1396

INTERSTATE COMMERCE COMMISSION

REPORT OF THE DIRECTOR OF THE BUREAU OF SAFETY IN RE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE BOSTON & MAINE RAILROAD AT BALLOCH, N H, ON FEBRUARY 13, 1928

June 22, 1928

To the Commission

On February 13, 1928, there was a derailment of a freight train on the Boston & Maine Railroad at Balloch, N H, resulting in the death of three employees and one trespasser, and the injury of one employee

LOCATION AND METHOD OF OPERATION

This accident occurred on that part of the Connecticut River Division extending between Springfield, Mass, and Windsor Vt, a distance of 109 11 miles In the vicinity of the point of accident this is a single-track line over which trains are operated by timetable, train orders, and an automatic block-signal system Balloch is 3 47 miles south of Windsor The initial mark of derailment appeared at a public road crossing at grade located about 5,870 feet south of Balloch station, while the final derailment occurred opposite the station Approaching the point of accident from the south the track is tangent and the grade is practically level The track is laid with 85-pound rails, 33 feet in length, with an average of 19 ties to the rail length, and is ballasted with gravel and cinders The track is well maintained There is a passing track just south of the station, on the west side of the main track

The weather was clear at the time of the accident, which occurred at about 12 50 p m

DESCRIPTION

Northbound freight train extra 2607 consisted of 33 cars and a caboose, hauled by engine 2607, and was in charge of Conductor Lamoureaux and Engineman St Marie This train left Claremont Junction, 4 46 miles south of Balloch, at 12 38 p m, and while traveling at a speed estimated to have been about 35 miles per hour was derailed on account of the breaking of the lower arch bar on the left side of the rear truck of the twelfth car behind the engine, Westmoreland Coal Co car 1543

The first portion of the train, including the forward truck of the twelfth car, was not derailed, but the rear truck of the twelfth car was derailed and forced the west rail out of line near the north switch of the passing track, at a point about 300 feet south of the station The coupling broke between the twelfth and thirteenth cars, and all of the cars in the rear of the twelfth car, with the exception of the forward truck of the last or thirty-third car and the caboose, were derailed and scattered about at various angles to the track The seventeenth to the twenty-first cars, inclusive, were thrown to the west against the station building, which collapsed as a result thereof, and the fire from a stove located in the station caused the wreckage to ignite the flames entirely consuming the station and the five cars thrown against it Those killed and injured were section men, together with one highway employee, who were in the station at the time of the accident, having just finished their noon meal

SUMMARY OF EVIDENCE

None of the members of the crew was aware of anything wrong prior to the accident Engineman St Marie said that on looking back he saw a number of cars being derailed and that he therefore placed the brake valve in full release and opened the throttle in order to keep the forward portion of the train clear of the wreckage, this part of the train finally being brought to a stop with the rear end of the twelfth car about 1,930 feet north of the station Fireman Jenks and Head Brakeman Dominy felt the air brakes apply from the rear, and on looking back they saw the cars being derailed Conductor Lamoureaux and Flagman Sullivan were riding in the caboose, the conductor thought the train came to a stop as a result of a burst air hose until he was informed otherwise by the flagman, who had been riding in the monitor of the caboose and saw the cars being derailed Flagman Sullivan immediately went back to flag After the accident members of the crew saw the broken arch bar that caused the accident, and they said the fracture appeared to be an old one, only a small portion of the break being new

Westmoreland coal car 1543, a hopper car, had a stenciled capacity of 100,000 pounds, it was built in October, 1904 It was inspected on its arrival at East Deerfield yard, located about 71 miles south of Balloch, during the night of February 12, no exception being taken to its condition The train also was inspected by members of the crew at various points en route, but no defective condition was discovered so far as car 1543 was concerned Apparently the arch bar failed in the vicinity of a crossing located about 5,870 feet south of Balloch station, the planking on the crossing at that point being marked on the outside of the west rail for the entire length of the crossing, the depression in the planking being about 3 inches in width and about one-fourth inch deep No further obstruction was encountered by the broken arch bar until the south switch of the passing track was reached, located about 2,800 feet north of the crossing, at which point the west rail of the passing track was struck and forced eastward, throwing it out of line The arch bar evidently then rode high enough from this point northward to avoid further damage to the track until the frog of the north switch of the passing track was reached, near the station, and after passing over the frog the arch bar apparently dropped inside the switch point, throwing the main track out of line and precipitating the derailment

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 to train extra 2607, Boston & Maine Railroad, at Balloch, N H , on February 13, 1928, was caused by the fracture of a lower arch bar in the rear truck of Westmoreland coal car 1543, the twelfth car from the engine This arch bar was located on the west, or left, side of the truck, according to the direction the train was running

