

NEWCASTLE AND DISTRICT ELECTRIC LIGHTING CO.'S POWER STATIONS.

BY MR. W. D. HUNTER, OF NEWCASTLE-UPON-TYNE.

The Newcastle and District Electric Lighting Co. was formed in January 1889 for the purpose of supplying the City of Newcastle-upon-Tyne and the adjoining districts with electrical energy. The nominal capital was £50,000, and the first issue of shares was limited to £15,000. Considerable delay was experienced in obtaining the necessary powers from the Board of Trade. The interval was, however, utilized for acquiring a station, and purchasing and erecting the requisite plant and machinery. A convenient and centrally-situated station near to the River Tyne was acquired, by purchasing a portion of the Forth Banks Works belonging to Messrs. R. and W. Hawthorn Leslie and Co., which originally formed their Marine-Engine Department, previous to the establishment of the large works at St. Peters.

The station was equipped with three Lancashire boilers, 30 feet by 7 feet 6 inches, and four Parsons single-phase turbo-electric alternating generators of 75 kilowatts capacity each. The total capacity of the Forth Banks Works at present is 3,000 kilowatts. This includes two 400-kilowatt continuous-current turbo-electric generators which were erected about two years ago, to meet the

immediate demand for electrical energy for power purposes. This demand continues to grow, and in order to keep pace with it the Newcastle and District Electric Lighting Co. are now erecting at their new works in the Close two continuous-current turbo-electric generators of 1,000 kilowatts capacity each.

The Forth Banks Works are peculiarly situated on the side of a hill, the engine and boiler-rooms forming terraces one above the other. Advantage of such a site could not have been taken without great expense had it been necessary to provide substantial engine foundations, but with the Parsons turbine these can practically be dispensed with. The total area of the engine-room is only 400 square yards, and in that space, as stated above, there are fixed turbo generators representing a total capacity of 3,000 kilowatts. Water is drawn for condensers from the River Tyne. The water-pipes are laid in a brick-lined tunnel about 100 yards long, and terminate in a condenser chamber sunk to mean tide level. There are two sets of condenser plant, one for surface condensation dealing with light loads, and the other for jet condensation and capable of condensing 48,000 lbs. of steam per hour.

Plate 50 shows the engine-room, and Fig. 2, Plate 51, shows the arrangement of surface-condensing plant. The pumps are worked by an engine fitted with rocking levers and spear rods, the engine being fixed at boiler-room floor level. This plant was made by Messrs. R. and W. Hawthorn Leslie and Co., and has been at work for nine years, to the entire satisfaction of the company. Figs. 3 and 4, Plate 51, show the arrangement of jet-condensing plant, which was specially designed to take advantage of the position in relation to the River Tyne. The water-pumps are situated at mean tide level, the air-pumps only deal with air and vapour, and the jet water rises to a considerable height in consequence of the vacuum formed; the "head" against the pumps at the bottom of the well is therefore comparatively small; the vacuum obtained is generally within an inch of the indications of a standard barometer. The contract was carried out by Messrs. John Abbot and Co., of Gateshead, the pumps being supplied by the Worthington Pumping Engine Co., and air-pump engines by Messrs. Carrick and Wardale,

of Gateshead. The cost of repairs and renewals for this plant during the six years it has been in operation, is practically represented by the cost of inspection.

CLOSE WORKS.

The site of the new works, at present being constructed and equipped, is immediately on the side of the River Tyne, situated about midway between the High Level and Redheugh Bridges. The works when completed will have a capacity of 12,000 kilowatts, or about 20,000 indicated horse-power.

The engine and boiler-rooms, with coal-store overhead, run parallel with the river from which the circulating water for condensers will be drawn. Coal will be brought to the works in barges and conveyed to the coal-bunkers and furnaces by special plant. The workshops, stores, &c., will be situated at the east end of engine-room, where provision is left for building these on. The cross section, Plate 52, shows clearly the relative positions of the various parts of the machinery, and the photograph, Fig. 7, Plate 53, gives a back view of the boilers. The following is a brief description of the more important parts of the plant.

Turbo-Electric Generators.—The two generators are each of 1,000 kilo-watts capacity, the electromotive force being 500 volts and the speed about 1,800 revolutions per minute. By adopting this size of generator, excellent results in regard to economy of steam are obtained, as will be seen from the following Table (page 444), giving particulars of a test made at Heaton Works on one of the generators for the Newcastle and District Electric Lighting Co.'s Close Works.

Plate 54 is a photograph of the generator tested as above. It will be observed that the machine is of the tandem form, and had really two dynamos, each of 500 kilowatts capacity. The armatures are interchangeable, and if necessary one dynamo may be run independently of the other. The steam-turbine portion of the generator is of the makers' latest improved construction, and is arranged for the full expansion of steam from the boiler pressure to

