INTERSTATE COMMERCE COMMISSION

REPORT OF THE DIRECTOR OF THE BUREAU OF SAFETY IN RE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE NEW YORK CENTRAL RAILROAD AT WATKINS GLEN, N. Y., ON MARCH 11, 1928

JANUARY 3, 1929.

To the COMMISSION.

On March 11, 1928, there was a derailment of a freight train on the New York Central Railroad at Watkins Glen, N. Y, resulting in the death of two employees and the injury of one employee

LOCATION AND METHOD OF OPERATION

This accident occurred on the Fall Brook subdivision of the first district of the Pennsylvania division, extending between Corning and Lyons, N Y, a distance of 71 36 miles; in the vicinity of the point of accident this is a double-track line over which trains are operated by time-table, train orders, and a manual block-signal system The first mark of derailment appeared on the northbound main track at a point about 1,200 feet north of Watkins Glen passenger station; approaching this point from the south there is a 2° curve to the left 1,613 feet in length and then the track is tangent for a distance of 270 feet, the initial mark of derailment appearing on this tangent at a point about 183 feet from its southern end. The grade for northbound trains is 0 4108 per cent descending at the point where the first mark appeared The track is laid with 105-pound rails, ballasted with rock, and maintained in good condition

The weather was clear at the time of the accident, which occurred at about 8 28 a m

DESCRIPTION

Northbound freight train CD–34 consisted of 87 cars and a caboose, hauled by engine 2794, and was in charge of Conductor Dean and Engineman Straub This train passed Watkins Glen at 8 25 a m, according to the train sheet, and was derailed just beyond the station while traveling at a speed estimated to have been about 20 or 25 miles per hour, the derailment apparently being due to the breaking of a lower arch bar in the rear truck of the second car ahead of the caboose, Cambria & Indiana Railroad coal car 667.

That portion of the train ahead of the coal car involved was not derailed, and that particular car remained coupled to the forward portion of the train and only its rear truck was derailed The last car in the train and the caboose broke away from the rest of the train and were derailed to the east, the caboose coming to rest at a point about 1,000 feet north of where the first mark of derailment appeared, while the car came to rest at a point about 1,400 feet beyond the caboose The employees killed were the middle brakeman and the flagman, who were riding in the caboose at the time of the accident

SUMMARY OF EVIDENCE

The first mark of derailment appeared on the frog of a trailing-point crossover, the mark being on the outside of the west rail of the northbound track. Apparently the wing of the frog was struck solidly by some heavy object, supposedly the truck of the car first to be derailed The truck seemed then to climb over the frog and strike the guard rail at the switch; the stock rail was turned over, and also the next rail beyond it, while the switch stand was broken due to the switch having been trailed through by the derailed equipment. Between this point and the point where the head portion of the train came to a stop, ties were marked, apparently by derailed wheels, and at another intervening crossover switch, a facing-point switch, the stock rail and wing of the frog were badly bent, as well as the switch points, apparently by the same equipment which caused the damage at the first crossover; this second crossover switch is located about 2,200 feet north of the crossover switch first mentioned. Examination of the rear truck of Cambria & Indiana 667 showed a broken arch bar on the left side of the rear truck and the truck showed signs of having come in contact with the frogs and rails previously mentioned

Conductor Dean stated that the first intimation he had of anything wrong was when the caboose reached the first crossover switch north of Watkins Glen passenger station, and he immediately applied the air brakes in emergency from the rear of the train; he estimated the speed of the train at that time to have been about 20 or 25 miles per hour Engineman Straub, Fireman Anderson, and Head Brakeman Littlewood were unaware of anything wrong prior to the time the air brakes were applied from the rear; they estimated the speed of the train to have been about 25 miles per hour On going back from the engine after the accident Head Brakeman Littlewood saw the broken arch bar in the rear truck of the coal car involved.

Car Inspectors Sebastian Root and Wendell Root had inspected train CD-34 in the yard at Corning Their inspection covered couplers and attachments, grab irons, brake rigging, arch bars, etc. No defective condition was discovered, however, so far as Cambria & Indiana 667 was concerned.

The evidence having indicated that the accident was caused by a broken arch bar, an investigation into the reason for the failure of the arch bar was conducted by Mr James E Howard, engineer-physicist, whose report immediately follows.

Report of the Engineer-Physicist

The accident at Watkins Glen, N. Y, on March 11, 1928, in which freight train CD-34 was involved, was due apparently to the fracture of a lower arch bar in the rear truck of Cambria & Indiana Railroad coal car No 667, the second car in front of the caboose

Figure No 1 is a view of this car, with a new truck, after rerailing

An incipient crack was subsequently found in the lower arch bar in one of the truck frames of the car next the caboose, Cambria & Indiana coal car No 622.

