The Cassilis Hydro-Electric Plant

Description of the Installation, Together with Some Tests Recently Carried Out.

By A. Allison, A.M. Am. I.E.E.

The hydro-electric plant of the Cassilis Gold Mining Company, Gippsland, Victoria, is one of the few installations of any magnitude in Australia. The plant was installed for the purpose of giving cheaper power to operate the company's mines and works, replacing, as it did, a steam plant previously in use. This latter had entailed a heavy expenditure, and was responsible for a fuel bill of £500 per month. The ores being of a refractory nature, the profits of the company were seriously affected by the power question alone. The power station is situated in a remote and inaccessible part of Gippsland, some nine miles from Omeo, on the Cobungra River, about a quarter of a mile above its junction with the Victoria River. The water for the plant is obtained from the Victoria, about four miles above the junction, full advantage being taken of the Victoria Falls, which enable a working head of 410 feet to be obtained, with a race 3½ miles long. This race has a cross section of 15½ square feet, and a grade of 10 feet to the mile, and is capable of delivering 40 cubic feet per second. It terminates in a pressure dam, 1 chain by 1½ chains by 9 feet deep, which allows the sand in suspension in the water to settle before the water enters the pipe column. The latter is 1650 feet long, and has an average diameter of 31 inches. It is made up of malleable steel piping, and reduces in three steps of equal length from 34 inches to 31 inches to 28 inches diameter. It has a factor of safety of 4.

The power station plant, which is designed for double its present capacity, consists of a Voith's pelton wheel, having a capacity of 670 b.h.p., running at 500 revolutions per minute, coupled through a flexible coupling to an A.E.G. 3-phase generator of 500 k.v.a. normal capacity, and is capable of maintaining an overload of 25 per cent. for a short time. The exciter is mounted on the main shaft. There is also a separate exciter set, with turbine and governors complete, of 10 kw. capacity, to act as a spare exciter, and supply the station and local lighting. The main turbine has two nozzles playing the water tangentially on to the pelton wheel, these being opened or closed by the

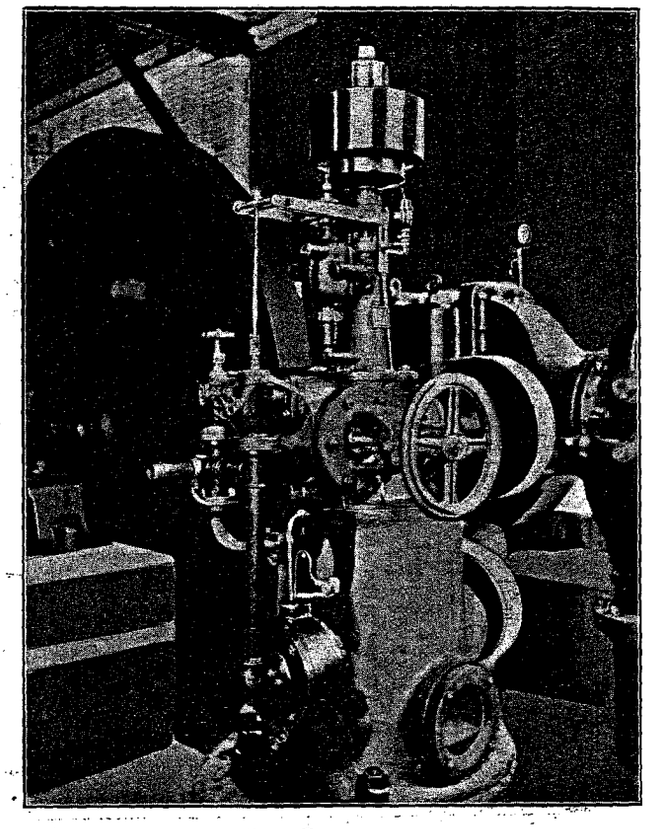
General View Cassilis Mine Plant.

governors, according to the load. Thus, for all loads, a maximum saving of water is effected. The governing is carried out hydraulically, or, rather, by oil, since the movement of the piston operating the gates of the nozzles is produced by oil under a pressure of 10 atmospheres. The system of governing by oil pressure is a decided improvement on that done by water, as, even when the water is filtered, it is not an uncommon thing for grit to get into the valves, and so upset the working of the governors. Their action may be seen from the following sketches:—

