INTERSTATE COMMERCE COMMISSION

REPORT OF THE CHIEF OF THE BUREAU OF SAFETY COVERING THE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE ST LOUIS-SAN FRANCISCO RAILROAD AT KNOBVIEW, MO, ON DECEMBER 21, 1919

DECEMBER 10, 1920

To the Commission

On December 21, 1919, there was a derailment of a passenger train on the St Louis-San Francisco Railroad near Knobview, Mo, which resulted in the death of 3 passengers and the injury of 26 passengers and 2 dining-car employees After investigation of this accident I respectfully submit the following report

The Eastern Division of the St Louis-San Francisco Railroad, on which this accident occurred, extends between St Louis and Monett, Mo, a distance of 282 miles It is a single-track line over which train movements are governed by time-table, train orders, and an automatic block-signal system Approaching the point of accident from the west there is a tangent 2,600 feet in length, followed by a 3° curve to the left about 1,400 feet in length, and then a tangent of 1,560 feet in length to the point of accident The point where the first wheel was derailed is on a 1 per cent descending grade From this point eastward the grade varies from 1 3 per cent descending to 0 54 per cent descending, the latter being the grade at the west passing-track switch, at which point the first serious damage occurred The track in the vicinity of the point of accident is laid with 90-pound rails, 33 feet in length, tie-plated and single-spiked to about 20 hardwood ties to the rail The ballast consists of about 12 inches of gravel, the gauge, alignment, and surface of the track were in good condition and well maintained At the time of the accident a light fog prevailed

Eastbound passenger train 2d No 10 consisted of 1 baggage car, 1 mail car, 1 baggage car, 1 coach, 1 chair car, 5 Pullman sleeping cars and 1 dining car in the order named, hauled by engine 1062, and was in charge of Conductor Myers and Engineman Tice This train, en route from Oklahoma City, Okla, to St Louis Mo, left

Newburg, Mo 21 miles from Knobview, at 7 32 a m and at 8 18 a m, while traveling at a speed of about 35 miles an hour was derailed at a point about one-half mile west of the west passing-track switch at Knobview The wheel first derailed ran on the ties on the inside of the left rail until it encountered the left or north switch point of the west passing-track switch At this point the chair car and all of the sleeping cars were derailed, the chair car and the first sleeping car striking the engine of a westbound freight train which was standing on the passing track

The engine and first 5 cars of train No 10 remained coupled together and came to a stop with the engine about 1,450 feet east of the switch points Of this portion of the train, only the chair car was derailed, the rear truck of this car having been the first part of the train to derail This car came to rest leaning against some of the freight cars on the siding, with its right side quite badly damaged, as seen in illustration No 1 The train parted between the fifth and sixth cars, the rear portion of the train coming to a stop with the last car, which was not derailed, just east of the switch points The front end of the sixth car, which was the Pullman sleeper Iolanda, was demolished for about 20 feet by reason of its coming in contact with the front end of engine 26, of the freight train Illustration No 2 shows this car, resting on its side after having been cleared from the track The next four cars, although derailed, remained upright and were not seriously damaged, while the dining car, the last car in the train, was not derailed or damaged The front end and side of engine 26 were badly damaged, as shown in illustration No 3

The first indication of derailment was a flange mark on the ties about 7 inches south of the north rail, nearly 3,000 feet west of the west passing-track switch This mark continued on the ties paralleling the track until it reached the switch point The force of the blow broke off about 10 inches of the switch point, the track and frog were displaced, and it was at this point that the six rear cars of the train, with the exception of the last, left the track There were also about 60 spikes cut off or bent on the inside of the north rail, evidently caused by the derailed wheel There were no indications of any character west of the passing-track switch to show that any of the wheels of the south side of the train had been off the track

An inspection of the equipment of train 2d No 10 disclosed that the axle of the leading pair of wheels of the rear truck of the chair car the fifth car in the train, had broken within the wheel-fit of the south wheel, the break being 1 to 1½ inches from the outside of the wheel (See fig 4) Apparently this axle broke when the train