Each of these arch bars was made of steel, 5 inches wide by 1¼ inches thick in cross section dimensions respectively. The fractures were progressive, originating at the upper outside corners of the bars directly under the edges of the column castings, at the angle made by the horizontal and diagonal parts of these members

Figure No. 2 shows the appearance of the fractured surface of the bar from the truck of car No 667. At its deepest place the progressive fracture had reached to the middle of the thickness of the bar; crosswise to nearly its full width This part of the bar was dark colored, had a smooth surface with a rippled boundary, presenting the usual characteristics of a progressive fracture The portion of the bar which failed at the time of the accident was granular in appearance Approximately, one third of the cross section of the bar was separated by the progressive fracture.

The fracture of each arch bar originated in its gross sectional area, and not where it was materially reduced by the presence of a column-casting bolt hole.

The ages of these fractured bars are unknown Car No. 667 was built in the month of February, 1912 Presumably the bars were 16 years old at the time of the accident

These were 50-ton cars, which in service would usually carry full loads. Each truck frame, therefore, would be loaded, in round numbers, with 35,000 pounds. Subsequent tests on such frames showed a wide margin in strength between working loads and ultimate strength as determined under static conditions, and also an entirely different manner of fracture

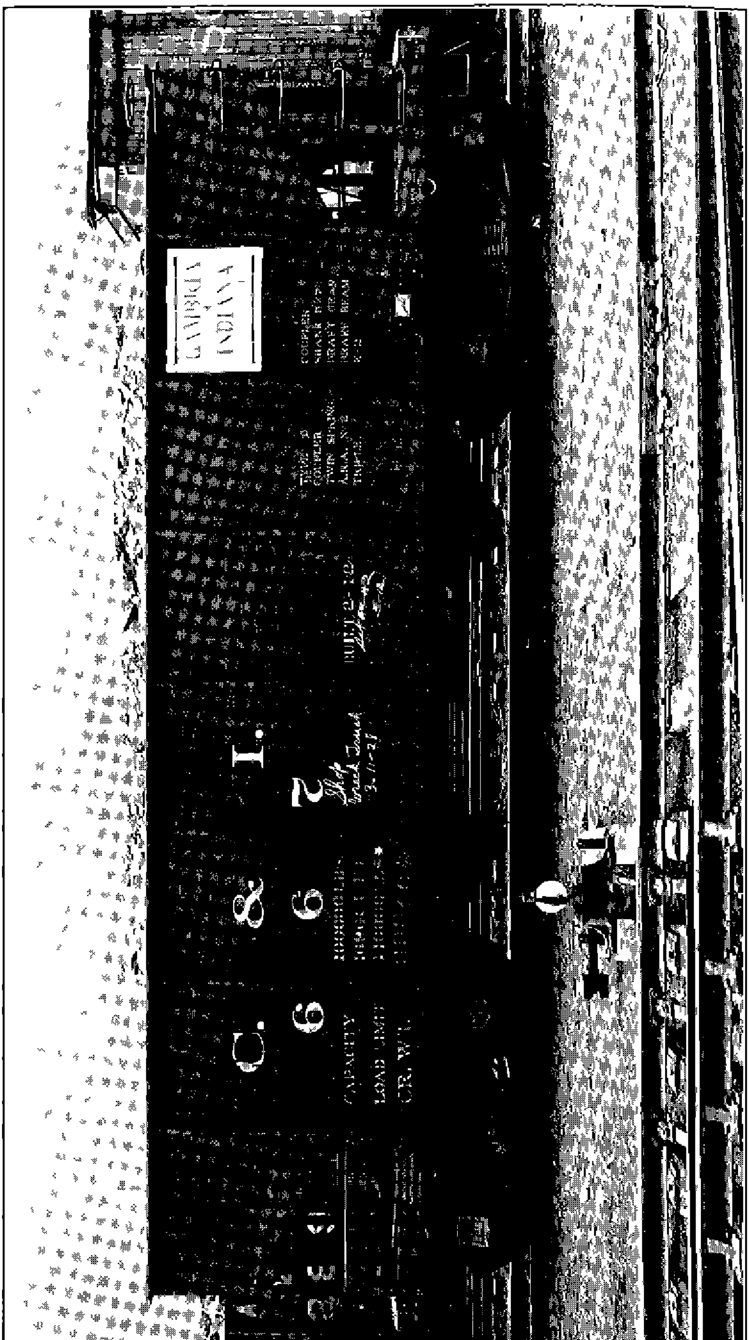

FIGURE 1.—Cambria & Indiana Railroad coal car No 667 with new truck, after rerailing

