THE ELECTRICAL EQUIPMENT OF THE NORTH WESTERN RAILWAY POWER STATION AND WORKSHOPS AT MOGHALPURA.

By K. PRESTON.

Introduction.

The history of the North-Western Railway Equipment for the supply of Electrical Energy for the driving of Workshop Machinery and general purposes is one of continual growth and helps to confirm the theory that a cheap and reliable supply of Electrical Energy automatically creates a demand for more.

The original Power Station situated at Lahore was equipped with two 250 KW and two 125 KW steam generating sets and in 1909-10 the number of units supplied from this station was approximately half a million units per annum. On completion of the new Locomotive and Carriage Shops at Moghalpura in 1911 the Lahore Power Station was closed and the present station was brought into service.

In 1919-20 the number of units supplied was over 3½ million and it is anticipated that within three years from date the annual output will be in the neighbourhood of 6 million units.

Energy is distributed to the Locomotive Shops, Carriage Shops, Signal Shops, Railway Bungalows and Offices, etc., and within the next 12 months will be supplied in bulk to the Military Authorities at Lahore Cantonment. The total number of motors connected to the system is approximately 600 and the number of fans 2,000. The whole of the energy has been distributed hitherto on the continuous current 3 wire system at a pressure of 450 volts but to meet the future demands it was decided in 1918 to install 3 phase alternating current generating plant and distribute to substations situated in Lahore and in the other Workshops at a pressure of 3,300 volts. Energy will also be supplied to Cantonments at this pressure and converted there by rotary converters into 450 volts direct current for distribution to bungalows, etc.

The change from direct to alternating current was necessary, partly to enable the energy to be distributed economically with the minimum amount of copper and partly to enable the Railway to use alternating current motors which have certain inherent advantages as compared with direct current motors.

To illustrate the saving in copper by the use of high tension alternating current transmission it may be mentioned that to transmit with a drop of five per cent. 1,000 kilowatts at 450 volt continuous current a distance of half a mile, which is the approximate distance from the Power House to the centre of load in the various Shops, requires approximately 90,000 pounds of copper as against 10,000 pounds, when transmitting at 3,300 volts alternating current.

The aggregate capacity of the generating plant will be 6,000 kilowatt when the extensions now in hand are completed and the equipment will then comprise :

Six Babcock and Wilcox Water Tube Boilers.

One Economiser.

Two 2,000 Kilowatt Turbine Alternator Sets.

Four 400 Kilowatt High Speed Steam Engine Driven Generating Sets, three of which are fitted with one 400 kilowatt continuous current generator coupled in tandem with one 375 kilowatt alternator.

Three 750 kilowatt La Cour motor converter sets 3,300 volts alternating current to 450 volts continuous current, the function of which is to act as a link between the steam driven continuous current generating sets and the turbine driven alternators.

Boilers.

The heating surface of each boiler is 4,020 square feet and steam is generated at 160 lbs. per square inch pressure superheated 100 degrees giving a final steam temperature of 470 degrees Fahr. at the boiler stop valve. All boilers are fitted with variable speed chain grate automatic stokers having a grate area of 98 square feet and the normal evaporative capacity of each boiler is 12,300 pounds of water per hour. Gases pass through the main flue 8 × 8 feet into the economiser, which raises the temperature of the feed water from 90 degrees Fahr. up to 280 Fahr., and thence pass into the main stack which is 225 feet high, 33 feet diameter at base and 11 feet at top with an internal diameter of 9 feet. In the summer months it is possible to get a draft of one inch water gauge at the stack base and five eighths inch at boiler furnaces. The difference in temperature between the flue gases at the inlet and outlet of the economiser is 200 degrees Fahr. and a saving in coal consumption of about 15 to 20 per cent. is obtained by its use. The raising of the feed water to 280 degrees Fahr. by passing it through the economiser before it enters the boilers considerably reduces scaling and corrosion in the drums and tubes and it is possible to keep a boiler on range for three months without overhauling or cleaning other than by the usual method of blowing down.

The 400 KW Steam Generating Sets are of the triple expansion vertical type running at a speed of 300 r. p. m. and are fitted with forced lubrication to all wearing parts. An automatic

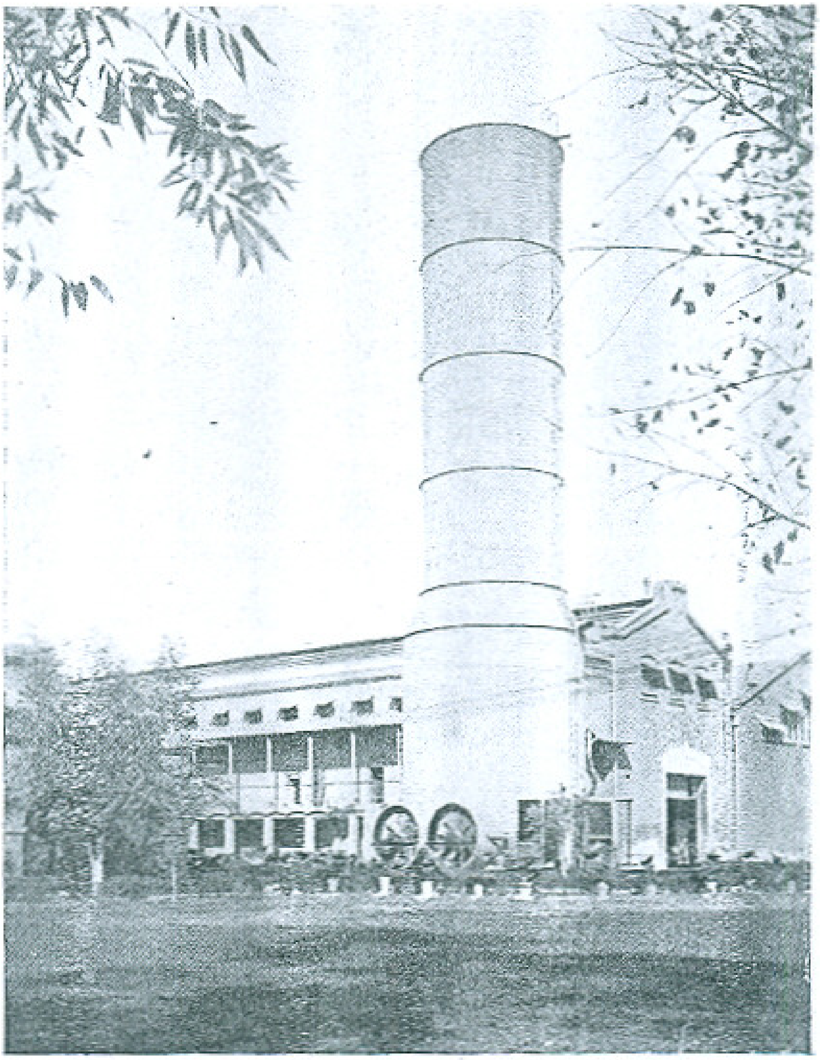


PLATE I.
ALL STEEL FORCED AND NATURAL DRAFT COOLING TOWER.
150,000 GALLONS.

expansion valve to vary the cut off at different loads is also fitted and the steam consumption when exhausting into a vacuum of 26 inches is 22 lbs. per KW hour (16·4 lbs. per B. H. P. hour). Normally all four sets exhaust into a jet condenser capable of dealing with 41,000 lbs. of steam per hour and of maintaining a vacuum within 4 inches of absolute. Cooling water for this condenser is supplied from an all steel forced and natural draft cooling tower 100 feet high by 20 feet dia. capable of reducing the temperature of the cooling water from 125 degrees Fahr. to 92 degrees Fahr. when dealing with 150,000 gallons of water per hour. Forced draft is used for this purpose during the summer months and natural draft during the winter months. The tower is illustrated on plate I.

Turbine Plant.

The turbine plant and its accessories now being installed is of special interest as it is the first of its kind installed in the Punjab.

Each set is capable of delivering 2,000 kilowatts 3,300 volt 3 phase 50 cycles at 80 per cent. power factor when running at a speed of 3,000 r. p. m. and exhausting into a vacuum within 3 inches of absolute. Each set will also develop 2,500 kilowatts for two hours when exhausting into a vacuum of within 4 inches of absolute.

