is $11 \times 2.5 \div 16 = 1.72$ foot-tons. On some of the railways which adopt this type train for the calculation of the bridges the heaviest rail in use is 85 lb. per lineal yard, having a moment of inertia about the neutral axis of 27 inch units and the neutral axis 2.67in. from the base of the rail. The maximum stress therefore under live load only is $61.9 \times 2.67 \div 27 = 6.12$ tons per square inch, or, adding the allowance for impact, which in this case would be 100 per cent., 12.14 tons per square inch. This is under ideal conditions supposing all the sleepers to be equally packed. In practice this stress would often be exceeded if the type engine were actually put in service, and, according to investigations made by the author, involving the observation of the maximum depression of sleepers under heavy six-coupled and four-coupled engines, this stress is actually exceeded in practice. With these engines the rails distribute axle loads approximating 20 tons over three or four sleepers, resulting in high stresses in the rails.

Admittedly the breaking stress of rail steel is higher than that of the mild steel generally used for bridge construction; but the higher breaking stress results from the hardening of the steel, which does not permit a material to be used, as regards its tensile strength, with a low factor of safety. As a broken rail would be quite as likely to cause an accident as the failure of a small culvert, there is no reason for adopting such a much lower working stress for the covering to the culvert than for the rail.

Mr. Waddel, in his "De Pontibus," claims that the impact system of calculation is the only rational one, *even if the allowances are wrong*, as it carries the allowance for impact into every detail and rivet of the bridge, whereas the variable unit stress method does not. This is not strictly true, because it has been quite a common practice in this country to vary other unit stresses than the tensile stress, adopting, for instance, two-thirds of the tensile stress for the shear stress in rivets and one and a-half times the tensile stress for their bearing resistance. It is questionable whether there is any need to carry the effect of impact into the masonry or brickwork of piers and abutments and their foundations, and in any case it would mean the revision of the unit stresses commonly adopted in the design of these.

The results of British practice would seem to show that a fair allowance for impact would be as follows:—About 45 per cent. for very small spans, decreasing to 30 per cent. for 100ft. spans and 20 per cent. for 200ft. spans. The allowance for all bridges constructed with jack arch or concrete floors to be reduced to 20 per cent. The unit tensile stress in all cases to be 7.15 tons per square inch. These allowances could be more conveniently indicated in a table than by a formula, and for spans up to 100ft. are indicated in Fig. 3 by the dotted line.

It is to be noted that the type trains adopted for calculation purposes in American practice exceed the heaviest engines running by a far greater margin than it is usual to allow in this country. In some cases the type train gives equivalent distributed loads 50 per cent. higher than the equivalent loads corresponding to the heaviest engines on the line. As, however, the American and Canadian construction gauges will permit of a considerable increase in the size of locomotives, whereas the heaviest engines in this country approximate very closely to the loading gauge, leaving, for instance, hardly any room for a funnel, there is reason in making more provision for future increase of weight.

One cannot help thinking that the desire to facilitate the design of really big bridges has had something to do with the development of the impact system of calculation, and if these high moving loads are made the excuse for adopting a higher unit stress than, say, seven and a-half tons per square inch, there is a danger in really large spans where the live load is negligible and the allowance for impact nil, that the actual working stress, although produced by a steady load, may be too high, leaving an insufficient factor of safety to cover those deficiencies of workmanship and material and accidental stresses due to unforeseen circumstances which do not figure in the calculations.

THE CHICAGO, MILWAUKEE, AND ST. PAUL ELECTRIC LOCOMOTIVES.

THE electric locomotives being built by the General Electric Company of America for the Chicago, Milwaukee and St. Paul Railway are, as our readers know, exceptional machines. They are larger than any other engines so far constructed, and another novel feature is that they have been designed for continuous-current regenerative control. Notwithstanding that the pressure is 3000 volts, the large capacity involves collecting heavy currents, with the result that they are being fitted with special collectors. We described the main features not long ago, but in a recent article in the *Electric Railway Journal* Mr. A. H. Armstrong gives some further particulars. An exhaustive series of tests have just been made on the first sample motor, built at the Schenectady Works, which have demonstrated that it has ample capacity to meet the heavy demands that will be placed upon it under actual operating conditions.

The motors are wound for 1500 volts and two are connected in series. Power is transmitted from the motors to the axles through twin gears, the arrangement corresponding to that employed on the Great Northern, Detroit Tunnel, Baltimore and Ohio, and Butte, Anaconda and Pacific Railways, except that springs are used in the axle gears. On account of the high voltage for which the motors are wound, the commutator width is small, thus allowing more space for armature iron and copper, with the result that each motor has a continuous capacity of 375 horse-power. This is the first instance where such a liberal motor capacity has been required and provided for, and the large capacity has been secured in an axle motor without departing from well-known and thoroughly tested forms of construction.