Speed.	S. V. P.	Cyl. Vac. 30" Bar.	Superheat. F°.	Volts.	Average Kw.	Water.	
						Lbs. per hour.	Lbs. per Kw.-hour.
1690	138	26	71	500	1011·6	21734	21·48
1680	140	26	86	500	909·0	18610	20·47
1700	142	26·2	128	500	894·6	17760	19·85
1660	144	26·3	132	500	890·7	17020	19·1
—	144	26·3	135	500	882·9	17171	19·43
1700	145	26·3	137	500	874·04	16983	19·43
—	145	26·3	137	500	901·06	17500	19·42
1680	146	26·3	136	500	896·7	17302	19·29
1640	142	26·4	136	500	862·2	16479	19·11
—	142	26·6	133	500	877·2	16800	19·15
1640	146	26·3	131	500	944·17	17903	18·96
1660	140	26·3	142	500	986·6	18434	18·78
1710	135	26·3	146	500	942·5	17559	18·52
1710	135	26·4	182	500	942·6	17460	18·52
—	140	26·5	195	500	878·06	15857	18·06
1710	146	26·6	221	500	863·28	15493	17·94
—	145	26·5	237	500	897·84	15922	17·73

It should be noted that these results were obtained when the machine was running some 10 per cent. under full load. At full load, with a 27-inch vacuum and 240° F. superheat, the consumption would fall to about 17·0 lbs. per kilowatt-hour.

that corresponding to within one inch of the barometer. The expansion is carried out in three barrels or cylinders of definite length and diameter to suit. The revolving portion is carried on large journals, and transmits the power to the armatures through a special claw coupling arranged at one end. At the opposite end a worm and thrust collars are fitted, the former being geared to a wheel which works the oil-pump for automatic lubrication by means of a crank-disc shaft. The fixed portion of the cylinder is designed to rest upon the supports provided at each end and at the exhaust, the foot is rigidly bolted to the bedplates, while at the

steam end provision is made for the foot to slide on the pedestal without altering the alignment; provision is thereby made for any alteration due to expansion.

It will be observed that steam is brought right on to the cylinder top, and is controlled by suitable valve gear as near to the working shaft as possible, so that all losses are minimised. The steam enters the first chamber and passes the "runaway" valve, which under ordinary working conditions is open; the steam is then in contact with the working valve, and the quantity passing is controlled by means of the steam relay gear fixed directly above. This gear is automatic in its action, and works in conjunction with an electrical solenoid. In addition, there is provided a pulsating motion to keep all parts of the lever and valve gear in movement, and to ensure prompt action on any change of load being made. The electric solenoid is energised by the main circuit, and maintains automatically constant voltage at all loads. The action is as follows: Should the voltage rise above the normal on change of load the solenoid core is lowered, and a small balancer piston hung at the opposite end of the lever is raised a proportionate amount; this allows the steam which keeps the regulating valve in action to escape more quickly, and the valve closes a little. If the voltage falls, the opposite effect is produced, and so quick is the response to any change of load that it is easy to maintain the pressure within 2 per cent. of the normal.

The dynamos are of the latest type, and embody all the improvements which experience alone can show to be desirable. Great care is taken to ventilate the armature thoroughly, and as much skill is required to effect a balance, extra attention is given to the various parts both before and after they are assembled on the shaft. The brush rocking-gear is very interesting; it is automatic in its action, and is controlled directly from the steam cylinder. The effect is to place the brushes instantly on the best working position of the commutator, no matter what the change of load may be. The floor space occupied by each machine is 38 feet 6 inches by 6 feet, or only 231 square feet area.

The heaviest parts do not exceed:—

Cylinder Bottom	5 $\frac{1}{4}$ tons.
„ Cover	3 $\frac{1}{2}$ „
„ Shaft	2 $\frac{1}{2}$ „
Armature	3 „

Mr. Parsons kindly lent the author a model, which was exhibited, of a 4,000 kilowatt generator, which gave an excellent idea of the proportions of this large machine.

Boilers.—The five boilers at present erected were made by the Stirling Boiler Co.; they are illustrated in Fig. 7, Plate 53, and Plate 55. Each of these boilers is capable of evaporating 18,000 lbs. of water per hour at 250 lbs. pressure per square inch. The boilers are fired with chain grate stokers, which work with absolute smokelessness in this type of boiler. Each boiler consists of three top drums and two lower water drums connected by banks of tubes. The feed is admitted to the back top drum, passes down the last bank of tubes, and thereby comes in contact with the hot gases before they leave the boiler, thus reducing the chimney temperature to a minimum. The feed-water being heated in its passage down the back bank of tubes deposits mud and sediment in the bottom drum, whence it can be readily blown off, and as this drum is far removed from the fire no injury will result from a considerable accumulation of solid matter in same. This arrangement of the boiler thus has an economiser and purifier action, so that if there is any deposit, it takes place in the rear position and the water is purified before reaching the tubes over the fire. With the special design of combustion chamber, shown surrounded on three sides with fire brick, a high initial temperature is obtained, thus ensuring perfect combustion and an absence of smoke; it also admits of an inferior quality of coal being burned with high efficiency. The design of the boiler is simple, as the tubes are expanded direct into the drums, and access to the interior is obtained by opening five manhole doors. The makers supply a simple arrangement for cleaning the interior of the tubes, and provision is made for a steam-jet to blow soot off the outside surfaces. The author obtained from the Stirling Boiler Co. a working model of one of their boilers, which was put in

operation at the meeting to show the manner in which the water circulated.

