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Sir J. W. BAZALGETTE, C.B., President, in the Chair.

(*Paper No. 2029.*)

"Electric Lighting for Steamships."

By Andrew Jamieson, Assoc. M. Inst. C.E. and F.R.S.E.

Although it is not more than three years since the first application of incandescent electric lighting to the general illumination of steamships, the advantages accruing therefrom have been so fully recognised, that already more than one hundred and fifty ships have been fitted with it, and scarcely a man-of-war or a first-class passenger-steamer now leaves the builder's hands without having it on board. This rapid success is mainly due to the following causes:—

I. Electric lighting on the incandescent system, when properly fitted, is more healthful, cooler, more easily handled, and more artistic than other systems of lighting; there is no smell, and no products of combustion to tarnish giltwork; it is more agreeable in every way than any of the older methods of illumination.

II. The danger from fire is less, as neither matches nor lighted tapers are required.

III. The daily cleaning and replenishing of lamps, as well as the keeping in store of highly inflammable oil, paraffin, or candles, can to a great extent be dispensed with.

IV. The expense of maintenance is not much in excess of that of the older methods of illumination (in some cases less), whilst the space occupied by the plant is not great, and its position near to, or in, the engine-room causes no annoyance to passengers.

Best position for the Dynamo and its Engine.

As the dynamo which furnishes the electricity for feeding the incandescent lamps has to be driven at a uniform velocity, neither the ship's main engines, nor the donkey-, nor winch-engines, are suitable for the purpose. The dynamo must have an engine for itself. It is, in most cases, necessary to place this special engine and the dynamo in such a position that the men on watch at the main engines can, with a minimum of trouble, also attend to the electric plant.

This position, therefore, is naturally somewhere near the starting-platform, and if possible on the ship's floors, so that undue vibration and noise may be avoided. Frequently a convenient recess can be provided, either immediately behind the main starting-platform or opposite to the thrust-block, just outside the screw-shaft-tunnel door (Plate 1, Fig. 1). Only in large installations will it pay to have on board an electrician, solely to attend to the dynamo, its engine, and lamps. In such cases, a convenient and cool position is generally selected between decks, in the same compartment with, or in that next to, the refrigerating machinery, if such should be on board, so that one man may attend to both of these novel appliances (Plate 2, Fig. 2).

Where practicable the axes of dynamos with large, heavy armatures should be placed fore and aft, to obviate as much as possible the effects of gyrostatic action, since the angular velocity due to rolling is greatest athwartship. In dynamos where the weight of the armature, its velocity, and radius of gyration are small, gyrostatic effects will not produce any appreciable increase of pressure on the bearings, whatever the position of the dynamo.

The following formula, kindly supplied by Sir William Thomson, with examples, will render this matter clear:—

$$L = \frac{W\,k^2\,\Omega\,\omega}{g} \text{ and } P = \frac{W\,k^2\,\Omega\,\omega}{g\,l}.$$

Where L = moment of couple on axis.
P = pressure on each bearing.
W = weight of armature.
k = radius of gyration about axis.
$\Omega = \frac{2\pi}{T} A$ = maximum angular velocity of dynamo in radians[1] per second, due to rolling of ship.
$A = \frac{\pi d}{180}$ = amplitude in radians per second.

[1] Radian is unit angle in circular measure.

d = degrees of roll from mean position.
T = periodic time in seconds.
$\omega = 2\pi n$ = angular velocity of armature in radians per second.
n = number of revolutions of armature per second.
l = distance between bearings.
g = acceleration due to gravity.

Take the case of a ship rolling 20° from the mean position, with a periodic time of sixteen seconds.

$$\text{Then} \qquad \Omega = \frac{2\pi A}{T} = \frac{2\pi}{T} \times \frac{\pi d}{180} = \frac{2\pi^2 \times 20}{16 \times 180} = \frac{\pi^2}{72} =$$

0·137 radian per second.

Examples.

With a Siemens' S D_o dynamo machine, running at six hundred revolutions per minute, weight of armature 500 lbs., radius of gyration 0·3 foot, and distance between bearings 3·3 feet, the gyrostatic pressure on each bearing only amounts to 3·6 lbs.

With a Siemens (W 16) alternate-current machine, running at thirteen hundred revolutions per minute, weight of armature 148 lbs., radius of gyration 0·7 foot, and distance between bearings 1·4 foot.

$$\text{Then} \quad \frac{W k^2 \,\Omega\, \omega}{g\, l} = \frac{148 \times 0{\cdot}7^2 \times 0{\cdot}137 \times 136}{32{\cdot}2 \times 1{\cdot}4} = 30{\cdot}6 \text{ lbs.}$$

To take an extreme case, such as an alternate-current machine, with a heavy armature running at two thousand revolutions per minute, let the weight of armature be 500 lbs., the radius of gyration 1·2 foot, and the angular velocity of ship's roll in radian per second 0·3. If the distance between the bearings were 1·5 foot, there would be a pressure on each bearing of about 930 lbs. Such a dynamo is not likely to be used on board ship.

Selection of a Dynamo

In selecting a dynamo it is necessary to determine whether or not it fulfils certain requirements :—

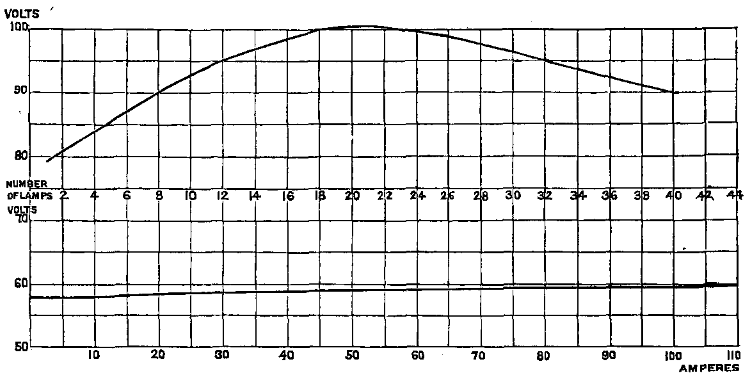
I. It must develop electromotive force suitable for a certain lamp, when driven at a definite speed.

II. It must be self-regulating; that is, the electromotive force generated at the given speed must remain constant to within 5 per cent., whether working one lamp or more, or the full number of,

B 2

lamps. It is preferable to have a slight fall in electromotive force as the number of lamps is reduced[1] (Fig. 1).

Fig. 1.



The Upper Curve represents the Electromotive Force of a Pilsen Dynamo with Pacinotti Armature as fitted on board S.S. "Thistle," July, 1884.

Speed of dynamo, 440 revolutions per minute. Electro-magnets two wound in series, and two in shunt circuit with armature. Shunt magnets, 64 ohms. Series magnets, 0·31 ohm. Armature, 0·54 ohm. The fall in electromotive force from 20 lamps to 1 lamp is an advantage where an ordinary governor is used, but the fall to the right with from 20 to 40 lamps in circuit is a disadvantage. The lower curve represents the electromotive force of compound wound "Victoria" dynamo D2 type, suited for 100 lamps of 20-candle power, requiring 60 volts electromotive force. The dynamo was maintained at a constant speed, and shows a remarkably straight curve with a slight rise as the number of lamps is increased.

III. There must be no emission of sparks at the commutator-brushes.

IV. When running light, or with less than the full number of lamps, there must be no undue heating of any of the parts.

V. The conductivity of the copper wire with which it is wound must not be less than 96 per cent. of pure copper.

VI. The insulation-resistance of the armature and electro-magnets should not be less than 10,000 ohms per volt generated at the required speed.[2] The dynamo should be tested mechanically and electrically before it is put on board ship, and afterwards, when fixed in position, by a final trial of not less than six hours' duration, with its own engine, and with all the lamps in circuit, before being passed by the electrical engineer.

There is considerable diversity of opinion regarding the limit of speed of a dynamo on board ship. Amongst practical men (ships' engineers in particular) there is a decided objection to speeds

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[1] Remarks by Author, p. 24.

[2] This refers to a dynamo for one hundred lamps, p. 89.

exceeding six hundred to six hundred and fifty revolutions per minute. At higher speeds, one thousand to two thousand revolutions per minute, which are common in installations on land, the bearings need greater attention, there is more noise, more vibration, and, in a pitching, rolling ship, more gyrostatic action and more tangential inertia, tending to burst the armature. Besides these objections, direct driving of the dynamo-armature from the crank-shaft of a fast-speed engine is very popular, and such engines cannot be relied on at speeds of over six hundred revolutions per minute for any lengthened period. As a consequence of this general desire for low speeds, most of the best forms of dynamos, the Siemens (Plate 3, Figs. 7 and 8), the Edison (Plate 2, Fig. 4), the Edison-Hopkinson (Plate 2, Fig. 3), the Victoria (Plate 3, Fig. 6), the Ferranti-Thomson (Plate 2, Fig. 5), and the Pilsen-Schuckert, have been specially modified for ship use, so as to produce the required electromotive force and current, at speeds varying from four hundred to six hundred and fifty revolutions per minute. In order to effect this, their weight and bulk have to be greatly increased, and consequently their weight-efficiency is proportionately reduced.

Selection of an Engine and its Fittings.

The success or failure of an installation on board ship depends as much upon the engine as upon the dynamo, and every care should be taken to procure one that needs the minimum of attention, and is not likely to break down. The engine should be capable of, say, driving the dynamo during a voyage to Australia and back, without a hitch and without requiring overhauling. The demand for such engines, more especially for those driving direct, has led to the production of a great variety, many of them excellent in workmanship and in detail.

