A paper presented at the 166th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

ELECTRICITY IN THE NAVY.

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The recent progress in the application of electricity to naval purposes has been very marked. It would be well to sketch the development of this form of energy in the naval service and its numerous applications both for lighting and power in recent years, and to conclude a brief historical summary by a comparison of our own vessels with those of foreign navies.

The advantages of electricity on board ship from a military point of view have long been recognized, particularly with regard to the incandescent lamp and the electric projector. In the old installations these features were alone considered, and anyone having experience with electric lights on shipboard will testify to their advantages over the old method of illumination; less liability to fire, reduction in radiant heat, greater illuminating power, no smoke or disagreeable odors, and no vitiation of the atmosphere by the consumption of oxygen, all these advantages adding greatly to the efficiency of the ship and the health, comfort and cheerfulness of the personnel.

The U. S. S. *Trenton* was the first man-of-war in the world to be lighted by the incandescent lamp. This installation was made in 1883, and consisted of a single dynamo, supplying current to 238 lamps, with a total candle power of 3090. The installation of the electrical apparatus of the ship was superintended by Lieut.-Commander R. B. Bradford, now Rear Admiral and Chief of the Bureau of Equipment. This officer became executive of the vessel, and has been closely identified, both officially and from personal interest, with the development of electricity in our navy.

The lighting of the *Trenton* proved a success and was in operation for a full three years' cruise, and confirmed the opinion that no modern vessel is complete without a plant for lighting by electricity.

The proved efficiency of the *Trenton's* installation and the valuable experience gained in that vessel led to the application of electricity for lighting other vessels. The ships authorized by Act of Congress in August, 1882, viz., the *Dolphin*, *Atlanta*, *Boston* and *Chicago*, were so equipped, and since that time an electric plant has been looked upon as an essential feature of all vessels of war, and the scope has been extended to include both lighting and the electric drive of numerous auxiliaries which have hitherto been controlled by steam or hydraulic power.

The early ships were provided with one generator, hence in case of breakdown it was necessary to have recourse to oil lamps. The specifications for the next vessels, authorized by Act of Congress in 1885 and 1886, called for two complete plants, each an exact duplicate of the other. This was not decided upon without some opposition. It was proposed originally to install two generators, one of large capacity to supply the night load and a smaller one to furnish current for lamps required during the day. This idea was finally abandoned on account of the possible overpowering of the smaller dynamo by the large one, unless carefully watched, the decreased relative economy of small generators, and the diminished number of spare parts necessary in a duplicate installation.

The standard voltage on board our ships until recently was 80 volts, a standard adopted by several foreign services. Recently the standard has been changed from 80 to 125 volts, and the latter voltage is to be used in the majority of the vessels now under construction and in all future installations. The considerations that led to this change and the advantages accruing therefrom are discussed by an officer who presents a paper on the subject at this meeting, and who served as a member of a special board ordered by the Navy Department to decide on the voltage best adapted to naval purposes

Under the old regulations the electrical illumination of a ship came under the cognizance of the Bureau of Navigation, and the searchlights with their accessories under the Bureau of Ordnance, and separate generators were installed for these purposes. At present, all generators are installed by the Bureau of Equipment, which also includes under its cognizance searchlights, wiring, conduit fixtures, switchboard, dynamo-room fittings, wiring appliances and supplies, and accessories and instruments necessary for the care, maintenance and preservation of the electric plant.

Each bureau installing electrically operated machinery has cognizance of and installs the motors and controlling apparatus for this purpose. It is thus seen that the electrical installation of a ship falls under the control and supervision of the Bureau of Equipment, Bureau of Construction and Repair, Bureau of Ordnance and, to a more limited extent, the Bureau of Steam Engineering.

The advantage of the electric drive for auxiliaries appears to be as evident as the superiority of the incandescent lamp over the oil lamp or candle for illumination. The confidence engendered by the use of electricity in the early ships and the rapid commercial development of motors and their controlling apparatus gave an impetus to the use of the electric drive on shipboard, and at the present time we find motors installed for ventilating blowers, ammunition hoists, turret-turning, elevating and loading of guns, workshop machinery, and the handling of boats and heavy weights. Steam or hydraulic power for auxiliarydriving has been relegated to the background, and the day is not far distant when auxiliary machinery of all descriptions will be operated by electricity.

The motor is peculiarly well adapted to naval use. Compared with steam, the cutting of bulkheads and decks is reduced to a minimum, and hence the water-tight system is more efficient, the circuits may be better protected than in the case of steam pipes and offer a smaller target. The cutting of a circuit by shot involves no danger to the personnel, and to surrounding appliances, and in case of accidents is more readily repaired. There is no leak from joints and valves, and no appreciable loss of energy in elbows and turns, no loss by condensation, and much less by radiation. The motors are also more efficient and there is relatively less loss in small motors than in small steam engines; they are less likely to get out of order; there are no reciprocating parts to adjust and their operation is simpler and requires less supervision.

The advance of electricity for naval purposes may be illustrated by a comparison between the electric plant of the *Indiana* one of our first battleships, completed and commissioned in 1895, and that of the *Kearsarge*, one of our latest battleships, commissioned in 1900. The displacement of the *Indiana* is 10,200 tons, and she is equipped with three 24-kilowatt, 80-volt generators for supplying current to 500 incandescent lamps, four 60-centimetre searchlights, two 2 h.p. ventilating motors for dynamo-room, four ¼ h.p. portable ventilating blowers, with winches and ammunition hoists, covering about 36 h.p., or a total output of 67 kilowatts, about 7 watts per ton of displacement.

The *Kearsarge*, with a displacement of 11,525 tons, is provided with seven 50-kilowatt generators, compound-wound, direct-connected, 80 volts, to supply the following demand for lighting and power:

	WATTS.
700 incandescent lamps	48,000
4 30″ searchlights	6,000
Ventilating motors and portable fans	98,000
Ammunition hoists and whips	115,138
Training, elevating and rammer motors	171,580
Boat-cranes and winches	216,350

a total of 655,240 watts, or approximately 57 watts per ton of displacement.

In this connection the practice abroad is shown in representative vessels of the German, Russian and French navies:

GERMANY.

Furst Bismarck:—Battleship, 10,650 tons displacement, with an electric generating plant of 325 kilowatts output, supplying current to 900 incandescent lamps, 44 motors for ventilation, drying-room, ammunition hoists, gun-training gear, coal winches, refrigerating plant, and searchlights.

Kaiser Frederick III.—Armored cruiser, 11,130 tons displacement. Five generators, with output of 324 kilowatts supplying power in watts as follows: Incandescent lighting, 38,260; searchlights, 55,500; ventilation, 28,340; ammunition hoists, 78,440; gun-training gear, 8,880; coal winches, 7,400; refrigerating plant, 4,500.

RUSSIA.

Retvizan:—Battleship built at Cramp's Shipyard, Philadelphia, Pa. Electric installation, three 132-kw., four 66-k.w. and one 60-k.w. generators with a maximum output of 588 kilowatts. These generators supply current to 1167 incandescent lamps six 30″ projectors, and the following auxiliaries:

4 turret-turningmotors,
4 elevating motors.
4 rammer motors.

4 turret ammunition hoists.
12 60″ blowers for forced draft system.
18 motors for hull ventilation.
6 pump motors.
2 boat-crane motors.
1 capstan motor.
8 ash hoist motors.
1 steering motor.
30 ammunition hoist motors for battery.
2 submerged torpedo motors.
1 workshop motor.
1 torpedo lathe motor.
1 bread-mixing motor.
1 laundry motor.

Also a number of portable fans, helm indicators, and other electrical signaling devices.

FRANCE.

Jena:—Battleship. Displacement 12,052 tons. Two generators of 98.4 k.w. capacity, and two of 49.2 k.w. capacity. Total output, 295.6 kilowatts.

The general subject of electrical installations will be taken up under the following headings: Dynamo-rooms and Accessories, Generators, Circuits, Wire and Wiring Appliances, Motors, Interior and Exterior Signaling or Communicating Systems, Searchlights and Incandescent Lamps.

DYNAMO-ROOMS.

For security in time of action, the dynamo room is located below the water line underneath the protective or armored deck, in close proximity to the source of steam supply. The chief considerations are protection, ventilation, accessibility, and a central position for the economical distribution of electrical energy. The compartment assigned to the dynamos may be a single one between transverse water-tight bulkheads, or may consist of two or more such compartments in the larger vessels. Fig. 1 shows the general arrangement of dynamos in the U. S. S. *Alabama*, in four dynamo-rooms between two transverse water-tight bulkheads. This plate also shows the arrangement of steam and exhaust piping. The dynamo room is generally provided with its own ventilating system and contains the switchboards, searchlight panels, rheostats, tool boards, work benches, oil and waste tanks, and the accessories necessary for the efficient operation of the plant.

The generators are mounted on light steel foundations, consisting of plating, angle and channel bars, with a yellow pine or teak backing, and are further braced by stanchions tying the flat or platform to the protective deck above, and stanchions bracing to the deck below, with such other stiffening bars and braces as may be found necessary to reduce vibration to a minimum.

Heretofore the dynamos have been located in the same portion of the vessel. the dynamo-rooms forming subdivisions of one general compartment between transverse water-tight bulkheads. The rapid development of the electric drive and its application to ammunition hoists and gun operation has made the question of dynamo-rooms and their location one of the most important in ship design. In the proposed 16,000-ton battleships recently authorized by Congress, it is proposed to install the generators in two separate compartments, the dynamo-rooms to be entirely independent of each other electrically, and to be situated at opposite ends of the vessel. Each dynamo-room is to be supplied with four 100-k.w. sets, which will supply the output necessary to handle the battle load, for lighting and all auxiliaries. All forward circuits will be supplied by a distri-

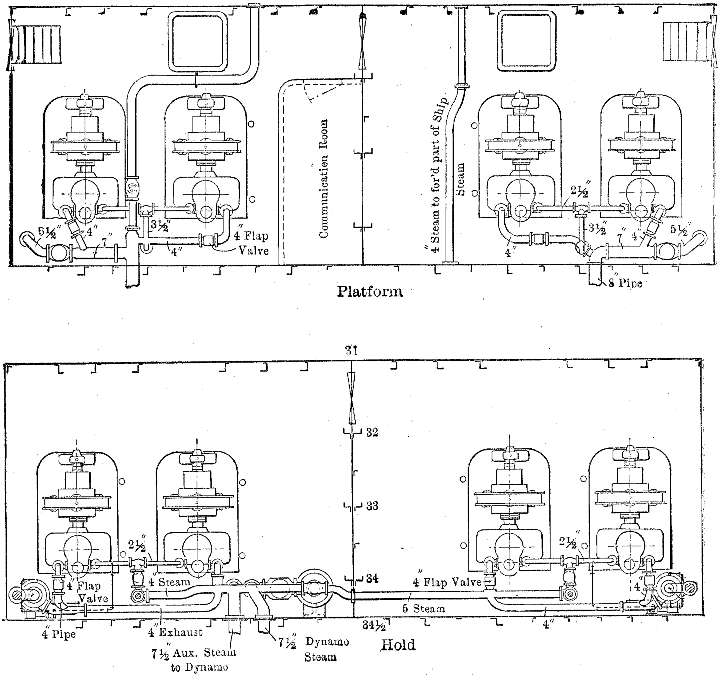


FIG. 1.—Arrangement of Steam and Exhaust Pipes in Dynamo Room, U. S. Battle Ship *Alabama.*

buting board located near the forward dynamo-room but separated from it; all after circuits from the after distribution board, similarly situated. By suitable transfer switches both the distributing boards may be electrically connected and the entire load thrown into either dynamo-room at will. This will increase the military efficiency of the installation, as in case of accident rendering either dynamo-room uninhabitable, the battle load may be thrown on the remaining room.

ENGINES AND DYNAMOS.

The generating set of the *Trenton* above referred to, consisted of a horizontal Armington and Sims 9½″ by 12″ simple engine, belted to an Edison under-type dynamo, and although heavy and cumbersome as compared with generators of the present type, it gave good and efficient service. The dynamo was shunt wound, 100 volts, 120 amperes and rated as a 150, 16 c.p. light machine. Belted sets were installed on several vessels up to the latter part of the 80's, when direct-connected sets first made their appearance.

The Edison under-type dynamos were found to produce an effect on the ship's compasses, owing to magnetic leakage and large stray field, a defect which has been entirely obviated by the use of multipolar or ironclad types of generators.

The early direct-connected sets had horizontal engines and by ingnieous design were fairly compact and not excessive in weight. The disadvantages were inefficiency in steam consumption, inaccessibility for repair and cleaning, and excessive vibration.

In 1889 horizontal engines were abandoned in favor of the vertical type. The first vertical engines were two cylinder non-condensing, designed for an initial steam pressure of 80 pounds, cranks at 90°, but the pounding which resulted made necessary the spacing of 180° between cranks in subsequent designs.

The dynamos direct connected to these engines were 4-pole machines with field coils on the vertical and horizontal axes bringing the lower field coil into a position where it was subjected to oil and water, and much trouble was experienced with this coil in this arrangement of poles.

The valve chests were located between the cylinders, main-shaft bearings being provided between the cranks and eccentrics, thus giving five bearings to the sets, four on the engine proper and one on the commutator end of the shaft. The latter bearing was of the self-oiling ring type, the others being lubricated by oil cups. Oval wear in the cylinders developed in these sets, due to rocking of the piston, *i. e.*, lateral play, existing in the cross heads. This was at first remedied by the use of tail rods and later by a new design of crossheads and guides, and the use of conical pistons. The engine and armature shafts were in common, and it was almost impossible to remove and replace the armature without springing the shaft. The defects developed in service in these sets were soon overcome, the poles were spaced diagonally on the field frames and the engine and dynamo shafts were no longer made combination, but joined by flanged couplings securely bolted, and the driving communicated by a cross-key through a key-way common to both faces of the shaft flanges.

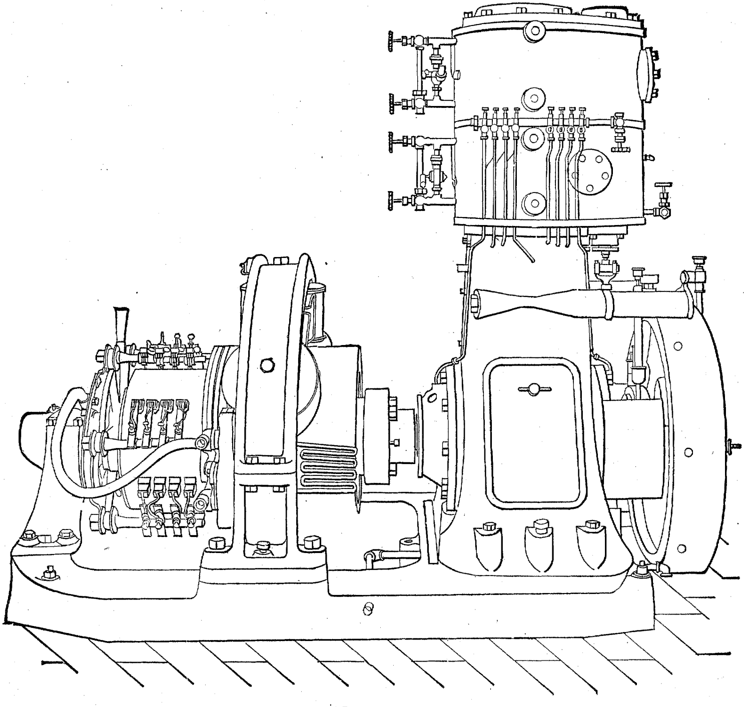


FIG. 2.