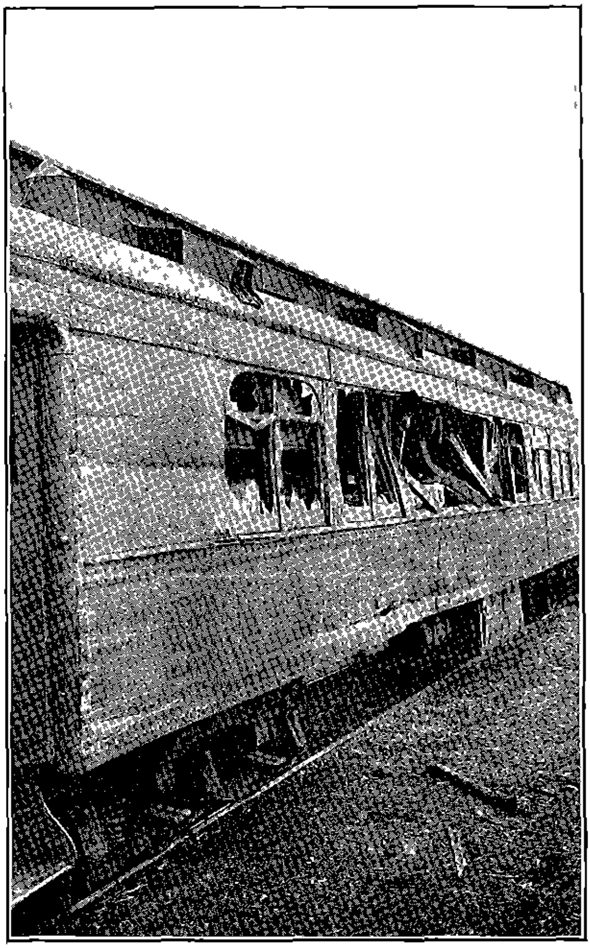

Fig 1 —Side view of chair car No 753 after derailment Axle under this car was broken

Fig 2 —View of Pullman sleeper Iolanda on its side after having been cleared from the track

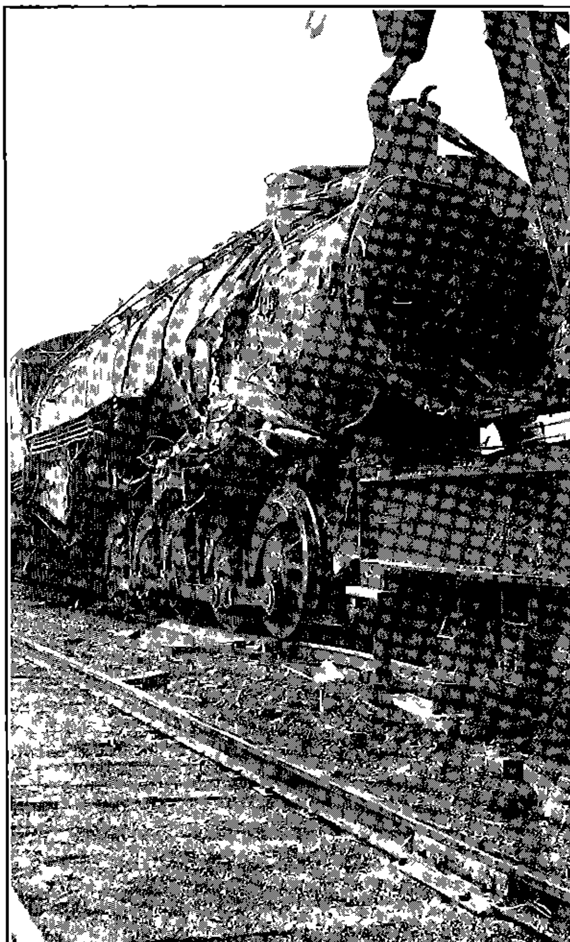

Fig 3 —View of freight engine 26 showing damaged front and side after side swipe of passenger train 2d No 10 was on the straight track preceding the 3° curve and when it broke released the weight from the journal, allowing excessive weight on the journal at the opposite or north end of the axle This lifted the south wheel from the rail and carried it in that position while moving over the straight track, and as the train rounded the curve it is very apparent that the truck with the broken axle was forced toward the outside of the curve and with the right leading wheel up clear of the rail, the left wheel dropped off on the inside of the rail The flange of this wheel evidently made the marks found on the ties, and when this wheel struck the switch point at the passing track resulted in the general derailment

Engineman Tice stated that the first intimation he had of anything wrong with his train was a little jerk He then noticed that the air had been applied from the train and he immediately placed the air valve in the lap position and sounded two short blasts of the whistle to indicate to the conductor that he had detected the application of the air brakes At about the same time he glanced back and saw the train was derailed and he then reversed the engine and made every effort to stop quickly He stated further that he had noticed no irregularities in the operation of his train prior to the derailment and in his estimation he was running at a speed of between 35 and 40 miles an hour at the time