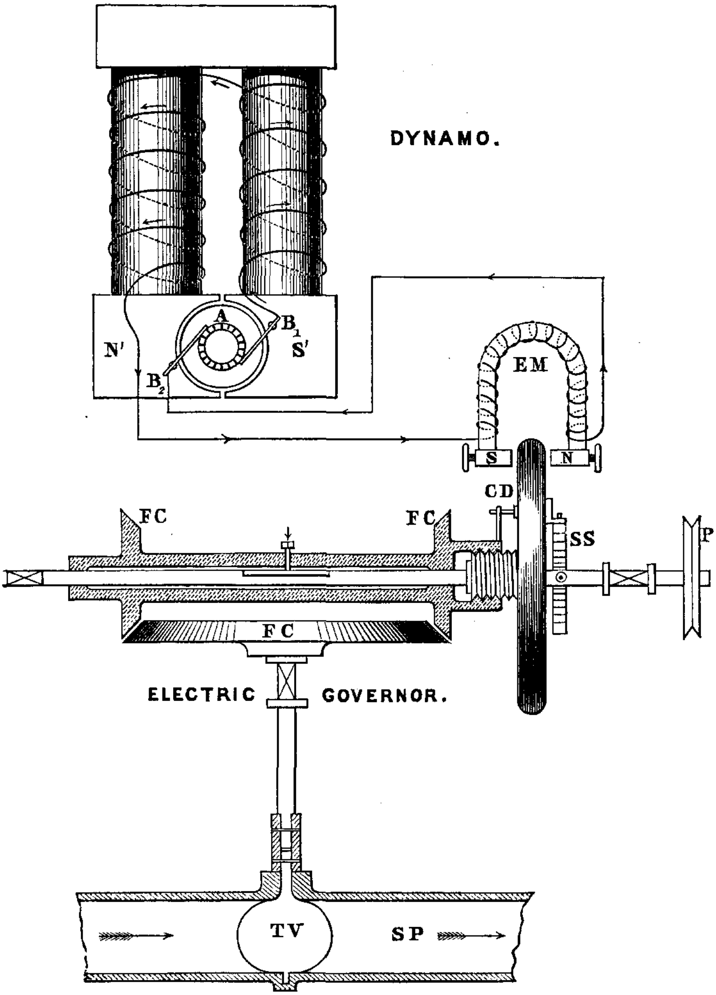
It is frequently necessary that the engine should be capable of doing its work when supplied with steam either from the main- or from the donkey-boilers, so that the electric light may be available in port as well as at sea. This entails a capability for working under variable pressures, and thus the size of the engine must be adapted for the lower pressure. A reducing-valve may with advantage be used when working from the main-boilers, thus wire-drawing the steam down to the normal pressure of the donkey-boiler.

One of the most important adjuncts to the engine is its governor. It should be sufficiently sensitive and reliable in action to keep the engine within 5 per cent. of its normal speed, with a load varying 90 per cent., and a boiler-pressure varying 10 lbs. per square inch. No mechanical governor can do this, and consequently great vigilance has to be exercised on the part of the attendant. A tachometer, or continuous speed-indicator, with a large dial, is usually fitted to or worked from the dynamo-spindle, and a pilot or test lamp is hung between the terminals of the dynamo, or in some easily-seen position, to give warning of any departure from the normal speed and the electromotive force. The Author recently heard of a case in which fifty of the two hundred Swan lamps on board a large passenger-steamer were suddenly broken through a failure of the governor.

A good electrical governor, which shall automatically open and close the throttle-valve, in perfect synchronism with the load, or work to be done, and leave the valve in its last position until a change is made either in the load or in the steam-pressure, is greatly to be desired. The Author, having attempted to solve this problem, may be pardoned for describing his design; because, no matter how perfect the self-regulation of the dynamo may be, that alone will not prevent the breaking of the lamps or undue variation in their light, should the engine be improperly governed or attended to.

The electrical governor (Fig. 2) consists of a copper disk, CD, revolved between the poles of one pair or more of small electro-magnets, EM, actuating a throttle-valve by means of a spring and cones. The wire carrying the current for exciting these electro-magnets is joined in direct circuit with the shunt wires surrounding the dynamo-magnets. If preferred, it may be connected up in series with, or as shunt or compound shunt-series circuit, to the main circuit feeding the lamps, or advantage may be taken of the magnetic poles of the dynamo. There are, therefore, neither contacts nor unsoldered connections to get out of order. The copper disk is loose on the governor-spindle, and is driven, through the intervention of the spiral spring SS, by gearing or by a band passing round one pulley on the dynamo shaft, and another pulley keyed on the governor axle. The centre of the copper disk has a projecting screw on one side, which engages one end of the sliding-sleeve having two friction-cones, FC, FC. Between the friction-cones FC and the throttle-valve TV, a device (not shown) exists for preventing an overturning of the throttle-valve to the right or to the left. When all the lamps, say one hundred, are lighted, and a normal current is passing through the electro-magnets, EM, the copper disk experiences a certain resistance to rotation

FIG. 2.



JAMIESON AND ALLEY'S ELECTRIC GOVERNOR FOR REGULATING THE SPEED OF ENGINES DRIVING DYNAMOS SO AS TO KEEP THE ELECTROMOTIVE FORCE CONSTANT.

N', S', North and south poles of dynamo-magnets. A, Armature of dynamo. B_1 B_2, Brushes of dynamos. E M, Electro-magnet of governor with its wires in direct circuit with those of the dynamo-magnet wires. N, S, Adjustable north and south poles of governor electro-magnet. C D, Copper disk revolving between N, S and connected by—S S, Steel spring to governor-spindle which is driven by—P, Pulley direct from dynamo-axle. F C, Friction-cones or wheels. T V, Throttle valve, working in S P, Steam-pipe.

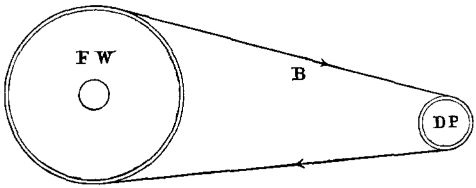
due to the Foucault currents generated in it. This resistance is balanced by the spiral spring; but should any number of the lamps, say ten, be turned out, immediately a stronger current passes through these electro-magnets, and simultaneously with this the speed of rotation of the dynamo, and consequently of the governor, is increased, due to the diminution of the load. This combined increase of current and of speed causes stronger Foucault currents to be generated in the copper disk. It therefore experiences more than the normal resistance to rotation. The effect of this is to coil up the spiral spring SS, thus bringing the left-hand friction-cone into gear with the larger horizontal cone attached to the throttle-valve, and closing the latter about 10 per cent. Whenever the admission of steam has been sufficiently reduced to suit the altered circumstances of the lighter load, the spring, reasserting itself, causes the friction-cones to ungear, leaving the throttle-valve in its last position until a change is made in the number of lamps. Should more lamps be lighted, a reverse action to that described takes place. The normal current in the electro-magnets is reduced simultaneously with a diminution of speed; consequently the poles, NS, are less strongly magnetized, and weaker Foucault currents are generated in the copper disk. There is then less resistance to its rotation; this permits the spiral spring to bring the right-hand cone into gear, thus opening the throttle-valve to the desired amount. When that is done the cones ungear automatically, and the valve is left in position until a change is necessary. This governor is sensitive and quick in action, does not "hunt," and keeps the electromotive force constant.

Methods of Driving Dynamos.

The position and space available for the engine and dynamo on board ship are the first points which have to be considered before determining the mode of driving which shall be adopted.

Should there be sufficient room between decks near the boilers it is more economical to use a comparatively low-speed engine, with fly-wheel and belting or cotton-rope drive, to obtain the necessary speed from an engine making, say, one hundred and fifty revolutions per minute. This plan is often adopted. For example, in the s.s. "Manora," lately built by Messrs. William Denny and Bros., of Dumbarton, for The British India Steam Navigation Co., and fitted by Messrs. King and Brown, of Edinburgh, with Siemens direct-current dynamo for two hundred Swan lamps, a Tangye engine, running at one hundred and sixty revolutions per minute, drives the dynamo at six hundred and fifty revolutions by means of an india-rubber belt direct from the fly-wheel (Fig. 3).

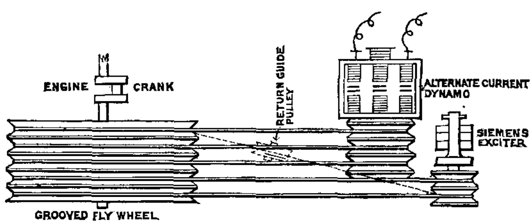
Fig. 3.



F W, Fly-Wheel. B, Belt. D P, Dynamo-Pulley.

In the s.s. "Chicago," fitted with electric light by Messrs. Siemens Bros., an endless cotton-rope is employed, passing from a broad-grooved fly-wheel to the grooved pulleys of Siemens's alternate-current dynamo and direct-current exciter. The return to the fly-wheel for the rope is effected by a cross-connection under a guide pulley fixed to the floor, as shown in Fig. 4.

Fig. 4.



Plan of Cotton Rope Drive.

In all such cases the dynamos are fixed upon slides, and can be screwed backwards or forwards so as to adjust the tension of the belt or rope. Where the belt-drive is short, there is also fitted a tightening pulley. This was done in the case of the s.s. "Oregon," fitted by the Edison Co. with Mather and Platt's engines and Edison-Hopkinson dynamos. Such methods of driving dynamos take up a good deal of space. It is often necessary to fit the plant into some small corner of the engine-room, where it is impossible to provide for a belt-drive, and in such cases a direct-driving-engines gearing, or Messrs. Siemens Bros. frictional drive, may be resorted to. Plate 2, Fig. 3, shows the Edison-Hopkinson dynamo driven by a "Tower" spherical engine at five hundred and fifty revolutions per minute, as applied to the steam yacht "Cuhona."

As examples of vessels fitted with direct-driving engines, the s.s. "Pateena" and s.s. "Adelaide," both first-class passenger steamers, despatched from the Clyde for local traffic in Australasian waters, may be instanced, as their electric-light arrangements were carried out by the Edison Co. under the supervision of the Author. By referring to Plate 1, Fig. 1, and Plate 2, Fig. 4, with index of parts, the position of the dynamo and engine in the ship and the details will be understood.

In the s.s. "Pateena" there were one hundred and sixty Edison 16-candle-power lamps, and in the s.s. "Adelaide," one hundred and thirty-one lamps of 16, and four of 100 candle-power, the latter being for facilitating the receiving and discharging of passengers and luggage when in port.

In each case, the Westinghouse engines and the dynamo were bolted to one cast-iron sole-plate placed in a recess near the starting-platform on the ships' floors. Their speed was regulated for five hundred and twenty-five revolutions per minute, which was found sufficient to generate an electromotive force of 90 volts, giving the required 16-candle-power with the lamps as specially provided. Steam was supplied at pleasure either from the main- or the donkey-boilers, at pressures varying from 50 lbs. to 90 lbs. on the square inch, the stop-valve acting as a reducing-valve. Although the best mechanical governors that could be got were fitted, it was found that the speed rose 25 per cent. when 99 per cent. of the lamps were switched out, the remainder being considerably stressed, though not broken during the short space of time that was permitted to intervene before slowing down.