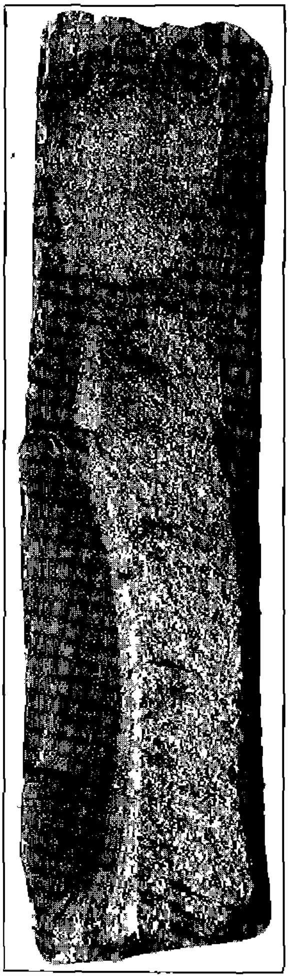

Figure 2.—Fractured surface of steel arch bar of car No 607 showing extent of progressive fracture which occurred in service

Figure No 3 shows the appearance of the incipient fracture in the arch bar from car No 622 Its progressive character is shown It began at the upper corner of the bar, extended radially, and reached a depth of half the thickness of the bar when final rupture occurred The final part was fine granular, radiating from the progressive portion of the fracture

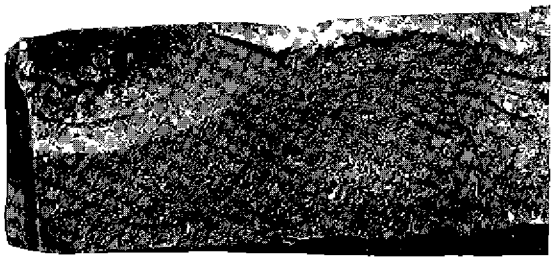

FIGURE 3—Incipient fracture at corner of steel arch bar of car No 622

The presence of an incipient fracture in a truck frame affords a potential opportunity for an accident

Chemical analyses and tensile tests showed the metal of these two bars to be as follows

Chemical composition

	Carbon	Manganese	Phosphorus	Sulphur	Silicon
Car No 667					
Outside	0 23	0 50	0 024	0 034	0 035
Center	24	47	025	030	029
Car No 622					
Outside	25	36	024	036	013
Center	28	38	026	040	013

Tensile tests

	Yield point, pounds per square inch	Tensile strength, pounds per square inch	Elongation, per cent in 2 inches	Contraction of area, per cent
Car No 667				
Outside	32,170	61 860	35 0	60 5
Center	29 270	57,300	36 0	62 5
Car No 622				
Outside	34 070	58 350	36 0	61 2
Center	39 750	63 410	33 5	58 7

Appearance of fractures, fine granular

The tensile test pieces were taken out of the bars longitudinally

NOTE.—These results are reported in the usual manner. The yield point is in the vicinity of but somewhat above the elastic limit of the steel. Values for tensile strength and contraction of area are correct. Those which purport to indicate the elongation of the metal include local contraction at point of rupture, hence present fictitious values which have no definite relation to the ability of the metal to elongate under its own strength.

The microstructure of the metal of the arch bars, 3 per cent nitric-alcohol etch, vertical illumination, 100 diameters magnification, is shown by Figures Nos. 4 to 7, inclusive.

There was no structural evidence of work done during fabrication which would attach responsibility for the fracture of the bars to either heat or mechanical treatment.

The lower arch bar of the opposite frame in the truck of car No. 667 was examined. This bar proved to have been made of wrought iron, and was clearly of more recent fabrication than its steel companion, which failed. The steel bar showed wear and abrasion at the column casting bolt holes, whereas the wrought-iron bar showed none.

Bending tests, in full cross section, were made with each bar. They were flattened at their bends over the axle box seats, then reversing the bends. The appearance of the fractures thus made are shown by Figure No. 8. The wrought-iron bar was tough and fibrous, the steel bar brittle when the strains were reversed. The wrought-iron bar, when pickled in hot hydrochloric acid, displayed the characteristic fibrous appearance of that metal while the steel bar had a uniform gray surface. Figure No. 9 shows the appearance of the bars, in cross section, after pickling.

