them and bring the matter to the customer's attention when making a call. If the customer is interested, he might go further into details. (F. C. Morrison; K. A. Shaick, 1909.)

HEATING.

Electric heating and cooking apparatus should be exhibited in the display room and such articles as are not made second hand by a few days use should be placed on trial if there is a fair prospect of a sale. The flat-iron is usually placed on trial for 15 or 30 days. Some companies, however, do not make free trials except in the summer months as they find that most irons placed on trial in cold months are returned.

Advertising through enclosures with bills and making demonstrations in show room or in local department stores will aid in selling heating appliances. (Colorado Springs Electric Co.; Augusta Railway & Electric Co.; H. E. Ryden; J. F. Gilchrist, 1905.)

Street-car advertising seems to pay for advertising flat-irons, water heaters, chafing dishes, coffee percolators and table lamps. (The Edison Co. of Altoona, Pa.; Wm. Rawson Collier, 1908.)

The rate for electric energy for heating, cooking and charging storage batteries should be special, where the amount of energy used is great. (Colorado Springs Electric Co.; United Electric Light Co.; J. W. Cartwright, Jr.; Augusta Railway & Electric Co.; C. M. Wright, 1905.) The regular power rate should apply. (F. Ellwood Smith, 1905.) No special rate is made. Heating appliances are not included in the recorded installation and this is equivalent to a special rate, in that the recorded installation appears on the bill as having been used longer by an amount equal to the heater consumption. The units consumed by the heater are thus charged for at the lowest rate that is obtained upon the particular bill in question. (C. W. R., New York Edison Co., 1905.)

From such data as the writer has gathered, most companies seem to be furnishing heating devices at their regular lighting rates, although a few sell energy for heating on their power schedule. Very few, if any, have a special rate for heating. (John F. Gilchrist, 1905.)

The rate we have found very satisfactory is to take the combined wattage of the utensils, reduce to horsepower, divide by two and rate the same as power. (Wm. Rawson Collier, 1908.)

A special rate of 4 cents per kw-hr. keeps up our load at the station when commercial motors shut down for meal hours. (J. C. Schade, 1908.)

BATTERY CHARGING.

Use of electric vehicles is best encouraged by advertising, proper rates and proper supervision of the charging department by an experienced storage-battery and mechanical engineer whose duty it should be to see that the owners of vehicles get the highest efficiency from their operation.

If there are no live agents for electric vehicles in your town, arrange to represent a good make. For selling commercial vehicles the company might guarantee to maintain same for one year, maintenance to cover tires, motors, wiring and battery and necessary charging. This would have a tendency to encourage the most profitable class of vehicles, the commercial. (James T. Hutchings, 1909.)

ELECTROLYTIC AND ELECTROCHEMICAL WORK.

Arc lamps for forcing growth of vegetation are used with considerable success.

According to the "Electrical Age" of April, 1905, "electricity, in the growth of plants, has been found useful for forcing and increasing the yield, but it is only recently that a foreign grower is said to have found that by the use of colored globes on arc lamps the coloring of the flowers can be altered. A red globe gives a more intense color and a yellow globe a more delicate color." (F. Ellwood Smith; E. A. Taylor, 1905.)

Practically it would not pay a central station to go after this business as the matter seems at present to be only an experiment. (Douglass Burnett, 1905.)

ISOLATED PLANTS.

Isolated-plant competition can be met successfully only through most intelligent and persistent effort. The cost of plant operation should be figured accurately, including interest and depreciation, and compared with the cost of central station service. Special forms for such purpose are indispensable. An owner will frequently be willing, upon proper presentation of the case, to show his figures and enable the central station man to discuss them with him and point out the inaccuracies where the comparison appears to be in favor of the plant. There is no question that the isolated plant is passing, and that in the case of new buildings, regardless of size, the central station company can by intelligent work clearly prove its case to the satisfaction of the prospective customers. A list of isolated plants abandoned in favor of central station service in the territory in question is found to be a most convincing argument. The central station company should constantly keep before the public through its advertising methods the fact, if such is the case, as it should be, that in practically all new buildings being erected and equipped the idea of an isolated plant is abandoned and central station service invariably adopted.

In the case of proposed plants the first thing to be done is to form as nearly as possible an accurate estimate of the probable consumption of energy by the building under consideration and determine how the load will be divided between light and power; also, often the power load in a large building will have a greater demand than the lighting load especially in view of the advent of the tungsten lamp. Go over the plans and lay out the lighting and if possible, as it probably will be, show how the operation of the elevators will give a very uneconomical operating curve.

After these points have been taken up bring forward tabulations of operating costs in similar installations (preferably abandoned plants). This will often bring up costs entirely ignored by the customer, the most important of which usually are capitalization, depreciation and obsoles-contractors or dealers to take proper care of the business. (W. W. cence charges.

The rates offered by the central station must be right. A central station should be able to obtain this class of business with its regular schedule of rates.

The furnishing of steam heat in towns where the station is prepared for this business will often simplify the isolated-plant situation.

In cases where the isolated plant is installed some help in the disposal of the engines and generators is usually given by the central station and when the energy supplied by the station is not adapted to the elevators, and other machinery previously used a great many companies furnish the new equipment on an easy-payment plan, even in some cases accepting the old apparatus in part payment at prices at which it can readily be disposed of to dealers for use out of their territory. (W. W. Freeman; S. M. Bushnell; Augusta Railway & Electric Co.; W. H. W., New York Edison Co., 1904; B. W. Mendenhall; W. A. Cowling; Ludwig Kemper; R. N. Kimball; E. W. Lloyd, 1907.)

CONTRACTING.

Contracting by Central Station.—In cases where contractors do not push the business properly or where excessive charges are made by contractors, the central station should enter the contracting field for its own protection. A reasonable profit should be made on this department. (Charles H. Peters; F. C. S., Malden Electric Co.; A. C. Greenman; A. R. MacKinnon; Augusta Railway & Electric Co., 1905.) However, where there are good live contractors who do good work at reasonable prices the central station should co-operate with them. (A. C. Greenman; L. W. Emerich, 1905.)

Free wiring of customers premises does not pay. While there are many cases where a little help along this line will bring in returns, these would be only isolated cases. This would apply to cities from the smallest to the largest. (Geo. B. Lander; A. O. Whitmore; E. E. Larrabee; Geo. L. Colgate; Fair Haven Electric Co.; Little Falls Water Power Co.; E. H. Mather; G. W. Hubley; S. S. Ingman; E. W. Lloyd; A. F. Hall; Chas. H. Peters; John F. Gilchrist, 1904.)

Sale of Appliances.—It is sometimes advantageous for the electric light company to take the agency for motors, supplies, etc., in towns where there are no contractors or dealers to take proper care of the business. (W. W. Freeman; Little Falls Water Power Co.; Geo. L. Colgate, 1904.)

The central station should sell motors and supplies to its customers at a close margin. No outside contractor has the same interest in the customer as the central station and this is also true in soliciting where the profit does not cause the same enthusiasm and hustle for new power business that actuates the station solicitors.

The principal advantage is the close bond established between the company and consumer and the opportunity to keep out the dealer who will eventually try to install an isolated plant. The company's attitude should be that while it will uphold reasonable prices it is only in the business for the protection and advancement of its own interests. (S. Morgan Bushnell; John F. Gilchrist; Augusta Railway & Electric Co., 1904.)

SECTION XXII.

Contracts and Rates.

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LIGHTING.

Discrimination.—When operating company owns lamps and furnishes renewals, it is desirable but not practicable to discriminate in meter rates for different types of illuminants.

Sliding Scale.—In a town of 20,000 inhabitants, a sliding scale seems to be good, is the general opinion; but a demand system of charging would probably be more equitable.

A system of rates that is generally being adopted by lighting companies is the demand system in some form; either the Doherty rate or some other form. A sliding scale rate is also largely used. The flat meter rate is used in most cities for at least a part of the consumers. Flat rates for special purposes are desirable, when the company controls time for turning on and off.

A long-hour small consumer should have a better rate than the short-hour large consumer, especially where the consumption of the large consumer comes at the peak of the load. It is very often hard to follow an equitable principle when considering the question of better rates, on account of special conditions and competition.

For commercial service, a rate of 10 cents per kw-hr. is generally justified in any size town. A rate of 5 cents per kw-hr. is justified only with large and long-hour consumers, and a rate of 3 cents per kw-hr. is practically never profitable for lighting consumers.

Where a motor-generator set is installed by a power customer, so that he may receive his lighting at the power rate, the difficulty should be overcome by the operating company, either by a special lighting rate, depending on conditions, or a maximum demand power rate charged. Most companies prohibit such an installation.

Moore Tube.—It is the general opinion that Moore tubes should not require a higher rate than other forms of illuminants. This fact is on account of the inability of an electric company to make different rates for different illuminants.

Nernst Lamp.—In charging for service where Nernst lamps are used, it is customary to charge for energy on a meter basis, the same as for other forms of illuminants; especially in commercial service. For street lighting, however, a flat charge is generally made in the same manner as for an arc system. In commercial business, flat rates are sometimes given where the company owns the lamp, but seldom where the consumer owns it. Meter rates are more equitable.

In summer resorts, rates should be from 25 per cent. to 50 per cent. higher than all year business.

SPECIAL POWER.

Rates.—From 1½ to 3 cents per kw-hr. is the varied charge for power to consumers with an average of 2,000 to 3,000 kw-hr. consumption per month.

The average amount paid per hp-year for 0.80 to 1.00 load factor business on single-phase load is approximately $15.00 per year for 5-hp. motor and $30.00 per year for a 7½-hp. motor.

Power vs. Light.—Power consumers should have a lower rate than light consumers, because the business helps to improve the all day efficiency of the plant. It does not add proportionately to fixed charges, maintenance, attendance, etc. The business may come on the peak load, but it also comes when the load is not anywhere near the peak. The diversity in time of maximum demand among power consumers is much greater than light consumers, consequently the valleys in the peak should be more equalized.

Demand.—The most accurate commercial method of ascertaining demand on polyphase installations, if the power schedule is based on a demand charge, is to use a Wright demand meter on each phase or by counting revolutions of the disk of a watt-hour meter and taking an average of 10 one-minute tests. Take tests periodically. Some companies figure the demand on actual equipment.

Break-Down Service.—There are various rates charged for break-down connection to consumers operating isolated plants. One company charges regular rates, with a maximum of 10 cents per month per 16-candle-power lamp, or its equivalent, connected, on one year contract. Another company charges a minimum bill of $1.00 per kw. of equipment rating; never less than $5.00—then a high rate for use during peak load and a low rate off peak.

Night Service.—In a small residential town, night service alone is more profitable, and a possible small power load should not be worked up, especially if it overlaps the regular lighting load. In a manufacturing town conditions might exist where the power business would be larger than the lighting business, and in such a case should be looked after. It would all depend on conditions. The power rate would depend on operating expenses and hours of use.

Refrigerating plants are generally given a low rate on account of their high load factor, although they usually overlap the high peak on Saturday nights.

Rates—Water-Power.—In the New England States, where a plant is run by water-power, the general experience has been that the lowest profitable rate to charge is from 2½ to 3 cents per kw-hr. Where a steam plant has to be kept in readiness this figure is just a little low.

HEATING.

Special Rates.—Most companies are not making special rates for energy used for cooking and heating. This may become justified when the use of such equipment becomes large enough. Extra meters would be required with special rates, and the amount of additional revenue would have to be taken into consideration, to determine if the special rate be justified. In the industrial field, lower rates and separate meters are usually necessary. Heating devices are sometimes connected to power circuits. Some companies combine the wattage of utensils, reduce it into horse-power, divide it by two, and rate the cooking outfits as if they were power.

Competition with Gas.—It is practically impossible to compete with dollar gas, from a cost point of view. Energy would have to be sold for about 1 cent per kw-hr.

DOHERTY OR DEMAND RATE.

The Doherty rate is a rate outlined several years ago by Mr. Henry L. Doherty, and was based on Mr. Doherty's idea that each consumer should pay his portion of expense incurred and thereafter receive energy at a fair profit to the company.

It is essentially a combination flat and meter rate. The combination is effected by three considerations; first, a yearly demand charge; second, a fixed consumer charge; third, a charge for energy consumed. These are described in detail, as follows: 1. A yearly demand charge, regulated and fixed according to the hourly maximum demand of appliances or lamps connected; which charge takes care of all fixed expenses of the company, such as are occasioned by the installation of proper distribution systems, interest on investment in these, taxes, depreciation, etc. 2. A fixed consumer charge, to cover such expenses as are occasioned by investment in installation, maintenance, removing and reading of meters; billing, collecting, office work, free work, etc. 3. A charge for energy or gas representing the consumption, which covers all items, varying in proportion to consumption, such as fuel, boiler room expenses, labor, renewals, repairs, etc.

These different charges may, and do vary in different cities, according to existing conditions.

Where the Doherty rate is used, a systematic count can be made periodically of lamps or equipment, to see that contract maximum demand is not being exceeded, or an automatic controlling device can be used to limit the maximum demand. There are several automatic controlling devices on the market, which can be installed at a reasonable expense.

The Doherty rate has been proven to be practicable for cities of all sizes. It has been used, and is used, in towns of 3,000 population up to the largest cities in the country.

There is no known instance where the Doherty rate has proved a failure, once having been tried. The only objection offered by anyone to this rate is the fact that it appears complicated to a consumer when first presented to him, but after a consumer becomes educated as to what the rate actually does for him, he is satisfied.

The Doherty rate has been applied to power consumers. The basis of computation in one city is $9.00 per consumer per year, plus $24.00 per hp-year, plus 2 cents per kw-hr. for energy consumed. Another city has a charge of $12.00 per consumer per year, plus $24.00 per hp-year, connected, and 3 cents per kw-hr. energy consumption. The maximum monthly charge per consumer is fixed by the number of 16-c-p. lamps connected, or other equipment, figured on an equivalent basis. The structure value of stations should enter into the costs, besides the meter connections and other operating expenses.

We can most equitably allow for increased investment required to serve customers with a poor power factor, by a system of cost based on a readiness to serve charge, plus a production charge.

Maximum Demand.—Where a maximum demand meter is installed, some companies figure bill on demand shown for a particular month, and some on total demand shown for the year. The latter seems to be the more general. Where a maximum demand meter is not installed, the demand, in residences, is figured on some portion of the total actual installation, but under no circumstances, on less than one-third of the installation. In commercial business, the maximum demand is obtained by a count of the whole equipment.

Where a power rate is composed of a primary charge for a certain use of maximum demand and a secondary charge for excess current, the best way to protect a company against a small use of the demand for a large installation is to charge a heavy minimum, independent of the rate. On power installations it seems to be more equitable and easy to charge a demand on rated horse-power of motors rather than on maximum demand, as shown by indicators.

In the demand system of charging, the maximum should not be a nominal sum for all consumers, but should be made proportional to the consumer's maximum demand. This is one of the main points of any demand rate.

The demand system of charging has had a good effect on load curve. The increased consumption resulting from its being understood by consumers will eventually justify a reduction in base rate.

SLIDING SCALE.

A sliding scale can be justified by decreasing cost of distribution as consumption increases.

Discount for increased average daily use per lamp is justified by the greater economy of operation. Railroad rates are regulated by an Interstate Commerce Commission, but an electric company is more under the jurisdiction of municipal authorities, and at present there is no law forbidding a sliding scale of rates. However, there are apt to be such laws at any time. A sliding scale is better if it is based on the ratio of consumption to size of installation.

TWO RATE OR EXCESS.

