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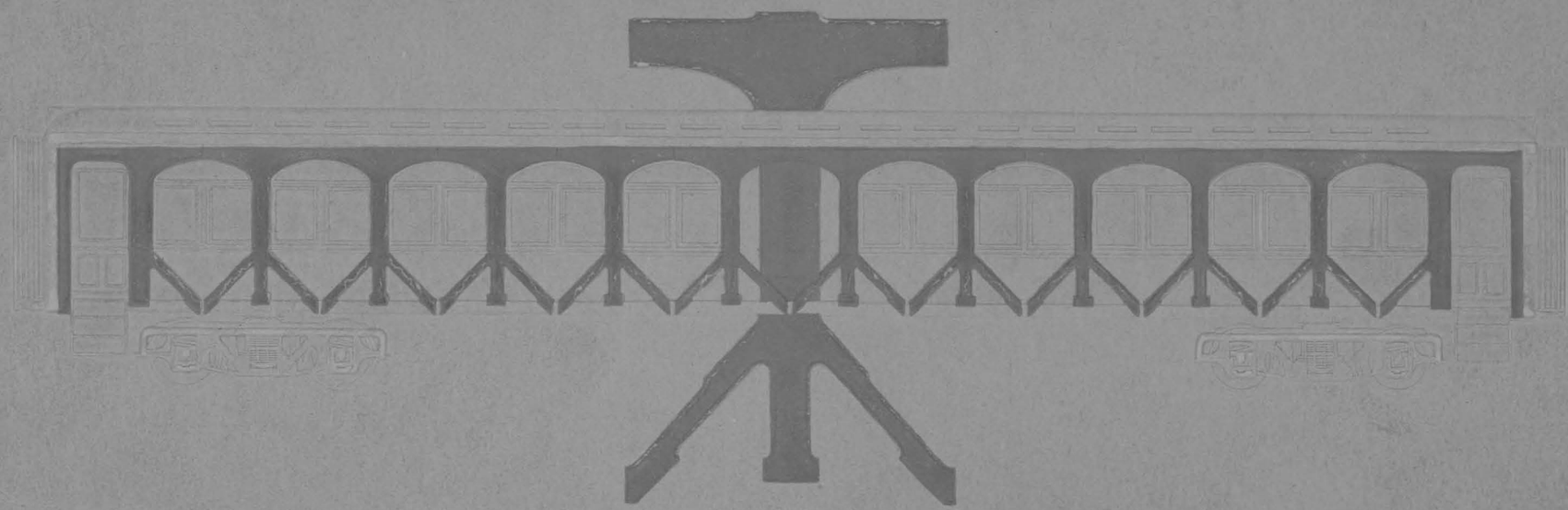
STEEL CARS



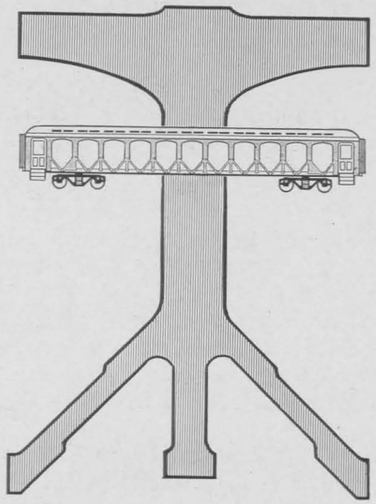
PASSENGER SERVICE

Pressed Unit-panel Side-truss Passenger Coach—New York, Westchester & Boston Railroad

Otis Allen Kenyon

STEEL CARS

SIDE-TRUSS CONSTRUCTION



L B STILLWELL CONSULTING ENGINEER

100 BROADWAY

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THE PROBLEM

IN constructing steel passenger cars to meet the exacting service requirements of this day of close competition and low rates per passenger mile, it is highly important that full advantage be taken of the strength and other physical properties of the material entering into the construction of the car in order that the finished structure may combine as far as possible the essential features:

1. Safety and comfort of passengers.
2. Low cost of operation.
3. Low cost of maintenance.
4. Moderate first cost.

Constructions which follow the prevailing designs of wooden passenger cars do not meet satisfactorily the above requirements, because with this type of construction it is impossible to utilize fully the properties of steel. For example, the heavy steel belt rail at the window sills is practically in the neutral axis of the side of the car, if the roof and letter-board are assumed as the compression member and the side sill as tension member of the structure. If, however, the belt rail is assumed as the compression member, then the letter-board and roof are subject to distortion when the structure is under full load and any deflection occurs. This method of construction has been followed in wooden cars, as the elasticity of the wooden structure permits of considerable deflection, but if used in steel cars the results eventually will be serious.

A general analysis indicates the character of design required for solution of the problem. Taking up the requirements in the order named:

1. SAFETY It is obvious that the safety of passengers will be greatly increased if the sides, roof and floor construction of the cars can be made sufficiently strong to prevent serious distortion or collapse under shock of collision or derailment.

2. COST OF OPERATION It is equally obvious that such a structure to be as light as is consistent with adequate strength, must have its members distributed and associated in a manner to secure the maximum strength within the permissible weight. Excessive weight means excessive cost of motive power per car mile, and the permissible weight must be deduced from careful consideration of this factor and of the conditions surrounding the service in which the cars in question are to be used.

3. COST OF MAINTENANCE The design of the structure must be so thorough in all its details that full strength development of each individual member is secured through its joints and connections. Admittedly the strength of a chain is that of its weakest link, and the maintenance cost of a steel car structure will be determined primarily by the security of the joints in the framework.

4. COST OF CONSTRUCTION Of two cars, the lighter will be the lower in first cost, all other features being substantially the same.

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THE SOLUTION

THE solution of the problem is to utilize the full height of the side of the car for a truss, using the side-plate and letter-board as the compression member and the side sill as tension member, connecting these by the usual window posts or piers, and then framing them securely together to develop fully the strength of each member.

Such a structure when consistently designed will weigh less and will cost materially less to build, maintain and operate than any other type of construction now in general use. It will also insure the safety of passengers in a degree that can be realized by no type of construction wherein the shock-resisting members are located principally in the underframe, and therefore offer but little obstruction to an overriding car in collisions.

In the ordinary steel passenger car the load is carried by side girders below the windows. They have an effective depth of approximately three feet. In the side-truss car the effective depth of the girder is about seven feet. The belt rail in the side-truss car is near the neutral axis and consequently only a light water table is required.

To illustrate one of the advantages of the side-truss, it may be assumed that the side-frame is required to resist at the center a moment of 2,000,000 inch pounds; then comparing girders of the heights given above, we have:

Stress on top and bottom members, three-foot girder, 55,600 lb.
Stress on top and bottom members, seven-foot girder, 23,800 lb.

Thus, it is evident that in addition to the elimination of the weight of the belt rail, less than one half as great sectional area is required in the side-sill of a seven-foot girder as in that of a three-foot girder for equal fiber stress.