The fracture of the arch bar and tie strap of the truck frame made an opening through which the spring plank, its nest of helical springs and the truck bolster dropped upon the track, leading to the derailment of the rear part of the train, 21 cars The derailment took place when the point of a passing track switch was reached, a distance of 317 feet south of Balloch station A part of the train left the roadbed, collided with and destroyed the station, where the fatalities connected with the accident occurred

Figure 1 is a partial view of the type of arch-bar frame which fractured It consisted of an upper and a lower arch bar, a tie strap, two column castings, and through bolts

Figure 2 shows side views of the two lower arch bars of the rear truck, the shape of the west arch bar after fracture, and the location of incipient cracks in the east arch bar

Figure 3 is a detailed view of each arch bar, from their under sides, comprising sections which include the bolt holes of the column castings The fracture of the west arch bar originated at its inner lower corner, directly below the rear edge of the spring plank It extended thence in an oblique direction to the bolt hole of the column casting completing the rupture of the bar by the fracture of the section between the bolt hole and the outer edge of the bar The presence of the column casting bolt hole offered a path for the extension of the line of rupture, but was not primarily a vital factor in originating the fracture

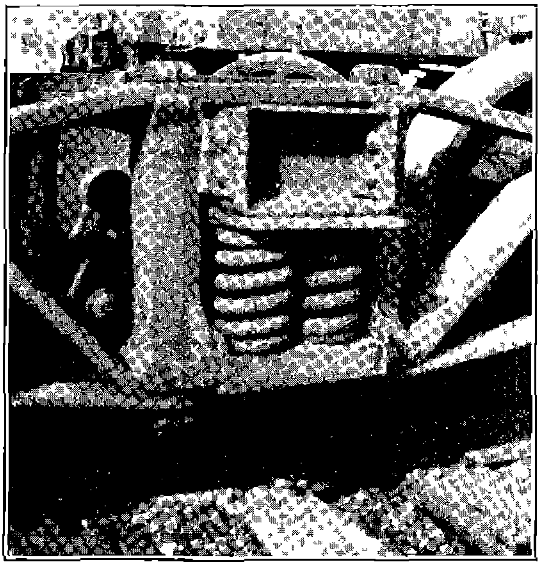
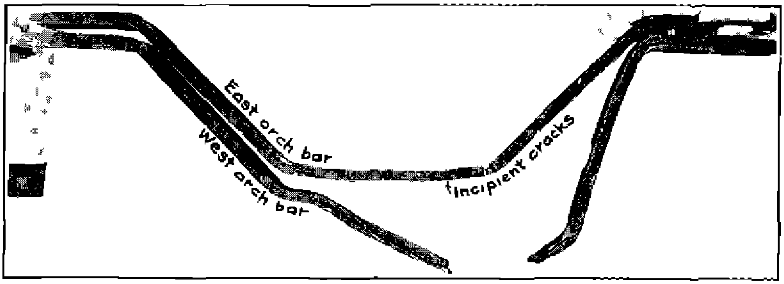


FIG 1—Partial view of arch bar frame in forward truck of derailed car



Direction train traveled

←

FIG 2—Lower arch bars from rear truck of derailed car Arch bar from west frame fractured Incipient cracks in arch bar from opposite side of truck Bars made of wrought iron

The points of origins of the incipient cracks in the east arch bar will be noted They also were located directly under the rear edge of the spring plank They extended from the under edges of the bar obliquely toward the bolt hole of the column casting These cracks were in process of extension when the accident occurred A derailment from the rupture of the east arch bar of this truck was in prospect.

The condition of the forward truck of this coal car became a matter for consideration. It was dismantled but found to be in good condition. In fact it was found to be of more recent fabrication than the rear truck, although the age of either truck was not known. The car was built in October, 1904. If a part of the original construction of the car, the fractured truck was 24 years old.

The seats of the spring plank and column castings of the fractured truck were much worn. At each edge of the spring plank seat of the east arch bar the metal was worn to a depth of a sixteenth of an inch. Under the middle of the width of the plank there was no loss of metal by abrasion. The arch bar itself was bent concave, in downward direction, clearing the plank at the middle of its width. The seats of the column castings were worn to a depth of an eighth of an inch. Similar conditions were displayed by the fractured bar.