Fireman Hilderbrand stated that he looked back along the train about a half mile before reaching the point of derailment and saw nothing wrong He estimated the speed at the time of the derailment to be between 35 and 40 miles an hour

Conductor Myers stated that he and the train porter were sitting in the fourth car of the train approaching Knobview and the first intimation he had of the impending accident was a jerk as the car went over the switch point at the west end of the siding Realizing that something was wrong, the porter jumped up and pulled the signal cord Conductor Myers thought the train was traveling at a speed of between 35 and 40 miles an hour at the time of the derailment

Train Porter Barry stated that at the time of the derailment he was riding in the fourth car of the train, and when he felt the jerk he jumped up and pulled the signal cord and then opened the emergency valve He estimated the speed at the time at 35 or 40 miles an hour

Members of the crew of extra 26 who witnessed the derailment of train 2d No 10 variously estimated the speed at the time at between 20 and 30 miles an hour

At the time of the accident none of the employees involved had been on duty in excess of the statutory period and all had had the required rest period before going on duty

Investigation definitely developed the fact that the cause of this accident was a broken axle on the fifth car in the train. An investigation for the purpose of ascertaining the reason for the failure of this axle was conducted by Mr. James E. Howard, engineer-physicist, whose report follows:

REPORT OF THE ENGINEER-PHYSICIST

According to the records of the St. Louis-San Francisco Railroad the broken axle was furnished by the Standard Forgings Co., Indiana Harbor, Ind., under Master Car Builders specifications which called for the following chemical composition:

C	0.45
Mn	.50
Si	.05
P	.05
S	.04

Its journals were 5 inches diameter by 9 inches long.

It was mounted on wheel 50385-519 and 50386-442 at the north shops of the railroad company, Springfield, Mo., on September 12, 1917. The wheels were pressed on with a force of 118 tons each. The axle was first put under dining car No. 637 and there used until February 26, 1919. It was then taken from its truck, at the west shops of the company, the tires of the wheels turned, and on March 11, 1919, replaced under chair car No. 753, where it remained until the time of its fracture.

The axle failed with a progressive fracture, the origin of which was at the periphery of the wheel seat, but located within the hub of the wheel. The surface of rupture was from 1 to 1½ inches below the outer face of the hub.

Figures Nos. 5 and 6 are end and side views, respectively, of the axle as it appeared after removing the wheel. It required a pressure of 250 tons to remove the wheel at the fractured end, and 260 tons pressure to remove the other wheel. The concentric curved line which shows on the end view, about 4¼ inches diameter, represents a depression on the fractured surface made by the follower of the wheel press in forcing the axle from the wheel.

Examination of the fractured surface showed the progressive character of the break. Its initial point was at the circumference of the axle. At the surface of the wheel seat the plane of rupture followed a tool mark made by the lathe tool in turning the axle. The primitive surface of rupture was deflected after following the tool mark a short distance, and then merged with a second plane of rupture. The latter also had its origin at the peripheral surface of the wheel seat, and likewise at a circumferential mark made by the lathe tool. There was an extension of the first plane of rupture shown by a fine crack on the circumference of the axle; also two other incipient cracks which were located quartering with the primitive point of rupture.

The surface of rupture progressively extended until three-quarters or more of the cross section was fractured, then final separation of the axle occurred, precipitating the derailment

Chatter marks of the lathe tool appear on the turned surface of the wheel seat marks which are indicative of heavy cuts having been taken in turning forgings At the broken end, the wheel seat was not concentric with the adjacent part of the forging About one-eighth inch had been turned off one side of the forging, and one-half inch from the other side, in the formation of the wheel seat The feed of the lathe tool was 15 per inch

The eccentricity of the wheel seat is not regarded a vital matter, nevertheless it is desirable to have axles balanced as well as the heavier rotating parts of motive power and equipment This is a feature not to be disregarded in high-speed machinery It is indexical of careful workmanship when this feature has been observed and in the case of important members, such as axles, susceptible to injuries in fabrication and when being assembled, it is assuring that due care has been taken

The chief cause which contributed to the failure of this axle is assigned to the rough cut taken in the lathe when the wheel seat was turned No mechanical, physical, nor chemical tests were made on the fragments of this axle None appeared necessary The origin of the rupture was clearly shown, and the character of the turned surface furnished a reason for its occurrence

