The Industrial Outlook.

[NOTES ON THE ELECTRIC RAILWAYS IN BOMBAY AND MADRAS.]

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THE steam locomotive, although highly improved in recent years, has got its own limitations as regards efficiency, tractive effort and speed. The application of electricity for traction has proved its superiority over the steam drive in the above respects and the railways all over the world are electrifying their railroads utilizing either economical hydro-electric power or steam electric power from large central stations. Not only the suburban lines near big cities, but also the main lines radiating from centres of trade, commerce and industry have greatly benefitted by the conversion into electric drive. In Switzerland where there are no coal fields, almost the entire railway system has been electrified as the country is rich in water power. In recent years the railways in India have been carefully considering the change into electric drive and the schemes carried out by the G.I.P., B.B. & C.I., and the S.I. Railways, have proved the superiority of the electrified systems to such an extent that other railways will follow suit in due course.

The heavy suburban traffic of Bombay, a city of nearly $1\frac{1}{4}$ million inhabitants, and the important long distance passenger and goods traffic especially over the Ghat sections, where the elevation suddenly rises up to 2000 ft. above sea level with gradients of 1 in 37, constitute conditions that are very favourable for electric drive especially as power was available from hydro-electric power stations nearby. The B.B. & C.I. Railways have electrified their suburban section between Bombay and Borivli (30 miles) and the G.I.P. Railway have electrified not only their suburban sections between Bombay and Kalyan (30 miles) but also their main lines from Kalyan to Poona on the South-East and to Igatpuri on the North-East.

The South Indian Railway have electrified their suburban section from Madras Beach to Tambaram ($18\frac{1}{2}$ miles) and are also contemplating main line schemes to be taken up in the near future.

The suburban schemes of the G.I.P. and B.B. & C.I. Railways are both on the broad gauge and are similar in design and equipment of sub-stations including rotary converters, etc. The suburban scheme of the S.I. Railway is on the metre gauge and their sub-stations are equipped with mercury arc rectifiers instead of rotary converters. The main line scheme of the G.I.P. Railway is an extension of their suburban system, but the traction is carried on by suitable passenger and goods locomotives, the latter equipped with regenerative braking for service over the Western Ghats between Kalyan and Poona and Igatpuri.

The following is an abstract of the technical features of the G.I.P. Railway:—

1. Capital Expenditure—	
Suburban Scheme	Rs. 2·74 crores
Main line Scheme	Rs. 6·50 ,,
2. Route mileage of track electrified	181 miles
Length of single track electrified including sidings ..	571 ,,
3. Number of Suburban motor coaches	53
Number of Passenger locomotives	24
Number of Freight locomotives	41
4. Aggregate HP of Passenger locomotives	51,990
Aggregate HP of Freight locomotives	1,06,600
5. Number of sub-stations ..	15
Aggregate capacity of sub-station plant	1,00,000 Kw.
6. Steam Power Plant and equipment	4 alternations of 10,000 Kw. each. 6 Boilers of 60,000 lb. steam per hour each.
7. Length of 100,000 volts Transmission line	272 miles.

The suburban system of the G.I.P. Railway was electrified by 1925 and the main lines by 1929. The traction is of the 1,500 volt D.C. system, power being derived through rotary converters in the various sub-stations. Four of the sub-stations receive their power from the Tata Hydro-Electric Companies, at 22,000 volts from the Tata stations at Dharavi and Kalyan. The other sub-stations which feed the main lines from Kalyan to Poona and Igatpuri are fed from the G.I.P. Railway steam electric plant situated near Kalyan, through extra high tension lines at 95,000 volts which run mostly parallel to the railway lines. The wisdom of having installed a steam power plant, when there was sufficient hydro-electric power available nearby has been questioned. The railway authorities seem to justify the steam plant and say that at the time of negotiations with the Tata Companies, conditions being adverse, there were doubts if they could guarantee priority of supply in the event of shortage of water following a bad monsoon and consequently continuity of service was not certain. In any case if conditions have improved since, it would be economical to draw more power from the Tata Companies and conserve their coal for places where the electrification has not been extended, especially as the railway power plant is so designed as to inter-link with the Tata network.

The steam power plant is designed for pulverised coal and is equipped with 6 boilers each of 60,000 lbs. per hr. steam output and 4 turbo alternators each having an economical and continuous maximum rated output of 10,000 Kw at 6,600 volts with an overload capacity of 20% for 2 hrs. and 65% for 2 minutes. Each generator is connected through an oil circuit breaker to the low tension side of its own 11,000 KVA 95,000 volts step-up transformer and also to the high tension side of its own 1800 KVA unit transformer which feeds the auxiliaries connected with that set. In all the G.I.P. sub-stations the converting plant consists of suitable transformers and rotary converter sets each comprising two 750 volts 1,250 Kw machines in series to give a 1,500 volts D.C. supply. In three of the sub-stations, all switchgear including that for starting, synchronising and connection to the busbar are designed for manual operation, and in others there is automatic operation, *i.e.*, each rotary converter is automatically started, synchronised, and connected to the busbars following the closing of a low voltage control switch. Six of the sub-stations on the main lines are unattended and fitted for supervisory control from the neighbouring attendant sub-stations. All the rotary converter sets and their switchgear are designed for receiving power from the 1,500 volts D.C. line, from the locomotives regenerating as well as for normal operation. A portion of the regenerated energy is absorbed by ascending trains up the ghats and the remainder is converted into alternating current in the sub-stations and delivered to the transmission lines. On the average about $4\frac{1}{2}$% of the input to the rotary converters is returned to the transmission lines. Taking the total input as 6,00,00,000 Kw. hrs. per annum, the energy returned to the high tension lines would be 27,00,000 Kw. hrs. per annum. This saving is ample to pay the capital charges on the extra cost of equipping the freight locomotives with exciters and additional switchgear for regeneration, a further advantage being the reduction in brake block renewals.