One two-rate plan of charging is 7½ cents per kw-hr. on the first and second hours' use of equipment, figured on a 26-day month for power and commercial lighting and a thirty day month for residence lighting and 5 cents per kw-hr. for the third and fourth hours' use, and 2 cents per kw-hr. for the rest of the day. The rate for power should be lower than that for light, especially if it is day consumption. The lower charge should be based on operating expenses alone, although in some special cases the lower charge would vary with output and should be figured accordingly. The main objections to this system seem to be that it does not follow absolutely the cost; also it would be difficult to make a customer understand and be satisfied with it. One company has tried a system of two rate charging for power by giving a low rate during the day and a very high rate when the business overlapped the peak. Some companies using the two-rate principle, fix the number of hours to charge a high rate by the number of high peak hours as shown at the plant in an average month. If the high charge in the two-rate plan is occasioned by the fixed charges of the plant, these charges may be determined by dividing the annual fixed charges by the sum of the maximum demand of the consumers, measured in kilowatts. The result will be the proper charge to make per year per kilowatt of maximum demand. Dividing by 365 would give the charge per day. The high rate number of hours would depend on conditions of profit.

MINIMUM.

The ideal basis for a minimum charge seems to be the maximum load. Small or moderate size stations cannot afford the installation of maximum demand meters. In that case, the minimum could be based on lamps installed, or their equivalent. Some companies take a percentage of lamps or equipment installed for residences and actual installation for business houses, and base the minimum thereon.

Theoretically, the minimum should be based on the cost of maintaining service for any certain consumer, but it is not always practicable. Some companies have a fixed minimum for residence consumers. Meter rents should be included in minimum bill.

Each consumer should be required to consume enough energy so that the profit on this amount will at least cover the interest and reading of meters and other such expenses. Every consumer should guarantee a monthly minimum; otherwise, some portion of his costs would be met by some other consumer, which is unfair.

Consumers who will not agree to paying a minimum usually are not profitable. To avoid discrimination, a minimum charge should be made to consumers supplied from a bus line as well as from separate transformers.

Under the two-rate or excess plan, some companies fix the minimum by figuring the consumption of equipment on maximum demand for a time equal to the average peak load time.

DISCOUNTS.

Opinions are divided as to the point of having a high rate per kilowatt-hour with a liberal discount, or a low rate with a small discount. The arguments for the high rate are:

That what the consumer gets off a bill rather than what the net bill is, is what impresses him most. A high rate enables a company to favor desirable consumers.

Arguments for the low rate are that consumers comparing rates with other cities, see the high part only and do not consider the discount.

A large percentage of the arguments against excessive rates is based on the gross rate. Conditions of electric supply and cost vary greatly in different parts of the country, and it is practically up to these conditions as to whether the high rate or low gross rate is better.

When in close competition, it would not be well to make special discounts during the season of long lighting hours, but rather have an automatic system of rates that would take care of this point, such as the Doherty system of charging. It is a good plan to give discount for prompt payment before a fixed date; the result simplifies accounting and collections.

There should be a fixed discount for all consumers for prompt payment and no variation according to consumption. The primary rates should take care of the difference in rates occasioned by difference in consumption. It is theoretically better to have fixed rates and adhere to them, but special cases come up which have to be taken care of where special discounts have to be based on individual conditions and requirements. Special discounts, however, cause a great deal of controversy and should be carefully considered before they are given.

A special discount should not be given where a customer is using small heating appliances or motors, with a consumption not large enough to warrant a separate meter. The appliances should be put on the lighting circuit and charged lighting rates: In some cases consumers are willing to pay a large enough minimum to warrant taking the business.

It seems to be best that motors of all sizes should get the same discount for the same hours' service. A demand rate takes care of this point. However, on account of elements of competition that enter into the large installations, the larger motors are given larger discounts by most companies.

PENALTIES.

Regarding the advisability of charging a 5 per cent. penalty for non-payment of bills within 10 days from date, J. T. Cowling, R. Louis Lloyd and the Augusta Railway & Electric Co., found it to be illegal. R. V. West and S. R. Inch strongly advocated a cash discount of from 5 to 10 per cent. for prompt payment. Douglass Burnett advised the elimination of bad accounts while W. H. Zimmerman alone held for the penalty which he set at 10 per cent. (1905).

FLAT RATES.

Meter rates are much more desirable than flat rates in any size town, in all classes of business, except for commercial lighting, where a circuit is cut in and cut out at a certain time each night, either by the company or by automatic devices. In some small towns the large consumers are put on a meter and the small ones on a flat rate. This is owing to the company not wishing to make the investment in meters and other incidental expenses. A fair rate for this class of business is 75 cents per 16-candle-power lamp per month. Under 5 lamps it rarely pays to meter consumers in small towns. It is unwise to make a flat rate to any consumer on what he declares conditions are.

Flat rates should never be used unless there is some kind of arrangement for cut off.

Flat rates are advantageous in display or decorative lighting, also in municipal arc lighting or in any case where the company can get long-hour use and have control over the lighting and shutting off of the equipment.

MUNICIPAL RATES.

In figuring on difference to charge when an underground circuit is to be used instead of the overhead circuit in municipal arc lighting, consider the additional investment per lamp required and take 10 per cent. of this amount, which should represent about the additional revenue to be secured for each lamp, over and above the amount usually charged for lamps fed from an overhead system. From $56.00 to $150.00 per arc per year is about the range of charges for municipal street lighting in this country.

In changing from an all-night schedule to a moonlight schedule, the only saving which can be figured for the station is a saving in fuel, and a slight saving in the maintaining of lamps. Adjust rates for change accordingly.

ARC LAMPS.

The rate per kilowatt-hour is lower on series arc systems flat rate than the same service on the multiple system, because the hours of burning are known and fixed in advance on series arc systems. Multiple arcs are likely to be burned during the peak only; series arcs burn longer hours and the load is constant and determined in advance. Over-time arc service is given by some companies, where a flat rate is maintained for certain hours and if further use is required it is obtained by a double-throw switch in a switch box, one side of which is connected to a switch in the building, operating the lamps through a meter. The lamps are thus always on the direct circuit or on the meter circuit. The customer is billed for the contract price and also for any other consumption as shown by the meter.

DISPLAY LIGHTING.

It is good practice to take signs on flat rates and operate a time switch, or preferably, have a patrolman to turn them off at the proper time. Patrolmen are considered better than time switches on account of reliability. If signs are on meter, the revenue will not be as much. Rates can be figured on comparison with regular rates of company, on a six hour basis for the whole year. Flat rates are given on signs, window lighting and outlining burning until midnight. This plan induces long-hour consumption and broadens the peak load.

One company figures in making flat rates on display lighting, 6 cents per kw-hr. Another company figures the installation on a 6-hr. basis, with the readiness to serve rate as a means of arriving at the charge.

A uniform rate for different cities for national advertisers has been suggested, but nothing done as yet. Business is secured now mainly by correspondence on different rates, depending on the individual city. One company has sent its sign representative through the country, calling on the large national advertisers, with excellent results.

Some companies give signs free and install window lighting and outlining free, on condition of a 2-yr. contract on flat rate for 6-hr. burning per day.

STORAGE BATTERY RATES.

Some companies take this business on power rates; some have a flat meter charge of 5 or 6 cents per kw-hr. In residence districts the charging must not be done during peak load time. A minimum is usually charged, figured on the same basis as a power minimum.

One company has a sliding rate on this business, where the amount per kilowatt-hour is determined by the amount of consumption each consumer guarantees per month.

OFF PEAK BUSINESS.

Some companies find it necessary to make special discounts in securing off peak business, such as isolated plants, storage battery charging, signs, window lighting, etc., but usually this class of business can be obtained through the use of some form of the demand system of rates. This works especially well, as the business is usually long hour.

Where a consumer uses electricity all day at regular rates and desires to use it all night also, it is not necessary to install two meters to give him an equitable cheaper rate for his additional consumption; a demand system of charging, such as the Doherty rate will automatically give him cheaper rates for the additional business. Thus, for the day use he would pay the fixed charges, plus the production charge; for the night use he would pay only the production charge.

RATES IN COMPETITION.

During the season of long lighting hours, it is not well to make special discounts over the ordinary discount offered during the season of short lighting hours simply to compete with other illuminants. A rate based on demand would operate automatically and give cheaper service during the long hour season.

In competition with gas, city for city, gas is undoubtedly cheaper, candle-power for candle-power, when most forms of electrical illuminants are considered. Get business by showing advantages of electricity. A severe cut in rates to meet competition is not valuable in the long run.

Some electric companies claim that they can compete with gas at $1.50 per thousand, with electricity at 11 cents per kw-hr.

Considering actual cost for power, electricity at 1½ cents per kw-hr., competes with natural gas at 27 cents per thousand; from the same point of view, electricity at 2 3/5 cents per kw-hr., will compete with gas at $1.00 per thousand, figuring 20 cu. ft. per hp-hr.

No special rates are necessary to compete with gas engines in power work. Ordinary rates, unless they are exorbitant, as compared with gas, will get the business. The actual cost is usually more, but the simplified form of getting power will more than offset the difference in actual cost.

MISCELLANEOUS.

In changing from flat to meter rates, where flat rates have been the system of charging, first determine on some meter rate fair to both consumer and company and then put it into effect and adhere positively to it. Notify consumers of change and give reasons.

The spring is the best season to make the change. Explain to consumers that each one under the new system is to get exactly what he pays for. If solicitors are employed, it is best to make use of them in making the change. A personal explanation will be more effective than notices.

Some companies have not changed completely from flat rate to meter rate but have reduced the flat rate and then made an additional charge for energy consumed.

It is possible to develop a system of charging where every consumer would pay prices proportional to his individual costs within an error of 10 per cent., but it could not be universally applied.

Companies generally do not charge a meter rate in addition to price for energy consumed, but agree on the point that the minimum should be large enough to take care of meter investment and maintenance.

It is well to combine energy registered from the same service but on different meters and put the consumption on the same bill, with a consequent lower rate for the consumer, but this rule should not apply to energy consumed at different localities.

Some undesirable business will always be on the books, and apportioning charges where they belong does not restrict output; it certainly increases it. A community, as a whole, probably cannot adopt such a system, but ought to get as close to it as possible and as far away from the opposite method, namely, a universal flat rate.

Objections to schedule such as follows:

Guaranteed	avg.	use	of	4	hr.	daily	per	lamp,	8	cents	per kw-hr.
"	"	"	"	5	"	"	"	"	7	"	" "
"	"	"	"	6	"	"	"	"	6	"	" "
"	"	"	"	8	"	"	"	"	5	"	" "

With the guaranteed amount of energy monthly specified in contract, power and light to be reckoned on a 16-candle-power basis.

Would discourage proper installations. The consumer will not install as many lamps as he requires.

Might premiumize undesirable business, being on a monthly basis. In a winter month a consumer would use a large quantity of energy and would receive a low rate. In summer his demand would remain the same, but the company would receive very little according to demand. Schedule is high for long-hour power users. but good if it can be secured.

Rates to Employes.—Employes should have electricity at cost of manufacture. Some companies give employes light at power rates and encourage lavish use for advertising purposes.

Literature.—Below is a list of interesting articles on the rate question and on cost, arranged in chronological order.

"Cost of Electricity Supply," Arthur Wright, 1896. Municipal Electrical Association, England.

"Charging for Electric Current on the Wright Demand System," R. S. Hale, 1896. Electrical Engineer, October 21st.

"Profitable Extensions of Electricity Supply Stations," Arthur Wright, 1897. N. E. L. A.

"Public Lighting in Relation to Public Ownership and Operation," Alex. Dow, 1896. N. E. L. A.

"Equitable, Uniform and Competitive Rates," Henry L. Doherty, 1900. N. E. L. A.

"Some Principles Underlying the Profitable Sale of Electricity," Arthur Wright, 1901. Institution of Electrical Engineers.

"The Four C. System," L. R. Wallis, 1901. N. E. L. A.

"Rates," Henry L. Doherty, 1901. Northwestern Electrical Association.

"Presidential Address of Henry L. Doherty," 1902. N. E. L. A.

"Results Obtained from the Use of the Wright Demand System of Charging," John W. Ferguson, 1904. Association of Edison Illuminating Companies.

"The Boston Rate System," A. S. Knight, 1904. Association of Edison Illuminating Companies.

"Graded Costs of Electric Supply," Mathias E. Turner, 1904. Ohio Electric Light Association.

"Preliminary Draft for Report of Committee on Rates and Costs." N. E. L. A., 1905.

"Report of the Committee on Cost Determination," 1905. Ohio Electric Light Association.

"Maximum Demand," J. S. Codman, 1905. Electrical World and Engineer, September 23d.

CONTRACTS—FORMS AND SPECIFICATIONS.

Street Lighting.—In one city provisions in existing contract for tests on arcs or incandescent lamps for street lighting for a municipality are as follows:

"The company agrees that the city may, at all times, with or without the company's knowledge, employ a competent person to test the electric currents or energy furnished to any or all of said lamps, and to examine and test the street lamps to ascertain whether or not the company is complying with terms of the contract, and for such purpose, the company agrees that such competent person may have access, at all reasonable times, to all said lights, poles, wires and fixtures of the company in the streets and other public places in the city and used in the carrying out of the contract. The city agrees to indemnify and save harmless the company against any and all claims for damages, loss, cost and expense on account of injury to persons or property arising in any way out of the employment, act or neglect of such person."

In another city arc lamps are tested by the city by ammeter in circuit and voltmeter across the lamp terminals, lamp having been specified in these terms as corresponding to certain watts consumption.

In contracts for incandescent street lighting, a company should not specify time of renewals of lamps, if it can be avoided. As to guarantee of candle-power, specifications vary from 4 per cent. initial tests difference to 20 per cent. difference. Some companies specify number of renewals that will be allowed during a year. In one instance, company is limited to a minimum of 24-c-p. initial tests on 25-c-p. lamps. In another case, company agrees to renew lamps whenever the candle-power falls below 80 per cent. of the normal.

A contract for incandescent street lighting should specify the average candle-power instead of initial candle-power. Candle-power of street lamps can be tested in position by mounting photometer on wagon and testing the lamp in actual service.

In wording a contract for street lighting, watts per lamp should be specified instead of the candle-power. A good sample of contract covering this point is as follows:

"The arc lamps shall be of the 6.6 ampere alternating-current enclosed pattern, requiring an electrical power of 422 watts on an average and not less than 410 watts in any case." Some companies use the watt basis but add words 2,000-c-p. or 1,200-c-p. nominal or so-called.

The following is suggested as a good way to define candle-power or size of lamps furnished under municipal contracts: "The arc lamps shall be of the——type, and shall have a capacity of——amperes with a difference of potential of——volts between the terminals, and shall require for their proper operation not less than——watts in any case; said electrical power to be measured between the terminals of the lamp."

General Customers.—A short form of contract for electric service to general customers is more satisfactory than a long form, giving all details. One company has a short form in which the consumer receives and acknowledges the receipt of a printed form of the rules and regulations of the company. These contracts should also specify that the consumer agrees to abide by the rules and regulations. In all contracts, the general conditions should be stated briefly and as clearly and precisely as possible, to give the company protection in the event of legal complications.

Definite Term.—It is the general opinion that there should always be a definite term for all contracts. In case of competition, long term contracts are the best to take, although there is a question as to whether they will hold good with the consumer. The moral effect is good at least. Long term contracts discourage prospective competition. One company aims to renew contracts from time to time, even though competition is not threatened. Contracts usually run for a minimum of one year and in cases of a wholesale rate on large consumption, they are made for five or six years.

