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STEEL PASSENGER CAR FRAME CONSTRUCTION.

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(Read before a meeting of the Mechanical Section, December 3rd, 1914.)

There are four distinct types of framing for steel passenger cars. These types as actually built vary more or less in proportion as well as in the size of the plates and bars used. Such variations taken together with the different weights of other parts of the car and with different general dimensions make it practically impossible to draw any satisfactory conclusions as to the merit or weight of any particular type of framing when comparing cars built by different designers for different railroads.

The following data were prepared for the sole purpose of determining, if possible, what necessary difference existed in the weight of different types of frame construction when designed for the same loads and stresses.

As only the centre sill, bolster, crossbearers and side frames are concerned in the comparison, no reference whatever is made to the detail of any other part. To make the comparison strictly theoretical would be a waste of time, and therefore it is necessary to establish certain standards for those items which enter into the construction of the members concerned, the dimensions of which are not capable of calculation, but are proportioned in accordance with good practice. In this case, such items are principally as follows:

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The minimum thickness of any plate is taken at 1/8", and the moment of inertia of web plate is not considered in calculating girders, side posts, etc., unless the thickness is 3/16" or over. The flange members have the area of rivet holes subtracted, except in the case of flanges that are in compression only, in which case the total area is used. All of the several designs are considered to be built of structural steel with the exception of cast steel centre plates, centre sill separators above centre plate, cast steel connections between bolster and crossbearer ends and side sills. The maximum stress allowed in bolster flanges is 12,500 pounds per square inch and 16,000 pounds elsewhere, except that in one or two cases where the moment of inertia of web plate has not been taken into consideration, the stress has been allowed to slightly exceed this figure.

When the actual weight and load of the car is known, it is comparatively easy to determine the stresses due to this total weight, but the stress due to end shocks cannot be accurately determined either theoretically or by experiment. In the absence of authentic information as to the actual magnitude of these shocks it has come to be a generally accepted practice to consider these as equivalent to a static load of 400,000 pounds acting along the line passing through the centre of gravity of the existing resistance capacities of the buffer and draft gear attachments. Further, it is commonly considered that modern high capacity buffers have a capacity of 250,000 pounds and draft gears 150,000 pounds. These figures have been verified by numerous tests of gears that have been in service and, while the individual equipments will vary considerably, the above figures are about the average. As these capacities are respectively 5/8 and 3/8 of the total, and as the vertical distance between the two centre lines is 12½", the resultant centre line is 7 13/16" above the centre line of draft gear which is taken at the usual standard height of 34½" above the rail.

Cars designed on this basis, while not indestructible by any means, are successful in resisting what are usually considered wreck conditions; in fact there has never yet been a wreck reported involving steel cars in which a sill meeting these requirements was said to have failed in a manner indicating that further increase in strength was either necessary or desirable. This item is specially noted, as needless increase in weight should be carefully avoided in order that cars be as nearly as possible of uniform strength, thereby eliminating the damage that will certainly result in accidents, if some of the cars are decidedly stronger and heavier than others. In such cases it invariably happens that the weaker car is seriously damaged, and if the stronger car provides any additional safety for passengers it is confined entirely to passengers in that particular car, and is obtained at the expense of greatly decreased protection for passengers in adjacent cars. This point should have very careful consideration when designing any type of car for any class of service and if it had been considered long ago, especially in regard to the operating of cars of light construction, in trains with heavier cars, the destruction which is due almost entirely to the strong cars crushing the weaker, would have been avoided.

The standard 72′ 8″ sleeping car that has been selected for this example represents about the maximum requirements of load carrying capacity for passenger cars in general use. As illustrated in Fig. 1, Pl. I., the car is assumed to be equipped with a body suspended dynamo and two sets of batteries, each set consisting of 12 lead cells. There is the usual body brake rigging including auxiliary and supplementary reservoirs and water tank with air pressure system for lifting the water into the car. In addition to these items, the water tank is assumed to be filled with water, and the car equipped with a storm sash. The live load is considered to be 53 passengers at 160 pounds each, with 50 pounds each additional for luggage.

An examination of the weight distribution indicates that the smoking-room half of the car will produce the maximum bending moments, partly on account of the weight of the batteries and dynamo, and partly because there is less weight beyond the bolster at this end of the car than at the other where the heater is located.

To simplify calculations, the car is assumed to be symmetrical about its cross centre line.

The four distinct types referred to may be described as follows: No. 1,—Heavy centre sill construction, the centre sills acting as the main carrying member. No. 2,—Side carrying construction, the sides of the car acting as the main carrying members, having their support at the bolster. No. 3,—Underframe construction in which the load is carried by all the longitudinal members of the lower frame. (The lower frame in this case is interpreted to include the side girder below the windows.) No. 4,—Combination construction, in which the side frames carry a part of the load, transferring it to the centre sills at points remote from the centre plates so as to utilize the uniform centre sill area.

It is obvious that type 1 construction cannot possibly equal the others in weight, therefore, no diagrams or other particulars are submitted concerning it.

In type 2, all the weight of the car body and loading, except the body bolsters and a piece of the centre sill from half way between centre plate and end sill to half way between centre plate and outside crossbearer, is either carried directly by the side frames or is transferred to them. In other words, the sides carry all the load except that resting directly on the centre plates. This explains the very small centre sill bending moment shown in the diagram amounting to only 65,000 inch lbs. positive moment, (Line E-E on diagram) and 43,000 inch lbs. negative moment, (Line F-F on diagram) for the part where the batteries are located which is much the heaviest loaded section. The weight of the vestibule is assumed to be carried by the end frame which is practically a solid plate with an opening in the centre for the end door. The end construction and vestibule are both carried by the side frames.

Each crossbearer has a distributed load of its own weight plus the floor materials immediately above. The inside crossbearer receives 5,017 lbs. from the centre sills and two separate loads of 700 lbs. from the batteries. The outside beam has similar loads and in addition supports the dynamo weighing 685 lbs. However, the bending moment does not exceed that in the other beam as the load transferred from the centre sill is only 4,289 instead of 5,017 lbs. The details of both beams are the same, consisting of top and bottom cover plates, riveted to the flanged edges of single web plates. The bolster carries a distributed load consisting of its own weight and the floor material above. These items do not, however, enter into the stresses to any appreciable extent. Practically all the stress in the body bolster is due to the transfer of weight from the side frames. In this example the load on each end is 26,304 lbs., and the lever arm is assumed to be 49 inches. This is correct as the centre plate is 12" wide and the sill channels are riveted to a steel filler block.