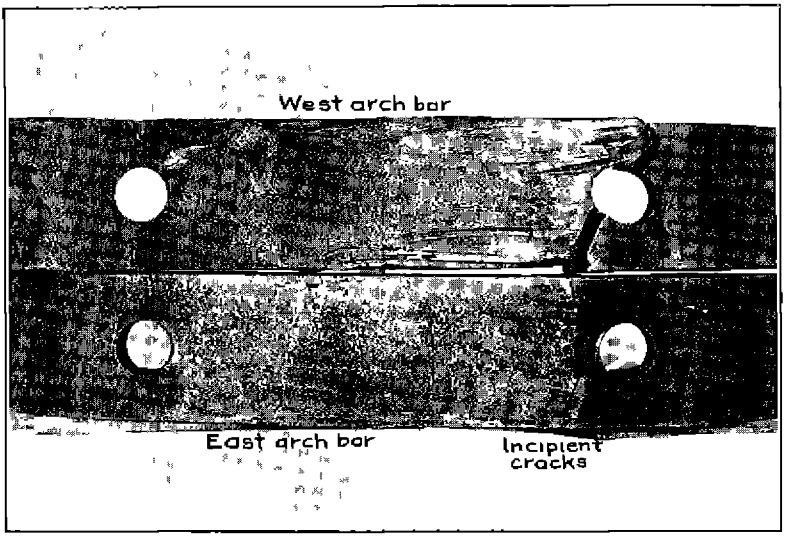


FIG. 3.—View of fracture of west arch bar and incipient cracks in east arch bar

An explanation is called for concerning the loci of the incipient points of rupture of these two arch bars, fractures which originated in the solid bars in close proximity to the column-casting bolt holes where the sectional areas of the arch bars were much reduced. The gross sectional area of the arch bars, 5 inches wide by 1¼ inches thick, was 6.25 square inches each. Across the bolt holes the area was 3.95 square inches, a reduction of over 36 per cent. Notwithstanding this reduction, only 2 inches away fractures originated in the solid bars, in one of which the fracture was complete, precipitating the accident.

In each bar the inception of rupture bore a definite relation to the edge of the spring plank in the plane of concentrated repeated stresses. Facts of this kind should not be overlooked in the design of rolling stock or wherever shocks, vibratory effects, or repeated stresses are to be met. It is admittedly a difficult matter to realize that such a difference in conditions should prevail within the short distance of two inches as illustrated in the rupture of these arch bars.

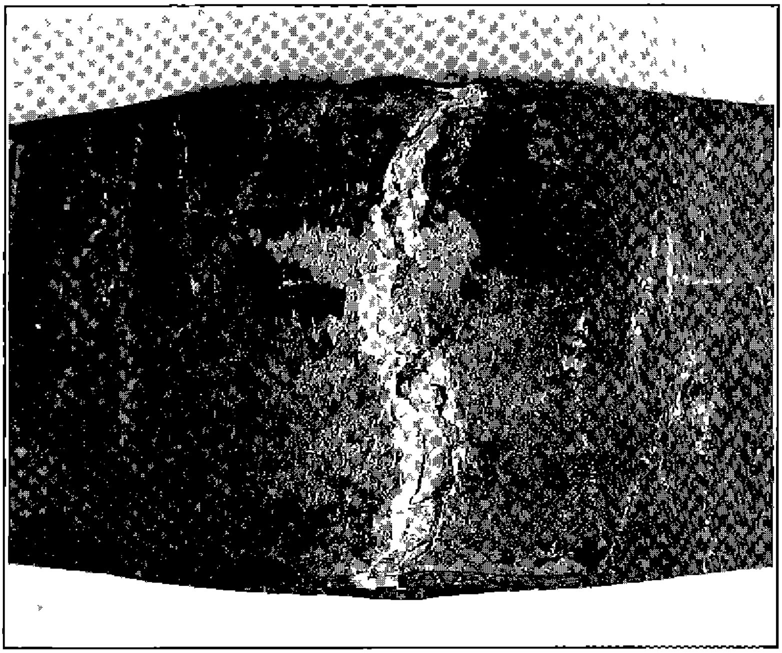


Fig. 4.—Fracture of west arch bar under bending test. Bent 180 degrees at location 15 inches from fracture which caused the derailment.

With such examples presented the deduction follows that caution should be exercised in attributing causes of failure to inferior physical properties of the materials used when the trouble perchance lies in the design of the structure.

The metal of the west arch bar, in the extension of the line of fracture, displayed some toughness, the metal about the bolt hole was elongated. A bending test was made of the full section of this bar, the fracture of which is illustrated by Figure 4. A moderately tough fibrous fracture was exhibited. The bar bent nearly 180 degrees before rupture. The difference in the characteristics of the service fracture and the bending test will be noted. In service there was no display of toughness in the metal, at the origin of fracture, in the bending test there was toughness.

The dominating idea in the usual examination of fractured material attaches to the query whether the fractured metal met the original specifications governing its acceptance, but a matter which rarely has a relation to the actual cause of fracture. In the present case, however, it is believed that a better grade of wrought iron *would* have postponed if not averted fracture.