Desirability of Contracts.—Not many electric companies are now attempting to furnish electric energy to consumers without a form of contract being signed by the consumer. It is always better to insist on a contract being executed and that the charge be made in accordance with the contract. If consumer desires to use service without contract, it can be explained that there will be no basis of charge and that some question may arise as to the proper method of charging. It is best to make all contracts for a year at least and have it understood that in the event of removal or for such other cause as may possibly prevent consumer from using the service, contract may be cancelled at his wish.

Legalty of Contracts.—It is not advisable to test legality of lighting contract, principally because of the consequent notoriety of the suit and the fact that the resulting newspaper publicity concerning apparent profits, would be damaging to a company. It may be possible to hold consumer to contract, if damages are shown, but books would have to be brought into court, with the above result. The result of a contract from the nature of our business is a good moral effect rather than a legal obligation. It seems best, therefore, to not attempt to enforce contracts by process of law. A contract should be a simple and distinct understanding between the parties thereto, and it should be flexible enough so that should unforseen circumstances arise beyond the control of either of the parties, there might be some method of arriving at proper agreement without going to law.

Checking of Contracts.—When customers, who are on some form of a demand contract, install more lamps without notifying the company, the company should take some steps for protection. Some companies install Wright maximum demand meters for a means of checking installations fixed by contract; others make periodic counts of equipment either once or twice per year. Sometimes added installations can be caught by the noticing of a sudden rise in bill without apparent reason; also a fixed minimum can be made and whenever the rate falls below that minimum a re-check can be made and contract changed as the check indicates.

Settling Disputes with City Contracts.—A fair method of settling disputes between cities and companies as to whether the company is actually supplying 2,000 candle-power or 1,200 candle-power lamps is to test lamps with a portable voltmeter, with the proper officials present. A standard 450-watt enclosed arc lamp should test up as a 6-ampere lamp at 75 volts, then the requisite number of watts (450) are secured. All lamp contracts with the city should be on a wattage basis. The terming of them in candle-power is obsolete because there is so much room for disagreement. If direct-current series lighting is used, a lamp consuming 490 watts with a clear globe, is approximately equivalent to 2,000 candle-power; in other words, an ammeter showing 9.8 amperes per lamp and average pressure across the lamp terminals of 50 volts.

Miscellaneous Contracts.—Most companies put out fans during the summer on flat rate contract. Some companies have considerable winter business also for keeping windows free from frost, circulating air, etc. It is customary sometimes to rent fans at an additional rental over the regular flat rate. From $2.00 to $3.00 per month is the range of flat rates. Business is more profitable when taken on a flat rate contract than it is when placed on a meter, although many companies have not yet taken up the flat rate method.

Some companies using prepayment meters do not require a contract to be signed, but most of them do. One company at the time a meter is to be installed asks a consumer to sign a contract which allows the consumer to discontinue service at any time, and also allows the company to remove the meter and lamps and to cancel contract at any time the consumer fails to deposit in the meter a sufficient amount to warrant the maintenance of the service.

SECTION XXIII.

Accounting and Statistics.

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Accounting and Statistics.

GENERATING AND SUBSTATION.

Operating Records.—A proper list of operating records for use in analyzing the operations of a steam plant, would be, daily records of all supplies such as coal, oil, waste, grease, etc., water if purchased, or as a check upon evaporative results.

Records of pressure, temperatures and vacuum, by recording gauges. Records of engine and boiler service with a chart showing the load in relation thereto at least once a week.

Chief to carry his own log book, showing all work done, all troubles, cause and remedy.

See 1905 Question Box, Page 479, for samples. (F. B. Sharpe, 1905.)

Diversity Factor.—Defining the diversity factor as that number by which the sum of the consumers' maximum loads must be divided in order to equal the actual observed maximum load on the station, then the best way to get the diversity factor would be to have a maximum-demand meter for each customer, and from the sum of the maximum-demand readings and the actual observed maximum output of the station, compute the diversity factor. The consumers' maximum-demand meter can be dispensed with where the installation is such that the maximum load can be estimated. (C. C. Bishop; R. S. Hale, 1909.)

Power-Factor.—Voltmeter reading times ammeter reading equals apparent watts. Indicating wattmeter reading equals true watts. Power-factor equals the true watts divided by the apparent watts. (W. O. Haymond, 1907.)

See formulas, 1907, Question Box, pages 306-307. (H. L. W.; C. E. I. Co.; John Cyrus Distler, 1907.)

Load-Factor.—The load-factor of a station may be figured in four different ways, depending upon what the figures are to be used for. By taking the ratio of the average to (1) the absolute maximum kilowatt, (2) the average daily maximum kilowatt, (3) the kilowatt-rating of the plant, including spare units, and (4) the kilowatt-rating of units operated during the period considered. The load-factor probably most commonly used is the ratio of the average load to the highest maximum during a period of one year, but it would be better to state the components of the ratio and the period covered whenever the term "load-factor" is used. (E. J. Fowler; B. E. Morrow; B. J. Denman, 1907.)

DISTRIBUTION SYSTEM.

Arc-Lamp Repairs.—In keeping account of arc-lamp repairs, lamps repaired in the shop are charged to one account number, and repairs made on lamps in service to another. The total cost is divided by the average number of lamps in service during the month or year to get the cost of repairs per lamp. Globes and carbons are also charged to separate accounts in order to find quickly the cost per lamp of either. (P. J. Smith, 1909.)

Keep only the cost of repairs per lamp per year and do not keep individual lamp costs, but divide the annual cost over all lamps. (A. C. Bostwick, 1909.)

Meter Record.—Each meter on its purchase should be given a company's number and badged. A meter record book should be kept, showing the company's number, manufacturer's number and the necessary data regarding the type and rating of the meter. Every meter should retain the company's badge until condemned or destroyed, when the badge should be removed and filed, not being used again. Every meter should be accounted for in the record book, either as set, in stock, away for repairs, or destroyed. (A. T. Beauregard, 1906.)

Use the card system—one card for each meter. The cards are numbered consecutively to correspond with given numbers of the meters, not the factory number. On each card is space for the factory number, make, constant, size and date received, also space to show a record of tests, dates of same, by whom tested, location of meter, and change made in re-calibration (D. W. Beaman; C. E. Inman; T. H. T. & L. Co.; E. C. Deal; Philadelphia Electric Co., 1906.)

Tranformer Record.—A convenient method of keeping a transformer record is to use the card system, having a feeder index and a numerical index. In one case the cards for each feeder are grouped together, while in the other each make of transformer is grouped and the cards are arranged numerically. See 1905 Question Box, page 476 for forms. (A. C. Greenman, 1905.)

Connected Load Record.—Connected load can be conveniently carried in a specially ruled book dividing the business into the various classes, such as arc, incandescent, power, incandescent arc, etc. Names and load of each customer entered from the installation slips, in black ink.

Names and load of customers going off the system entered from the slips showing disconnection and cause, in red ink.

Enter the loss after those gained, subtract the amount and carry the balance ahead the same as any other entries. (Philadelphia Electric Co., 1905.)

In connection with the engineering department, have a series of cards showing the connected load on each feeder, and each transformer. When a house is connected the amount of installation is posted to the feeder record, the transformer record, and a card arranged for the house, so that records at all times will show the connected load on each feeder and transformer, and also the installation at the house. When house is disconnected, this amount is deducted from the load on feeder, and transformer. (Frank W. Frueauff, 1905.)

Distribution Losses.—To ascertain the various distribution losses, meter the total output of station, the output of each feeder, and the consumption of each customer. This will give the total losses for each circuit; the transformer and meter-shunt losses are readily secured, and the line losses can be closely approximated. The balance of the loss is that due to slow meters, theft of energy, etc., and represents the preventable loss. See 1906 Question Box, page 434, for form. (S. R. Inch, 1906; G. Wilbur Hubley; J. H. Hallberg; W. T. N., New York Edison Co., 1904.)

COMMERCIAL OFFICE.

Consumer's Ledger.—Loose-leaf ledgers are preferable to a bound ledger for keeping customers' account for the following reasons. More flexible than the bound book. Expedites the bookkeeper's work. More easily balanced. Monthly balance is much simplified. Accounts are more easily followed, which assists materially in their collection. The placing of new or additional customers' names in geographical order, or in the order that meters are read, which is the main feature of merit in connection with the card system, can not be accomplished with the bound book system, but may be very nearly so with the loose-leaf system, especially if the system adopted embodies all of the features that an up-to-date loose-leaf system may and should possess; among such features being the horizontal monthly balance idea, a means of carrying balances forward to the next page without turning same, provisions for making a number of changes of customers' names in the same account space, at the same address, and the possibility of placing additional customers' names in geographical order, or, in any event near enough for all practical purposes and without detriment to the system. Such a system embraces all of the desirable features as to security, etc., of the bound book (which is lacking in the card system) with the additional desirable features that the bound book does not possess. (L. M. Wallace; Douglass Burnett; W. T. Nolan, 1909.)

Loose-leaf ledgers may be used for keeping customers' accounts, and they are preferable to cards, but not to bound ledgers. A bound book gives a permanent record which can not be tampered with without disclosing the fact. (P. S. Young, 1909.)

Card system of bookkeeping is vastly superior to the old method of keeping consumers' accounts in a series of ledgers. There is a saving of 27 per cent. in actual cost of cards over the books formerly used. (Geo. B. Tripp; Geo. L. Colgate, 1904.)

After using card-ledger system four or five years for consumers' accounts, same was closed, and transferred to loose-leaf ledger. After using loose-leaf ledger for two years, the old bound book was found to be preferable and accounts were transferred to that. (Little Falls Water Power Co. of Minnesota, 1904.)

In a company of any size time will be saved in having the ledger written up to follow the meter reader's route. (P. H. Korst; Clayton Geiger; H. J. Meyer; F. Ellwood Smith; Fred M. Lege, Jr.; Douglass Burnett; Alex. J. Campbell; J. W. Clapp; T. J. Walsh, 1905; Frank W. Frueauff; Geo. E. Burns; P. S. Young; G. H. Cushman; F. C. S., Malden Electric Co.; R. N. Kimball, 1906.)

The alphabetical order of consumers, will be found the better arrangement for companies where consumers number from 1,500 to 2,000. (S. H. Smith, 1906.)

Flat rate and meter consumers should be kept together regardless of class or service. (J. R. Shurtz; Geo. E. Burns, 1906.)

Flat rate consumers should be kept in the back of the consumers' ledger in alphabetical order, with a note of the page and line on which their meter charge appears. (S. H. Smith, 1906.)

Meter Constants.—The following brief explanation and comparison will be of service in dealing with the question of meter constants with the customer.

A too rapid movement of the disk in the meter would introduce mechanical troubles as there is a speed limit to any mechanical construction. To insure a long life of the jewel bearings, the disk should not make over 50 rev. per min. at full load. The disk of a 60-lamp meter makes exactly the same number of revolutions per minute, at full load, as does the disk of a 30-lamp meter. It is, therefore, evident that while the dial will record at full load exactly the same amount as will the dial of a 30-lamp meter at full load, yet double the energy has passed through the 60-lamp meter, and therefore, in a 60-lamp meter, the dial reading must be multiplied by 2 to get correct consumption. All energy consumed passed through the meter. The dials record in inverse ratio to the constant. For these mechanical reasons, and to reduce the manufacturing cost, the meters and dials are built of standard sizes, with proper calculations for the proportional amount of energy registered, which accounts for the use of the constant.

Make a comparison with a pair of beam scales on which are used different weights such as 1-2-3 pounds, and so forth, the arms or levers remaining standard, and the size of the weights varying with the load. (Paul Lupke, 1907.)

On page 51 of the General Electric Company's catalogue No. 3197 it is shown that the speeds of the 7.5-amp. and the 15-amp., 220-volt, three-wire Thomson watt-hour meters are each 27.5 rev. per min., or 1,650 per hour at full load. If 7.5 amp. at 220 volts are passing through the meter for one hour, then $7.5 \times 220 = 1{,}650$ watt-hours; therefore, one revolution of the disk of the 7.5-amp. meter is equivalent to one watt-hour. In the case of the 15-amp. meter it will be seen that 15 amp. for one hour at 220 volts equals 3,300 watt-hours, or one revolution of the disk is equivalent to two watt-hours. Inasmuch as the dial mechanism of these two meters is exactly the same, it would follow that the dial indication of each would be the same, namely 1,650, although double the amount of energy has passed through the 15-amp. meter as through the 7.5-amp. meter. It is, therefore, necessary to multiply the dial reading of the 15-amp. meter by the constant of 2 in order to obtain the correct amount of energy. (Philadelphia Electric Co., 1907.)

Record of Orders.—Each class of order should be designated by paper of a different color. Orders to be in book form, numbered consecutively, with an original, duplicate and triplicate for each number. The numbers contained in each book are printed on the front cover of the book and are used to account for each order. As orders are drawn, the original and duplicate are forwarded to the superintendent, the triplicate remaining in the book as the office record. The original order is retained by the superintendent and the duplicate handed to the foreman on the job. Upon completion of work the original and duplicate are turned into the accounting department, with memoranda concerning same attached thereto, and all information as to completion of order, meter number, and the like indorsed on the original. The order then goes to the meter index clerk, who makes proper entry in the index book as to meter, and from there to bookkeeper, who opens the account on the ledger. The order is then delivered to the order clerk, who accounts for it by stamping the triplicate copy retained in the book "Entered" and erases the corresponding number printed on the cover of the book. The order is then filed alphabetically, awaiting the coming through of the initial bill, but is not filed permanently until the first bill has been rendered to the customer. This method checks the rendering of every initial bill. The order clerk by referring to the first page of the book on which all serial numbers of the orders contained in that book are printed, can ascertain at any time the serial number of any order unchecked and outstanding. These unchecked numbers should correspond with the original orders held by the superintendent, and, as they are checked once a month, all orders are accounted for. Uncompleted orders are checked periodically with the superintendent. All books are indexed and can be readily referred to. (United Electric Light & Power Co., 1909.)

All orders should be made out in triplicate on order blanks. As orders are received they are entered in order book, with the name, address, nature of order, and a space for the date of completion. The original and duplicate are sent to the shop. The duplicate remains in the shop for permanent reference. (W. T. Nolan, 1909.)

Vest pocket memoranda slips have proven of great value. These should be carried at all times by all employes for use in reporting anything of importance that may come to their notice. See Bulletin, April, 1909, page 318, for sample. (Fred. C. Hand, 1909.)

Reading Meters—Delay.—Where repeated delay in reading meters is caused by buildings being closed on the first call, arrangement should be made with the occupants for a key to the building or room. Numbered tags should be attached to keys. Numbers should be kept by the company and a record kept of the keys furnished the different meter readers. (F. B. Owen, 1905.)

Mail the customer a return postal card upon which is printed a diagram of a meter dial, and request the customer to mark on this card the exact position of the meter hands and return to company. (F. Ellwood Smith, 1905.)

Cut off the service until an agreement can be made between company and consumer to read the meter by some means without delay to meterman. (Clayton Geiger, 1905.)

Communicate with the customer, either by telephone or letter, at residence or business address, if same can be ascertained. (W. R. B., New York Edison Co., 1905.)

Reading Meters—Continuously.—A station having 5,000 meters could read its meters continuously during the month with the services of one man, reading an average of 200 meters per day. Regular daily readings equalize the work of billing and bookkeeping, placing each business day on a basis that is uniform with every other day. (Douglass Burnett, 1908.)