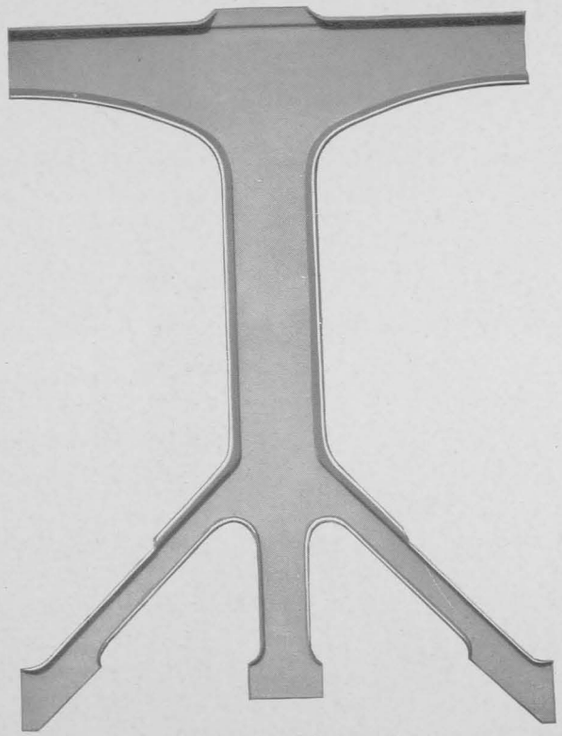
The above example does not take deflection into account. For the purpose of comparison on the score of deflection, it may be assumed that the cross-sectional area of the belt rail and side sill in the three-foot girder is 4 sq. in. each, and that in the seven-foot girder it is half that, or 2 sq. in. each. Then the relative deflections which are inversely proportional to the moments of inertia are:

For the 3-ft. girder $\frac{1}{I} = \frac{1}{2 \times 4 \times 18^2} = 0.386$ For the 7-ft. girder $\frac{1}{I} = \frac{1}{2 \times 2 \times 42^2} = 0.1417$

That is, the deflection of the three-foot girder is nearly three times that of the seven-foot girder. In actual practice this ratio may be slightly less, due to flexure of the posts of the side-truss. However, it is a fact that with the side-truss construction no attention need be given to deflection, whereas in the ordinary type of construction deflection is often the determining factor.

The side-truss construction is designed solely for fiber stress and when thus designed no measurable deflection will take place even under full load.

Finally, with reference to weight. The side frame saves nearly all the weight of the belt rail and approximately one half the weight of the side sill when designed for fiber stress alone, and for equal deflection it saves much more, because of weight that must be added to the shallow girder to bring the deflection within the limit.

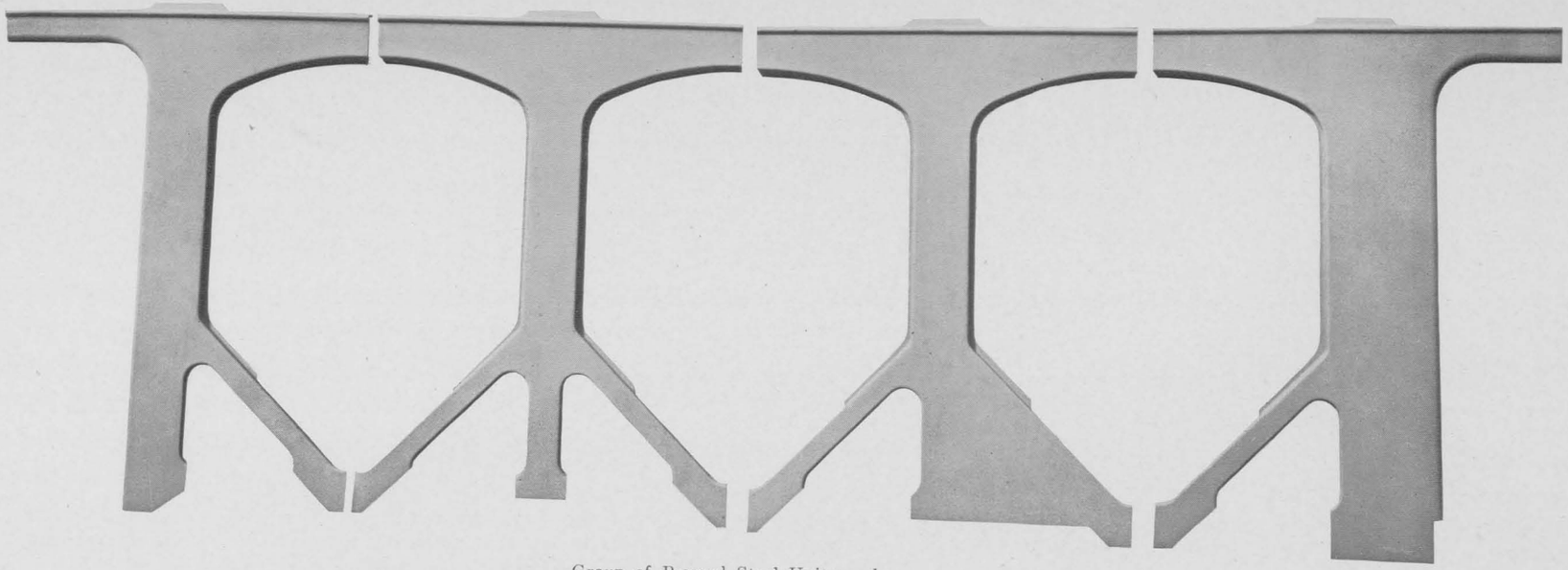


Pressed Steel Unit-panel

PRESSED UNIT SIDE-TRUSS

THE first cars constructed according to the side-truss method were designed for the Hudson & Manhattan Railroad Company, and were built up of standard rolled steel shapes. More recent progress in methods of manufacturing steel cars permits the substitution of pressed-steel forms of great strength and light weight for the heavier standard rolled steel shapes, and therefore a greatly simplified system of car construction has been developed. The most distinctive feature of the new system is the unit-panel side-truss illustrated herewith. Each unit includes a main post, diagonal braces, letter-board and side-plate channel all pressed from one piece of steel. The elimination of joints by this method of construction is obvious and the distribution of strength members is ideal.

The pressed unit-panel side-truss offers great possibilities to the designer of steel passenger cars, and as a practical demonstration of what may be accomplished in the way of improving existing practice, attention is directed to the illustrations on the following pages which show the construction of the pressed unit-panel side-truss motor coaches built for the New York, Westchester & Boston Railroad Company.



