All Steel Passenger Cars

Pennsylvania Railroad

First Installment

THE Pennsylvania Railroad has ordered the construction this year of 200 all-steel cars for its passenger equipment. The company has gone further in the direction of the use of steel than has hitherto been attempted, and the order now placed is also the largest yet given for this class of equipment. The Pennsylvania's policy in this respect is the result of a long period of inquiry and experiment, in which the late President Cassatt took an active part. After several cars had been built the president appointed a committee of motive power officials to make a thorough report on the design to be adopted and the orders just placed are in accordance with the recommendations of that committee.

The demand for passenger cars which would be stronger and better able to meet the severe conditions of service, has led to the consideration of other materials than wood for their construction.

Growing scarcity of suitable timber and its rapidly increasing price have played an important part in the development, for wooden cars will soon cost as much as those of non-combustible materials.

For several years passenger cars have been continually made stronger and heavier, with a view of decreasing the cost of maintenance and of rendering them less subject to damage in event of accident. This increase in strength was finally obtained largely by means of steel reinforcement at the platforms and in those parts affected by the pulling and buffing strains.

The next stage in the natural development was in the use of an underframe built entirely of steel. Freight car construction had passed through the same stage only a few years before, and experience derived from this source was available for use in designing passenger equipment.

In selecting the materials for a non-inflammable car there is not a long list to choose from. For the frame, structural portions, and outside sheathing, steel is the only suitable material.

For the inner lining, with which the passengers come into contact, steel possesses the necessary mechanical strength and can be worked up into the innumerable forms required. It does not, however, lend itself easily to artistic decorations, as in the case with wood. Sheets of composite material made by compressing vegetable pulp or asbestos are excellent non-conductors of heat and sound, but some kinds are not fireproof and none possesses sufficient mechanical strength to warrant its general use as a material for bulkheads and inside lining. For head lining these materials have been found very satisfactory, as they are not subjected to great wear or mechanical injury. Sheet steel with a fibre or asbestos board cemented to its unexposed surface has been adopted for inside lining, as this combination possesses most of the necessary properties.

Coverings used in upholstery as well as carpets for the floors may be treated chemically to render them non-inflammable.

For the floor, corrugated sheet steel plates, covered with any one of several cement mixtures, have given very satisfactory results.

Paints used in interior decorations are of a composition which will not produce smoke, or noxious fumes if subjected to heat.

As a structural material, steel possesses distinct advantage over wood. Wood must be used with reference to the direction of its grain, and at joints as well as in tension elements, steel reinforcement is nearly always necessary. Steel on the contrary can be flanged, shaped, or jointed to meet almost any condition. The art of steel car construction is a new and developing one, and designs made in Altoona were not obtained by laboriously substituting a metal part for each piece of a wooden car. Conditions were accurately analyzed and structures designed to meet them, regardless of whether the result had the same general form as the wooden parts which it superseded.

In the development of steel passenger cars the Pennsylvania Railroad has from the first played an important part. When steel cars were proposed for use in the New York Subway, none of the car builders in the country was in a position to furnish them, so it came about that the first motor car was built at Altoona in 1902.

In 1904 designs were made for a 58-foot passenger coach, which had a steel underframe and a steel outside sheathing up to the roof. The interior finish was largely of composite board and the roof was of wood covered with copper. One car of this type was built, but as it contained about 1,500 pounds of wood further development of the designs was considered necessary.

The next was a 60-foot baggage car, completed in November, 1906, and closely followed by a 70-foot mail car turned out in February, 1907. In the two latter cars an infinitesimal amount of wood was used.

Designs are now prepared for a 70-foot dining car, also for a 70-foot passenger coach. The latter car contains but 300 lbs. of wood (used for brake rod guards, window sash, and arm rests for the seats). The interior finish is of steel except the headlining, which is of composite board. Designs are being completed for a Suburban type car, 54 feet 4 inches long.

After carefully considering the problem from all sides, the Pennsylvania Railroad Company has decided to adopt two types of steel passenger equipment:

(*A*) For through trains; drawn by a steam or electric locomotive, and comprised of mail, baggage, sleeping, dining or day coaches; a long car of heavy construction suited to withstand the strain incident to pulling, coupling, or buffing long trains.

(*B*) For suburban trains; drawn by a locomotive or propelled by motors upon the truck axles; a short car of lighter construction well suited to operation in frequent short trains to accommodate the traffic.

The general dimensions of the equipment is given in the following table:

Passenger Coach—Length, 70 ft. 5¾ in.; weight, 113,500 lbs.; capacity, 88 persons; trucks, 4 wheel.

Mail Car—Length, 71 ft. 4⅛ in.; weight, 128,000 lbs.; trucks, 6 wheel.