A very satisfactory way is to use only two readers, who read continuously 26 days in the month. The customers being notified that bills will run from date of reading to date of reading, and the bill delivered two days after said reading. Each customer's discount limit is calculated from the date of meter reading. (Hartford, Conn., Electric Light Co., 1908.)

From a meter department standpoint, it is advisable to have one man read meters continuously. Taking the whole force for four or five days at the end of the month to read meters, cripples your testing and repairing too much. (Leadville, Colo., Light & Power Co., 1908.)

Meters should be read between the 18th and 25th of the month, which will give ample time for calculating all bills before the first of the month. (Wm. Rawson Collier, 1908.)

Reading Meters—Districting.—Meter reading laid out in routes. Meter cards are loose-leaf form, each class of service of different color. Customers' ledger written up in same order. Routes are so arranged that meter reader has to go the least possible distance from one customer to another, and are arranged without regard to feeders, or circuits. (F. C. S., Malden Elect. Co.; J. W. C., Edison Electric Illuminating Co. of Boston; J. J. Cagney; E. C. Deal, 1906.)

Reading Meters—Duplicate Readings with Customers.—The leaving of a duplicate reading of the meter with the customer constitutes another liability of error, unless the duplicate be a carbon copy (which is not easily obtainable if the original be a loose card or strong sheet intended to form a permanent record), and, if a discrepancy between such reading and the account rendered should occur, the possession of such duplicate would form undisputable evidence against the company. (J. J. Cagney, 1906.)

It would not assist to any great extent in eliminating complaint with the average customer. Should be left only on special request. (W. R. B., New York Edison Co., 1906.)

Duplicate reading should be left with customer, and customer should be encouraged to keep a record of his own readings for comparisons with ours. (Frank Beckwith; M. C. Turpin; W. H. Greenslit; A. O. Fretz, 1906.)

Rebates—Fast Meter.—When meter is found fast on the complaint of customer, rebate should be made only on the bill in question. (F. L. Leitner; C. W. Higgins; C. S. Jennings; L. Lauriat, 1909.)

Rebate should be made for three months previous to the time of test, the amount depending on what per cent. registration of the meter is found to be out. (G. D. Gratton, 1909.)

Four per cent. is the limit established by law in New York State, that is allowable before a rebate is made, for variation of a customer's meter from the standard meter. (C. G. Durfee, 1909.)

Rebate—Creeping Meter.—If meter has been found to be creeping forward, rebate should be made to cover overcharge. (W. H. C.; F. B. Sharpe; Charleston Consol. Railway, Gas & Electric Co.; Geo. B. Lauder; F. C. S., Malden Electric Co.; Douglass Burnett; L. E. Watson; A. F. Hall; E. A. Bechstein; O. J. Bushnell; C. W. Koiner; F. G. Proutt; J. W. Cowles, 1905.)

Rebate should be made, but customer should not be told it is the fault of the meter. Find some defect in the house wiring, a ground in the house, etc. (E. D. Kelley; Colorado Springs Electric Co.; A. Peters, 1905.)

Rebate should not be made. The amount of overcharge would probably be very small. An acknowledgement that meter crept would soon be a matter of discussion among a good many of your other customers. (C. H. Peters; A. R. MacKinnon; Edison Electric Illuminating Co. of Brockton, 1905.)

Slow Meter.—When meter has been found to be running slow, notify customer, so that if bills increase after meter has been recalibrated the cause will be understood. (Jas. E. Davidson, 1909.)

Meter Records.—Use a card system, giving name, address, number of meter, size, make, constant, date when installed and returned. Behind this in same file use a test card, showing date and kind of test, whether it be a complaint, special, periodic, etc. (Colorado Springs Electric Co., 1905.)

The company's books show a record of consumption, and a card for each meter should be arranged to keep a record of the meter with the number of revolutions it makes. (Augusta Railway & Electric Co., 1905.)

Arrange the customers' reading cards according to street and number in loose-leaf binders, with a card index. (O. J. Bushnell, 1905.)

Meter Readings on Bills.—Meter readings on bills give the customer confidence. (W. H. Banes, 1904.)

Give the customer every item of information concerning the company's charge for energy and encourage the customer to read his own meter and check his monthly bills, so as to satisfy himself of their accuracy, rather than to have any doubt concerning them. Any idea on the part of the customer that there is any secrecy or mystery concerning the company's meters tends to prejudice the customer against the company. (W. W. Freeman, 1904.)

In the majority of cases the customers pay no attention to the meter readings, in some cases, however, the statement of the meter readings seems to be a source of satisfaction to the customer. (A. S. Price, 1904.)

If a minimum charge is made, and the bill is below this amount, it is better to omit all readings. (C. H. Peters, 1904).

Meter Deposits.—In asking for a deposit, explain to the customer, that the company selling the energy can not collect for same until sometime subsequent to delivery, therefore the deposit is required as security for the payment for energy used. Where the customer has an established credit it is good policy to waive the requirement of a deposit. (P. S. Young; H. M. Bengler; C. A. L., New York Edison Co.; P. Ingalls, 1906.)

Where customer has service in both residence and place of business and has no established credit, he should either make two deposits, or make one in sufficient amount to cover both places. (T. H. T. & L. Co.; F. C. S., Malden Electric Co.; C. A. L., New York Edison Co.; P. Ingalls, 1906.)

Billing System.—Different forms of bills should be used for light service, power service, merchandise, wiring, etc., with different colored papers. Discount to be allowed should be specified on each form in a prominent place. One form for all items would be very unsatisfactory, in cases where discount might be allowed on any one item. Customer would be liable to take discount from the whole. (Chas. H. Peters, 1905.)

Billing—Deducting Discounts.—Percentage discount should not show on bills when made out. (Geo. B. Lauder; W. H. Banes; C. H. Peters; C. W. Hubley; Augusta Railway & Electric Co., 1904.)

Percentage discount should show on bills. (J. H. Hallberg; C. C. Gartland; F. C. S., Malden Electric Co., 1904.)

Bills should give customer full information concerning every feature of charge. (W. W. Freeman, 1904.)

Discount should be figured and deducted on the stub. (E. E. Larrabee, 1904.)

Bills are made out gross, discount and net, and so shown on ledgers. After time limit for discount, gross amount is charged. At the end of the month charge is made against customers who did not avail themselves of the discount. (J. T. Brady; E. H. Robinson, 1908.)

High Bill—Correct Meter.—In cases where meters are found correct, on test for high bill, a good-natured, convincing argument, and an invitation to an exhibition test of meter with fixed load will generally satisfy customer. (C. R. Price, 1907.)

Satisfactory results can be obtained by re-arranging lighting installation. (Bennington Electric Co., 1907.)

In some cases allow a moderate arbitrary rebate, stating distinctly that it is not done because of any question of the correctness of the bill, but because it is felt that a certain amount of give and take is better for all parties. (A. J. Campbell, 1907.)

Rebate should not be made, as same spreads to other customers, and they expect, and rightly, that they are entitled to a rebate. A lamp wired free, or a cheap reading lamp will often satisfy. (W. M. Lewis, 1907.)

Post card bills are in use by electric, gas, water, and telephone companies in our city, (Albert S. Price, 1904). Although it may not be illegal it does not seem desirable to give publicity to customers' private accounts, (E. H. Mather, 1904). However, there is a law against the use of post cards for "duns," (Editor, 1904.)

Computing—Maximum Demand.—The net bill where a two-rate maximum demand system is used may be calculated by taking the sum of the total kilowatt-hours multiplied by the low rate, and the kilowatt-hours at the high rate multiplied by the difference between the two rates.

For instance, if the rates are 14 cents for the first 30 hours' use of the maximum, and 8 cents for the remainder, the net bill equals, 0.08 × total kw-hr. plus 0.06 × kw-hr. at 14 cents.

Where a three-rate system is used an algebraic formula can be derived, For instance, if the rates are 10 cents for the first 30 hours' use of the maximum demand, 5 cents for the second 30 hours' use, and 3 cents for the remainder, where the low-rate kilowatt-hours are less than the kilowatt-hours at 10 cents, the net bill equals 0.05 (total kw.-hr. plus kw-hr. at 10 cents), and when the low-rate kilowatt-hours are greater than the kilowatt-hours at 10 cents, the net bill equals 0.03 (total kw-hr. plus 3 times kw-hr. at 10 cents). (G. E. McKana, 1907.)

Hollerith System of Tabulating.—Very satisfactory results obtained by the system in analyzing revenue. For the principle and diagram see 1906 Question Box Pages 424, 425. (V. A. Henderson, 1906.)

Very economical, making it possible to do with low priced female labor what formerly required high priced bookkeepers. It acts as a safeguard from a bookkeeping point of view, and affords the company a check on the work of the bookkeeper. It has abundant capabilities in the direction of the analysis of expenses. (H. M. Edwards, 1906.)

While there is no saving in cost of compiling earnings, much additional information can be obtained without cost. (F. W. Frueauff, 1906.)

GENERAL.

Water-Power and Steam Plants.—On a system operating several water-power and steam plants all connected to the same transmission line, steam plants being run over the peak load only, the best method of arriving at the cost per kilowatt-hour water-power as against steam, would be to charge each station with the cost of operating it, and credit it with kilowatt-hours output, then add to the cost of production by water, such amount of steam expense and attendance as would be charged for maintenance alone. Steam plants should be credited with amounts thus added to water-power cost. Substation and line expenses could then be distributed between steam and water on basis of recorded kilowatt-hours developed by each. (R. R. Laxton, 1906.)

Estimate labor and fuel expended at steam plants when not delivering current as stand-by expense. Deduct this cost from steam-plant operating expense and figure cost per kilowatt-hour on each class of power service according to output. Then to each figure of kilowatt-hour cost add the stand-by cost per kilowatt-hour, being the total steam stand-by cost divided by the entire output of all stations. This will give only an approximate comparison of costs. The actual costs per kilowatt-hour for use in making rates should be operating costs of all plants divided by the total output. (Herbert McNulta, 1906.)

Operating Expenses.—When operating both lighting and railway departments from one station, the most accurate method of accounting would consist of three separate and distinct departments; the station or manufacturing department, the lighting department, and the railway department; the station selling its output to the other two by meter cost; cost at the station should include all operating expenses, taxes, insurance, depreciation, and a portion of the office expense and superintendence. (Herbert McNulta, 1906.)

To determine operating expenses of lighting and railway departments, charge direct to the department concerned in so far as possible, and where impossible to do this, pro-ratio on a basis of kilowatt-station rating, kilowatt-hours, and gross earnings. (T. H. T. & L. Co.; R. R. Laxton; P. S. Young, 1906.)

Cost of Energy.—When calculating the total cost of energy delivered on the busbars, the following charges should be included; station operating expenses, such portion of the office and general expense as is chargeable to the station, taxes and fire insurance on generating plant, accident insurance on station labor, depreciation on station, and interest. (E. H. Mather; W. H. Banes; Chas. H. Peters, 1904.)

Plant or Betterment Account.—Plant or betterments are generally charged to construction. Such charges are closely scrutinized and only those expenditures which cover a bona-fide addition to the plant are so considered. A written description of all work planned, with an estimate of the cost, should be submitted upon proper form to the management, and after approval, be signed by the executive and given a job number. The account to be charged is determined at the same time. No expenditures should be charged to construction except through the job system; hence, at the end of any period, the company is enabled to make a construction exhibit by general accounts, and also by specific jobs under each general classification. (H. M. E., New York Edison Co., 1903.)

New Equipment.—When substituting new equipment for old or worn out, same should not be charged to capital. Charge should be made to repair account, and credit should be given this account for amount received from the sale of such old machines. A proper method would be to charge each month a certain amount to operation, crediting same amount to some contingent fund. (J. E. Tangway; A. Peters; F. Ellwood Smith, 1906.)

Capital account should only be charged with the excess cost of new equipment over the value on the books of that which it replaces. (P. S. Young, 1906.)

Discount on Treasury Bonds.—The proper name that should be given to the account to which discount on treasury bonds, as sold, should be charged, is "Unamortized Debt Discount and Expense," as prescribed by the New York Public Service Commission. It is a suspense account. Just before the close of a fiscal period there should be credited to this account, and charged to an account called "Amortization of Debt Discount and Expense," a proportion of such discount based upon the life of the bonds to maturity. The latter account is an expense account. Handled in this way the discount on the bonds will be all charged off in expenses by the time the bonds mature. If bonds are sold above par, the excess over par should be credited to an account called "Unamortized Premium on Debt," which is also a suspense account. Just before the close of a fiscal period a proportion of the premium based upon the life of the bond to maturity should be charged to this account and credited to an account callled "Amortization of Premium on Debt," which is an income account. The New York Public Service Commission does not permit the whole of the premium from the sale of bonds at more than par to be carried at once to an income or a surplus account. It does, however, permit a corporation at its option to carry the whole premium in the suspense account until the maturity of the bonds, when the whole amount must be carried to surplus. (I. V. H. Gill; J. C. Collins; B. J. Denman, 1909.)

DEPRECIATION.

Method of Determining.—Charge "operation" or "maintenance" monthly or yearly with an amount equal to what depreciation is estimated to be; credit "depreciation fund" with such amounts. Whenever any part of the equipment is abandoned, scrapped or sold, charge "depreciation fund" with the original cost price less salvage, and credit "equipment" with the same amount. Whenever a piece of apparatus is rebuilt, charge "depreciation fund" with such cost of rebuilding less enhanced value, due to improvement, and credit "equipment" with the same amount. (W. J. Greene, 1902.)

Estimate the probable life of the different parts of the plant, dividing it into real estate and buildings, steam plant, electric plant in buildings, distribution system and installation. When these ages or periods of life are determined, an amount of money is deposited to a renewal fund annually, which placed at compound interest will amount to the first cost of the apparatus or plant at the end of the period of life that is set for that apparatus. Then, at the end of the period when a machine is supposed to have entirely worn out, there is an asset or fund in bank ready for the purchase of a new plant, or for renewal purposes, should any part of plant be rendered useless before the period of life expires.

In making an estimate of the period of life of the different parts of a plant, consideration should be given to the fact that real estate usually appreciates in value. Buildings depreciate very slowly if well constructed, and machinery will always sell for something, even though rendered useless, or very inefficient as compared with new machinery. (Horatio A. Foster, 1902; H. M. E., New York Edison Co., 1903; S. E. Schweitzer, 1908.)

The accounts necessary to satisfactorily handle "Depreciation," and for the proper recording of results are: Reserve for Maintenance Account, Replacement Account, Unfinished Installation Account, and Installation and Property Account.

Determine the amount to be set aside to take care of the probable depreciation on the company's plant during the following twelve months, arriving at same on the percentage basis, figured on the capital of the company. This amount should be entered on the books in equal monthly amounts, by debiting Maintenance Account (Expenses), and crediting Reserve for Maintenance Account (Reserve for Depreciation).

That the Installation and Property account may at all times show the original cost of existing property, a Replacement Account is kept, to which is transferred the cost value of property no longer in existence.

The cost of repairs and renewals to keep the plant in first-class operating condition should be charged to the proper Expense Account.

In making a new installation, or changing an old one, the investment during construction is charged to Unfinished Installation Account. This account is charged with the cost of the new plant, and with the cost of dismantling the old plant. When the installation is finished, the amount of the investment is transferred to the completed Installation and Property Account, and credited to the Unfinished Installation Account, the cost of the abandoned plant, plus the cost of dismantling, being charged to Replacement Account, and credited to Installation and Property Account. Salvage on property disposed of is credited directly to Replacement Account. At the end of the fiscal year the balance of the Replacement Account is transferred to the Reserve for Maintenance Account, and is the net depreciation on the plant for the year. (L. M. Wallace, 1907.)