The turbines are of the pure impulse type with one velocity impulse wheel carrying two rows of blades, the function of this wheel being to reduce the steam pressure and consequently confine the maximum temperature to the high pressure and of the turbine casing which, with the first set of nozzles, is constructed of cast steel. The low pressure portion of the turbine casing is of close grained cast iron of a special mixture suitable for the moderate temperatures and pressures to be dealt with after the steam has passed through the velocity wheel. The steam and pedestal bearing which also carries a Mitchell type thrust block is designed with freedom to slide in an axial direction over a steel feather key in the bedplate and thereby automatically takes care of any expansion in the shaft and rotor.

Oil is supplied under pressure to all bearings by a direct driven rotary oil pump and in addition an auxiliary steam driven oil pump is fitted and automatically comes into action in the event of the oil supply from the rotary pump failing or during shutting down and starting periods.

The method of governing the turbine deserves attention as with this type of prime mover it is of the utmost importance that the speed of rotation shall only vary between very fine limits under all conditions of load. When the electrical load is suddenly reduced the whole of the difference in load exists between the turbine and generator, the turbine producing more power than is called for by the generator. This excess of power is absorbed by the rotating elements in the form of kinetic energy and consequently the speed of rotation tends to increase rapidly. When a sudden increase of electrical load occurs the converse takes place and the extra power required by the generator is supplied at the expense of the kinetic energy of the rotating elements, consequently the speed of rotation rapidly decreases.

To meet these conditions and to maintain a constant speed it has been necessary for turbine manufacturers to develop a governor which is extremely sensitive to all load variations and one in which frictional resistance is eliminated as far as possible. The governor gear fitted to the turbine at Moghalpura is known as the Relay Series type in which the power required to obtain the governing effect is not directly applied to the govenor valve but operates an auxiliary power system which in its turn is used to open and close the steam valve on the turbine.

The motive power employed on this auxiliary power system is all under pressure and the general principle is shown diagrammatically in Fig. 1.

The operation is as follows: if the load on the turbine increases, the governor sleeve "E" falls slightly the floating lever "F" moving with the sleeve. This movement has the effect of lowering the oil distribution valve "B" thus admitting pressure oil to the underside of the relay piston "C" and at the same time permitting oil to escape from the top side. The relay piston then rises, due to the difference of pressure, carrying with it the throttle valve, "H" thus allowing a greater quantity of steam to enter the turbine.

The piston rod, in moving upwards carries with it the lever "F" which now has its fulcrum at "E" and thus the oil distribution valve is brought back to its normal position and equilibrum is re-established.

Fig. 2 shows diagrammatically the above principle as actually adopted on the turbines, the three valves V1, V2 and V3 being mechanical operated by a main oil relay piston. Valve V1 the main valve, through which all the steam passes, controlls by throttling, up to about 60 per cent. of the normal load. When this valve is lifted to the extent necessary to pass the required quantity of steam, a stop on the spindle of the relay piston engages a bell crank lever which operates full load nozzle control valve V2. When V2 is fully opened a further travel of the relay piston opens the overload nozzle control valve V3.

The guaranteed permanent speed variation between no load and full load with the load suddenly thrown on or off is 4 per cent