Group of Pressed Steel Unit-panels

FRAMING

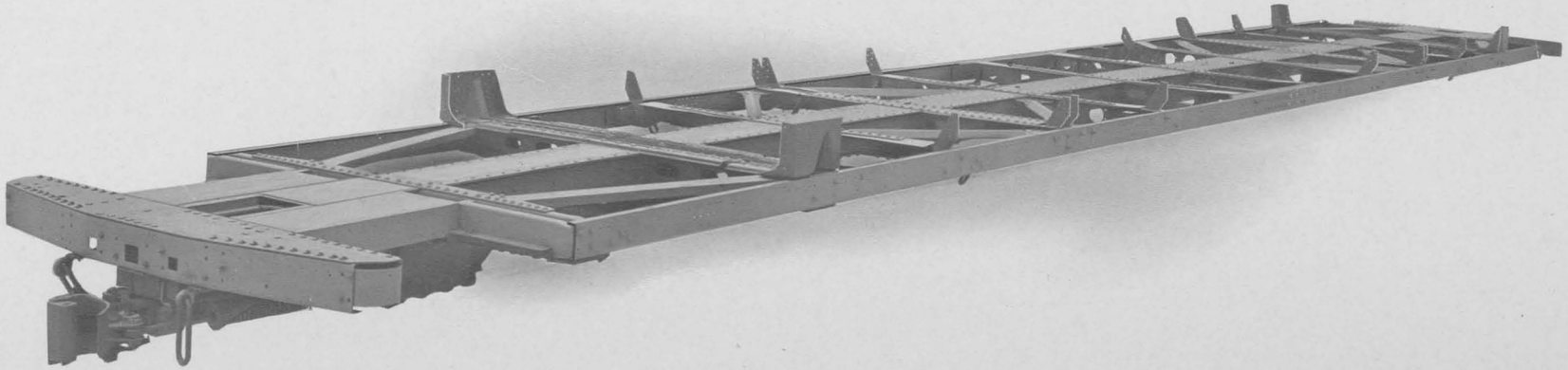
THE method of framing the pressed panels into a side-truss car is shown on the opposite page, which represents the side-frame and under-frame of the New York, Westchester & Boston Railroad passenger coach designed by the firm of L. B. Stillwell.

UNDER-FRAME As the center sills are supported at each main post by cross bearers spaced about 5 feet 6 inches on centers, deflection of the center sills is eliminated and a comparatively light and shallow center sill of uniform section is ample to withstand the shocks and strains of buffing and draft as well as those of collision. This uniform depth of center sill not only reduces weight, but also provides an unobstructed area for the application of air-brake equipment and of electrical control apparatus when used.

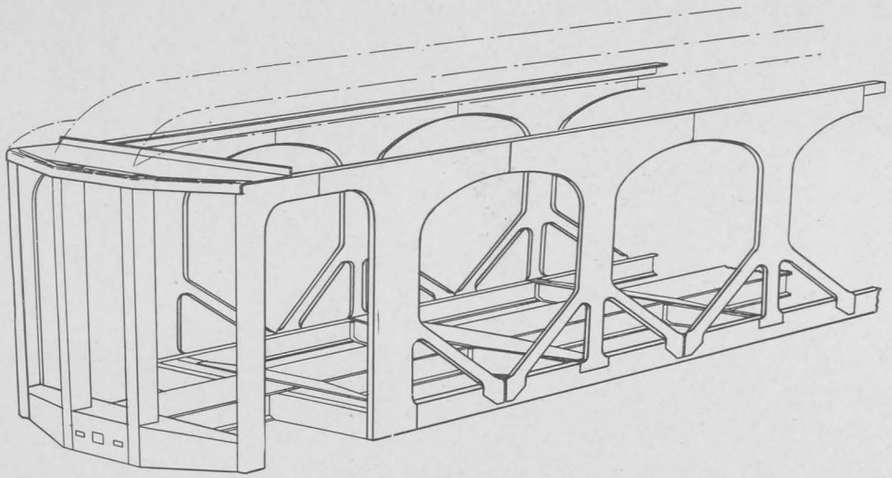
The matter of unobstructed area beneath the floor is of importance on all new passenger cars since it is highly probable that within the life of a properly designed steel coach it may become desirable to equip it for electric operation, and, therefore, it is advantageous to adopt an arrangement of under-frame and vestibule that will permit the application of electrical apparatus and simplify its maintenance.

SIDE-FRAME The unit panel side-truss frame insures a rigid structure free from measurable deflection and capable of withstanding shocks of collision that would wreck steel cars of the usual type. It is obvious that the shock resistance of a structure is dependent upon the strength of the members composing it and their relations to one another. As before shown, the full development of the members is best secured by their association in truss form. It is, therefore, possible to provide a suitable structure to withstand with minimum damage such collision shocks as a contemplated service may be subject to, the only limitations being the permissible weights.

ROOF Considerable structural value can be developed in the roof, especially if associated with a suitable deck sill. For example, the type of roof applied to the New York, Westchester & Boston cars is at once light, strong and of low cost, as the deck eaves, etc., are eliminated and a continuous carline of simple outline is utilized. Any style of roof can of course be combined with the truss side-frame.



Side-frame and Under-frame



Method of Assembling Pressed Unit-panels

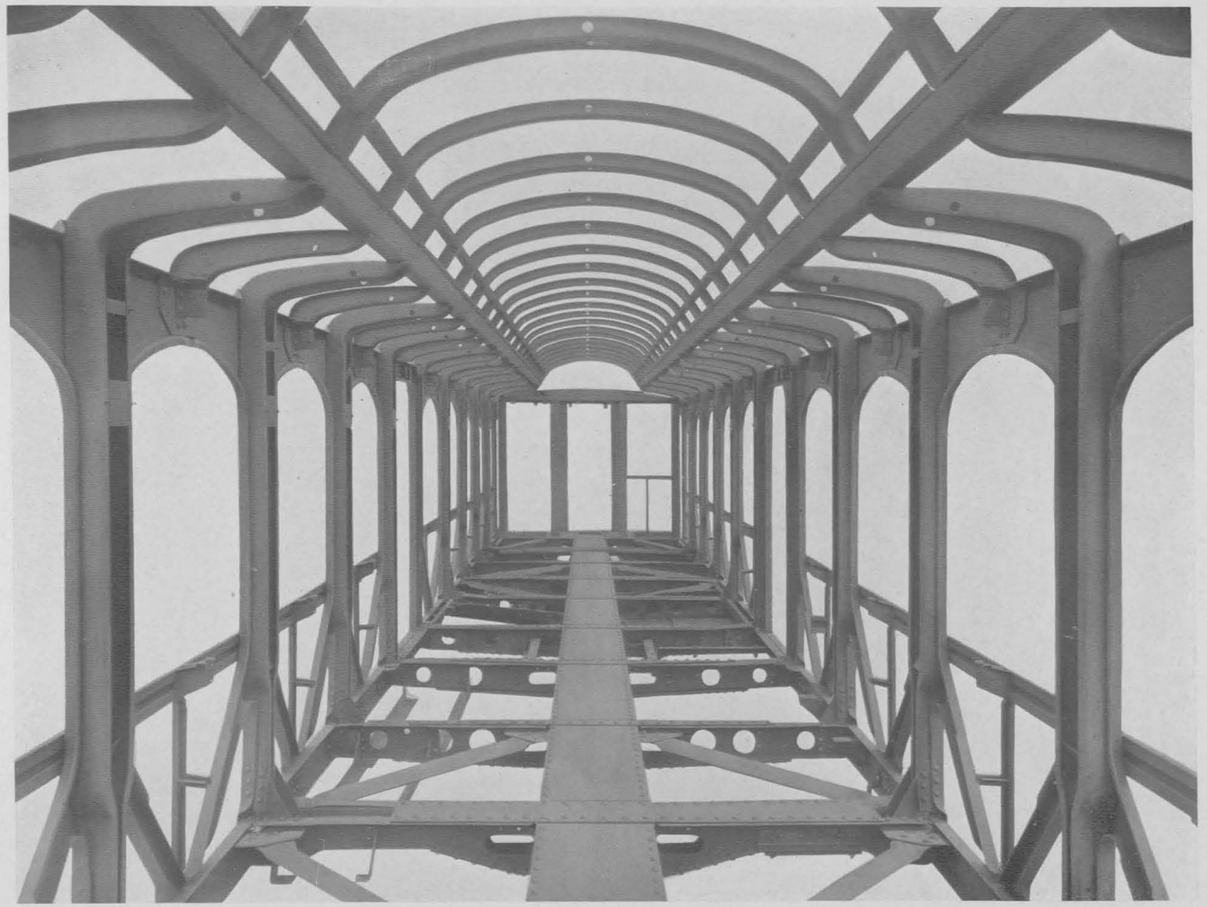
RIGIDITY

THE illustration on the opposite page shows well the unique character of the framing of the Westchester cars. Even a cursory study reveals the extraordinary staunchness resulting from the practically uniform distribution of the shock-resisting members throughout the structure.