Percentage.—While the depreciation charged on the equipment of electric light companies has not been standardized, reports on the subject seem to arrive fairly unanimously at the following figures:

Buildings and similar fixtures	2 to 4 per cent.
Boilers	10 per cent.
Steam equipments	5 to 7 per cent.
Electric equipments overhead	10 per cent.,

the latter running from about 7 per cent. on wire, 10 per cent. on poles. etc., to 15 per cent. on lamps, hangers, etc.

Percentage as above would average with considerable uniformity at 7 to 7.5 per cent. on the whole equipment exclusive of land. (Alex. J. Campbell, 1906; C. W. Koiner, 1905; C. A. Keller, 1907; B. G. Jamieson, 1909.)

Percentage of the structural value would be the proper figure to use, arriving at this percentage by taking each piece of apparatus separately (P. S. Young, 1906.)

Water-Power Plants.—With modern direct-connected, horizontal water-wheel units and generators, with dams, buildings, etc., of concrete and steel on good rock formation, the average depreciation on buildings and machinery should not exceed 5 per cent.; on buildings and dams, 3 per cent.; water-wheels, 6 per cent.; revolving field alternator, 5 per cent.; and electrical apparatus, 10 per cent. (W. F. Kingan, 1904.)

STOREROOM.

Record of Stock Supplies.—A good method of keeping stock supplies is to charge all goods that go into storeroom to supplies, and to credit every item that is taken out of the storeroom to supplies, and charge it to whatever account it is used for. A book or card record, according to individual preference, can be used for each class of material, from which a balance can be taken, to agree with the general ledger. (A. C. Blinn; C. S. S., New York Edison Co., 1903; Union Electric Light & Power Co.; C. A. Kellar, 1904; J. R. Shurtz; P. S. Young, 1906.)

A good method is to keep only the money value of the stock, and not a running account of the amount of the different kinds of stock on hand. The money value of the stock is kept on debit and credit system, charging out to the proper job when it is drawn out. Depend upon frequent inventories for information as to the amount of different material on hand. Each department receives weekly reports of most active stock in which it may be interested, as to amount on hand. (Edison Electric Illuminating Co. of Boston, 1903.)

It is often found desirable to give each article to be used a number instead of a name. A system whereby the number is the page number of the stock ledger lends a great deal of aid. The number scheme should be applied to the part of the stores where best adapted. (J. R. Schurtz, 1906.)

Record of Line Tools.—A good system for keeping a record of line tools when they are issued from the storeroom with the object of preventing excessive wear and tear, loss and theft, would be to either hold the foreman of lines responsible for all tools issued to him from the stockroom or have a set of tools for each lineman and charge same up to him. Check up at the end of each month. If any tool is worn out or broken, replace it. If any is lost, make the lineman pay for it. A saving in loss of tools will justify the expense of such a system of records. (H. Clyde Parrish; Albert E. Mace, 1908.)

Average Cost.—Where certain material has been purchased under separate orders, and the cost price in each case is not the same, the average or composite cost is theoretically the proper rate to charge the department using the material, although it is not incorrect to charge out the first lot at its own cost and the remainder at its separate cost. (P. S. Young, 1909.)

Stock Clerk.—With a station output of a little in excess of 1,000 horse-power, it would not be advisable to keep a storekeeper. The amount of saving that a storekeeper would effect in so small a plant would not offset his salary. (G. B. Lauder; Alex. J. Campbell; C. S. S., New York Edison Co., 1903.)

It would be an economical practice to maintain a storekeeper in a plant of any size. (S. S. Ingman; Walter L. Mulligan, 1903; E. H. Robinson, 1907.)

Scrap Disposal.—The best method for control and disposal of scrap was answered by the Editor, advising the use of an open receptacle for daily accumulations, transferring its contents from time to time into a larger one provided with lock and key. The detailing of a competent man to sort the contents when the transfer is made, will save valuable material from being scrapped, and the man in charge can receive bids from junk dealers on the remainder. (1903).

MISCELLANEOUS.

Selling Price of Electric-Lighting Plant.—The only equitable method of arriving at the selling price of an electric-lighting plant is on the basis of the net earnings, as the business the company has spent time and money in working up is quite as much an asset as the apparatus. Estimate the amount of repairs and renewals necessary to put the plant in first-class condition. Capitalize the plant on the basis of a certain percentage of its net earnings, and subtract the estimated cost of repairs and renewals, to arrive at the proper selling price. (H. T. Hartman, 1903.)

Wattless Current.—The value that should be put on wattless current depends on the design of the system. If the system is designed for 100 per cent. power-factor, the effect of wattless current is to reduce the earning capacity of the system by the amount by which the apparent watts exceed the true watts. On this basis it would be fair to charge the same price per kilovolt-ampere of apparent demand that would be charged per kilowatt of true power furnished, subtracting, however, the fuel cost that would be saved. In case, however, the system is designed for operation at a power-factor of less than 100 per cent. (all alternating systems should be so designed), the value of the wattless current is only Fixed Charges, Electrical Losses, and Profit on the excess electrical capacity provided. (Stone & Webster Engineering Corps. 1908.)

OPERATING STATISTICS.

Electrical Losses—Percentage.—The percentage of loss between the station metered output and the customers' metered energy, with standard modern transformers and meters, should be between 30 and 40 per cent. (H. T. Hartman, 1903.) 20 to 30 per cent. (W. T. M., New York Edison Co., 1904.) 20 to 25 per cent. (G. Wilbur Hubley, 1904.) 15 to 25 per cent. (P. Junkersfeld, 1905.) 24 per cent. (A Peters, 1905.) 25 to 30 per cent. (E. B. Greene, 1905.) 26 per cent. (A. T. Lloyd, 1906.) 27.5 per cent. (S. R. Inch, 1906.) 25 per cent. (H. C. Stoddard, 1907.) 19.9 per cent. (Alex. J. Campbell, 1907.) 25 to 35 per cent. (H. M. Case, 1908.)

Ratio—Percentage.—The ratio between the total kilowatts of meter rating and the total installation or maximum load, eliminating that part of the installation, or maximum load that is not supplied on a meter basis shows ratio to total installation to be 81.5 per cent., ratio to maximum peak load 19.2 per cent. (S. R. Inch, 1906.)

Ratio—Station Output.—The ratio between the kilowatt-hours during the week of smallest station output, and the week of largest station output, comparing summer and winter loads, 44.5 per cent. (L. L. Elden, 1906.) 41.5 per cent. (S. R. Inch, 1906.) 53 per cent. (C. W. Higgins, 1906.)

Ratio—Peak Load.—The ratio between the peak load in kilowatts on the week of smallest average peak load, and the week of heaviest average peak load, comparing summer and winter loads, 33½ per cent. (S. R. Inch, 1906.)

Summer peak is 70.7 per cent. of winter peak. (C. W. Higgins, 1906.)

The ratio between the kilowatts of maximum peak load, and the kilowatts of total connected installation, 41.2 per cent. (L. L. Elden, 1906.) 43 per cent. (A. Peters, 1906.)

Demand Ratio.—The ratio between maximum indications taken from demand indicators on consumers' premises and maximum station load on station having complete equipment of demand indicators, is commonly known as the "diversity factor" and in using same it should be stated whether the station maximum demand is taken at the switchboard or at pressure of supply to customers. If the latter definition is used, the distribution loss does not enter into the question of the diversity among customers in the time of taking their maxima. With last definition, diversity factor for a station is likely to lie between 1.25 and 2. Diversity factor of residence customers only will lie between 2 and 3, and for power may vary greatly and may run up to 4 and 5. (J. S. Codman, 1907.)

Hours' Use of Maximum Load.—Taking as a basis the maximum peak load in kilowatts, and the annual station output in kilowatt-hours, the equivalent number of hours' use per year of the maximum load on an annual output of 6,544,000 kilowatt-hours, with a peak of 2,440, would be 2,682 hours, or 7 hours and 24 minutes per day. (C. W. Higgins, 1906.) 2,421 hours. (L. L. Elden, 1906.)

Coal Consumption.—The average coal consumption per kilowatt-hour at the watt-hour meter on the switchboard in plants having direct-connected non-condensing engine, should be 7½ lb. (G. R. W., Malden Electric Co., 1904.) 12 to 20 lb. (D. Kennedy, 1904.) 9 to 12 lb. (E. H. Mather, 1904.) 3.75 to 4 lb. (S. S. Smith, 1904; C. W. Koiner, 1905.)

In condensing plant, coal consumption per kilowatt-hour at switchboard, 6 lb. (W. W. Fuller, 1906.)

Fuel Cost.—The cost of fuel per kilowatt-hour for the highest grade of stations in this country is about 0.3 cent. In average railway central stations the cost is about eight-tenths of one cent per kilowatt-hour based on fuel at an average of $3.00 per ton. In ordinary small stations, designed without much regard to economy of operation, the cost of fuel frequently runs as high as 1¾ cents per kilowatt-hour. (H. A. Strauss, 1906.)

Station rating 950 kw., with slack bituminous coal at $1.25 per ton, average cost of fuel, 0.6 cent per kw-hr. (W. H. Fellows, 1906.)

Station rating 1,500 kw., with coal at $2.60 per ton, average cost of fuel, 1,043 cents per kw-hr. (B. J. Denman, 1905.)

Station rating 2,500 kw., using New River bituminous coal, average cost of fuel, 1 cent per kw-hr. (W. W. Fuller, 1905.)

Cost Overhead Repairs.—The average cost of repairs on overhead lines should not exceed 0.09 cent, per annum, per kw-hr. sold. (G. Wilbur Hubley, 1905.) The average cost should be about 0.055 cent. (J. J. Gaffney, 1905.) The average cost should be between 5 and 10 per cent. of original investment, not including copper investment, according to the soil poles are set in, and the elements to which the cross arms and pins are subjected. (J. F. C., 1905.)

Meter Accuracy.—With modern induction meter it would be expected that at least 85 per cent. of the meters will maintain accuracy within 2 per cent., and 10 per cent. of the meters within 5 per cent. of absolute accuracy, and remainder at variable percentages of accuracy, owing to accidents or moral conditions of service. (G. Wilbur Hubley, 1904.) 75 per cent. of induction meters within 2 per cent., 100 per cent. within 5 per cent. With commutator type of meter none will come within these limits. (F. C. S., Malden Electric Co., 1904.)

Percentage of Meter Variation.—No percentage of meter variation should be allowable on consumers' meters for no load. It is customary in good practice to take some percentage basis as light-load point, at which the meter must possess a certain degree of accuracy. This percentage represents a percentage of the meter's rated capacity. 10 per cent. load is being adopted generally by the larger companies as being light load point where a certain degree of accuracy is necessary. A good modern meter should not show an error, plus or minus, exceeding 2 per cent. from 10 per cent. load to 50 per cent. overload. (E. W. Gough; P. H. Hodges; The Colorado Springs Electric Co.; Chas. H. Peters; G. Wilbur Hubley; A. H. A., New York Edison Co., 1905.)

Load Factor—Effect Upon Operating Costs.—Apportioning the operating expenses, or the total costs between the lighting and railway departments in a plant furnishing service to both systems on the basis of kilowatt-hours for the respective service, is unjust to the railway department. Fixed charges should be distributed in proportion to the demand of the respective systems if the peaks lap. Distribution of operating expenses should depend upon load factor. Decreasing load factor from 35 per cent. to 25 per cent. will increase operating expenses per kilowatt-hour in modern stations about 33 per cent. (B. J. Denman, 1908.)

Water-Power Plant.—A modern water-power plant of about 1,500-hp. rating can be operated for $3.00 to $4.00 per hp-year, which includes only labor and material used at the power station. (E. H. Mather, 1904.)

A water-power plant with a total rating of electrical machinery of 620 kw., with a flume of wood three miles long, supplying, at maximum, water, enough to develop 500 kilowatts at switchboard, shows the following operating expenses per kw-hr., not including any depreciation, superintendence, taxes or general expense:

Repairs to building	0.007 cent
Repairs to dam and conduits	0.097 cent
Repairs to turbine and electrical machinery	0.102 cent
Labor, dynamo tenders	0.242 cent
Labor, flume tenders	0.053 cent
Sundry supplies	0.014 cent
Total	0.515 cent

(Herbert McNulta, 1904.)

NEW BUSINESS.

Rate of Increase.—The rate of increase in 16-c-p. equivalents of connected installations may fairly be expected from year to year in cities of the first class, to be, 9 per cent. (J. R. Shurtz, 1906.)

Lamps Lost—Percentage.—A fair percentage of lamps lost per year, to lamps gained, would be, for every 100 16-c-p. equivalents connected, 39 16-c-p. equivalents are disconnected. 75 per cent. of the cut-offs due to reasonable business, change of location, and discontinuing business. 25 per cent. due to competition, dissatisfaction, and non-payment of bills. (E. W. Lloyd, 1907.)

About one lamp disconnected to every three added. (B. C. Adams, 1906.)

Gross Income—Flat-Iron.—The average gross income from an electric flat-iron per month, on a 6 cent rate, based on five hours' use per week, would be 60 cents. (L. D. Mathes, 1907.)

50 cents per month. (Wm. Rawson Collier; W. M. Bell, 1907.)

6 kw.-hr. (G. E. McKana, 1907.)

Investment—Percentage.—Where prospective new business requires an increase in equipment of station or line, the net earning should be sufficient to cover a liberal allowance for depreciation, and a fair return on the money invested. In general, the estimated yearly net earnings should show from 10 to 25 per cent. on the additional investment. (P. Junkersfeld, 1904.) 20 per cent. (Fred B. Hubbell, 1904.) 10 per cent. (E. H. Mather, 1904.)

REVENUE.

Revenue Producer.—The best revenue-producer, next to the flat-iron in domestic use, is the quart water-heater. (Wm. Rawson Collier, 1907.) Cereal cooker. (L. D. Mathes, 1907.) Coffee percolator, and radiators. (W. M. Bell, 1907.)

Industrial Apparatus.—The three most successful pieces of industrial apparatus as to income outside of the motor, the arc lamp, and the incandescent lamp, are probably the flat-iron, the water-heater, and the coffee percolator. (Wm. Rawson Collier; L. D. Mathes, 1907.)

Average Income.—For a city of the first class, a fair average income from the sale of energy per kilowatt-hour billed for commercial service, light and power, would be 7 cents with steam coal costing $2.75. (J. R. Shurtz, 1906.)

Gross Income—Increase.—The rate of increase in gross income from current sales, from year to year, in cities of the first class, may fairly be expected to be eight per cent. (J. R. Shurtz, 1906.)

SECTION XXIV.

Management and General Policy.

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Many subjects that are logically classified under the general title of "Management and General Policy" are of sufficient importance in themselves to require separate treatment. For example "Electric Heating," "Electric Power," "New Business," "Contracts and Rates," "Accounting and Statistics" and a part of "Meters" contain a large mass of material that relates to General Policy. (Editor.)

COMPETITION.

"Intelligent work by solicitors" is a concise summary of nearly all the answers and few refer to the necessity of low price and the advantages of steam heating system; the general impression as set forth by all seems to be that the greatest obstacles are lack of knowledge on the part of both sides to the controversy as to requirements and costs, the failure to state the facts properly to the right party at the right time, the adverse influence of self-interested persons, and the difficulty of obtaining intelligent, thorough, persistent and painstaking solicitors. (W. W. Freeman; J. H. Hallberg; S. S. Ingman; S. M. Bushnell; Augusta Railway & Light Co.; W. H. W., N. Y. Edison Co., 1904; F. D. Sampson; S. M. Bushnell; C. A. Graves; R. R. Lapston; Birmingham Railway, Light & Power Co., 1906; Fred Leslie; E. W. Lloyd, 1907.)