Boiler Feed Pumps.—The Boiler Feed Pumps, Fig. 6, Plate 53, are supplied by Messrs. G. and J. Weir, Cathcart, and consist of two of this firm's well-known standard single direct-acting pumps, each $9\frac{1}{2}$ inches diameter water cylinder by $12\frac{1}{2}$ inches steam cylinder and 24 inches stroke. These pumps are single cylinder double-acting and vertical. The pump ends are of cast-iron fitted with gun-metal liners, and the pump rods are of cold rolled manganese bronze. The valve gear is positive, that is, the steam valve can never be in such a position that the pump will not start immediately steam is turned on. In these pumps the steam is used expansively, and the cut-off can be regulated from the outside, while the pumps are working, thus making them extremely economical as regards steam consumption. The pumps are very simple, and all the parts are readily accessible.

Coal Conveying Plant.—The type of coal conveying plant has not been definitely fixed upon; four alternative designs are illustrated in Plate 56. In each case the plant is designed to discharge the coal from barges as they come alongside the jetty or quay wall, afterwards distributing it along the coal bunkers in front of the boiler-house, whence it is fed into the hoppers of mechanical stokers.

Fig. 10 (Scheme A) is a design by Messrs. Barry Henry and Co., of Aberdeen. The electric cranes are fitted with Hone's grabs, capable of holding one ton of coal. These deliver into Ingrey's registering weighing machines, from which the coal is taken to the bunkers by means of elevators, and distributed by means of a push plate conveyor. A weighing and recording machine is provided for each boiler, so that by comparing the total weight of coal received and the weight of coal burned, the stock can be correctly ascertained.

Fig. 11 (Scheme B) illustrates the design submitted by Messrs. Babcock and Wilcox. The conveyor consists of a double-link chain carrying a series of pivoted buckets suspended in such a

manner that they maintain their vertical positions, and are free to revolve on their axles at all points of their path, excepting those points at which it is necessary to dump or empty them, and this dumping is automatically performed in a very simple and efficient manner, by means of a cam action, whilst the buckets on being released from the dumpers right themselves and are ready to be refilled. The system of buckets passes through the cycle of its action, continuously filling and emptying, or "dumping," at any position arranged for them, this being performed by merely moving a small lever. Ashes can be dealt with independently or simultaneously with coal in this type of conveyor, and by means of an ash hopper situated under some part of the conveyor run, ashes can be stored until a convenient time for their removal, when they can be discharged by means of a special controlling valve into any conveyance that may be used.

The design submitted by Messrs. E. Bennis and Co., of Bolton, is illustrated in Fig. 12 (*Scheme C*), and shows that the whole apparatus is contained in a small space and that the arrangements made for actuating the grab and distributing the coal are very complete.

The proposal submitted by Messrs. Graham Morton and Co., Leeds, is shown by Fig. 13 (*Scheme D*), and provides for taking the coal from barges by means of two grabs worked by electric cranes. It is then passed through a weighing machine and elevated to the bunkers, over which it is distributed by means of a push plate conveyor. The coal to each boiler is measured by means of a special machine which registers the amount contained in a revolving apparatus.

All the above designs embody many interesting points which cannot be touched upon in a Paper of this description.

A 15-ton overhead traveller, supplied by Messrs. Vaughan and Son, Manchester, spans the Close Works engine-house. The girders and end carriages are of the box riveted type, the latter being each fitted with two steel-tyred travelling wheels. The crab is carried on four steel runners, keyed on steel axles revolving in gun-metal bearings; spur gearing is used throughout, the whole being

machine-cut with the exception of the barrel wheel and pinion. In conjunction therewith a magnetic brake is provided to sustain the load. When current is switched on to the hoisting motor, it puts into circuit an electro-magnet possessing sufficient power to raise the brake lever, and render the brake inoperative at the moment that hoisting or lowering commences, and also during their continuance. Directly current is switched off the motor, the brake applies itself automatically and without any attention whatever on the part of the operator. The advantage of this is obvious, as if from any cause during working operations the current should fall, the brake magnet would instantly release the brake and allow it to take charge of and sustain the load. There are two barrels, each machine-grooved and fitted with wire rope; the large barrel has right and left-hand grooves to secure vertical lifting and equal distribution of load on both girders. Both barrel hooks revolve on hardened cast-steel balls and plates.

The speeds of the crane are as follows :—

Hoisting, 15 tons at	4 feet per minute.	
„ 7½ „ „	8 „ „ „	
„ 2 „ „	30 „ „ „	small barrel.
Longitudinal traverse, 200 feet per minute	} light.	
Cross „ 100 „ „ „		

By regulation of the controllers the above speeds can be varied instantly from maximum to zero. The three movements of the crane are effected by three series-wound motors, each having its own controller, the latter being carried on the crab and operated by cords from the ground floor. The powers of the motors are :—

Hoisting,	6 H.P. at 300 revolutions per minute.
Longitudinal traverse,	6 H.P. at 600 „ „ „
Cross „	3 H.P. at 300 „ „ „

For short periods these are capable of developing double their rated powers. In connection with the hoisting gear, a stop motion is provided for the purpose of automatically breaking the circuit and preventing overwinding. The efficiency is about 50 per cent., the loss including all the mechanical friction of the gear as well as that of the motor.