Figure 5 illustrates the appearance of the east arch bar after fracture by bending test. The incipient cracks shown on Figure 3 are here shown as the edges of the dark-colored areas on the fractured ends of the bar. In this cut the bar is viewed from the underside. Fractures began at each of the lower corners, and extended progressively upward and obliquely toward the bolt hole.

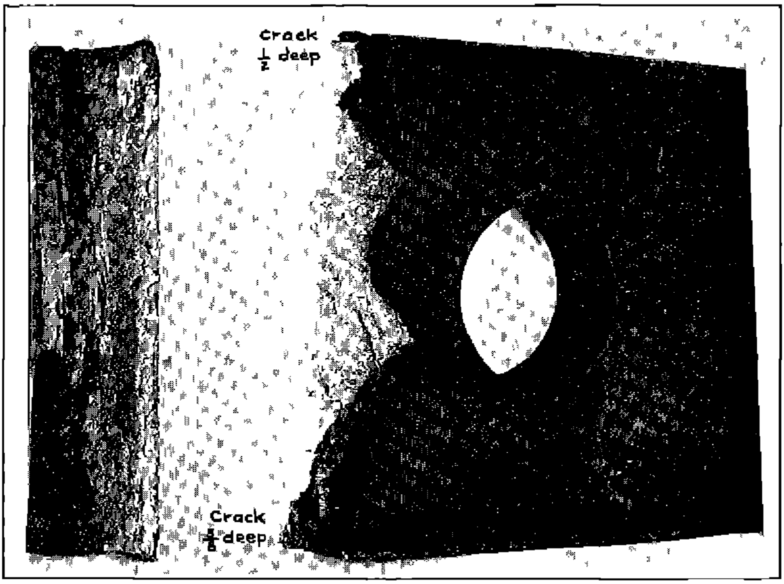


FIG. 5.—Fractured surface of east arch bar under bending test. Dark colored parts of fracture represent incipient cracks which were formed in the bar during its period in service.

The metal of the bar beyond the incipient cracks retained its toughness, a feature to be borne in mind, which distinguishes wrought or puddled iron from the behavior of carbon steels of any grade. This peculiarity of retention of toughness, notwithstanding the presence of an incipient crack, gives special value to wrought iron in many situations. Other features of value will be mentioned.

Figures 6 and 7 illustrate the appearance of tensile test pieces after fracture. Those shown by Figure 6 represent test pieces in

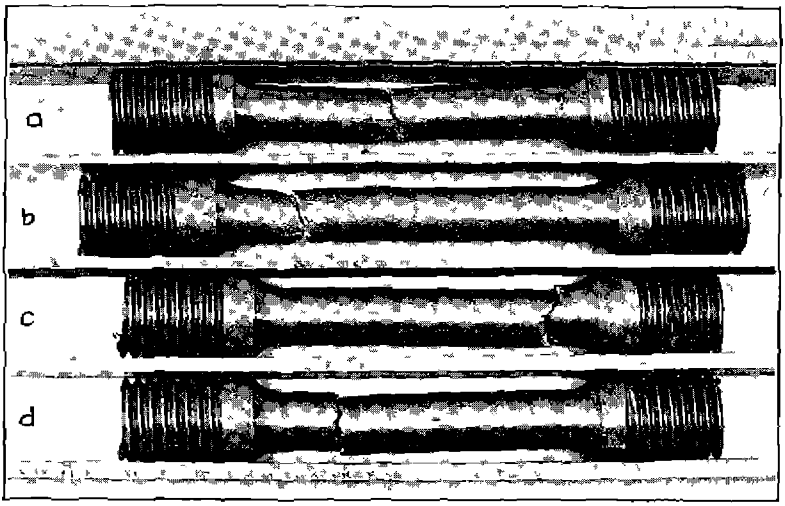


FIG. 6.—Fractured tensile specimens from east and west arch bars, natural state of the metal.

a, east arch bar, longitudinal specimen; b, west arch bar, longitudinal specimen; c, east arch bar, crosswise specimen; d, west arch bar, crosswise specimen.

the natural state of the metal, that is, the test pieces were taken from the ends of the arch bars and tested without treatment of any kind. One specimen from each bar was tested in longitudinal direction, and one from each in crosswise direction. It is well known that the strength of wrought iron is greater in lengthwise