General vigilance, the best of service, square deal and courteous attention to the business and customers and the avoidance of cut-throat policies toward the competitor. (James R. Shurtz; C. A. L., N. Y. Edison Co.; Ralph R. Laxton, 1906.)

Gas Competition.—When one company is furnishing both electric light and gas, push the gas side for short-hour consumers with a large demand and push the electric side for long-hour consumers where the demand is not great. (H. H. Scott, 1902.)

If just building up a business give the consumer the choice; if one department of the business is approaching the capacity of the works push the other, but do not disparage either. (C. E. Burroughs, 1904.)

Gas Arc and Welsbach Competition.—With gas at $1.25 per thousand feet, the editor suggests getting the customer to try an enclosed arc lamp on flat or meter rates in comparison with the Welsbach; point out the good qualities of the arc lamp and begin the campaign against Welsbachs as the hot weather comes on, and the advantages of fans and a cooler form of illumination become evident. Let the company furnish lamps and charge a minimum of $2.50 per arc lamp on a yearly contract. (Geo. L. Colgate, 1903.)

Gas Engine Competition.—The superiority of the electric motor in all respects and the advantage of securing an unlimited capacity of service must be the most prominent features. (W. W. Freeman; C. K. N., of N. Y. Ed. Co.; Augusta Ry. & Elec. Co., 1904.) Proper installation of motors, cutting out all the waste shafting generally used with gas engine drive. (E. W. Lloyd, 1904.) Impossible to meet gas competition on the basis of cost, but a list of gas engines displaced by electric motors will prove valuable. (W. W. Freeman, 1904.)

Humphrey Gas Arc Lamp.—Companies must rely on the superiority and reliability of electric service as they cannot compete on the basis of equality in cost. (W. W. Freeman; Augusta Ry. & Elec. Co., 1904.) Trial installations of arc lamps, Meridian incandescents or Nernst lamps. (W. R. Gardener; W. W. Freeman; Geo. L. Colgate; Augusta Ry. & Elec. Co.; E. A. M., N. Y. Ed. Co., 1904.)

Gas Arc Lamps Against Meridian Incandescent Lamp.—A good competitor. (Francis W. Willcox; R. W. Rollins, 1904.)

The Meridian lamp cannot compete in candle-power and operating cost with the Humphrey gas arc, but it is far superior both in artistic appearance and from the health standpoint. (Peninsular Elec. Light Co., 1904.)

Welsbach Competition.—Regarding what can be put up against the Welsbach burner for street lighting (cost and character of light considered) in a town whose annual appropriation is about $6,500, and where the gas company is getting $25.00 per lamp all night, twenty-five nights per month. Geo. L. Colgate suggests the Nernst lamp; the Malden Elec. Co., 25 c-p. series incandescent lighting; Geo. Mayer states that a 32 c-p. lamp burning 4,000 hours per year will net 0.052 per kw. at $25.00 per annum and leave a profit. (1904.)

Meter Rates in Competition.—As to whether it is advisable to make a reduction of 10 to 20 per cent. on meter bills during the season of long nights and heavy loads when in close competition with gas, most of the answers advise a standard rate for the year round. (Jas. B. Foote; W. W. Freeman; Geo. L. Colgate; Toledo Ry. & Light Co.; E. H. Mather, 1904.)

Ten or twelve cents per kw-hr. is the price suggested for selling electricity using 16 c-p., 3.6 watt lamps, 120-watt Meridian and 44-watt Nernst lamp to compete with gas at $1.50 per thousand cubic feet, using mantle with burner. This is a lower rate than most companies make on a maximum usage; so it would probably be better to convince the customer of the desirability of electric over gas lighting. Hold out the superiority of the electric light over the gas illumination, for which the public is willing to pay more proportionately for the same area lighted. Electric companies are competing with gas more or less successfully regardless of price charged for current. (W. W. Freeman; Geo. L. Colgate; M. W. Hanks; T. B. Whitted; Geo. Mayer, 1904.)

Gasolene Competition.—The general advice is for the companies to talk about gasolene danger, odor, inconvenience, etc. (Ludwig Kemper; P. L. Utley, 1906.) C. K. M. suggests Nernst lamps. Electric light companies are paying special attention to illumination so as to give the customer the best possible service for the money. (Van Rensselaer Lansingh, 1906.)

As to the most successful method used in meeting the competition of the F. & P. gasolene lighting system. Ludwig Kemper states that he has found Gem units and other high-efficiency lamps a great help. He also puts stress on fire danger, insurance, odor, and mantle cost. Have been successful in using Harter clusters and tantalum lamps; clusters installed free of charge, and lighting furnished on a flat rate basis, at a cost that does not greatly exceed that of gasolene and cost of keeping up the system. (Fred Leslie, 1907.)

Gas and Electric Combination Fixtures.—As to the advisability of installing a limited number of combination fixtures or brackets for gas in electrically lighted stores, churches, etc. W. W. Fuller and Ralph R. Laxton advise that this be done but in such a way as not to point out the reasons. It is not good policy to encourage the installation of gas since reliability of service is one of the prime requisites for securing business. (B. J. Denman, 1906.)

DEVELOPMENT OF MARKET.

Power Business.—Power market can be best developed with a low meter rate well advertised, and with a service as at present adopted by the Niagara Falls Power Co. to make up for loss of time when motor is not running at full capacity. (R. J. Patterson, 1902.) Advocate reducing manufacturing and distributing cost per kilowatt-hour to a minimum and present advantages of electric power to the public through capable solicitors. (F. H. Mather.) Sell motors on a small margin of profit, make rates to customer for power so as to be favorable when compared with burning of coal. (Chas. H. Peters.) Employ competent engineers to solicit power business and clarify many misty ideas in the minds of consumers at the present time. John F. Gilchrist combines in his opinion those of the two foregoing, and adds the necessity of willingness on the part of the company to assume part at least, if not all, chances in the matter. General enlightenment of the customer, favoring those with a high average demand in the matter of rates, and a reasonable reduction in the rate as quantity increases; also, make the basis of measurement the volt-ampere, and not the watt, and charge for the input to the motor, giving the customer choice of several bases for charging, and offering good discounts to customers who are willing to shut down their motors in whole or in part during the time of the peak lighting load. (P. G. Gossler, 1902.)

Lighting Business.—Suggest the reduction of rates. (Jas. W. Cartwright, 1905.) Suggest placing all lamps and motors on separate generators and circuits, making the regulation of the lighting circuits as nearly perfect as possible, rates as low as possible, and advertising through capable solicitors. (E. H. Mather.) Favor reduction in the price of service, if possible, also giving three or four months service free. Regard the first plan as a delicate undertaking and to be applied only under conditions of good understanding of the situation. (R. J. Patterson.) Uniform voltage, frequent renewals and customers' wants anticipated. (Chas. E. Scott.) Suggest perfect service at a reasonable rate, and selling fixtures almost at cost; courtesy on the part of employees and giving a new lamp for every four or five dollars' worth of energy consumed in order to insure laying aside of blackened globes. (Chas. H. Peters, 1902.) Satisfied old customers are the best advertising. (H. H. Taylor.) An interesting illustration was given by the president of a personal experience with a new central station established two years ago, (1909) when the power sales showed a phenomenal increase of about 70 per cent. in a year. The system used was offering a premium to wiremen for every lamp wired up; the installing after the first half year of a three-wire interconnected secondary system, maintaining an almost uniform voltage, establishing a system of free lamp renewals and reducing rates to about 50 per cent. of the customers. System of rates used was one where it lay in the power of the consumer to fix his own rates. Another plant, which was a water power plant, was developed rapidly on the basis of 50 cents per lamp for the consumer on a flat rate, 25 cents per lamp for consumer on the so-called Doherty rate, and 5 cents per lamp for the consumer on a straight rate.

The best method of increasing the number of consumers is attention to complaints and prompt adjustment; employment of good solicitors; rates low enough to permit free use of energy equipment of small stores and residences in residence districts with particularly attractive fixtures and devices; taking steps to get a few lamps in good residences even if the wiring has to be done on a concessional basis; keeping old customers pleased; using turn-down lamps and a sliding meter rate that gives special advantages to long-hour consumers; replacing fuses and making minor repairs without charge; courtesy on the part of all employees. (1904.)

Extra holiday lighting for decorative purposes is desirable business because it is one of the best of advertising mediums, showing the customer what can be done with electric light. (Union Elec. Light & Power Co.; W. W. Freeman; E. E. Larrabee; J. H. Hallberg; E. H. Mather; John F. Gilchrist; F. E. Eaker; W. R. Gardener, W.R B., N. Y. Edison Co., 1904.)

Not desirable business except from the standpoint of serving the customer with what he wants, because it adds to the heaviest load in the season of the heaviest load. (Geo. L. Colgate; W. H. Banes; The Sherbrooke Power, Light & Heat Co.; Edgar B. Greene, 1904.)

Not desirable because it is a temporary line of business, but sometimes it must be taken on to accommodate yearly customers and if the plant is capable of handling the extra business it is good advertising. (Geo. B. Tripp; G. H. Gushman; S. S. Ingman, 1904.)

Nernst Lamps.—The Nernst lamp obtains more business for a company than could otherwise be secured. Nernst lamps on the alternating-current system and the enclosed arc lamp on the direct-current system. (R. W. Rollins.) The three- and six-glower lamps secured the return of a number of customers who found the usual arc light too expensive. They have also been effective in retaining customers who found the incandescent too expensive (J. P. R., Jr.; N. Y. Edison Co., 1904.)

Day Service in Small Towns.—As to whether a day service is justifiable in a small town and what kind of power business could be worked up and also what power rate should be charged, four out of seven think the service not justifiable as it is too expensive for the income received and brings up the ever-present question of the lapload. (Charleston Consolidated Railway, Gas & Elec. Co.; Geo. B. Lauder; F. L. Williamson; C. W. Koiner, 1905.) It is justifiable if in a manufacturing town, and the rate depends entirely upon the hours the power is to be used and the operating expense. (F. C. S., of the Malden Elec. Co.)

Test all kinds of steam plants in order to get the cost of operation for comparison with electric motors. (Augusta Ry. & Elec. Co.) It is justifiable if you can get sufficient business, and the power rates must be figured from expense. (Douglass Burnett, 1905.)

The Small Residence Customer.—This class of customer has been found satisfactory in the main, although prices have to be made to allow for the fact that the customer usually comes on at the peak of the load, and that there are possibilities of introducing heating appliances, which class of business has a large future. (Frank Beckwith; B. J. Denman; Ludwig Kemper; Van Rensselaer Lansingh; C. A. L., N. Y. Edison Co.; Ralph R. Laxton, 1906.)

Loss by Death or Failure.—Dudley Farrand advises the use of universal letter changeable signs as protection against loss in case of death or failure of the free-sign customer. It would be necessary to make the average high enough to cover a certain amount of loss. (Geo. N. Tidd, 1908.)

Display Lighting.—To encourage window lighting, outlining of buildings and the use of decorative signs Ludwig Kemper reports an extra 10 per cent. discount allowed provided the lights burn every night until 11 o'clock. The Pueblo Suburban Traction & Lighting Co. has flat rates. Fred Leslie reports special advertising to encourage window lighting, a special rate, and furnishing signs at cost, to encourage the use of decorative signs. G. E. Williamson answers in general that any display lighting is an advertising medium and an appeal must be made to the merchant's pride. E. W. Lloyd gives their regular rule for installation of lights in windows with the rates the consumer must pay for either reflector or trough lighting. (1907.) (See also New Business Section XXI.)

Care of consumers, brings up the question as to whether sufficient care and interest are shown for new consumers after they have been obtained. All answers agree that they are too frequently neglected, and that more trouble should be taken to maintain an interest in them and to keep them satisfied. (Ludwig Kemper; J. A. Lane; Chas. G. Cook; F. C. Sargent; Douglass Burnett; Pueblo Suburban Traction & Lighting Co., 1907.)

GENERATING PLANTS.

Electric Plant in Small Town.—As to how small a town would justify the building of an electric light plant, Frank Beckwith states that with a 100-kilowatt outfit in a town of 3,000, the net dividends averaged 10 per cent. per year for 17 years of business; not so much depends upon the size of the town as upon the possibility of supplying power to manufacturers. Successful operations have been carried on in first-class resident towns with some 2,000 population. (James R. Shurtz, 1906.)

Ice as a By-Product.—The advantages of the combination of an ice plant with an electric light plant, especially in smaller communities, according to the Union Central Light & Ice Co., are that the same power may be used for both plants, operating cost is only slightly higher for both plants than for one, and, day current being necessary, the same attendants can successfully operate both departments. (1907.)

MUNICIPAL OWNERSHIP.

S. S. Ingman refers to the reports of the United States government as a result of its recent canvass through the electric plants as a valuable contribution to the subject. The U. S. agent informed Mr. Ingman, however, that in the majority of cases the method of keeping records of the operation of municipal plants made it much more difficult to secure the necessary data than in the case of plants operated by private parties. (1903.)

As to the best way to educate the public to a realization of the fallacy of municipal ownership, the answers advocate that public service corporations watch carefully reports of municipal plants, compare costs and be persistent in the bringing of this data to the notice of the public. S. S. Ingman, George Hubley, E. H. Mather caution the public service corporations to give the best service possible and charge only enough to net a reasonable return. W. R. Gardener advocates that facts and figures to illustrate points against municipal ownership be placed in the hands of citizens in order that they may combat municipal ownership intelligently. (1904.)

As showing a municipal electric lighting plant in this country operated economically and successfully, J. M. Cartwright refers to the municipal reports of Bangor, Me. (1904.) The trouble with most municipal plants is an excess of economy, charges belonging to the lighting plant being paid by other departments. (1905.)

That the granting of a percentage of their gross earnings by many companies throughout the country to their respective cities has had a tendency to subdue municipal ownership agitation, J. J. Cagney states as fact, although Mr. Gardiner, Jr., considers the matter open to grave question. James R. Shurtz answers in the negative. He considers the agitation a wave passing over the country, and advocates as a remedy the reducing of prices charged to the city for municipal lighting, so that there is not an unfair comparison between the municipal operation of plant and private corporations. (1906.)

Systematizers.—The editor states that their company's policy is to invite suggestions which being found worthy, are awarded a monetary prize, and holds that an inside systematizer is better than one from the outside, for he knows where economy, progress and improvement can be made, having a knowledge of inside details. (1909.)

INSURANCE.

Liability insurance can be effected more satisfactorily and at a lower cost through some company. (W. W. Freeman, the Sherbrooke Power, Lighting & Heating Co.; E. H. Mather; the Editor, 1904.)

Results secured from accident insurance do not warrant the expense. T. H. T. & L. Co., United Electric Light Co., Birmingham Railway Light & Power Co. and F. D. Sampson carry both public and employees' insurance. (1906.)

Inspection of Wiring.—Six parties are usually interested in having the underwriters certificate covering the electric equipment of a building properly issued. The underwriter, tenants, owners, wiring contractors, fixture contractors and the light company. The owner and tenant of the property should be particularly interested, but all parties except the contractor are responsible in corroborating the inspection and obtaining the certificate. (D. C. Jackson.) Contractors, however, may be required by their contract to pay for their inspection. The various parties are interested in the order named—owners, tenants, underwriters and supervising architects; contractors only to the extent of getting their pay, which is frequently not contingent upon the certificate of inspection. The light company may have a form of contract in which its responsibility for installation of interior wiring is limited to wiring done by it as a contractor. Cities should have ordinance providing that cut-in shall be made by lighting companies only after proper certificate has been issued. (Ralph R. Laxton, 1906.)