Condensing Plant.—The condensers and pumps, which are shown in the cross section of the buildings, Plate 52, were made by Messrs. John Abbot and Co., of Gateshead. The condensers have each a cooling surface of 3,000 square feet; ample provision is made for examination by means of large doors, and the internal arrangements are all in accordance with the latest Admiralty practice. The pump cylinders are fitted with liners, and have rods of Delta metal. Ample passage ways are provided in the circulating pump so that the velocity of water never exceeds 4 feet per second at any part. The engines for driving these are of the vertical compound type, with provision for admitting high-pressure steam to low-pressure cylinder for starting. The bedplate is bolted to fixed girders above the pumps, and two heavy balanced fly-wheels are provided. The pump-rods are balanced by means of rocking levers and weights worked off the cross-heads. The engines were made by Messrs. Carrick and Wardale, of Gateshead.

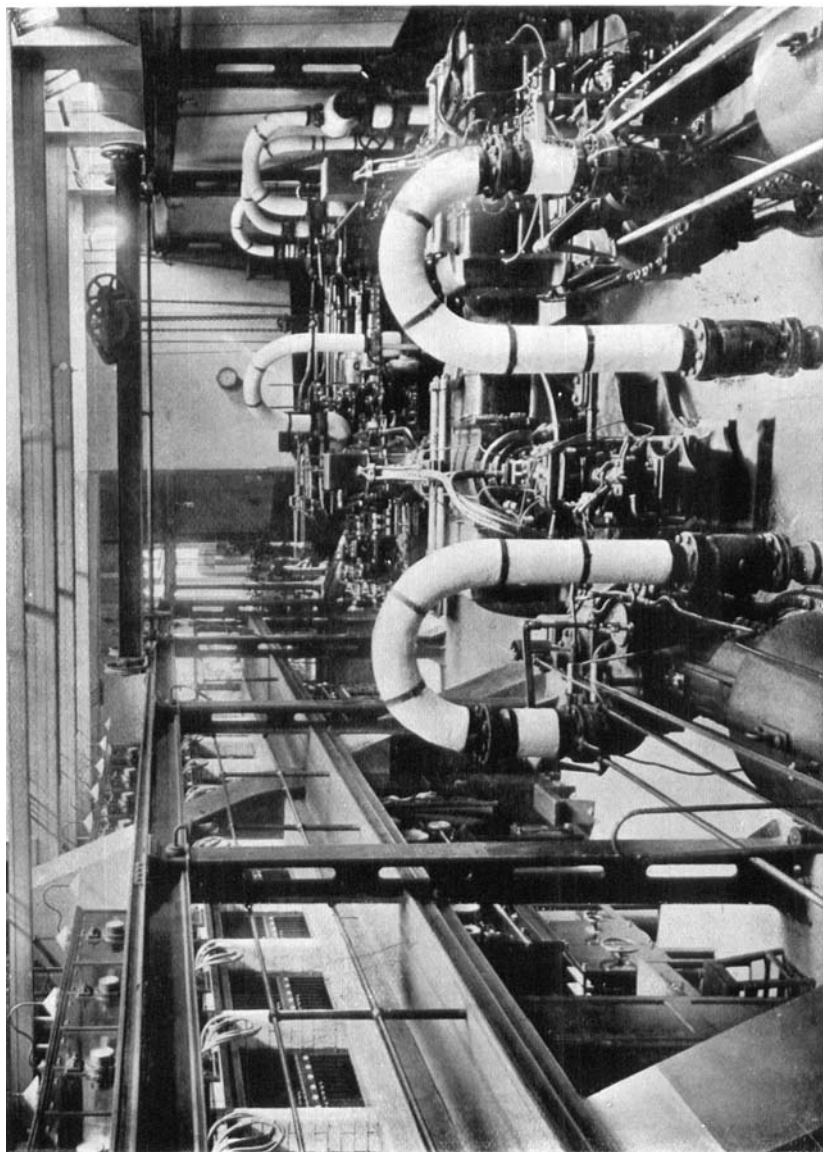
Switch-board.—The switch gear is of the cellular type, constructed by Messrs. Ferranti, and consists of heavy black enamelled slates grouted into the station wall, and divided off into a number of pigeon-hole recesses by vertical division slates, the principle being to have a complete compartment for each apparatus used on the gear. The switchboard comprises six dynamo panels. Plate 57 represents a general arrangement view of the entire switchboard, from which it will be seen that each of the six dynamo panels on the right include the following:—voltmeter; ammeter; two single-pole switches with reverse current automatic devices; and section of regulating table on which the open type regulating resistances are controlled by means of a hand-wheel. In the centre of the board will be seen a large 6,000 ampère watt-meter placed between the bus-bars to register the total watts generated by the machines. An earth recording ammeter with cut-outs and one mid-wire ammeter are placed under the watt-meter panel in the regulating table. Continuing to the left will be seen provision for two balancers complete with main switches, ammeters, and starting resistances. The three-wire feeder panels are arranged to the left of the board,

and each panel comprises 2 voltmeters, 2 ammeters, 2 switches, and maximum current automatic devices provided with time limit relay. Each generator and feeder panel is designed to carry 1,000 amperes, and to break under the severer conditions likely to be existent under emergencies. In designing this gear it has been the aim to simplify the connections to a minimum degree consistent with the efficiency and convenience of working. As a result the entire arrangement is simple and easy for the operator to understand, and having all connections clearly visible before him there is very little opportunity for errors to be made, which otherwise might lead to disastrous results. It is impossible to place too great stress upon the necessity of rendering the switchboard free from fire risks. The theory of splitting up the whole into small compartments has been carefully considered with this in view. Moreover, there is an absence of inflammable material, and when compared with the old flat board type of switch-gear, it is not only interesting but eminently satisfactory to see the way in which strip cable connections are avoided. The cellular type of switch-gear as constructed by the Ferranti Co. has been very widely supplied to high-tension alternating current systems. The advantages thereby derived are so obvious that although the continuous-current board is only of recent introduction, yet it is already becoming a standard type for continuous current purposes.