Referring to Fig. 1, 10 is a rotary pump pumping the oil into the pressure chamber 8, which is kept about half full, so that the resilience of the air confined in the chamber will be sufficient to keep the working pressure constant under working conditions. A spring relief, or safety valve (15) keeps the pressure at 10 atmospheres, and allows the oil in excess of that used by the governor to leak back into the oil tank (9). The centrifugal force of the weights (18) of the governor is counterbalanced by the spring (27) which controls, by its setting, the degree of stability or sensitiveness of the governor. In Fig. 3 is shown in detail the relay piston valve controlling the ports of the main cylinder (5, Fig. 1). The oil under pressure leaks through the central portion of the spindle valve to the top and bottom of the piston valve (55), the pressure being constant on either side as long as the spindle valve remains in a definite position. A movement of 1-32 inch up or down is sufficient to close or open the exhaust on the bottom side of the piston valve, so that the piston valve moves accordingly up or down, as the equilibrium of the pressures are upset. This, in turn, opens or closes the main ports. The central fulcrum (38) is capable of being screwed up or down by hand, and consequently decides the speed at which the machine will run. To prevent racing or hunting of the machine, the central fulcrum moves with the rise or fall of the sliding sleeve (51) of the governor, so that the action of the governor is always being neutralised thereby. The movement of this fulcrum is effected through the arm (6), by which it is attached to the main piston. With this arrangement, the machine would govern sluggishly, were it not that the relative movement of the fulcrum (38) is allowed to slip behind that of the arm (6), the connection between the two being through the spring (44) and the amount of slip being controlled by means of the oil dash pot (29). The governor then responds quickly, and is very sensitive to any sudden or great change in speed. The valve (31) allows the oil to escape, and in turn is controlled at the top by the weight (39). With the present setting there is no tendency to hunt; the maximum variation above and below the normal speed is not more than 1½ per cent.

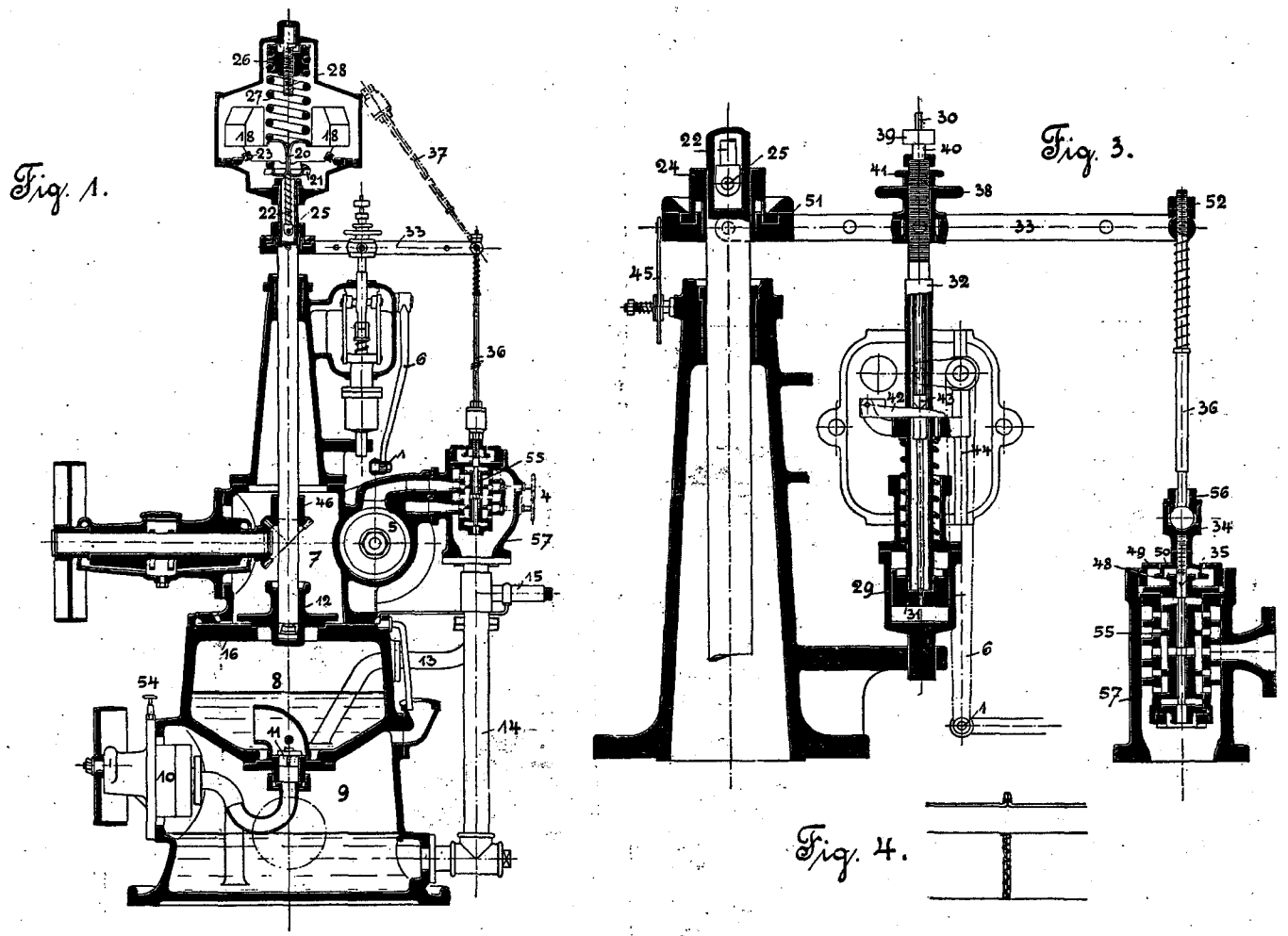
The governor is both sensitive and powerful. The time intervening between a change of the load and when the gates of the turbine starts to open or close to suit that load is three seconds. Should the water be shut off suddenly, due to the load going off rapidly, a bye-pass valve opens and allows the water to escape, thus relieving the column of excessive pressure due to water hammer. The amount of opening of the bye-pass valve corresponding to any particular pressure is capable of adjustment, no pressure not greater than the normal having any effect.