Tests have been quite frequently made on similar fractures, the results of which have relieved the steel from responsibility in causing rupture When a defect of machine practice is encountered, one which invariably tends to shorten the life of the axle, it does not clarify the situation, as a rule, to enter upon an investigation of the properties of the steel used in the fabrication of the axle The real cause of failure may be clouded by profuse introduction of data, important in themselves, but not attaching to the paramount issue

Failures of other axles have furnished examples in which features of design and mechanical matters have been overlooked, the omission of which led to premature rupture Figure No 7 shows the appearance of a trailer axle which ruptured from apparently preventable causes This axle failed at the end opposite that shown by the cut, at the junction of the rough turned central portion and the abrupt shoulder next the wheel seat A rough cut had been taken across the middle of the length of the axle, and an abrupt shoulder left at the end of the turned portion Each of these features doubtless had an influence in promoting early failure Figure No 8 shows the appearance of the fracture of this axle This failure was a progressive one, beginning at the circumference of the axle at a distance of 2¾ inches from the inside face of the hub of the trailer wheel The diameter of the axle at the place ruptured was 8½ inches

This axle was furnished by its manufacturer in the condition it was expected to be used, excepting the fitting of the wheel seats and journals It was finished on those surfaces in the shops of the railroad on which it failed The responsibility for its rough turned section rests primarily upon the manufacturer of the axle

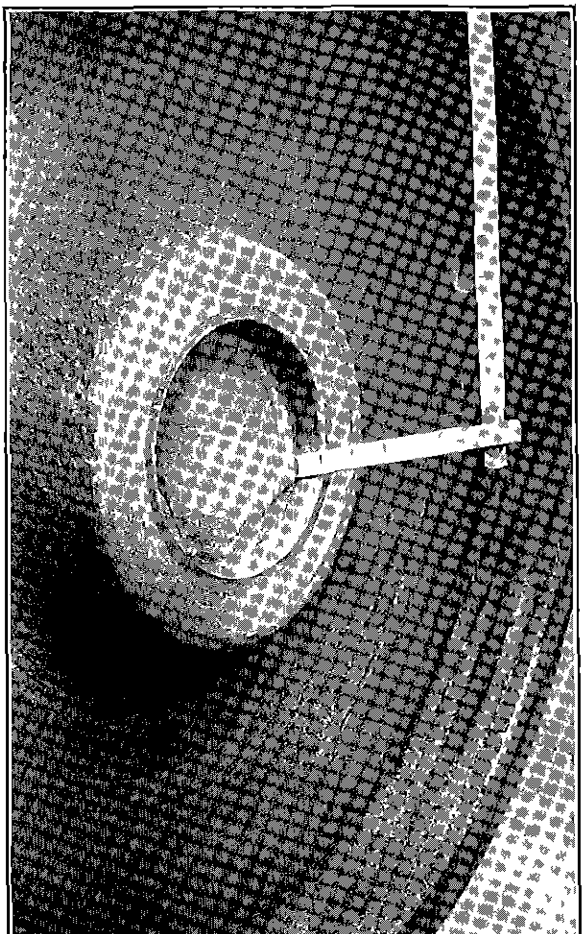

Fig 4 - View of broken axle of chair car No 753 Plane of rupture 1″ to 1½″ within the outer face of hub of wheel

Failures of driving axles have been witnessed in which the planes of rupture were located near the middle of the lengths of the journals The incipient points of such planes of rupture coincided with circumferential lines, evidently representing tool marks in turning the axles Finishing cuts in the lathe had not obliterated them Axles 11 inches in diameter have failed in this manner Apart from the influence of defective surface metal, the magnitude and number of stresses received in service did not appear sufficient to account for these failures

It is not difficult usually to identify the incipient point of rupture in the failure of an axle, and such identification in the majority of cases has placed responsibility for failure upon the design or the treatment of the axle rather than upon inherent trouble in the quality of the metal Different grades of steel necessarily possess different degrees of endurance but premature failure may occur in any grade from the causes connected with fabrication processes

Attention has generally been directed to the avoidance of sharp reentering angles in steel shapes, yet on the other hand there are places in which sharp external corners are objectionable Locomotive side rods have failed with origins at sharp exterior corners A chance hammer blow on a sharp corner may lead to rupture Side rods are exposed to alternate bending stresses and require the same care in their fabrication which attaches to all materials which are required to endure repeated stresses Well-rounded fillets are generally provided at the webs of side rods Well-rounded exterior corners would also be of advantage