The locomotives have been designed to meet the exacting conditions of varying temperatures from 40° F. min. to 130° F. max. and the heavy monsoons near Bombay. For the suburban service each train unit consists of one motor coach and three trailers, the normal train during rush hours being made up of 2 units. Seating capacity of each unit is I class 15, II class 42, and III class 384. The motor is of 275 HP and the weight of the four-coach unit is 218 tons, *i.e.*, 5 HP per ton of train. The freight locomotives are designed with the wheel arrangement comprising of 2 sets of 3 coupled axles, so that there is less tendency to skidding of wheels and no chance of breaking of coupling when starting up the 1 in 37 gradients and running away in down grade. They are equipped with 4 motors each of 650 HP 1,500 volts rather than 6 of 750 volts so that a lower crawling speed is possible. Further they are equipped with axle driven generators for regenerative working when the locomotives are hauling trains down the ghats. The complete electrical equipment is easily and conveniently divided into 2 groups so that in the event of any electrical failures one group can be immediately isolated without affecting the operation of the other thus reducing the possibility of a train being stalled and blocking the road. All the auxiliaries, such as vacuum pumps and compressors, are in duplicate and a 50 volts battery is installed with sufficient capacity to give 4 hours supply for lights and control circuits.

The passenger locomotives for the main lines were designed to meet the growing demand of traffic with improvement in the timing between Poona and Bombay. They have a tractive effort of 7,500 lbs. at 70 miles per hour and can maintain a speed of 57 miles per hour up a gradient of 1 in 150. These locomotives have to work in combination with a freight locomotive while going up the ghats and should share the load properly at the speed desired, that is, of the total tractive effort of 40,000 lbs. required, the passenger locomotive should be responsible for 16,000 lbs. leaving 24,000 lbs. for the freight engine, both running at a speed of about 30 miles per hour. Similarly, the locomotives have to run in combination under regenerative control down the ghats. The motor equipment of the passenger locomotive consists of six motors of 750 volts with two groups of control apparatus and all safety devices. It is remarkable that 41 freight locomotives and 24 passenger locomotives have efficiently replaced 171 steam locomotives including 96 ghat engines.

The G.I.P. Railway main line electrification scheme is the largest and the most comprehensive in the British Empire, with perhaps the recently electrified Southern Railways between London and Brighton coming next. The combined G.I.P. and B.B. & C.I. suburban electrification schemes have helped Bombay to successfully overcome the housing problem and develop the suburbs till now considered impracticable.

THE SOUTH INDIAN RAILWAY ELECTRIFICATION—MADRAS.

The S.I. Railway have adopted the 1,500 volts D.C. system very similar to the traction system of the Bombay Electric Railways, but the track is of metre gauge and the scheme is of special interest in that it was not merely the conversion of existing steam-operated lines to electrical working, but included the construction of new tracks and stations to accommodate suburban traffic between Madras and Tambaram, that had increased so much as to impede the main line services. Another novel feature is that the 1,500 volts D.C. supply is obtained by means of 1,500 volts 1,500 Kw mercury arc rectifier sets instead of rotary converters used in Bombay. Power is obtained from the steam power plant of the Madras Electric Supply Corporation at 33,000 volts and is supplied to the mercury arc rectifiers through suitable transformers and switching apparatus which are designed for automatic operation. These rectifiers can take 100% short time overloads easily.

The service on this system was opened in April 1931 and has been working quite satisfactorily. The traffic has tremendously increased with better speed and comfort and has electrification scheme. A new double track for the electric trains has been constructed from Madras to Tambaram (18½ miles) and certain shunting yards near Madras have been electrified so that shunting operations and freight services can be carried out with electric locomotives. There are two rectifier sub-stations, one at Egmore and the other at Meenambakam, with the car sheds located at Tambaram.