A bank of three single-phase transformers, of 150 kw. each, connected up on "star" on the low pressure side and "delta" on the high-pressure side, raises the alternator voltage of 500 to 12,000 between phases.

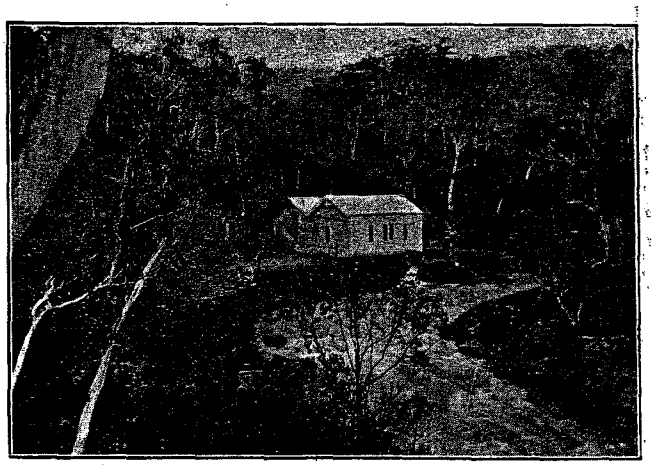


Oil Governor.

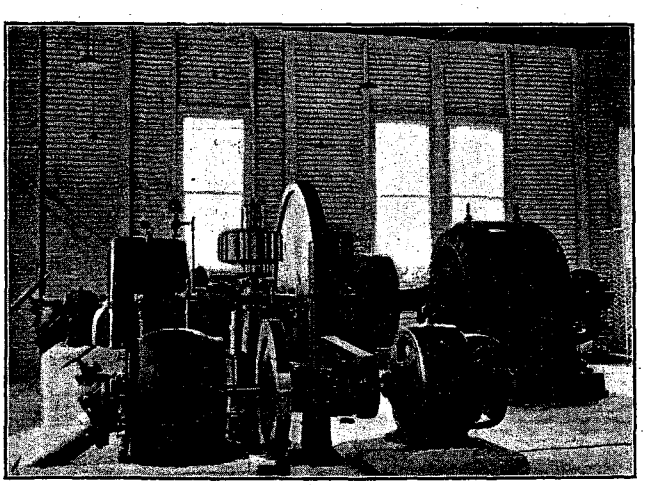
The switchboard has all the necessary gear for switching and regulating the supply of power. For the control of the voltage, a Tirrill regulator is employed, and has proved a very necessary adjunct for the good working of the system. When working without it in circuit, great difficulty is found in operating the hoist motors, and even when close hand regulation is attempted, the voltage is unsatisfactory. This regulator has done duty month in and month out without "sticking up" or losing the voltage, and holds the pressure at the terminals of the largest motor (300 h.p.) well within 2 per cent. of the normal working pressure. The surging experienced by some operators is the re-



OIL GOVERNORS.