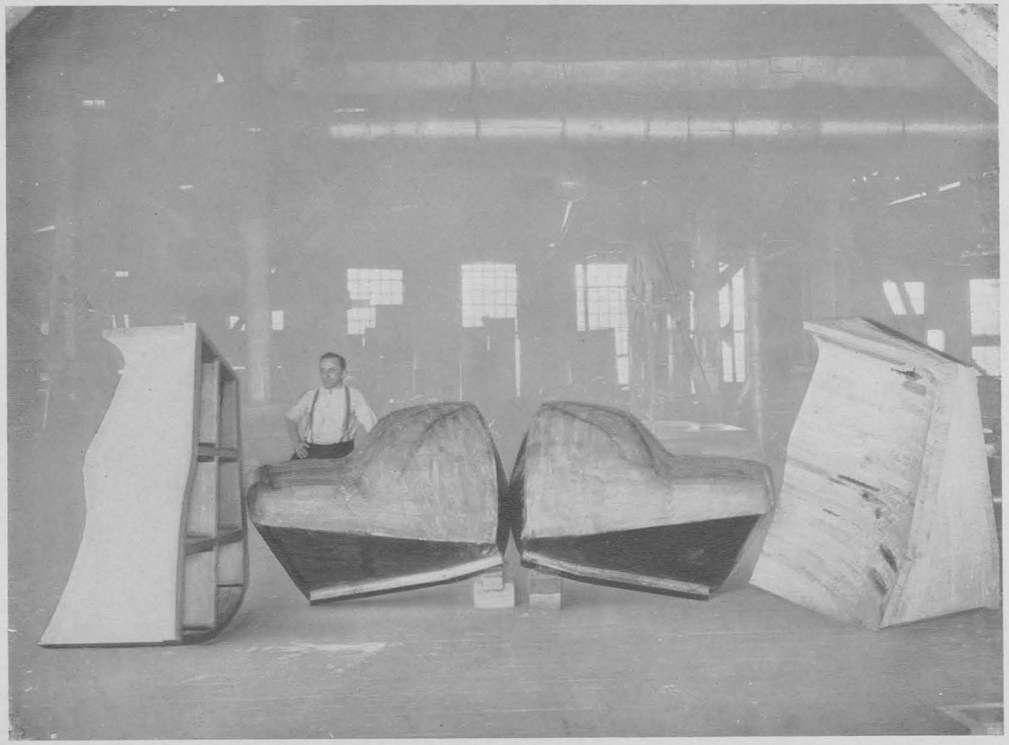
It will be noted that the center sills are of uniform depth throughout their entire length. They are fitted with cover plates both top and bottom, the enclosed space being utilized in this particular instance as a duct to convey the air for cooling the motors. They are supported and kept in rigid alignment by cross bearers that transfer the load to the side-frames.

The roof framework is made up of pressed steel carlines bent in arch form and riveted to the deck sills, which in turn are riveted directly to the ends of the side-posts.

The complete structure forms a practically non-collapsible cage that will afford a maximum degree of protection to the passengers in case of collision or derailment.



Framing of New York, Westchester & Boston Railroad Car



Patterns for Hood Sheets

SHEATHING

BELOW the belt rail the car is sheathed with $\frac{1}{16}$-inch steel plates riveted to the belt rail and the side sill. The posts above the belt rail are not sheathed. Joints in the side sheets are covered with $\frac{1}{8}$-inch battens, and all joints are made absolutely watertight.

The roof sheathing consists of $\frac{1}{16}$-inch steel plates extending in one piece from side-plate to side-plate. The sheets are lapped across the carlines, securely riveted, and then welded by the oxy-acetylene process to form a watertight joint.

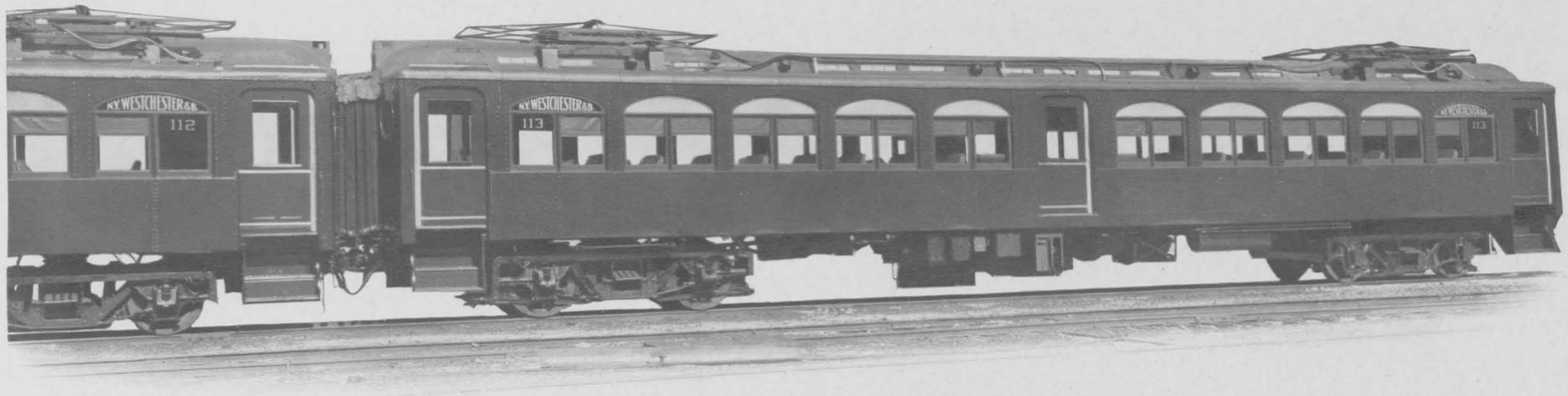
The hoods are pressed from two sheets and riveted together in the middle. Patterns for the hood sheet dies are shown in the accompanying illustration.

New York, Westchester & Boston Railroad Pressed Unit-panel Passenger Coach

NEW YORK WESTCHESTER & BOSTON CAR

THE pressed steel unit-panel side-truss cars of the New York, Westchester & Boston Railroad are full steam road size.

Length over coupler faces	72 feet
Length over end sills	61 feet 4½ inches
Length center to center of trucks . . .	47 feet 7½ inches
Seating capacity without center doors . .	86
Seating capacity with center doors . . .	78
Weight car body and trucks	81,500 pounds
Weight of electric equipment, including two 175-horse-power alternating-current motors	37,500 pounds



New York, Westchester & Boston Railroad Cars—Showing Vestibules

Interior New York, Westchester & Boston Railroad Passenger Coach

INTERIOR

TO overcome the disadvantage resulting from the high heat conductivity of steel, the entire roof and the space below the windows are lined with a ¾-inch layer of special insulating material, faced and bound with fireproof burlap. This insulating material also deadens sound and thus contributes to the noiseless operation of the car, which is a striking feature of this type of construction and is due primarily to the rigidity of the structure.