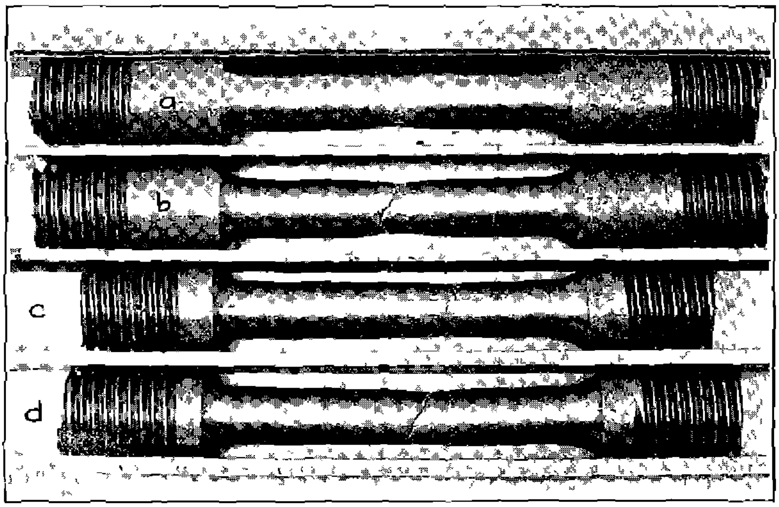


FIG. 7.—Fractured tensile specimens from east and west arch bars after treatment.

a, east arch bar, longitudinal specimen, cold swaged; b, west arch bar, longitudinal specimen, cold swaged; c, east arch bar, longitudinal specimen. Heated to 1,400° F. and quenched in water; d, west arch bar, longitudinal specimen. Heated to 1,400° F. and quenched in water.

than in crosswise direction, the results of the tests being normal in that respect

Figure 7 illustrates the appearance of test pieces from each arch bar after special treatment of the metal A longitudinal specimen from each bar was cold swaged The metal was extended under the hammer 20 per cent, after which the tensile specimens were prepared A longitudinal specimen from each bar was quenched in water from a temperature of 1,400° F

These special tests were made for the purpose of showing how wrought irons may be treated and still retain good workable properties Wrought irons are immune from certain dangers which are menacing to other metals

The following table shows the results of the tests made with the specimens taken from the arch bars, the photographs of which appeared on Figures 6 and 7

Tensile tests of specimens from east and west arch bars

[Specimens 2 inches long, 0 505 inch diameter]

Description	Yield point	Tensile strength	Elongation	Contraction of area
	Lbs per sq inch	*Lbs per sq inch*	*Per cent*	*Per cent*
Metal in natural state from the bars				
East lengthwise	27 500	40 500	11 3	20 9
West lengthwise	28 000	42 000	20 5	21 8
East crosswise	27 500	33 000	2 8	5 8
West crosswise	25 000	26 500	4 0	11 5
Metal of bars after treatment longitudinal specimens				
East swaged	51 000	65 000	6 3	27 5
West swaged	49,000	57, 250	8 0	29 2
East quenched	16 000	60 250	17 3	24 1
West quenched	38,000	52 750	22 0	28 8

These results are reported after the usual fashion of tensile tests The yield point is somewhat above the elastic limit of the metal The tensile strength represents the maximum stress reached The elongation is a distorted factor of little real value It includes the local contraction of the specimen, and does not therefore show the ability of the metal to stretch under its own strength The true elongation of the metal in a tensile test is the amount it has stretched when local contraction begins and increase of tensile stress has ceased The contraction of area as reported is a true value

These tests show the metal of which the arch bars were made to have been of inferior grade, unsuitable for the important place which they occupied Responsibility for the accident presumptively attaches to the use of a poor grade of wrought iron in these arch bars

As a metal wrought iron commends itself for such places as arch bars A superior grade of metal would eventually succumb to repeated alternate stresses and fracture without display of toughness if exposed to sufficiently high stresses. There is no grade of iron or steel which will not do this under adverse conditions. The reason why wrought iron is a good metal for certain places is on account of its retention of toughness at the root of an incipient crack. A fibrous metal has this property. A granular or crystalline metal becomes brittle when an incipient crack is once started.

The gain in tensile strength of the swaged specimens will be noted. Swaging and cold rolling have the same effect in kind on the tensile strength of the iron. General elongation was practically destroyed, but contraction of area not apparently disturbed.

Quenching from a high temperature had a profound effect on the tensile strength of the iron. Each of the four features of the tests showed substantial gains. Unlike carbides of iron, no hardening or embrittlement of the metal attended sudden quenching.

Good contraction of area has long been regarded as a valuable feature in metals against sudden and unexpected rupture. It is recalled that the late Professor Jenney, of the Technical High School, Vienna, Austria, attached special importance to this feature, regarding it as an index of superiority of high degree. In view of the fact that ability to display permanent elongation may be destroyed without having shown an appreciable set, the retention of good contraction of area becomes a safeguard against brittleness of fracture, and therefore a feature of practical value. If service conditions or special treatment fail to impair "contraction of area" as a factor, its practical importance is certainly well founded.

The higher physical properties of steels have enabled them to nearly drive puddled iron out of the market. So little use is being made of wrought iron that its peculiar properties may eventually be lost sight of. This opportunity therefore will be availed of to introduce some tests which have been made on wrought irons.