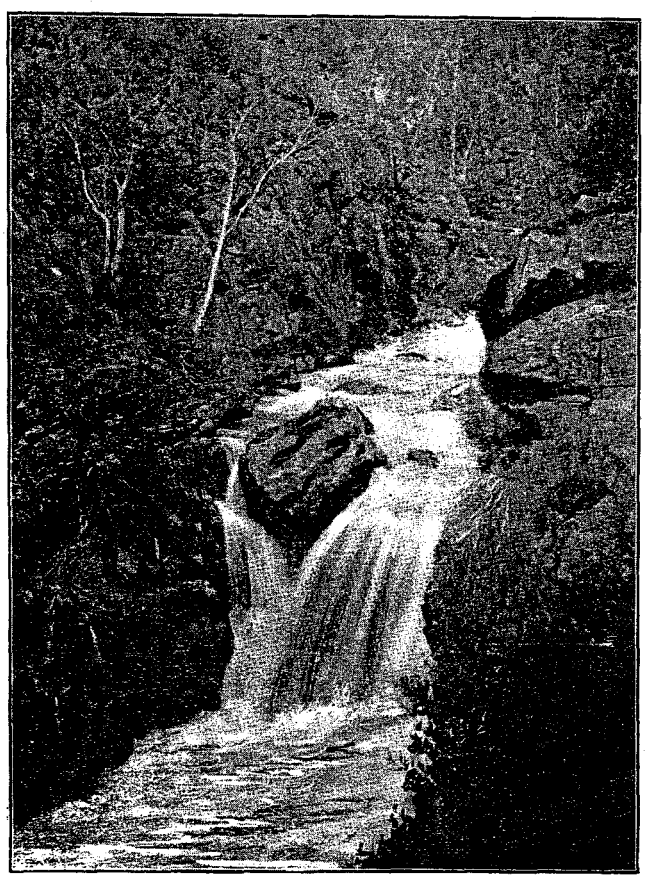
POWER STATION AT COBUNGRA.



MAIN SET 670 H.P. PELTON WELL and 500 K.V.A. GENERATOR.

sult of improper adjustment and attention, and the unjust accusation that has sometimes been made of this regulator being still in its experimental stage, is usually due to carelessness or ignorance on the part of those concerned. With proper adjustment and a reasonable amount of attention, there should be little or no trouble.

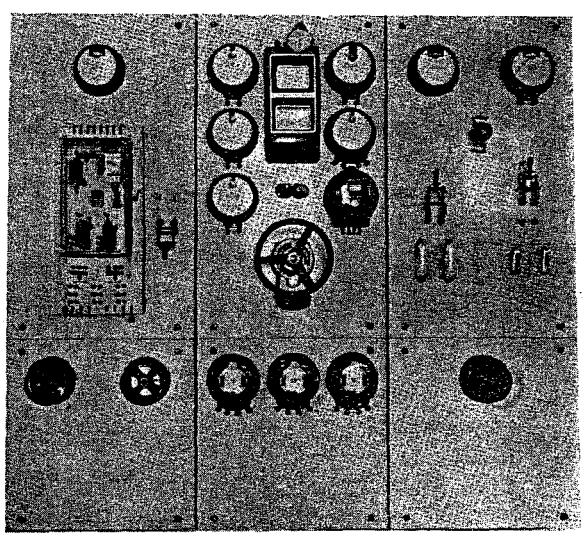
The energy is transmitted to two sub-stations—one at the works and the other at the mine. The former is equipped with 3 single-phase transformers of 125 kw. each—for reducing the voltage from 12,000 to



PORTION OF VICTORIA FALLS.