The interior finish consists of a lining of fire-resisting Agasote secured in place by drawn steel molding.

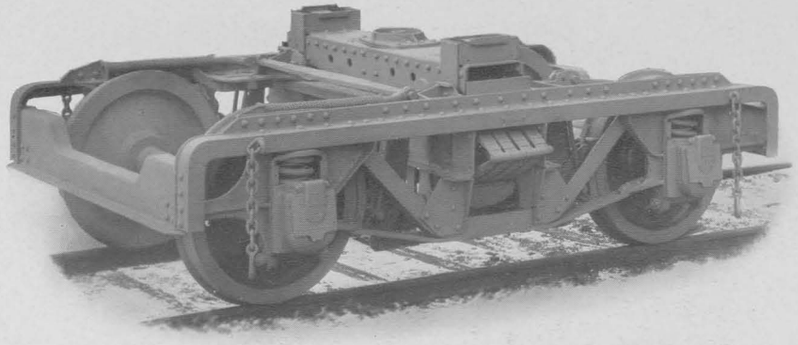
The sanitary qualities of the car have been furthered by rigorous elimination of lodging places for dust and dirt. All inter-sections of surfaces have been rounded so as to avoid deep crevices and sharp projections.

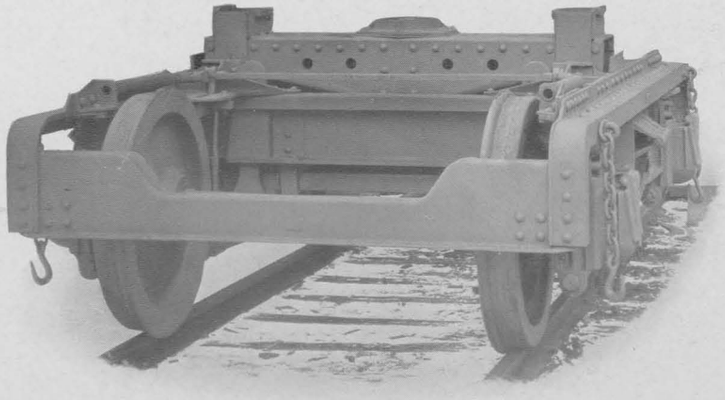
The actual seating capacity of this car is 86, but the side doors displace four of the seats and thus reduce the seating capacity to 78 passengers. The seats are of the walk-over type. They have an all-steel frame and are covered with Pantasote.

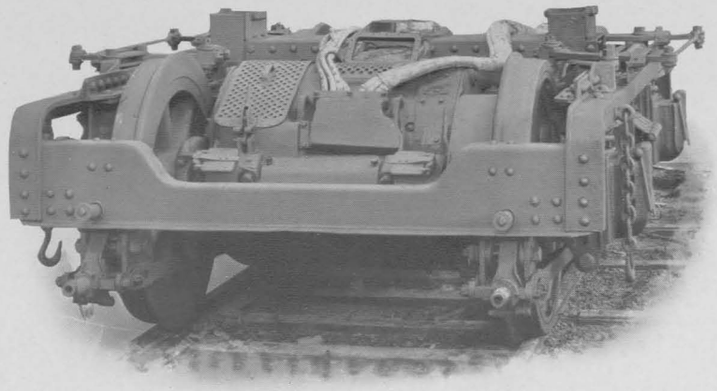
The floor is of Karbolith and all joints with vertical surfaces are filleted to one inch radius to facilitate cleaning.

TRAILER TRUCKS

THE Westchester car trucks were designed by the firm of L. B. Stillwell to meet the special requirements of heavy suburban service. They are simple in design, and in actual service have proved to be extremely easy riding. The side-frames are of the arch-bar type with cast steel pedestals enclosing triple-coil journal-box springs. The top arch-bar is a Z-bar, and the inverted arch-bar is a heavy angle securely riveted to the back of the top flange of the arch-bar over the journal boxes. The transoms are pressed steel channels, and are attached to the side-frames by large cast steel gussets. The bolster is of the box type and made of pressed steel. It is 14 inches wide and rests on quadruple elliptic springs.

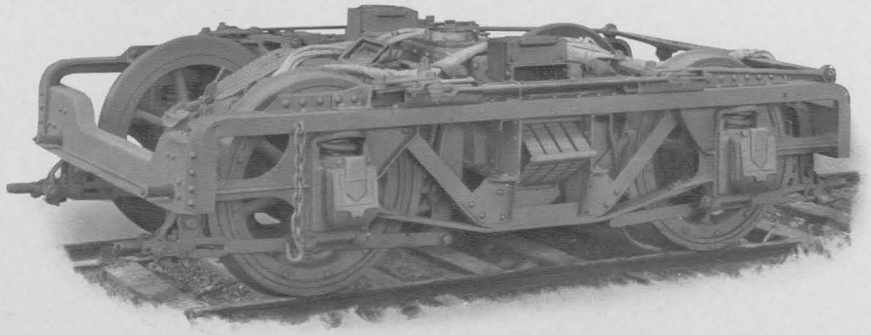






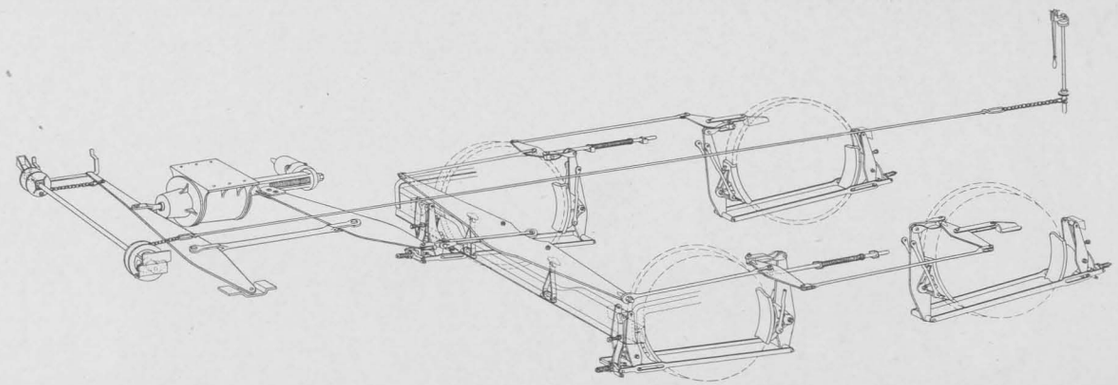
MOTOR TRUCKS

THE motor trucks are similar in design to the trailer trucks, except that they have larger wheels and axles, and are fitted with a different type of brake rigging. The weight of the rotating parts of the motor, the high speed of operation and the frequent station stops required the design of a special brake equipment for this service. The motor trucks are therefore fitted with two brake shoes per wheel, and a brake rigging system which provides for rapid and full adjustment for brake shoe wear.