The whole arrangement is exceedingly compact, and has served its purpose admirably in these two ships, the engines only requiring to be looked to every half-hour or so, as they are self-lubricating throughout: in fact, the whole of the lower parts are continually running in oil. The engines are single-acting and the cylinders vertical, so the pressures are always in one direction; pounding is thus avoided, and no adjustment need be made for wear in the bearings. The "Pateena" has been running for more than a year, and the lighting has given entire satisfaction.

Plate 2, Fig. 5, is a side elevation and plan of the Ferranti plant (driven by the Westinghouse engine) supplied by the Hammond Electric Light Co. to Messrs. William Denny and Bros. for the s.s. "Arawa" (Plate 1, Fig. 2) and s.s. "Tainui," which they have just built to the order of the Shaw, Savill and Albion Co. for their New Zealand trade. On each of these vessels a complete double set of Ferranti plant was fitted on one strong cast-iron sole plate.

Provision was made for coupling the plant together while running at full speed, five hundred and fifty revolutions per minute, and thus feeding the whole of the three hundred 20-candle-power lamps with current at an E.M.F. of 100 volts; or each set of plant could be worked independently, and by a combination of switches, either plant could be made to feed any section or set of sections of the ship at pleasure; thus greatly minimizing the chance of failure of the light on board.[1]

Another popular direct-driving steam-motor is Brotherhood's well-known three-cylinder engine, which is shown in Plate 3, Figs. 6 and 7, as applied this year to the electric lighting of H.M.S. "Triumph" and the Brazilian ironclad "Riachuelo." The first adoption of this engine to electric lighting on board ship (arc system) was in 1876, when Messrs. Sautter, Lemonnier and Co. of Paris, fitted up the French ironclad "Richelieu" with a "search light." Since that time the above firm alone have adapted three hundred and fifteen of these engines to electric lighting purposes, of which two hundred and forty-two were for use on board ship, principally for war ships, viz., France one hundred and sixty-one, Italy forty-seven, Austria thirteen, Russia eight, Denmark five, Brazil, Norway, the United States and Turkey eighteen. Altogether, up to date, six hundred and sixteen Brotherhood engines have been applied to driving dynamos.

Considerable improvements have been made in this engine since it was first introduced, the latest being piston-valves, thus doing away with the long steam-passages and the leakage through the former kind of disk-valve, and a flexible coupling (Fig. 5) whereby the stress due to wear of the dynamo spindle-bearings, and any untruth in the line of the same with that of the engine shaft, are reduced.

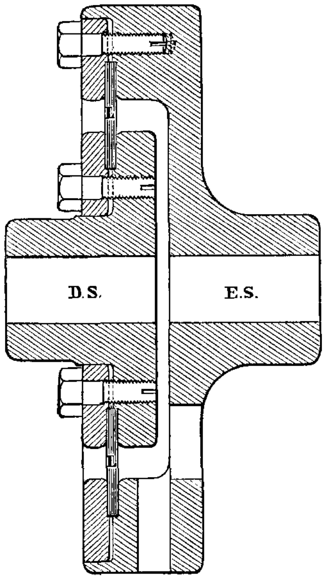
The largest engine of this type that has been applied to dynamo driving is one indicating 42 HP., running at six hundred and ten revolutions per minute, and consuming about 4 lbs. of coal per indicated HP. per hour.

Mr. A. C. Kirk, M. Inst. C.E., the managing partner of Messrs. Robert Napier and Sons, has applied internal cast-iron gearing, in the case of three large Mexican mail steamers which his firm has lately built, to getting up the necessary speed between the engine and dynamo. The arrangement is strong and compact, there is no chance of slipping, and the noise is tolerably well overcome by encasing the gearing in a wooden muffling-box. The whole plant

[1] Remarks by Author, p. 24.

is placed in a recess in the engine-room on the ship's floors, where it can be attended to by the men on watch at the main engines.

Fig. 5.



E S, Engine Shaft. D S, Dynamo Spindle. L, Leather Disk.

Messrs. Siemens Bros. have lately brought out a compact form of rolling contact or friction drive (Plate 3, Fig. 8), thus enabling an ordinary vertical engine to work their direct-current compound shunt-wound dynamo at any desired speed. The dynamo-pulley F P, which is covered with papier-mache, is caused to bear evenly on the engine fly-wheel F W, by means of two adjusting rods A R. The dynamo is supported in a cradle on cross-bearings or trunnions, which relieve the armature and its spindle from any stress except that due to the torque necessary to revolve it. This arrangement has given great satisfaction wherever it has been introduced, the only special precaution being to keep the paper-pulley dry and free from oil.[1]

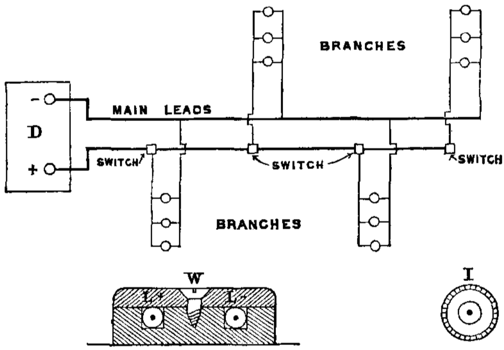
System of Leading Wires and their sizes.

There are two systems upon which leading wires may be fitted on board ship, the one with forward and return, main and branch

[1] Remarks by Author previous to discussion, p. 24.

leads, or what may be termed the double-wire system, as in Fig. 6:—Plate 1, Fig. 1, plan of s.s. "Adelaide," is an example of a ship wired on this system.

Fig. 6.

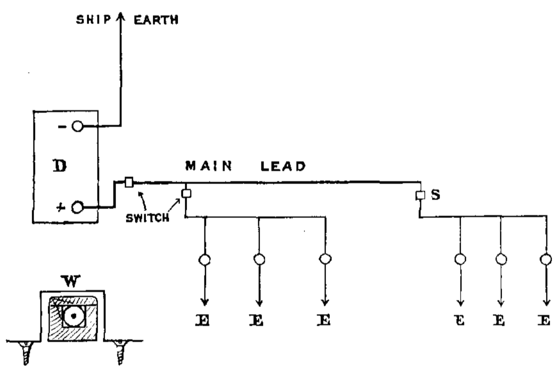


Double Wire System.

D, Dynamo. W, Wooden Casing (cross-section) for carrying and preserving leads (L +, L −) I, Metal Pipe (cross-section) for carrying leads in boiler-rooms. The circles represent lamps.

The other system uses the iron plating and beams of the ship as a return for the electric current, and so may be called the single-wire system, as in Fig. 7.

Fig. 7.



Single Wire System.

D, Dynamo. W, Wooden Casing for carrying and preserving leads. E, Earth-connections. S, Switches. The circles represent lamps.

The advantages of the latter system are these: it is less costly, more easily fitted, and offers about one-half the resistance to the current, as only about one-half the length of wire required for the first system suffices. The disadvantages are, that a fault in the insulator or dielectric of the leading wire has a more direct effect upon it than upon the double-wire system, for any accidental connection of the conductor with the iron of the ship at any point, short-circuits the wire at that point. It is also found that if, through the ship leaking, salt water should penetrate the dielectric to the conductor, the latter will soon be eaten through by galvanic action, sub-chloride of copper and soda being formed. Faults of this description have occurred with both systems and given considerable trouble, but with first-class dielectrics, good joints, and by carefully encasing the leads in varnished or paraffined grooved wooden casings, such accidents should not happen, as the conductor would then be protected by a waterproof casing throughout except at the switches and lamps. Plate 1, Fig. 2, plans of s.s. "Arawa" and s.s. "Tainui," are examples of ships wired on this system, but extra care and the very best insulated leading wires have been used throughout, as verified by the Author's tests.[1]

All joints in the leads should be carefully made by experienced workmen. They do not require to be so well done as in submarine telegraphy, as they have not to withstand the water-pressure, and the requisite insulation-resistance is not so high; nevertheless the metallic junctions should be thoroughly well soldered, the dielectric ends cut down to a taper with a sharp knife, and thereafter the whole covered with wrappings of felt, pure rubber, and waterproof tape, being finally varnished.[2]

It is most important that the size of the conductor should be sufficient to carry the necessary current without causing more than 2 to 3 per cent. loss of the electrical power developed in heating them. Sir William Thomson's law for bare conductors, viz., not less than 1 square-centimetre for 50 amperes, which is based on the principle that the total loss is a minimum when the two component losses are equal, *i.e.*, when the annual cost of power wasted in heating the conductor is equal to the yearly interest plus depreciation on its value, is too liberal an allowance of copper in the case of well-insulated short leads; besides which he has omitted to add the insurance on the value of the wire which, in the case of ships' fittings, amounts often to 7 per cent. The Author

[1] Reply to discussion, p. 90.

[2] Detailed rules for making joints in electric light leads. "Munro and Jamieson's Pocket Book of Electrical Rules and Tables," p. 230. Third edition. Also remarks by Author previous to discussion.

has used a rule which he finds to work well in practice for ships' leads where the length is never great, viz.:—

"The conductor to be of best copper of not less than 95 per cent. of the conductivity of pure copper, and to have a cross section of 1 square millimetre for every ampere and a half of current passing through it (which is at the rate of about 1,000 amperes to the square inch); the insulation-resistance of the whole circuit when fitted including all switches, &c., to be not less than 1,000 ohms per volt of electromotive force generated by the dynamo."

Before fitting the wires, specimens of not less than 100 feet should be selected, immersed in sea-water, or brine-water for twenty-four hours, and then carefully tested for insulation-resistance, and not passed unless they give over 10 megohms. Specimen joints should be treated in the same way and give at least 100 megohms each.