Static tests were made on the vertical strength of arch-bar frames, through the courtesy of the Gould Coupler Co., at Depew, N. Y., on frames furnished by the New York Central Railroad Co., described and with results as follows:

Description	Weight of frame pounds	Ultimate strength, pounds
Secondhand wrought steel arch bar truck frame, 50 tons capacity, [illegible] by ¼ inch bars	758	196,000
New wrought iron arch bar truck frame, 50 tons capacity, 5 by 1½ inch bars	799	197,000
Old secondhand Haskell & Barker arch bar truck frame, 4½ by $1\frac{7}{16}$ inch bars	–	134,000

The manner of failure was the same in each of these frames. The arch bars remained intact. Failure occurred by reason of the shearing of the axle-box bolts, the shearing planes being between the upper and lower arch bars.

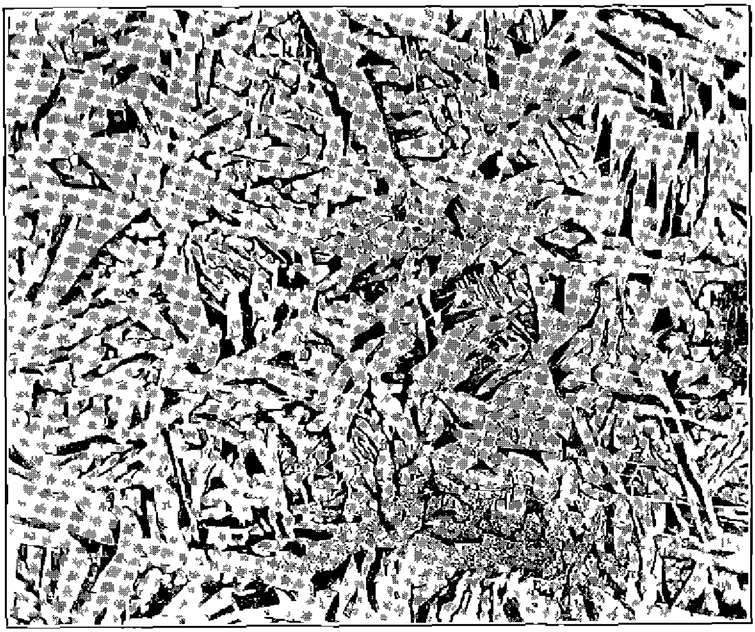

FIGURE 4.—Microstructure of arch bar, car No. 667, outside. Magnification 100 diameters.

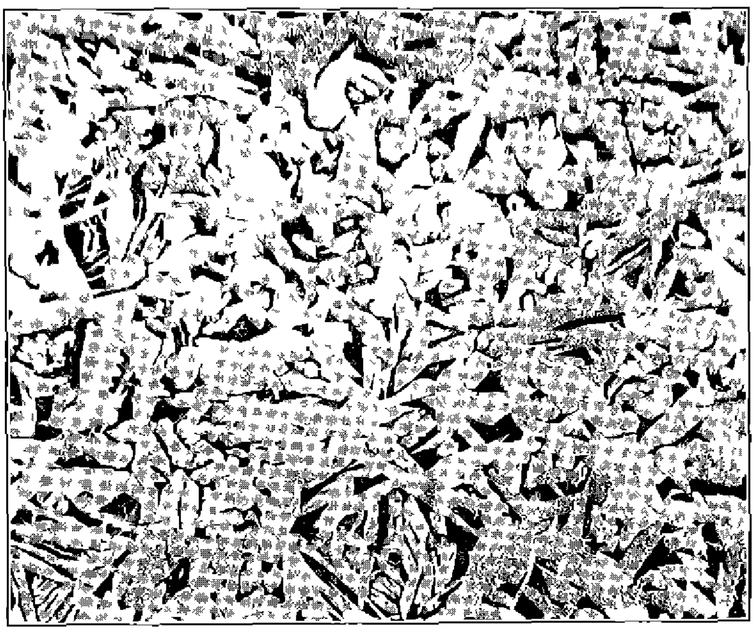

FIGURE 5.—Microstructure of arch bar, car No. 667, inside. Magnification 100 diameters.