550—together with a high-tension switch and a low-tension switchboard of 6 panels. The latter is similarly equipped, except that the transformers are of only 35 kw. capacity each. Spare transformers are kept at all stations. The loading on these sub-stations consists of (1) a two-stage high-speed compressor built by Bellis and Morcom, with a capacity of 1600 cubic feet of free air per minute, compressing to 110 lbs. per square inch. This is driven by a motor of 300 h.p. running at 300 revs. per minute, to which it is connected by a flexible coupling. (2) For the operation of the battery, winches and suction pumps, two 75 h.p. motors are required; while (3) for the workshop, agitators, stone breaker and filter press, motors of 15 h.p. are sufficient. Besides these, six 2 h.p. motors are used for blasts, etc. All the motors are designed for 550 volts, and for lighting small transformers reduce the voltage from 550 to 110.

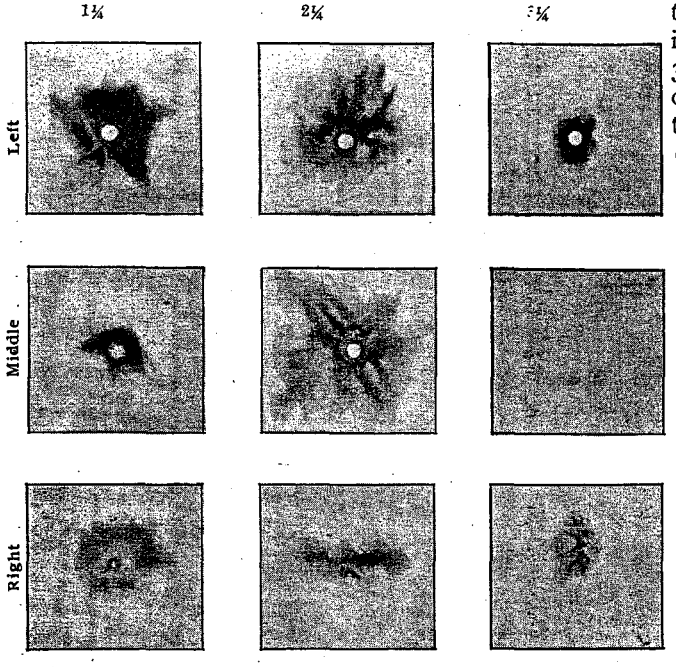
The transmission line is 16½ miles long, and consists of three No. 5 A.W.G. or B. and S.G. hard-drawn solid copper wires, spaced 5 feet apart from each other at the apices of an equilateral triangle. The poles occur at intervals of 160 feet, and the insulators are of white porcelain, tested to withstand 80,000 volts. With full load of 400 kw. at .80 p.f., the ratio of the loss of power to power supplied is 11.8 per cent., and that of pressure drop to pressure delivered is 9.75 per cent. The line pressure at present is 12,000 volts between phases, but in the event of the duplication of the plant, the voltage can be raised to 21,000 volts between phases

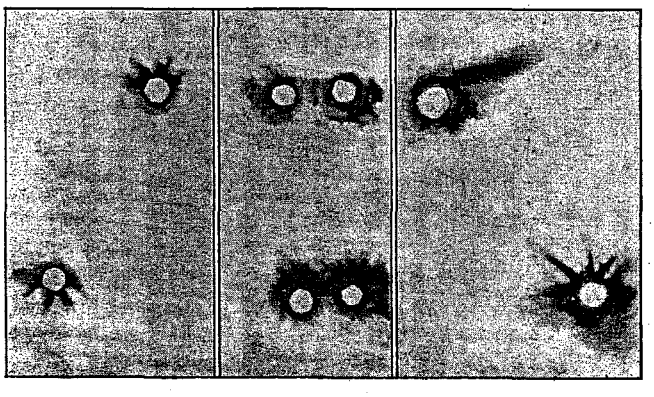


POWER STATION SWITCHBOARD.

by connecting the high-tension side of the transformers in "star" instead of "delta," as at present. Transmitting, then, with double the amount of power at this higher voltage, the line losses and voltage regulation would be even better than before, similar ratios to the above for a load of 800 kw. at .80 p.f. being 7.7 per cent. and 6.4 per cent. respectively. An automatic high-tension circuit breaker, with series transformers, controls the overloads at the power station, and at the sub-stations are h.t. circuit breakers, with series and shunt transformers, which cut out on overloads or voltage failures. For the protection of the line and apparatus against lightning, the stations have G.E. roller type arresters installed. These are of the low equivalent, non-arching, multigap type, with series and shunted gaps. The equivalent spark gaps are set to 1¼ inches, 2¼ inches, 3¼ inches, and 6¼ inches The performance of these arresters has been excel-