The introduction of high-speed tool steel has given impetus to shop practices which have resulted in economy in certain machine operations The opportunities offered by such steels call for a proper discrimination of what are permissible depths of cuts and feeds in machining critical parts of axles and other parts of running equipment which are susceptible to injurious effects from machine operations

An earlier report, published by the Commission, covering an accident caused by a broken axle, occurring near Hoffman, Ill, June 7, 1915, presented data on the effects of heavy machine cuts in the machining of axles The removal of a chip by a lathe tool is a shearing action It should be done in critical cases, with a minimum disturbance to the metal next below the chip removed Shearing and punching of steel of the grades used in axles is objectionable on account of severe local strains set up in the steel by these operations with the danger also of forming incipient cracks The punching and shearing of steel has been abandoned on important engineering structures Brittleness and loss in strength attend such operations in hard steels

The introduction of high-speed tool steel has gradually led to machine practice in the employment of roughing cuts in the lathe which closely approach if they do not equal the severity of the operations of punching and shearing Thus operations admitted to be objectionable if performed by a power punch or shears are being permitted if performed in a lathe or planer Punches and shears have a comparatively limited range of adaptability which materially

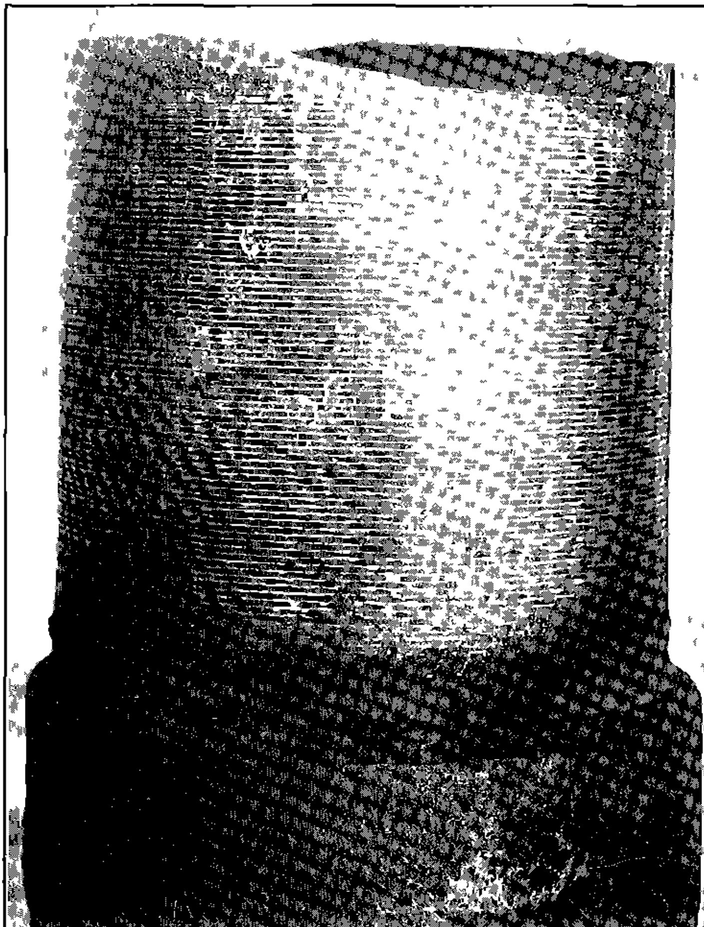

Fig 6 —Side view of broken axle showing character of turned surface of wheel seat
Origin of fracture at tool mark on rough turned surface of wheel seat