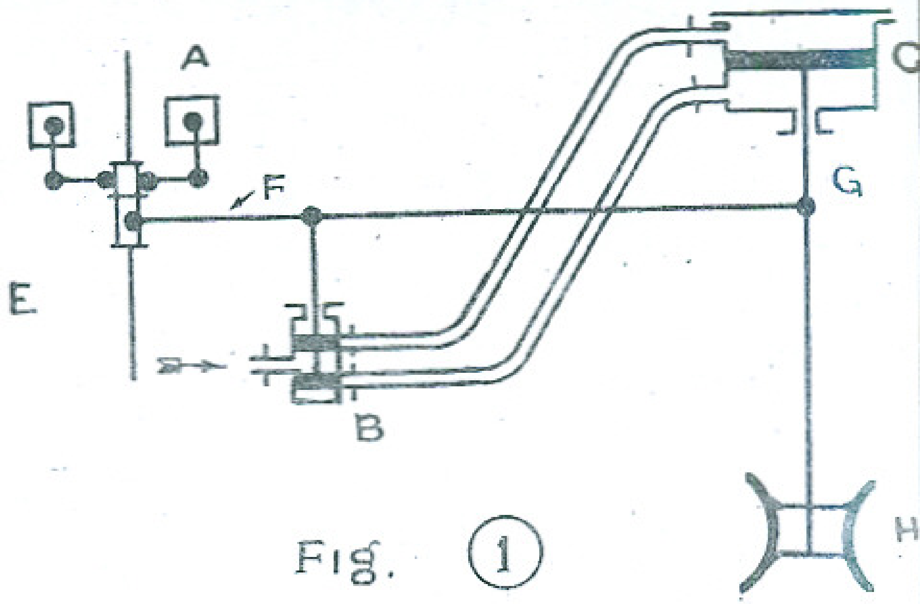


Fig. 1

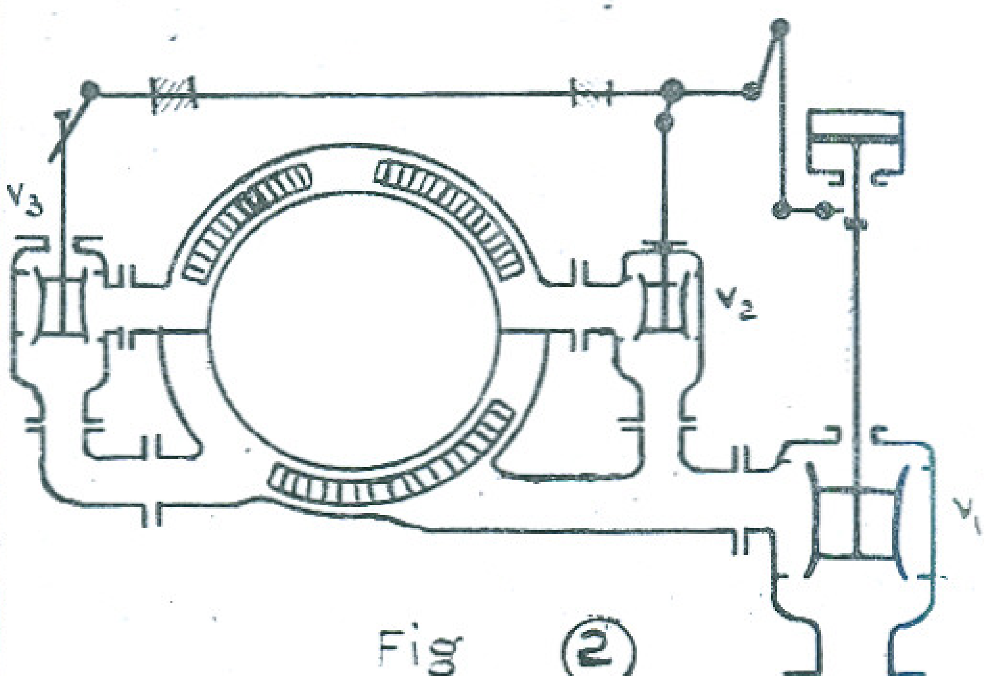


Fig 2

DIAGRAM OF GOVERNOR GEAR

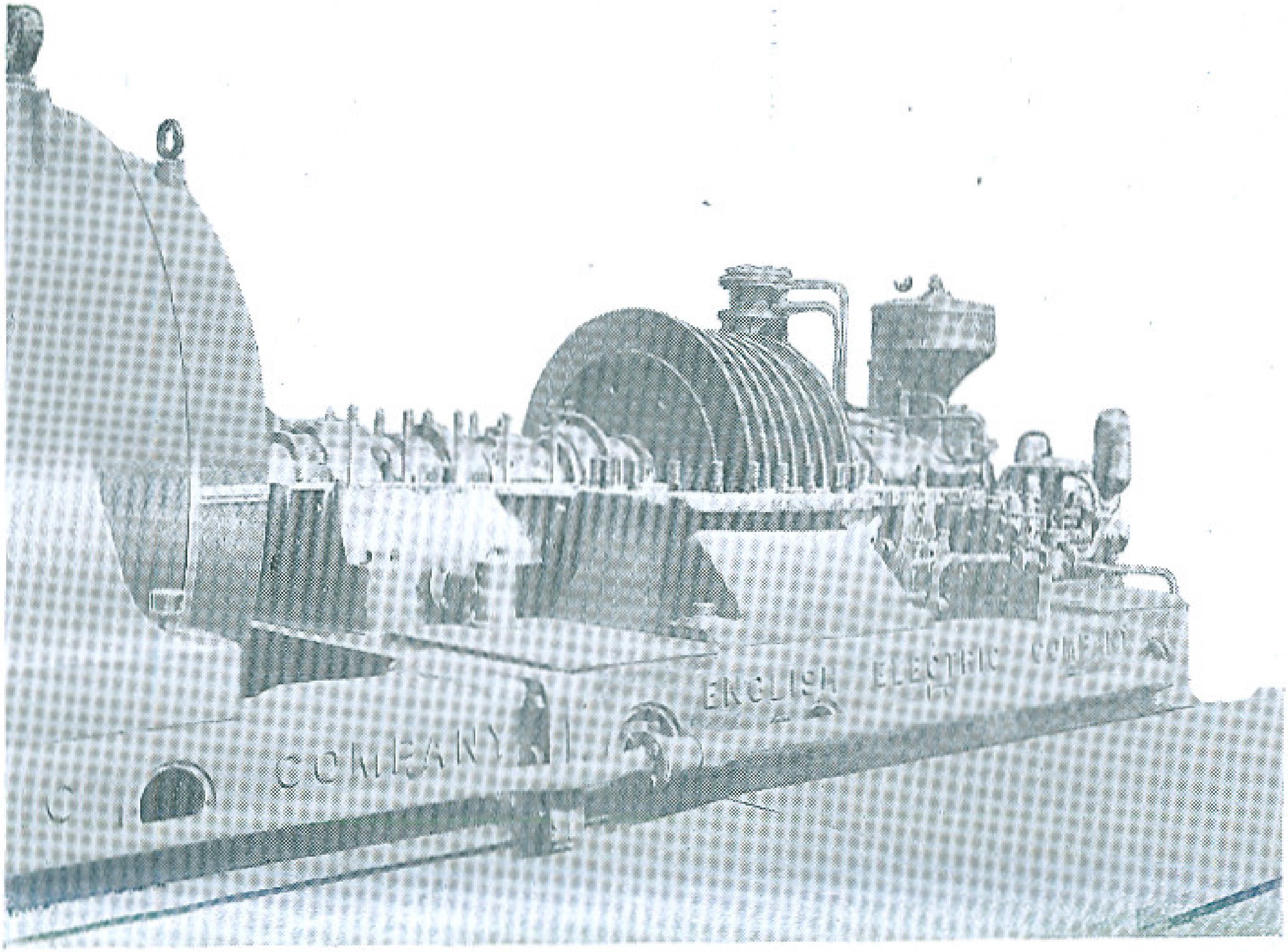


PLATE II.
2,000 K. W. TURBINE SHOWING BLADING AND DISCS.

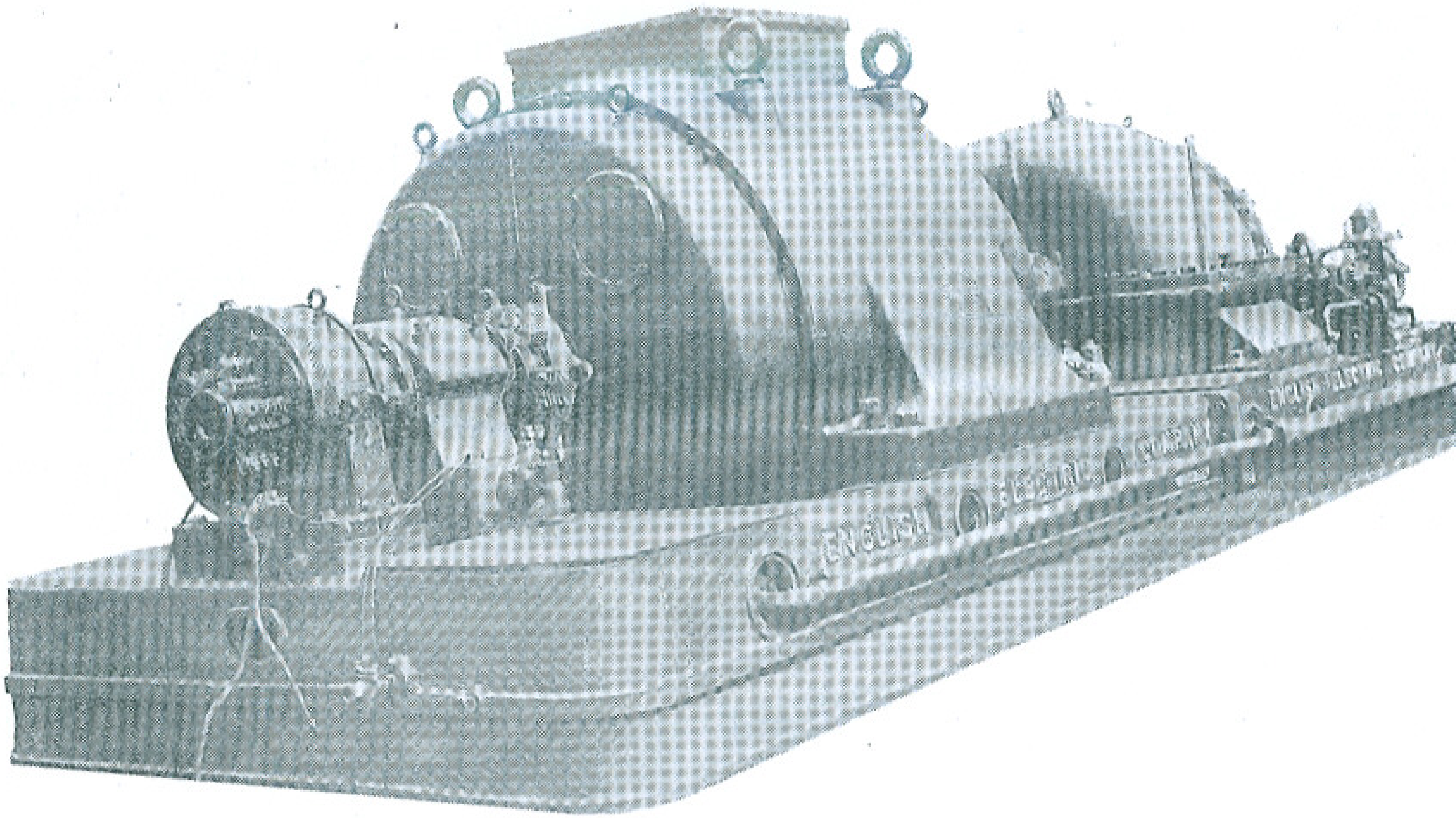
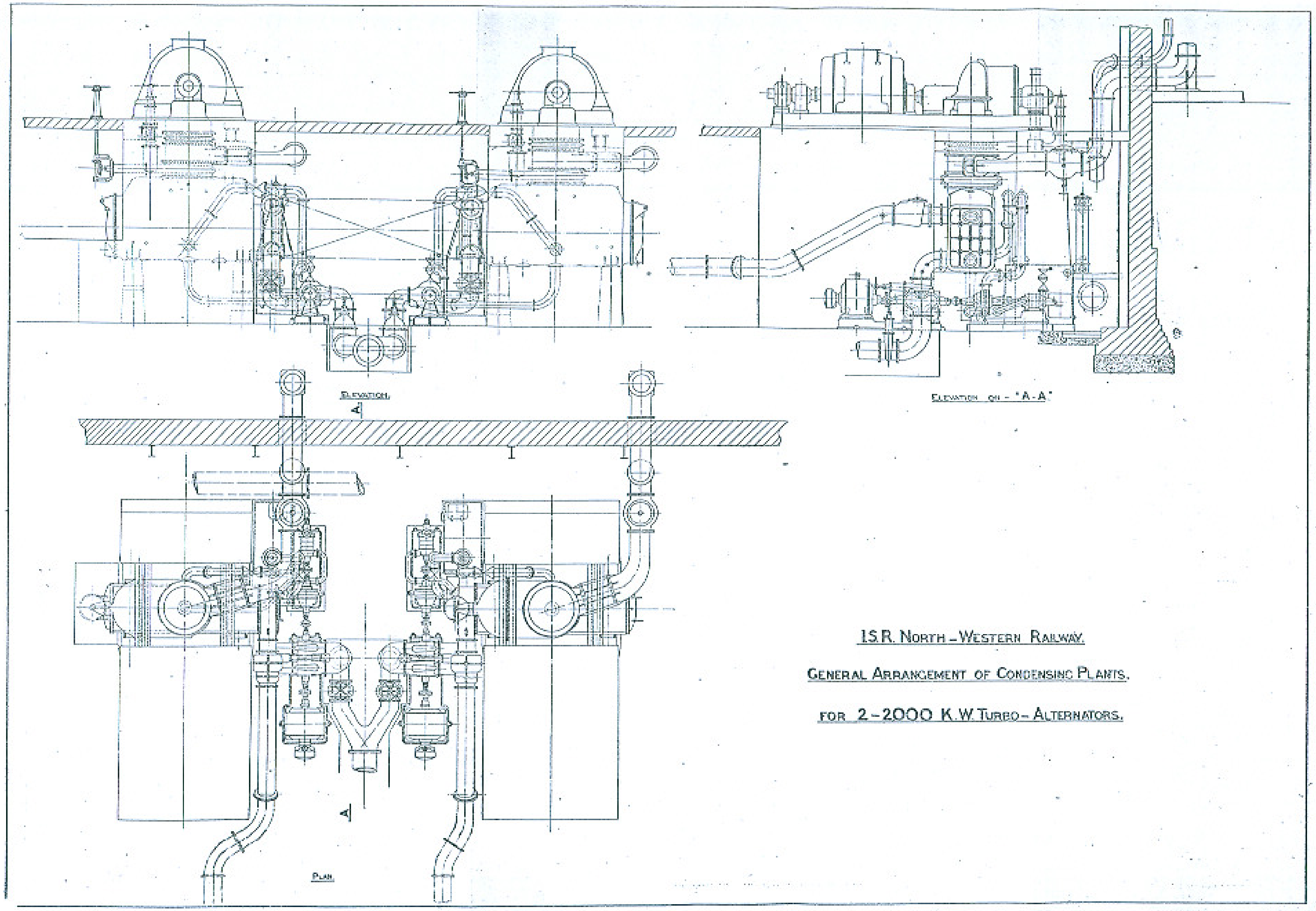