Although the above rule for the size of conductors is considerably in excess of that required by theory for mere safety from heating, and not applicable to large and long district mains, it has been found in practice to give excellent results in small installations on board ship and in houses, where the maximum current conveyed by any leading wire does not exceed 300 amperes, and the farthest lamp is not more than 100 yards from the generator. The required sizes of the conductor are easily calculated or found direct from the Tables[1]; those for even single lamps are of sufficient size and strength for rough handling. There is not the slightest danger from heating in any part of the circuit, and the rule is economical when applied to the best class of insulated leads. Based upon this rule, in the following Table (p. 16) will be found the most common sizes of leading wires used in ship installations, and which the Author is in the habit of handing to contractors working to his specifications.[2]

It is seldom that on board ship more than 300 amperes are generated by any single dynamo; and, as several main leads usually spring from the dynamo-room to various parts of the ship, the current in any one of them seldom exceeds 100 amperes, so the wires do not vary greatly in size, and generally four sizes will suffice for a ship.

Insulation-resistance is too often neglected by electric-light engineers. Amongst submarine-telegraph engineers it is con-

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[1] "Munro and Jamieson's Pocket Book of Electrical Rules and Tables," pp. 178, 217–222, 223–226. Third edition.

[2] Reply to discussion, p. 89.

TABLE for SIZES of SHIP LEADS (WELL INSULATED).

For Swan 20-Candle-Power or Edison 16-Candle-Power Lamps.

Maximum Number of Lamps to be carried.	For 45 to 60 Volt Lamps Requiring 1·5 to 1·1 Amperes.	For 90 to 110 Volt Lamps requiring 0·8 to 0·6 Amperes.
	Board of Trade Wire-Gauge; Branch Leads.	Board of Trade Wire-Gauge; Branch Leads.
1	No. 18 wire	No. 20 wire
2	" 16 "	" 18 "
3	" 15 "	" 16 "
10	" 10 "	" 12 "
	Main Leads' Strand.	Main Leads' Strand.
20	7 No. 15s.	7 No. 16s.
25	9 " 15s.	7 " 16s.
45	19 " 16s.	7 " 14s.
60 to 70	19 " 14s.	19 " 16s.

sidered of vital importance to watch the insulation-resistance with the most rigid accuracy, not only during the manufacture of a cable, but during its submersion and after it has been laid; whereas in the case of electric lighting, those charged with the fitting up of an installation very seldom think of, or even know how to take, insulation-tests, either of the dynamo or of the leading wires. The Author has found great difficulty, in most installations with which he has been connected, to get the contractor to recognize the importance of this test; in fact he has only met with one instance in which the contractor himself used testing-apparatus which would detect a small flaw in the insulation of the wires after they had been fitted. To this general neglect of testing conductor- and insulation-resistance may be attributed some of the failures that have occurred.

It is far from right to allow leads to be run up like bell-wires, without the slightest knowledge as to whether a flaw or a fault has crept in, and all engineers should insist upon rigid inspection, as well as thorough and searching tests, before an installation is passed. The insulation-resistance-standard need not be nearly so high as in the case of submarine cables; but nevertheless it does require to be several hundred times more than the copper-resistance, otherwise a fault will soon develop, and short-circuiting occur, under the combined influences of the electromotive force and damp or wet.

The dielectric should, therefore, in addition to being a good insulator, be thoroughly watertight, and as little liable as possible to be affected by atmospheric changes.

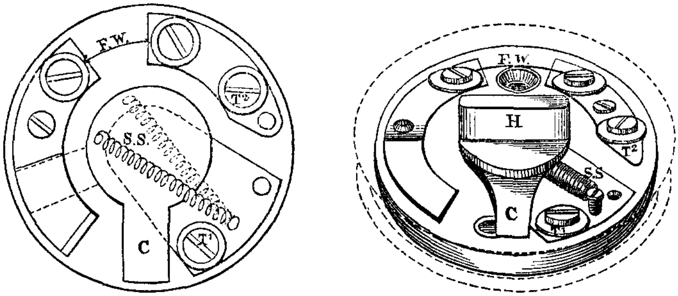
Switches and Fusible Junctions.

There are three methods of arranging the main switches on board ships, the first by having all situated in the dynamo room, whereby the circuits are wholly controlled by the man attending to the engine and dynamo. The second, by having one main switch to control the whole current, near the dynamo, with the others situated where the different main circuits branch off, so that they can be turned off or on by the ship's servants as required. The third method is to have main switches, not only in the dynamo room, but also at the base of the different departments. The last plan introduces unnecessary complication, and the first can only be carried out when all the different circuits spring direct from the dynamo room. The second is more general, and serves all requirements now that self-regulating dynamos have been introduced, and if care be taken that too many of the circuits are not put in or cut out at one time, so as to overtax the powers of the engine-governor. In most installations each lamp is fitted with a switch, so that every passenger may turn on or off his light at pleasure, which is no doubt convenient for the passenger; and after the novelty has passed away there need be little fear, in a well-regulated ship, that the privilege thus afforded will be unduly taken advantage of, or the switches or lights tampered with. One of the best and simplest forms of these small switches, introduced into this country by Mr. H. C. Harold, is shown in Fig. 8. The merit of this switch is that it remains hard on or hard off as the spiral springs S S act on each side of the dead point. The contacts are scraping contacts and can be easily cleaned. Fig. 9 shows the Hammond Co.'s switch for the same purpose.

An excellent form of main switch, as fitted by Messrs. William Denny and Bros. into the Shaw-Savill steamers, is shown in Fig. 10, where double-spring scraping-contacts are provided on each side, and the lower contact projects beyond the upper one, so that any accumulation of dirt due to "sparking" on opening or breaking circuit may be readily removed by cleaning it with emery-cloth.

Fusible or safety wires should be introduced into all the main and branch circuits. The size for the branch circuits being such that they will give way before the current becomes dangerously

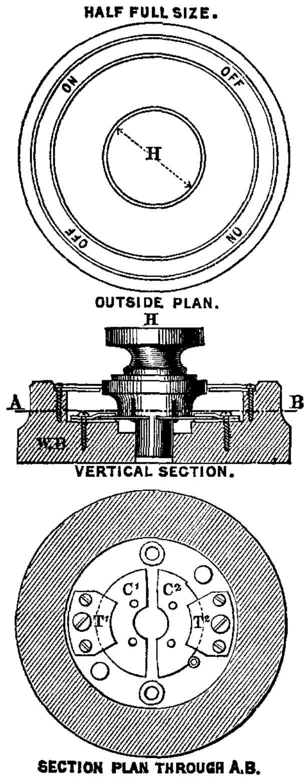
Fig. 8.



The Lundberg Improved Electric Light Switch.

C, Contact Tongue, which may be turned to right for contact and to left for free by handle H. S S, Spiral Spring, which keeps C hard on or hard off. T^1 T^2, Terminals to which the leading wires are attached. F W, Fusible Wire, generally composed of tin or of composition metal.

Fig. 9.

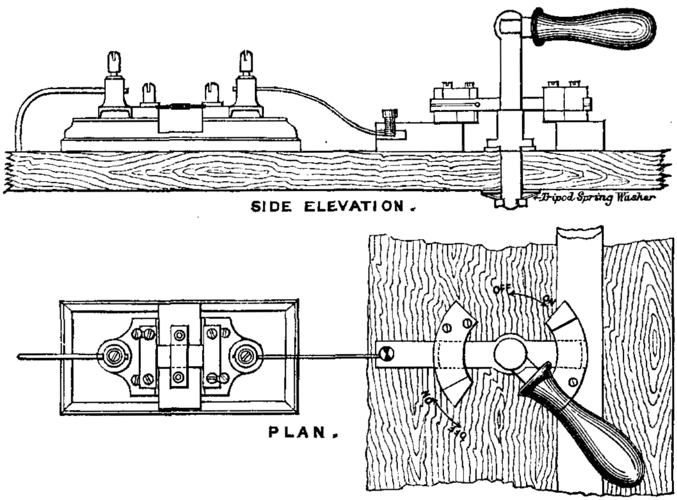


The Hammond Electric Light Co.'s Switch for Branch Circuits.

H, Handle. C^1 C^2, Contact Plates. W B, Wooden Base.

strong for the smallest leading wires of the section. In most instances the small safety "cut-outs," which some firms introduced in circuit with each lamp, did not act so as to save the lamps from destruction. To guard an Edison or Swan lamp, requiring 1 ampere or less, from breaking through excess of current, the fusible wire, to be of real use, would have to be so very fine as to be difficult, from a mechanical point of view, to handle or replace. A neat method of overcoming this mechanical difficulty has, however, been fitted into the s.s. "Manora." A thin

FIG. 10.



MAIN SWITCH ARRANGEMENT, S.S. "ARAWA," WITH HEDGES' FUSIBLE BRIDGE.

Scale $\frac{1}{6}$.

narrow strip of tinfoil in the form of a double hook or **S**, is pasted on a piece of insulite, to stiffen and support it, each end of the **S** being fixed down by means of a screw, whereby the current feeding the lamp has to pass through the tinfoil. Its dimensions are such that it will fuse with about twice the normal current required for the lamp.

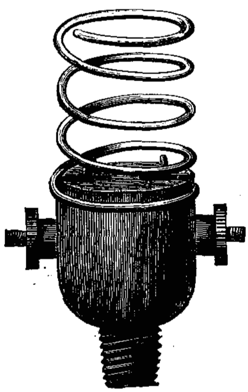
All fusible wires or "cut-outs" should be so fitted that they can be readily inspected and replaced by fresh ones when required. They should be as short as practicable, so as to increase the resistance of the circuit as little as possible.

LAMP-HOLDERS, LANTERNS, AND GLOBES.

In choosing the kind or form of lamp to be used, there is so little difference between the efficiency and lasting powers of those of the different makers, that the chief things to be attended to are, that they should be of the required candle-power when supplied with the current and electromotive force of the selected dynamo.

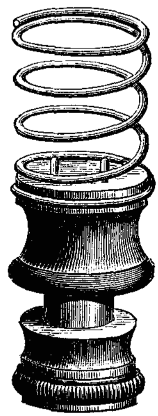
Lamps of 10-candle power are sufficient for most cabins, of 20-candle power for saloons, music-rooms, smoke-rooms, boiler- and engine-rooms, and of 50- or 100-candle power lamps, for side-lights, masthead-lights, gangways, and hatchways, or a cluster of 20-candle power lamps.

FIG. 11.



For Double Wire Circuit.

FIG. 12.