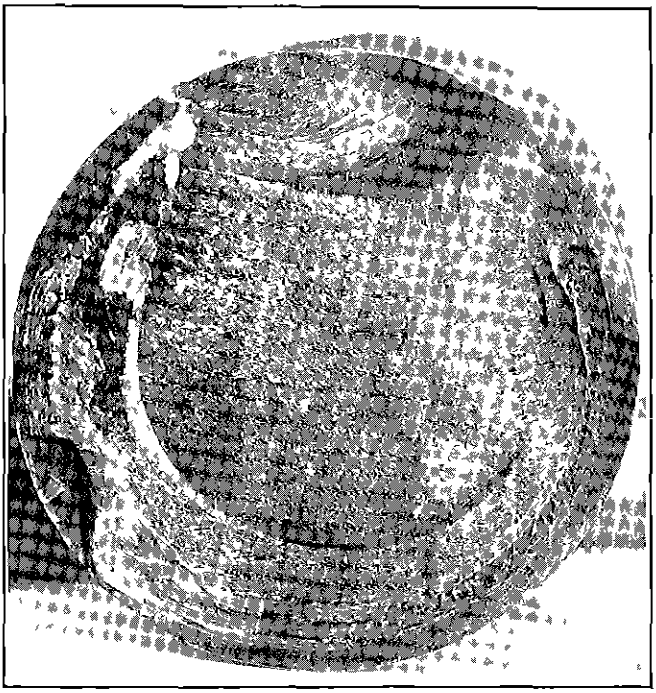

Fig 5—End view of broken axle after wheel was removed Progressive fracture having its origin at circumference of axle 1½″ within outer face of hub

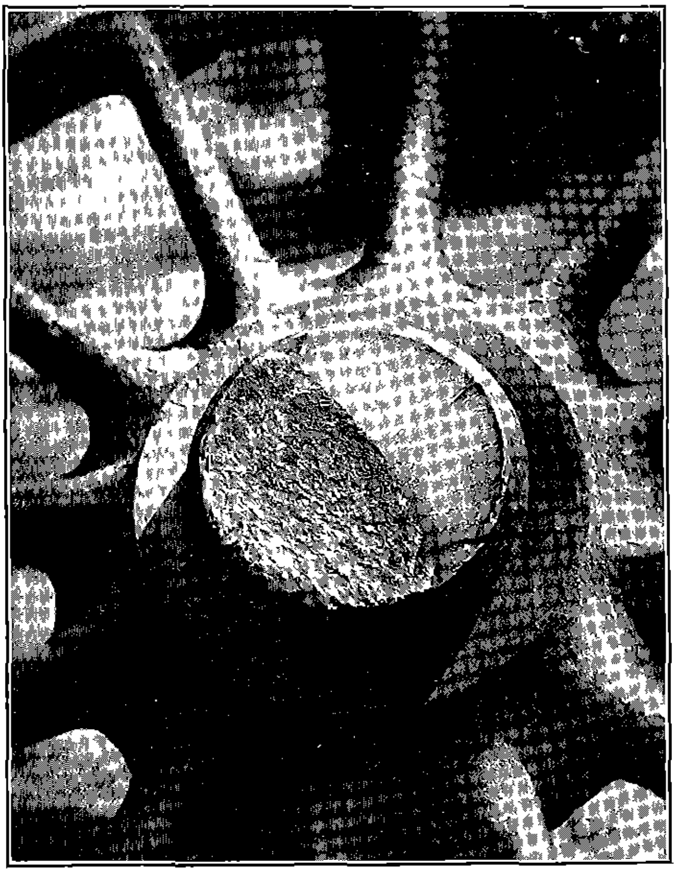

Fig 8 —Appearance of progressive fracture of trailer axle

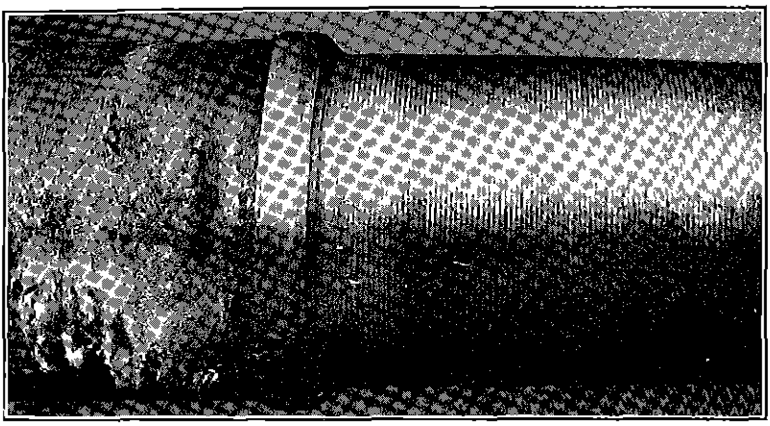

Fig 7 —Appearance of a trailer axle which fractured at the shoulder at end opposite that here shown Its failure attributed to a rough cut in the lathe used in turning the middle of the length of the axle together with the abrupt shoulder next wheel seat restrict their use, whereas the flexible adaptability of lathes and planers bring to them a wider range of work