PLATE III.

2,000 K. W. TURBIN WITH ALTERNATOR AND EXCITER.



Elevation.
Elevation on - "A-A"
Plan
I.S.R. North-Western Railway.
General Arrangement of Condensing Plants.
for 2-2000 K.W. Turbo-Alternators.

An overspeed device is fitted to the turbine and automatically shuts down the machine in the event of the speed exceeding the normal speed by more than 10 per cent.

Alternators.

The alternator to which the turbine is coupled through a special type of claw coupling is of the revolving field type, all high tension windings being contained in the stationary part. The rotating field and shaft are forged in one piece from best quality steel and all windings on both the stationary and revolving parts are insulated with moulded mica. The temperature rise on any part of the windings is guaranteed not to exceed 60 degrees Fahr. by thermometer and 75 degrees by resistance. Cooling is obtained by induced draft fans fitted on the shaft which draw air through a wet air filter placed externally to the machine.

Each filter is capable of dealing with 12,000 cubic feet of air per minute and the air which passes through this filter is thoroughly cleansed before it enters the alternator, a very necessary precaution in view of the dusty atmosphere of the Punjab.

Plates II and III illustrate the general appearance of the complete turbine alternator and exciter. The auxiliary oil pump and governor gear are clearly shown at the end of the turbine.

Condensers.

The turbine exhausts into a Worthington surface type condenser designed to maintain a vacuum within three inches of absolute when dealing with 32,500 pounds of steam per hour and when supplied with cooling water at 92 degrees Fahr. The cooling surface is 5,000 square feet and the ratio of cooling water to steam condensed is approximately 80 to 1. The circulating water pump, air pump and condensate extraction pump are of the rotary type driven by one alternating current motor and the power required to drive these auxiliaries is equivalent to five per cent. of the total output of the turbine. Plate 4 shows the complete general arrangement of the turbine, alternator and condenser.

Cooling Tower.

The circulating water for the condenser is cooled by passing it into a Cooling Tower capable of reducing the temperature of 250,000 gallons of water per hour from 110 degrees to 92 degrees Fahr. with a wet bulb temperature of 83 degrees.

Experience with the existing all steel Cooling Tower showed that deterioration due to corrosion of the plates surrounding the galvanised iron fillings in the body of the Tower was a serious factor and to overcome this difficulty it was decided to instal for the turbine plant a forced draft tower constructed of ferro concrete, This tower is 60 feet high by 35 feet diameter and the general construction is shown on plate 5, the specification to which the tower has been built being given in the Appendix I. It will be noted that the tower is of the forced draft type, air being supplied by four ten feet diameter fans each requiring approximately fifteen brake horsepower for driving purposes. It is anticipated that it will be possible to obtain sufficient cooling effect easily to maintain 27 inches of vacuum in the hot weather and 28 inches during winter months. As each inch of vacuum effects a saving of approximataly half a pound of steam per KW hour in the steam consumption it will be obvious how important it is to provide for proper and efficient condenser water cooling arrangements when turbines are used as prime movers.

Switchgear.

The high tension switchgear for control of the alternators and high tension feeders is of a design somewhat different to that usually employed for gear of this type and is a compromise between American and English practice. The general arrangement is illustrated in plate 6 from which it will be noted that it is of the remote control mechanically operated type. All high tension gear is contained in a separate chamber access to which is impossible except by authorised persons and for this reason the usual interlocking and other similar safety devices have been eliminated. The maximum voltage on the operating board shown on the switchboard gallery in plate 6 is 110 volts. Voltage regulators of the Tirril type are fitted on the main operating board to maintain automatically a constant voltage under all load conditions.

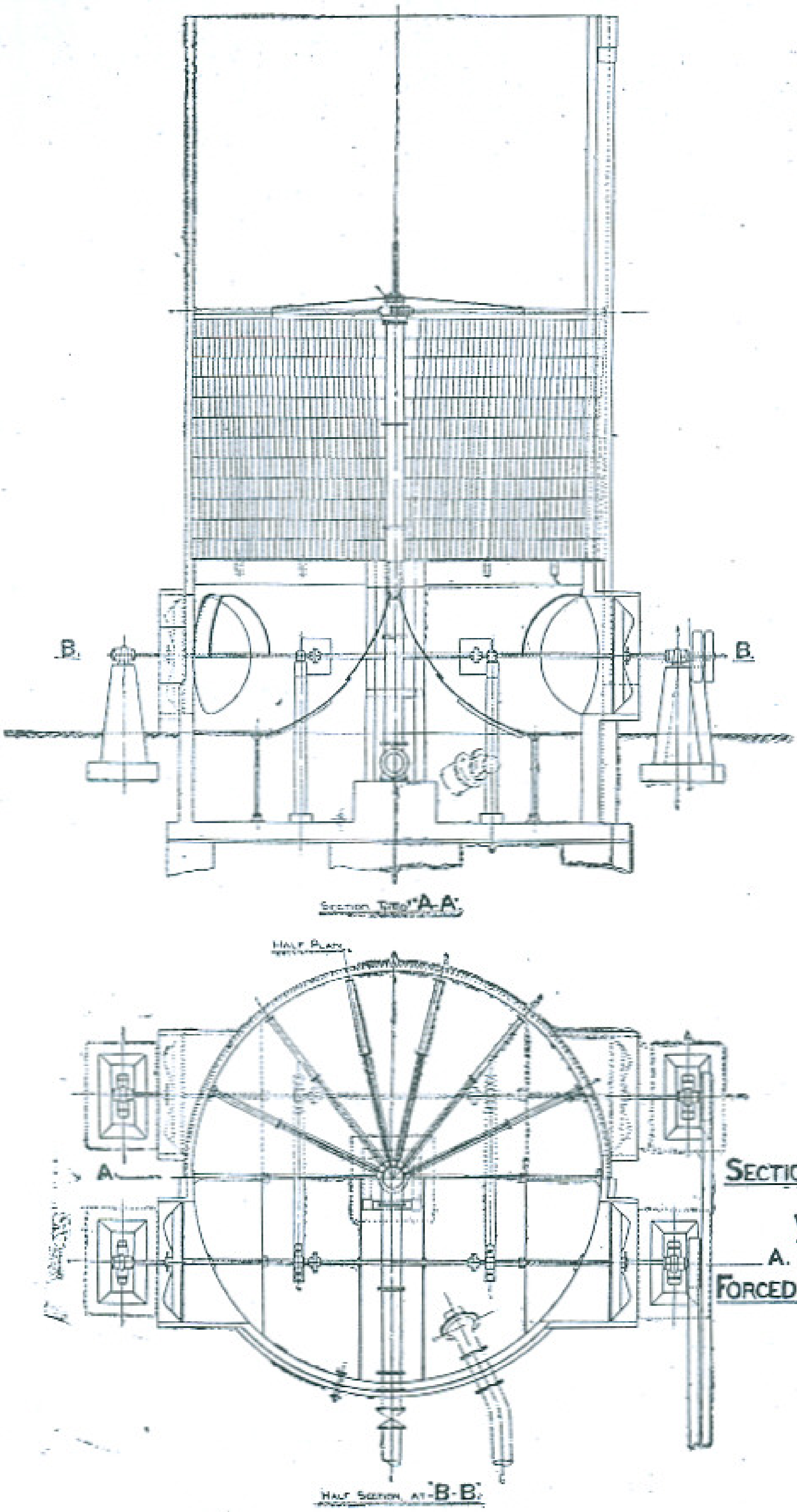
Special devices have been fitted to all switches controlling the generators in the form of balanced protective gear. Briefly described the function of this gear is automatically to disconnect the generators from the bus bars in the event of a fault developing in the windings, the out of balanced current set up thereby causing the trip coils of the oil switches to opearate and trip the switch.

