The New Passenger Locomotives

Of the Chicago, Milwaukee & St. Paul Railway

W. R. Stinemetz
Heavy Traction Division,
Westinghouse Electric & Mfg. Company

THE ten passenger engines which the Westinghouse Company is building for operation on the electrified section of the Chicago, Milwaukee & St. Paul Railway embody many novel features not existing in the present engines. They are the most powerful locomotives in passenger service, a single locomotive having capacity sufficient to haul a 950-ton train (12 coaches) over the entire mountain section at the same speeds as called for by the present schedules. The rating is 4000 horse-power for one hour, or 3200 horse-power in continuous operation, with a starting tractive effort of 112 000 pounds. The speed on level track will be about 56 miles per hour and about 25 miles per hour on the two percent grades.

One interesting characteristic which is desirable in passenger service, but which has not heretofore been attained with this type of electric locomotive, except at the expense of heavy rheostatic losses, is flexibility of running speeds.

Speed Regulation—These engines have nine running positions without rheostatic loss, ranging from 8 to 56 miles per hour, depending on the load. This feature affords greater flexibility in the manipulation of the train and is of value in governing the power load of the system during peak load conditions. It is accomplished by using six 1500 volt twin motors on the locomotive, arranged for three-speed combinations consisting of,—

Position 1—One set of six motors in series.
Position 2—Two sets of three motors in series.
Position 3—Three sets of two motors in series.

These combinations give one-third, two-thirds and full speed.

Two additional running speeds are obtained on each speed combination by means of inductive shunts on the main motor fields. This cuts down the current peaks, saves rheostatic losses and enables the power demand over varying profiles to be kept more nearly constant.

Twin Motors—The use of twin motors, as shown in Fig. 4, with quill drive, not only permits the most effective use of the space between the driving wheels, but also the use of two armatures, each wound for 750 volts and geared to the same quill, thereby obtaining the advantage of better commutating characteristics inherent with low voltage motors.

Low-Voltage Auxiliaries—The complication and hazard of high-voltage apparatus is minimized on these locomotives by the use of low-voltage auxiliaries. The motor of the motor-generator set used for train lighting and charging the storage battery is the only high-voltage apparatus among the auxiliaries. The resultant simplification secured by the use of low-voltage appliances decreases the complications of installation, maintenance and operation. Ordinary inspection can be carried on, including the functioning of all switches and auxiliaries, with complete absence of 3000 volt power inside the locomotive.

Regeneration—The use of regenerative control for holding trains when descending grades is such an important function in these locomotives that special arrangements have been perfected to secure positive operation of this feature over widely varying speeds. The same main motor combinations for motoring are used for regenerating except that the fields of the main motors are separately excited over a wide range by axle-driven generators. These are so connected with balancing resistances, that inherent stability in the motor characteristics during regeneration is assured, irrespective of whether the changes in line voltage are sudden or gradual.

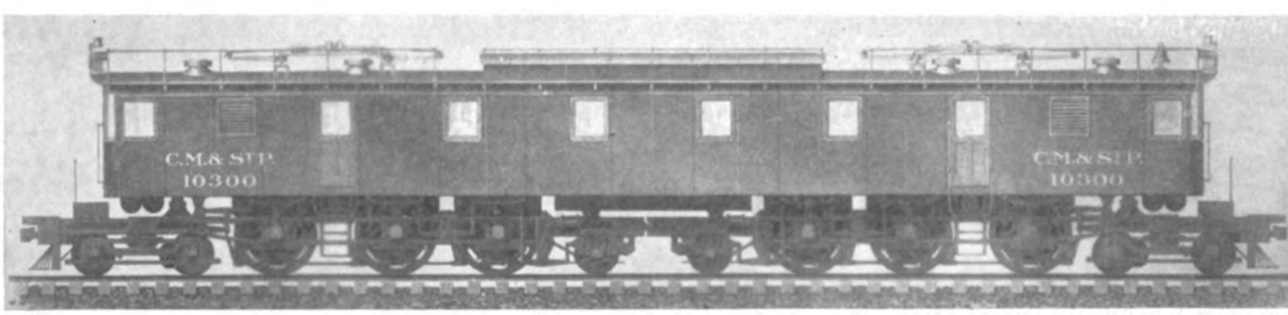

FIG. 1—THE NEW 4000 HP PASSENGER LOCOMOTIVE OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

Axle-Driven Generators—While the regenerative braking of trains lessens the duty on the air-brake equipment, further safety in braking with electric engines is introduced with the axle driven generators. These machines are mounted on the inside axles of the guiding trucks of the locomotive and, in addition to exciting the motors during regeneration, furnish the power for operating the air compressors and blower motors when the locomotive is hauling. This method insures a current supply to the air compressor motors irrespective of the overhead trolley supply, and the train can be taken down the heavy grades under control with power off the line.