Nothing can be done by central station men to promote uniformity in interpretation of insurance rules concerning wiring installation by inspectors of the underwriters association. (J. A. Lane.) But at periodical meetings of the representatives of the underwriters association, the local contractors and the company, questions may be asked and answered and insurance rules discussed and explained. (Chas. G. Cooke, 1907.)

EMPLOYEES.

Eight-hour Shift Firemen.—All answers agree that shorter hours increase efficiency and advocate an 8-hour shift for firemen. (R. J. Patterson, Waterville, Me.; E. H. Jenkins, San Antonio, Texas; W. L. Abbott, Chicago; E. J. Bechtel, Toledo, O., 1902.) A small plant on an 8-hour shift would be too expensive, but it is sometimes beneficial to have two 10-hour shifts and one 4-hour shift. (R. J. Patterson.) Shorter hours bring a direct saving in coal; consequently in expense. (W. L. Abbott; E. J. Bechtel, 1902.)

Unskilled Labor.—The effect upon the electrical industry would not differ from that upon any other industry employing boys or young men of no skill or experience in operating. (The Boston Edison Electric Illuminating Co., 1903.)

Carelessness in Maintaining Rules.—It hardly pays to be too exacting with employees; if carelessness is habitual discharge the man. Railroad companies have found that warning, suspension and discharge is the best system. (Geo. B. Lauder; W. R. Gardiner; E. H. Mather; Augusta Railway & Elec. Co.; W. T. M., N. Y. Edison Co.; Geo. L. Colgate; Andrew F. Hall; G. Wilbur Hubley, 1904.)

Characteristics Desirable to Employees.—The best method of employing labor is through an apprentice system, making the young men serve in the various departments and increasing their salaries as they become proficient. High school education and good habits are the entering requisites. (F. G. Prout, 1905.)

Rules.—W. J. Buckley has edited a book containing rules formerly used by Jas. I. Ayer when in charge of one of the St. Louis Lighting Companies. Books of rules are published also by the Pacific Gas & Elec. Co. of San Francisco, The Ottawa Elec. Co. of Ottawa, Canada, and The Shreveport Gas, Elec. Light & Power Co., of Shreveport, La. (1908.)

Rotation of Duties.—Rotation of duties for employees in small companies where the station and line force consist of not more than 10 or 12 men is advantageous. (J. H. Enright; Alexander J. Campbell; F. C. S., Malden Elec. Co.; James R. Shurtz; A. O. Fretz; Wm. H. Gardiner, Jr.; Ralph R. Laxton, 1906.) C. W. Higgins holds it not advisable as each class of work requires long service to become proficient and the man, if only slightly acquainted with the duties, might make serious or fatal mistakes; W. W. Fuller states that the benefits gained would be offset by increase in maintenance cost, and suggests that a school intended to accomplish the same end would do no harm.

Free Night Schools.—Free night schools for employees in the manufacturing and distribution departments would be most useful. Any system that would tend to promote efficiency would re-act to the benefit of the service. (W. W. Fuller; F. C. S., Malden Elec. Co., W. H. Gardiner, Jr., 1906.)

R. C. Dooley of the Casino Technical Night School of East Pittsburg, Pa., names the following companies as having apprenticeship systems elaborately developed. General Electric Co. of Lynn and Schenectady, New York Central Railroad, Sante Fe Railroad and the Wanamaker Co.; and Bulletins 1, 1907, and 6, 1908 published by the Department of the Interior, Washington, will furnish detailed information. (1910.)

Night Troubles.—A plant without a night inspector and whose city contract requires that every light be inspected and seen burning between 9 and 10 P. M. has its arc light man work from 10 A. M. to 10 P. M. at regular monthly salary. Trouble calls are so few that they are taken care of as they come. (W. H. Thomson, Jr.) Each one of four men acts one week in rotation as trouble man, and is on from 6:30 A. M. to 8:30 P. M. (A. Peters.) Have a trouble man come on in the afternoon and look after trouble from the beginning of peak to midnight. If extra hours are put in pay at regular rates. (Herbert McNulta.) Have tried the practise of allowing employees to take daily turns at night of 1½ to 2 hours at the office, giving an equal time before quitting in compensation. (F. M. Van Dervoort.) Have had good results from establishing telephone connection with the homes of one or more competent trouble men, customers and city police informed of the arrangement. (Ralph R. Laxton, 1906.)

Employees Clubs.—We are in favor of the establishment of social or other clubs among the employees and suggest alternating talks of general interest with entertainment features. (E. A. M., N. Y. Edison Co., 1906.)

Superintendent of Gas and Electric Plants.—It depends entirely on the size of the company and the ability of the man whether one man should act as superintendent of both gas and electricity departments. One, if it be a small town. (J. A. Lane.) One for each department would tend to promote a higher efficiency. (F. C. Sargent, 1907.)

Merit Systems.—Detail of a system for following up each branch of the solicitor's work is as follows: At the beginning of the year each solicitor is given his quota, which he is expected to get. After the power solicitor has contracted 75 per cent. of this he receives a commission of 1 cent per 16 c-p. lamp equivalent and in addition 50 cents for each contract. After the light solicitor has contracted 80 per cent. of his quota he receives the same commission, these commissions being paid in addition to a regular salary. The sign solicitors receive a salary, in addition to which they receive the first week's income from the sign. (E. W. Lloyd, 1907.)

Employees Relief.—The United Elec. Co. of Springfield, Mass., and the Philadelphia Elec. Co. both have beneficial associations for their employees. The United Elec. Co. carries employees' liability insurance and takes care that its employees get a square deal when the matter has left its hands. Philadelphia has a membership of nearly 1,250 in its beneficial association covering sickness and accident disability, to which the company and employees contribute equally. (1909.)

DISTRIBUTING SYSTEMS.

Interference of Moving Houses.—All time over two hours is charged for at each crossing. (Fred H. Beck.) No ordinances in Corsicana regulating house moving, but Lighting Co. collects for all work done in letting house-movers through leads and charges for shut-downs when unable to prevent them. (W. H. Thomson, Jr.) No charge for moving wires. (G. B. Leland.) Town has a defective ordinance which cannot be enforced, and although we always charge for the work we have never been able to collect. (L. E. Watson.) Must be notified by the house-mover and are compelled to cut the wires and make repairs, but at the expense of the house-mover. (The Colo. Springs Elec. Co.) Company should be paid for the loss and the actual expense incurred caring for the company's wires. At least one city refuses to issue a permit for the moving of buildings until satisfactory arrangements have been made with the company. (F. Ellwood Smith.) Owner or building mover must notify the company in writing 24 hours before moving. (F. S. C., Malden Elec. Co., 1905.)

Free Wiring.—The consensus of opinion is in favor of keeping the cost of wiring down to a reasonable figure to insure a first-class job and to encourage house wiring in general. (E. E. Larrabee; Chas. G. Giles; Fred B. Sharpe; Edison Electric Illuminating Co. of Boston; P. A. Bertrand; F. L. Williamson & Co.; John F. Gilchrist; A. W., N. Y. Edison Co.) Find it necessary to do wiring, but prefers letting it out to other parties. (S. S. Ingman.) Wire only if a fair profit is realized from it and not unless contractors are unjust in their charges. (Guy C. Gum, 1906.) It is not good policy to do free wiring, but it is frequently desirable to do this work at cost or at a very small margin of profit. (Geo. B. Lauder; O. A. Whitemore; E. E. Larrabee; Geo. L. Colgate; Fairhaven Elec. Co.; Little Falls Water, Power Co.; E. H. Mather; G. Wilbur Hubley; Andrew F. Hall; Chas. H. Peters; John F. Gilchrist, 1904.) It might be to the interests of the company where the guaranteed income per lamp is sufficient to warrant it. (F. E. Eaker.) It pays to do some wiring free, other at cost, depending upon the contracts it can secure. (S. S. Ingman, 1904.)

Free wiring is detrimental to a company's interests although it may encourage a few customers. It causes ill feeling among contractors who are usually very generous and who might, if kept in good humor, boost the company's interests. (J. A. Lane; Fred Leslie; H. Zimmerman; J. F. Fujaszi, 1907.)

Ludwig Kemper and Douglass Burnett hold it a successful scheme to wire houses and other buildings on installments, handling them as any other credit would be taken care of. (1907.)

Free Repairs.—With regard to the advisability of charging lighting customers for small jobs of repairing, such as inserting fuses, repairing sockets, etc., the large majority deem it not advisable to charge unless new material has to be furnished or it consumes too much time. (A. O. Whitemore; E. E. Larrabee; T. D. Evans; F. E. Eaker; E. H. Mather; Augusta Railway & Electric Co.; F. C. S., Malden Elec. Co.; E. S. Alrich; The Sherbrooke Power, Light & Heat Co.; Andrew F. Hall; Fred B. Hubble; C. F. Peters; R. Kinnon, 1904.) It is best to have all such work done by contracting companies. (Geo. L. Colgate; S. S. Ingman, 1904.) Union Elec. Light & Power Co. and the Fairhaven Elec. Co. are the only two who charge for such work.

Replacement of Fuse.—Company replaces fuses of the link or Edison type, but not the enclosed type free of charge. (L. A. Coleman, 1909.) On a meter basis it is for company interest to keep fuses in, consequently replace them free of charge. (Walter Flint.) Charge for all fuses unless blown by lightning or some cause attributable to service of the Company. (R. H. Tenney, 1909.)

Inspection.—Customer's installation must be inspected and accepted by underwriters before connections can be made. (Geo. L. Colgate.) Inspect to prevent theft of current, grounds, etc. (C. W. Humphrey.) Thorough inspection by the company is demanded to make sure that the underwriters rules have been properly carried out, and to guard against the already too prevalent impression that all fires of unknown origin are electrical. (H. B. Gear; C. J. Abbey, 1904.)

The Augusta Railway & Elec. Co. inspects for the insurance company but makes no charge. F. C. S., Malden Elec. Co. is for the National Code and to maintain an inspection system depending upon requirements of the Local Underwriters Association. Cost of inspection paid by consumer also, or changes made at consumers' expense. (Douglass Burnett; Philadelphia Electric Co., 1905.)

Company has the right to protect its own and its patrons' interests and refuse service if a test shows that connections have not been properly made and its lines or apparatus would be in danger. (Ralph R. Laxton.) Not, if owner and tenant assume risk for property damage for improper work. (J. W. Clapp.) Company should give its reasons for protest in writing holding itself willing to make connection provided the customer will agree in writing to assume all risks, H. T. Hartman, 1905.)

It is unreasonable for an insurance inspector to refuse a certificate because old concealed wiring has not been completely removed when a house has been rewired entirely independent of the condemned system. .(J. A. Lane; John McFeeley.) In many cases it is impossible, and where possible, most expensive to remove concealed wiring, and if the old wires are cut off close to the old outlet and the old outlet closed up, there can be no danger when the new wiring is carefully insulated and run free from the old. (1907.)

When a company does its own inspecting and has an application for connecting a building that has been wired for some years but does not conform to the insurance requirements at the present time although it did at the time it was wired, if the old wiring is safe, in a small town where the requirements are not strictly adhered to, connect; if the wiring is unsafe, refuse to connect unless it is made to conform to the underwriters rules. Do the new wiring up to the requirements. (D. Thompson, 1908.)

Motor Cycles for Inspectors.—Keep an automobile for general inspection work as it more than pays for itself in time saved. (Parker H. Kemble.)

Furnish your men with bicycles; the time saved more than pays for the cost of maintenance. (The New Brennen Electric Light Co., 1907.)

Street Connection.—The light company pays for street connection as it generally owns the service wires up to and including the meter. (Madison Light & Ry. Co., Colo. Springs Elec. Co.; Chas. H. Peters; F. S. C., Malden Elec. Co.; W. H. Zimmerman; Andrew F. Hall; J. F. Dostal; United Electric Light Co.; L. E. Watson; F. G. Proutt; F. W. Bullock; E. A. Bechstein; R. V. West; C. W. Koiner, 1905.)

LAMPS.

Nernst Lamp Renewals.—Require the customer to supply his own Nernst lamps, but the company furnishes free renewals. (F. H. Golding; J. M. Uptegraff; G. O. Nagle, 1902; Union Elec. Light and Power Co., 1903.) The company furnishes and maintains Nernst lamps, but not in sizes smaller than three glowers. (E. F. Phillips, 1903.)

Union Elec. Light & Power Co. has used theNernst lamp in but one place commercially, but it is satisfactory. We have them in stores where they have given very little trouble. (A. M. Jones.) There are hundreds of installations of Nernst lamps in commercial use. (C. W. Rice.) We have 110 three glower lamps in service for commercial use. (E. F. Phillips.) We use them throughout the drafting room, office and pattern shop. (A. C. Eastwood, 1903.)

Renewal Low Candle-power Lamps.—Central stations are apparently getting more liberal in making free renewals and installations of four candle-power lamps, but a comparatively small number are as yet committed to this practise, those that do renew four candle-power lamps do not feel that they can renew the two candle-power. (John F. Gilchrist.) We do not furnish free renewals. (E. E. Larrabee.) We furnish free renewals and carry four candle-power lamps to exchange. (F. E. Smith.) We do not furnish less than eight candle-power free. (Geo. B. Lauder; LaCrosse Gas & Elec. Co.; Sherbrook Power, Lighting & Heating Co.) We renew nothing less than sixteen candle-power. (S. C. Bosworth). We give the customer whatever candle-power he wishes. (G. C. Gum.) The price of current should include cost of renewals. (A. W., N. Y. Edison Co.) Four candle-power lamps do not justify free renewals. (The Editor, 1903.)

Dipping Lamps.—As a general rule stations do not seem to dip lamps for customers free of charge. F. E. Smith and the LaCrosse Gas & Elec. Co. and J. N. Bissell do not, while the Sherbrooke Power, Lighting & Heating Co. frost lamps but do not include colored lights free of charge. If a company undertakes to make renewals it seems desirable to give its customer a choice of plain or dipped glass. (A. W., N. Y. Edison Co., 1903.)

Outage Inspector.—The price obtained for street arc lights should never be so low that it does not cover the cost of a special inspector. (Union Elec. Light & Power Co.) A recording station wattmeter is a satisfactory solution. (A. Peters; J. H. Hallberg.) Policemen report any trouble with the lamps. (Augusta Railway & Elec. Co.; S. S. Ingman, 1904.) Furnish lamp trimmers with blanks, so that they may make a report on the conditions of the lamps. (Chas. H. Peters, 1904.)

Nernst Lamp on Flat Rate.—If a given amount of light must be furnished on flat rate the lighting company can furnish it most economically by the use of Nernst lamps. (G. L. Colgate, 1904.)

Fittings for Meridian Lamps.—The question as to whether it is the best practice to charge for fittings of Meridian lamps or to furnish them free, is answered in various ways. United Elec. Light Co. furnish the Meridian lamps and fittings free of charge. C. M. Wright and J. W. Cartwright, Jr., charge for the lamp. Baltimore Cons. Gas & Electric Light Co. charges for the fittings. C. W. Koiner also charges for the fittings and the first installations of lamps and furnishes part, or all of renewals free. (1905.)