Tandem compound engines have been used extensively and were first installed on the U. S. S. *Chicago*. They are shown in Figs. 2 and 3. They have given excellent results, although not as efficient noras accessible as the cross-compound engine required by the present specifications. The excessive height of this type of generator, not only assembled, but the additional head-room necessary to remove pistons and rod, prohibits their use in naval installations with the comparatively small height between decks. Fifty kilowatts would seem to be the maximum capacity allowable in generators of this design, and they could only be used in a majority of vessels by making special provision for the removal of pistons.

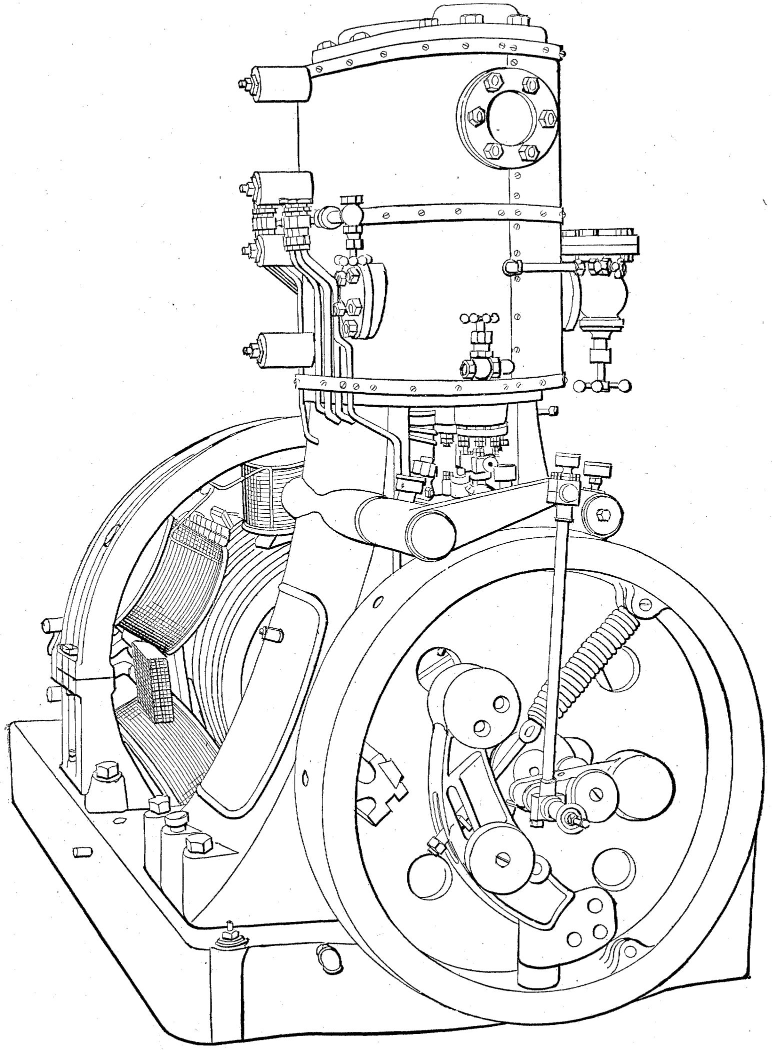


FIG. 3.

Lubrication in the steam spaces is not allowed, as the auxiliary boilers in some cases have been injured and the crown sheets dropped in spite of the precaution of removing oil from condensed steam. To lessen further the liability of oil working into the cylinders, the stuffing boxes are specified to be at least as long as the length of stroke of engine. These boxes are to be accessible from the outside of the enclosing casing of the engine to facilitate adjustment.

Forced lubrication is an essential factor in attaining satisfactory operation of a generator, and is now required on all sets furnished the navy. A pressure of from 10 to 20 pounds is prescribed in the lubricating systems, but the bearings are to be so designed that forced lubrication is not a necessary feature to insure cool running.

The smaller sets, 2½ and 5 k. w., for torpedo boats and destroyers are designed for high speed, in order that reduction in weight may be attained. This involves a rather uneconomical steam consumption, but inasmuch as these sets are not subjected to continuous running, as in battleships and cruisers, the increased weight of steam required for their operation is not considered in the attempt to reduce all torpedo boat weights to a minimum.

The 2.5 k. w. sets give an output of 5 watts per pound, the 5 k. w. sets 3.865 watts per pound, although some 5 k. w. sets have been installed with an output of 5 watts per pound weight of set.

The 16-k. w. sets, although of comparatively high speed (400 to 500 r.p.m.) show a weight efficiency rather lower than would appear consistent with other types. These sets give 2.86 watts per pound, whereas the 32 k. w. sets give 3.14 watts and the 100 k. w. sets 4.55 watts per pound. The specified water consumption of all sets is rather liberal, as it is the aim to secure fair efficiency with great durability, and sacrifices are made to ensure the latter characteristic in naval installations.

Generators have improved step by step with the commercial type, and the specifications now in force embody no requirements that are not fulfilled by the best types of commercial machines, excepting that the rating of these generators must be changed to conform to the specified heating limits and overload requirements. An allowable temperature rise of 33½° C. in armature appears at first sight rather low, but taking into consideration the high temperatures in many of our dynamo-rooms in tropical service, the low heating limits assigned are justifiable.

A two-hour overload of 33⅓% is specified in order that a machine running at or near full load may be capable of handling a sudden call for a motor load or searchlight, thus obviating the delay caused by being compelled to start a new machine.

The present specifications issued in November, 1901, based on experience, are outlined as follows:

Each set to consist of an electric generator direct-coupled to a steam engine, both mounted on a common bed-plate.

The sets as a whole shall be as compact and light as is consistent with a due regard to strength, durability, and efficiency. The standard sizes with their corresponding maximum allowable speeds, weights and over-all dimensions are:

TABLE 1.

Size in kilowatts.	Revolutions per minute.	Weight in pounds.	Length in inches.	Width in inches.	Heightin inches.
2.5	800	500	32	20	30
5	750	1,300	50	28	40
8	550	2,500	64	34	50
16	450	5,600	78	40	60
24	400	7,300	88	48	68
32	400	10,000	101	52	78
50	400	16,000	110	60	85
100	350	22,000	125	70	95

The design shall provide for accessibility to all parts requiring inspection during operation, or adjustment when under repair. Sets are to be designed to operate right-handed, *i. e.*, counter clockwise when facing the commutator end, or left-handed, as required. The design to be preferably such that the same parts may be used in each, in order to avoid increase in number.

The sets must be capable of running without undue noise, ex cessive wear, or heating. Must be balanced and run true at all loads up to 33⅓% above rating; must be capable of running for long periods under full load and without continued attention.

Cast or wrought iron shall not be used for bearing surfaces, except in cases of cylinders, valve chests, and crosshead slides. Both upper and lower halves of main bearings to be removable without removal or displacement of shaft.

The driving shaft must be fitted with thrust collars or other suitable device which will prevent a movement of the shaft in the direction of its length, as might be caused by the rolling of the ship.

The combination bed-plate to be a substantial casting, and provided with accurately spaced drilled holes for securing to foundation.

An oil groove of ample width and depth to be cast in the upper flange of bed-plate, to be continuous around the engine and to be provided with a stopcock for drainage. The lower side of the combination bed-plate to be planed perpendicular to the line of stroke of engine.

Seats for all boltheads and nuts to be faced. All nuts to be case-hardened, and to be U. S. standard sizes. Where liable to work loose from vibration, nuts are to be secured by use of jam nuts and spring cotters. All bolt ends to be neatly finished. The two halves of the main coupling to be either keyed to, or forged solid with the engine crank and armature shaft. The coupling to be bolted together by well-fitted bolts, driving to be done by a cross-key set in the faces.

ENGINE.

Engines are to be of the automatic cut-off vertical inclosed type, designed to run condensing with maximum practical efficiency at all loads, but capable of satisfactory operation when running non-condensing; to be of sufficient indicated horsepower to drive the generator for an extended time at the rated speed, when said generator is carrying a one-third overload.

Sizes $2\frac{1}{2}$ k. w.,5 k. w., and 8 k. w., to be simple engine, single or twin cylinder at the option of the contractor. Sizes of 16 k. w. and above to be cross-compound with cranks set at 180°.

The normal steam pressure under which the engine, running condensing with 25-inch vacuum for different size sets, is to operate, and the maximum allowable water consumption per kw. hour output of the set are:

TABLE 2.

K.W.	Normal steam pressure.	Water consumption per K.W. hour, full load.
2.5	100	105
5	100	90
8	100	65
16	100	44
24	100	40
32	100	37
50	100	35.5
50	150	33.5
100	150	31

In testing, correction shall be made by calorimeter for entrained moisture. Superheating shall not be used in the test.

Engines must run smoothly and furnish the required power for full load at any steam pressure within 20% (above or below) of those given above and exhausting either to condenser at 25 inches vacuum or to the atmosphere. Must be able to bear without injury the sudden throwing on or off of one and one-third times the rated full load of the generator, by making and breaking the generator's external circuit.

The length of stroke of the engine to be not less than the diameter of the bore of the high-pressure cylinder.

The cylinders to be made of hard, close-grained charcoal iron, bored and planed true, of sufficient thickness for operation after re-boring once, steam and exhaust ports to be short, of ample area and free from fins, scales, sand, etc. Cylinders to be fitted with the usual drain cocks, all drains to end in one outlet. In addition to these drains, relief valves are to be fitted to each end of each cylinder, and both high-pressure and low-pressure valves are to be free to lift from their seats to relieve the cylinder of water.

The low-pressure cylinder must be fitted with a flat, balanced slide valve; a piston valve on the low-pressure cylinder will not be accepted.

The pistons to be of cast iron or steel, strongly ribbed, light and rigid, and fitted with self-adjusting rings, each piston to have two or more rings. Rings to override counterbore of cylinders, to prevent wear to a shoulder.

Piston rods to be of forged steel securely fastened to pistons and crossheads. Crossheads to be of steel with adjustable shoes. Connecting rods to be of steel with removable babbitt-lined boxes for crank pins and bronze boxes for crosshead pins.

The crank shaft to be forged in one piece; counterweights for balancing reciprocating parts to be forged with it or securely fastened thereto. Valve rods, eccentric rods, and rocker shafts, as well as all finished bolts, nuts, etc., to be of best forged steel.

The governor to be of the weight and spring type, arranged to operate the high-pressure valve by a shifting eccentric, thus automatically varying the valve travel and point of cut-off. No dash-pots or friction washers shall be used in its construction.

The speed variation must not exceed 2½% when load is varied between full load to 20% of full load, gradually or in one step, engine running with normal steam pressure and vacuum. A variation of not more than 3½% will be allowed when full load is suddenly thrown on or off the generator, with constant steam pressure either normal, 20% above, or 20% below normal, and exhaust either to condenser or to atmosphere. No adjustment of the governor or throttle valve during the test shall be necessary to ensure proper performance under any of the above conditions.

Stuffing boxes for piston rods to be slightly longer than length of stroke, in order that no part of the rod exposed to the oil in the enclosure will enter the cylinders. Stuffing boxes for piston rods and valve rods to be accessible from the outside of the enclosing case of the engine.

A guard plate to be provided to prevent oil from being thrown against the lower cylinder heads and valve chests.

Engines are required to operate satisfactorily without the use of lubricants in the steam spaces. The lubrication for all other working surfaces shall be of the most complete character. No part shall depend on squirt-can lubrication.

Forced lubrication shall be used wherever practicable, which includes engine shaft, crank pins, crosshead bearings, eccentric, etc. The engine shall be capable of satisfactory operation with a low grade of lubricating oil, and the forced lubrication shall not be a necessary factor for its cool and satisfactory running. The intent of the forced lubrication is to reduce friction, noise and attention required.

The pressure for such forced lubrication shall be approximately 15 pounds per square inch, and shall be between 10 and 20 pounds under all service conditions.

The bed-plate is to contain a reservoir and cooling chamber of ample capacity, to be provided with a strainer which may be removed without interrupting the oil supply. The pump is to be direct-driven by a crank or eccentric on the engine shaft, construction to be simple and durable, and to include a proper guide or support for the plunger rod. The pump to handle clean oil only, not drawing from the top or bottom of reservoir.

GENERATOR.

To be of the direct current, multipolar type, compound-wound long-shunt connection, designed to run at constant speed and to furnish a pressure of 125 volts at the terminals, at rated speed, with load varying between no load and one and one-third times rated load.

The magnet yoke or frame to be circular in form, to have inwardly projecting pole-pieces, and to be divided in half horizontally, in all generators above 5-k.w. capacity, the two halves being secured with bolts, to allow the upper half with its pole pieces and coils to be lifted to provide for inspection or removal of armature. Pole pieces to be bolted to frame, bolts to be accessible in assembled machine to enable removal of field coils without disturbing armature or frame. Magnet frame to be provided with two feet of ample size to ensure a firm footing on the foundation.

Facilities for vertical adjustment of frame to be provided in sizes of 16 k.w. and above.

Armature spider to be designed to avoid shrinkage strains; to be accurately fitted and keyed to shaft and to have ample bearing surface thereon.

The disks or laminations to be accurately punched from the best quality of thoroughly annealed electrical sheet steel, slots to be punched in periphery of laminations to receive armature windings. Disks to be magnetically insulated from one another, and securely keyed to spider or held in some other suitable manner to obviate all liability of displacement due to magnetic drag, etc. Space blocks to be inserted between laminations at certain intervals to provide ventilating ducts for cooling the core and windings.

Laminations to be set up under pressure and held securely by end flanges. Bolts holdings these end flanges must not pass through laminations.

The commutator bars or segments to be supported on a shell, which must be either part, of, or directly attached to the spider, to prevent any relative motion between the windings and these segments. Bars to be of hard drawn copper finished accurately to gauge. Insulation between bars to be of carefully selected mica and not less than 0.03 inch thick, and of uniform thickness throughout.

Bars to line with shaft and run true, to be securely clamped by means of bolts and clamping rings. Bolts to be accessible for tightening and removable for repair.

Brushes to be of carbon. In sizes over 5 k.w. there shall be not less than two brushes per stud, each brush to be separately removable and adjustable without interfering with any of the others. The point of contact on the commutator shall not shift by the wearing away of the brush.

Brush holders to be staggered in order to even the wear over entire surface of commutator; the generator to be provided with some device for shifting all the holders simultaneously. All insulating washers and brushes to be damp proof and unaffected by temperature up to 100° C.