The Paper is illustrated by Plates 50 to 57.

[NOTE.—*The Discussion on this Paper was combined with that on Mr. Hopkinson's and Mr. Woodhouse's Papers, and commences on page 464.*]

Fig. 1. *Engine Room from North End,
Forth Banks Works.*



Forth Banks Works.

Fig. 3.
Jet-Condenser.

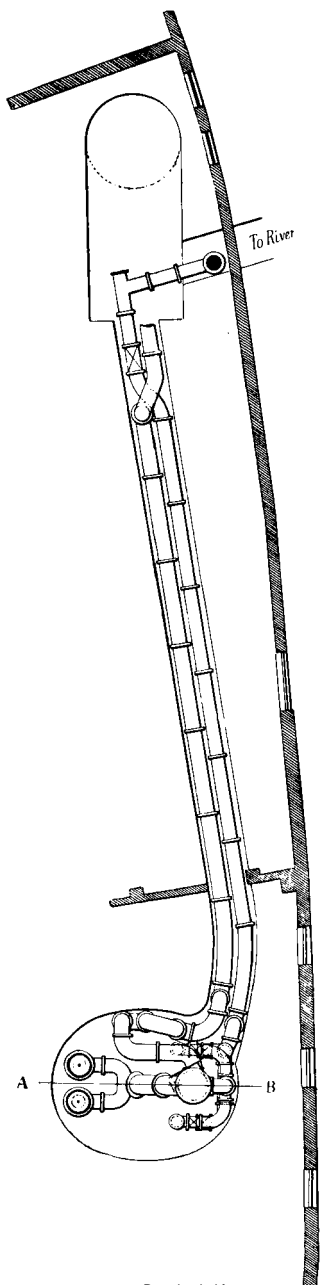


Fig. 2.
Surface Condensing Plant.

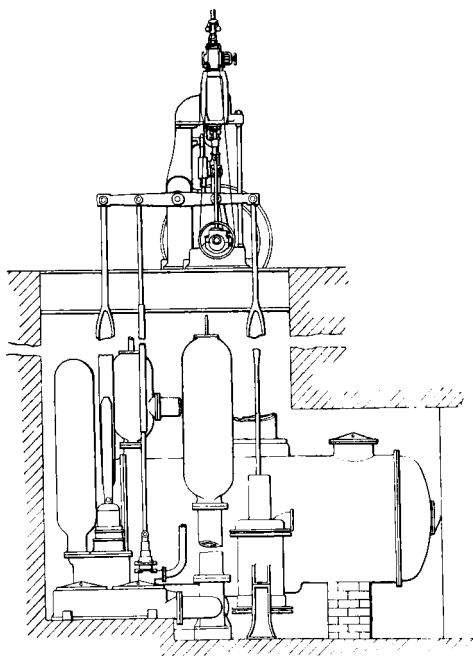


Fig. 4. *Section on line A.B. Fig. 3.*

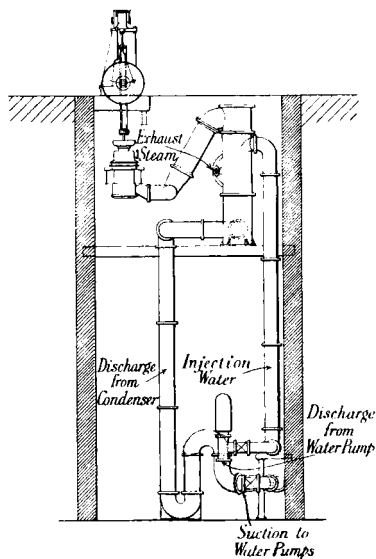


Fig. 5. Cross Section, Close Works.

Plate 52.