Train Heating—Heat must be assured under any conditions of failure of other equipment or delays to trains. The heating plant therefore, is entirely independent of the electrification, each locomotive being equipped with an oil-fired boiler, designed to burn crude oil. Provision is made for a storage of 3600 gallons of water and 750 gallons of oil in each engine.

Center of Gravity—The center of gravity of the main running gear, including motors, will be 41.5 inches above the rails and the height of the center of gravity of the complete locomotive will be 63 inches above the rail, while the non-spring supported weight on any single driving wheel will be that of wheels, axles and driving boxes only.

FIG. 2—THE ELECTRIFIED SECTIONS OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

MECHANICAL FEATURES

Cab and Running Gear—One of the most noticeable features of the new locomotive is the concentration of all the auxiliary and control apparatus in a single cab. This emphasizes the modern tendency in design toward the conservation of weight and space for a maximum output of power. The cab is carried on two main running gears, each having a four-wheel guiding truck, three driving axles in a 16 ft. 9 in. rigid wheel base, and a two-wheel trailing truck. It thus corresponds to two Pacific type running gears coupled together and having two-wheel trucks on the adjacent ends.

The main running gear center pins are located midway between the first and second driving axles of each running gear. On one running gear the center pin is

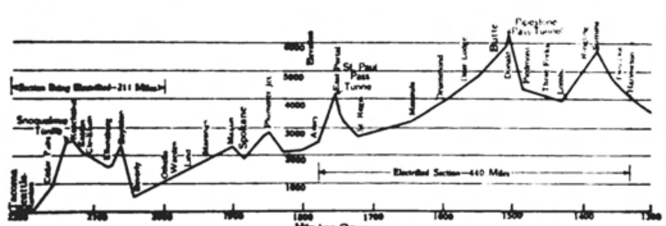

FIG. 3—PROFILE FROM HARLOWTON, MONTANA TO THE COAST

designed to restrain the cab both longitudinally and laterally, while on the other running gear the center pin restrains the cab only in the lateral direction, permitting free relative longitudinal movement. This arrangement of rigid and floating pins relieves the cab of all pulling and bumping strains, due to the train load, as these are taken directly through the running gear side frames and bumpers.

The driving wheels are 68 inches in diameter and carry 55 000 pounds per axle. The guiding trucks have 36 inch wheels and the two-wheel trucks each have a load of 39 000 pounds at the rail, with approximately 62 000 pounds distributed on each of the four-wheel trucks. The complete locomotive with a total length over coupling of 90 feet will weigh, ready for service, 266 tons, with an adhesive weight of 330 000 pounds.

Flexible Drive—The quill drive affords a means for permitting a motor located well above the road bed to drive an axle which, with its wheels, is free to follow the rail independently. It is evident that this drive secures all the advantages of a flexible gear in cushioning the transmittal of torque and avoids the road shock far more effectively than with the common flexible gear construction and mounting.

Equalization—Each main running gear is arranged with a three-point equalization with the single point to-

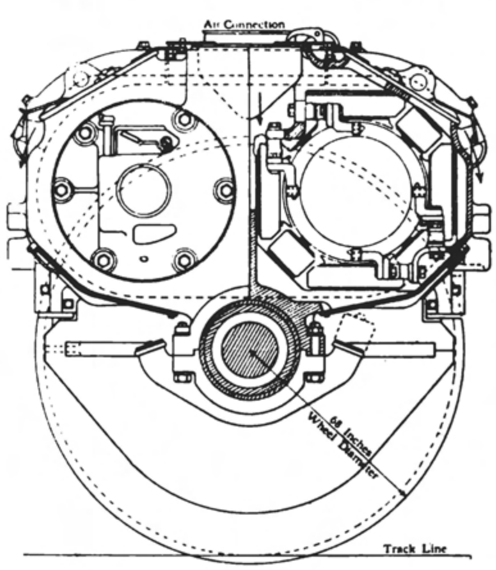

FIG. 4—CROSS-SECTION OF A TWIN MOTOR WITH QUILL DRIVE

ward the end of the locomotive, in accordance with accepted steam locomotive practice. The four-wheel guiding truck center pin and cross equalized leading pair of driving wheels are equalized together on the longitudinal center line of the locomotive. This arrangement combines all the advantages of the standard front end construction of the "American" and "Consolidation" types of steam locomotives. The two remaining pairs of driving wheels and the two trailing wheels of the main running gear are side equalized together again, following accepted steam locomotive practice.