In the table below the leading particulars of the engines are given:—

Length over all	112ft.
Total wheel base	103ft.
Rigid wheel base	10ft. 6in.
Total weight	520,000 lb.
Weight on drivers	400,000 lb.
Weight on driving axle	50,000 lb.
Weight on guiding axle	30,000 lb.
Diameter of driving wheel	52in.
Diameter of guiding wheel	36in.
Number of driving motors	8
Total output, continuous rating	3000 horse-power
Total output, one hour rating	3430 horse-power
Tractive effort, continuous rating	71,000 lb.
Per cent. weight on drivers	17.75
Speed at the above tractive effort	15.75 miles per hour
Tractive effort (one hour rating)	85,000 lb.
Per cent. weight upon drivers	21.2
Speed at this tractive effort at 3000 volts	15.25 miles per hour

A study of the train dispatcher's sheet covering performance on mountain gradient divisions on American railways reveals the fact that in general it is customary to assign such a trailing tonnage to a locomotive on the ruling gradient as to demand a tractive effort at the driven rims equivalent to approximately 18 to 19 per cent. of the weight upon the drivers. In other words, steam practice calls for a locomotive which can operate for long periods with a coefficient of 18 to 19 per cent., leaving the difference between this value and the slipping point of the drivers as a sufficient margin with which to start on ruling gradients. Under similar track conditions the uniform torque of the electric locomotive should make available some 10 per cent. more tractive effort than is possible with the reciprocating drive of a steam engine having the same weight upon the drivers. But until sufficient operating experience is available to prove that an electric locomotive can be rated at 20 per cent. coefficient of adhesion, it seems reasonable to adhere to the present steam practice.

The goods locomotives are guaranteed to have a hauling capacity of 2500 tons trailing load on all gradients up to 1 per cent., and their heaviest duty will be to haul this

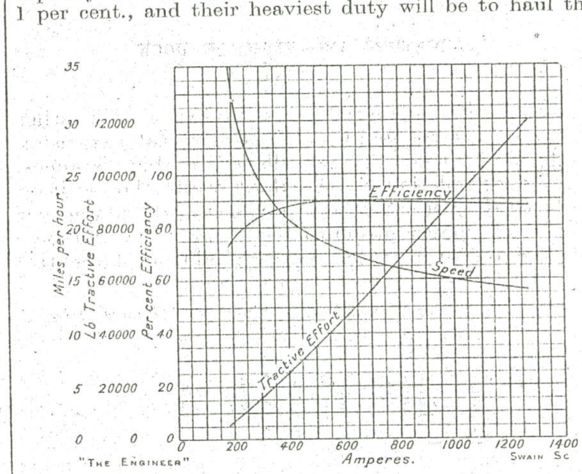

Fig. 2—CHARACTERISTIC CURVES

load from Lombard to Summit over the Belt Mountains, a distance of 49 miles, with a ruling gradient of 1 per cent. and an average gradient of .7 per cent over the entire distance. Including the locomotive—260 short tons—the gross train weight of 2760 short tons will require a tractive effort of about 72,000 lb. on the 1 per cent. ruling gradient, based upon a train resistance of 6 lb. per ton. This practice corresponds to the continuous rating of the locomotive, and brings out the interesting fact that these locomotives are so proportioned as to motor capacity that they cannot be overloaded under normal service conditions. The necessity of rating main line electric locomotives upon a practically continuous basis is still further emphasised in the case of the St. Paul engines by the introduction of regenerative braking. The heavy demands upon the motors is intensified by the introduction of regenerative braking. The heavy load upon the motors when operating on the up gradients may be nearly duplicated during the following down gradient when regenerating. A 2 per cent. gradient requires a motor output of 46 lb. per ton on the up gradient, and gives 34 lb. per ton on the down gradient. Making due allowance for internal locomotive losses, it is evident that the motor output when operating as a generator will approximate 60 per cent. of its input when hauling the same train up a 2 per cent. gradient. Hence the need of making provision for a practically continuous motor capacity.

It is interesting to compare the relative capacity of the new electric locomotives with the Mallet engines which they will replace—see Fig. 1. The following table gives the leading details of the two types of engines:—

	Mallet.	Electric.
Total weight	555,700 lb.	520,000 lb.
Weight on drivers	324,500 lb.	400,000 lb.
Rated tractive effort	76,200 lb.	85,000 lb.
Per cent. weight on drivers	23.5 per cent.	21.2 per cent.
Rated tonnage (1 per cent. gradient)	1800 tons	2500 tons
Tractive effort for above tonnage	54,000 lb.	71,700 lb.
Coefficient of adhesion	16.7 per cent.	17.7 per cent.
Wheels per guiding truck	Two	Four
Weight per axle	54,000 lb.	50,000 lb.
Total weight on one rigid wheel base truck	162,000 lb.	100,000 lb.