The side frame loading is that weight which occurs on the side where the dynamo is located. The distributed weight includes the side and one-half the roof as well as the upper berths and proper portion of seats, passengers, floor materials, bulk head, partitions, lockers, etc. P_1 is ½ of one vestibule. P_2 is ½ of one end and parts carried by it except the vestibule. P_3 is the load transferred by the outside crossbearer. P_4 is the centre battery support. P_5 is the load transferred by the inside crossbearer.

The side frame, supported as it is 8 feet from the end, is subject to a negative bending moment of 2,930,300 inch lbs. at the centre of the car and a positive moment of 683,900 inch lbs. at the bolster. If the side frame was considered as a girder having a depth equal to the distance from side sill to side plate angle (91 1/2"), the maximum stresses would be obtained by dividing the above moments by the section modulus of the girder. In this example, however, the window openings introduce a condition that requires special treatment.

It is obvious that any force acting in the top chord must be transmitted to it through the posts; therefore, if the posts are weak, they will not transmit the force desired and the result will be that the girder below the window will be over-stressed and also that the window openings may be deflected out of square to a serious extent. Examination of the problem will show that if each post is designed to act instead of the usual diagonal truss member, the posts just inside the points of supports will have to be very strong and consequently much heavier than it is feasible to use. Further study will develop the fact that if all the posts are fairly strong, their combined strength will equal the total required to cause the top chord to act as in a truss. When the posts meet this condition, it can be assumed that the necessary transfer of stress from the posts near the supports to those near the centre occurs through the girder below the windows. This method is not entirely satisfactory as it does not provide a simple and accurate means of calculating the stresses either when the total strength of all the posts does not equal the above requirements or when various sizes and spacing of posts occur as in actual construction; and to take care of this the bending moment diagram illustrated just below the loading diagram was developed.

To start with, the usual diagram is drawn and at the first post inside the point of support a reduction in height equal to the resisting moment of that post is made (in this example the first post is on line B—B and as it is very wide, its resisting moment is correspondingly large, 880,000 inch lbs.). In this scheme it is assumed that the girder below the windows takes care of all the bending moment except that which the posts can take regardless of whether or not the posts are strong enough to cause the frame to act as a truss. Therefore, with a moment of 880,000 inch lbs. opposed to the moment in the girder the maximum bending moment anywhere between these posts must be 880,000 inch lbs. less than if the posts were not there. Following out this theory, with the other posts a further reduction is made at line C—C where there is an ordinary post 15 inches wide having a resisting moment of 346,000 inch lbs. Another reduction of the same amount is made at post on line D—D. This last reduces the diagram to the left of line D—D so that the maximum negative bending moment now occurs at line D—D instead of the centre of the car.

So far, the assistance from posts beyond the point of support has not been considered. The method of handling this is shown in the diagram. After deducting the post moments, there remains a maximum total negative moment of 2,100,000 inch lbs. To balance this at the bolsters there is a bending moment of 683,900 inch lbs. due to overhanging load, to which may be added the value of the corner post, taken in this case as 366,100 inch lbs. These two added total 1,050,000 inch lbs., and this subtracted from 2,100,000 leaves 1,050,000 maximum negative moment on line D—D. Such conditions giving the same maximum moments, positive and negative, are desirable, but can be assumed to exist only when the sum of the resisting moments of posts beyond supports and overhanging load is equal to or exceeds one-half the total moment.

The maximum stress in the side girder below the windows in this example is 16,300 lbs. per sq. inch compression in belt rail at line D—D, calculated without considering the inertia of the web plate and using net area of belt. Had these items been figured including the inertia of web and gross area of belt, the stress would be considerably below 16,000 lbs. per sq. inch.

The determination of the compression in the top chord is merely a matter of adding the resisting moments of the several posts and dividing by the distance between the centre of gravity of the side girder and the side plate angle. In this case the total compression is 25,910 lbs., which, divided by the area of the angle 2.41 sq. in., equals 10,750 lbs. per sq. inch., as the stress.

Particulars as to the section modulus and maximum stresses are shown on the stress diagram, but a few points should be mentioned by way of explanation. It will be noted that, although the centre line of end shock is .56" above the neutral axis of the centre sill, it is not necessary to include the bending moment created by this eccentricity in the summary of stresses in the centre sill, because the sill is supported against vertical bending by the bolster and crossbearers which are spaced at relatively short distances. The sill is provided with a 5/16" top cover plate which extends from the end sill to a point about two feet beyond the bolster, and increases its capacity as a column very considerably, providing all necessary reinforcements at the point where it might be likely to fail, namely, at or near the bolster.

When anything of this sort is under consideration there arises immediately the question, "how does it prove out in actual practice?" In this case, so far as ability to support its weight and a very considerable live load is concerned, the answer is contained in Fig. 2, Pl. I., which is a diagram of a 72' 8" steel first-class coach tested before applying any interior finish or equipment; in other words, the test was made on the mere shell of the car with gas tanks, reservoirs, etc., attached underneath. The distributed load applied to this car was equivalent to over 40 tons distributed load in an entirely complete car; that is equivalent to putting a live load of 40 tons on the car when it is ready for service. Reference to the diagram will show that the maximum deflection between the truck centres was less than 5/16", including any slackness that may have existed in the structure; for there was no initial load applied and then released before starting to take the measurements. The permanent set was nil.

Unfortunately authentic information is not available for detailed description as to deflection of the other types under similar loading, but the writer has notes of a somewhat similar test of a Type 3 construction made before the structure above the windows was in place, and in that test the deflection at the centre was approximately 1" with 0.17 permanent set. The sections used in this car were well up to the average for this style of construction, therefore it is reasonable to presume that this deflection is about right for Type 3.

