example is rather high and the live load is considered to be 66,000 lbs., which is considerably above the actual requirements for a baggage car or a mail car. The United States Railway Mail Service Department specification for a steel full postal car specifies a maximum of 50,000 lbs. live load. The bending moment in a 74 passenger car is less than in the above example. It can, therefore, be assumed that if an underframe is designed to withstand a bending moment of approximately 5,900,000 in. lbs. and an end shock of 400,000 lbs. it will be suitable for all classes of passenger cars.

The stresses imposed upon the underframe from end shocks must be dealt with separately. The underframe must be considered as a column and both direct and eccentric forces must be considered and for members in compression the stresses must be reduced in accordance with usual engineering practice. The American Railway Engineering Association has adopted an empirical formula reading as follows:—

$$16000 - 70\frac{L}{R}$$

which has been approved by the U. S. A. Mail Service Department and allowed 20 per cent. greater fibre stresses than arrived at by using the above formula.

The above requirements for the underframe could easily be satisfied if the car designer could change the construction to suit the conditions, but unfortunately a number of standards are established which the car designed cannot change, such as truck height, coupler and buffer heights and the general clearance dimensions of cars. The car designer has, therefore, to compromise and be satisfied with a design which as closely as possible comes up to an ideal construction when considered from an engineering standpoint.

The sections shown in figs. 2 and 3 satisfy the requirements for a modern underframe in relation to load and end shocks. It will be observed from the respective figures that the extreme fibre stresses come well below the required limits of the U. S. A. Mail Service specification for all steel full mail cars, which is used as a foundation for all passenger car designs of today. The underframe considered in this example is probably not the most economical construction, for all designs but I have endeavored to give due attention to the construction from a maintenance standpoint, and not employed any section with less thickness than ⅜ in., in order to provide ample bearing value for all rivets and to give reasonable allowance for deterioration, and an attempt has been made to reduce the number of different sizes of material so it will be noted that the size of centre sill cover plates and centre sill web plates are all the same. All angles employed are also of one size. All plates are ⅜ in., so that the majority of details required can be obtained from the scrap cut from centre sills. The object, however, when analyzing the above underframe is not to produce an ideal design, but to show what a complex problem a car designer has to contend with.

End Framing.—It is necessary to have a substantial end frame to prevent telescoping, particularly if an efficient anti telescoping device is not employed. An end framing built in accordance with U. S. A. Mail Service Department specifications which calls for a section modulus for vertical end members not to be less than 65, of which 75 per cent. must be concentrated in the door posts and posts adjacent to door posts and the entire framing well secured offers a very good construction which is amply strong.

Side Framing.—To prove that the superstructure of a wooden car is equally as strong as the steel construction of a steel car, I will compare the side posts in wood and steel cars. Fig. 4 shows a standard section of a wood post and fig. 5 shows a typical design of a steel post for steel cars. For comparison of strength of the two posts, as shown in figs. 4 and 5 consider the ultimate strength of ash to be 12,000 lbs. per sq. in. and 60,000 lbs. per sq. in. for steel; in other words, the steel to be five times as strong as ash, when these materials are subject to bending. In order to get expression as to strength for side posts, I wish to refer to the U. S. A. Post Office Department's specification for the construction of steel full postal cars, which reads as follows:—

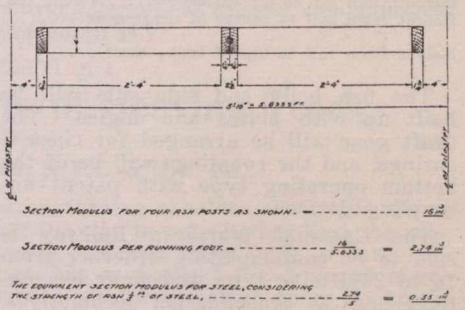

Figure 4.

"The sum of the section moduli taken at any horizontal section between floor line and top line of windows, of all posts and braces on each side of car, located between end posts, shall not be less than 0.30 multiplied by the distance in feet between the centre of end panels, a panel length being considered as the distance between lines of rivets in adjacent vertical post."