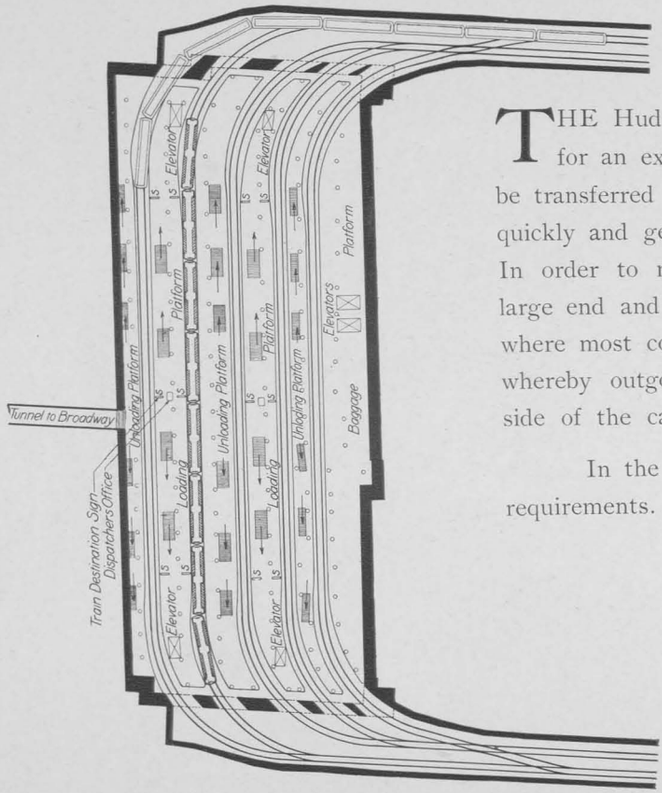


FOUNDATION BRAKE GEAR

THE Westchester cars are fitted with an independent foundation brake gear and brake cylinder for each truck. One control valve regulates the air pressure in the two cylinders. This arrangement of foundation brake gear minimizes weight, leaves the under-frame clear for electrical control apparatus, facilitates prompt release of the brakes without heavy release springs and provides for an effective hand brake.



Foundation Brake Gear and Clasp Brakes for Motor Trucks

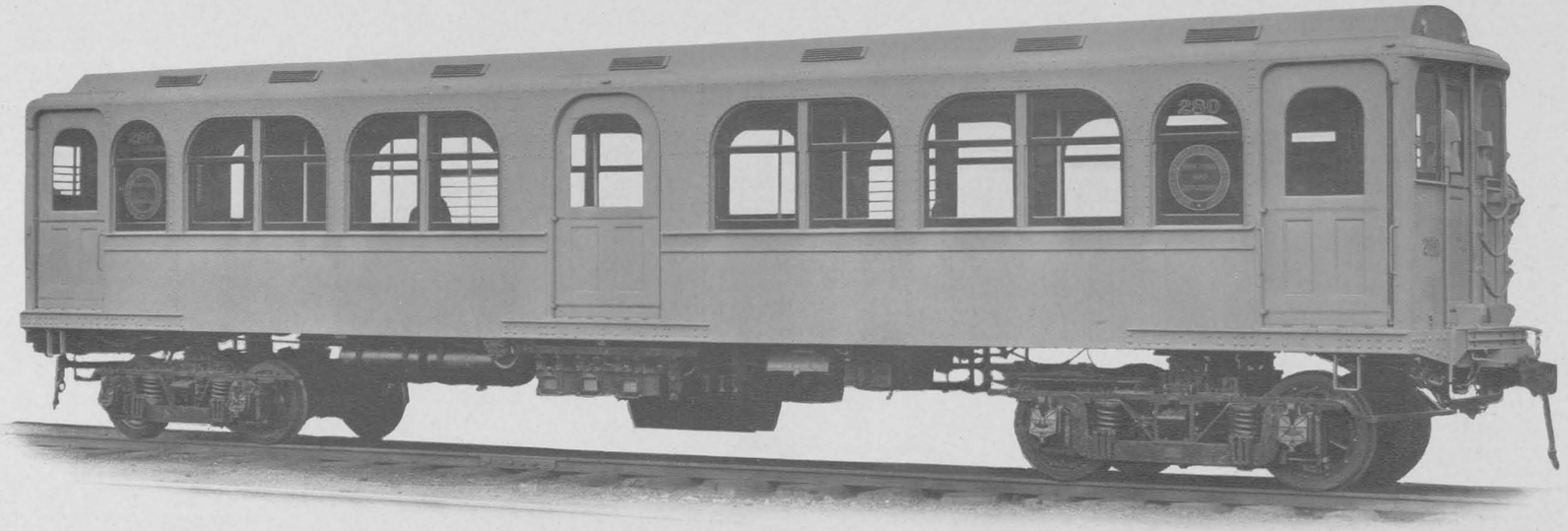


Hudson Terminal Platforms

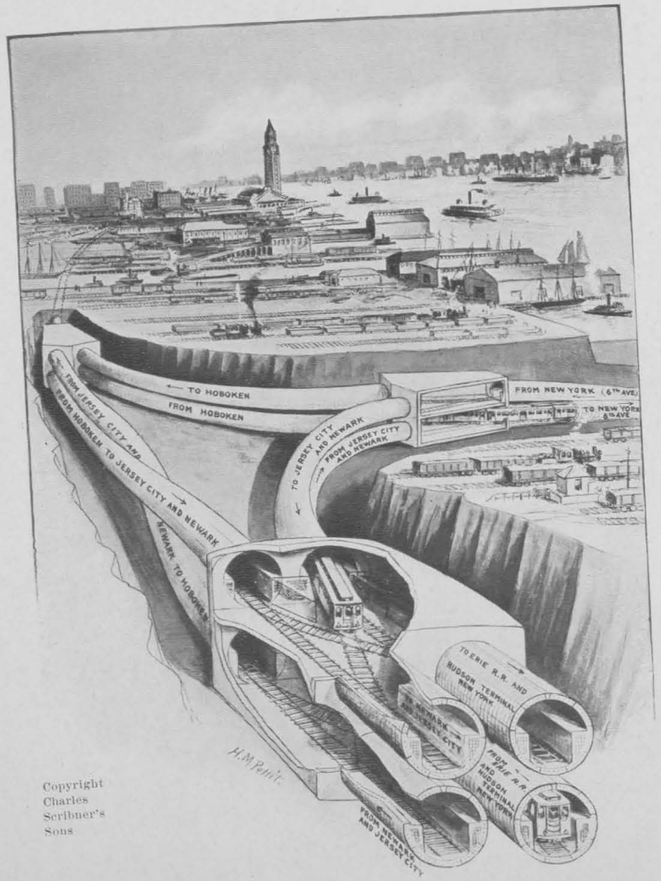
HUDSON & MANHATTAN RAILROAD CARS

THE Hudson and Manhattan Cars, of which there are at present 190 in use, were designed for an extremely difficult service. Passengers are received from long steam trains and must be transferred to the small tunnel cars without delay. The tunnel train must be able to load quickly and get away so as to allow another to pull in before the steam train is entirely unloaded. In order to meet the requirements of quick loading and unloading, the cars are provided with large end and middle doors operated from the ends of the cars. In the Hudson terminal station where most commuters leave the trains rapid unloading is accomplished by a system of platforms whereby outgoing and incoming traffic are effectively separated; outgoing passengers enter one side of the car, while incoming passengers simultaneously leave the other.