The loading for the centre sill and side girder in a car of Type 3 is calculated to be a load that rests directly on these parts; that is, neither is considered to carry any load that requires to be transferred to them through the crossbearers. The three crossbearers are merely to form a substantial connection between the sides and the centre sill and cause each to support the other in case of one being subject to any unusual load as might occur in case of accident. The concentrated loads shown are practically the same as those mentioned in detail in connection with Type 2, except that on account of the crossbearers not transferring any load, the dynamo appears as item P_4, 480 pounds on centre sill P_2, and 205 pounds on the side girder. The floor materials and partitions immediately inside of the end door are assumed to be carried by the end of the centre sill and are shown as item P_2, 326 pounds, while the end frame of the car is assumed to be carried on the extreme end of the side girder and appears as item P_1, 1,125 pounds. The entire weight of the vestibule is assumed to be carried on the end of the centre sill. This would scarcely be proper if the centre sill had a very shallow depth at and beyond the centre plate, but in this case where the sill is a 16" box girder with very heavy top and bottom cover plates, it is a proper assumption.

The load shown produces a comparatively large positive bending moment at the centre plate and a relatively small moment at the centre of the car which, of course, is a desirable condition. The bending moment in the side girder is comparatively large at the centre of the car due partly to the rather heavy loading near the centre, and also to the very small amount of weight beyond the bolster. The bolsters are shown double as is customary in cars with six-wheel trucks, but this does not affect the bending moment at the centre of the car, for instead of the maximum positive moment occurring at the centre line of truck, the bending moment is now zero at this point, and the maximum positive moment occurs at the centre line of bolster nearest the end of the car.

The diagram shows the particulars of centre sill and side girder construction and stresses. It will be noted that no top plate angle is used but the belt rail is increased from the sizes used in Type 2 from 3 sq. inches to 4½ sq. inches area, and the sill angle is 6 x 4 x ½" instead of 6 x 4 x ⅜". All of the centre sill members are assumed to be continuous between end sills excepting the bottom cover plate which extends from the top of draft gear to a point 5' 6" beyond the centre plate.

It will be noted that maximum compressive stress occurs at section C—C in the centre sill, and totals 17,000 pounds per sq. inch. This is permissible as it is customary to allow twenty per cent. increase in maximum stress when necessary to take care of secondary stresses due to end shock acting eccentric to the centre line of gravity of the sill, with the understanding that the sum of all direct stresses must not exceed 16,000 lbs. per sq. inch. A maximum tension of 16,300 lbs. per sq. inch on section C—C of the side girder is permissible on account of the moment of inertia of the web plate not having been considered in computing the section modulus.

The load disposition is worked out on the same lines in Type 4 as in Type 3, and the concentrated loads on the centre sill are practically the same except that there is a relatively heavy loading at crossbearer line B—B and at the end sill. It will facilitate a quick understanding of the disposition to consider this as similar to Type 3 with the bolsters separated to 192" centres instead of 56". The bending moment at the centre of the car in the centre sill is slightly less than that in Type 3, but is nearly double as much at the centre plate, on account of the increased spread of the bolsters or crossbearers. The bending moment in the side girder at the centre of the car is approximately the same as in Type 3 There is no positive moment at the bolster as in Type 3, but a gradually diminishing negative moment, brought about by the presence of side frames which are relatively rigid and which transfer their loads to a centre sill of comparatively shallow depth and relatively flexible. The centre sill, balancing as it does over the centre plate midway between the end sill and the crossbearer, acts as an equalizer and ensures the same transfer of load from the side frame at the end sill as at the crossbearer, with the result that the bending moment between crossbearers is exactly the same as if the side frame was supported at the truck centre, line E—E. To further explain the action of this system of frame, a considerable load may be imagined as applied in the vestibule of the car, producing a bending moment in the centre sill, and as soon as this deflected the rigid connection between the end of the centre sill and the end of the side girder would cause the latter to act as a beam overhanging its support at the crossbearer. There would result on the crossbearer a considerable increase in load which would instantly be transferred by the crossbearer to the centre sill. The exact disposition of this transfer of load is dependent on the deflection of the centre sill and the side frame, and the transfer ceases as soon as a state of equilibrium is arived at. In other words, any load applied to this car either between or outside of the centre plates, is transferred around in such a manner as to balance over the centre plate. The same remarks regarding the centre sill and side frame construction (particulars being contained in the diagram) apply to this type as to Type 3. The side frames are exactly the same except that the somewhat larger bending moment in the side girder requires an additional sixteenth on the belt rail and side sill angle. The centre sill is very simple, consisting of two 18" 45-pound channels with ½" x 24" top and bottom cover plates; all members are continuous between the ends of the car. The maximum compressive stress of 17,590 lbs. per sq. inch at section C—C of centre sill is permissible for the same reason as was given in Type 3, viz., on account of secondary stress.

To make comparison of the principal load carrying members, their areas, weights per lineal foot, and total weight per car, these have been tabulated, for convenience of reference, with the omission of minor details that cannot be compared to any advantage. The chief item of interest in connection with the centre sills is the weight of 7,000 lbs. for Type 2 as compared to 10,000 lbs. for Type 3, and 12,000 for Type 4. On the other hand the bolsters in Type 2 are somewhat heavier than in Type 3 and considerably more so than in Type 4. As Type 4 does not have any regular bolster, it

COMPARISON OF PRINCIPAL LOAD CARRYING MEMBERS WITH AREAS, WEIGHT PER FOOT & TOTAL WEIGHT OF CAR.