As the turbine continues to rotate for 15/30 minutes after the main steam valve is closed it will be realized that considerable damage can be done to the windings of the alternator in the event of a fault unless means are provided to suppress all excitation. To ensure this being done a field suppression switch is provided on each alternator, the function of this switch being to automatically and instantaneously to cut off the current from the alternator field in the event of an internal defect in the high tension windings of the machine.

Distribution.

Continuous current at 450 volts is distributed by overhead mains from the main switch board in the Power House to sub-

PLATE 5.



SECTIONAL ARRANGEMENT OF WORTHINGTON FORCED DRAUGHT COOLING TOWER

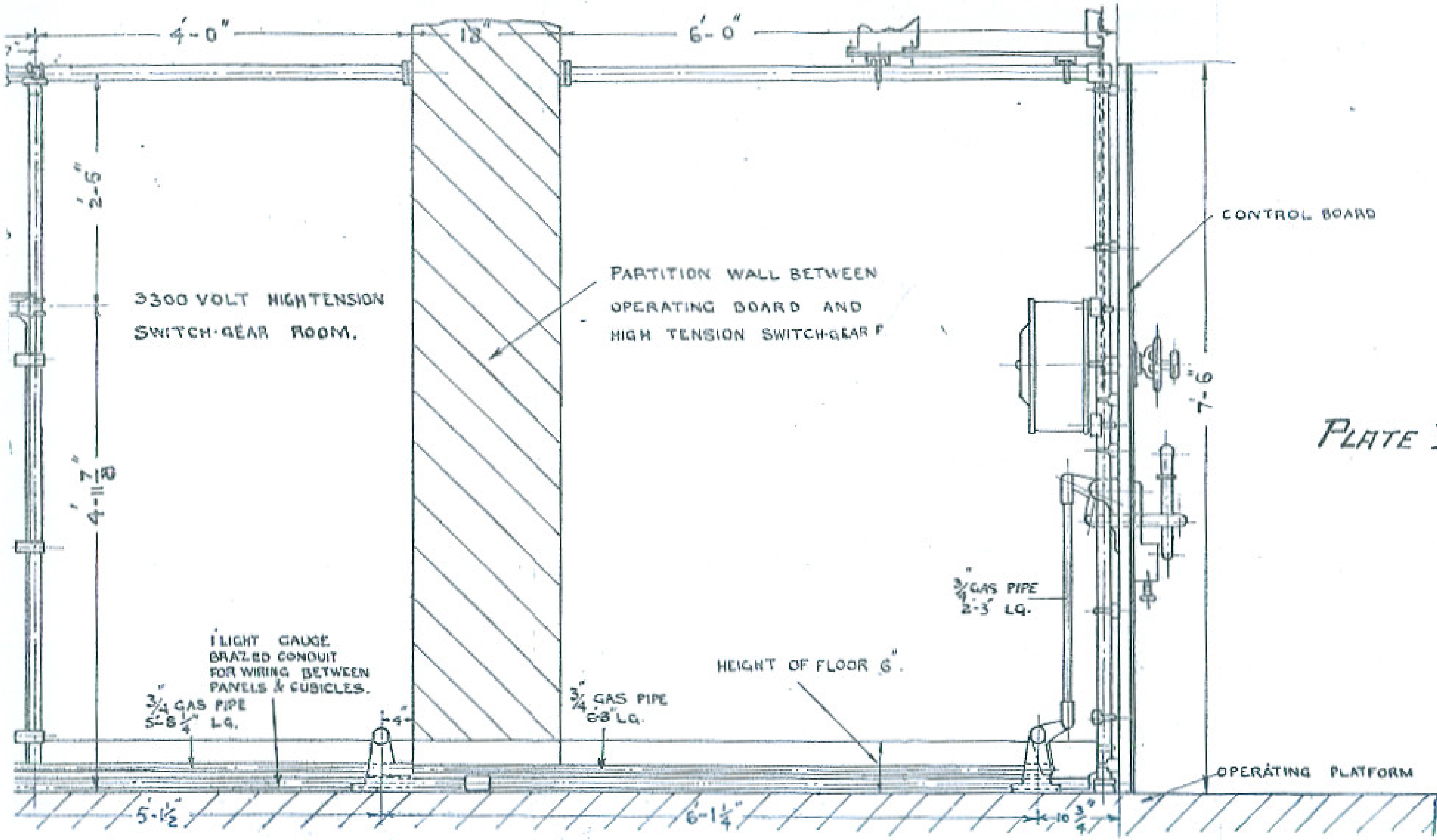

4'-0"
13"
6'-0"
2'-5"
4'-11 7/8"
3300 VOLT HIGHTENSION
SWITCH-GEAR ROOM.
PARTITION WALL BETWEEN
OPERATING BOARD AND
HIGH TENSION SWITCH-GEAR
CONTROL BOARD
7'-6"
3/4" GAS PIPE
2'-3" LG.
1" LIGHT GAUGE
BRAZED CONDUIT
FOR WIRING BETWEEN
PANELS & CUBICLES.
3/4" GAS PIPE
5'-8 1/4" LG.
4"
3/4" GAS PIPE
6'-8" LG.
HEIGHT OF FLOOR 6".
OPERATING PLATFORM
5'-1 1/2"
6'-1 1/4"
10 3/4"

PLATE VI

listribution boards in the various shops and thence direct to the motors. Alternating current at 3,300 volts is distributed by overhead mains to substations in the various shops where it is transformed down to 400 volts and distributed direct to the alternating current motors. The equipment of each substation consists of 2 oil-cooled transformers each of 300 KW capacity at 80 per cent. power factor together with the necessary high and low tension switch gear. Additional transformers or substations will be installed as and when the load demands them and the whole scheme has been laid out with a view to facilitating extensions when required.

Motors.

Although the alternating current motor is more simple in design and easier to maintain than the continuous motor one of the essential conditions of its successful and efficient use is that it should operate on its rated full load as nearly as possible otherwise the power factor of the entire system is adversely affected. This means increased copper losses, and overheating in the generators, bad voltage regulation and introduces other factors which are very undesirable in a power scheme.

Further the speed variation of an alternating current motor is not so easy to obtain as with the continuous current motor and it is not therefore altogether desirable for the individual driving of machine tools such as lathes, drills, shearing machines, circular saw benches, etc., which give a comparatively poor load factor.

The general principle adopted at the Moghalpura Workshops is to use alternating current motors for all line shaft drives, pumps, blowers, compressors, etc., which give a steady load and continuous current motors for large wheel lathes, saws, wood working machinery, etc., which require to be run at varying speeds or which do not give a steady load. This question of load factor is most important particularly in this country where the workman is inclined to take things easier than his brother working in a more temperate climate and where efficient supervision is not always easy to obtain. To illustrate this it may be mentioned that during some recent tests it was found that the energy meter charts clearly indicated when the Works Manager or Foreman were walking through the Shops under test.

Method of drive,

When commencing the electrification of the Shops at Moghalpura it was the policy to reduce group driving of machines to a minimum and to install individually driven machine tools wherever possible.

