Mr. Burnside.

continuous rating. This plant consisted principally of two 18,750-kilowatt Parsons turbines with Babcock-Wilcox boilers, and followed generally the lines of the existing plant, although modified in several details. One interesting departure in the extensions was the substitution of water sluicing of ashes from the ash-hoppers for suction plant. The ashes would be sluiced into a tank outside the boiler-house gable and under the yard surface, and loaded thence on wagons by a derrick crane and automatic grab.

Correspondence.

Mr. Scott.

Mr. E. KILBURN SCOTT remarked that it was difficult to discuss in detail Papers which described actual power-stations such as Barton and Dalmarnock, for it must necessarily be assumed that the engineering had been done as well as possible, with standard plant, and along well-known lines. But it was possible to say a good deal on broader and more general issues, as, for example, whether the time was ripe to break away from the template pattern stations which were so common in this country, and which these Papers described. He was of opinion that the time had arrived for the introduction of entirely new methods, in order to bring the cost of operation of fuel-consuming plants more into line with that of hydro-electric plants. There was, for example, a vast difference between the cost per unit at, say, Rjukan in Norway, Terni in Italy, and Shawinigan Falls, Canada, to mention only a few foreign hydro-electric plants, and fuel power-stations in this country. Consulting and other engineers in the United States and Canada and in certain Continental countries, where large hydro-electric and steam power-stations were comparatively near together, had an incentive towards improvement which was lacking in England, because in those countries the cost of electric energy was thought of in terms of cheap hydro-electric power. Power-station design was in a rut in this country, because many engineers had been in the habit of allowing certain boiler-making firms to prepare complete drawings and specify their own plant. Naturally these firms specified boilers of the sizes and types which they could easily make. As a result, stations with boilers evaporating about 50,000 lbs. of water per hour were very common. There was no longer any interest in looking round power-stations, as they were all so much alike. By the adoption of boilers of 16,020 square

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Mr. Scott. feet heating-surface, and 100,000 lbs. of water evaporation per hour (125,000 lbs. overload), the Barton station had set a much-needed precedent; but, even so, it meant that there were three double boilers to each 27,500-kilowatt turbo-generator. At Colfax, near Pittsburg, there were four boilers, each with 27,680 square feet of heating-surface and 250,000 lbs. per hour evaporation (333,000 lbs. on overload), to supply steam to each 60,000-kilowatt unit of turbo-generating plant. The Detroit Edison Company was installing six boilers, each of 29,000 square feet heating-surface, giving 300,000 lbs. per hour and 400,000 lbs. on maximum load. The Union d'Électricité had installed at the Vitry power-house near Paris, four boilers of 21,600 square feet heating-surface and 138,000 lbs. evaporation per hour (192,000 lbs. maximum). For the Gennevilliers power-station there were to be four boilers of 19,350 square feet heating-surface and 150,000 lbs. per hour (242,000 lbs. maximum) evaporation capacity. The above-mentioned boilers were arranged for firing with pulverized coal, and that was

	Gennevilliers. Paris. Stoker-fired Plant.		Barton, Manchester. Stoker-fired Plant.	Gennevilliers, Paris. Pulverized Fuel.
Type of Boiler . .	Stirling.	B. & W.	B. & W.	Ladd Belleville.
Number of boilers	5	20	9	4
Pressure: lbs. per sq. inch . .	355	355	375	440
Heating - surface boilers: sq. ft.	22,600	14,316	16,020	19,500
Heating-surface of superheater: sq. ft.	10,760	8,180	6,072	..
Temperature of steam: °F. . .	707	707	738	720
Evaporation, normal: lbs. per hour . . .	132,000	88,000	100,000	150,000
Evaporation, accelerated: lbs. per hour . .	176,000	117,000	120,000	242,000
Guaranteed efficiency: per cent.	75	75	85	85
Floor space of boiler: sq. ft. .	$38 \times 36 = 1,368$	$38 \times 25 = 950$	$51 \times 22 = 1,122$	$32 \times 22 = 704$
Evaporation per sq. ft. of boiler floor space: lbs. per hour . .	$\frac{176,000}{1,368} = 128$	$\frac{117,000}{950} = 123$	$\frac{120,000}{1,122} = 107$	$\frac{242,000}{704} = 344$
Height of boiler-house from basement: ft. .	90	90	90	100