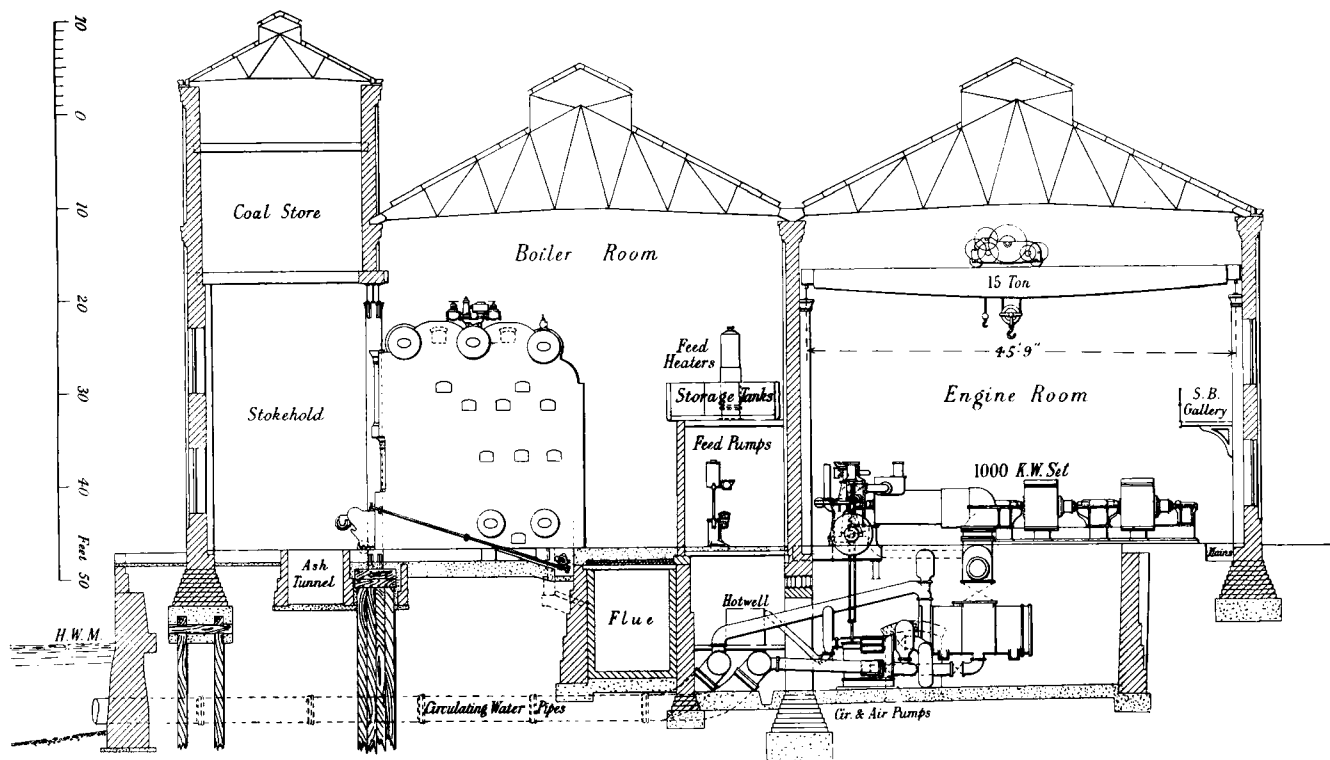


Fig. 6. *Boiler Feed Pump.* Steam Cyl. $12\frac{1}{2}"$ } 24" Stroke.
Water " $9\frac{1}{2}"$