SECTION.	DESCRIPTION. 2	DESCRIPTION. 3	DESCRIPTION. 4	AREA IN SQ INS. 2	AREA IN SQ INS. 3	AREA IN SQ INS. 4	WEIGHT PER LINEAL FT. 2	WEIGHT PER LINEAL FT. 3	WEIGHT PER LINEAL FT. 4	TOTAL WEIGHT PER CAR. 2	TOTAL WEIGHT PER CAR. 3	TOTAL WEIGHT PER CAR. 4
CENTER SILL AT CENTER OF CAR	2-10" 30# SHIP C's 1-3/8"x24 PLATE	1-3/8x30" PLATE 2-4"x3"x7/16 L's 2-5/16x29" PLATES 2-3"x3"x3/8 L's	2-18-45# C's 2-1/2"x24" PLATES	17.66 9. 26.66	11.25 5.74 18.10 4.22 39.31	26.5 24. 50.5	60. 30.6 90.6	38.20 19.50 61.60 14.35 133.65	90. 81.6 171.6	6945	10054	12279
CENTRE SILL AT BOLSTER.	1-5/16x24" PLATE 2-10"-30 SHIP C's 1-3/8x24" PLATE	1-3/8x30" PLATE 2-4"x3"x7/16 L's 2-5/16x15" PLATES 2-3"x3"x3/8" L's 1-1/2"x24" PLATE	2-18"-45# C's 2-1/2"x24" PLATES	7.5 17.66 9. 34.16	11.25 5.74 19.30 4.22 12.00 42.51	26.5 24. 50.5	25.5 60. 30.6 116.1	38.20 19.50 31.60 14.35 40.80 144.45	90. 81.6 171.6			
BOLSTER NEAR CENTER	1-3/4"x16" PLATE 2-3/8" WEB PLATES 1-3/4x16" PLATE	1-3/8"x8" PLATE 1-3/8 WEB PLATE 1-3/8x8" PLATE								3103	2550	1600
CROSS BEARERS NEAR CENTER	1-5/8x6" PLATE 1-5/16" WEB PLATE 1-5/8x6" PLATE	1-3/8x8" PLATE 1-1/4" WEB PLATE 1-3/8x6" PLATE	1-3/8x15" PLATE 2-3/8" WEB PLATE 1-3/8x15" PLATE							1870	1355	1505
ONE SIDE ABOVE WINDOWS	1-4"x4"x5/16 L 1-1/8x13" PLATE 1-1 3/8x7/8x3/16 L	1-1/8x13" PLATE 1-1 3/8x7/8x3/16 L	1-1/8x13" PLATE 1-1 3/8x7/8x3/16 L	2.41 1.63 .39 4.43	1.63 .39 2.02	1.63 .39 2.02	8.2 5.55 1.32 15.07	5.56 1.32 6.87	5.55 1.32 6.87	7380	7645	8046
ONE SIDE BELOW WINDOWS	1-3/4x4" BAR 1-1/8x36" PLATE 1-6x4x3/8" L	1-SPECIAL 4" BAR 1-1/8x36" PLATE 1-6x4x1/2" L	1-SPECIAL 4" BAR 1-1/8x36" PLATE 1-6"x4"x9/16" L	3.00 4.50 3.61 11.11	4.25 4.50 4.75 13.50	4.50 4.50 5.31 14.31	10.2 15.3 12.3 37.8	14.6 15.3 16.2 46.0	15.3 15.3 18.05 48.65			
ONE POST.	1-3/16x15" PLATE 2-4"-5.25# C	1-1/8x15" PLATE 2-4"x1 3/4x1/8 P.S. C's	1-1/8"x15" PLATE 1-4"x1 3/4x1/8 P.S. C's	2.81 3.10 5.91	1.87 1.87 3.74	1.87 1.87 3.74	9.56 10.54 20.1	6.37 6.37 12.74	6.37 6.37 12.74	4840	2794	2794
TOTAL WEIGHT PER CAR OF CENTER SILL, BOLSTERS, CROSS BEARERS & SIDE FRAMES										24138	24398	26224

should be explained that the 1,600 lbs. consist of centre plates, centre plate braces, side bearing castings that are secured to the side of the car, and tie plates between centre sill and side sill. The crossbearers of Type 2 are considerably heavier than the other two on account of there being four per car as compared to three and two respectively in the other cases. The comparison of longitudinal side frame members is interesting on account of the small difference between the three types of car, but the posts in Type 2 are considerably heavier than in Types 3 and 4. This is to be expected in view of the important part that they take in supporting the load.

The grand totals indicate no appreciable difference between Types 2 and 3 and a slight increase, less than ten per cent., for Type 4, which fact compels the conclusion that all three types are good.

This paper is not intended to be a treatise on how to design steel cars or any part of them, and it may not be exactly in order to say very much about the merit of the three different types, but a few remarks may assist in enabling each individual to form definite opinions of his own as to the merits of each type as observed in service, and more especially when the opportunity presents itself to examine cars that have been in accident. The great importance of a minimum weight for a given standard strength was mentioned in a preceding paragraph. As to ability to support their own weight and the usual maximum live load, there is no question but that each is entirely satisfactory. The same remarks also are absolutely correct with regard to end shocks in coupling and uncoupling and collisions, so long as the cars remain on the track in the same horizontal plane.

The condition that usually results in numerous injuries and loss of life is the telescoping of cars, as it is called, when the underframe of one car gets above the underframe of the next car and plows through the comparatively light superstructure. When this occurs it is impossible to express what happens in terms of a static load at a given location, but it has come to be generally accepted as inevitable that some damage must result to the vestibule and car end no matter what construction is used. The greatest protection to passengers is effected by making the end construction very strong, not necessarily to resist bending but rather to prevent tearing away at the fastenings. As a telescope contemplates conditions where the centre sills are not in line, some exponents of the comparatively light centre sill construction argue that the very large and powerful centre sills do not afford any additional protection but are actually objectionable because of the increased probability of their tearing away the end superstructure.

For resisting end shocks above the floor level, side swiping and bending, Type 2 is doubtless stronger than the others on account of the comparatively heavy top plate angle and the stronger post construction.

Advantages for the large heavy centre sills are not so easy to find, but there is one important condition where they would probably show up to advantage and that is in case of a collision where a locomotive strikes the car. A modern locomotive would not be at all likely to climb into the car, and if the speed was great even the heaviest car construction could not be expected to stand up against the massive castings and heavy steel plates used in locomotive construction; but it is quite reasonable to presume that the stronger the centre sill construction in the car the less the damage which would result.

From construction and operating standpoints the shallow centre sill car has the advantage of not interfering in any way with the locating of brake rigging and other equipment under the car, and it materially facilitates quick and thorough inspection in service.

PLATE 1.

SLEEPING CAR.

CLASS P.S.72.E.
CAPACITY 53 PASSENGERS.