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the main reason why such very large overloads were possible. Of course, for such firing, the boiler-houses had to be differently proportioned; one feature was that they were higher, and another that the evaporation per square foot of space occupied by the boiler was much greater than with stoker firing. This was shown by figures in the Table on p. 426, which gave the height of Gennevilliers boiler-house as a little more than that of Barton, but the evaporation per square foot of boiler area as nearly three and a quarter times as much. One reason for the difference was the greater height of the combustion-chamber. He looked upon pulverizing of fuel as a step in the right direction; and the fuel should be preferably the semi-coke from low-temperature distillation. Mr. Scott.

Mr. John Warrack was particularly interested in the method adopted for generator-protection at Barton station. During the past 10 years he had had to deal with the repair and maintenance of the larger generators of the Victoria Falls and Transvaal Power Co., which were thirteen in number, and ranged in size from 12,000 to 18,000 kilovoltamperes, being comparable in size with the Barton generators. They were each provided originally with a limiting resistance in the neutral earth connection, and the stator winding was inside the differential protection, which included the generator transformers. The cast-iron grids forming the resistance were frequently found to be broken, thus destroying the protection; and when this had not happened, considerable damage was often done to the stator, in the event of a fault, before the generator was switched out. An attempt was made to limit the damage by placing a high-tension fuse in the neutral earth connection, together with a current-transformer operating a relay. In many cases this arrangement acted very well, but sometimes the fuse failed to clear, and considerable damage resulted. It was evident that the fault current would have to be interrupted before it had reached a value sufficient to blow the fuse, and to do this a current-transformer with a ratio of 1/25 (0·2 ampere to 5 amperes) was inserted in the neutral, the secondary being short-circuited with a fuse and relay. When the fault current reached a high enough value, the fuse was blown, and the relay operated and switched out the generator. The short-circuit impedance of the current-transformer was so high (about 500 ohms) that no additional resistance was required, and the protection was easily tested by isolating the transformer and applying 220 volts from the lighting circuit to the primary terminals, when the relay would operate if all were in order. It was noticeable that a small triple-frequency current flowed through the earth connection all the time the machine was running excited, and that had to be allowed for in Mr. Warrack.

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Mr. Warrack. setting the relay. This method of protection had so far given very satisfactory results, and the damage to a stator was so small that it was difficult to locate the fault. This method was much simpler and cheaper than a neutral resistance and oil switches, it was much more sensitive than any form of differential protection, and the impedance in the neutral was so high that no damage was done to the stator. The probability of a short circuit between turns of the same phase in alternators of the size installed at Barton appeared to be very remote; and with the split-winding protection, which was really a form of differential protection, the fault would have to develop to a dangerous extent before the relay operated. A much more common fault, in his experience, had been a defective joint or broken connection—it was difficult to say how far those faults would have to develop before the split-winding protection operated. The neutral protection he had described operated when the insulation on a joint started to char, but so far it had not had to deal with a broken connection.

Messrs. Allott and Pearce Messrs. ALLOTT and PEARCE, in reply, remarked that in the most efficient stations the fuel cost was 75 per cent. of the station operating costs, and pulverizing, whether right or wrong, could not possibly make the operating cost of fuel-using plants comparable with that of hydro-electric plants. It would be noted from the Table given by Mr. Scott that the efficiency of the Barton station, using solid fuel, was the same as that of the Gennevilliers station with pulverized fuel. With reference to the details given by Mr. Scott regarding the boiler-equipment in various foreign stations, it was necessary to state that "floor space" and "evaporation" must be carefully defined before they could be usefully discussed. In any case the variation in the capital cost of the buildings due to any economy in floor space would not be sufficient to affect appreciably the overall running-cost, and any variation in the height or loading of the building structure also became a factor.

The method of generator-protection described by Mr. Warrack appeared to possess some advantages in the case of generators not directly connected to the bus-bars, but obviously it only afforded protection against faults to earth, and therefore for complete protection it must necessarily be employed in conjunction with one of the well-known differential systems. The primary winding of the current-transformer appeared to be unnecessarily small, and a short-circuit impedance of 500 ohms was certainly exceptionally high.