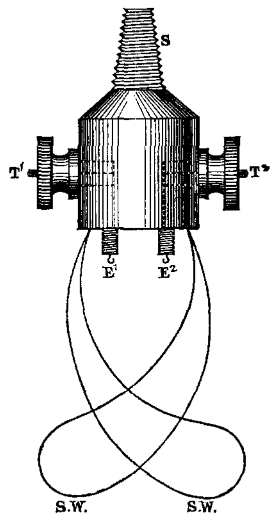
For Single Wire Circuit.

MESSRS. SIEMENS' TERMINALS FOR SWAN LAMPS.

It is important that the holders for the lamps should enable good, easy, but firm contacts to be made between the terminals of the lamp and the leads, and that the vibration of the ship should not work the contacts loose or permit of the filament being unduly shaken, which action is found considerably to reduce the life of the lamps (Figs. 11, 12, and 13).

Lanterns, and globes have been designed, not only for use on land, but also for ship purposes, and in this respect the electrician has been ably assisted by those who make it their business to provide these appliances. Such appurtenances should be both elegant and durable, and be fixed so that the light is shed downwards on the passenger, rather than hung on a level with his eyes, the most approved plan of lighting being to suspend short brackets with their globes from the ceiling over the centre of the tables, so that they are clear of the passage-ways and wine-glass holders, and distributed so as to give a uniform light, as in Messrs. Siemens Bros. fittings, which have given great satisfaction. The original plan of fixing the electric-lamps inside or attached to the oil-lamps is in great measure discontinued, as an unnecessary complication. In some steamers, where the cabins enter off the saloon, devices such as lanterns of triangular section

FIG. 13.



HAROLD'S GLOW-LAMP HOLDER.

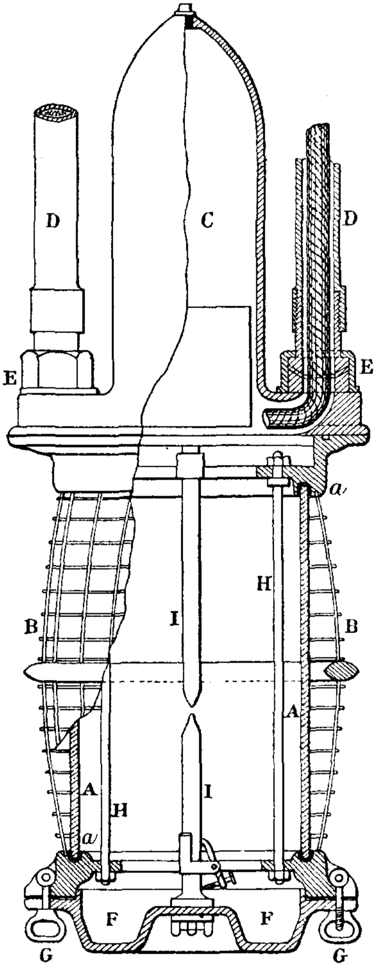
S, Wood or Ebonite Screw. T¹ T², Brass Terminals. E¹ E², Electrodes to attach to the lamp platinum hooks. S W, Spring Wire for keeping the glow-lamp tight and yet easy in position.

have been resorted to. By this means the cabins and the saloon are simultaneously lighted, but in this respect each particular shipbuilder or owner has more to say than the electrical engineer. In the engine-room, lanterns with reflectors and wire-cage protectors are largely used, as well as lamps attached by flexible leading wires, to permit of the engineer inspecting different parts of the machinery. In the boiler-rooms the lamps are so fixed as to cast their light directly upon the water-gauge glasses, that the height of the water in the boilers may be readily and easily observed from the stokehole floor.

Arc Lamps on Board Ship.

Arc lamps are seldom used on board passenger-steamers, but they have been found of great use in telegraph steamers, in facilitating paying out, picking up, and repairing operations when conducted at night, and in spotting "mark buoys."

Fig. 14.



Scale ⅛.

A, Glass Cylinder enclosing arc lamp 15,000-candle power, made water-tight by indiarubber rings *aa*. B, Copper Wire Cage protecting glass cylinder. C, Dome enclosing mechanism of lamp. D, Copper Conductors from dynamos, enclosed in indiarubber tubing. E, Hydraulic Joints at the ends of conductors. F, Removable Door of lamp for adjustment of carbons. G, Wing-Nuts for ditto. H, Rods connecting top and bottom portions of lamp. I, Carbons 20 millimetres in diameter.

They are largely used in foreign navies, as well as on board British men-of-war. In such cases the arc light is placed inside a revolving holophote case (fixed upon the bridge or well forward), and fitted with a lens and reflector, so as to throw a concentrated beam of light in any desired direction, with the view of inspecting an enemy's position, or of guarding against the attack of torpedo-boats. Such lights are worked from a separate dynamo, and require to be at least 10,000- to 20,000-candle-power. They have been applied successfully by Messrs. Siemens Bros., the Silvertown Company, and by the Anglo-American Brush Company to English men-of-war.

A novel application of the arc light for salvage- and fishing-purposes has been fitted by Messrs. Paterson and Cooper to the s.s. "Tilly," for fishing in Batavian waters. The installation consists of a Gwynne vertical engine, supplied with steam from the ship's main boilers, a Phœnix dynamo, and the submarine lamp of 15,000-candle-power. It is represented in Fig. 14 as fitted with paying-out gear and well-insulated leading wires to reach any required depth. This is the only instance known to the Author of the adaptation of the electric-arc light to submarine purposes, but if the idea is practicable and successful there is ample scope for its application.

Electric-lighting installations on board ship, as well as on land, should be thoroughly well carried out in every particular. Many of the disappointments, failures, and accidents which have occurred have been caused by want of knowledge or carelessness, either on the part of those ordering plant or of those executing orders. The Author recalls to memory Mr. Preece's well-timed caution, in his Paper "On Electrical Conductors," where he says:—"It cannot be too strongly urged that specification without rigid inspection is valueless. . . . Many administrations object to the expense of thorough inspection, and the result is they are the recipients of the rejected material of those who do rigidly inspect."[1]

The Paper is accompanied by numerous illustrations, from which Plates 1, 2, and 3, and the Figs. in the text have been prepared.

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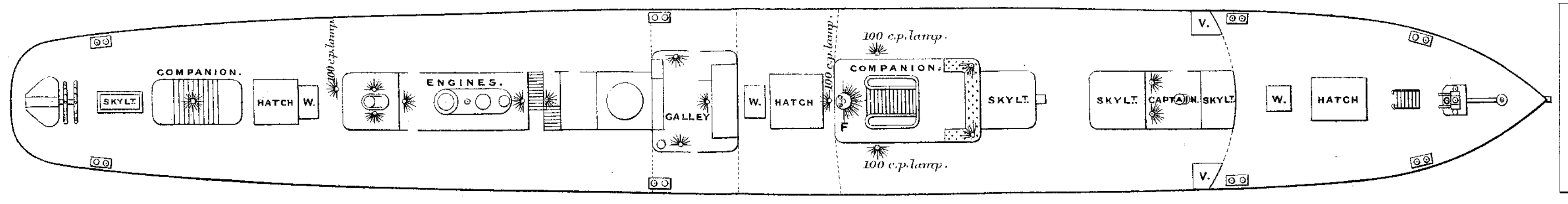
[1] Minutes of Proceedings Inst. C.E., vol. lxxv., p. 74.

ELECTRIC LIGHTING FOR STEAMSHIPS.

Fig: 1.

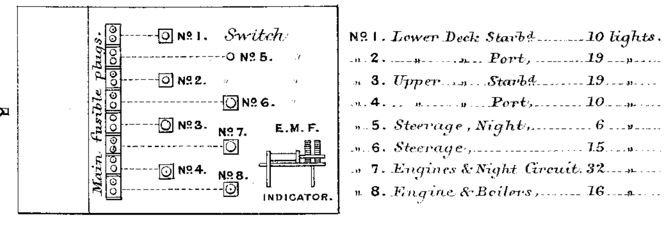
S. S. ADELAIDE.

Fitted on Return Wire System.

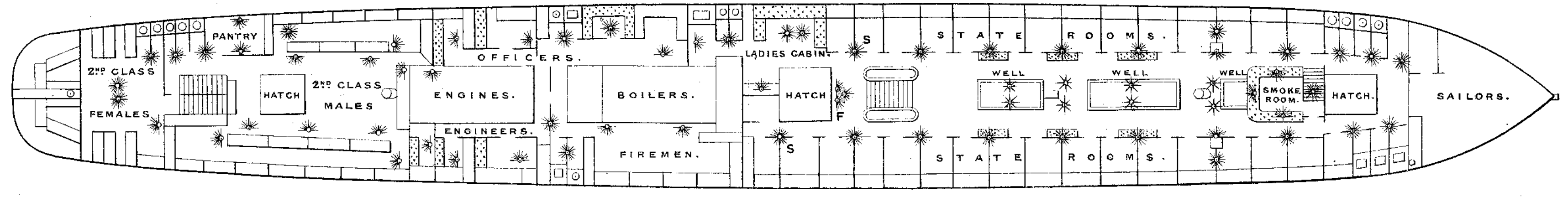


PLAN OF AWNING DECK.

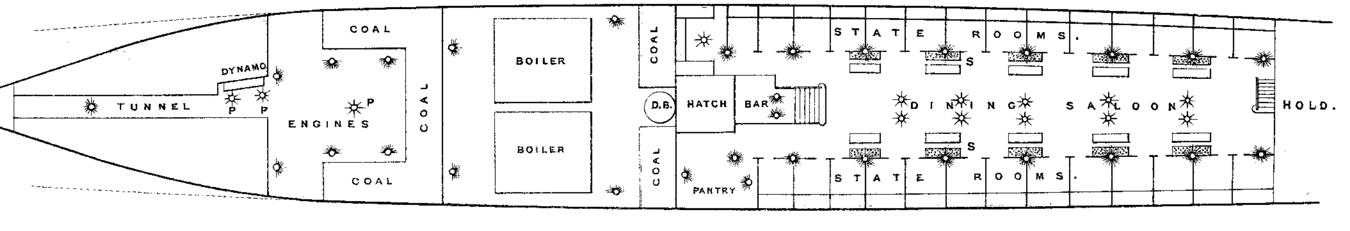
S. S. ADELAIDE.



ELEVATION OF SWITCH BOARD.



PLAN OF MAIN DECK.



PLAN OF LOWER DECK.

INDEX OF PARTS ONLY LETTERED.