Forty-six years ago it was the privilege of the writer to make some tests on single and double refined wrought irons. They were bars 2 inches in diameter, 80 inches long. The original tests, made in 1882, showed in round numbers, elastic limits of 25,000 pounds per square inch, tensile strengths a little above 50,000 pounds per square inch, elongation above 20 per cent, and contraction of area in the vicinity of 40 per cent.

Elongations were measured on 10-inch lengths and results given on sections independent of local contraction of area.

The lengths of these bars were such that retests of the metal were practical to make. Features which were attracting notice in those earlier days were illustrated in some of the tests. The late Professor Thurston had called attention to the exaltation of the elastic limit by reason of overstraining loads. That is, a new and higher elastic limit was acquired following a period of rest than the limit of the overstraining stress Stress-strain curves are modified according to the manner in which the loads are applied Arresting the test after the tensile strength was reached and slightly passed and then renewing the same after an interval of rest, resulted in increased tensile resistance All of these phenomena indicated that the particles of iron, set in motion by an external force, gained in rigidity if allowed an interval of rest

The gain in strength once acquired remains, but is lost by exposing the iron to a moderately high annealing temperature Current tests have indicated that restoration of primitive strength is attained with hardly measurable change in dimensions of the specimen annealed

Returning now to a discussion of the retests of the bar of double-refined wrought iron, originally tested in the year 1882 After remaining in a state of repose for an interval of 22 years the bar showed an elastic limit of 66,000 pounds per square inch, tensile strength, 70 000 pounds per square inch, contraction of area, 28 per cent, referred to the sectional area as it existed when the retest was made On the original sectional area of the bar—that is before reduction in diameter in the first test—the tensile strength was 61,200 pounds per square inch

Forty-six years total elapsed when the iron was again retested The tensile strength still remained at its acquired maximum value It had a value of 72,000 pounds per square inch, with a contraction of area of 25 6 per cent Thus it appears that the forces of cohesion enhanced by early overstraining and rest retained their increased resistance for nearly one-half a century with no indication of release, the metal in the meantime having been exposed to atmospheric temperature only

Figure 8 shows the appearance of tensile specimens after fracture, which were taken from this bar of wrought iron, originally tested in 1882 Figure 8 *a* represents the test piece in the natural state of the iron, figures 8 *b* and 8 *c* after the metal had been annealed at 900° and 1 400° F, respectively

The results of these three specimens appear on the following table

Tensile tests of specimens of double-refined wrought iron, 46 years after original test

[Original tensile strength, 50 000 pounds per square inch]

Description	Tensile strength	Contraction of area
	Lbs per sq inch	*Per cent*
Specimen 8 *a* natural state	72 000	25 6
Specimen 8 *b*, annealed at 900° F	60 600	31 8
Specimen 8 *c* annealed at 1 400° F	48 600	36 0

It will be seen that annealing at 900° F. lowered the tensile strength which it had acquired by overstraining, an amount nearly 12,000 pounds per square inch, and exposure to the higher annealing temperature of 1,400° F. lowered it another 12,000 pounds per square inch, the latter value being below the primitive test. Finishing temperatures have an influence on primitive strength, hence this result does not require special comment. It is a matter of interest, however, in the study of the physics of this metal, to note that the relief in rigidity of 12,000 and 24,000 pounds per square inch for the two annealing temperatures, respectively, was accomplished with hardly any measurable change in the linear dimensions of the iron.

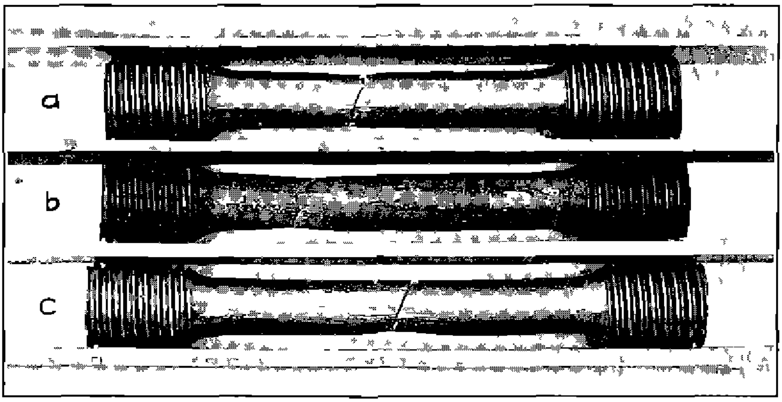


FIG. 8.—Specimens from bar of double refined wrought iron. Original test made in 1882.

a, tested in natural state after 46 years' rest; b, annealed at 900° F.; c, annealed at 1,400° F.