Finished armature to be true and balanced both electrically and mechanically, that it may run smoothly and without vibration. The shaft to be provided with suitable means to prevent oil from bearings working along to armature.

All copper wire to have a conductivity of not less than 98%.

The shunt and series field coils to be separately wound and separately mounted on the pole-pieces. The shunt and series coils, respectively, of any one set to be identical in construction and dimensions and to be readily removable from the pole-pieces.

The testing voltage for sets under 16 k.w. shall be 1,000 volts and for sets of 16 k.w. and above shall be 1,500 volts, and the source of the alternating e.m.f. shall be a transformer of at least 5 k.w. capacity for sets of 50 k.w. and under, and of at least 10 k.w. capacity for sets of greater output than 50 k.w.

The test for dielectric strength shall be made with the completely assembled apparatus and not with its individual parts, and the voltage shall be applied between the electric circuits and surrounding conducting material.

The tests shall be made with a sine wave of e.m.f., or where this is not available, at a voltage giving the same striking distance between needle points in air, as a sine wave of the specified e.m.f. As needles, new sewing needles shall be used. During the test, the apparatus shall be shunted by a spark gap of needle points set for a voltage exceeding the required voltage by 10%.

With brushes in a fixed position there shall be no sparking when load is gradually increased or decreased between no load and full load; no detrimental sparking when load is varied up to one and one-third times rated load; no flashing when one and one-third load is removed or applied in one stage.

The jump in voltage must not exceed 15% when full load is suddenly thrown on and off.

The temperature rise of the set after running continuously under full rated load for four hours must not exceed the following:

TABLE 3.

	Method of measurement.	Maximum allowable rise in °C.
		°
Armature	Electrical	33⅓
Commutator	Thermometer	40
Field coils	Electrical	33⅓
Shunt rheostat	Electrical	75
Series shunt	Thermometer	40

The rise of temperature to be referred to a standard room temperature of 25° C. and normal conditions of ventilation. Room temperature to be measured by a thermometer placed 3 feet from commutator end of the generator with its bulb in line with the center of the shaft.

The generator to be capable of satisfactory operation for a period of two hours, carrying one and one-third times its rated full load, and no part shall heat to such a degree as to injure the insulation.

Generators of the same size and manufacture to be capable of operation in parallel, the division of the load to be within 20% throughout the range. The magnetic leakage at full load shall be imperceptible at a horizontal distance of 15 feet, measurements to be taken with a horizontal force instrument.

The minimum allowable efficiencies of the generators are as follows:

TABLE 4.

K. W.	Loads.			
	1⅓.	1.	¾.	½.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
2.5	78	78	76	73
5	80	80	78	75
8	84	84	83	80
16	87	87	86	84
24	88	88	87	85
32	88	88	87	85
50	89	89	88	86
100	90	90	89	87

The cross-compound type of engine now used exclusively in the new installations for sets above 8 k. w. shown in Fig. 4, which gives sectional plans of dynamo engines for the *Wisconsin*, designed and manufactured by the Union Iron Works. Cylinders 8½″ and 13½″ diameter; stroke 8″ r.p.m. 400; initial steam pressure 100 lbs.; h.p. 50; over-all dimensions, length 8′ 3.5″, width 3′ 7″, height 6′ 3″.

Fig. 5 shows multipolar 8-pole, 24 k. w., 400 r.p.m., 80-volt, generating set manufactured by the General Electric Company for the *Olympia.* The details of this generator and the tabulated result of test are as follows: Weight, 9,385 lbs., complete; extreme length 84″; extreme width, 52″; extreme height, 77½″ over all; number of cylinders, two; cranks at 180°; inertia governor, steam pipe 2½″; exhaust pipe 4″; diameter high pressure cylinder 7½″; diameter low pressure cylinder 12″; stroke 8″.

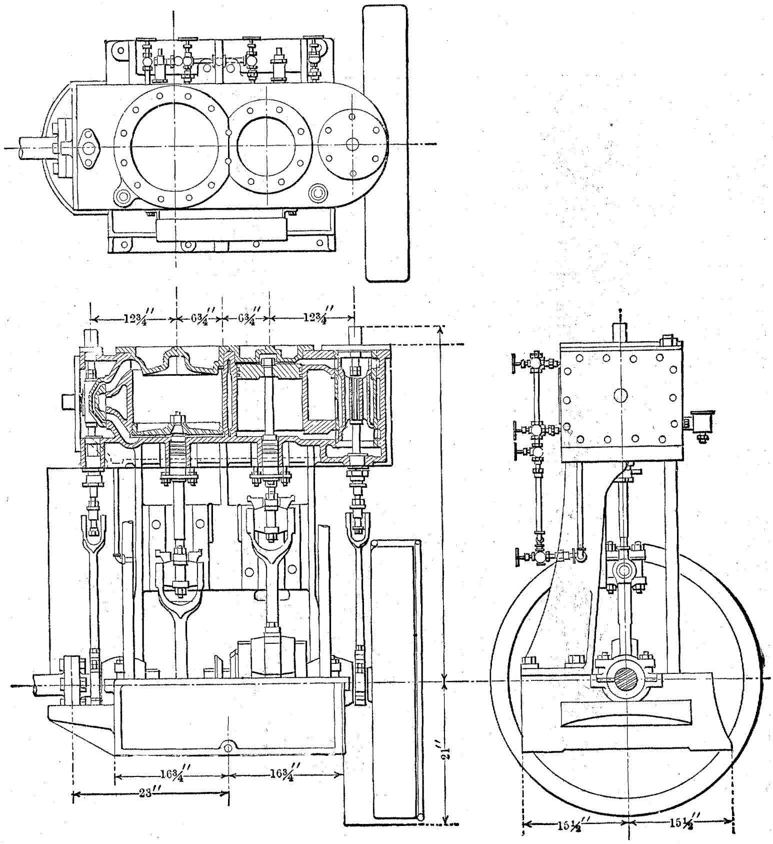


FIG. 4.—Engine 8½″ x 13½″ x 8″ stroke for 32 k.w. Dynamo.

Dynamo dimensions: Volts 80°; amperes 400; r.p.m. 400; poles 8; number of carbons per brush 1; dimensions of brushes 1¼″ x ⅝″.

TESTS.

Heat run.—4 hours at 394 amperes. Terminal volts 81.8 to 81.5; steam 100 lbs; vac. 22 to 21.5; r.p.m. 406; temperature air 28.2° C. at beginning, 30.2° C. at end of run.

Temperature at end of heat run: Armature core surface, 51°C.; commutator bars, 55.5°C.; pole tip leading, 47.5°C.; pole tip trailing, 48°C.; main bearings, 52°C.

Overload run, two hours at 33$\frac{1}{3}$% overload. Temperature of air during run, 30°C. Temperatures at end of run: armature core surface, 59.5° C.; commutator bars, 59.5°C.; pole tip leading, 53.5°C.; pole tip trailing, 54° C.

Average water consumption during four hour heat run, 33.6 per k.w. hour.

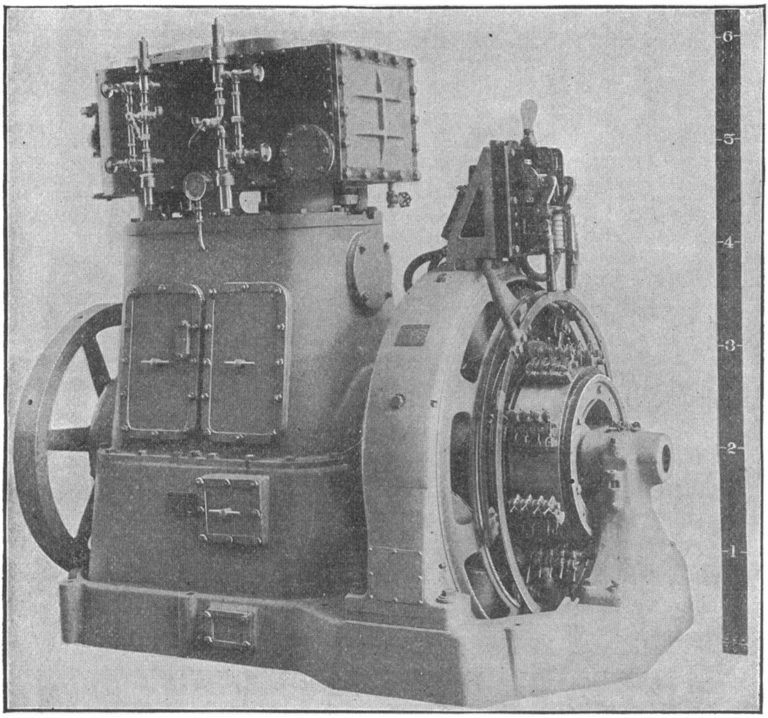


FIG. 5.—MP 8–32–400–80 Volt Form D Generating Set, with 7½″–12″ x 8″ Cross-Compound Form H General Electric Engine.

OUTPUT AND EFFICIENCY.

I^2R brush, 768 watts.
I^2R armature, 1,600 watts.
I^2R series, 422.4 watts.
C. E. shunt, 753.3 watts.
Core loss and friction, 1,637 watts.
Total losses, 5,180.7.

Volts, 80.
Amperes, 400.
Input, 32,000 watts.

Losses, 5,180 watts.
Outputs, 37,190.7 watts.
Efficiency, 86%.

TABLE 5.

ENGINE REGULATION.

Full load to no load.

Revolutions.			Volts.			Amperes.	Steam.	Vacuum.
Steady.	High.	Low.	Steady.	High.	Low.			
410	435	415	81	91	81	0	100	21.5
415	410	405	81	81	72	400	100	22.0
410	436	415	80.8	92	81	0	100	21.5
415	410	405	81	81	72	400	100	21.5
410	435	415	80.8	91	81	0	100	21.5
415	410	405	81.1	81	72	410	100	21.5

Average difference, 5.
Average difference per cent., 1.25.

TABLE 6.

Compounding Test—Hot.

Armature.		Field.		R. P. M.	Steam.	Vacuum.
Volts.	Amps.	Volts.	Amps.			
81.2	0	64	12.27	415	100	22.5
81	405	64	12.29	410	100	22.5
82.3	303	65	12.49	412	100	22.5
82.6	202	65.2	12.52	415	100	22.5
82.4	101	64.8	12.43	416	100	22.5
81.2	0	64.0	12.29	416	100	22.5
81.2	101	64.0	12.29	414	100	22.5
81.5	202	64.5	12.31	412	100	22.5
81.5	303	64.5	12.32	412	100	22.5
81	405	64.0	12.29	410	100	22.5

SWITCHBOARDS.

Switchboards are designed to give great flexibility to the distribution of electric energy and admit of a variety of combinations of generators. The present boards are more uniform in design than in the old installations, and a standard has finally been adopted which may be used for any number of dynamos.

The design of the switchboard in general is such that any dynamo or combination of dynamos operating in parallel may be run on any circuit or combination of circuits. These circuits are: search-light, light, power, and one for each electrically operated turret, the operation of the turning mechanism of which requires a separate dynamo.

In the larger installations, the switchboard has a generator panel, a lighting distribution panel, a power distribution panel and a searchlight panel. The first three are continuous and form one board, the last is separated from the main board. When the installation consists of two generating sets only, the lighting distribution panel and power distribution panel, and, when space permits, the searchlight panel may be combined.

The switchboard is arranged for connecting the negative lead of each machine to a horizontal common negative bus-bar, by a single-pole, single-throw switch. When the dynamos are more than three in number, each one is arranged for connection to either of two horizontal equalizer or bus-bars by means of single-pole, single-throw switches. For installations of three dynamos only, one equalizer bus-bar is necessary, and for two dynamos a single equalizing switch is used.

The positive lead of each dynamo connects to a vertical bus-bar. The circuits, five in number, each lead from a separate horizontal bus-bar. At each crossing of these two sets of bus-bars (the number of points will be the product of the horizontal and vertical bus-bars), connections can be made by means of single-pole, single-throw switches, placed horizontally. Switches all hinge from dynamo bus-bars and throw to the left.

The arrangement of the dynamo panel is such that all the switches and instruments (except voltmeters) necessary for the control of one dynamo are in a vertical line, and consists of (starting from the top) a single-pole automatic circuit-breaker, an ammeter shunt, an ammeter handle for operating field regulator, voltmeter receptacle, such field controlling switches as the turret turning system requires, positive dynamo switches connecting to circuit bus-bars, switch to common negative bus-bars, switches to equalizer bars, and last, a switch for shunting around the series field of dynamo when turret turning system so requires.

The arrangement of the voltmeters allows the voltage of any dynamo to be read on either of two voltmeters, allows all the voltmeters to be interconnected for calibration and allows the simultaneous reading of the voltage of any or as many dynamos as it may be desired to connect in parallel at any one time.

The power distribution panel contains a double pole switch, fused, for each motor circuit, a main negative power switch, a main negative switch for each turret-turning circuit,and such other auxiliary switches as the turret-turning system may require.

The light-distribution panel contains a double-pole switch, fused, for each lighting circuit, a main negative lighting switch, and when a separate searchlight panel is used, the light distribution panel contains a main negative searchlight switch.

The switchboard is to be provided with a lamp ground-detector with a switch for breaking ground connection. In addition, a voltmeter ground detector is to be provided with leads to a selective plug receptacle to assist in determining circuit which the ground is on. All switches and bus-bars are of hard drawn pure copper, with conductivity not less than 96%. When the hinge carries current,s witches are provided with spring hinge washers, with ready means of adjusting them. All circuits terminate and all connections are made on the back of the board. Name plates are secured to the board near the circuit switches showing the serial number of each circuit and the character and location of its load.

Ammeters and voltmeters for generating sets are marked with the number of the set; ammeters and voltmeters for searchlight circuits are marked with the name and number of the particular light.