A point of interest in electric locomotives, without connected wheels, is the result of weight transfer due to tractive effort. This is caused by the drawbar pull being exerted at the coupler height which, with the reaction at the rail, tends to lift the leading end and depress the trailing end. This changes the weight distribution and increases the tendency to slip. The method of equalization described reduces the weight variation on the driving wheels to only six percent from normal when pulling at thirty percent adhesion. The careful attention given to the details of design and operation insures that these new engines will mark an epoch in the advancement of the design of electric locomotives for steam railroad passenger service.

Factors that Determine Maximum Rating

Of a Direct-Current Machine for a Given Speed

F. T. Hague

THERE are two principal limitations to the output of direct-current machines, depending upon whether the limitation is first reached in heating or in commutating capacity. For continuously rated machines, this classification is usually determined on the basis of speed; low-speed machines being invariably limited in continuous capacity by heating, while high-speed machines usually find their limitation in commutating capacity. In this latter class are high-speed motor and reduction-gear-driven generators, high-speed, low-voltage electrolytic generators, and similar machines. Machines adapted to abnormal duty cycles of high peak and continuous load capacity have their limitations fixed by the relative magnitude of these two factors. Reversing rolling mill motors represent a type requiring extreme peak load capacities, and they are usually rated in terms of their peak load capacities, as fixed by commutation limits, the temperature limitation being usually well above the required continuous capacity. Non-reversing units may have relatively lower peak loads and higher continuous loads, so that heating may gradually become the predominating limitation in this case. The dividing line in these types of machines is usually disassociated from speed conditions, and fixed by load and service conditions.

Even though the output of high-speed machines may be limited by commutation, this does not necessarily imply that they are rated with less margin of safety than lower-speed machines, although this margin may be of a different character. High-speed machines have the advantage of the most favorable electric and magnetic design proportions, the best grades of materials and the most accurate adjustments. Direct-current machines are built to commutate satisfactorily at definite maximum ratings, which are the bases of guarantees. The relation of this maximum rating to the normal load rating is different for different types of service, and is a partial measure of a machine's margin in operation. For instance, gear-driven sets carry 25 percent overload for two hours, motor-driven sets 50 percent. for two hours, railway type generators carry from 100 to 200 percent overload for a few minutes, while mill motors carry peaks of four to six times full-load at definite short intervals. When it is stated that a machine's output is limited by commutation, it is evident that this limitation is first encountered at its maximum loads, and may be practically no indication of the machine's ability to carry its normal load with satisfactory commutation. Any high-speed machine, regardless of all other meritorious features it may possess, must have its rating determined by its ability to commutate successfully. High efficiency, low temperature rise, and low first cost, are important factors but they cannot outweigh bad operation at the commutator.

Since commutator operation must be a criterion of rating of large high-speed machines, any method of determining the maximum capacity, which it is possible to build at any given speed, must be predicated upon certain assumed design and operating limitations. These limitations are fixed by commutating conditions, and are true limitations only to the extent that they are fixed in conformity with the experience acquired through the building, testing and operation of many machines in various classes of service over a long period of years. Improvements in mechanical and electrical designs, development of new manufacturing processes, improvements in grades of materials, etc., are vital factors, constantly tending toward the extension of these various limitations, so that they are not permanently fixed. Thus some of the limitations in present practice differ radically from those of ten years ago, and it is to be expected that, as improvements demonstrate their efficiency and become incorporated in designs (as commutating poles have done in all classes of power machines, and as compensating pole face windings are doing in certain special lines of machines), still further and perhaps more radical improvements and extensions will be made.

An evident condition is that any one arbitrary set of limitations cannot be equally applicable to all high-speed machines of various voltage classes and different service applications. In each particular voltage class, and in each type of service application, there are a few special limitations which are of fundamental importance. For instance, in 250 volt machines, flashing practically takes care of itself, and the principal problems are commutation, brush rigging and mechanical commutator design suitable for handling the large currents involved. In the 600 volt class machines, all design limitations are met under favorable conditions and there is no one all important limitation. This favorable condition permits the building of the largest possi-