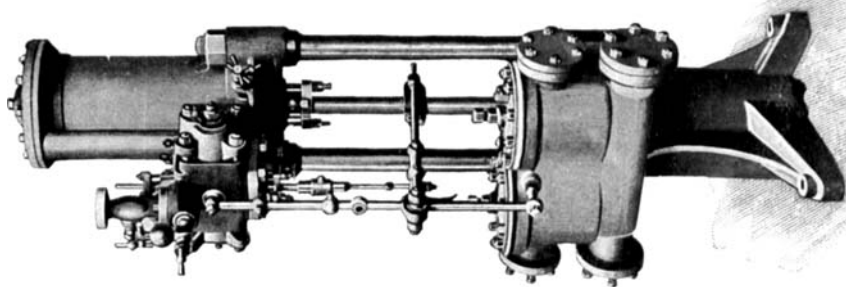


Fig. 7. *Back View of Boilers, Casing incomplete, Close Works.*

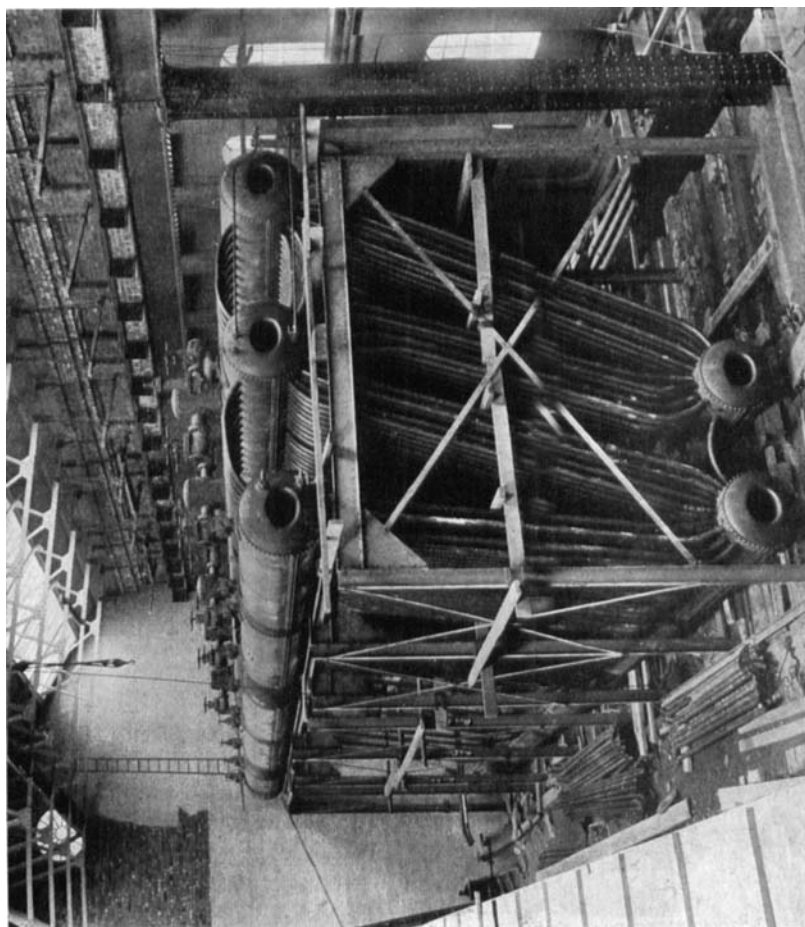
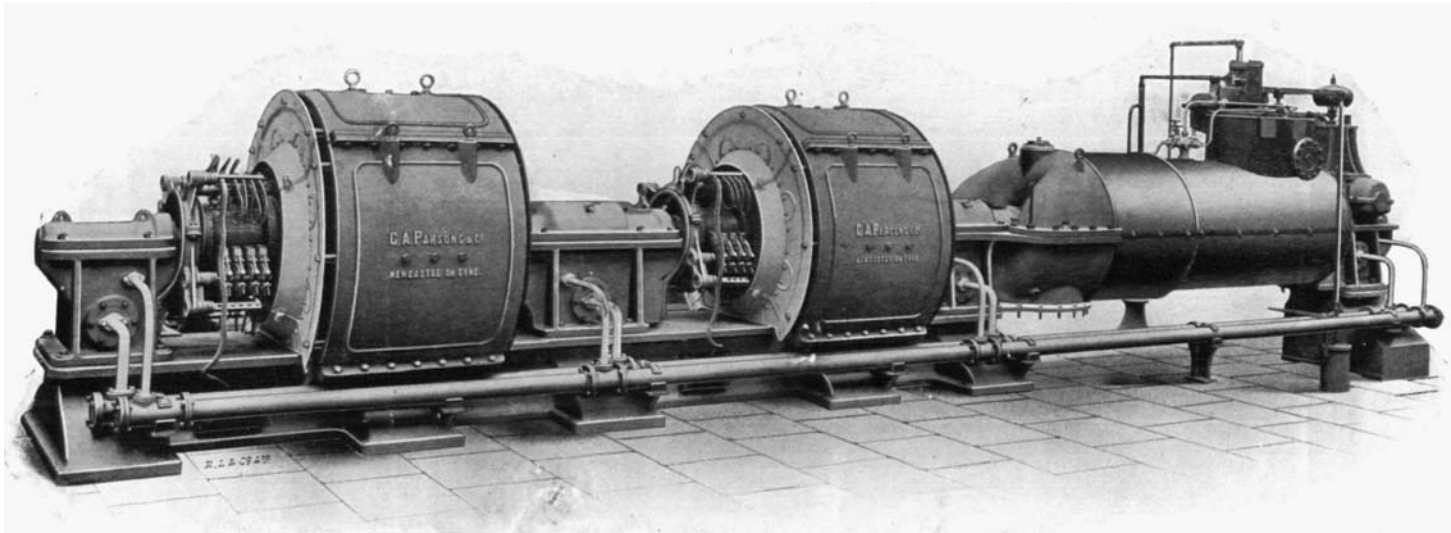


Fig. 8. 1,000 Kw. Generator for Close Works.



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Fig. 9. *Stirling Boilers. Cross Section of 1 of the 5.*

Close Works.