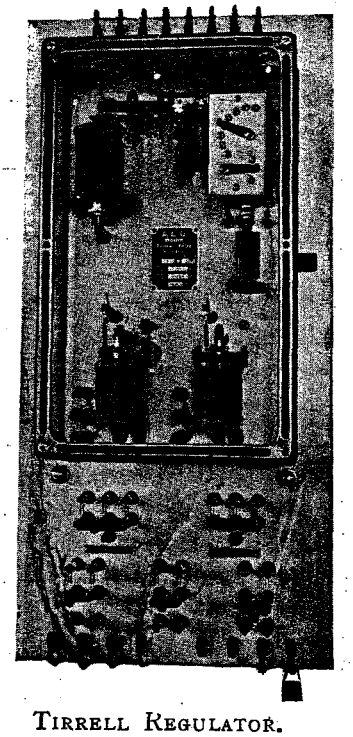
lent, considering that insulators have been shattered on the main line, and that over 50 thunderstorms occur in each year, some of which are very severe. As an auxiliary to the G.E. arresters, and to relieve them of their worst static stresses, the writer has installed supplementary horn arresters at the power station, with resistances to limit the current to full load line current. This has reduced the tendency of





3¼

the fuses in circuit with the G.E. arresters, to blow under severe conditions. The equivalent spark gap is, therefore, kept at its lowest and normal distance. Appended are actual sizes of some test papers punctured up to the 3¼ inch gaps. Note the calibre of the holes, which represent fair heavy currents. The first group of nine test papers show the effect of installing an auxiliary horn arrester on an outside wire (the right), to work in conjunction with the other arresters. After a very severe thunderstorm, in which a couple of line insulators were shattered, these papers, which were in the gaps of the G.E. arresters, were examined, and it can be seen that the stress on the same line as the auxiliary was least, little or no dynamic current following the static spark discharge. The test papers in the line adjacent were only punctured in the 1¼ and 2¼ inch gaps, whereas those in the other outside line showed punctures up to the 3¼ inch gap. Other tests have given similar results, displaying clearly the advantages of such a combination. The fact that the small gap in the horn arrester (which was set at ½ inch) allows it to act first, so



TIRRELL REGULATOR.