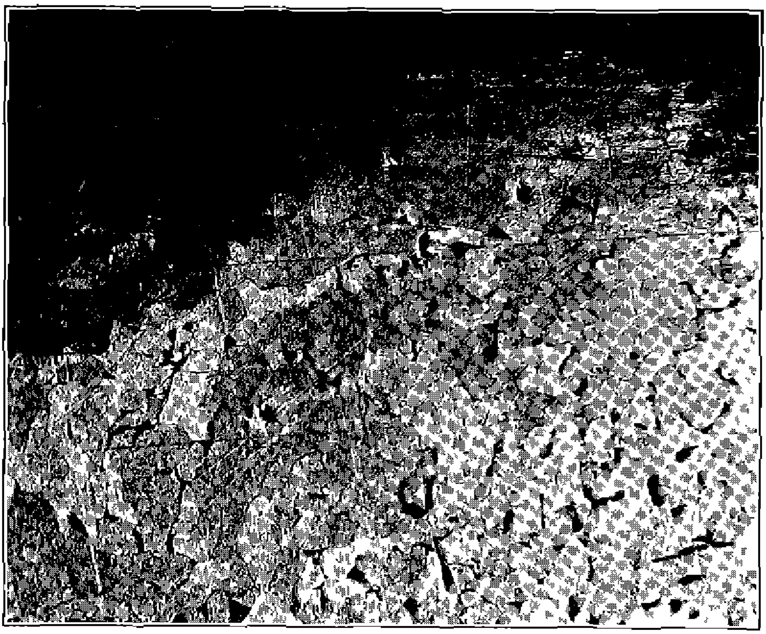

FIGURE 6.—Microstructure of arch bar car No. 622, outside. Magnification 100 diameters.

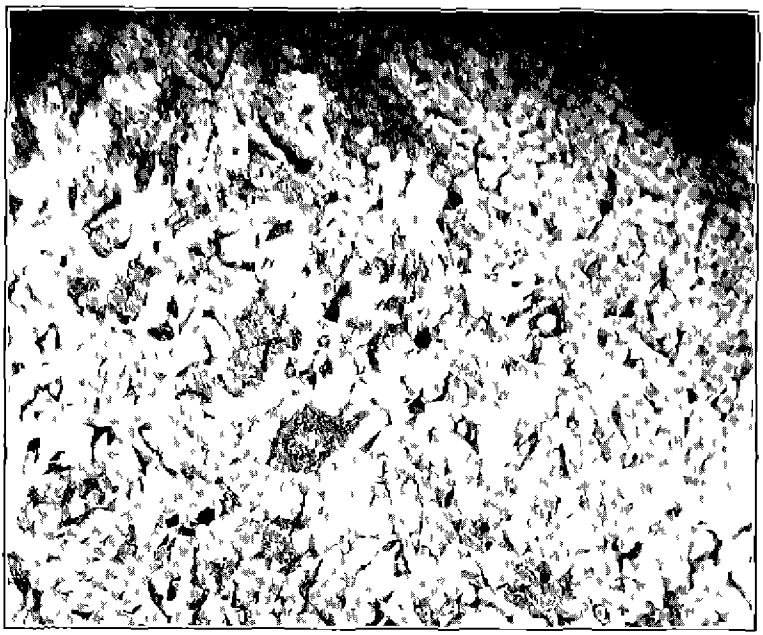

FIGURE 7.—Microstructure of arch bar car No. 622, inside. Magnification 100 diameters.

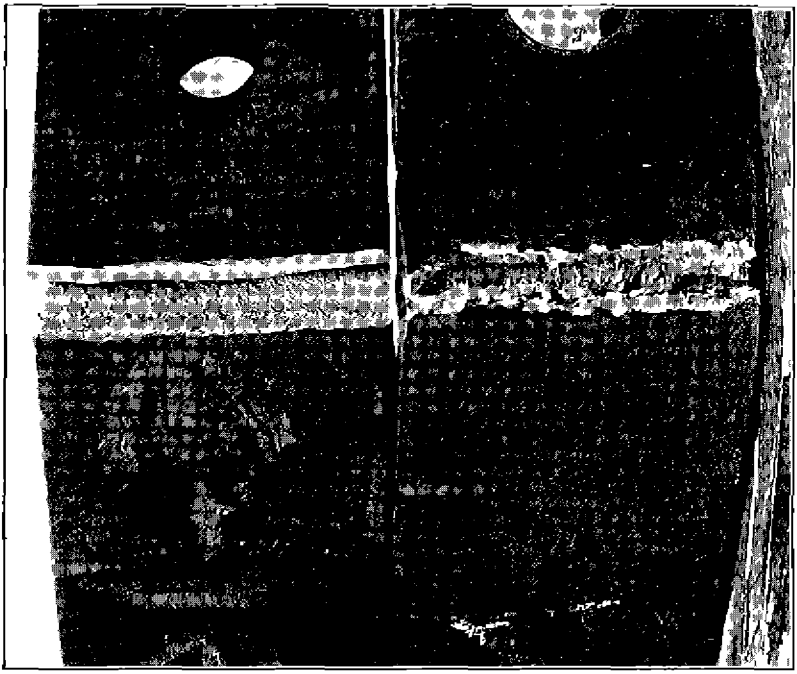

FIGURE 8—Fractures of arch bars of car No 667 after bending tests Steel bar on left of cut from bar which caused accident Wrought iron bar on right of cut, from opposite side of truck