Experience has shown that this policy is an excellent one for the motor manufacturer who sells a large number of small motors, but that it is not always the most desirable one for the consumer partly on account of the difficulty in getting suitable supervision and skilled labour to maintain the motors, and partly on account of the capital cost of the machines. For these reasons group driving is now being extended in the Moghalpura Shops and steps are being taken to reduce the number of motors in operation by standardizing on 30 H. P. and 50 H. P. machines for all line shaft drives. Both these sizes are of the wound rotor slip ring type fitted with brush lifting and short circuiting devices and three bearings. The third bearing adds considerably to the cost of the machine but it is a refinement that is likely quickly to pay for itself in the case of alternating current motors in which the clearance between the stationary and rotating parts is generally in the neighbourhood of 0·06 inches and in which any undue wear on the bearings, unless stopped in time, invariably means extensive damage and rewinding of the machines.

In addition to the driving of the usual kind of machine tools and line shafts, electric power is used throughout for driving air compressors for the supply of power to pneumatic drills, chisels, etc., and also for hydraulic flanging presses.

In addition an electric welding plant has been introduced recently and has already effected considerable saving by enabling worn and damaged parts of locomotives to be renovated and put into service again.

Proposals are now under consideration for the installation of a small electric furnace and also for the electric heating of rivets.

Conclusion.

Although a cheap and reliable supply of power is essential for the development and carrying on of any industry using machinery, some of the statements that have been made in the non-technical press and elsewhere regarding the industrial prospects of this Province, when all the various hydro-electric schemes are in operation, seem to savour of undue optimism and in the writer's opinion might not bear close investigation. In this connection it may be mentioned that the monetary value of power per annum supplied to the Railway Workshops, Moghalpura, is approximately two per cent. of the sums paid in wages and for materials in these shops.

This ratio would probably be increased in the case of such industries as flour milling, spinning and weaving where the whole of the operations are done by machinery but it can be accepted as correct for general Engineering Workshops and might be used as a guide to calculate approximately the amount of industrial development necessary fully to utilize the power available from the various hydro-electric projects now under consideration in the Punjab.

APPENDIX I.

Specification of Reinforced Concrete Work for Forced Draught Cooling Tower, Size 35′ Diameter by 60′ High, Having four 10′ Diameter Fans. Duty.—250,000 Gallons per hour. For Indian State Railways, Moghalpura Power Station, Lahore.

Loads and stresses.

The tower has been designed for a wind pressure of 50 lbs. per square foot acting on the whole diameter of the shell, and the working stresses have been taken as 600 lbs. per square inch for concrete in compression, and 16,000 lbs. per square inch for steel in tension.

The pressure on the ground will under ordinary circumstances be less than one ton per square foot and if a wind pressure of 50 lbs. per square foot be acting on the whole surface of the tower the pressure will not exceed $1\frac{1}{2}$ ton per square foot. The grid supporting the patent filling has been designed to carry safely 100 tons.

Foundations.

If the ground is capable of carrying the $1\frac{1}{2}$ ton per square foot, it will not be necessary to provide any special foundation except the 3″ thick layer of mass concrete indicated on the drawings. This will be required in any case in order to provide a clean and level base on which to lay out the reinforcements for the 9″ bottom slab. Should it, however, be deemed necessary to take the foundation further down, it should be done in mass concrete as shown on the drawings, *viz.*, a 4 feet wide ring under the shell and 11 feet diameter cylinder block under the centre of the tank. For this purpose the bottom of the tank has been designed to carry the weight of the water over the 10 feet span and on to the mass concrete foundations, allowing a stress of 22,000 lbs. per square inch for steel in tension.

Mixture of mass concrete.

The mass concrete in the foundations to be composed of stone or gravel, sand and cement, all as described in the specification in the following proportions :—

Stone or gravel	27	cubic feet.
Sand	$13\frac{1}{2}$	,, ,,
Cement	$4\frac{1}{3}$	cwts.

Larger sizes (up to $1\frac{1}{2}''$ gauge) of stone or gravel may be used as aggregate for the mass concrete.

Quantities.

The total quantity of concrete in the Reinforced Concrete Work is 245 cubic yards. Allowing 5% for waste, this means approximately :—

72 tons of cement.
130 tons of sand.
250 tons of stone or gravel.

Add cement for cement washing, and cement, sand and gravel for Mass Concrete Work.

Total quantity of steel reinforcements :—

0 tons	$\frac{1}{2}$ cwt.	$1\frac{1}{4}''$	diameter mild steel rounds.
1 ,,	$13\frac{1}{2}$,,	$1''$	ditto.
0 ,,	$7\frac{1}{4}$,,	$\frac{7}{8}''$	ditto.
0 ,,	$7\frac{1}{2}$,,	$\frac{3}{4}''$	ditto.
1 ,,	$10\frac{1}{4}$,,	$\frac{5}{8}''$	ditto.
0 ,,	$1\frac{3}{4}$,,	$\frac{1}{2}''$	ditto.
6 ,,	11 ,,	$\frac{3}{8}''$	ditto.
0 ,,	$5\frac{1}{4}$,,	$\frac{1}{4}''$	ditto.

Total ..10 tons $17\frac{1}{2}$ cwts.

About 4 cwts. of Binding Wire will be required.

Cement.

Cement to be slow-setting Portland Cement complying with the latest Specification of the British Engineering Standards Committee to be thoroughly aerated before leaving the Manufacturers' Works and to be stored in a proper damp-proof shed immediately on arrival at the site.

Sand.

Sand to be clean and gritty, and free from clay, vegetable or bituminous matter, to pass through a mesh $\frac{3''}{16}$ square measured in the clear, and to obtain as far as possible no particles that will pass through a mesh $\frac{1''}{24}$ square measured in the clear. It should preferably contain all sizes within these limits and of different samples the one with the least proportion of voids should be used (voids not to exceed 33 %).

Aggregate.

The aggregate to be clean and hard gravel or broken stone, such as granite, basalt or flint, to be in pieces in the nature of cubes and not flakes. All aggregate should be of mixed sizes from $\frac{1}{4}''$ to $\frac{3}{4}''$ gauge. All stones under $\frac{1}{4}''$ and over $\frac{3}{4}''$ gauge shall be rejected and no clay, vegetable or bituminous matter or other impurity to be contained in the aggregate. Voids in the aggregate not to exceed 50 %.

Water.

Water to be fresh and clean, free from earthy, vegetable or organic matter, acids or alkaline substance in solution or suspension.

Proportions.

Concrete to be composed of stone or gravel, sand and cement all as before described in the following proportions :—

Stone or gravel ..	.. 27 cubic feet.
Sand ..	.. 13½ ,, ,,
Cement ..	.. 6½ cwts.

Gauge boxes of proper construction to be provided by the Contractor for accurately measuring and mixing the materials and no concrete to be mixed except by accurate and perfect measurement of the aggregate, sand and cement. The boxes for the sand and aggregate shall be of such sizes as to allow for the use of one complete bag of cement of known weight.

Concrete Test Cubes.

A few 6″ Concrete Cubes to be made of the materials proposed for the work before this is put in hand. Such cubes to be tested for ultimate crushing strength which should not prove less than 2,000 lbs. per square inch at 28 days after mixing.

Reinforcements.

The reinforcing steel to be mild steel rounds having an ultimate tensile strength of not less than 28 to 32 tons per square inch, with an elongation at point of fracture of not less than 20% in eight inches. No welds must be made in any bars except when specified, every bar must be in one length without joint. All steel must be clean and free from oil or dirt, all loose scale or rust to be brushed off the bars. Cold test bars are to bend through an angle of 180 degrees around a diameter equal to $1\frac{1}{2}$ times the diameter of the test bar, and close down upon itself without cracking.

Certificates.

A factor's certificate and guarantee should as far as possible accompany every consignment of steel and cement delivered on the works.

Centering.

The centering and moulds necessary for the formation of the concrete shell, grid and piers to be very carefully constructed and erected true and rigid, it must be properly braced and of sufficient strength to easily carry the dead weight of the liquid concrete without deflection, particular care to be taken that all joints be tight enough to prevent leakage of the cement. The centering to be so designed that concreting of the shell can be carried out in lifts of not over 4 feet for the lower 14″ thick part, not over 3′ 6″ for the 10″ thick part, and not over 2′ 6″ for the upper 6″ thick part and for the 10″ square columns supporting the grid and the fan shafts. All boards for the centering to be dressed on the face and both edges so as to make the joints as tight as possible. The face of all moulds to be given a coat of lime wash or soft soap to prevent the adhesion of the concrete to same.