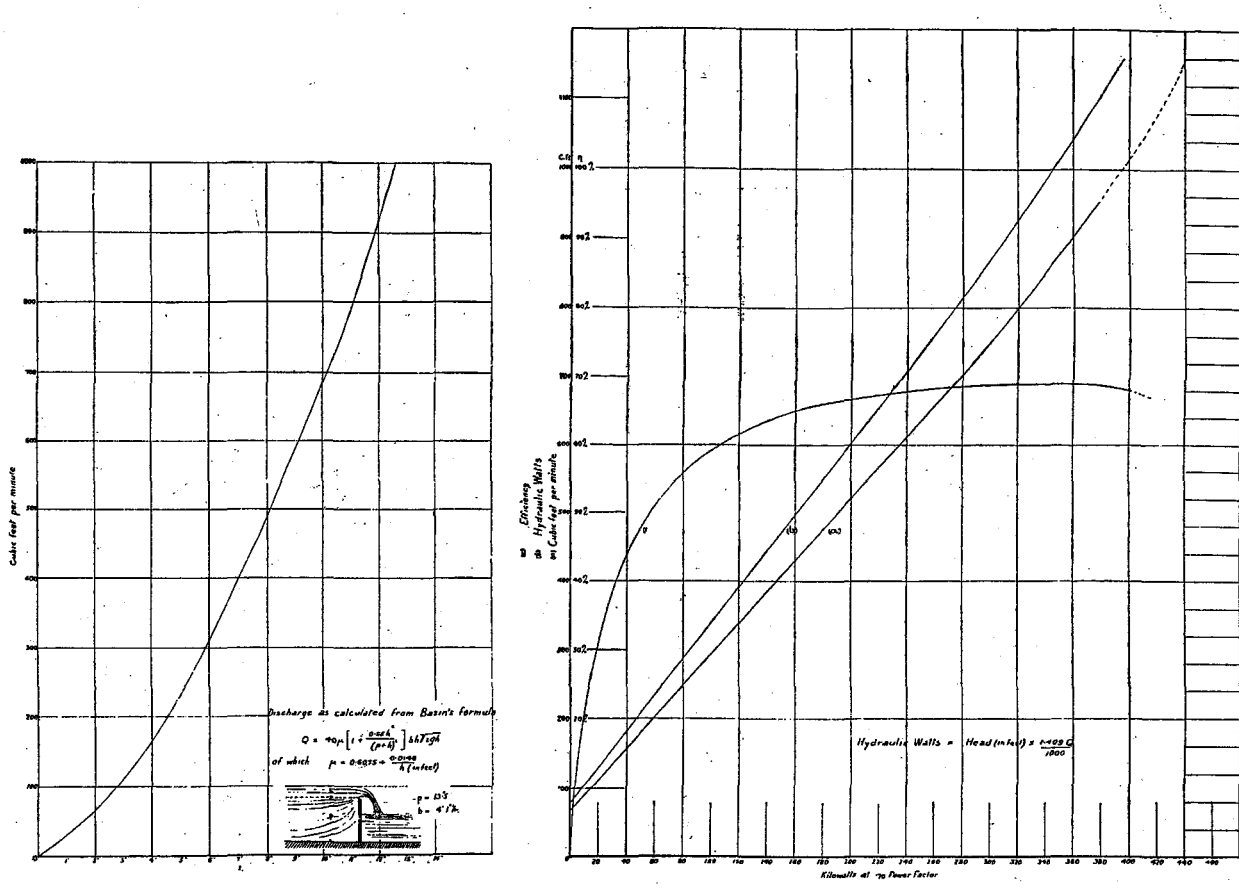
that damping results in the adjacent wire suggests to the writer that horn arrestors with small spark gaps, installed at regular intervals over the line on the middle wire, would have the effect of damping the surges in the two adjacent wires, and act in the same manner as an overhead earth conductor.* The writer was led to the investigation and practical application of the spark gap distance, and the spark lag with transient voltages from a perusal of some recent work on the subject by Dr. C. P. Steinmetz (Proc. Amer. Inst. E.E., Nov., 1910). The other

* This arrangement of arresters would only be applicable where the neutral of the system was not "earthed," as in the present instance

three test papers were obtained in the 3¼ inch gap before the horn arrestor was attached.

The telephone line is run approximately 13 feet from the main line poles, and, when in order, is comparatively quiet as far as the static and current induction from the main line is concerned. Two or three times during the operation of the plant, the telephone has served as an indicator of trouble in the main line by the excessive induction, due to unbalanced currents in the main line, which resulted on partial or complete shorting or earthing.

mately, a power factor of .70 over the whole range, from 60 to 380 kw. The effect on the efficiency curve with unity p.f. would be to slightly peak this towards full load, and would probably increase the full load efficiency by 1 or 2 per cent. The combined efficiency of the turbine and generator would then be in the vicinity of 70 or 71 per cent. at full load. In measuring the water, the loss of head due to pipe friction was allowed for throughout the test. It amounted to 2.5 feet at full load, according to Weisbach's formula:—



EFFICIENCY TEST CURVES.

Rough tests of the performance and efficiency of the plant were made by the writer, and are given below.† These show that the performance is at least what might be expected, but must not be considered as rigorous, since certain refinements in the measurement of the water discharge and the calibration of wattmeters were not able to be made without the incurrence of considerable expense. The loading on the alternator was made with the actual working load, the instruments on the switchboard indicating, approxi-

$$h = \left(.0144 + \frac{.01716}{\sqrt{v}}\right) \frac{l}{d} \frac{v^2}{2g}$$

Where h = loss of head.
l = length of pipe in feet.
d = diameter of pipe in feet.
v = velocity of water in feet per second.

The cost per unit generated is .4d. depreciation, and interest, etc., being reckoned at 11 per cent., which allows a fairly high percentage for amortisation or obsolescence of the plant.