There are 17 articulated coach units, each consisting of one motor coach and 2 trailer coaches; 4 locomotives and 2 battery tenders. The articulated motor coach units are arranged for multiple unit working, so that trains may be made up with 3, 6 or 9 coaches according to the traffic requirements. The electrified equipment has been designed to give an average speed of 40 miles per hour with a fully loaded train over the whole distance with station stops at an average interval of 1½ miles. A three-coach unit is carried on 4 bogies and the power equipment consists of 4 motors of 122 HP each, connected permanently in pairs in series, one pair being mounted on each of the two intermediate bogies. The motors are of self-ventilated type, but owing to the excessively dusty conditions the ventilating air is drawn from inside the coach through ducts and sliding flexible joints. Power control is on the all-electric cam shaft system similar to that in use on the G.I.P. Railway, and the whole of the control equipment is housed in a compartment at one end of the centre coach, which also contains a 4 Kw 1,500/60 volts motor generator set for supplying the control and lighting circuits, and exhauster driven by a 1,500 volts motor. An emergency battery is also provided, which is charged automatically and floats across the terminals of the motor generator set. Ten of the train units contain I, II, III class and seven contain entirely III class. The weight of a unit is 73 tons. The 4 locomotives are fitted with articulated bogies each equipped with two nose suspended axle-hung motor rated at 160 HP. As in the case of the motor coaches, the ventilating air is drawn from the interior of the vehicle which in turn has air inlets fitted with filters. The superstructure is of the box cab type with the control equipment mounted in a centre compartment, with a driving position at each end. The electrical equipment of the locomotives is generally similar to that of the motor coaches with the exception that it is not arranged for multiple unit operation, and 3 running positions are provided in series and also in parallel by means of weakened field notches. The locomotives are capable of hauling 500 ton freight trains or 250 ton passenger trains at a speed of from 25 to 40 miles per hour. They are 32 ft. long over buffers, 8½ ft. wide with a weight of 42 tons. Braking of the units is by compressed air, but vacuum brakegear is fitted in addition, to suit the existing rolling stock.

One of the chief difficulties encountered in laying out this electrification scheme was the fact that there were a number of small yards at some distance from the main line which could not conveniently be provided with overhead construction although at the same time it was extremely undesirable to have to provide a steam locomotive whenever movement had to be carried out at these yards.

The problem was solved by providing in addition to the locomotives two battery tenders equipped with heavy duty batteries capable of supplying power to the locomotives at 440 volts. When a locomotive is required for service of the kind indicated one of these tenders is attached to it and after the limit of overhead construction has been reached the pantograph is lowered and by changing over a single switch the locomotive runs on the 440 volts supply from the battery. These tenders which weigh only 21 tons have a capacity of 158 Kw hrs. at the 5 hr. rate of discharge of the battery and they are equipped with a complete charging switchboard and other auxiliaries.

The South Indian Railway have not only built new type of stations to handle the suburban traffic on the electric trains, but have done away with all the level crossings in Madras City which has improved the main roads and relieved the traffic congestion. When the hydro-electric power of Pykara is available for the South Indian Railway, they may take up the electrification of the main lines near Coimbatore, Madura and Trichinopoly and also the mountain railway up the Nilgiris.

The Government of Mysore are also investigating the electrification scheme for the Nanjangud-Mysore-Bangalore system. Electric power is available at every railway station on the line between Nanjangud and Bangalore, in addition to the 35,000 volt sub-stations at Bangalore, Closepet, Chennapatna and Mysore. The scheme as worked out by the South Indian Railway for their metre gauge lines with mercury arc rectifiers seems adaptable with advantage for the Mysore Railways. Unlike Madras and Bombay, Mysore cannot buy cheap seaborne coal, is located far away from Indian coalfields and is compelled to pay very high rates for the coal required for their locomotives. Both the Mysore Railways and Cauvery Hydro-Electric Power schemes are owned by the State which helps a great deal in the economy of the electrification. The approximate cost of electrification may be in the neighbourhood of 18 to 20 lakhs. With a guarantee of power supply from the Cauvery Power Station at Sivasamudram and prospects of saving money going out of Mysore to the extent of the cost of coal purchased from outside the State, the electrification scheme deserves very careful consideration so that the details will be worked out at an early stage and the conversion to electric drive may be taken up with advantage.

The Railways which radiate from Calcutta are also considering suburban electrification as a first step which may later lead to main line electrification. Unlike Bombay, Calcutta is situated very near the largest coalfields in India, and it is possible to generate power economically in large central stations with steam power even though there are no big hydro-electric power stations nearby. The ordinary steam locomotive has to carry its own raw materials, such as coal and water, and use them in a boiler whose efficiency is far below that of large modern pulverised coalfield boilers and drive an engine whose efficiency is much lower than that of the central station steam turbines. The logical procedure is to generate power economically at a suitable steam or hydro-electric power station and distribute the energy to hundreds of locomotives with minimum of loss. The first step in nation-building is the conservation and proper development of the natural resources, and electrification plays a very important part.

Traction on the D.C. system is one phase of development, as there are several railways running on A.C. systems using single phase or three phase supply. The mercury arc rectifier which has just come into the field of D.C. traction has various modifications, which make it useful in converting power from 3 phase A.C. systems to single phase A.C. or *vice versa*. Recent investigations have shown that the mercury arc rectifier will play a very important part in the future electrification schemes as it is capable of heavy overloads and adapts itself easily for automatic operation.