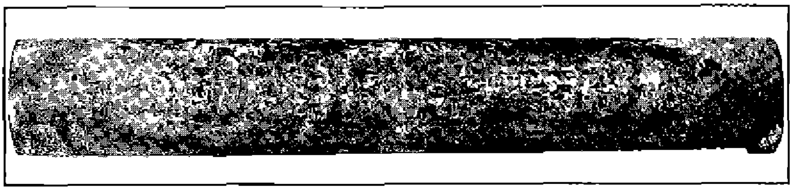


FIG. 9.—From bar of double-refined wrought iron tested in 1882. Strain gauge measurements made after different treatments.

Figure 9 represents a section 12 inches long, 1.85 inches diameter, from the bar of double-refined iron, from which this and the several test pieces were taken. Strain gauge measurements were made on this section, three gauged lengths 10 inches long each, spaced circumferentially 120° apart, and designated by the letters *a*, *b*, and *c*.

The bar was first subjected to progressive annealing temperatures from 200° F. to 1,400° F., with increments of 200° each. There were apparently some minor changes at times in plus or minus directions on the gauged lengths, but on the whole it could not be said that any material change occurred. It was heated in an electric furnace and furnace cooled.

After the several annealings were completed the bar was suddenly heated in an open fire to approximately 1,700° F. and cooled in lime. This treatment caused an average shortening of 0.0027 inch, equivalent to a compressive stress of 7,300 pounds per square inch, based on a modulus of elasticity of 27,000,000 pounds per square inch.

The bar was next heated along elements *b* and *c*, about 8 inches each, with an oxy-acetylene torch, and cooled in the air. Element *b* was first heated. When cold it was found shortened 0.0122 inch, equivalent to 32,900 pounds per square inch compressive stress. Element *c* was shortened 0.0057 inch. Element *a* was increased in length 0.0023 inch. That is, the two elements heated and overcompressed at the time, when cold, were shorter than originally, while the element not heated was longer finally.

In the next operation element *a* was heated with a torch in the same manner as before. When cold this element was shortened, the two unheated ones were each lengthened.

The bar was next heated in a gas furnace to 1,700° F. and furnace cooled. Each element was found shortened. It was again furnace heated to 1,700° F. and quenched in water. Each element was again shortened. It was next heated to 1,100° F. in an electric furnace and quenched in water. It contracted in length a moderate amount. Finally it was heated rapidly in an electric furnace to 1,250° F. and quenched in water. Very pronounced contraction in length then resulted. The mean total contraction of these several treatments was 0.0328 inch, equivalent to a stress of 88,560 pounds per square inch.

In review when one or two elements were heated they were found to have been shortened when cold. The unheated elements were lengthened. When the entire bar was heated there was a contraction in length on each gauged length.

The examination was completed by boring out the metal of the core of the bar, leaving the walls 0.13 inch thick, whereupon the shell expanded on each gauged length. The surface metal at the end of the series of tests was therefore in a state of internal compression, equivalent to a stress of 28,350 pounds per square inch, or not far from the elastic limit of the metal.

In tabulated form these results appear as follows

Treatment of double refined wrought-iron bar

[Tensile strength, original test made in 1882 50,000 pounds per square inch]

Treatment	Successive changes on gauge lengths		
	a	b	c
Last annealing at 1,000° F	—	—	—
Annealed at 1,200° F	+0.0005	+0.0004	+0.0003
Annealed at 1,400° F	−.0001	−.0004	+.0001
Heated suddenly in open fire to 1,700° F., cooled in lime	−.0052	−.0033	+.0004
Elements *b* and *c* heated with acetylene torch about 8 inches of length	+.0023	−.0122	−.0067
Element *a* heated with torch	−.0062	+.0107	+.0005
Annealed in furnace at 1,700° F	−.0025	−.0106	−.0024
Heated to 1,700° F., quenched in water	−.0072	−.0083	−.0103
Heated to 1,100° F., quenched in water	−.0007	−.0013	−.0003
Heated suddenly to 1,250° F., quenched in water	−.0132	−.0148	−.0149
At this stage the total changes in lengths from the original length of the bar of the three 10-inch gauged lengths were	−.0320	−.0346	−.0319
The mean contraction, therefore, was −0.0328. Provided the metal was capable of displaying such a high degree of elastic compression or resilience, this amount of compression would be equivalent to a stress of 88,560 pounds per square inch			
Core of bar bored out, walls now 0.13 inch thick	+.0104	+.0106	+.0106

Mean expansion, +0.0105, equivalent to 28,350 pounds per square inch compression

Other examples might be added, showing the behavior of wrought irons under what would seem unfavorable conditions. Tests made in 1901 on best puddled iron showed a decided advance in the value of the elastic limit after a few days rest following an overstraining load. With an original elastic limit of 32,700 pounds per square inch the test piece was loaded to 35,000 pounds per square inch, causing a permanent set of 0.24 inch in 10-inch lengths. After a rest of eight days, without load, it sustained a stress of 40,000 pounds per square inch without additional set. It displayed an increased set at 41,000 pounds per square inch. This grade of iron showed gains in rigidity ranging from 4,000 to 7,000 pounds per square inch, according to the overloads applied and intervals of rest.