The quoted paragraph will probably be clearer to us if we reconstruct it to read as follows:—"The average section moduli on each side of car for side posts must not be less than 0.30 per running foot."

We will now consider one section of one side in a standard railway car, now being largely used, the section being from

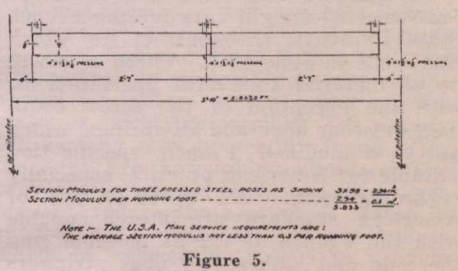

Figure 5.

centre to centre of pilaster, which includes lower windows with gothic above. The length of such section in a railway car is, on an average, 5 ft. 6 ins., or 5.8333 ft. The number of posts in 5.8333 ft. section is 4 for wood cars, 2 narrow and 2 wide, and 3 for steel cars. Referring to figures 4 and 5 we note that comparative section modulus for steel is 0.5 and for wood 0.55, the wood posts being 10 per cent. stronger than the steel post. Both constructions, however, meet the U. S. A. Mail Service requirements. This comparison shows that, as far as the strength of the side of a wooden car, when considered perpendicular to its side, which is vital in case of wreck, is at least in some instances stronger than a steel car. I wish, however, to make it plain that no claim is made to the superiority of the side framing in a wooden car over a steel car, considering same as a carrying member or truss. A combination of wood and steel for side framing seems to me to be most practical.

Roof.—No one familiar with car construction and maintenance of cars will deny that the canvas roof, properly laid, gives remarkably good service; in fact, it will outlast the car if given reasonable care. When I say canvas properly laid, I consider it properly laid when it is applied in the same manner as the practice in shipbuilding, when laying canvas on the cabin roof, which lasts almost indefinitely if not abused. The steel roof, on the other hand, has not, up to the present, proved a success. Steel roofs having vertical expansion joint, about 1¼ in. in height soon wear out on account of the abrasive action of cinders. The deck screens in an all steel car are objectionable on account of pockets being formed behind the screen, in which gases, moisture and cinders collect which destroy the paint and in a short time a serious corrosion takes place, which cannot be detected before a car is sent to the shops for general repair. A steel car roof must be frequently painted, and it cannot be done with a canvas roof, if the regular "shopping" period for any reason is prolonged. In connection with the canvas roof it is understood that wood roof framing is properly constructed and tied together at frequent intervals with steel carline which should extend in one piece from side plate to side plate, to which they should be firmly secured.

The inside finish in all steel car is hard to restore to its original appearance, in case it must be touched up at isolated places, where the paint has been scratched, worn or peeled off. Wooden cars having stained and polished wood finish, can easily be restored to their original appearance in case the finish should be damaged.

In summing up I realize that I have only outlined passenger car design in a very general way, but I have tried to show what I believe to be the best design of car, looking from every angle, namely, economical from a railway, and safety and comfort from the travelling public standpoint, and to put this in a concise form, I believe that in designing a car for present use the following are the principle points:—

1. A steel underframe which will take care of all loads, strains and buffing shocks imposed on car, with an efficient buffer, draft gear and some device which will lock the trucks to the body of the car in case of accident to prevent telescoping or a turnover of the car, is absolutely necessary.
2. A substantial end frame which will stand a very severe buffing shock and prevent telescoping.
3. A combination steel and wood side framing and wood exterior finish.
4. A combination wood and steel roof covered with canvas properly laid.
5. An interior wood finish.

With this construction the railway can repair its own cars, in the old wooden car repair shops, without going to the expense of installing a considerable amount of modern machinery, which would be necessary with all steel cars. The travelling public will be provided with a car which will compare favorably in strength with an all steel car. The inside finish can be made more artistic, easier to maintain and simpler to renew when required. In case of wreck the passengers will have a chance to cut their way out from the debris, which is impossible in an all steel car.

The adoption of steam from the locomotive for heating passenger cars, and