In connection with the accident report above referred to, experiments then conducted showed that machine-tool cuts could be so varied that internal strains of compression would be introduced in some cases, while in others it was possible to reverse the strains and introduce those of tension Heavy chips are heated and acquire oxide tints after a few seconds exposure to the air straw colors, merging into a deep blue This effect is evidence of the severe mechanical effort expended in removing heavy chips To remove chips without permanently disturbing the physical properties of the metal next below requires careful turning, using sharp tools and taking light chips, the problem being how to detach surface metal without causing overstrain between the particles of the steel which become the surface of the finished axle Provided the surface metal is not affected beyond a certain degree the effect on the physical properties is negligible The limiting degree depends upon the severity of the stresses which the axle receives in service Since the stresses are variable from time to time and of magnitude not readily ascertained, it is prudent to minimize the effects of mechanical treatment through the exercise of care in fabrication

Heavy chips are commonly taken in turning the treads of forged or pressed steel wheels and rolled tires Regardless of the internal strains set up by the turning tools, the treads of steel wheels and tires when put into service immediately acquire internal strains of compression, the countereffect of the cold rolling which the rails receive This state of internal strain has advantages in opposing the formation of tensile cracks, while the abrasion of the surface metal of the treads of wheels soon removes the effects of the blue-chip lathe tools

The machining of the bore of a tire is a different matter from that of the tread Driving tires, shrunk on their centers, require careful turning on the surface of their bores in order to provide suitable shrinkage conditions While general smoothness is a controlling factor in the machining of shrinkage surfaces, independent of that requirement is the fact that a rough cut on the interior diameter of a tire is objectionable as that surface is put into a state of tangential tension when the tire is assembled and which it must continue to work under while in service Driving tires are retained on their wheel centers by frictional resistance alone Occasionally a broken tire is met on which the origin of rupture is located at an inner corner of its cross section, exhibiting the class of fractures displayed by side rods, previously mentioned Sharp corners or edges may well be avoided in such situations

Specifically stating the cuts and feeds which are being used in the current fabrication of axles, a cut along the middle of the length of an axle has been witnessed having a depth of five-eighths inch with a feed of one-eighth inch This cut reduced the diameter of the forging from 11 to 9¾ inches It constituted both the roughing and the finishing cut along this part of the axle This depth of cut is exceeded at times Cuts having a depth of 1 inch on a side reducing the diameter of the axle 2 inches have been reported

On wheel seats and journal bearings lesser depths of cuts are understood to be current practice, the customary depths not, however, being stated. Finishing cuts are taken on those surfaces. On wheel seats an allowance of one sixty-fourth inch on a side is reported, on journal bearings one thirty-second inch.

There is a relation, no doubt, between the depth of the affected zone, beyond the cutting edges of the lathe tool, and the depth of the cut, influenced by the feed of the tool, its shape and sharpness of cutting edge, and also influenced by the grade of the steel being machined. A distortion of the grain of the steel due to cold work of excessive degree is readily shown with the microscope. Steel of exhausted ductility, the result of repeated stresses of a degree competent to cause ultimate rupture, does not, however, appear to change the shape of the grain. The presence of internal strains either of tension or compression has evaded detection microscopically. Under the present circumstances it would seem prudent, in turning axles, to allow considerable depth of metal for removal by the finishing cuts. Following roughing cuts of $\frac{3}{4}$ to 1 inch on a side, two finishing cuts of graded depths might be desirable of aggregate depth of one-sixteenth inch.

While not relevant to the failure of the present axle, the practice of sudden quenching of axles that have run hot may be referred to. The sudden cooling of hot steel introduces internal strains. The quenching of forgings from temperatures no higher than 900° F. has introduced internal strains, the corresponding stresses of which ranged from 30,000 to 40,000 pounds per square inch.

Axles which fail by repeated stresses have longer or shorter lives, according to the magnitude of the service stresses. If the service stresses are sufficiently low, the life of the axle is practically indefinite, hundreds of millions of rotations not causing rupture. On the other hand, a comparatively small number of rotations will result in rupture if the working stresses are very high. The line of demarcation between these two zones is sharp, in linear dimensions the strains amounting to only a few ten-thousandths per unit of length. There is reason for believing that internal strains from heavy cuts of machine tools augment the stresses of service when of the same algebraic sign, whence it would follow that the elimination of such auxiliary strains would be a step in the right direction and tend to increase the margin in safe strength of the axle under working loads.

It will not be lost sight of that certain defects of structure, shape, or of fabrication, which do not appreciably detract from the strength of the axle under primitive tests, may ultimately shorten its life under repeated stresses.