Under favourable conditions the Mallet engine can haul 2000 tons on a 1 per cent. gradient, thus bringing its tractive effort up to 59,000 lb. and the coefficient of adhesion on its drivers up to 18.3 per cent. The electric locomotive weighs 94 per cent. of the combined Mallet engine and tender, and has a tonnage rating 23½ per cent. greater, based upon the same coefficient of adhesion in each case, that is, 17.9 per cent. This comparison indicates that the electric locomotive has a hauling

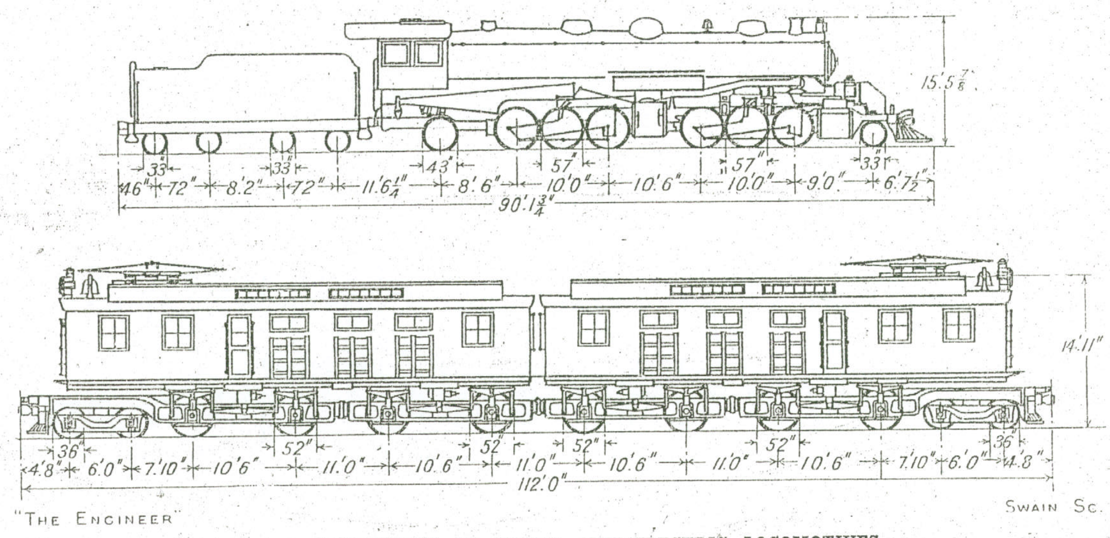

Fig. 1—COMPARISON OF STEAM AND ELECTRIC LOCOMOTIVES

capacity one-third greater than the steam engine and tender of the same total weight, has less weight per axle, and is provided with a four-wheel guiding truck in place of a two-wheel truck; requires no turntable, as it operates equally well in either direction, and eliminates the necessity for stopping to take on coal and water.

The same type of locomotive is used for goods and passenger service, the only difference between the two being the gear ratio, which is 4.56 for the goods engines and 2.45 for those intended for passenger service. In order to facilitate repairs the locomotives are being built in two halves, and each half can be provided with draught gear in place of the articulated joint and operated without the other half. One passenger locomotive will haul a trailing load of 800 tons over all gradients on the line without assistance, except upon the 2 per cent. gradient section over the main divide of the Rocky Mountains. Even on this gradient a 600-ton train can be hauled without assistance. This illustrates the exacting nature of the line, which demands that the passenger locomotives shall have the necessary motor capacity and smooth-running qualities successfully to haul an 800-ton train at 60 miles per hour on level track and also operate at over 20 miles per hour on the 2 per cent. up gradient. The conditions are made still more arduous by the electric braking and the provision of steam heaters for heating the train. Each engine is to be fitted with two oil-fired steam heaters, together with ample provision for the storage of oil and water.

As a result of numerous tests made on the test tracks at Schenectady and Erie, a new type of current collector is to be used. These tests indicate that a double-pan collector bearing against twin trolley wires is capable of taking off 2000 ampères at speeds as high as 60 miles per hour. This is several times the demand upon the collector which will be employed on the St. Paul locomotives. In designing the control gear provision has been made for enabling two locomotives to run together and to be operated on the multiple-unit system. But the enormous starting effort of two such locomotives—240,000 lb. at 30 per cent. coefficient of adhesion—makes such a combination of use only when it is employed on engines pushing at the rear of a train. The motors and starting resistances are designed to permit of a starting effort of 120,000 lb. being maintained on one locomotive for a period of five minutes without destructive heating.

The first locomotive will probably be placed upon the test tracks at Erie during September, and shipment will commence soon afterwards. The work on the overhead equipment and sub-stations on the first engine division between Three Forks and Deer Lodge will probably be finished and ready for the locomotives as soon as they are received. In Fig. 2 characteristic curves of one of the motors are given.

THE Highland Railway Company closed on the 7th inst. the Keith and Buckie branch line, including the stations of Buckie, Rathven, Drybridge, Enzie and Aultmore. Through traffic from the coast line will not be interfered with, as passengers going east can go through Cullen and Portsoy and those going west through Fochabers-on-Spey and Elgin. Mr. Park, the general manager, has told a protesting local authority that the branch has been closed because of a scarcity of locomotive power, and that unless the southern companies send help in the shape of locomotives and men other branches will have to be closed.