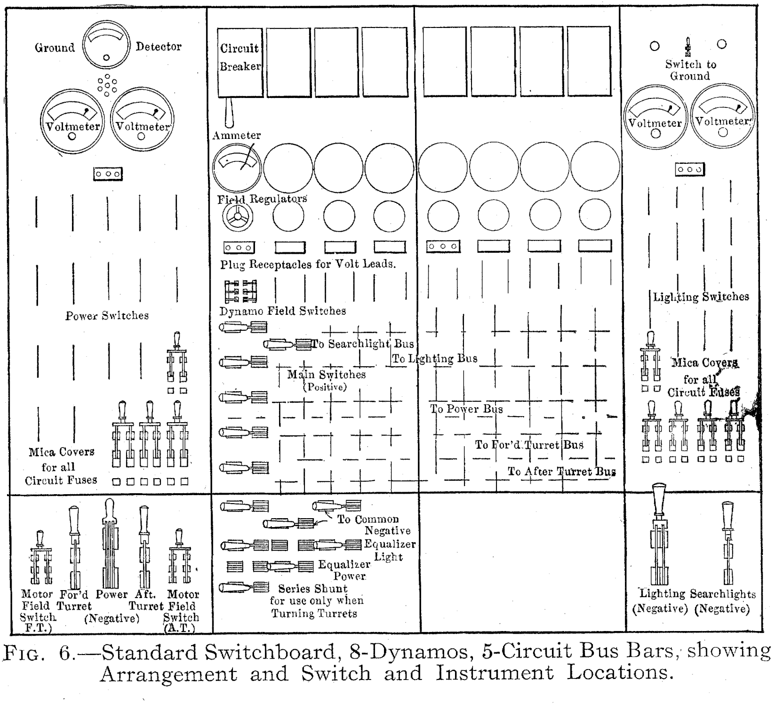
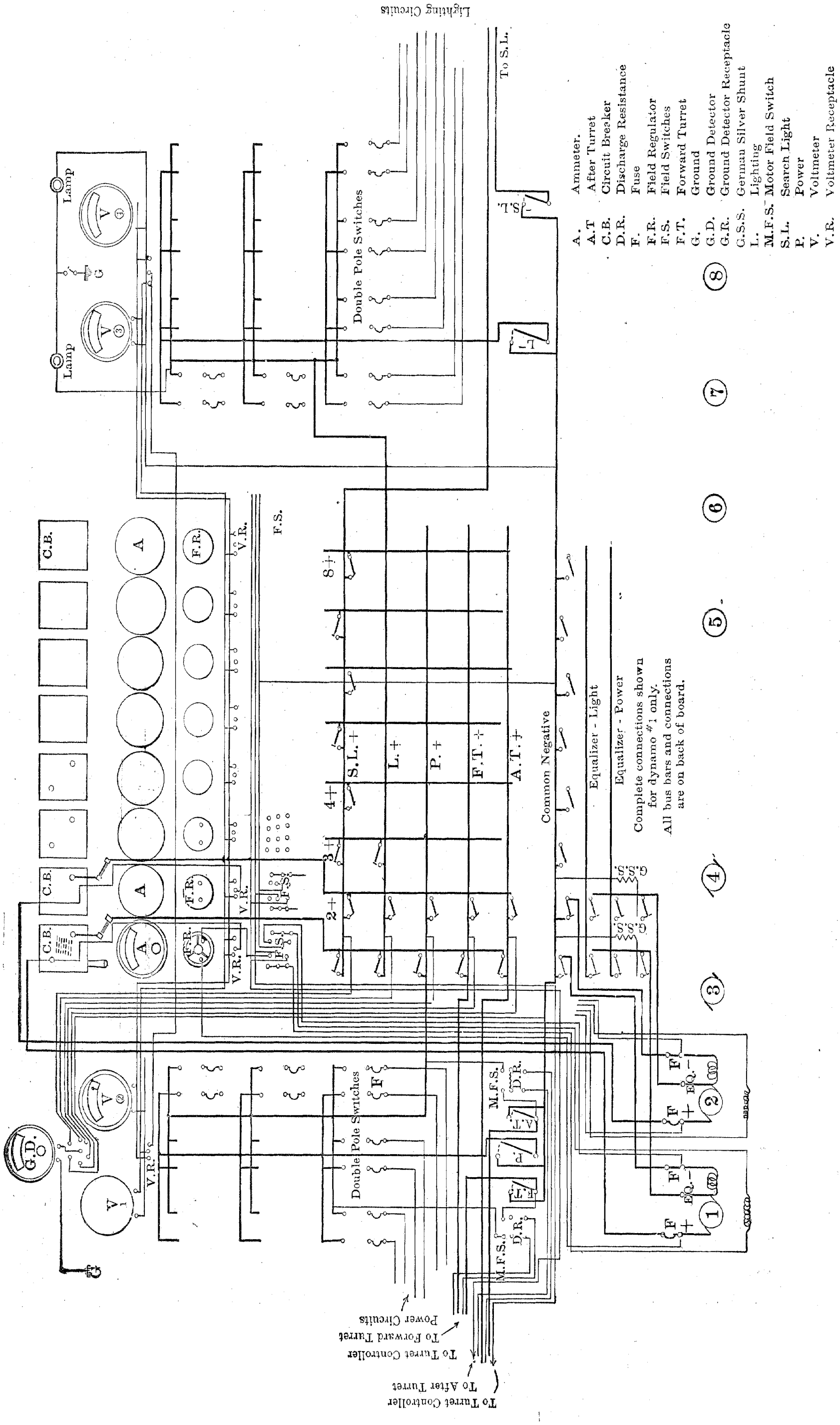


FIG. 6.—Standard Switchboard, 8-Dynamos, 5-Circuit Bus Bars, showing Arrangement and Switch and Instrument Locations.

Faces of slate panels are finished with black enamel. Panels are at least 1½″ thick, supported by a frame of all steel construction and secured thereto by through bolts.

Figs 6 and 7 show the standard switchboard adopted for future installations. This board is similar to the type to be installed in the *Maine*, *Missouri* and *Ohio*. The circuits are five in number, including separate circuits for each electrically turned turret. For paralleling the dynamos, there are two separate equalizer bus-bars, one for lighting and one for power.



Complete connections shown for dynamo #1 only.
All bus bars and connections are on back of board.

FIG. 7.—Diagrammatic Sketch of Standard Switchboard, arranged for 8-Dynamos and 5-Circuit Bus Bars.

There is no occasion for paralleling machines on searchlight or turret-turning circuits. Such dynamos as may be desired are connected to these equalizer bus-bars by removable blade plug switches.

When a dynamo is used to operate a turret-turning motor, the series field is short-circuited through a special German silver shunt, in addition to the shunt used on the dynamo itself. This is accomplished by a single-pole, single-throw switch at the base of the board, one switch to each machine. Referring to Fig. 6, each of the two dynamo panels is arranged in four vertical sections, each section containing all the apparatus necessary for the operation of one dynamo. Starting at the top, we have a single-pole automatic circuit-breaker on positive leg of dynamo (handle of circuit-breaker not more than six feet from deck), then the ammeter shunt on the back of the board, next the ammeter, then the wheel for operating the field regulator, the wheel being connected to the rheostat by a sprocket chain. Next comes the plug receptacle for voltmeter connections, then field control switches, consisting of three pairs of single-pole, single-throw switches, next five single-pole, single-throw positive dynamo switches, by means of which the dynamo may be connected to searchlight bus, lighting bus, power bus, forward turning bus or after turning bus. In the same vertical row, but on the lower panel, there are four single-pole, single-throw switches; the upper one connects the negative leg of the dynamo to the common negative bus-bar, the two middle switches connect to the equalizing bus-bars; the lower switch is to shunt the series field for turret turning.

At the left of the generator panel is the power distribution panel, containing as many double-pole, single-throw fused switches as may be required. Arranged at the top of this panel is a ground detector with selective plug receptacle, also two voltmeters with plug receptacle underneath. In the center of the power panel is a main negative power switch, single-pole, single-throw, while on each side are two single-pole, single-throw switches controlling the negative legs of the turret-turning circuits. The left hand switch is for the forward turret, and the right hand switch for the after turret. Again outside of these last mentioned switches are the field switches of the turret motors and the dynamos used for turret turning. These are double-pole, single-throw switches, with an extra set of long switch clips, across which is connected a field discharge resistance.

To the right of the generator panels is the lighting distribution panel, containing as many double-pole, single-throw switches as may be required. At the top of this panel is an ordinary lamp ground-detector with a small single-pole, single-throw switch to break the ground connection (this being necessary before using detector on power panel). This panel also contains two voltmeters with plug receptacle underneath. On the lower panel are two single-pole, single-throw main negative switches, one for lighting circuits and the other for searchlight circuits. Each dynamo contains on its headboard a main fuse on its positive leg. The field-control switches allow three methods of field excitation. By throwing the two upper switches, the machine is made self-exciting. By throwing the two middle switches, the machine is separately excited and controlled from the forward turret. By throwing the two lower switches, the machine is separately excited and controlled from the after turret.

The voltmeter connections are shown in Fig. 7. The plug receptacle on the power panel and the four receptacles on the left hand dynamo panel for machines 1, 2, 3 and 4 have a spacing of 1″ and 2″, whereas the receptacle on the lighting panel and those for machines 5, 6, 7 and 8 have a spacing of 1½″ and 2½″. By using the 1″ plug in any receptacle on the dynamo panels, the voltage of the machine is read on voltmeter No. 1; by using the 2″ plug the voltage can be read on voltmeter No. 2; thus we can read the voltage of any two machines on the left-hand panel and of any two machines on the right-hand panel simultaneously. With the 2″ plug in a receptacle on the dynamo panel and the 1″ plug in the receptacle on the power panel we have voltmeter No. 1 in parallel with voltmeter No. 2 for calibration. With the 1″ plug in any receptacle on the dynamo panel, the 2″ plug in the receptacle on the power panel and the 1½″ plug in the receptacle on the lighting panel voltmeters Nos. 1 and 3 are in parallel. By substituting the 2½″ plug for the 1½″ plug in the above arrangement, voltmeters Nos. 1 and 4 are in parallel. As only one plug of each spacing is to be furnished, it is impossible to make a short-circuit or parallel two machines on the voltmeter connections. An inspection of Fig. 7 shows this to be true.

When starting up a new machine to be paralleled with the one already running, the operation at the switchboard is as follows: First, close circuit breaker; Second, close equalizer switch; Third, close switch to common negative; Fourth, plug to voltmeter and adjust voltage by field regulator; Fifth and last, close positive switch.

For detecting grounds, the lamp detector on the upper part of the lighting panel is connected permanently across the common negative bus, and the positive leg on the lighting circuit panel; add when using the ground detector on the power panel, the ground connection on this lamp detector must be broken. The connections to this ground detector (on power panel) are such that when a circuit is grounded on the positive leg, the instrument will indicate when plugged to negative; and for a ground on the negative of any circuit, the instrument will indicate when plugged to any of the positive circuit bus-bars, provided, of course, that said bar is alive, and here it should be noted that a bar is alive when any switch in the horizontal row connecting to it, is thrown.

To locate a ground in the quickest possible manner, the group switches, *i. e.*, main negative and positive dynamo switches on the lighting circuit, should be opened; if the ground still appears the switches should be closed and the corresponding switches on each circuit opened (one circuit at a time) until the ground disappears. When the ground is singled down to one group, the circuit-switches on this group should be opened one at a time until the defective circuit is found.

CIRCUITS, WIRE AND WIRING APPLIANCES.

Circuits are installed on the main and feeder system. The feeders are connected to terminals on the switchboard and feed the mains as nearly as possible at the center of the load.

All wires for feeders, mains and branches are installed in enameled steel conduit except in passages and dynamo rooms, if not exposed to mechanical injury, when porcelain racked hangers are allowed. Moulding is no longer used except in officers' quarters or over hardwood surfaces, for the sake of appear ances. All feeders as far as possible run below the water line. Thorough water-tightness is observed for all leads into wiring appliances and fixtures and through all water-tight decks and bulkheads.

The conduit is secured to the metal of the ship by stout metal straps, and the wiring appliances are usually supported in place by the conduit. Conduit is made water-tight internally when necessary to prevent the flow of water from one compartment to another. For wire of below 60,000 c.m., cross-section twin conductor is run in the same conduit; above this size, two leads of conduit are used, one for each leg.

Circuits are divided into three classes, each being entirely distinct from the others: (1) searchlight circuits; (2) lighting circuits; (3) motor circuits.

Each searchlight is provided with a separate feeder from the switchboard through a double-pole switch, fused, rheostat, ammeter and double-pole automatic circuit-breaking device direct to the terminal lead of searchlight pedestal. A rheostat in a non-combustible frame is supplied for each search-light. The rheostat has a dead resistance which, when heated, gives a drop of from 55 to 65 volts, and also an adjustable portion in not less than ten divisions, each giving a drop of one volt for the normal current of the lamp. The value of the dead resistance depends on the size of the searchlight, large lights requiring higher voltage across the arc than the smaller ones, and this value is such that with 125 volts on the dynamo side, the variable resistance will give at the search-light from four volts below the best working voltage of the lamp to six volts above the best working voltage The maximum allowable rise in the rheostat is 75° C.

The feeders are of the following sizes:

13″	18,081 c.m.
18″	30,856 c.m.
24″	38,912 c.m.
30″	60,088 c.m.

Lighting circuits are divided into these two classes, each class having separate feeders and separate mains.

(a) Battle service.

(b) Lighting service.

Battle service includes every light installed below the protective deck and all lights above the protective deck which are necessary during action. This includes lights for the operation of guns, at ammunition hoists, boat-cranes, at controllers, ni military tops, on searchlight platforms, in conning tower, in signal tower, in limits, chart-house, signal and running lights, compass light, lights at main blowers above the protective deck, and such light as may be necessary to allow access to compartments and passages in action.

Lighting service includes all lights not above enumerated. The maximum load on lighting feeders does not usually exceed 75 amperes. The area of cross-section of the feeders and mains is such that the fall of potential from the dynamo terminals to the most distant outlet is not more than 3% at the normal load of the feeder. No feeder or main has a cross-section that will give a greater current density than one ampere per 1,000 c.m. All reductions in size of feeders or mains are fused and wherever mains are led off from feeders, it is done through standard feeder junction-boxes, having double-pole fuses, which blow on the basis of one ampere per 500 c.m. of the main. The branch outlets are fused for the normal rated load of three amperes and blow at six amperes. Fuses for feeders and mains are at the rate of one ampere per 1,000 c.m. and blow at one ampere per 500 c.m.

Motor Circuits.—Motors the normal full load circuits of which are less than 50 amperes are grouped on one feeder, and this procedure is followed up to a total load of 100 amperes. Large motors with full working load exceeding 50 amperes are installed with a separate feeder. The area of the cross-section of the feeders for motors is such that the fall of potential from dynamo terminals to motor terminals does not exceed 5% at normal full load.

Mains from motor feeders pass through feeder junction-boxes having double-pole fuses. Where several mains lead from the same feeder at one point a distributing panel with double-pole fuses is installed. All motor feeders and mains have a cross-section of not less than 1,000 c.m. per ampere for continuous service, and 500 c.m. per ampere for intermittent service.

Wire.—The wire used for electric circuits in the early naval installations consisted of a solid copper conductor covered with three layers of cotton braid, the inner one soaked in a bituminous composition, the outer one painted. In addition to the above protection, branch wires were tinned and covered with a rubber coating. This wire proved inefficient, the salt water finding its way to the conductor. To protect the conductor from this action, a lead covering was next introduced. The circuits were secured by iron staples usually without moulding.

A further step in the line of progress was made by using a tinned conductor wrapped with cotton thread, then a preparation of rubber with paraffined cotton braiding, the whole being protected by a lead sheathing. Fibre staples were used, a special tool being required to set them in place. Salt water found its way into these conductors where they passed through decks and bulkheads, whereas sections over boilers were thoroughly baked, resulting in disintegration of the insulating material and grounding of the lead covering. Specifications for the next installations required copper to be tinned, insulated by cotton wrapping, a layer of white rubber, and then the lead sheathing as before. Previous experience has shown the larger size conductors to lack flexibility and to tend toward rupturing the lead sheathing at bends, and accordingly stranded conductors for the larger circuits came into vogue.