Placing reinforcement.

All reinforcing steel is to be bent to shape as per detailed drawings and is to be accurately placed in the concrete in the positions shown on the drawings. Great care should be taken to see that all reinforcing bars are laid out correctly in every respect and are temporarily supported off the centering by small wooden or concrete blocks in order to prevent displacement before and during the process of concreting and the bars should be wired together in sufficiently many places with stout binding wire, say black annealed wire, No. 15 gauge. All longitudinal bars must be straight and fixed parallel to each other and the sides of the moulds. The bending of the bars is to be done cold. Unless otherwise shown on the drawing all reinforcing bars shall be protected by a covering of concrete equal in thickness to the diameter of the bars but not less than ½″.

Mixing concrete.

The concrete if mixed by hand shall be thoroughly mixed both dry and while the water is being added. The cement and sand shall be spread in thin layers and mixed dry until a uniform colour is attained. The aggregate shall then be added and turned over in a dry state until the three materials are thoroughly mixed. Water shall then be added with a rose, and the mixture turned over at least three times or until the concrete is of uniform colour and consistency throughout. The mixing shall be done on a suitable close jointed platform, otherwise a batch mixer of approved design shall be used. A competent man is to be in attendance to the mixing to approve each and every batch. Clean water shall be used in such a quantity that the resultant shall be what is known as a wet mixture.

Placing concrete.

Before placing any concrete the shuttering must be carefully cleaned of all sawdust, wood, dirt or other foreign matter, especially with regard to the bottom of the column boxes. All concrete must be conveyed to those parts of the work where it is to be used in such a manner that no perceptible segregation of the ingredients shall occur and the greatest care shall be taken during ramming to prevent any displacement of the bars, ties, links or stirrups and the other members of the reinforcement fixed in position before the commencement of concreting. All concrete which has commenced to set shall be protected from shock or vibration. The concrete shall be placed immediately after mixing and on no account to be incorporated in the work after it has begun to set. The initial set may in hot weather take place 15 to 30 minutes after the water is added. The concrete is to be thoroughly puddled into the forms and round the reinforcement as soon as it is placed so as to leave no voids in the work. It shall be well spaded back from the face of the shuttering to ensure a good surface. When concreting is once commenced it must be carried on rigorously to completion with as short periods of break as possible. The planes of the stoppage shall be thoroughly cleaned off and covered with about $\frac{1}{2}''$ thickness of liquid cement and sand mixture in the proportion of 1 to 1 before concreting is resumed. The plane of the stoppage must be at right angles to the direction of the reinforcing steel. After placing concrete in the forms, great care must be taken that it is not disturbed by walking or wheeling over, or by vibration of the forms in any way, until the concrete has thoroughly set. The top surface of all flat work shall be levelled off with a wood screed in conjunction with gauge blocks.

Freezing water.

No concreting shall be done when the temperature is below 34 degrees Fahr. on the falling thermometer or below 32 degrees Fahr. on a rising thermometer, and during cold weather a thermometer shall be kept on the Works. During frosty weather the exposed surface of green concrete must be properly protected uutil the concrete has thoroughly set.

Hot weather.

Exposed surface must be kept damp by frequent sprinklings with water, and be suitably protected from the sun during hot weather to avoid premature drying of the concrete, and subsequent cracking.

Striking Concreting.

Before any concreting is removed, it must be carefully ascertained that the concrete has set sufficiently hard to carry the loads on same. Under no circumstances may the centering supporting the concrete grid be struck before four weeks after it was concreted. The centering for the shell may be removed a few days after completion of the concreting, but the forms for the fan casings should not be removed until at least three weeks after the concreting of those is completed.

Finishes.

On the removal of the centering any small holes or cavities in the exposed surfaces are to be neatly filled by rubbing cement mortar into them, and afterwards all surfaces should be given two coats of cement washing and be rubbed down with carborundum stones in order to remove marks of the moulds as far as possible. When cement washing the inside of the shell and tank the cement should be mixed with some waterproofing compund, such as "Pudlo", or "Metalo", or "Ironite".

DISCUSSION.

Lieutenant-Colonel B. C. Battye said that his own opinion regarding the inherent advantages of alternating current motors for general factory purposes was confirmed by Mr. Preston. He asked if Mr. Preston could say definitely whether there were any particular processes in railway workshops which could not be carried out by A. C. motors and which *necessitated* the use of D. C.

He also noticed that they had adopted the La Cour convertor and asked if it had been installed with the intention of being able to run inverted so as to supply A. C. from the existing D. C. plant and if so whether any trouble had been anticipated with regard to the control of the frequency. A similar type of convertor at Viceregal Lodge, Simla, had been occasionally running inverted, but he was unable to say whether any difficulty had been experienced and would be glad if Mr. Milne would enlighten the meeting on this point.

He noticed there was apparently no separate oil supply for the governor and that contrary to the usual practice in hydro-electric stations, a common source of oil supply was used for both the bearings and the governor and he would be glad to know if any steps were taken to prevent grit from bearings getting into the governor oil and interfering with its operation. He noticed that there was no air vessel employed in conjunction with the governor oil supply so as to maintain its pressure in case of a failure of the oil pump: presumably this was taken care of by the reserve steam driven oil pump.

On page 86 it was stated that the permanent speed variation with load thrown off was 4% ; he would be glad to know what the temporary speed variation was, under both on and off conditions, in order to compare it with recent hydro practice, in which the tendency was to allow a very large speed rise, amounting to 16 or 20% when loads were thrown off, since under such conditions the frequency of the system was not likely to be affected, as the very fact of throwing off the load implied a disconnection of the machine from the main system.

He would also be glad to know if the special type of claw-coupling referred to on page 87 had been provided to enable the generator to be disconnected from the turbine at short notice, so that at some future date, the former might be used as a synchronous condenser in connection with the main Sutlej River Hydro-electric Project as advocated by him to Mr. Preston two years back.

He noticed that the temperature rise of 60° to 75° Fahr. specified was generally in accordance with standard practice in this country, in which a low temperature rise had always been specified on account of the supposed high engine-room temperatures likely to be met with. He was of opinion that a better method of specifying was to fix the maximun operating temperature under which the machine should be allowed to work together with a statement of the maximum ambient temperature of the engine-room. This was the method advocated by the British Engineering Standards Committee and was now general practice in connection with large machines, in both Great Britain and America. He had recently discussed this matter with the chief designer of the English Electric Company, who told him that he thought that it was quite possible that a large number of the early cases of breakdown of electric machinery in Calcutta, which had given rise to the local custom of specifying low temperature rises (*e. g.*, 35° and 40° Cent.) were due, not so much to overheating as possibly to a peculiar fungoid growth which was not possible in drier climates or at higher temperatures and that, therefore, distinct advantage might be gained by operating at higher temperatures. The latest standard practice of the Metropolitan Vickers Company was entirely based upon the use of high operating temperatures in combination with special insulating materials, like mica, capable of resisting these temperatures.

He would be glad to know if the wet-bulb temperature of 83° Fahr. quoted on page 87, had been arrived at as representing the worst possible conditions for water-cooling and if so whether this represented the conditions during the hot dry months of May and June, or during the rains. This was a question of importance in connection with the adoption of water-cooled transformers for all the sub-stations throughout the Punjab.

There were a few points in connection with the specification for reinforced concrete to which he would like to draw attention.

He would be glad to know how the placing time of 15 to 35 minutes quoted on page 95 had been arrived at ; he had examined the new power canal of the Queenston, of the Ontario Hydro-electric Commission, Chippawa, Ontario, during his recent visit to Canada and was surprised at the length of time allowed to elapse between the mixing of concrete and its "placing" at a point about 2 miles distant. The time could never have been less than 30 minutes which was probably only found possible owing to the low temperature at which the work was being carried out, usually below freezing point. He would be glad to know whether it had been found in practice that the mixture of 1 to 1 cement and sand for grouting "stoppage planes" had been found preferable to pure cement grouting.

With regard to the paragraph specifying that no work should be carried out below freezing point, it might interest the meeting to know that on the above-mentioned works in Ontario, concreting was regularly carried on with the thermometer well below freezing point. Special precautions were taken for heating the aggregate and sand with steam pipes before being placed in the mixer and for using warm water; but apparently no attempt was made to protect the concrete from the frost after it had been laid.