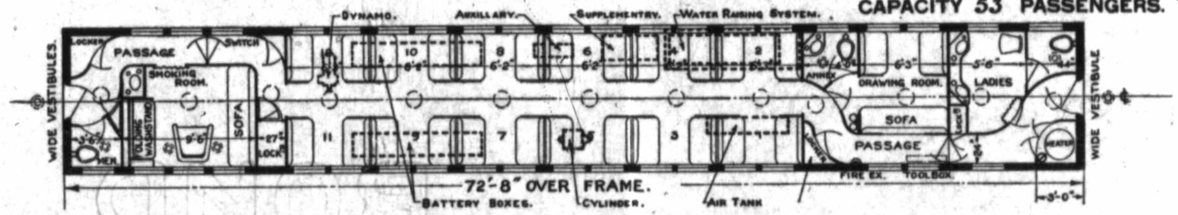
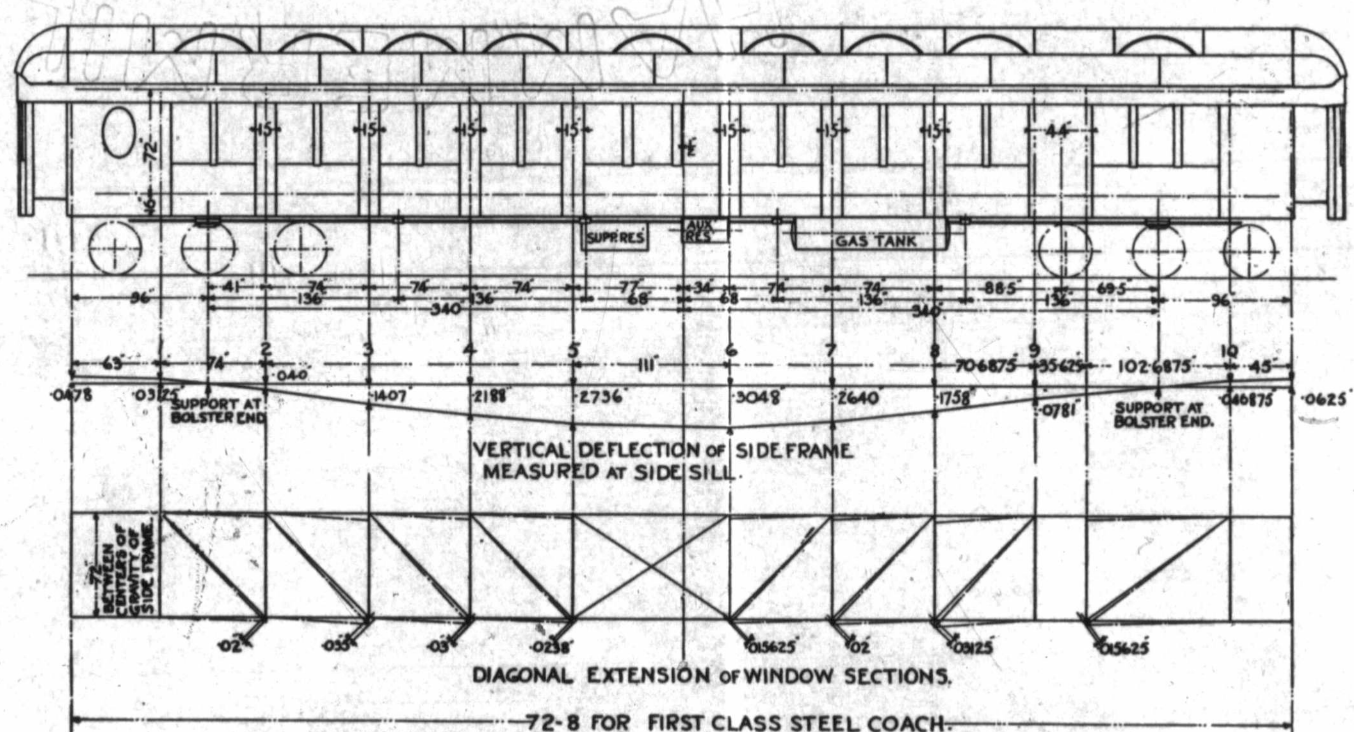


Figure 1.



DISTRIBUTED LOAD EQUAL TO COMPLETE CAR + 80769 POUNDS LIVE LOAD.

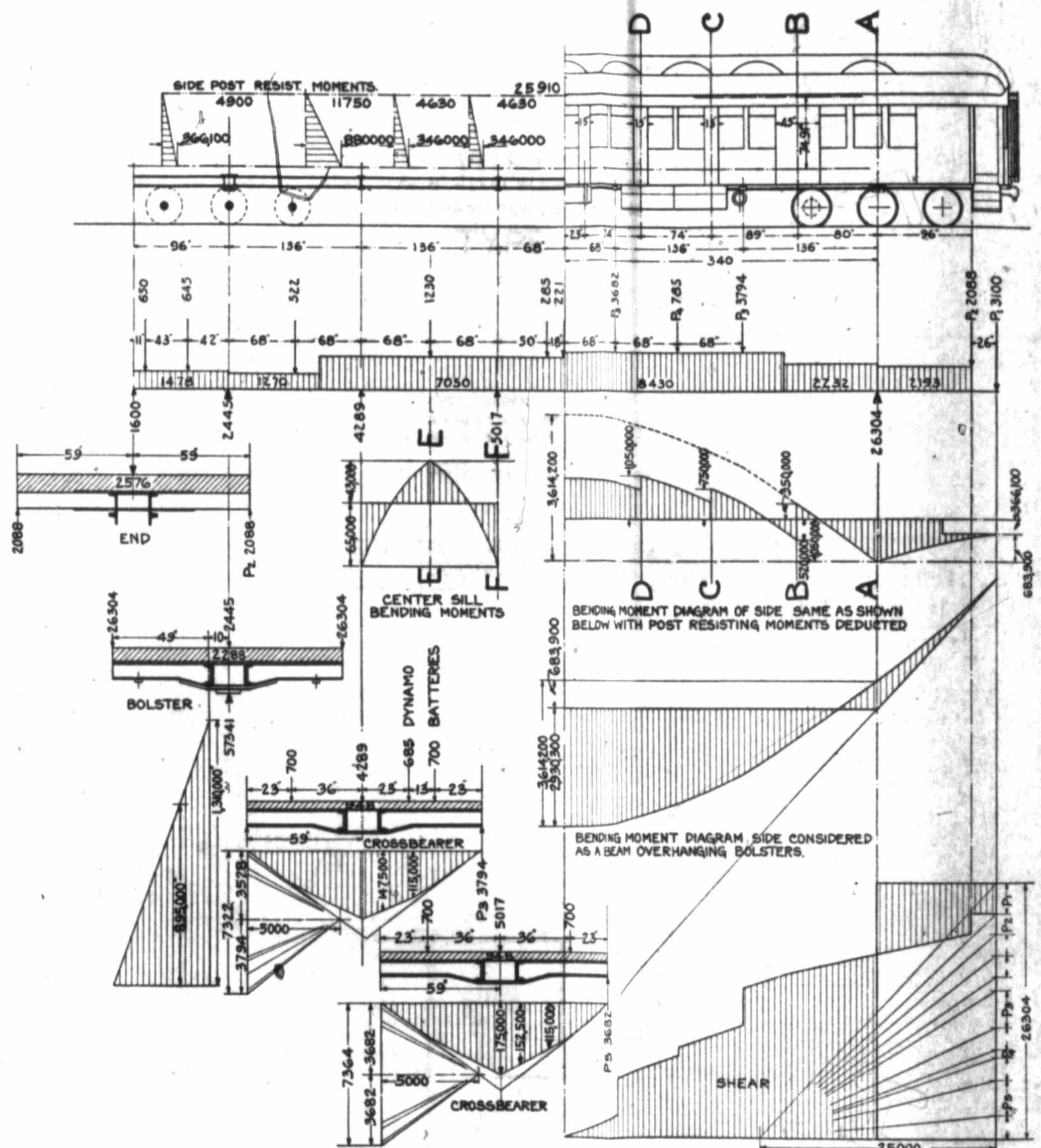
Figure 2.