S. *Main Switches.*	D.B. *Donkey Boiler.*
F. *Statue Figures. 3 Lights.*	W. *Winches.*
P. *Portable Lights.*	✱. *Lights.*

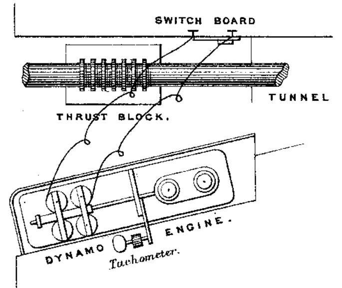
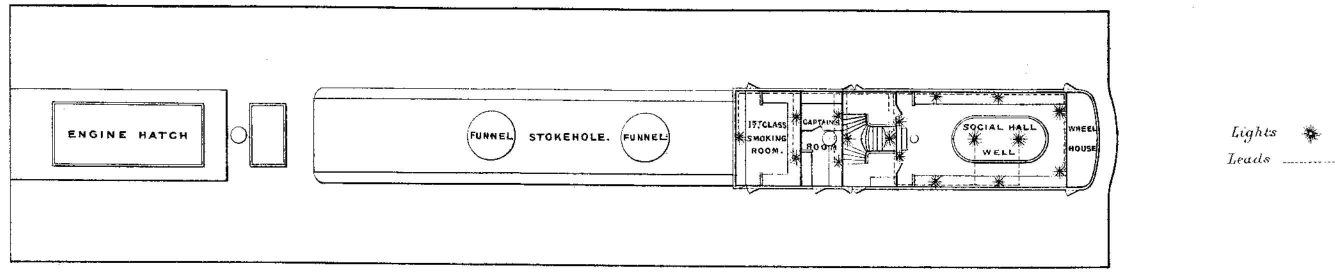


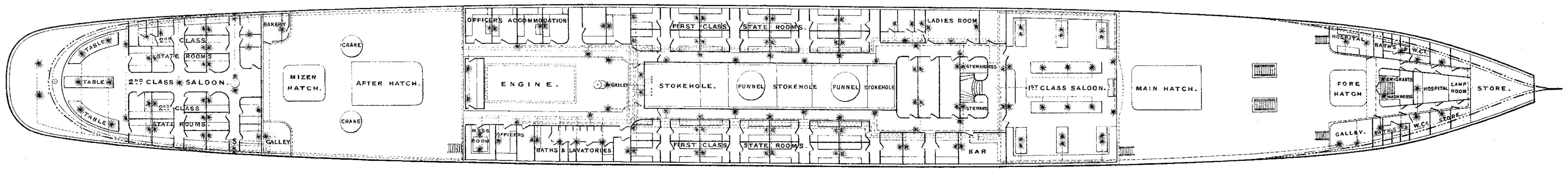
Fig: 2.

S. S. ARAWA & TAINUI.

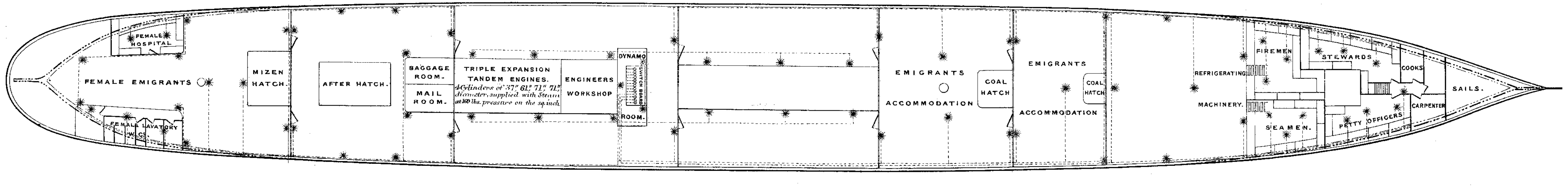
Fitted on Single Wire System, Ships plates as earth Return.



PLAN OF AWNING DECK. — 17 LIGHTS ONLY SHEWN.



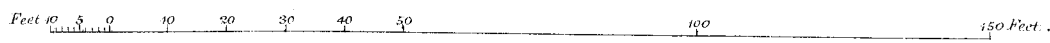
PLAN OF MAIN DECK. — 170 LIGHTS.



PLAN OF LOWER DECK &c. — 71 LIGHTS SHEWN.

In the S.S. Tainui the Dynamo Room & Engineers Workshop were shifted to the Port Side of Main Engine Room using a Marshall horizontal Engine with broad flywheel & two belts to drive Dynamos.

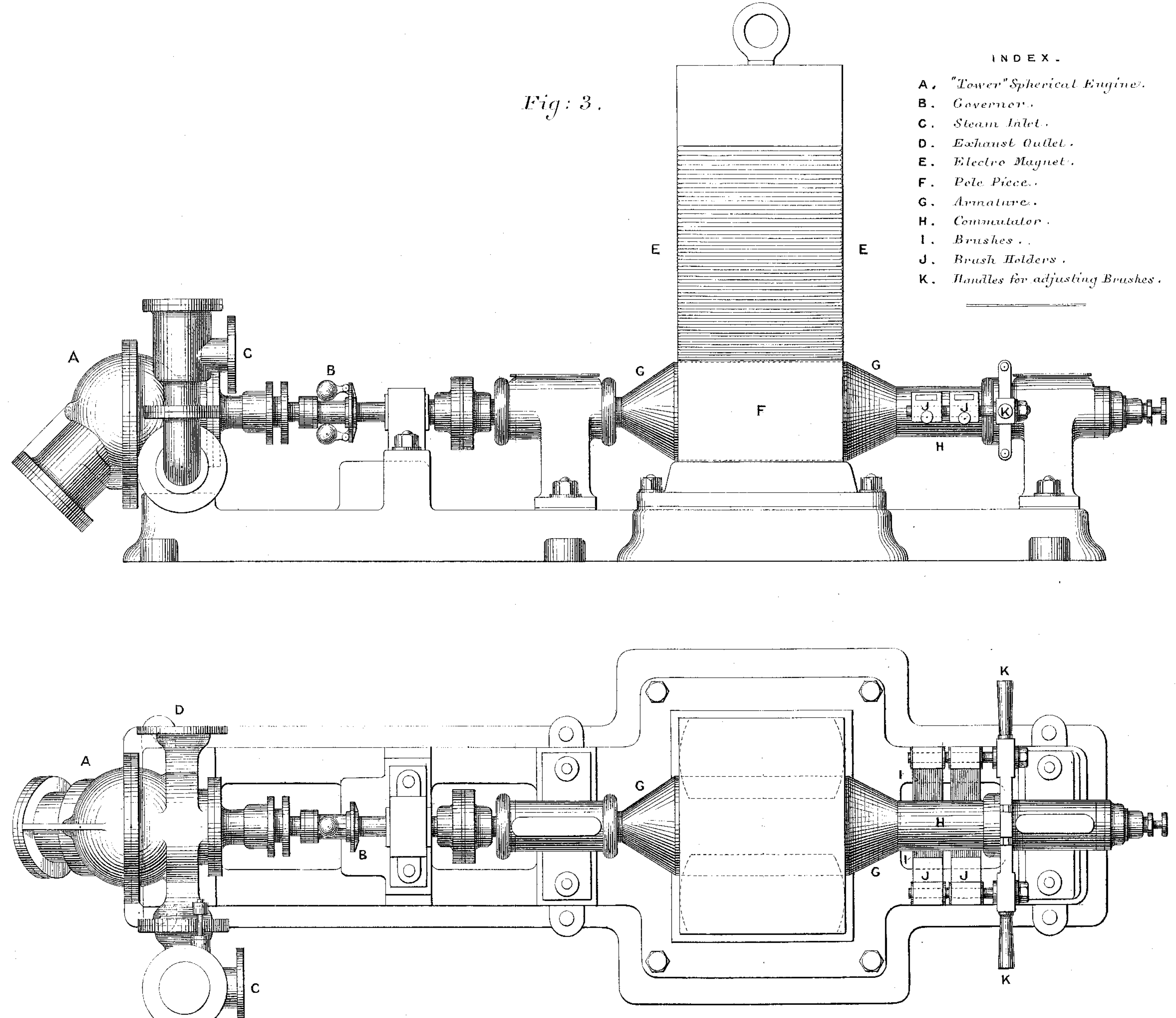
Scale of Feet.



ANDREW JAMIESON, DELT

THOS KELL & SON, LITH. 40, KING ST COVENT GARDEN.

Fig: 3.



INDEX.