In the days of puddled iron axles it was believed that the superior toughness of muck bar iron would make it a peculiarly valuable metal for axles. It was considered to be evidence of superior quality if the iron could be tied into knots. The low elastic limits of muck bar axles led to their prompt failure even under the low wheel loads then prevailing. Those axles in their failure displayed the same characteristics witnessed in steel axles—that is, they ruptured without display of ductility.

The degree in which axles are strained in service is not the same over all parts of their lengths, whence it follows that some portions will retain their primitive properties unimpaired while other portions reach a state of exhausted ductility This explains why it is generally futile to examine an axle for the cause of rupture at a place remote from its incipient point The proximate cause of rupture must be looked for at the place where it had its beginning The outer ends of journals are not critical portions of the axle Disks have been welded on the ends of straight journals, to form shoulders, without detrimental effect to the axle as a whole

Laboratory tests have shown that an intermediate stage exists in the progressive effect of repeated stresses in which stage there is loss of ductility, but preceding actual separation of the steel At this intermediate stage the restoration of ductility may be effected by the process of annealing, and with such restoration a return to normal tensile strength This accomplishment leads to a recognition of the fact that repeated stresses are competent to destroy ductility and effect the rupture of steel which initially is structurally sound and free from inherent tendency to rupture That preexisting planes of separation or weaknesses of the metal are not of necessity present as precursors of rupture

Since annealing results in the restoration of ductility, and as it is also known causes the relief of internal strains, and going a step further, it may effect a change in the density of the steel, therefore it seems probable that an intimate relation exists among these several properties Inasmuch as they represent changes through which the steel appears to pass in approaching rupture by repeated stresses and also represent the results of conditions to which axles are exposed, the failure of axles in service should be judged, in part at least, according to conditions of service and of fabrication as herein mentioned

In summation, the failure of the present axle is believed to have been precipitated by reason of the effects of a heavy cut taken in the lathe in turning the portion of the axle which embraced the wheel seats, causing a disturbance in the physical properties of the metal leading to its premature failure, locating the plane of rupture within the portion of the axle covered by the hub of the wheel, a place on the axle which from position should be exempt from rupture, unless affected by a special cause which the condition of the turned surface of the wheel seat appears to explain

SUMMARY

As shown by the report of the engineer physicist, the fracture of this axle occurred at the wheel seat, the surface of which ranged from 1 to 1½ inches below the face of the hub It is unusual to witness the fracture of an axle at this place, and is suggestive of some local cause affecting this part of the axle which precipitated rupture

The journal, including a short section of the wheel seat, was detached at the time of derailment The journal remained in good condition The section of wheel seat was bruised by its wabbling motion in the hub at the time of rupture

Upon pressing off the wheel the character of the surface of the wheel seat was revealed It showed that a rough cut had been taken in the lathe in turning the axle The line of rupture had its incipient point at the circumference of the wheel seat, coinciding with a tool mark Other incipient cracks on the same surface followed similar tool marks

In brief, the character of the surface of the wheel seat was apparently responsible for the failure of the axle From information at hand, on the results of repeated stresses on axles, the character of this surface is regarded as an adequate cause for its failure

Examples are not of infrequent occurrence in which surface defects of this nature have led to failures, although bending and other direct stresses did not reach a maximum at the place of rupture, thus showing the gravity of such defects, although located beyond the most strained zone However, it is one of the polemics of the case as to just what the stresses actually are at places where the normal stresses are increased by the presence of tool marks or other interruptions to the transmission of strains Experience has shown, nevertheless, that such surface defects are by no means negligible factors, ruptured members substantiating this point of view, leaving no doubts concerning the necessity of avoiding such contingencies Steel under the action of repeated stresses is clearly susceptible to premature rupture under the influence of slight surface defects

This is a matter which demands attention in the manufacture of axles Slight economy in first cost results from taking a rough cut, in turning an axle, omitting a proper finishing cut, economy incomparable with the dangers involved and expense incurred in its failure in service

Axles are vital members Lavish ependitures on interior fittings of cars are out of place if necessary precautions are neglected in the manufacture of the axles Current methods of inspection appear to have ignored or omitted consideration of the importance which attaches to the proper machining of axles Specifications governing their tests and acceptance are singularly lacking in reference to this feature, the neglect of which leads to the destruction of the axles and becomes a menace to the safety of travel It should be sufficient to call attention to these errors of omission to insure the introduction of corrective measures

Respectfully

W P BORLAND,
Chief, Bureau of Safety

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