COMPOSITION OF CAR	WEIGHT OF CAR NO TRUCKS	WEIGHT OF DISTRIBUTED TEST LOAD
STEEL SHELL ONLY NO INSULATION OR FINISH	63620 olbs	113268.28 lbs

DEFLECTION DIAGRAM

For 72 ft. 8 in. Steel Coach.

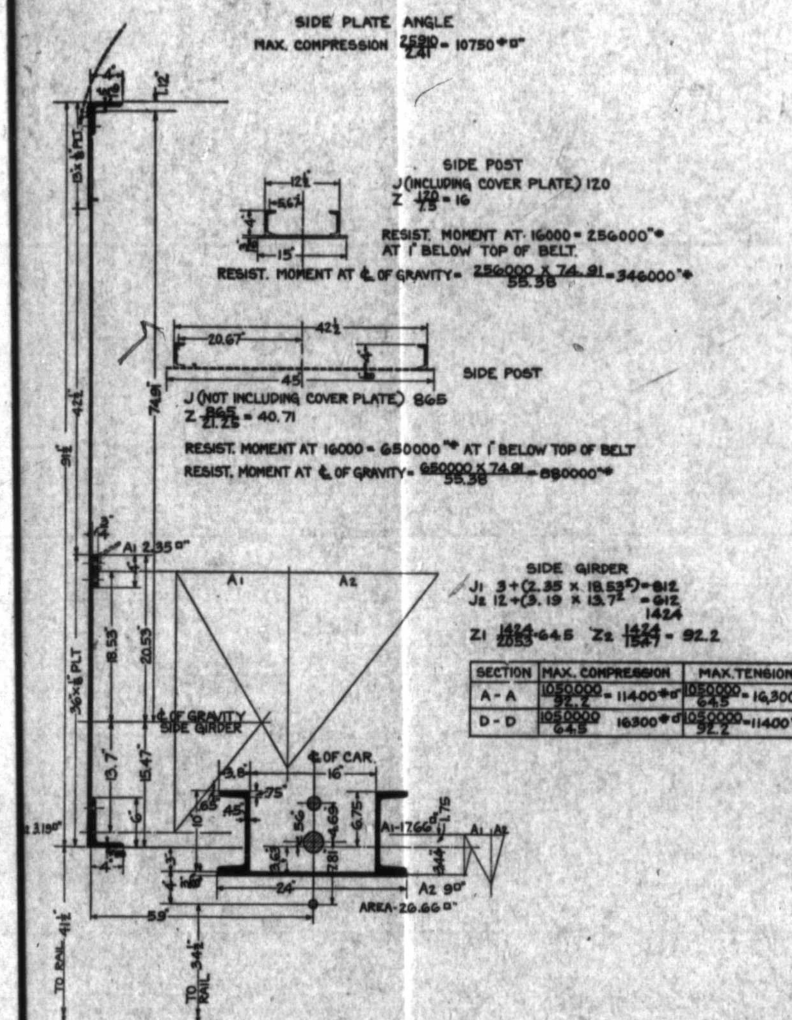
PLATE 2.



STRESS DIAGRAM
72' 8" STEEL SLEEPING CAR
FRAME CONSTRUCTION

TYPE 2.

MONTREAL NOV. 1914.



SIDE GIRDER

$J_1\ 3+(2.35 \times 18.53^2)=812$
$J_2\ 12+(3.19 \times 13.7^2\ =612$
1424

$Z_1\ \frac{1424}{2053}=64.5 \quad Z_2\ \frac{1424}{1547}=92.2$

SECTION	MAX. COMPRESSION	MAX. TENSION
A - A	$\frac{1050000}{92.2}=11400$ #☐"	$\frac{1050000}{64.5}=16,300$ #☐"
D - D	$\frac{1050000}{64.5}$ 16300 #☐"	$\frac{1050000}{92.2}=11400$ #☐"