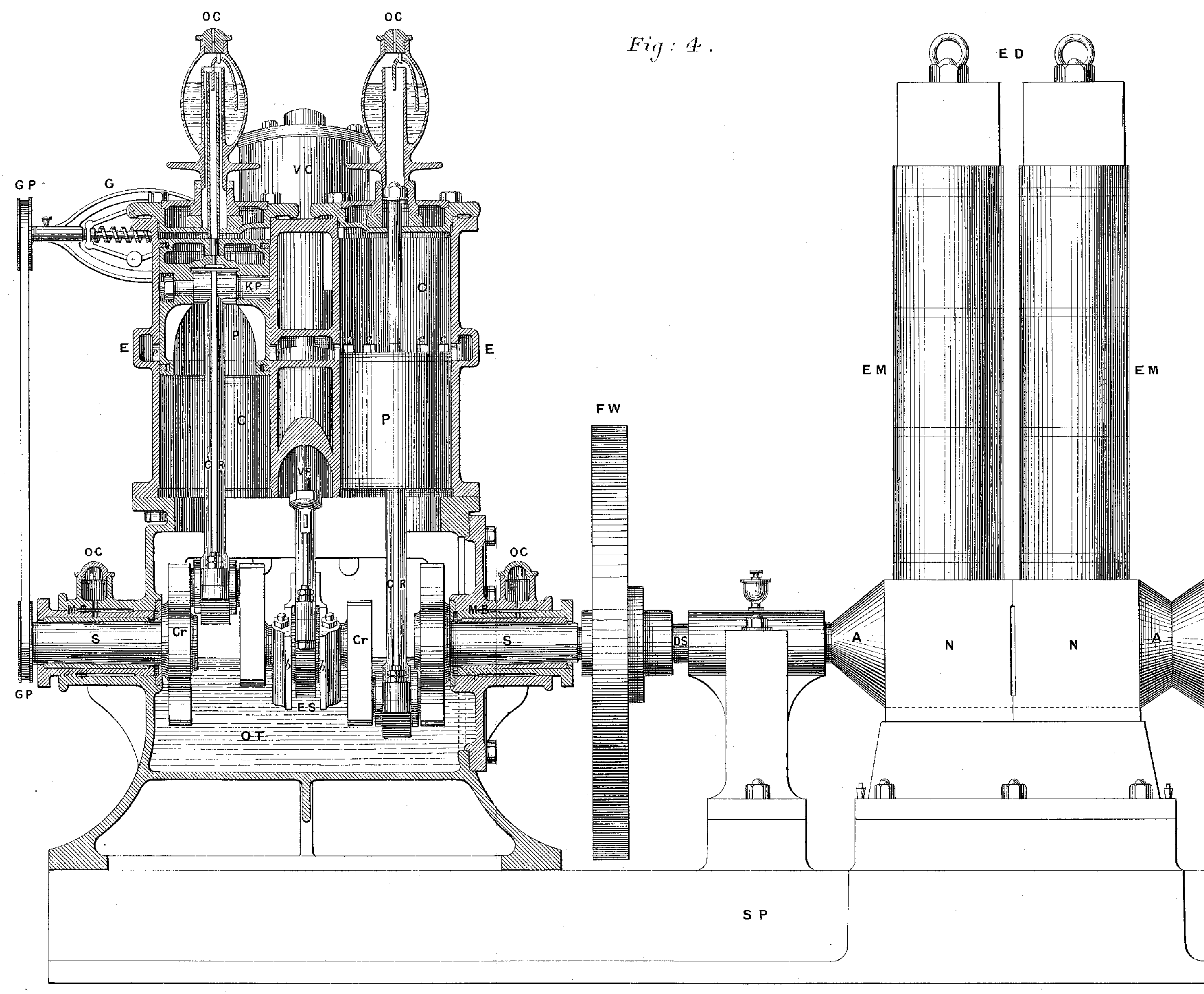
- A. "Tower" Spherical Engine.
- B. Governor.
- C. Steam Inlet.
- D. Exhaust Outlet.
- E. Electro Magnet.
- F. Pole Piece.
- G. Armature.
- H. Commutator.
- I. Brushes.
- J. Brush Holders.
- K. Handles for adjusting Brushes.

EDISON-HOPKINSON DYNAMO AS APPLIED TO THE STEAM YACHT "CUHONA."

Scale: 1 Inch = 1 Foot.

12 9 6 3 0 1 2 3 4 5 Feet.

Fig: 4.

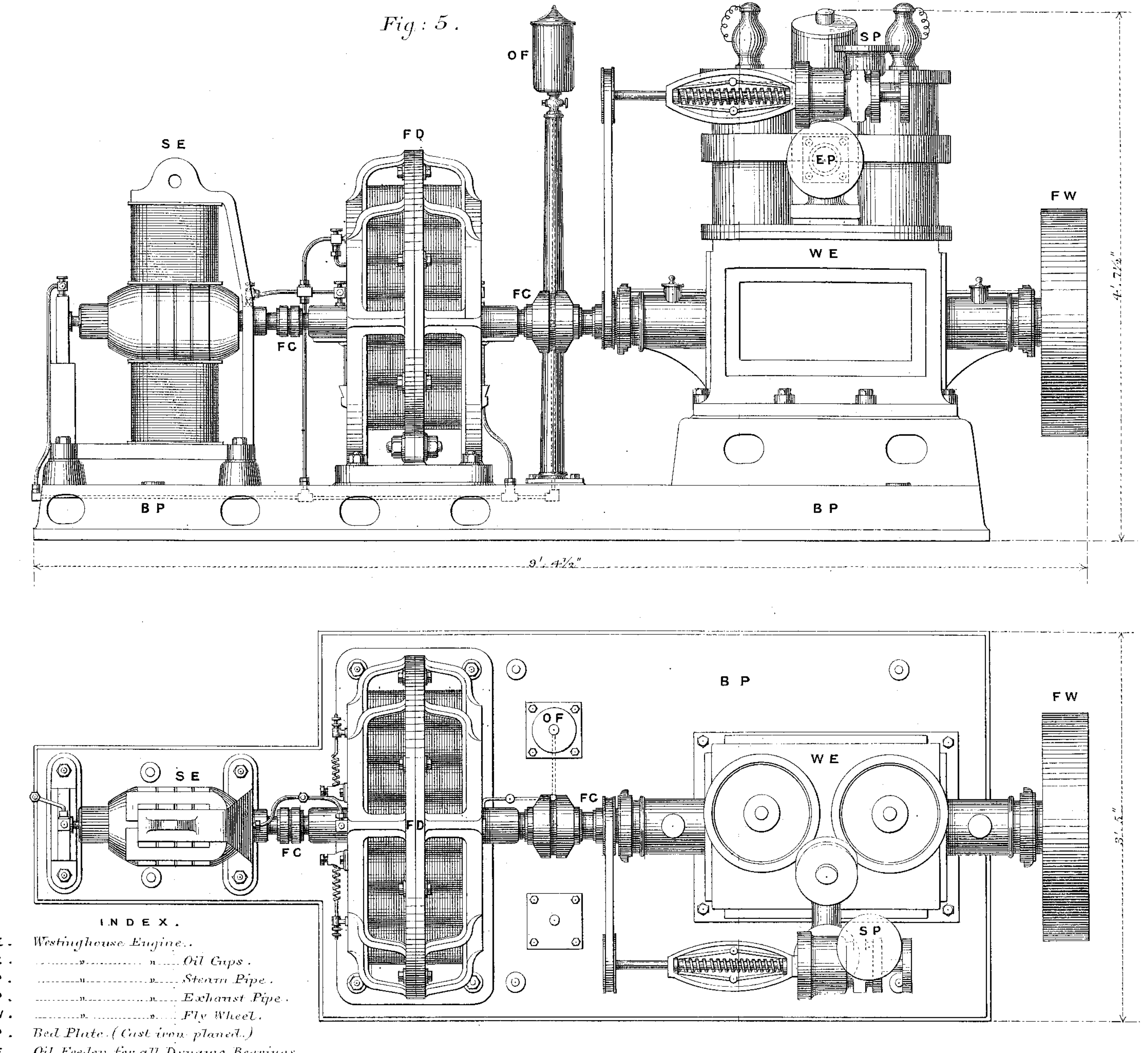


INDEX.

- C,C. Cylinders.
- P,P. Pistons.
- CR. Connecting Rods.
- KP. Knuckle Pin.
- Cr. Cranks.
- S. Crank Shaft.
- MB. Main Bearings.
- OC. Oil Caps.
- FW. Fly Wheel.
- DS. Dynamo Shaft.
- VC. Valve Chest.
- e,e. Annular Exhaust.
- E,E. Eduction Posts.
- VR. Valve Rod.
- ES. Eccentric Strap.
- bb. Balance Bobs.
- OT. Oil Tank.
- GP. Governor Pulleys.
- G. Governor.
- SP. Sole Plate.
- ED. Edison Dynamo.
- EM. Electro Magnets.
- NN. North Poles of Magnets.
- A. Armature.
- C. Commutator.
- B. Brushes.

WESTINGHOUSE ENGINE DRIVING AN EDISON DYNAMO AT 500 REVOLUTIONS PER MINUTE.

Fig: 5.



INDEX.

- WE. Westinghouse Engine.
- OC. ″ ″ Oil Caps.
- SP. ″ ″ Steam Pipe.
- EP. ″ ″ Exhaust Pipe.
- FW. ″ ″ Fly Wheel.
- BP. Bed Plate. (Cast iron planed.)
- OF. Oil Feeder for all Dynamo Bearings.
- FD. Ferranti Dynamo. (alternate current.)
- SE. Siemens' Exciter. (continuous current.)
- FC. Flexible Couplings.

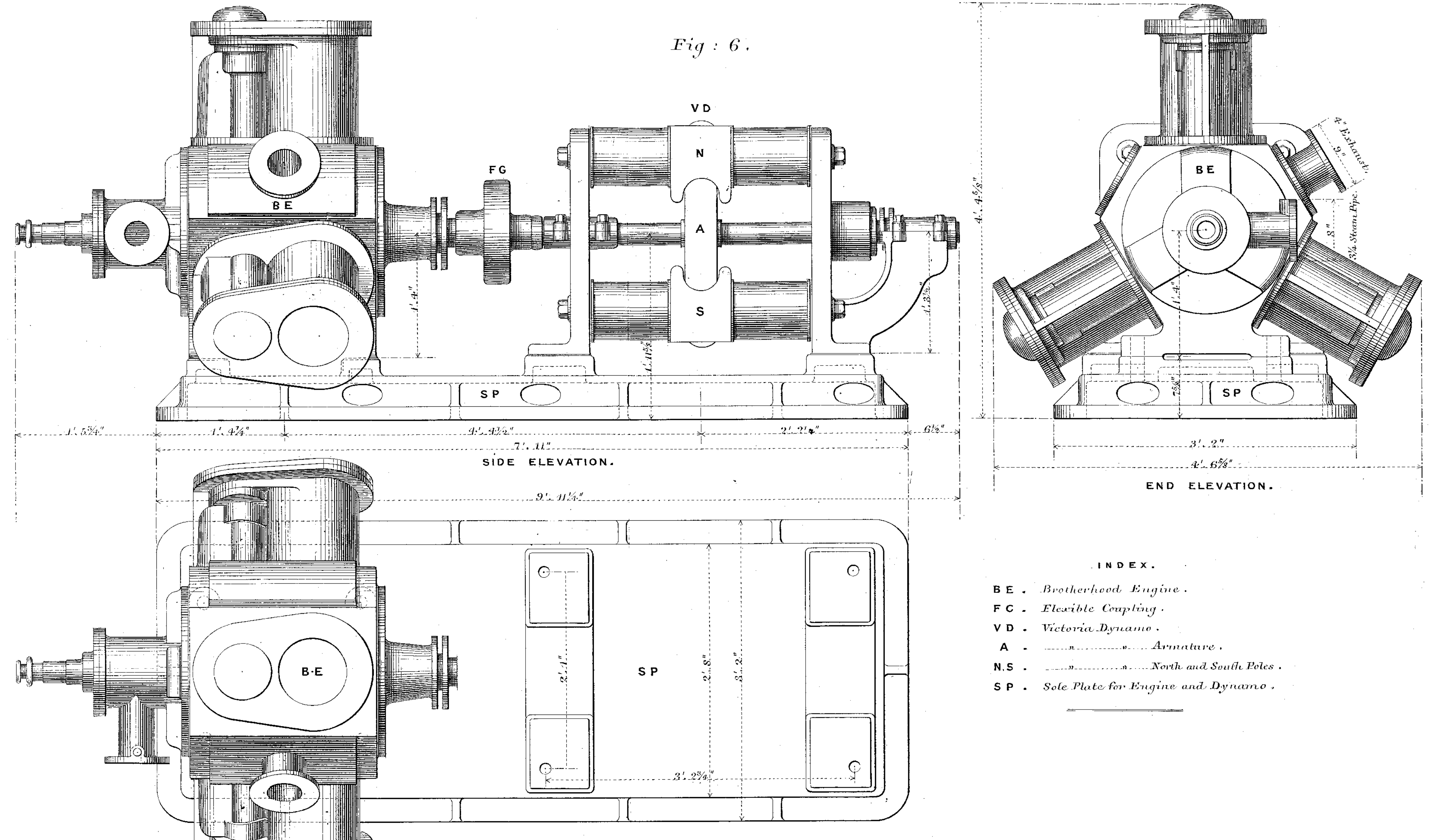
"FERRANTI" SHIP LIGHTING PLANT FOR 150 LAMPS OF 20 CANDLE POWER.