This wire was further improved by interposing a layer of pure Para rubber between the cotton wrapping and the vulcanized rubber. For this style of wire an insulation resistance of 1,000 megohms per mile was specified for a sample 500 feet long, after immersion in sea water for 24 hours.

The next step in the evolution of wire for ships' use consisted in coating the conductor with a heavy layer of cotton braid saturated with insulating compounds, which covering replaced the lead sheathing, the rubber coverings being relied upon to exclude moisture. This latter wire gave satisfaction and frequently outlasted the mouldings in which it was installed. The wire in present use conforms to the following requirements: All conductors to be of soft annealed pure copper wire. When greater conducting area than that of 14 B. & S. G. is required, the conductor shall be stranded in a series of 7, 19, 37, 61, 91 or 127 wires, as may be required; the strand consisting of one central wire, the remainder laid around it concentrically, each layer to be twisted in the opposite direction from the preceding, and all single wires forming the strand must be of the diameter given in the American wire gauge table as adopted by the AMERICAN INSTITUTE OF ELECLRICAL ENGINEERS, October, 1893.

The material and manufacture of the strand must be such that the measured conductivity of each single wire forming the strand shall not be less than 98% of that of pure copper of the same number of circular mils, the measured conductivity of the conductor as a whole to be not less than 95% of that of pure copper of the same number of circular mils; each wire to be thoroughly and evenly tinned; all single lighting conductors shall be insulated as follows:

First. A layer of pure Para rubber, not less than 1/64″ in thickness, taped or rolled on; if taped, the tape to lap one-half of its width.

Second: A layer of vulcanized rubber about 3/32″ thick.

Third: A layer of commercial cotton tape, lapped to about 1/32″ in thickness.

Fourth: A close braid to be made of No. 20 2-ply cotton thread, braided with three ends for all conductors under 60,000 c.m., and of No. 16 3-ply cotton thread, braided with four ends for all conductors of and above 60,000 c.m. The outside diameter over the braid to be in exact conformity with that tabulated.

TESTS.

The sample, after 24 hours immersion in sea water, must have an insulation resistance of not less than 1,000 megohms per nautical mile.

The test is to be at 72° F.

The sample is to be tested by the direct deflection method at a potential of not less than 200 volts.

Sample will be tested for a conductivity of not less than 95% of that of pure copper, having a cross-section of the specified number of circular mils.

Chemical tests will be made to determine the constituents of the different layers of the insulation.

Braid will be tested for waterproof qualities.

Physical tests will be first made for qualities of strength, toughness, dimensions, etc.

The physical and electrical characteristics of the insulation under change of temperature will be tested by exposing the finished conductor for several hours at a time, alternately, to a temperature of 200° F. (dry heat), and the temperature of the atmosphere, during a period of three days.

The tests for characteristics of the insulation will then be repeated, and must show no practical deterioration on the results of the former test.

All twin lighting conductors shall consist of two conductors, each one of which shall be insulated as follows:

First: A layer of pure Para rubber, not less than 1/64″ in thickness, taped or rolled on.

Second: A layer of vulcanized rubber about 1/16″ thick.

Third: A layer of commercial cotton tape, lapped to about 1/32″ in thickness.

Two such insulated conductors shall be laid together, the interstices being filled with jute, and covered with two layers of close braid.

Each braid is to be made of No. 20 2-ply cotton thread, braided with three ends.

The copper wire and tests of finished are conductor to be as specified for single conductor.

MOTORS.

Motor applications on board ships involve the use of all sizes of motors from 1/12 h. p. to 50 h. p. Fans for officers' quarters are of two sizes, 1/12 h. p. and 1/6 h. p., the former for 12-inch desk or bracket fans, the latter for 16-inch bracket fans. Small

¼ h. p. series motors are used on portable ventilating sets. These sets are necessary for temporary ventilation when working in such parts of the ship as are not reached by the main ventilating system.

The main ventilating system employs motors of all sizes from ¾ h. p., used with small exhausters, up to 15 h. p., which are used on the larger steel plate blowers. The controlling panels for these motors contain a double-pole line switch and a rheostatic starting-box with an automatic no-voltage and over-load release. A field rheostat for speed control is also mounted on the panel.

Ammunition hoists for 5-inch and 6-inch, and smaller guns, are either endless chain hoists or whip hoists, and are operated by shunt-wound reversible motors. A motor of about 3 h. p. is used for the endless chain hoist and motors as large as 6 h. p. are used on the whip hoists. The chain hoist motors as a rule are located below the protective deck. They drive through gearing and are controlled by a panel similar to those described for the blower motors, and in addition by a double-pole, double-throw reversing switch. These motors are fitted with solenoid brakes, which release when the lever is moved to first notch and set up when the lever is thrown to off position. Motors for whip hoists when located in exposed places on the decks or bridges, are made water-tight by means of iron plates over the hand holes set up against sheet-rubber gaskets. They are fed from the line through branch blocks and switches enclosed in water-tight boxes. An enclosed cylindrical reversible controller is used.

For turret guns chain hoists are also used, the motors being either suspended under the base of the turret or in the turret itself. These motors as a rule drive through a flexible cable, running over a drum on an intermediate shaft. Motors as large as 30 h. p. are required for the 12-inch mounts, motors of about 16 h. p. for the 10-inch mounts and 8 h. p. motors for the 8-inch mounts. The first two run at 350 r.p.m., the last at 400 r.p.m. Each gun in a turret has its own ammunition hoist motor. The controllers are operated by a single handle, capable of sudden reversal, and carry the load in either direction without change of speed. Automatic circuit-breakers are installed which break armature current only. The guns are elevated and depressed by shunt-wound motors of about 5 h. p. capacity, controlled in a manner similar to the ammunition hoist motors. For forcing the shell into the breech of the guns, rammer motors are used.

These motors are series-wound, and drive through a friction sheave so adjusted that in case the shell is set home before the motor is stopped, the slipping of the driving mechanism will hold the motor load down low enough to prevent the throwing of the circuit-breaker. These motors run at about 750 r.p.m., and are of 7 h. p. output for 12-inch mounts and 5 h. p. for 10-inch mounts. They carry the load in one direction only. Small motors are used to furnish air blast for clearing smoke out of the guns after firing.

Turrets are turned by motors operated on the Ward Leonard system, as at present installed, the use of a separate generating set being required for turning each turret. A system now under consideration embodies the use of a motor-generator for each turret, several of such motor-generators being supplied by one generating set. For 12-inch turrets, two 35 h. p. motors are installed, either one being capable of handling the turret alone. These motors, located diametrically opposite each other, drive a common cross-shaft through bevel gears, this shaft carrying near each end a separate worm, which actuates a pinion on a vertical shaft. The lower end of the vertical shaft carries a gear which meshes with an annular gear attached to the inner side of the barbette. The controller, located just under the sighting hood, is operated by one handle, and carries the load equally well in either direction. Automatic cut-outs are fitted at the limits of travel of the turrets.

Recent tests on turrets fitted as above show a nicety of control which is all that could be required. The turret was moved ten successive times, and only turned through an arc of 30.9 seconds. This would mean a single movement of 3.09 seconds, a distance scarcely discernible on the circumference of a 14-foot circle (the outside of the turret). The turret was turned throughout its range of travel, 136° starboard to 136° port, a total of 272° in less than 45 seconds. The weight of the mass moved was about 600 tons.

Boat-cranes as at present installed have but one motor for both hoisting load and revolving cranes, although on ships now under construction, separate motors will be used for each purpose. About 50 h. p. will be used on the larger cranes for hoisting and lowering, and about 25 h. p. for revolving the crane. The control of the hoisting motor is by means of a resistance continuously across the line, the speed being controlled by the amount of the resistance with which the armature is placed in shunt. With this system, should the load on the crane tend to drive the armature at a speed in excess of that corresponding to the position of the controller handle, the armature will drive a current through the local circuit and run at constant speed unitl shut down.

In addition to the above-mentioned uses, motors are used to drive air compressors for use in torpedo work, such compressors requiring about 25 h. p., for closing water-tight doors; for lifting hatches; for dough mixers; for driving machine tools in the ships' workshops; for laundry work, etc. Electrically-operated steering gear and electrically-driven pumps are not used in our navy, although some foreign powers have applied the electric drive to such auxiliaries.

Interior and Exterior Signaling.

The means of interior communication consist of voice tubes, electric call-bells and annunciators, telephones, fire-alarms, general alarms, warning signal, engine telegraph, steering telegraph, helm indicator, revolution and direction indicator, battle and range-order indicators and transmitters. When a limited number of orders are to be transmitted, the telegraph is used; when an unlimited number of orders are to be transmitted and interior communication is necessary, telephones or voice pipes are installed, telephones being used for the longest leads. Between important stations, both telephones and voice pipes are installed. Call-bells and buzzers are used without returns for minor purposes.

The fire-alarm system comprises an annunciator, near the captain's cabin (under the eye of the cabin orderly) and thermostats located in coal bunkers, magazines and storerooms near the same. When the temperature in these places rises above 200° F., the alarm is given at the annunciator and the location is indicated. The thermostat in present use, Fig. 8, consists essentially of a helix of metal ribbon (metal having a large expansive co-efficient) and a terminal block, with an adjustable contact screw. Its operation is based on torsional strain produced in the helix by a rise in temperature, thus completing the circuit through the contact screw in the terminal block. The spiral embraces the shank of a " T "-shaped casting, the lower end of the spiral being connected to the lower end of the shank. The top of the spiral ends in a flat piece which extends across the top of the casting. One arm of the " T " is extended and is provided with a screw terminal for attaching live wire. The spiral terminal is secured to an insulating plate of mica, Fig. 2, provided with a large hole in the center, through which the spiral is thrust, and other smaller holes by which it is secured to the spiral terminal, the other terminal and the bottom of the box.

The adjustable contact, Fig. 3, is a brass casting with an adjusting screw *a*, a screw terminal *b* for attaching the live wire, and two screws with washers *c* and *c* for securing the mica plate. A water-tight tube, Fig. 5, passes through a hole in the casting, Fig. 6, which forms the lower side of the conduit box, Fig. 7.

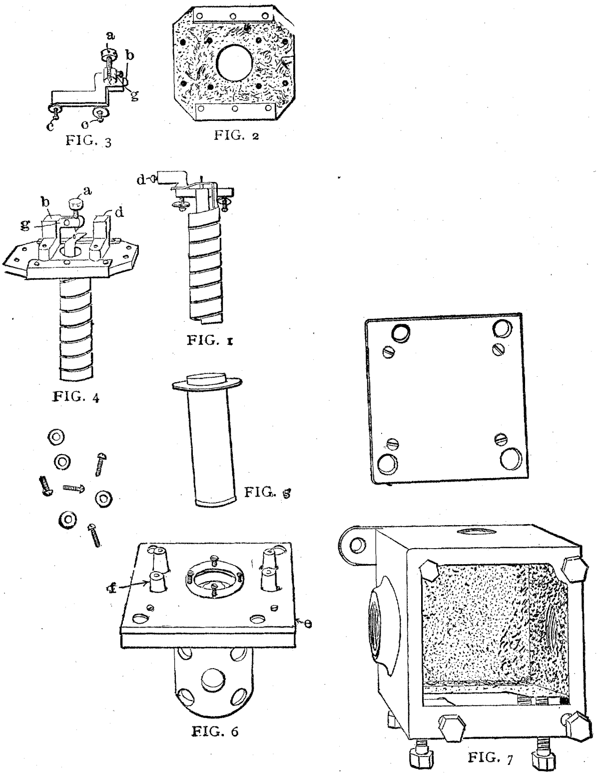


Fig. 8.—Conduit Thermostat, Type "A."

The top of the tube is flanged and is made water-tight by the rubber gasket *e*, Fig. 6, being secured by four screws. The mica plate with the spiral and terminals assembled thereon is fastened by four screws with washers to four studs *f*, Fig. 6, the spiral extending down into the water-tight tube.

To adjust, the working parts are taken from the box, Fig. 7, so as to be readily assembled. The proper electrical connections having been made (bell and battery in series with *b* and *d*

Fig. 4), the water-tight tube, Fig. 5, containing the spiral, is placed in water as deep as possible, without allowing the water to run over the top of the tube. The water is then heated and the rise of temperature is as follows:

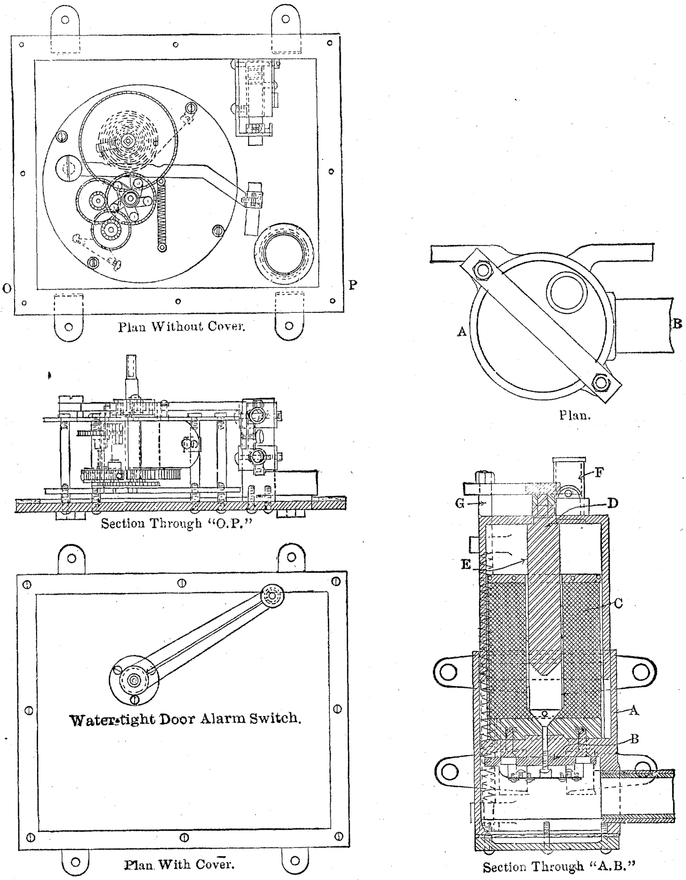
80° to 100° F. 5 minutes.
100° to 110° F. 10 "

When the temperature has reached the latter limit, the adjusting screw is run down until the circuit is closed and the bell rings. The fixture is made heavy with strong gear to resist mechanical injury.

General Alarm System.—This consists of a board on which is mounted a 12-inch gong and a brass case containing clockwork. The case contains a heavy coil spring which will give the alarm twice. The drum of the spring is connected by a gear wheel to a spindle carrying upon its outer end a star-wheel with an anti-friction roller at the end of each star. These projections of the star-wheel take against the face of a lug attached to the lower end of the bell-clapper, and as the star wheel revolves counter clockwise, it raises the clapper until the friction roller releases the lug, which allows the clapper to fall by its own weight and by the aid of a spring. Two electro-magnets with double armatures, one carrying a pin, control the release of the main spring. A train of gear wheels are connected to the main spring drive, controlling the speed of unwinding the spring. Connected with the gear wheel is an escapement disk with holes in the surface for the pin of an armature arm. The pin on the armature is controlled by a double armature designed to prevent the release of the pin by the shock of gun fire, or otherwise.