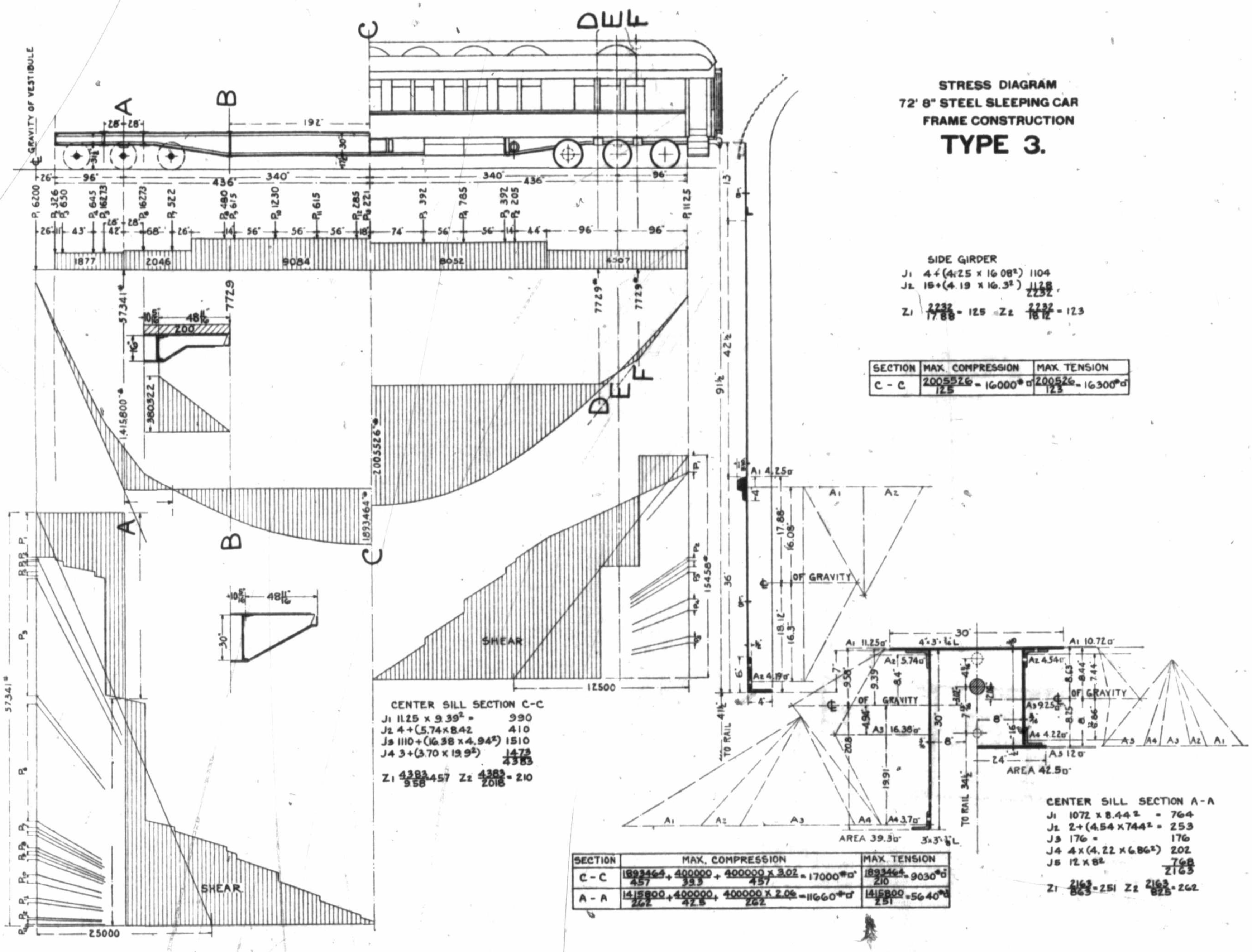
CENTER SILL

$J_1\ 132.6+(17.66 \times 1.75^2)=186.6$
$J_2\ 9 \times 3.44^2 = \underline{106.5}$
293.1

$Z_1\ \frac{293.1}{6.75}=43.5 \quad Z_2\ \frac{293.1}{3.63}=80.8$

SECTION	MAX COMPRESSION	MAX. TENSION
E - E	$\frac{400000}{26.66}+\frac{43000}{43.5}=15990$ #☐"	$\frac{43000}{80.8}=532$ #☐"
F - F.	$\frac{400000}{26.66}+\frac{65000}{80.8}=15805$ #☐"	$\frac{65000}{43.5}=1490$ #☐"

STRESS DIAGRAM
72' 8" STEEL SLEEPING CAR
FRAME CONSTRUCTION
TYPE 3.



SIDE GIRDER

J_1 4+(4.25 × 16.08²) 1104

J_2 15+(4.19 × 16.3²) 1128 / 2232

Z_1 $\frac{2232}{17.88}$ = 125 Z_2 $\frac{2232}{18.12}$ = 123

SECTION	MAX. COMPRESSION	MAX. TENSION
C - C	$\frac{2005526}{125}$ = 16000#□"	$\frac{200526}{123}$ = 16300#□"

CENTER SILL SECTION C-C

J_1 11.25 × 9.39² = 990

J_2 4+(5.74×8.42 410

J_3 1110+(16.38×4.94²) 1510

J_4 3+(3.70×19.9²) 1473 / 4383

Z_1 $\frac{4383}{9.58}$ = 457 Z_2 $\frac{4383}{20.18}$ = 210

SECTION	MAX. COMPRESSION	MAX. TENSION
C - C	$\frac{1893464}{457}+\frac{400000}{39.3}+\frac{400000 \times 3.02}{457}$ = 17000#□"	$\frac{1893464}{210}$ = 9030#□"
A - A	$\frac{1415800}{262}+\frac{400000}{42.5}+\frac{400000 \times 2.06}{262}$ = 11660#□"	$\frac{1415800}{251}$ = 5640#□"