With regard to use of waterproofing compounds the recent progress report of the American Society of Civil Engineers' Joint Committee, on standard specifications for reinforced concrete had decided *against* the use of any waterproofing materials and advocated on the contrary the employment merely of a rich mixture: this, he believed, was more or less in conclusion with the general opinion of concrete engineers now-a-days, although he had himself made use of a mixture known as "Medusa" which consisted of a stearate of calcium, for the reinforced concrete tank and pressure duct in the Simla project, 10 years before.

With regard to the mixture specified on page 93, he would like to take the opportunity of drawing the attention of the conference to the latest method of proportioning concrete, by the "surface area of aggregates", a method which was, he believed, originally investigated by Abrams and Edwards in America and had recently been adopted as their standard method by the engineers of the Ontario Hydro-electric Commission and used by them on a very large scale for all the concrete work on the recent Queenston Power project, involving immense quantities of concrete. Some interesting pamphlets by Mr. R. B. Young of the Commission were available in his office and could be obtained from the Commission's Office in Toronto on application by anyone interested.

He could not close the discussion without reference to Mr. Preston's concluding remarks with regard to Hydro-electric power on page 90. He was in entire agreement with Mr. Preston in warning the public against undue optimism with regard to Hydro-electric developments and considered that very much of the newspaper publicity recently given to this subject might prove more harmful than otherwise. At the same time he wished to point out that although private syndicates might in some cases be charged with over optimism, the same could not be said of Government. In this recent report on the Sutlej River Project he had taken special precautions to avoid anything in the nature of speculative or optimistic estimates of revenue and had actually been twitted by some of his electrical friends with being over-cautious. He produced for the benefit of the meeting a chart showing the rate of growth of industrial power in mills in the

Eastern half of the Province covered by the Project from 1900 to the year 1920, and pointed out that the revenue estimates in his report were based entirely upon the exterpolation of these rates of growth at a rate equal to the average of the four years immediately preceding the war, with a reasonable percentage increase in this rate of growth, two years after the completion of the Project, but not before. The revenue estimates for this Project were, therefore, based entirely upon normal natural growth of industry in the province and took no cognizance whatever of any hypothetical demands such as railway electrification, irrigation, tube-well pumping, electric-chemical industries and such like, which usually formed a happy hunting ground for company promotors.

Finally on the other hand he wished to draw the attention of the conference to the enormous difference in the economic value of water power derived from storage schemes, such as those on the Ghats supplying Bombay, and those depending upon the normal flow of snow-fed streams, such as those in the Punjab.

The fundamental differences between these two types of hydro-electric supply were not fully appreciated. In the first type every single gallon of water stored and consequently every kilowatt hour sold was of value and power could not be economically sold except by the kilowatt hour; in fact the basis of economic production was in every way similar to that of a fuel driven plant. The second case, which applied generally throughout the Punjab, was entirely different: under these conditions water if not used went to waste and consequently power could be sold by kilowatt year; thereby resulting in a very much cheaper form of power for industries of high load factor. An excellent illustration of this was the use of the small electric furnaces referred to on page 90. When stream flow power was available (as in the Punjab) these furnaces could be operated during off peak-loads without any extra charge for power, *i.e.*, practically "*free*" power. With stored water this would be impossible and every kilowatt hour used by the furnace would have to be charged for, just as much as if supplied from a steam plant. It was for this reason that he thought that the Punjab had a greater future, as a user of water power than Bombay.

Rai Bahadur Makhan Lal said that Lieut.-Colonel Battye had just stated that the question of temperature in the designing of electric machinery was of no consequence, but from experience it was found that it was of considerable importance. At Jammu pumping station when the temperature of the motor rose above 65° C. it had to be shut down for fear of the insulation being burnt, which had actually happened several times.

Mr. Livingstone-Learmonth remarked that the question as to when alternating and when direct current should be used appeared to be uncertain. Perhaps the author could give some information as to the limit of lead up to which it paid to use direct current on the construction of large river works, taking into account the advantages of D. C. system with a highly variable load factor.

He also enquired if, when the Mogalpura electrification was introduced, there had been an available oil supply at Attock, Diesel or semi-Diesel oil engines would have been installed instead of steam plant.

Mr. Preston replying to the discussion said that with regard to the points raised by Colonel Battye continuous current motors could be eliminated entirely but as stated in the paper they were preferable for certain classes of machine tools and if continuous current was available he would certainly recommend its use for these kinds of machine tools.

The motor convertors were intended to transform from A. C. to C. C. and would not be required to convert from C. C. to A. C.

A boiler pressure of 160 lbs. was decided upon because this was the working pressure of the existing boilers and it was thought desirable to standardize. He was not certain that pressures above 200 lbs. per square inch were suitable for Indian conditions on account of the class of labour available for operating purposes.

One oil pump supplied the oil for both the governor operating gear and for bearing lubrication. The pressure at which the oil left the pump was between 40 and 60 lbs and this was reduced to about 15 lbs. by a reducing valve before entering the oil coolers and lubrication system.

The 4% speed variation was the figure guaranteed by the manufacturers and compared favourably with the guarantees offered by other firms who tendered for the contract. No trouble was anticipated in this respect.

The special claw coupling was not suitable for the purpose suggested by Colonel Battye.

With regard to the temperature rise on the alternator he was aware that higher temperatures were advocated by manufacturers in Europe and America but it had yet to be proved that these higher figures were suitable for Indian conditions and he would prefer some one else to do the experimenting. Undoubtedly the ultimate temperature was the one that mattered and as the atmospheric temperature in the Power House sometimes reached 125° Fahr. in the hot weather it was possible that the ultimate temperature of the windings would touch 125° plus 60° which was exceedingly close to the figures advocated by Colonel Battye.

The cooling tower was built to specification by the Civil Engineering Department of the Railway and during the visit to the Power House the Executive Engineer, Captain Carson, would be able to answer the points raised. A mixture of 1 to 1 was quite satisfactory for grouting purposes. The wet bulb temperature of 83° was the highest average wet bulb temperature recorded in the Punjab for a period over 30 years and the figure was obtained from records available in the India Office.

With regard to Colonel Battye's remarks in connection with the concluding paragraph of the paper, the criticism was not directed against the Rupar Hydro-electric Scheme but was intended as a mild protest against the articles that have appeared in the press and speeches made by prominent men in this Province who ought to know better. He would repeat that he did not think the advent of the various Hydro-electric Schemes now under discussion was going to convert this Province from an agricultural into an industrial one. There were so many other factors to be considered and whilst cheap power was decidedly an aid to the establishment of industries it alone could not create them. Statements such as had been made were likely to do more harm than good and he ventured to think that they should be discouraged. Personally he believed that the Rupar Scheme would have to be developed apart from the question of power supply for industries and that in time the Government of India would be compelled to look to it for the supply of energy required for the electrification of the North-Western Railway between Lahore and Delhi.

CORRESPONDENCE.

LIEUTENANT-COLONEL B. C. BATTYE wrote, in continuation of his remarks, that he had noticed that the author had adopted wet air filters for his generators. It was now becoming more general practice in the larger steam stations in England (and the Americans were just beginning to adopt the same practice), to "*circulate*" the cooling air through a special air-cooler instead of filtering fresh quantities of air from outside. It was claimed that this avoided the danger of condensation during sudden changes in climate at times of light load or when starting up before the machine had time to warm up. In the Sutlej River Project they had provided for large air filters for filtering the cooling air during dust storms, but were considering whether they would be justified in adopting a circulatory system instead. Where dust storms were infrequent and filtration could be put out of operation for weeks at a time, the filtration method would appear to have advantages. He would like to know Mr. Preston's opinion on this method with regard to the conditions pertaining in Lahore.

Rai Bahadur Makhan Lal had not quite appreciated the purport of the writer's remarks with regard to temperature rise. He did not necessarily advocate an increase in the actual operating temperature of the machine but a more scientific method of specifying the actual temperature conditions under which the machine should operate. It was quite possible under certain conditions this might result in a lower temperature than the old method of specifying.

Mr. Preston wrote that with regard to the use of a closed circuit system of air cooling for the alternator it might be possible to adopt this type in Hydro-electric or Steam Stations where an unlimited supply of cool water was available for passing through the air cooler but it would not be possible to utilize the closed circuit system at the Moghalpura Power House as sufficient water was not available for cooling purposes. It seemed to possess certain advantages over the ordinary wet or dry air filter and the results of the experiments now being made in England and elsewhere would be of great interest.