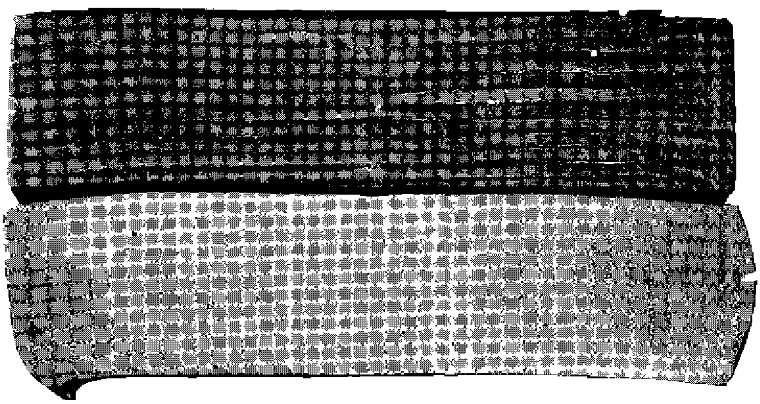

FIGURE 9—Appearance of arch bars car No 667 after pickling Upper figure of the cut, cross section of wrought iron bar Lower figure of the cut cross section of steel bar

It was not apparent, from trammel readings taken immediately prior to the shearing of the axle-box bolts, that the yield points of the bars was reached up to the time of ultimate strength of the frames. The bolt holes in each bar were permanently elongated. The shearing of the bolts relieved the strains of compression and tension, respectively, in the upper and lower arch bars whereupon their ends slid past each other, in the case of the new 50-ton frame, a distance of 1 inch.

Figure No. 10 illustrates the appearance of the new 50-ton frame after the test. Trammel measurements were made on the bars where the gauged lengths 31, 32, and 33 were indicated by chalk marks.

Tests were made on unit frames, steel castings covered by New York Central Railroad pattern F-6098, and the Gould Coupler Co.'s pattern TF-5077. The chemical composition of the metal in these frames was as follows:

Carbon	Manganese	Silicon	Phosphorus	Sulphur
0.29	0.71	0.32	0.020	0.021

Tensile test showed the metal to have an ultimate strength of 76,550 pounds per square inch, elongation 29.5 per cent and contraction of area 61.9 per cent.

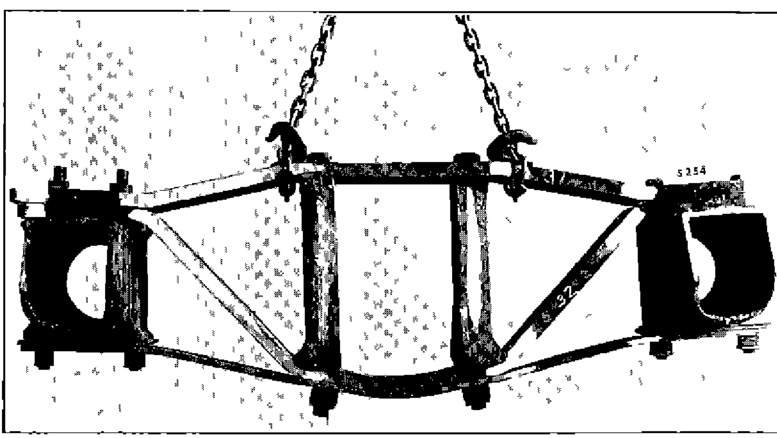

FIGURE 10.—Appearance of new arch bar frame for 50-ton car after test. Axle bolts sheared, on left side. Upper and lower arch bars slid by each other.

Tests of the frames Steel castings Loaded vertically

	Elastic limit approximate, pounds	Ultimate strength, pounds	Fractured
First frame	180,000	590,000	Diagonal tension member, at fillet near journal box
Second frame	162,000	587,000	Do
Third frame	175,000	612,000	Diagonal tension member near spring plank fillet

The fractures of the first and second frames were at chaplets in the diagonal tension members, through sound metal The fracture of the third frame occurred in the diag side of the casting at some small blow holes and sand inclusions

Figure No 11 represents diagrammatically the outlines of these cast-steel frames

Referring to the arch-bar frames, the difference in the manner of failure exhibited by those in service over those which were tested to destruction in the testing machine is a striking feature and one of importance to recognize In service the frames failed under comparatively low loads, at a certain locality, whereas in the laboratory, a wide margin in strength was displayed and failure occurred at another place