The action of the mechanism is as follows: The electro-magnets with connections to line attract the horizontal and vertical armatures when the circuit is closed. The top of the horizontal armature takes under the adjusting screw on the end of a vertical armature and thus prevents the vertical armature from moving toward the magnets until the top of the horizontal magnet is driven in to clear the screw. When the vertical armature is attracted to the magnets, the pin taking the escapement disk is driven clear. Through the train of gear wheels, the main spring is then released and continues to revolve the star wheel, sounding the alarm for thirty seconds, or until the pin again falls into a slot in the escapement disk.

The contact-makers are usually located in the conning tower or the captain's stateroom, and from these points the entire system of gongs may be put in operation. The contact-maker consists in general of a water-tight box containing a hard-rubber base upon which are secured six contact sections, separated from each other. A spider carrying switch lever is also secured to the hard rubber base on the under side. A metal spring on the spindle of the switch keeps it away from the contact sections and thus leaves the circuit open. The gongs are on battery circuits in multiple.



Plan Without Cover.

Section Through "O.P."

Water-tight Door Alarm Switch.

Plan With Cover.

Plan.

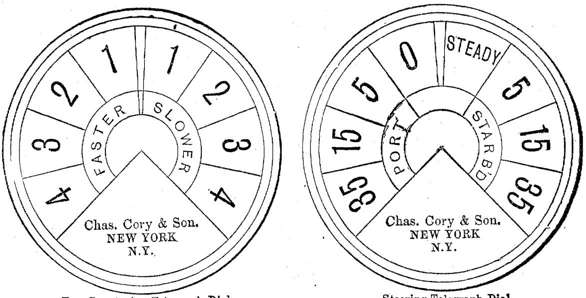
Section Through "A.B."

FIG. 9.

Solenoid Whistle.—These whistles, one of which is shown in Fig. 9, are used as a signal for closing water-tight doors, and consist of a contact-maker, which is usually placed in the pilot house, and solenoid whistles located throughout the ship. The whistle consists of a brass case, A, forming the chamber for wire terminals, space for the conduit terminal, outer cylinder of apparatus and lugs for securing the whole to the bulkhead. An insulated base, B, secured to the brass case carries a coil, C, incased in a brass cylinder, with hollow center about 1 inch in diameter. The plunger coil, D, forming an air chamber above the solenoid, is of iron, being an inverted hollow cylinder fitting closely over the outside of the coil and inside the brass case A. It is closed at the top and carries the armature plunger, E, of iron projecting downward into the solenoid. A shrill whistle, F, is mounted on this plunger case over a hole through the top of the cover. Two rods, G, fastened to lugs on the base of the brass coil carry spiral springs fitted between the lugs on the plunger cylinder and the lugs in the base, forcing the plunger up until it takes against a bridge on the top of the rods. This is the normal position of the plunger cylinder. Each wire terminal is fused on a porcelain base with a fuse of 3 amperes capacity.

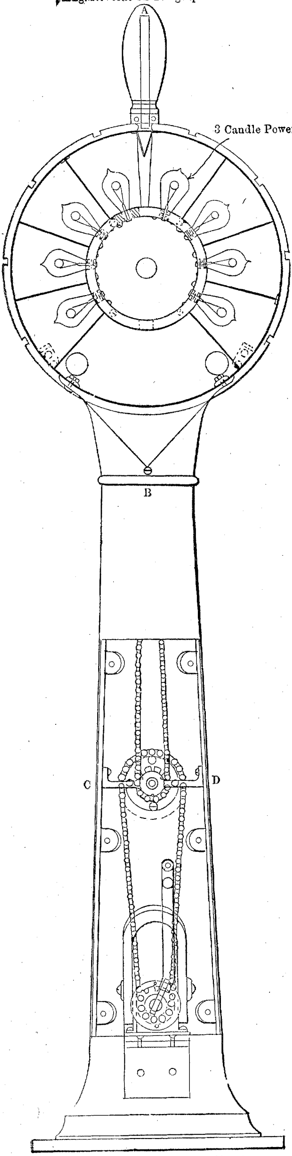
The action of the whistle is as follows: When the circuit is closed by the contact-maker in the pilot-house, the current flows through the coil of the solenoid, exerting a strong pull downward on the plunger E, and drawing the plunger cylinder D downward against the force of the springs. There being no escape for the air in the air chamber of the cylinder, except through the whistle, it gives a shrill sound. When the circuit is broken by the contact-maker in the pilot-house, the coil no longer exerts a pull on the armature, and the two spiral springs force the plunger cylinder back to its upper position at the time the contact-maker again closes the circuit, and the whistle is made to sound again as before, this action lasting for about 35 seconds, giving a succession of shrill, sharp whistles.

The electrical engine-telegraphs located in the pilot-house and conning tower are only used to signal an increased or decreased number of revolutions, and are chiefly used in steaming in squadron, the range of signals being sufficient to preserve formation. The speed designated by the flag officer is telegraphed by means of the ordinary mechanical telegraph and small variations from the speed, by the electrical devices. The transmitter includes an indicator and consists of a pedestal with a cylindrical case mounted thereon, containing the mechanism for ringing a magneto-bell at the indicator station and making an electric light burn behind a figure on the dial of the indicator. [See Figs. 10 and 11.] The form of a transmitter and its operating handles and clutch resemble the mechanical engine-room telegraph. On the spindle of the operating handle is a metal wheel

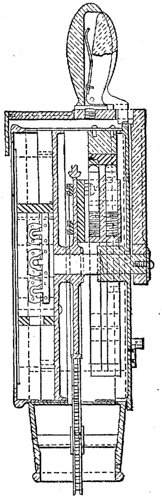


Eng. Revolution Telegraph Dial

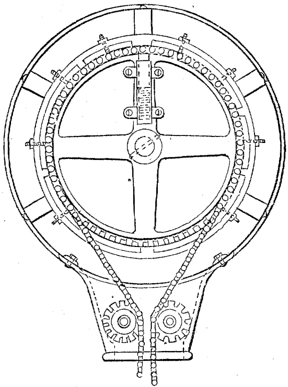
Steering Telegraph Dial



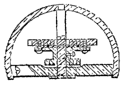
Front view showing Indicators



Section through A-B



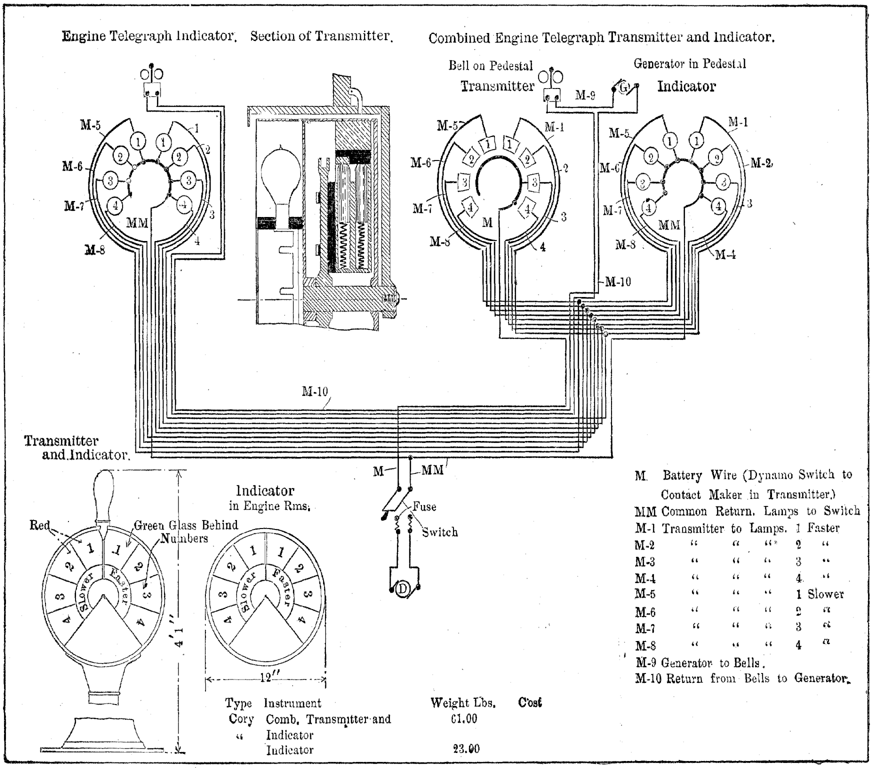
Back view showing Contact



Multiplying Gear on line C-D

FIG. 10.

geared to fit on a sprocket chain. This chain leads down into a pedestal to a multiplying gear, and thence another sprocket chain leads to an armature of a magneto-generator secured in the pedestal. Wires are led from the brushes of this magneto-generator to the magneto-bell in the engine-room. Fastened to the sprocket-wheel of the transmitter on the after side is a contact-maker insulated from the wheel. It carries a pair of earbons, each pressed outward by a spring in the base. The carbons make contact with metal sections secured to a circular hard-rubber base on the frame of the transmitter. One of these sections, connected to a common return wire, extends around the face of the instrument and is always in contact with the contact nearest the fuse. The other carbon makes contact with separate strips of metal, one for each order on the transmitter, which metal strips are connected with the section wires leading to the indicator and are insulated from each other. The



M. Battery Wire (Dynamo Switch to Contact Maker in Transmitter.)
MM Common Return. Lamps to Switch
M-1 Transmitter to Lamps. 1 Faster
M-2 " " " 2 "
M-3 " " " 3 "
M-4 " " " 4 "
M-5 " " " 1 Slower
M-6 " " " 2 "
M-7 " " " 3 "
M-8 " " " 4 "
M-9 Generator to Bells.
M-10 Return from Bells to Generator.

Type	Instrument	Weight Lbs.	Cost
Cory	Comb. Transmitter and Indicator	61.00	
"	Indicator	23.00	

FIG. 11.—Electric Engine Telegraph.

path of the current through the contact-maker when the pointer of the operating handle is over an order on the dial, is from the section wire contact into one carbon, through the metal socket, through the other carbon into the common return contact and out again to the line. A green glass is behind the numbers on the left side, which indicate slower speed. Sockets for the lamps are fitted to a hard-rubber base, and the connections to the wire are made in the center. Each lamp is connected to a common return and to that section wire which connects with a compounding contact in the transmitter. Each lamp is in a separate compartment, so that it can illuminate only one of the perforated numbers. The indicator in the engine-room is similar to the transmitter in all respects, with a magneto-bell placed above it. The figure shows the scheme of wiring, the current being taken directly from the main switchboard at normal potential. The magneto-bell on the indicator in each engine-room is wired in series with the transmitter in the conning tower and the pilot-house. A special arrangement is necessary on the transfer switch in the conning tower to bridge over the bell-circuits and not open the circuit. There is a transfer switch in the conning tower to cut out the pilot-house instruments when using those in conning tower.

Steering Telegraphs.—These are used to signal the desired degree of helm from the conning tower and the pilot-house to all steering stations. Combined transmitters and indicators are located in the conning tower and the pilot-house. Indicators are placed in the communication room, hand-steering stations on the upper decks and steering engine-rooms. These devices are exactly similar to the engine-telegraphs described above, except the orders on the dial.

Helm-angle Indicators.—These instruments, shown in Figs. 12 and 13, are installed at all steering stations, and indicate simultaneously the rudder angle at these stations. They are similar to the engine telegraphs, except the marking on the dials. The transmitter is located in the tiller room, the contact-maker, or arc, being secured on the rudder-head. The transmitter consists of a base of vulcanized rubber in the form of an arc, fastened to an iron bracket, carried on one of the protective deck beams Upon the base are fastened fifteen strips of brass of varying widths, the center line of the strips being at angles, 0°, 2½°, 5°, 7½°, 10°, 15°, 25° and 35°, with the center line of the ship. These straps are insulated from each other by narrow sections of slate,

the whole forming an arc of 60°. On the inner side of this line of fifteen contacts and close to it, is a continuous strip of brass extending over the same length of arc. The contact-maker con-
the section straps and the common return strap by spiral springs

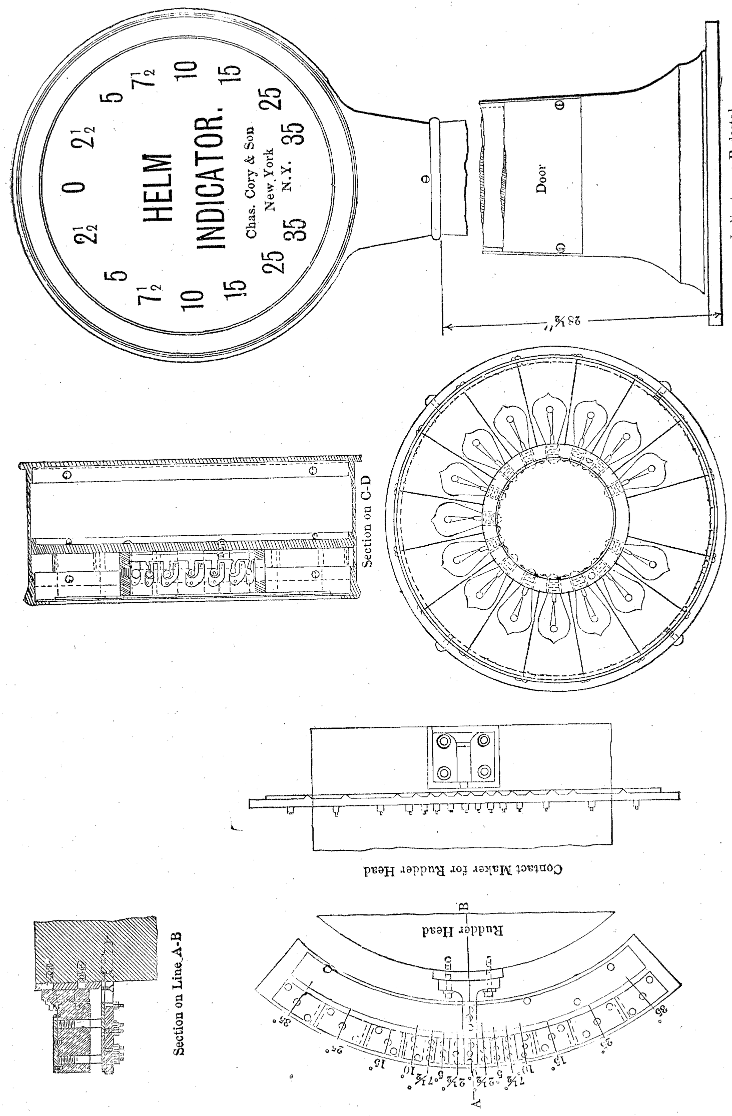
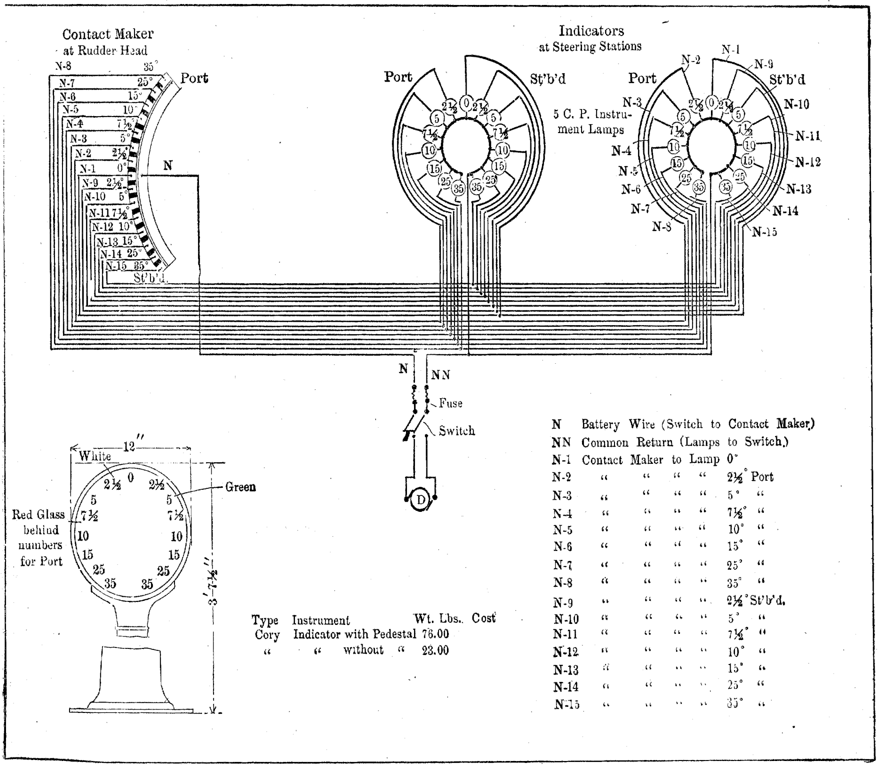