The split-winding system of protection described in the Paper and illustrated in *Fig.* 20 (p. 362) was only employed on the house-service generators, and consequently, as the windings consisted of

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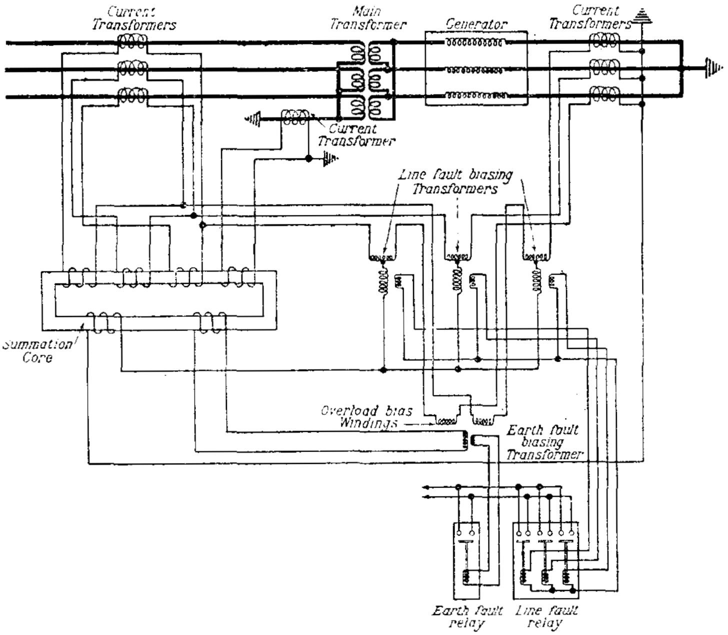
Messrs. Allott and Pearce.

a few turns only, and the neutral points were connected directly to earth, Mr. Warrack's criticisms did not apply. The resistance in the neutral-point earth-connection of the main generators consisted of substantial cast-iron grids built up into two parallel banks, and located in a position free from vibration. As the current through either bank was sufficient to ensure operation of the protective gear, the risk of failure arising from broken grids was not very great.

The system of protection originally installed on the combination of main generator and step-up transformers was the usual circulating

Fig. 1.



current differential arrangement as described on p. 358 ; but owing to the large unbalanced component of the circulating current due to the excessive increase in the magnetizing current of the transformers under conditions of momentary pressure-rise, it was necessary to have comparatively high values of the protective-relay settings, in order to ensure stability of the protective gear under the severe conditions arising from faults on the system, external to the generating station. The original arrangement had, therefore, been slightly modified, and it would be observed from the connections of the new system, shown in *Fig. 1*, that separate protection against faults to

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Messrs. Allott and Pearce.

earth was now provided on the primary and secondary sides of the step-up transformers, and consequently, a much more sensitive setting of the relay which afforded protection against faults to earth on the generator and transformer primary windings was now possible.

Mr. Burnside.

Mr. BURNSIDE did not agree with Mr. Kilburn Scott that Barton and Dalmarnock had followed stereotyped design. Stations of the same kind were bound to have a family likeness, but both Barton and Dalmarnock on the whole differed appreciably from preceding practice. He was inclined to agree that development had reached a stage when radical differences would appear in station design. The steady aim of all design had been to reduce the cost of the unit to consumers, not the reduction of operating-costs alone. In the discussion he had indicated that buildings and construction works generally should be regarded from a new point of view, in order that their capital cost might be reduced. Mr. Scott submitted that improvement at the steam generating end lay in the direction of the adoption of powdered fuel. Mr. Burnside agreed; but even in this matter the individual conditions and requirements of each station would have to be considered carefully. Powdered fuel had not yet reached the stage of universal application. If, as was likely, larger boiler-units were adopted, there was probably no other choice, because stoker areas required would become abnormal. With regard to the boiler-makers' part in design, he thought that, beyond specifying fully his requirements and conditions, a station engineer should not interfere in the first instance. Certainly he should require very full information from the boiler-makers, and subject it to careful scrutiny and comparison. His time to obtain modifications was between receiving and accepting a tender.

Mr. John Warrack's remarks regarding the protection of alternators were interesting, and no doubt his method of protection would be adopted widely, because of its simplicity and efficacy. His remarks suggested that alternator failures were much more prevalent on the Victoria Falls and Transvaal Power Company's system than at home.

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