In the design of these cars the external appearance was completely subordinated to structural requirements.



Hudson & Manhattan Railroad Passenger Car



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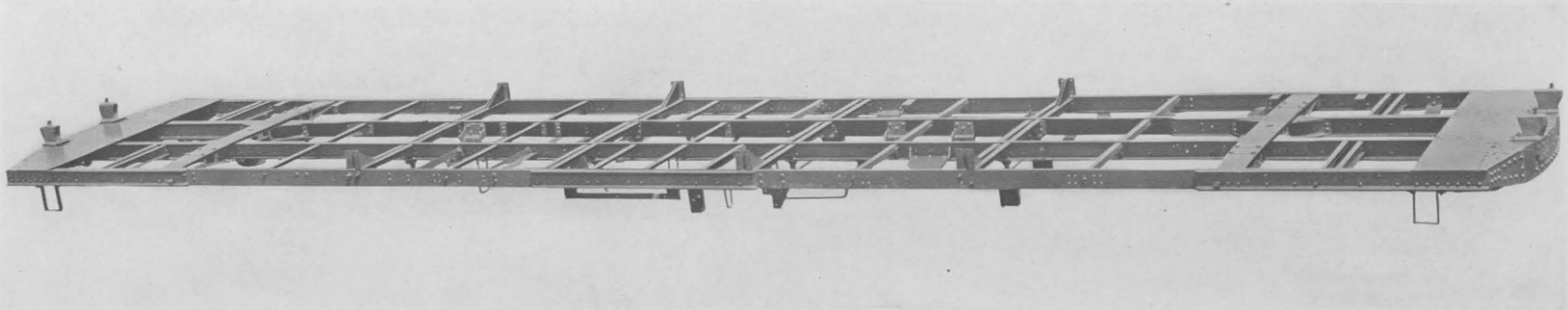
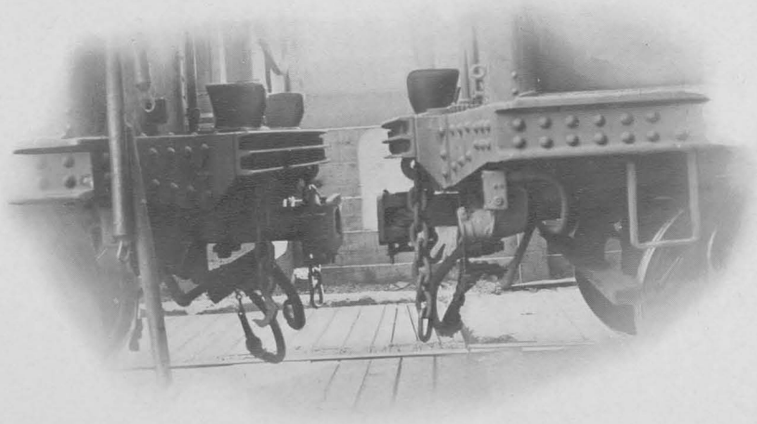
FRAMING

THE Hudson and Manhattan cars were constructed to fit closely the contour of the tubes, and, therefore, it was of prime importance to design a car structure that should possess a maximum degree of rigidity and thus prevent the buckling of a car in event of a collision which would cause it to jamb and stick in the tube. Furthermore, the severe grades, high speeds and frequent stops encountered in the regular service made it especially desirable to reduce the dead weight of the car as much as possible without sacrificing strength.

In was the combination of these extremely exacting conditions that brought about the development of the side-truss type construction shown on the opposite page. At the time these cars were designed it was not practicable to manufacture pressed steel unit panels and therefore the framing was built up of standard rolled shapes. However, the general principles of the side-truss construction set forth in the introduction, page 5, are followed in the design of the structure.





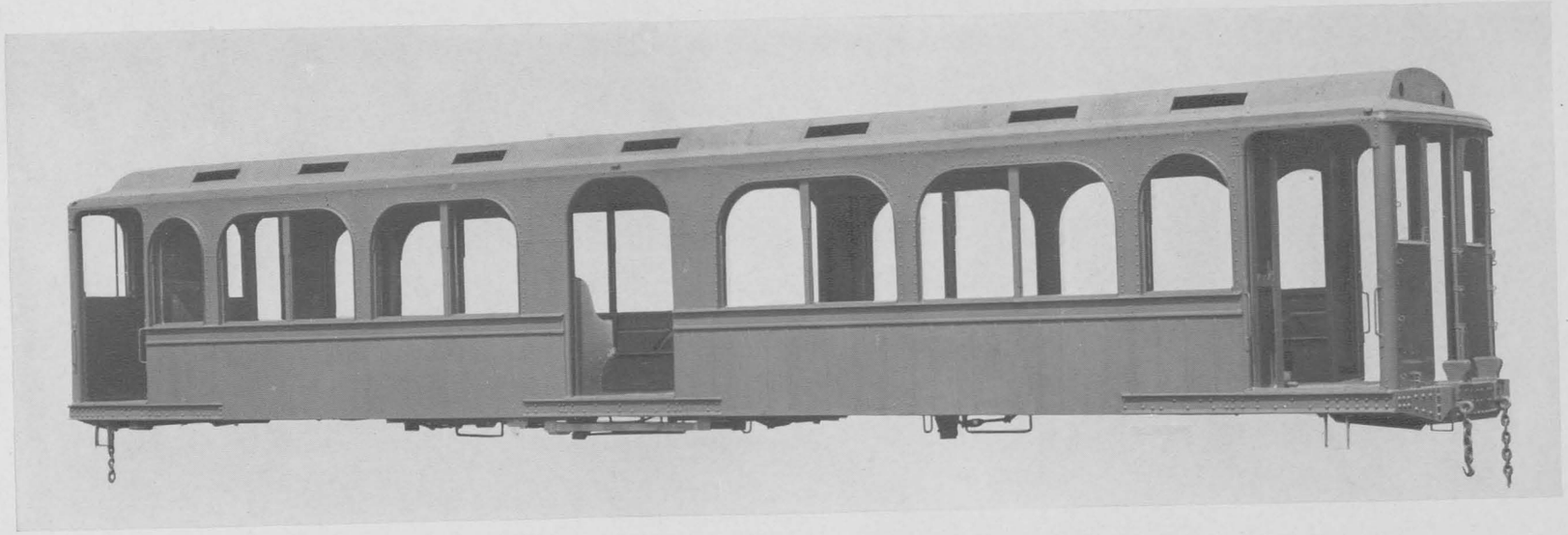
Anti-riding Devices

ANTI-RIDING DEVICES

THE buffer faces are equipped with deep-ribbed shields and a massive steel casting is mounted on each end of each center sill, so that when two cars are forced together, as in collision, they will firmly engage each other and take up the shock elastically without destructive deformation. The anti-riding devices are plainly shown in the accompanying illustration.

SHEATHING

The sheathing, in the form of $\frac{1}{16}$-inch plates, is riveted to the structure with $\frac{1}{8}$-inch rivets closely spaced, so as to form absolutely watertight joints. In no instance are the car frame rivets used to secure sheathing and therefore plates can be removed for repairs without in any way disturbing the car structure.