FIG. 12.

sists of a brass wire secured to the rudder-head, but insulated from it by hard rubber. Two holes bored in the ends of the arm carry the carbon contacts. These are forced downward against above the carbon, completing the circuit between the common return and the section straps. Each section strap is connected to the lamp in each indicator, corresponding with the angle at which the section strap is placed. Then, if the rudder is hard to port, the helm hard to starboard and the connection is made between the common return strap and the section strap through the carbons, the light in all indicators will burn 35° to starboard.

Revolution aud Direction Indicators.—These indicators, shown in Figs. 14 and 15, are located in the pilot-house and conning tower, one for each engine. The indicator consists of a circular water-tight case with glass face. The enamel dial is marked " ahead " and " astern " just over two small pointers. [Fig. 1.] Two sets of double-pole electro-magnets, A [Fig. 2], are mounted on the back of the case, one set for ahead and one set for astern. The figure shows the upper magnets only. Each set of magnets has an armature, B, pivoted on a vertical lug at the side of the coil, C. The end of the armature takes against



N	Battery Wire (Switch to Contact Maker)
NN	Common Return (Lamps to Switch.)
N-1	Contact Maker to Lamp 0°
N-2	" " " " 2½° Port
N-3	" " " " 5° "
N-4	" " " " 7½° "
N-5	" " " " 10° "
N-6	" " " " 15° "
N-7	" " " " 25° "
N-8	" " " " 35° "
N-9	" " " " 2½° St'b'd.
N-10	" " " " 5° "
N-11	" " " " 7½° "
N-12	" " " " 10° "
N-13	" " " " 15° "
N-14	" " " " 25° "
N-15	" " " " 35° "

Type	Instrument	Wt. Lbs.	Cost
Cory	Indicator with Pedestal	76.00	
"	" without "	23.00	

FIG. 13.—Helm Angle Indicator.

the side of a vertical spindle, D, which carries a pointer at the end. A score, or flat recess, is cut in the round spindle where the armature bears against it, which score lies against, and at an angle of 45° to the armature. When the armature is attracted to the magnets the end is driven against the spindle and turns it until the screw is flat against the armature, thus turning the spindle and the pointer at its end through an angle of 45°. When the circuit in the electro-magnet is broken, the magnets cease to attract the armature, and a spiral spring at the base of the pointer-spindle levels the spindle back to its normal position and the score again lies at 45° to the armature. The circuit is made and broken at each revolution of the shaft, and it depends upon the direction of the revolution of the shaft as to which set of magnets is energized. A switch is placed at the bottom of the indicator, and a spiral spring in the base to bring it back to mid-position when twisted to the right, and to close the circuit.

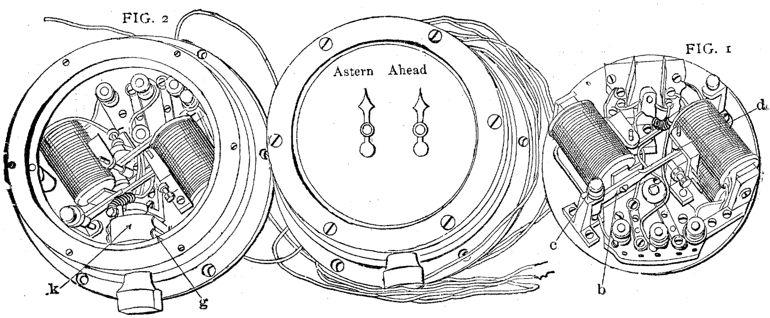


FIG. 14.

Two upright contact-strips of metal, G [Fig. 2], on each side, bear against a hard-rubber ring, K. Inserted longitudinally in this hard-rubber ring are two pieces of metal, which make connections with the upright strips, G, on both sides when the switch is twisted. This switch is in circuit with the common return of both sets of magnet wires, as shown in the diagram of connections [Fig. 5]. A lamp is installed in the indicator and illuminates the dial.

The contact-makers on the main shaft shown in Fig. 15, are located in the shaft alleys. An iron bracket in the bulkhead supports a hard-rubber base, A [Fig. 3]. A vertical sliding rod, B, is attached to the base and is in electrical connection with one wire of the common return. On the lower end of the sliding rod, a small gear wheel, C, is carried, gearing into a band, D, [Fig. 4], which is secured on the main shaft, being eccentric to the shaft.

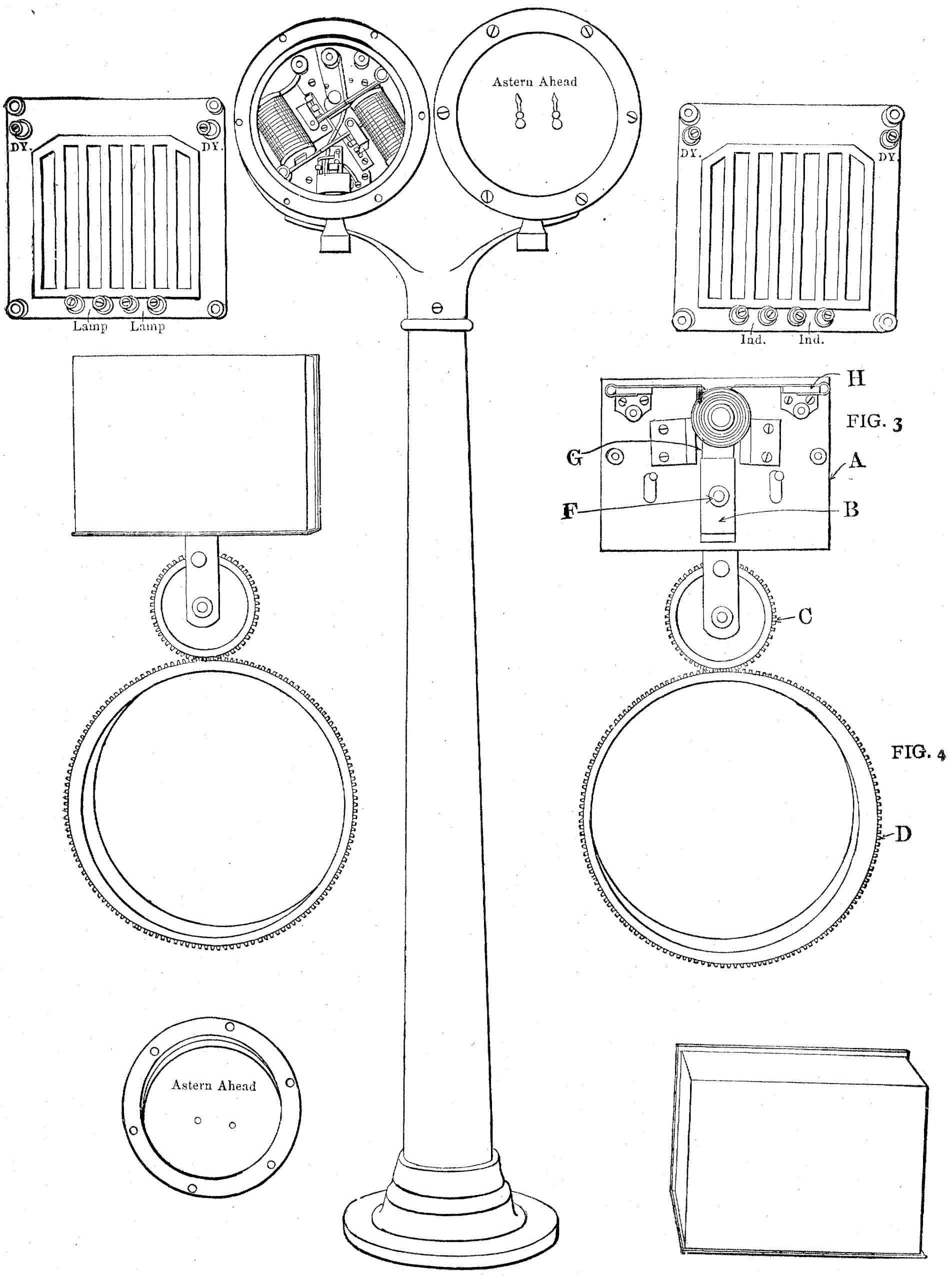

Astern Ahead
DY.
DY.
Lamp
Lamp
DY.
DY.
Ind.
Ind.
H
FIG. 3
G
A
F
B
C
FIG. 4
D
Astern Ahead

Fig. 15.

and having three-quarters of an inch throw. The teeth of this eccentric band are cut to fit those on the pinion on the sliding rod. When the shaft revolves a vertical sliding motion is imparted to the rod which is raised and lowered three-quarters of an inch at each revolution. A special spring is installed to keep the pinion in contact with the band. The rod is pivoted in about the center, F, the pivot pin working in a slot in the rod and the top being free to oscillate. When the shaft is turning ahead, the upper end of the rod is thrown inboard and takes against two small rollers, G, mounted on the base, avoiding friction as the rod is raised and lowered. One section wire leading to "ahead" magnets of the indicator is connected to a spring, H, mounted on a hard-rubber base above the sliding rod; the section wire leading to the "astern" magnets is attached to a similar spring on the opposite side. When the shaft is turning ahead, the connection between the end of the sliding rod and the section wire of the "ahead" magnet is alternately made and broken, and the indicators in the conning tower and pilot-house will show a deflection of the pointer for each revolution. When the shaft is turning astern, the connection is made and broken between the rod and the section wire leading to the "astern" magnet in the indicator.

Battle and Range Order Telegraphs and Indicators. These instruments, illustrated in Fig. 16, are used to signal the orders to the battery, ammunition supply and the range. The principle of the battle-order and range-order instruments is that each order on the indicator is shown by a separate 5 c.p. lamp, controlled by a separate switch on the transmitter. The orders are marked on the counter by transparent plates on the face of the indicators, each plate having a lamp behind it in a separate compartment. The orders on the indicators are only shown when the lamp behind the order is made to burn by turning the switch of the transmitter. Any number of orders may be shown at the same time. The instruments are wired in parallel and when a switch of the transmitter is turned, the corresponding order is shown on all the indicators. Fig. 16 shows the general design of these appliances. The orders signalled are, commence or cease firing, character of projectile to be employed, full or reduced charge, direction of the enemy and distance in yards.

ARDOIS SIGNALLING SYSTEM.

The object of the night signaling set, shown in Figs. 17 and 18, is to transmit rapidly and accurately under suitable condi-

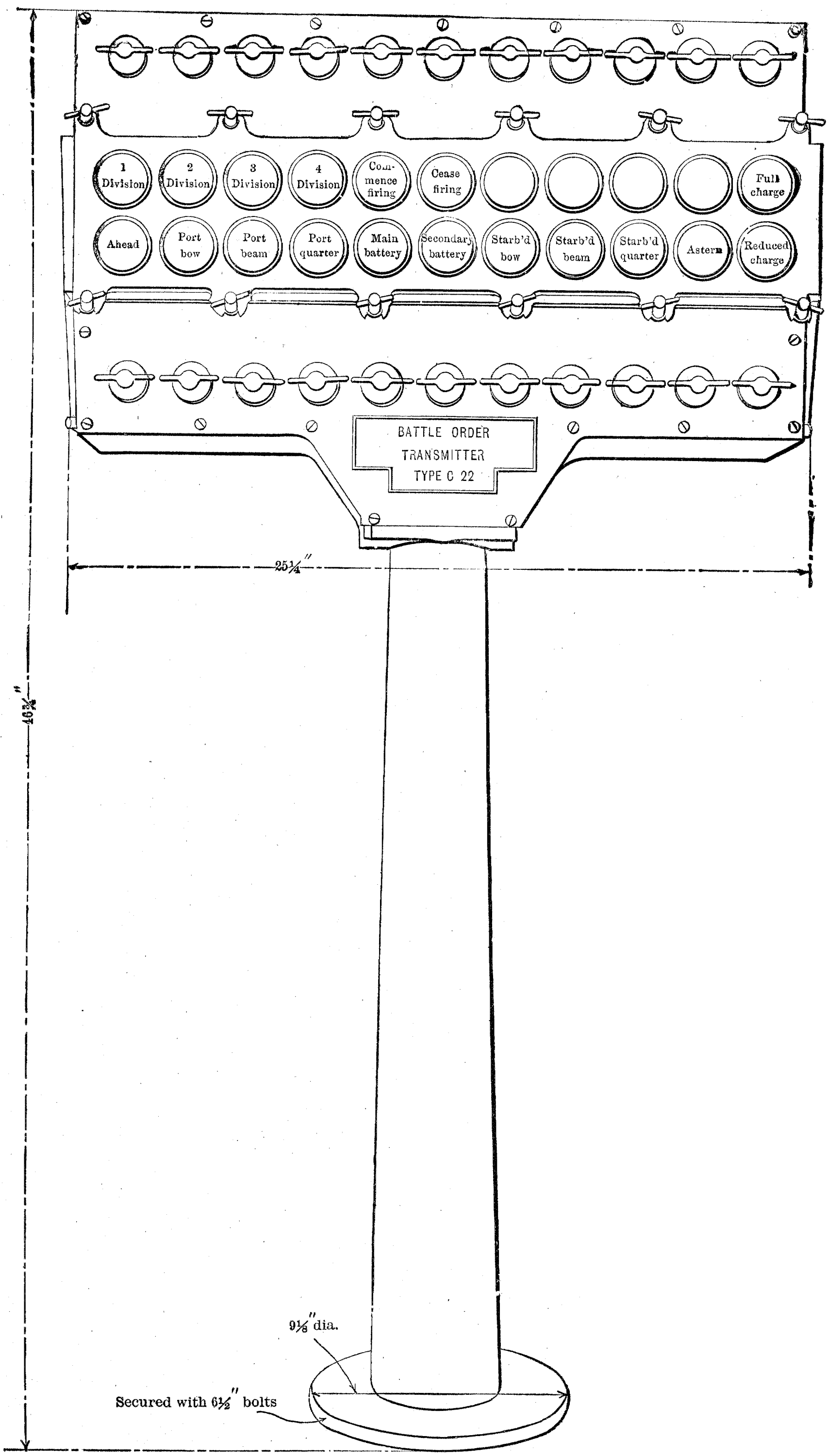


FIG. 16.—Battle Order Transmitter.