Baggage and Express Car—Length, 60 ft. 10⅛ in.; weight, 91,000 lbs.; capacity, 40,000 lbs.; trucks, 4 wheel.

Special Express Car—Length, 70 ft.; weight, 120,000 lbs.; capacity, 60,000 lbs.; trucks, 6 wheel.

Passenger-Baggage—Length, 71 ft. 1 in.; weight, 130,000 lbs.; trucks, 6 wheel.

Dining Car—Length, 71 ft. 11¾ in.; weight, 140,000 lbs.; capacity, 30 people; trucks, 6 wheel.

Suburban Car—Length, 54 ft. 4 in.; weight, 75,000 lbs.; capacity, 70 people; trucks, 4 wheel.

Comb. Suburban Car—Length, 54 ft. 4 in.; weight, 75,000 lbs.; trucks, 4 wheel.

DESIGN AND CONSTRUCTION.

In preparing the designs for heavy type equipment great care has been exercised to provide ample strength to resist end shock of buffing or collision. Standard steel freight cars are designed to resist an end shock equivalent to 300,000 pounds compression. Experience with freight cars during the last five years indicated that this is not excessively high. An experimental determination of this figure was made by allowing a dynamometer car, weighing 51,000 pounds, to bump a number of loaded freight cars standing upon the track. The dynamometer registered 607,000 pounds. Another experiment was made by allowing a loaded steel freight car and the dynamometer car, weighing together 181,400 pounds, to bump a loaded freight car standing on the track. The dynamometer recoreded 400,000 pounds. Impact, of course, cannot be measured in pounds, but the results give a general idea of the conditions of actual service. In collision between passenger and freight cars it is desirable that the passenger car should be the stronger in order to escape with as little injury as possible.

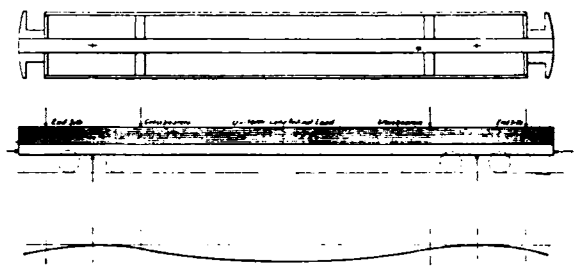
In computing loads upon the various members of the frame, it has been decided that a compression load of 250,000 pounds between buffers, also 150,000 pounds between draft gear, is to be added to the normal loads due to the weight of the car and lading. Under these conditions the combined fibre stress is limited to 12,500 pounds per square inch for cars in through train service and 20,000 pounds per square inch for cars in suburban service. In determining these stresses none of the material above the belt rail is included. The sides of the cars beneath the window sills form girders about three feet deep, for which the belt rail acts as the top flange and the outside sill, the bottom flange. Owing to their great length, the thinness of the web, and the comparative shallowness of the flanges, these girders would probably collapse if subjected to end thrust. In calculations, therefore, the web and upper flange are not considered as resisting any of the 400,000 pounds load assumed to represent the effect of buffing.

The superstructure of cars is made strong enough so that they can roll completely over without danger of collapse. Posts, carlines and other parts are proportioned under this assumption.

Ends of cars are framed with the idea of preventing one car from sweeping off the superstructure of the next one, when the under frame of one rises above the floor of the other in a collision. Deck or I-beams forming a frame about the end door, and securely fastened to both underframe and roof are proportioned with this idea in view.

In the design of framing for steel cars two general types have been developed. One, in which the center sill is made strong enough to resist the end loads developed by pulling and buffing, in addition to the transverse loads due to the weight of underframe, superstructure and lading. The other type, in which the plate girders formed by the sides of the car beneath the windows, are relied upon to carry the transverse load due to the weight of the underframe, superstructure and lading.

The center sill in the latter type is usually rather light,



CAR LOAD DIAGRAM—ALL STEEL PASSENGER CARS—PENNSYLVANIA R. R.

being designed to resist the end loads developed by ordinary pulling and light buffing. This type of framing follows the general form used in wooden cars where the transverse loads are carried by wooden trusses within the sides of the car reinforced by truss rods beneath the side sills.

By careful calculation it has been found that when the loads due to pulling and buffing are less than 100,000 pounds, the weight and cost of a car frame of either type will be practically the same. Where loads due to pulling and buffing exceed 100,000 pounds, the framing for the type, where the sides carry the load, increases considerably in weight. While for the center sill type, the loads due to pulling and buffing may equal the assumed value of 400,000 pounds without a material increase in weight.

For through train service subjected to heavy buffing and pulling, the center sill type of frame has been selected. It has also been used in designs for suburban type equipment, as it has been found that, with a modified form of center sill, sufficient room for motors can be provided between the under frame and truck.