Scale: ¾ Inch = 1 Foot.

12 9 6 3 0 1 2 3 4 5 Feet.

THOS. KELL & SON, LITH. 40, KING ST COVENT GARDEN.

ELECTRIC LIGHTING FOR STEAM-SHIPS.

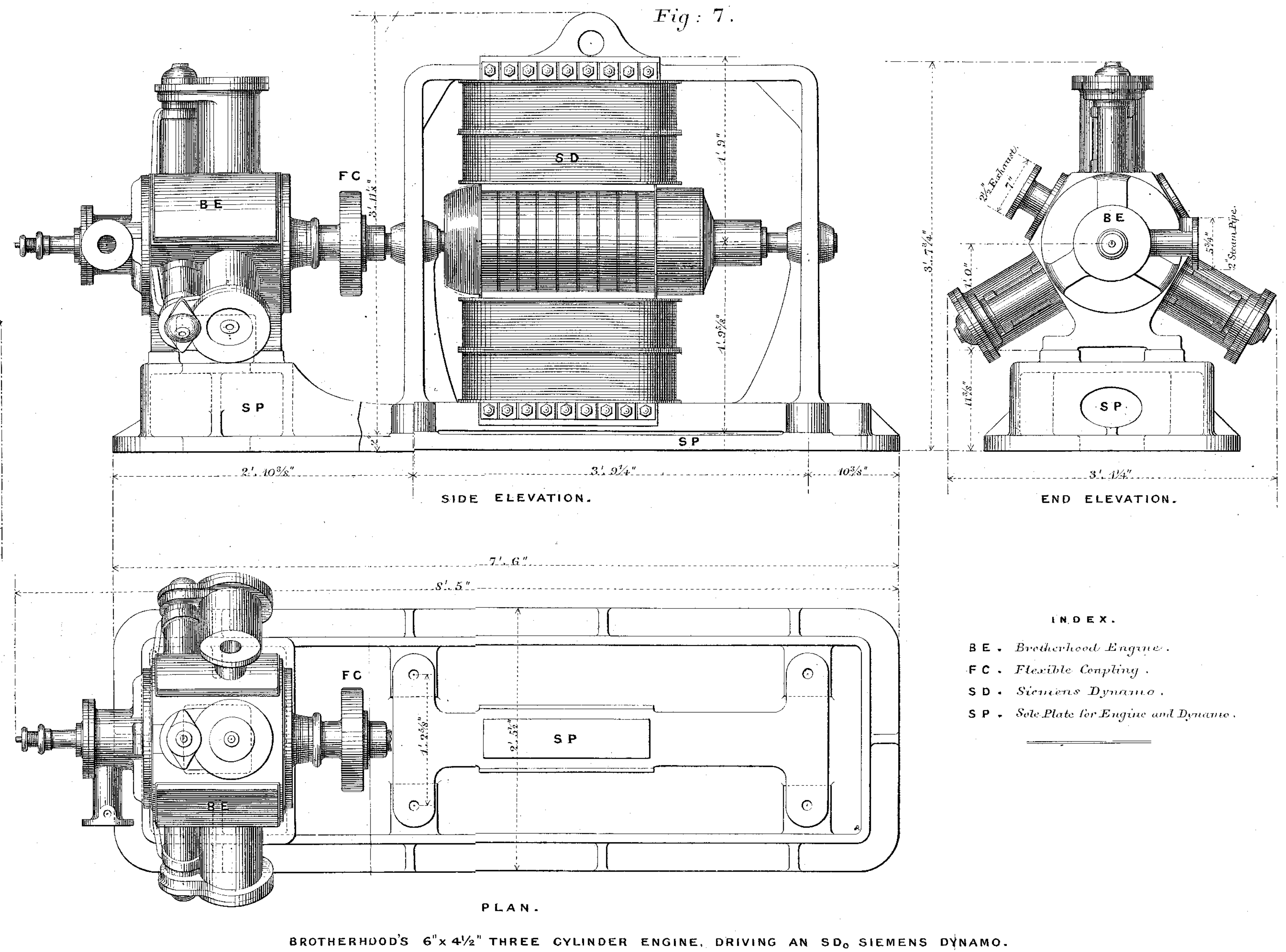


PLAN.

BROTHERHOOD'S 10" x 8" THREE CYLINDER ENGINE, DRIVING AN E_2 VICTORIA BRUSH DYNAMO.

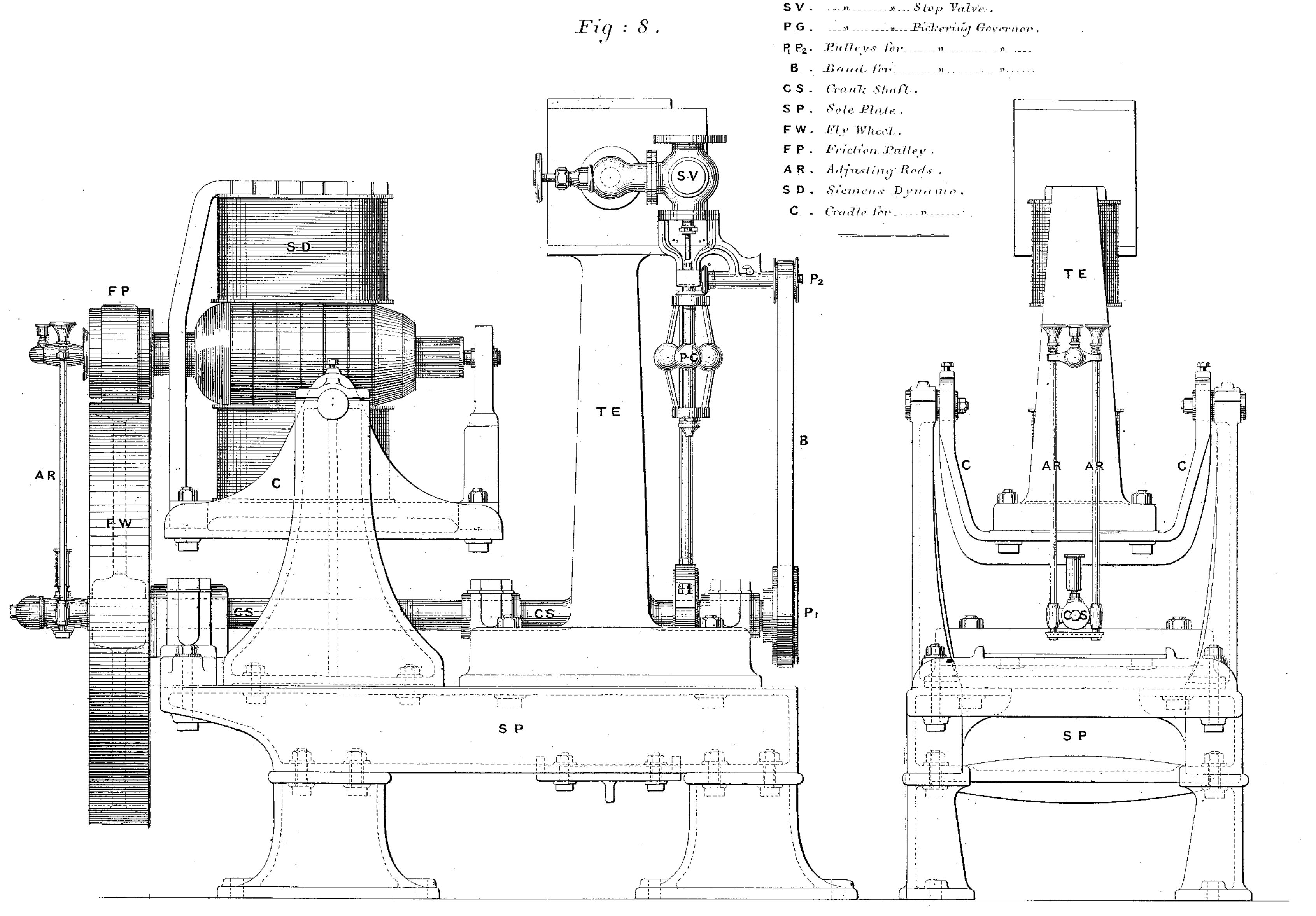
Scale: 3/4 Inch = 1 Foot.

12 9 6 3 0 1 2 3 4 5 6 Feet.



PLAN.

BROTHERHOOD'S 6" x 4½" THREE CYLINDER ENGINE, DRIVING AN SD_0 SIEMENS DYNAMO.



FRONT ELEVATION.

END ELEVATION.

TANGYE'S VERTICAL ENGINE, DRIVING A D_2 SIEMENS DYNAMO.

Scale: 1 Inch = 1 Foot.

12 9 6 3 0 1 2 3 4 5 Feet.

A. JAMIESON, DELT.

THOS KELL & SON, LITH. 40, KING ST COVENT GARDEN.