Arc Lamps.—We furnish free arc lamps and use a meter rate. (The Colorado Springs Elec. Co.; F. F. Williams & Co.; F. C. S., Malden Elec. Co.; A. Peters; Andrew F. Hall; J. F. Doestall; C. M. Wright.) The customer should pay for the wiring. (F. L. Williamson & Co.; A. Peters. It is a special service and it seems better to use a minimum charge, say a dollar per lamp per month. (Douglass Burnett.) To induce business it has been found advantageous for the company to furnish arc lamps on a minimum monthly for $3.00 when current is sold by meter. (R. V. West, 1905.)

Marking Incandescent Lamps.—The majority favors marking with hydrofluoric acid and making it a rule to exchange new lamps for marked lamps only. (H. B. Gear; M. A. Hogan; Electrical Testing Laboratories; Thomas S. Richardson.) We make free renewals conditional on the return of old lamps, not specifying whether the lamps shall be marked in any way. (Douglass Burnett.) We mark ours with a pencil. (Fred M. Lege, Jr.) An elaborate system in which lamps are marked with consecutive Dennison numbers and charged by specific number to the customer, the records being kept in a book, is justified when a company does not give free renewals but makes good defective ones. (Joseph Sheridan, 1905.)

MISCELLANEOUS.

Slow-paying Customers.—Allow the competitor to have them; there is no benefit in keeping them. (Geo. L. Colgate; E. P. Coleman; C. J. Abbey, 1904.) Arrange with the competitor that you will not install service for his delinquents and have him refuse yours. (Geo. Mayer.) Suggest courtesy and as liberal a policy as possible in discounts making the base rate fairly high with a large discount for prompt payment. The Editor; F. S. C., Malden Elec. Co.; Chas. H. Peters, 1904.)

Mill Lighting.—Mill lighting is not good business at regular rates when mills are operated only 55 hrs. per week. (Geo. B. Lauder; E. E. Larrabee; Wm. R. Gardener, 1904.) Good if rates are based on the maximum demand system. (Geo. L. Colgate.) It is better than none, although it is not the best business. (Fred B. Hubbell and The Sherbrooke Power, Light & Heat Co., 1904.)

Thawing Pipes.—All answers are to the effect that thawing out frozen water pipes is a profitable and satisfactory business. A rheostat is used to limit the current. (D. C. Shain; C. H. Peters; F. L. Williamson & Co.; D. C. Jackson; C. W. R., N. Y. Edison Co., 1905.)

Rebates.—Where the meter and meter readings are known to be correct, the majority are not in favor of rebating even in case of a large bill as it causes all kinds of trouble with other customers, and the consumer never forgets that you have acknowledged that your meter is subject to errors. (Ralph R. Laxton; Clayton Geiger; Wm. L. Lewis; Fred M. Lege, Jr.; Douglass Burnett; E. A. Bechstein; J. W. Clapp, 1905.) It is somewhat advisable to make a rebate to hold a customer in case of a large bill, guarding against indiscriminate rebates, or, if after a long argument and collateral evidence it has become certain that the business will be lost. (John F. Gilchrist.) Circumstances would have to determine it. (F. Ellwood Smith.) The collecter of the East River Elec. Co. gives a long argument against rebates. (1905.)

Inter-departmental Conferences.—E. H. Robinson, of Schenectady, reports three organizations; heads of departments, members of operating force and the accounting department. These meetings have resulted in a higher standard of efficiency through the close touch of one employee with the other. J. W. Cartwright, Bangor, Maine, says they hold a regular meeting of all heads of departments on Monday of each week, where all complaints between departments, customers' complaints, advisability of changes in the physical plant, etc., are aired, (1909.)

SECTION XXV.

Legal Questions.

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RIGHTS AND POWERS.

In General.—If a company is improving its service by installing alternating-current in the place of direct-current it can legally refuse to connect a person who demands direct-current. F. D. Sampson, Ralph R. Laxton; L. D. H. Gilmour, 1906.)

In Streets.—In general. A right of way for a pole line is usually permanent on streets of municipalities where charter rights are perpetual and there are no limitations in the franchise of the company. (Ernest H. Davis, 1906.)

Sometimes by statute the right to maintain a pole line becomes permanent only after the consent in writing of the owners of abutting property is given without limitation as to time. (L. D. H. Gilmour, 1906.)

If at the expiration of a franchise to an electric light company a city refuses to grant a new franchise it is under no further obligation to the Company but it cannot compel the company to suspend operations or to remove its lines from the street without compensation. (J. A. Lane, J. H. Enright, 1907.)

If a company has an exclusive franchise to erect poles and wires in a certain street or on a certain side of a street it can prevent any other company from erecting poles or wires in that street or on that side of the street. If its franchise is not exclusive it cannot prevent any other company from erecting poles and wires. Whether or not a franchise is exclusive is often a difficult question. (Charles H. Peters, 1905.)

A company erecting poles or wires in a street is liable for any injury done to the poles or wires of another company already existing in the street. Charles H. Peters; H. T. Hartman, 1905.)

It is thought by some that if a municipality desires to have the conduits of a private company moved, the expense of the moving must be borne by the company unless the franchise provides otherwise. (Ralph R. Laxton, 1906.)

It is thought by others that if a company installs its conduits in compliance with its franchise or charter rights and with the consent of the municipal authorities it cannot later be called upon to pay for changes required by the municipality. (J. J. Cagney, 1906.)

Others believe that if the change is absolutely necessary for public improvements, the company must pay but that if the change is merely for convenience the city must pay. (Ernest H. Davis, 1906; See 53 N. Y. Supp. 696.)

It is sometimes provided in the permit for constructing a conduit that the expense of moving it, as occasion arises, shall be paid by the company. (United Electric Light Co., 1906.)

A city may have to pay an electric company for any injury it may do to the company's property in a street in the course of the construction of public works. (Ralph R. Laxton, 1906.)

A telephone company cannot object to the use of 2,200-volt alternating-current by an electric company on poles used in common provided the electric wires are separated from the telephone wires a reasonable distance. (Ernest H. Davis; F. Ellwood Smith; J. J. Cagney; Ralph R. Laxton; L. D. H. Gilmour, 1906.)

In the case of the Western Union Telegraph Co. vs. The Electric Co., 46 Mo. App., 120 (3 Am. Elec. cases 425) it was decided that a reasonable distance to leave between the high-tension wires of an electric company and the wires of a telephone company attached to the same pole was three feet. A distance of five feet would constitute an absolute defence against any claim by a telephone company. (Ernest H. Davis, 1906.)

A telephone company may legally object to the use of 2,200-volt alternating-current if the proposed voltage is prohibited by ordinance or by the terms of the electric company's franchise. (Ralph R. Laxton, 1906.)

On Private Land.—A grant of a right to maintain poles on private land based on any consideration whatever gives a permanent right unless the term of such grant is specifically restricted. (J. J. Cagney, 1906.)

A grant of a right to maintain poles on private land should recite a consideration and should contain words of inheritance as "heirs and assigns" or "successors and assigns" if it is intended to be permanent. (Ralph R. Laxton, 1906.)

The law as to allowing a company to remove the wiring placed by it in a consumer's premises varies in different states. (Ralph R. Laxton, 1906.)

If electrical apparatus or wires of a company are screwed to a customer's walls they can be removed by the company, but if they are nailed to a customer's wall they can not be removed. (E. A. M., New York Edison Co., 1906.)

Some persons think that a consumer has a right to refuse to allow a company to remove electrical apparatus from his premises. (L. D. H Gilmour, 1906.)

Some persons think that a consumer has no right to refuse to allow electrical apparatus to be removed but that if they do refuse the company has little redress. (L. D. H. Gilmour, 1906.)

DUTY AND OBLIGATIONS.

To Customers.—An electrical light company is required to supply energy to all persons who desire it and who are willing to pay for it at reasonable rates. (F. D. Sampson; Ralph R. Laxton, 1906.)

An electric light company cannot refuse to supply energy to a person simply because that person is in the habit of making unwarranted complaints and accusations of dishonesty against the company. (F. D. Sampson, 1906.)

Without going into the legal aspects of the case it is stated by one company that they refuse to furnish service to customers whose wiring is not properly fused or who have not proper sized service wires. (Beaumont (Tex.) Ice, Light & Refrigerating Co., 1908.)

LIABILITY.

Poles and Wires.—There is no law in New York State prohibiting electric lighting companies from connecting their lines to inside wiring unless such wiring has been inspected by public authority. So far as known no court has held a company responsible for an accident to persons coming in contact with defective wiring which had not been inspected before the company made its connections. (M. C. Turpin, 1908.)

It has been decided that if it can be proved that the wiring was defective in a building damaged by a fire which was started by electricity from an electric lighting company's lines, the company is not liable. (See Guardian Fire Association vs. Quebec Railway, Light &

Power Co.) It is therefore safer for a company not to approve wiring. (R. N. Robbins; J. A. Lane. 1907.)

A company would not be liable if a building was damaged by a fire started by electricity from its lines if the wiring in the building had been passed by an underwriters' inspector. (J. A. Lane, 1907.)

Negligence.—"Electric companies....must exercise that reasonable care consistent with the practical operation of their business which would be observed by reasonably prudent persons under like circumstances, increasing the care with any change in conditions likely to increase the danger and giving due regard to the existing state of science and of the art in question." (Quotation from 15 "Cyc." page 471.) (L. D. H. Gilmour, 1906.)

Failure to use a guard wire to prevent telephone wires from coming in contact with electric wires may well be held to be negligence on the part of both companies. (See Rowe vs. New York and New Jersey Telephone Co., 9 Amer. Neg. Rep. 528.) (L. D. H. Gilmour, 1906.)

Negligence is a question of fact for the jury. (L. D. H. Gilmour, 1906.)

Proximate Cause.—It has been held in one case that neither the defective installation of electric light wires nor the fact that those wires were strung at a less distance from the ground than was required by ordinance was the proximate cause of an injury to a child who took hold of a broken telephone wire which had been thrown over the light wires and had become charged with the electric lighting current, but that such injury was the result of the child's own wrongful interference with the wires. (See Stark vs. Muskegon Traction & Lighting Co., Supreme Court of Michigan). (Ebensburg Light, Heat & Power Co., 1906.)

Measure of Damages.—If a company is liable to a person for an injury received through failure of the company to use reasonable care it is liable also for the death of the person regardless of the fact that he might not have died if he had been in perfect health. The company is liable for all the ill effects which naturally and necessarily follow the injuries in the condition of health in which the injured person was at the time. (See Owen vs. Kansas City, 4 Amer. & Eng. cases 590). (L. D. H. Gilmour, 1906.)

REGULATION AND CONTROL.

(See Rates and Charges.)

As Affected by Constitution of United States.—State authorities in fixing rates must not violate the restrictions of the constitution of the United States. (L. D. H. Gilmour; Ralph R. Laxton; J. J. Cagney; Ernest H. Davis, 1906.)

The Constitution of the United States provides that no person or company shall be deprived of property without due process of law and it has been determined that the fixing of inadequate rates is within the constitutional prohibition. (Ernest H. Davis, 1906.)

Under the Constitution of the United States a State cannot pass a law impairing the obligation of any contract. (Ralph R. Laxton, 1906.)

It has sometimes been thought that a state's authority to fix the rates of a company is not limited by the federal constitution unless the company is engaged in interstate commerce. (L. D. H. Gilmour, 1906.)

By State Government.—The Legislature of a State has authority to fix rates for public service. (Ernest H. Davis; L. D. H. Gilmour, 1906.)

The judges of state courts have no power to fix rates for electric service unless authorized by the constitution or the statutes of the state. (Ernest H. Davis; J. J. Cagney; Ralph R. Laxton; L. D. H. Gilmour, 1906.)

By a Municipality.—A municipality may fix the rates of public service corporations which operate under a municipal franchise if authorized so to do by the State Legislature. (Ralph R. Laxton; J. J. Cagney; Ernest H. Davis; L. D. H. Gilmour, 1906.)

An ordinance specifically authorizing electric signs is desirable. It should cover the following points; 1. Definition of an electric sign. 2. Materials and manner of construction. 3. Size and location. 4. Certificates and permits. 5. License fee. 6. Illumination to be required. 7. Proximity to private residences. 8. Fines and penalties. 9. Time when ordinance shall go into effect. (S. M. Sheridan; Federal Electric Co.; United Electric Light & Power Co.; Joseph O. Beck, Jr.; E. A. Mills; E. S. Mansfield, 1908.)

Contracts may be made between electric lighting and telephone and telegraph companies providing for joint use of poles in a municipality or in certain streets of a municipality, but a more effective way to insure joint use of poles is for the municipality to refuse to allow more than one pole line on a street. (T. H. Yawger, 1909.)

CONTRACTS.

With Customers.—The ordinary lighting contract is not of much legal value. It should be simple and clear as its chief value is its moral effect. (F. G. Proutt; Douglass Burnett; George N. Tidd; J. W. Cartwright, Jr.; 1905.)

It is doubtful if it is possible or desirable to hold a customer liable who has contracted for a year's supply and who discontinues the use of energy before his year is up. In order to recover the company would have to prove damage. (H. T. Hartman, 1905.)

It is doubtful if any rule in relation to payment of bills has any legal force unless it is a part of a contract signed and agreed to in advance by the customer. (Alex J. Campbell, 1907.)

With Municipalities.—In granting a franchise to a company a municipality may reserve the right to fix or regulate its rates and if the company then accepts the franchise it becomes a contract binding in all its terms. (J. J. Cagney; Ernest H. Davis; L. D. H. Gilmour, 1906.)

With Other Public Service Corporations.—Contracts may be made between electric lighting and telephone and telegraph companies providing for joint use of poles in a municipality or in certain streets of a municipality. (T. H. Yawger, 1909.)

A telephone company can rent space in a conduit of a lighting company. (T. H. Yawger, 1909.)

RATES AND CHARGES.

(See Regulation and Control.)

In General.—A company cannot legally charge unreasonable rates. (Birmingham Ry., Light & Power Co.; A. Peters; L. D. H. Gilmour; Ralph R. Laxton, 1906.)

Rates should be fixed so that each customer's bill shall bear the same fixed proportion to the cost of supplying him. This can best be done by a sliding scale based on the ratio of consumption to maximum demand. (J. S. Codman, 1905.)

It has not been definitely determined by the Courts whether rates may be fixed for the whole community on the basis of general averages or whether they must be based on individual costs in so far as these are determinable. (Ernest H. Davis; L. D. H. Gilmour, 1906.)

It is believed by some that the courts will not sustain a very high rate simply because such a rate in a few cases may be unprofitable to a private company and that on the other hand an average profitable rate can not be sustained as a legal maximum rate. (See Report of Messrs. Arnold & Carroll.) (See Electrical World, March 31, 1906.) (Ernest H. Davis, 1906.)

Legislation may be enacted prohibiting a difference in rates depending on the quantity of current delivered. (H. T. Hartman, 1905.)

A customer can be charged for any expense incurred by the company on account of his unwarranted complaints. (Ralph R. Laxton, 1906.)

Minimum Charge.—A company as a condition of service may require from the customer an agreement to pay a reasonable minimum charge. (See Gould vs. Electric Light Co., 60 N. .Y. St. Rep. 559.) (Ernest H. Davis, 1906.)

A minimum charge if imposed must be uniform in its application. (L. D. H. Gilmour, 1906.)

Discounts.—It is not unreasonable to charge less per unit to customers using a large amount of energy than to customers using a small amount of energy as rates to be reasonable must be based on costs and the cost of distribution per unit decreases as the consumption increases. Similarly discounts for increased average daily use per lamp are justified by the greater economy of operation of a company's station under such a load. (Douglass Burnett, 1905.)

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