The height from the track to the center of coupler is determined by law and the height to the top of the floor is practically regulated by custom. The center of the drawbar is therefore fixed at about 17 inches below the floor.

In wooden car construction the center sills are usually rather shallow and the coupler is supported below them. Loads upon the underframe, brought about by buffing, tend to bend down the ends of the car due to the fact that the center sills are not symmetrically loaded. In the steel car of the through train type, the center sill is made deep enough to bring the line of the coupler within its section.

With the heavy center sill frame, body bolsters used in wooden car construction are unnecessary, for the major part of the transverse load it delivered directly to the center sill which transmits it to the trucks through center plates carried on its under surface. The transverse loads which come upon the sides of the car and which must be transferred to the center girder are delivered at four points to equalize the loading. Referring to the accompanying illustration the center sill is a continuous girder, supported at two points and loaded with a practically uniform longitudinal load, which it carries directly, together with four transverse loads delivered to it from the sides of the car through cross bearers and body ends. The points of application of the concentrated loads are so selected, that the two loads at each end are about equidistant from the center plate. Under this condition it has been possible to obtain in the center sill practically equal fibre stress at the middle and over the center plates, thereby securing great economy in metal and avoiding the use of a center sill of deeper cross section at the middle than over the trucks. Symmetrical loading of the center sill gives a deflection under load indicated by line. Each of the four points is deflected practically the same amount. They therefore are always in line with one another and no load is placed upon the superstructure of the car by the deflection of the center sill. With the comparatively thin sheet metal used in sheathing the sides and roof it is of great importance to avoid unnecessary loading, as it is likely to cause loosening of the joints and working of the rivets in their holes. With this form of construction the side girders can be made comparatively light as they sustain little transverse load and are supported at four points. Side doors required by mail, express, or baggage cars can be located where most convenient without requiring any material strengthening in the side truss.

The following table gives the comparative strength and weight of steel and wooden cars:

	Standard Wooden Passenger Coach 53 ft. long	Heavy type Steel Passenger Coach 70 ft. long	Suburban Steel Passenger Coach 54 ft. long
Number of passengers	62	88	72
Car weight, pounds	91,000	*113,500	*75,000
Car weight, per passenger, lbs.	1,470	1,290	1,042
Area centre sill at middle of car, square inches	152	50	24.32
Area centre sill at centre plate of car, square inches	152	50	33.32
Stress in centre sills due to 150,000 lbs. compression on draft gear and 250,000 on buffer; lbs. per square in.	10,850	11,000	18,500
Comparative values of centre sills, per cent	25	100	60

* Estimated weight.

In the next issue, the details of design and construction of the various types of cars will be considered.

Tractive Force of the Mallet Compound Locomotive

By. T. F. Crawford, Engineer of Tests, Great Northern Ry.

TRACTIVE force, as an expression of the power which should be developed by a locomotive in hauling trains, is one of the most important items in locomotive operation. It is the fundamental basis for all locomotive comparison and tonnage rating, as it represents the actual work locomotives should perform.

Practical formulas for tractive force have been reduced and readjusted until we have an extremely accurate means for telling just what draw bar performance may be expected from a locomotive of any given size on any grade and under all conditions. This applies to simple engines and compounds of all types, except the Mallet articulated compound. The Mallet engine has not been extensively used in this country; and so far but few practical demonstrations have been made of its pulling power and consequently there still remains some question as to the proper formula to use in calculating the tractive force.

A compound of the Mallet type in which the steam is used to operate two independent engines under the same boiler, is somewhat similar to the cross-compound, considering each side independent. In the cross-compound however, it is essential that the work done by each cylinder be the same, owing to the fact that they each operate on the same pair of drivers. With the Mallet engines this feature is not absolutely necessary, for the power can be designed to suit the weight on drivers both front and back. In the existing types however, the work done by each engine is supposed to be equal. There is also the consideration of a long receiver and the fact that two high pressure cylinders exhaust into, and two low pressure cylinders receive their steam from the same pipe. Actual tests made with the two cylinder compound cannot be thoretically applied to the Mallet type of engine, although it is fair to assume that the results should not differ to any great extent.

The Baldwin Locomotive Works gives the formula for the tractive force of two cylinder compound, assuming that cylinder ratio is correct for an equal distribution of work:

$$T. F. = \frac{C^2 \times S \times 2/3\ P}{D}$$

Where C=Diameter high pressure cylinder.
" S=Length of stroke.
" P=Boiler pressure.
" D=Diameter of drivers.

For the Mallet compounds they simply double this and write,

$$\text{(a)}\quad T. F. = \frac{C^2 \times S \times 4/3\ P}{D}$$