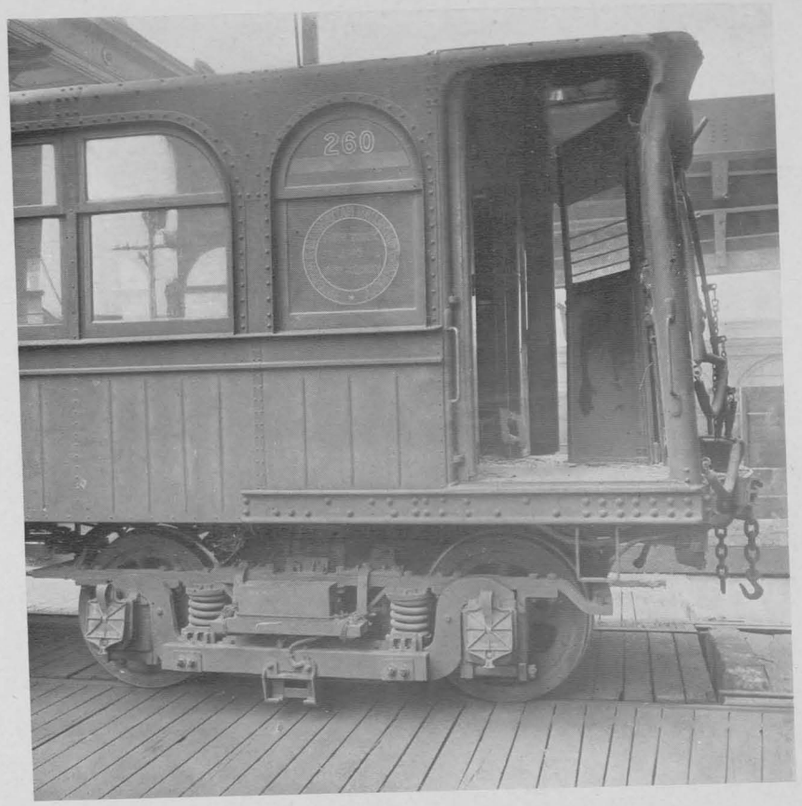
Sheathing of Hudson & Manhattan Railroad Cars

Normal Vestibule of Hudson & Manhattan Railroad Car

ACTUAL PERFORMANCE

A PRACTICAL demonstration of the rigidity of the side-truss type of construction is shown on the opposite page. These cars were in a head-on collision at approximately 25 miles per hour, and not a pane of glass beyond the vestibules was even cracked. The actual force of the shock may be judged by the condition of the vestibules.

The practically absolute rigidity of the cars is of prime importance in the operation of passenger service through tunnels, since the jambing of a car in the tubes due to flexure from shock would completely block the line.

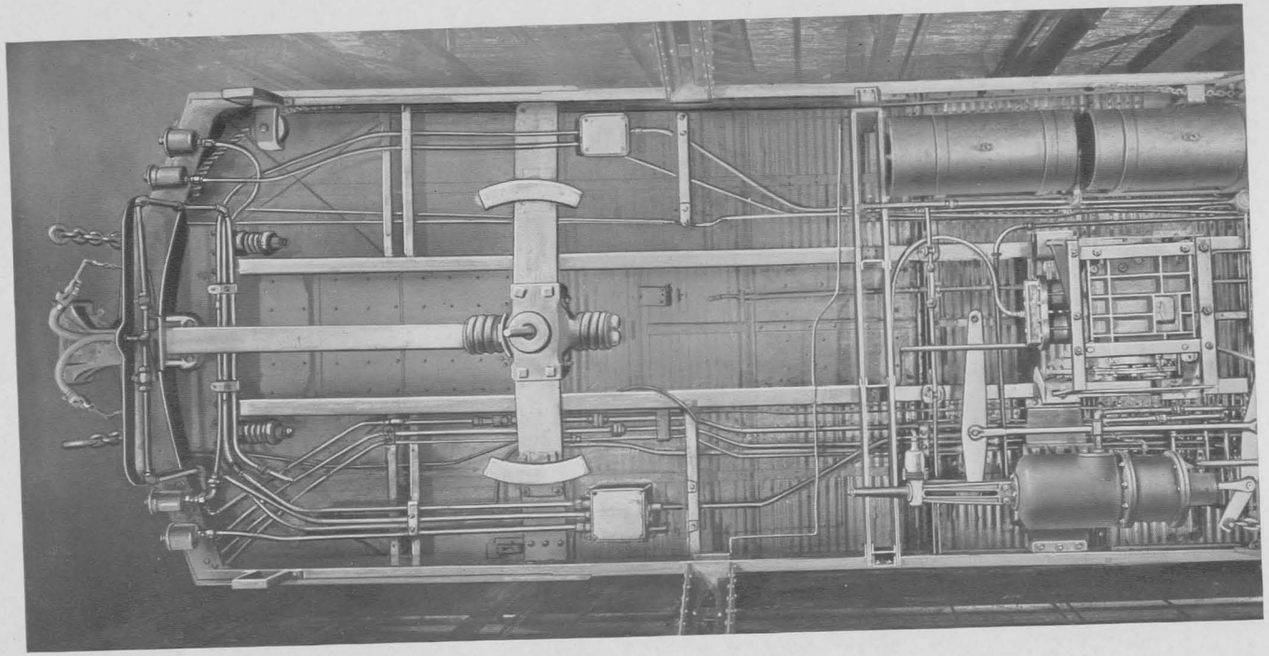


Vestibules of Side-truss Cars after Head-on Collision at Speed of 25 Miles per Hour

CONTROL EQUIPMENT

THE accompanying remarkable photograph was made in the car elevator of the Hudson & Manhattan Railroad. It shows plainly how necessary it is to have clear space below the car floor for the installation of equipment for controlling the motors and the brakes of an electrically propelled car.

It also shows that the under side of the floor of the side-truss car is perfectly free from obstructions. This is an important advantage, since, as was explained on page 8, a car that may have been purchased for operation in a steam train or as a trailer in an electric train, can be equipped with any system of electric control and with independent air brakes, without any modification in its structure.



Interior of Hudson & Manhattan Railroad Car

THE SANITARY CAR

THE interior trim of the Hudson & Manhattan Railroad cars is especially designed to promote cleanliness. Sharp edges, projections, corners and crevices which form lodging places for dust and dirt are systematically eliminated. Vertical and horizontal porcelain enameled hand rods take the place of the usual unsanitary leather strap.

The floor is smooth monolith cement, filleted flush up with the sheathing beneath the seats, thus facilitating thorough cleaning. The ceiling is finished in white enamel and both the color and form combine to make the lighting at once effective and pleasing. The seats are arranged longitudinally and are divided by barriers into sections of various lengths, and accommodating from two to five persons. This arrangement gives a maximum floor space for free circulation of the passengers and the barriers make the seats more comfortable and prevent crowding.

HUDSON AND MANHATTAN SHOPS

THE accompanying illustration shows the Hudson and Manhattan car repair shops and one of the car yards. These shops were designed by the firm of L. B. Stillwell, as were also those of the New York, Westchester & Boston Railroad.

Car Shops and Yards of Hudson & Manhattan Railroad

NOV 13 1912

PREPARED BY

OTIS ALLEN KENYON