liver only 50 per cent of their sea-level energy at 18,000 ft. elevation, while at 25,000 ft. the reduction is about 75 per cent.

The supercharger was first developed in the laboratory, and after factory tests was taken to the summit of Pikes Peak, Colorado,

Fig. 14. LePere Biplane Equipped with G-E Supercharger in Test Flight Above McCook Field, Dayton, Ohio

where for several weeks it was subjected to long continued operation tests in connection with an airplane engine. Its satisfactory performance under these conditions gave every assurance of its safety and practical value, and on August 2, 1919, the pioneer flight of an airplane equipped with a G-E supercharger took place at McCook Field, Dayton, Ohio.

A LePere biplane (Fig. 14) driven by a 12-cylinder Liberty Motor was used, and at an elevation of 18,400 ft. it attained a speed of 137 miles per hour as compared with its best previous performance, under similar conditions but without the supercharger, of 96 miles per hour.

The turbine rotor and the light weight impeller of the compressor are mounted on a common shaft (Fig. 15) and normally rotate at about 22,000 r.p.m., a simple valve in the exhaust piping of the airplane engine permitting the pilot full control of its operation. The weight of the entire equipment, including all necessary piping, is about 100 lb.

Electric Traction

Activities in the electric traction field were largely confined to the installation of automatic substations and the purchase of the one-man, light-weight safety cars. Electrification projects in the course of construction progressed satisfactorily, but few new developments were initiated. Because of the lack of financial resources, there was very little addition to power equipment by electric railways, with exception of the automatic substation.

Electrification

The principal electrification in the United States, and without doubt the most important project of its kind, is the Chicago, Milwaukee & St. Paul Railway, which has completed a 217 mile extension across the state of Washington from Othello to the cities of Seattle

Fig. 15. Biplane Equipped with a G-E Supercharger which can be seen back of the upper blade of the propellor

and Tacoma. The substations and the transmission lines are now ready for operation, and the overhead construction is completely installed. Locomotive deliveries were completed by the end of the year and electrical operation over the entire distance should be an accomplished fact early in 1920. Two freight locomotives were placed in operation in October, 1919, on the 2.2 per cent grade west of the Columbia River, releasing for other service five steam engines ordinarily used for pusher service on this grade.

The five bi-polar gearless passenger locomotives (Fig. 16) are now completed, the first unit having been shipped on November 1, 1919.

The electrification of the government owned steam suburban lines radiating from the city of Melbourne, Australia (Fig. 17), progressed materially during the year. About 200 miles of line are now operating electrically, the major part of the work having been completed since the war, which held up all construction work.

The contracts for this work were awarded some time ago, and included orders for 400 complete motor car equipments. Each equipment consisted of four GE-239, 750/1500-volt motors, multiple unit control, air compressors, and other accessories. Orders were later placed for four 1500-kw., 1500-volt synchronous converters which are now in operation, and control equipment was also furnished for 400 trail cars. This 1500-volt direct current electrification is apparently operating with all the success which was predicted for it, and work is being pushed rapidly on the completion of the remaining suburban lines

Fig. 17. 1500-volt Direct Current Multiple Unit Train on Victorian Railway, Melbourne, Australia

The Salt Lake, Garfield & Western Railway completed its change-over to electrical operation during the summer and is now operating about 21 miles of line with multiple unit equipment and G-E automatic substations.

Another electrification which will begin operation during the present year is the Hershey Cuban Railway, which will operate a line about 60 miles in length between

Fig. 16. 265-ton Gearless Passenger Locomotive in Test for Chicago, Milwaukee & St. Paul Railway

Havana and Matanzas, Cuba. About one half of this road is now operating with steam engines and the remainder will be new construction.

Fig. 18. 1000-kw. Automatic Railway Substation Installed for Pacific Electric Railway

The electrical equipment furnished includes G-E power and substation machinery, overhead line material, motor-car equipment and locomotives. The trolley potential will be 1200 volts direct current and the substations are of the standard automatic type, each containing two 500-kw. 600-volt synchronous converters operating in series. A third unit will be installed in each station as a spare.

There are seven electric locomotives on order, each weighing 60 tons. These will be used for hauling raw sugar and other freight to ports for shipment. The passenger traffic over this line will be handled by multiple unit motor cars, fifteen of which will be used, each equipped with four GE-263 motors and Type PC control.

Automatic Substations

The continued popularity of the automatic substation (Fig. 18) is shown in the increased orders for various types and sizes up to 2000-kw. and 1500-volts direct current. The largest unit so far constructed is a 2000-kw. synchronous motor-generator set now being installed for supplementing the power supply to the Michigan Central R.R. operating electric locomotives through the Detroit river tunnel.

Automatic substation equipment was sold in Cuba, Australia and New Zealand, and inquiries were received from other foreign countries. At the end of 1919, there were approximately 50 G-E equipments in operation and about twenty more either under construction or being installed.

Safety Cars

One of the most popular outfits in the electric railway field during the past year was the light weight safety car, large numbers of which were utilized to replace heavier equipment. Results obtained from the operation of these cars indicate that their use will, to a certain extent, assist operating companies in keeping down the cost of operation without the necessity of resorting to increased fares. Practically all safety cars employ the type

Fig. 19. Light Weight Safety Cars for Eastern Wisconsin Electric Co., equipped with GE-258 motors and K-63 control

K-63 controller, which was specially designed for this service. For motive power, the GE-258 motor has continued to be most popular (Fig. 19).