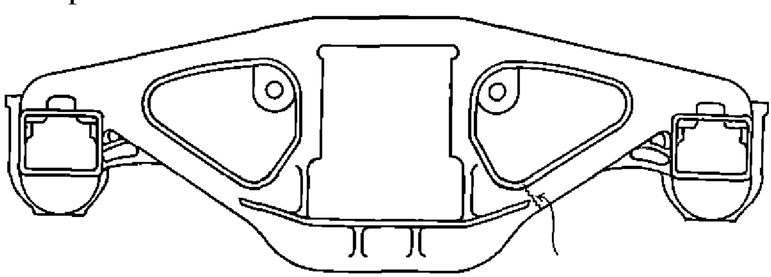

Figure 11 —Diagrammatic outlines of cast steel truck frames

A medium grade of steel was used in the fabrication of these bars which in laboratory tests, gave normal tensile properties The metal was strong and tough On the other hand service fractures were brittle, rupture being reached with no manifestation of ductility, an inherent property in the primitive state of the steel

The general term " fatigue " has been applied to fractures of this kind As a descriptive or explanatory term it has no definite meaning Its sole use consists in directing attention to the fact that conditions of service may be experienced in which any and all grades of steel will fracture in a brittle manner, and under conditions which they have previously endured for a time

Information upon this behavior of metals under the influence of repeated stresses has long been known, for over half a century

The historic work of Wohler, continued by Spangenberg, Bauschinger, and others in the last century, gave enlightenment upon the effects of repeated stresses. Wohler deduced the following laws: "Rupture of material may be caused by repeated vibrations, none of which attain the absolute breaking limit."

"The differences of the limiting strains are sufficient for the rupture of the material."

Shreve, in 1876, remarked, "Tests of iron and steel still go on for the purpose of determining their elasticity, their elongation under strain, their ultimate strength, and other qualities, while Wohler and Spangenberg's experiments show that it is very doubtful that these bear any proportion to the durability of the metals."

The fulfillment of certain prescribed tests generally governs the acceptance of material for current uses. If the possession of those properties demanded by governing specifications do not bear a known and favorable relation to causes of rupture the veneration sometimes entertained for specifications will be impaired. In fact, proponents are frequently engaged in the revision of specifications, whence it would seem that their acme had not in all cases been reached.

Touching upon observable phenomena in cases of repeated stresses, the writer's experience in the tests of several hundred steel and iron specimens has been to the effect that rupture was not reached without, strictly speaking, some minute permanent sets. Sets which would ordinarily escape notice but which were detectable with a strain gauge. Speculating upon what happens in the interior of a piece of steel, it is an unsolved problem whether the actual separation or detachment of adjacent particles, which marks the inception of rupture, is accomplished by a force inferior to the maximum tenacity of that material. Whether the external force applied is not augmented by internal strains the sum of which algebraically equals the ultimate tenacity of the steel, the external force, perchance, being only a fraction of its gross ultimate strength. The term progressive is preferred to fatigue as descriptive of what obviously transpires after the inception of rupture, and to extend the thought to an earlier stage, it is probably the better term to attach to conditions which precede actual separation and which are responsible for the practical destruction of the ability to display the phenomenon of elongation, excepting elastic.

Briefly enumerating what seems to be well established in reference to the effects of different stress on steels, cubic compression within practical limits does not affect the physical properties. However, certain plastic substances acquire a state of great rigidity under high cubic compression, a condition difficult to experimentally demonstrate if it exists in the case of steel. Under cubic tension the phenomenon of permanent flow or elongation would not seem possible Some orbital movement of the particles with reference to each other seems necessary to explain the phenomenon of permanent elongation, such as witnessed in tensile tests, and to a far greater degree in the operations of extruding, cold rolling, swaging, and wire drawing

Cold working in one direction commonly increases the tenacity of the metal in that direction Maximum values shown by the finer numbers of music wire have reached the extraordinary tensile strength of 460,000 pounds per square inch In free compression, that is, without lateral support, hardened steel has resisted 700,000 pounds per square inch

Based upon a modulus of elasticity of 30,000,000 pounds per square inch, these extreme values represent elastic strains of 1 5 and 2 3 per cent, respectively Against which the values of low-carbon steel have a capacity of only 0 1 per cent Depending upon circumstances, the range in elasticity of steels may take place anywhere within this wide scope of elastic movements Furthermore, the aggregate elastic extension, under restricted loads, may reach a total of several miles per linear inch of specimen under repeated stresses against 0 15 of an inch under tensile test But in addition to all of this, steel which is capable of displaying an aggregate extension of several miles when properly stressed will fail with almost absolute brittleness under repeated overstress