CENTER SILL SECTION A-A

J_1 1072 × 8.44² = 764

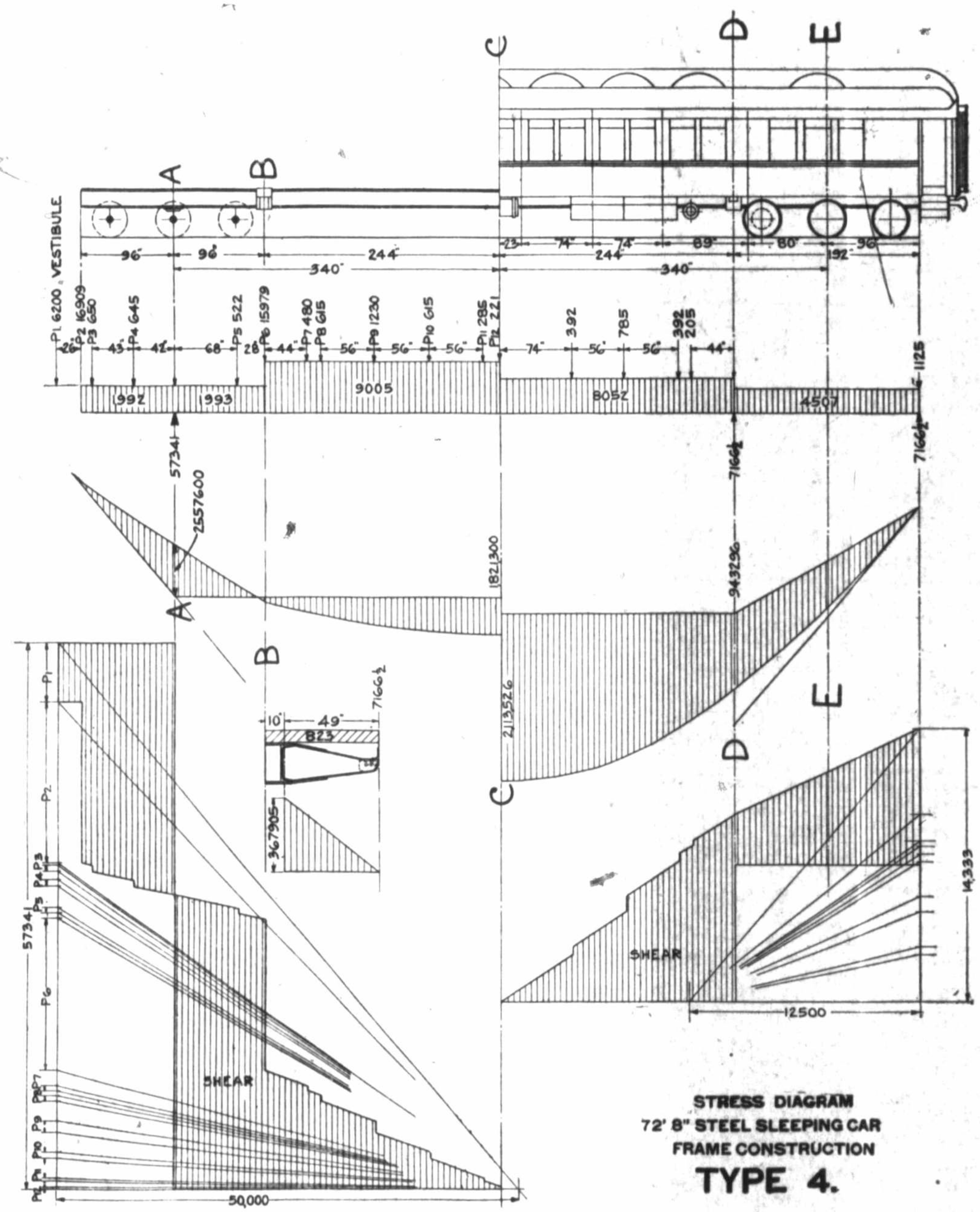
J_2 2+(4.54×744² = 253

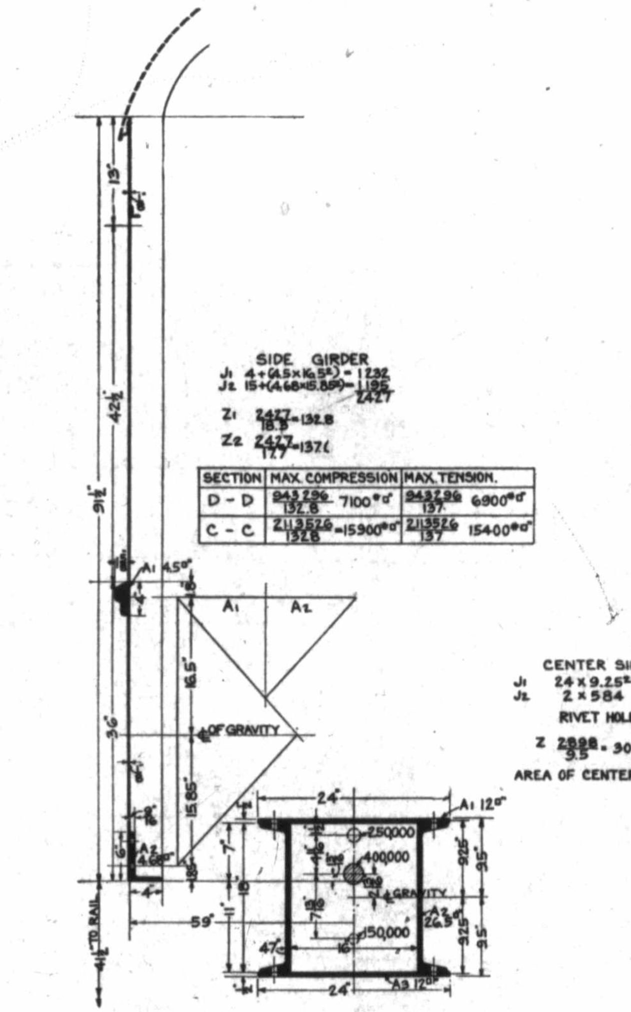
J_3 176 = 176

J_4 4×(4.22×6.86²) 202

J_5 12×8² 768 / 2163

Z_1 $\frac{2163}{8.63}$ = 251 Z_2 $\frac{2163}{8.25}$ = 262





SIDE GIRDER

J_1 4+(4.5×16.5²) = 1232
J_2 15+(4.68×15.85²) = 1195
2427

Z_1 $\frac{2427}{18.3}$ = 132.8

Z_2 $\frac{2427}{17.7}$ = 137

SECTION	MAX. COMPRESSION	MAX. TENSION.
D - D	$\frac{943296}{132.8}$ 7100#□"	$\frac{943296}{137}$ 6900#□"
C - C	$\frac{2113526}{132.8}$ = 15900#□"	$\frac{2113526}{137}$ 15400#□"

CENTER SILL

J_1 24 × 9.25² = 2054
J_2 2 × 584 = 1168
3222
RIVET HOLES 324
2898

Z $\frac{2898}{9.5}$ = 305

AREA OF CENTER SILL 50.5□"

SECTION	MAX. COMPRESSION	MAX. TENSION
A - A	$\frac{2557600}{305} + \frac{400000}{50.5} + \frac{400000 \times 2.81}{305}$ = 12270#□"	$\frac{2557600}{305}$ = 8040#□"
C - C	$\frac{1821300}{305} + \frac{400000}{50.5} + \frac{400000 \times 2.81}{305}$ = 17590#□"	$\frac{1821300}{305}$ = 5960#□"

STRESS DIAGRAM
72' 8" STEEL SLEEPING CAR
FRAME CONSTRUCTION

TYPE 4.