In order to meet the preference of some railways for a motor of this size with standard sleeve bearings instead of ball bearings, the GE-264 railway motor was designed and a considerable number of these are now in service. Approximately 1400 of these two motors have been sold during the present year. Other equipment for the light weight safety car includes the CP-25 air compressor and straight air brakes with safety devices (Fig. 20).

Fig. 20. Safety Car Handling Rush Hour Traffic at the Indiana Steel Co. Terminal, Gary, Ind.

Equipment for Metropolitan Railways

On account of the lack of financial means for adding to their electrical equipment, there was little activity in the purchase of equipment for heavy city, subway and elevated lines. Orders were placed, however, for 600 more GE-248 railway motors for the Brooklyn Rapid Transit Company, making a total of approximately 1600 of these motors now in service. The Boston Elevated Railway Company is also putting in service 200 electro-pneumatic air brake equipments and has placed orders for 232 GE-259 motors with tapped fields for replacing motors of an obsolete type now in use.

Electric Locomotives

Aside from the five 265-ton passenger locomotives which were completed for the new Chicago, Milwaukee and St. Paul electrification,* there were also two 70-ton switchers for the same line, which are now in operation on the Rocky Mountain Division.

Work is nearing completion on the 50-ton, 1200-volt locomotives ordered some time ago for the South Manchurian Railway in China, and on four 60-ton, 1200-volt locomotives for the Cienfuegos, Palmira and Cruces Railway in Cuba.

Other locomotives under construction include seven 60-ton units for the Hershey Cuban Railway previously mentioned, and a 30-ton switching locomotive for Harlowton Mills at Lawrence Mass., and other industrial types.

Miscellaneous Railway Equipment

The power limiting and indicating system installed along the lines of the Chicago, Milwaukee and St. Paul electrification has shown interesting possibilities. By the use of this scheme, the Company has been able to maintain an unusually high load factor, thus securing very nearly the minimum power rate provided for in the contract with the Montana Power Company.

High-speed Circuit Breakers

The intensive study of methods to protect direct current machines, particularly the 60-cycle 600-volt synchronous converter, from flashing, was continued during 1919 with important results and there were developed three graduated forms of protection which will now give immunity under all operating conditions.

First, commutating poles of a high reluctance type with much stronger field windings than those previously used were designed, tested in service and adopted as standard. This insures ample protection where operating conditions are favorable.

Second, where greater protection is required the machines can be provided with a type of flash barrier which has fully demonstrated its value in railway service on lines where severe short circuits are of frequent occurrence.

Third, the highest degree of protection includes the use, with the foregoing, of a newly developed high speed circuit breaker (Fig. 21) which has fully demonstrated its value under tests of much greater severity than those imposed by the most unfavorable conditions encountered in actual service.

* See article by W. D. Bearce in December, 1919, GENERAL ELECTRIC REVIEW.

the many railway automatic substations in service has encouraged the development of other generating and substations along automatic lines.

An automatic hydro-electric generating station was developed for the Blue River Power Company at Seward, Neb. This plant consists of a 240-kv-a., 120-r.p.m., 60-cycle, 2400-volt waterwheel-driven generator, and three 80-kv-a., 24,000/2400-volt transformers, and is the first of several stations to be installed on this system.

A second installation is for the Ontario Power Company at Ontario, Cal. This consists of one 500-kv-a., 60-cycle generator direct-connected to a Pelton waterwheel. Instead of being entirely automatic this station is controlled by pilot wires from a manually operated station a few miles below on the same stream.

When the operator desires to start the remote controlled plant, he closes the control circuit, which opens the nozzle to the Pelton wheel. When the machine is up to speed, he synchronizes it and then increases the load to any desired amount by a further opening of the nozzle.

The machine can be shut down at the will of the operator by closing a second control circuit, but in case of necessity, due to overload or hot bearings, this generator will shut down automatically.

Fig. 23. Automatic Hydro-electric Generating Station, Iowa Railway & Light Company. General view showing three 60-cycle, 500-kv-a., 60-r.p.m., 2200-volt automatically-controlled generators

Automatic Distributing Stations

An automatic distributing station was developed for the Malden Electric Company, Malden, Mass. This substation equipment comprises one 3000-kv-a. transformer plant fed over one 22,000-volt line, with a second as a spare. It feeds three 3-phase feeder circuits and three single-phase feeder circuits which are controlled by automatic oil circuit breakers with a so-called notching relay.

This relay (Fig. 25) will close a circuit breaker if it has tripped out, and reclose it

Fig. 24. Temperature Relay, with Cover Removed, used for Protection against Hot Bearings in Automatic Generating Stations

if it trips out the second time within a brief period. If the short circuit has not cleared itself by this time and the circuit breaker trips out a third time, the circuit will remain open until the circuit has been cleared and the switch closed by an operator. Thus the notching relay automatically performs the usual duties of an operator when a switch is tripped out in a substation.

One of the 3-phase feeder circuits leads to several constant current series lighting transformers. The switch in this circuit is opened and closed by means of a Warren time clock, and in addition is under the control of the notching relay.

Radio Communication

It was demonstrated during the war that practically continuous day and night transoceanic radio service could be effectively maintained. It is now a matter of history that radio was largely used for communication