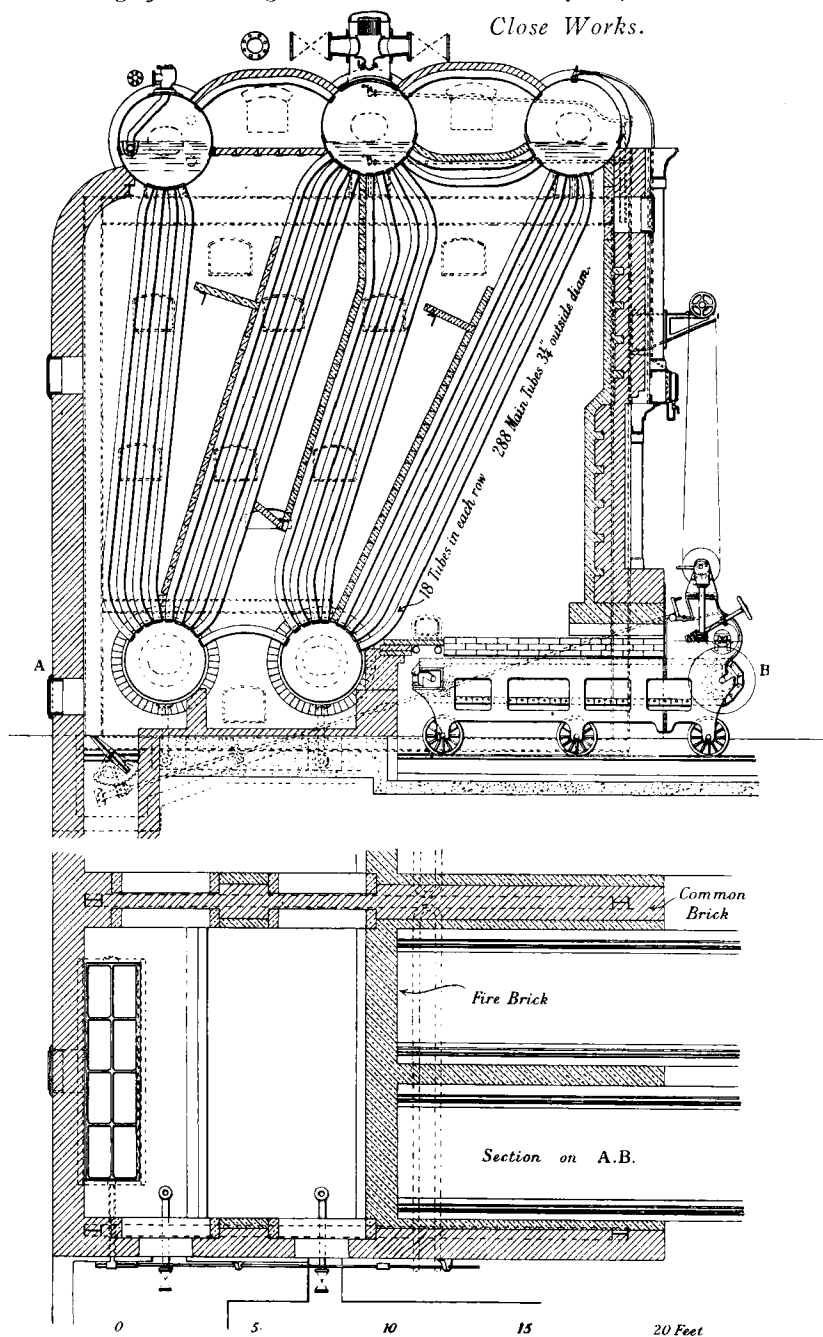
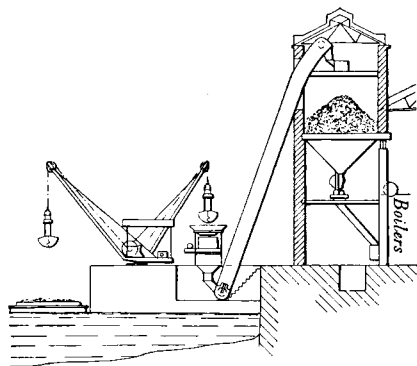


Fig. 10. Scheme (A).



Four Schemes for Discharging Coal, Close Works.

Fig. 11. Scheme (B).

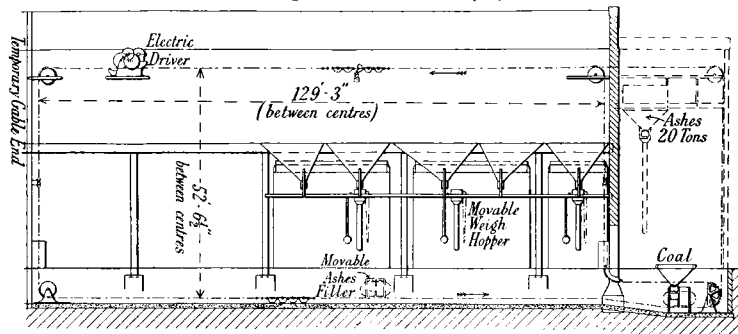


Fig. 12. Scheme (C).

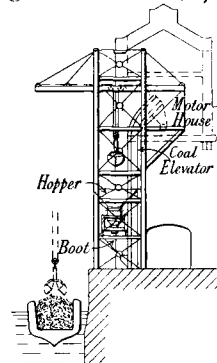
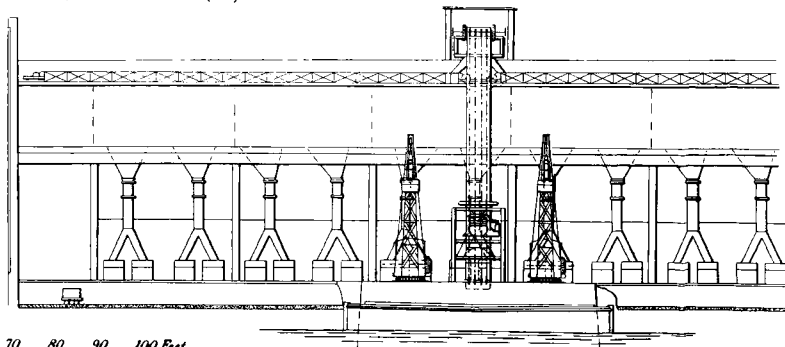
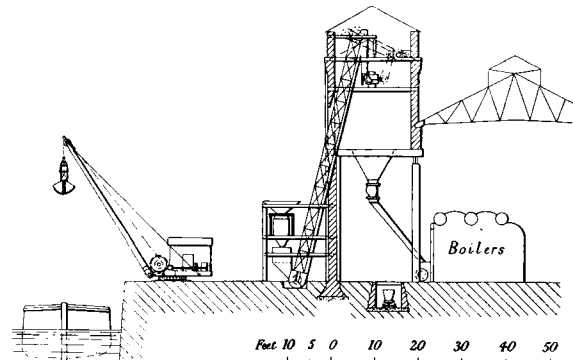


Fig. 13. Scheme (D).



Feet 10 5 0 10 20 30 40 50 60 70 80 90 100 Feet

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Fig. 14. Three-Wire Switchboard, Close Works.