tions, a pre-arranged code of signals to a distant point, as from one vessel to another, or for squadron and fleet tactics, and for signals between vessels and co-operating commands on shore. The method is as follows: With current on the circuit, by operating the handle of the switch lock on the keyboard, the various combinations represented by dots on the dial plate in Fig. 19, are made to appear by the illumination of lamps in the lanterns, and by working the handle of the pulsating switch on top of the

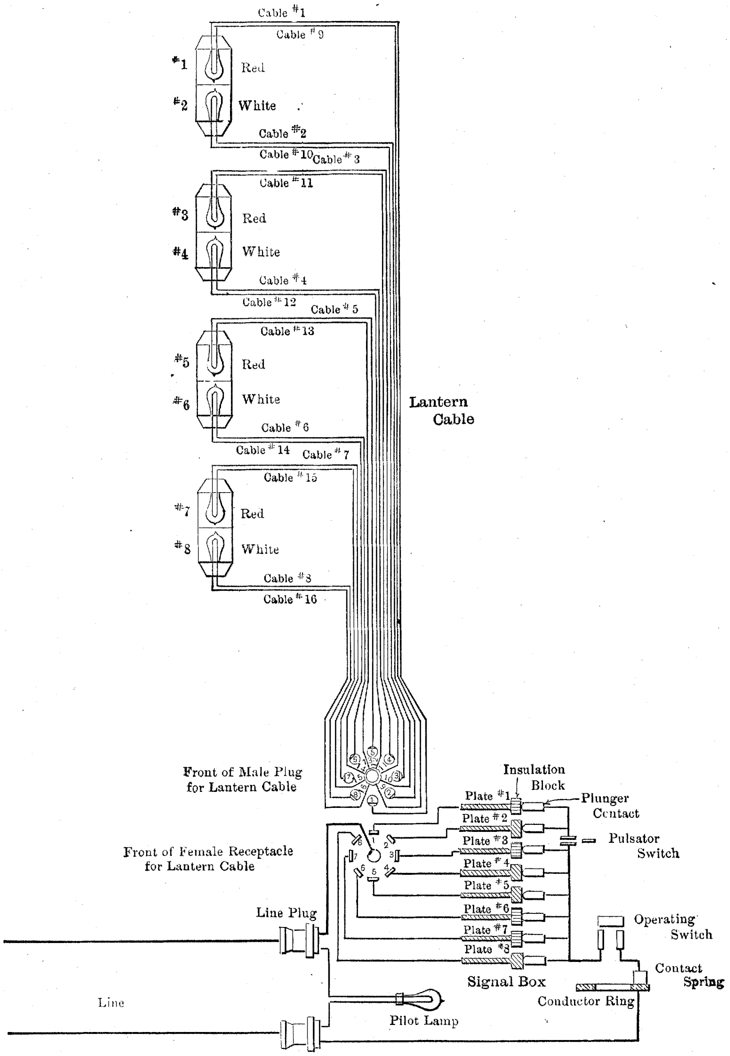


FIG. 17.—Hand Control Projectors.

spindle, the lights in the upper lantern are pulsated. The set consists of four double lanterns with lamps, a ladder, cable and keyboard. Each of the four lanterns shown in Fig. 18 has two compartments; the upper one has a red lens, the lower one a white lens. The wires from the cable pass through stuffing boxes in the center of the caps, which screw on each end of the lantern and make it watertight by a gasket. Each cap is fitted

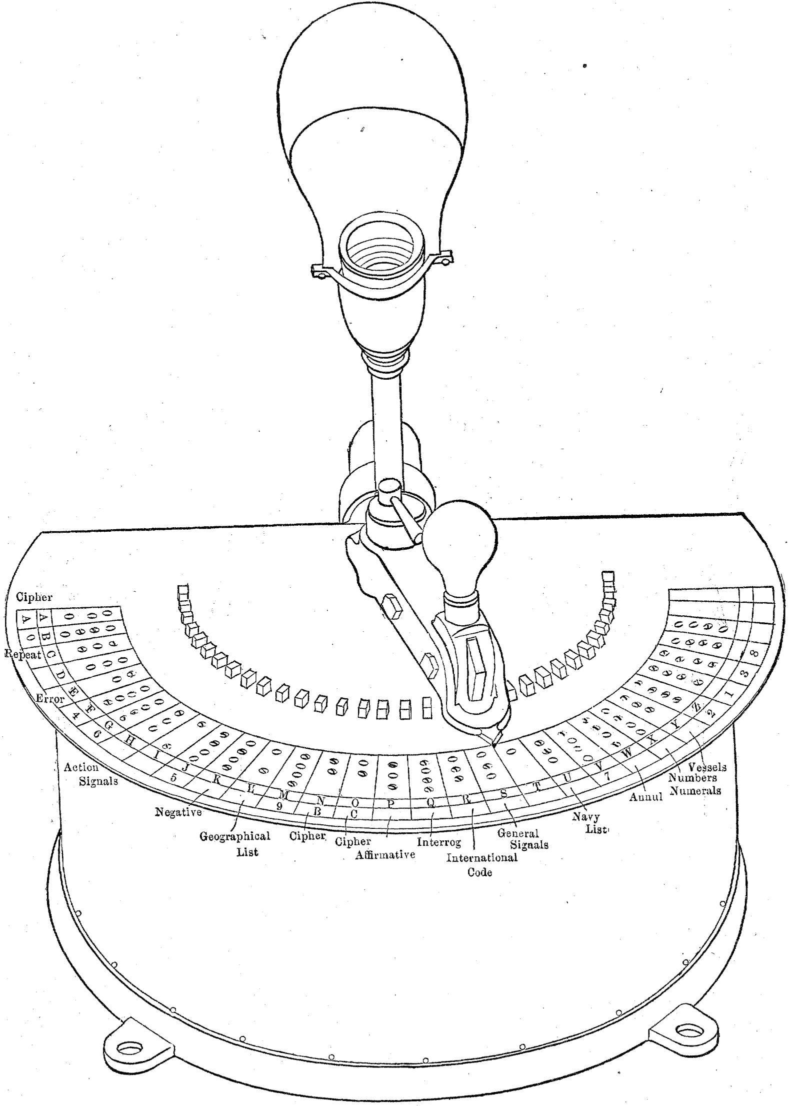


FIG. 18.—Connections for Signal Set Form "E."

with a socket and a standard 32 c.p. lamp. The ladder is made of galvanized iron wire. One end of the ladder is made fast to an outrigger, or short gaff, near the masthead and the other end is secured to a turnbuckle fastened to the deck. The cable consists of 16 conductors, each lamp having its own return wire. The wires connect to a plug which fits into a receptacle on the keyboard. The keyboard consists of a dial, handle for the pulsating switch, and the operating handle mounted on a water-tight box. It is illumined by a standard 32 c.p. lamp, supplied with a shade. The water-tight box contains the mechanism for connecting the lamps in the various combinations and consists of a rotating stud provided with eight spring-contact plungers, which rest against eight semi-circular plates. These plates are made up of insulating sections of hard rubber and composition, each of which is in connection with its respective lamp. When one of the contact fingers of the rotating stud rests on an insulating section, the circuit through the lamp is broken, but when it rests on a metal section, the circuit is closed. When the pointer is turned to the position on the dial corresponding with the desired signal, some contact plungers rest on the hard-rubber section and others on the metal section, thus connecting into circuit the desired combination of lamps.

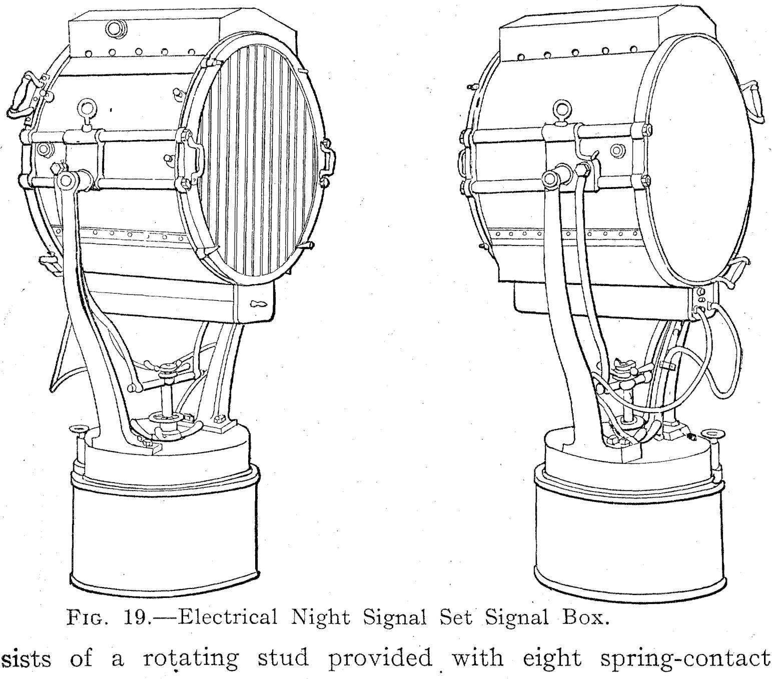


FIG. 19.—Electrical Night Signal Set Signal Box.

SEARCHLIGHTS.

Searchlights, Fig. 19, consist of a fixed pedestal, or base, surmounted by a turntable, carrying the drum in which are contained the lamp and the mirror. The base contains the electric connections and is arranged for bolting direct to the deck and platform. The turntable is free to revolve indefinitely in either direction in a horizontal plane, and may be clamped rigidly in any position, Fig. 20. The drum is trunnioned on two arms bolted to the turntable, and has a vertical train of 70° above horizontal and 30° below. This drum may likewise be clamped in any intermediate position. Parabolic mirrors are now used and are of highly polished glass, silvered on the back. The mirror is mounted in a separate metal frame, lined with non-conducting material in such a manner as to allow for expansion due to heat, and to prevent injury from concussion. The lamp is of the horizontal carbon type, designed for both hand and automatic control. It will burn for six hours without renewing carbons. The front of the drum contains a door of plain glass strips and a shutter for use in signalling. Until recently, the projectors were fitted with a system of electrical control for training the beam of light, but at present hand control is exclusively installed. The intensity of the beam of light is required to be such that on a clear, dark night a light-colored object 10 by 20 feet in size will be plainly discernible at

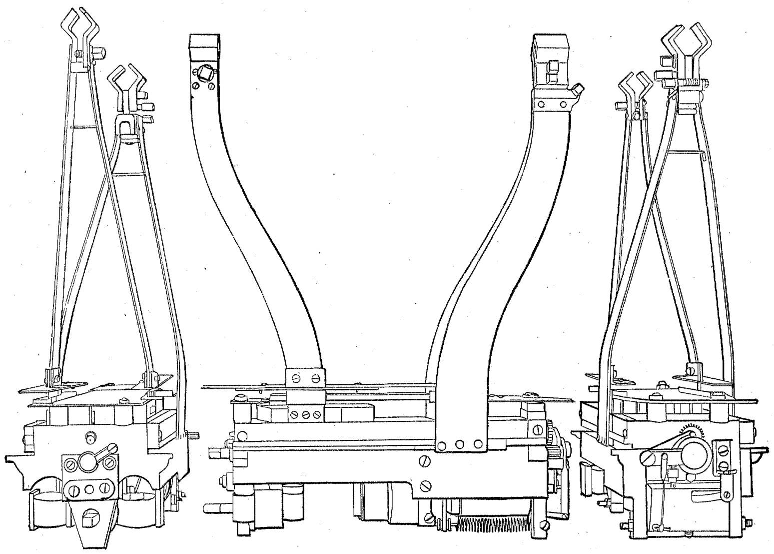


FIG. 20.

a distance of not less than 4,000 yards for the 18-inch projector, 5,000 yards for the 24-inch projector and 6,000 yards for the 30-inch projector. The current required for operation with the voltage across the arc for the four standard sizes is:

13–inch,	18–20 amperes,	45–48 volts.
18 "	30–35 "	47–50 "
24 "	40–50 "	48–52 "
30 "	70–80 "	49–53 "

Smeltzer carbons are used extensively and give good satisfaction, the positive carbon in the larger sizes being corded, with the negative carbon solid and in some cases having a core smaller than that of the positive carbon.

Incandescent Lamps.

Under the old practice, incandescent lamps were not only of a special voltage, but of a special type of bulb, and delay was experienced in supplying the service with the number required. Under the new voltage recently adopted, 125 volts at machine terminals, the lamp will be of 123 volts, with an allowed variation from 122 to 124 volts for the 16 c.p. lamps, and from 121 to 125 volts for the submarine, or diving lamps. The 16 c.p. lamp, the one most used, will conform in shape with the commercial type, and thus enable its purchase in the market as a common commercial article. It will be seen that the voltage of the lamp and the variation in voltage allowed, from 122 to 124 volts, is consistent with the maximum allowed drop on the lighting circuits, and will admit of the installation of lamps at the voltage at which they deliver their rated candle power. The following are the standard lamps allowed: 16 c.p., clear and frosted; 32 c.p. clear, and 150 c.p. clear, in the case of the diving lamp, besides instrument lamps for special purposes of 1 and 5 c.p. The average efficiency of the 16 c.p. lamp is to be between 3.4 and 3.6 watts per candle power; for the 32 c.p. between 3.4 and 3.8 watts per candle, and for the 150 c.p. diving lamp between 2.9 and 3.3 watts per candle power. The life of an incandescent lamp is an important consideration in naval installation, as the ships are so frequently removed from a source of supply. It is proposed to specify 800 hours for the 16 c.p., 500 hours for the 32 c.p., and 300 hours for the 150 c.p. lamp as the average life, with the above efficiencies, the lamps not to have lost more than 20% of their rated candle power while burning for these periods at the rated candle power.