The whole plant has been in operation for nearly 2½ years, and has had an excellent record compared

† In conducting these tests the writer wishes to acknowledge the valuable assistance of Mr. T. H. Upton.

with other hydro-electric schemes in Australia. This reflects credit on the contracting engineers (the Allegemeine Electric Co., then represented by Messrs. Staerker and Fischer, and now by the Australian Metal Co.) and on the late manager, Mr. Frank J. Coote, who was in a way largely responsible for the general layout of the plant. It suffers, however, like some other schemes, from lack of water during the dry seasons. The advisability of obtaining exact information —extending over a few years, if possible—on the minimum flow of water in rivers from which is to be deduced the source of power for any hydro-electric scheme cannot be too strongly urged. Such information cannot be obtained from the inhabitants of the district, and little weight should be given conclusions not obtained by reliable and experienced engineers. To trust to a layman on this point is to court disaster, and projected schemes, bolstered up by such uncertainties, have been known to be a failure financially, when realised, through occasional shortness of water. Australia, although having many climes within itself, is not a country where many hydro-electric schemes of great magnitude could be made a financial success. Its sister countries, the Dominion of New Zealand and the State of Tasmania, are favoured of the gods in this respect. Droughts and floods have combined to form a wholesale dread of inaugurating water power, but wherever possible markets for the usage of electric current lie undeveloped through neglecting this source of power, we have a great national waste. Conservation of water in dams would generally be necessary, and the value of the "by-product," as we may term the "disenergised" water, for irrigation purposes cannot be overestimated. The excellent load factor accruing from irrigation concerns presents to the engineer an attractive feature in the development of hydro-electric schemes.

ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

The first meeting for the year was held on 9th March, when the president, Mr. G. A. Julius, B.Sc., delivered the presidential address. After referring to the progress and financial position of the Association, Mr. Julius introduced a question of great importance to the engineering profession—

What is an Engineer?

He said, inter alia:—There is no profession so prostituted as this of ours. Any fitter's labourer can, without other qualifications, set up his plate as an engineer, and can, and does, practice as such without let or hindrance. This is not so in the great sister professions of law and medicine, and it should not be tolerated in our science, which I am conceited enough to believe is of equal, or even greater, importance in the life of the community. We cannot at present stop any man calling himself an engineer, but, as a body, we can, and should, absolutely decline to accept him to membership of our Association until we have thoroughly satisfied ourselves as to his qualifications. Do not think for a moment I am presuming to suggest that this or that course of training is essential. There are many ways of becoming a qualified engineer, and numbers of our ablest men have started their careers as unskilled labourers.

Engineering Progress.

Passing on to refer to important developments during the past twelve months, Mr. Julius first mentioned the Humphrey internal combustion pump (description of which appears elsewhere in this number). The next question of importance was that of steam versus internal combustion engines as prime movers. With very small units, the latter undoubtedly leads, but above, say, 50 h.p., the question is still in doubt. Steam is certainly the more reliable medium, and a plant can be allowed to get into a deplorable condition before it refuses duty; whereas a gas engine must be maintained up to a certain standard. So far as efficiency is concerned, the results realised with high class gas plants are practically unattainable with steam, but some very remarkable results have nevertheless been recorded. For instance, the turbo alternator sets recently installed at the Ultimo tramway station (Sydney) have each a nominal capacity of 5000 k.w. at 6600 volts, but their overload capacity is phenomenally high, being 7500 k.w. The steam consumption realised on tests *in situ* was 16 lbs. per k.w. hour, using steam without superheat.

On the new 4000 k.w. sets now in hand for the Sydney City Council the guarantees call for a consumption of steam at 100 degrees superheat of not more than 15¾ lbs. per k.w. hour at full load, and 17½ lbs. at half load. Practically speaking, these figures correspond to a consumption of 1.1 lbs. of good Newcastle coal per b.h.p., or reduced to the British standard, 1.03 lbs. of best Welsh steam coal per b.h.p. hour, which again gives a figure of approximately 260 b.t.u. per b.h.p. minute, a result directly comparable with the data given for the Humphrey pump. It must, of course, be remembered that the 250 b.h.p. expended in the case of the latter appliance was expressed at per pump horse power minute, i.e., it is inclusive of both engine and pump losses, whereas in the steam plant the 260 b.t.u. includes losses only up to the turbine shaft.

With another class of steam plant, viz., semi-stationary combined engine and boiler, in which