The obvious inference to be drawn from this evidence is not to neglect to search for the causes of failure of materials of construction in the conditions of service under which they have been exposed In the present case the failure of these arch bars was clearly the result of exposure to repeated stresses of a vibratory character

It must be said that a proper definition of the strains encountered in service, in railway material, is by no means an easy matter to reach That severe vibratory stresses are encountered there is no doubt Their magnitude, the vital feature, unfortunately is not known Amelioration of conditions will be reached by study, resulting in the designs of structures which provide for the transmission of vibratory waves with a minimum of local interference by reason of abrupt changes in cross-section dimensions in individual members or concentration of effect at the junction of assembled members In other engineering examples instances of rupture have been presented where only vibratory strains could have acted The loci of rupture of these steel arch bars, in their cross sections within a short distance of bolt holes which greatly reduced their cross section dimensions, but where vibratory waves were necessarily interrupted at the seats of the column castings, appear as results of the effects of such vibratory strains Vibratory action explains why these arch bars ruptured in service instead of the frames failing by shearing the axle-box bolts, the weakest details of construction under static tests.

The strength of the cast-steel frames should not pass unnoticed. It has long been known that steel castings, sound and well annealed, possess physical properties nearly or quite equal to good forgings. As early as 1877, A. L. Holley called attention to the properties of good castings, under the caption, "Solid Steel Castings for Ordnance, Structures and General Machinery by the Terrenoire Process."

Foundry practice in the making of steel castings has, in the main, been understood, but the actual production of sound castings results from exercising the care and observance of details which are known to be essential. Pouring temperatures, gating, venting, density of the sand, sink heads, freedom to contract in the molds, are elements which lead to success in the production of steel castings. The greater or less attention given these details signify the differences between sound and unsound castings, and the introduction of conditions which annealing can not correct.

It is sufficient, however, to say that good steel castings are being made, and that they have supplanted built-up members of wrought iron and forged steel in many places. Unit members have features of advantage in respect to the absence of mechanical joints. Riveted joints sustain and distribute stresses in a better degree than bolted members. Still in multiple riveting, whether chain or staggered, the loads picked up are variable on the different rows of rivets. The strains are also variable across the pitch of the rivets. Action of the same kind is experienced with bolted joints. Even in the state of its greatest efficiency no mechanical joint is quite the equivalent of a solid unit member. The maintenance of a bolted joint is a matter of importance.

Forgings of iron or steel are used for certain kinds of structures, drop forgings for small complicated shapes. The limitations for forged shapes is soon reached when castings must be used. Iron castings deficient in strength and toughness are not in general competition with steel castings.

Sand or slag inclusions and blowholes in castings must be regarded as defects, with the same stricture applying to rolled and forged members. In rolled shapes and forgings such inclusions are extended and possibly may be obscured, which is not the case in castings. Within limits this difference may be to the advantage of castings. Blowholes and slag inclusions, of moderated degree, are least objectionable when in their globular form. If drawn into acicular streaks and oriented perpendicular to the principal stresses received by the member their presence becomes more harmful.

With this review of the properties of materials it is believed that some of the causes of failure and the manner in which they occur will have been explained

In conclusion it appears that the accident to train CD–34 was due to the fracture of a steel arch bar, in the truck frame of the second car in front of the caboose And that an incipient crack existed in a steel arch bar in the truck of the car immediately next the caboose The latter a potential cause for an accident

That the stresses in service concentrated in the gross section of the bars, in close proximity to, but not at the net section where reduced by bolt holes The effects of repeated vibrations of strains was thus exhibited in the complete fracture of the arch bar under car No 667 and the partial fracture of the bar under car No 622

SUMMARY

The accident at Watkins Glen is attributed to the fracture of a steel arch bar in the truck of the second car in front of the caboose, while there was an incipient crack in the corresponding arch bar of the car next the caboose

These fractures were located in the bars at their edges, upper sides, and adjacent to the seats of the column castings The location of these fractures is ascribed to the effects of concentrated stresses and vibratory action received by the truck frames while in service

Static tests on similar frames displayed a degree of strength greatly in excess of the stresses which are called for under these cars when they are fully loaded

Furthermore, the manner of fracture in service differed from that of the laboratory tests In the latter tests the axle-box bolts sheared at the bearing between the upper and lower arch bars, developing a strength four times the estimated load carried by the frames in service The lower arch bars in the laboratory tests were not perceptibly overstrained

The inference follows that a due consideration must be given the character of the stresses received by railroad materials which these examples show reduce their resistance and eliminate the margin in safety which primitive tests or estimates of strength indicate they possess

Respectfully,

W P BORLAND, *Director*

U S GOVERNMENT PRINTING OFFICE 1929