In addition to the zone of increased rigidity immediately above the primitive elastic limit, the influence of overstraining seemed to reach even to the tensile strength of the metal, increasing that value in some degree.

Norway iron, nearly pure iron, was included in a series of tests made in 1901. Original tensile strength 41,800 pounds per square inch, contraction of area 71.7 per cent. Overstrained with 25,000 pounds per square inch, showed the usual exaltation in elastic limit, and after a rest of 7 days an apparent gain in tensile strength. Overstraining at 35,000 pounds per square inch with 7 days' rest showed a gain in tensile strength of 6,600 pounds per square inch, an increase too great to admit of any doubt of its existence and its cause.

On the other hand, some earlier annealing tests made 36 years ago on cold-rolled iron shafting showed a progressive decrease in tensile strength resulting from annealing temperatures ranging from 400° F to 1,768° F There was a corresponding lowering of the elastic limit and accompanying increase in both elongation and contraction of area

Examples of the behavior of wrought iron might be multiplied, all to the effect of illustrating its valuable properties It can be heated and quenched at any temperature without causing brittleness Its elastic limit and tensile strength is even raised by such treatment It can be overstrained and in a few days display increased rigidity requiring the application of a much higher stress before it takes an increased permanent set Overstraining a few thousand pounds above its primitive elastic limit, and it acquires an exalted elastic limit with increased resistance reaching even to its ultimate strength If strained up to its tensile strength, in a few months or years it will display a much higher strength As experiments herein quoted have shown, the gain in tensile strength remains a fixed quantity approaching a half century in time, hence it may be classified as a permanent gain

Different kinds of treatment show little or no effect upon its contraction of area If good contraction of area is retained, it is quite clear that warning will be given impending fracture when exposed to rupturing stresses

The effect of repeated alternate stresses on wrought irons are the same as corresponding stresses upon steels The ability to elongate is destroyed and rupture ensues without appreciable display of ductility, in the sense of taking a permanent set While the results of comprehensive experiments are not at hand, the belief is entertained that there is no metal which will resist rupture caused by repeated alternate stresses without displaying brittleness of fracture

High manganese steel, noted for its exceptional toughness, will fracture under repeated stresses without display of appreciable ductility This metal, however, has the exceptional ability of showing toughness in resisting the extension of incipient cracks Wrought irons and high manganese steel each show similar behavior in this respect

So far as known no internal fissure has been found in wrought iron The most drastic treatment, heating and quenching from high temperatures in oil, water, or brine none have caused the introduction of interior or exterior cracks Wrought iron is not as strong as common grades of carbon steels which are used in engineering structures It is stronger however, than the loads which engineering structures are supposed to be exposed to These remarks seem to be assuming a panegyric on wrought iron nevertheless they state only facts They are due as a testimony to a good all-round metal One of its striking features in the physics of the metal is its stability in dimensions while changes in strength are going on when exposed to different annealing temperatures

In conclusion, the cause of the present accident attaches to the fracture of the arch bar on the west or left side of the rear truck of Westmoreland coal car 1543 The type of fracture indicated exposure to repeated stresses, which in tension concentrated at the under side of the bar directly below the rear edge of the spring plank No criticism attaches to the use of wrought iron as the metal of the arch bar, criticism, however, does attach to the use of an inferior grade of wrought iron in this important place

SUMMARY

The cause of the present accident was due to the fracture of an arch bar in the rear truck of Westmoreland coal car 1543 Tests of the physical properties of the metal showed an inferior grade of wrought iron had been used in its fabrication A better grade of wrought iron doubtless would have postponed the accident or perhaps averted it

Prior to the accident fractures were in progress in each of the lower arch bars of the rear truck of this coal car Their origins were at the lower corners of the bars Each lower corner of the east bar had an incipient crack The fracture of the west bar started at the lower inner corner

They were progressive fractures of unknown date of inception, and difficult of detection in the truck frame under service conditions It is recognized that this type of truck frame is being superseded by others of unit or different construction Nevertheless a large number of arch bar frames are still in current service The manner of failure of this bar shows where attention should center in the inspection of trucks of this type

The engineer-physicist has dealt extensively with the physical properties of wrought or puddled irons They possess properties of peculiar value for many situations

Respectfully submitted

W P Borland *Director*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
U S GOVERNMENT PRINTING OFFICE
WASHINGTON, D C
AT
5 CENTS PER COPY
▽