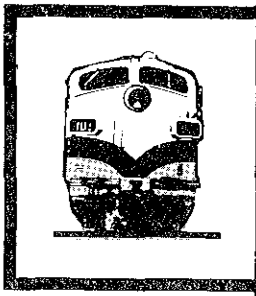
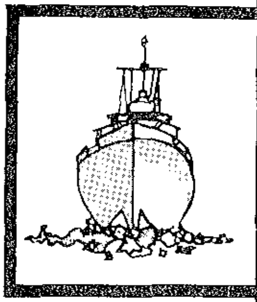
NATIONAL TRANSPORTATION SAFETY BOARD

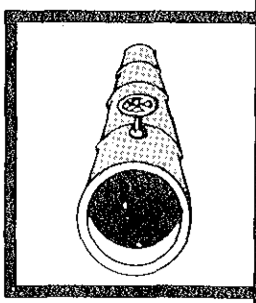


WASHINGTON, D.C. 20594



RAILROAD ACCIDENT REPORT

**DERAILMENT OF
AUTO-TRAIN NO. 4 ON
SEABOARD COAST LINE RAILROAD
FLORENCE, SOUTH CAROLINA
FEBRUARY 24, 1978**



UNITED STATES GOVERNMENT

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16. Abstract

About 2:10 a.m., on February 24, 1978, 19 cars and a locomotive unit of Auto-Train No. 4 derailed on Seaboard Coast Line Railroad trackage at Florence, South Carolina. Twenty-four of the 503 passengers were injured. The total accident damage was estimated to be $774,029.

The National Transportation Safety Board determines that the probable cause of the accident was a locomotive unit axle fracture that originated in an undetected void that developed during the manufacture of the axle. Contributing to the cause of the accident was the lack of a system for detecting an axle failure independent of crewmembers' inspection.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

Adopted: September 21, 1978

DERAILMENT OF AUTO-TRAIN NO. 4 ON THE SEABOARD COAST LINE RAILROAD AT FLORENCE, SOUTH CAROLINA, ON FEBRUARY 24, 1978

SYNOPSIS

About 2:10 a.m., on February 24, 1978, 19 cars and a locomotive unit of Auto-Train No. 4 derailed on Seaboard Coast Line Railroad trackage at Florence, South Carolina. Twenty-four of the 503 passengers were injured. The total accident damage was estimated to be $774,029.

The National Transportation Safety Board determines that the probable cause of the accident was a locomotive unit axle fracture that originated in an undetected void that developed during the manufacture of the axle. Contributing to the cause of the accident was the lack of a system for detecting an axle failure independent of crewmembers' inspection.

INVESTIGATION

The Accident

On February 23, 1978, Auto-Train Corporation (Auto-Train) train No. 4 departed Sanford, Florida, at 4:40 p.m., for Lorton, Virginia. The train consisted of 2 Auto-Train diesel-electric locomotive units and 43 cars. Airbrake tests and inspection of the train before it departed Sanford disclosed no defects. The train was being operated over Seaboard Coast Line Railroad (SCL) trackage by an SCL crew. At 10:48 p.m., the train departed from Savannah, Georgia, for Florence, South Carolina, where the crew was to be changed.

The engineer was operating the train from the seat on the right side of the lead locomotive unit. The fireman and a brakeman were seated on the left side of the lead locomotive unit. The conductor was in a dining car, and the flagman was in the caboose. The crewmembers had observed the train en route and took no exceptions to the train's condition. The locomotive units were not equipped with rearview mirrors to assist crewmembers in observing their train for defects. The train had passed a hot box and dragging equipment detector at Scranton, South Carolina, 20 miles south of the accident site. Crewmembers at both ends of the train had received "no defect" indications as they passed the detector.

An automatic signal, 2 miles south of the National Cemetery road crossing in Florence, displayed an "approach slow" aspect on the northbound track as the train approached the crossing. This required the engineer to promptly reduce the train's speed to 40 mph and to not exceed 20 mph at the next signal. He reduced the throttle position and made a brake application, reducing the train's speed from 70 mph to about 45 mph as the locomotive passed over the crossing. As the locomotive approached the crossing, the wheel-slip indicator light was activated, so the engineer reduced the throttle and actuated the sanders to correct the slippage. The only other wheel-slip actuation had occurred at the Santee River, about 52 miles south of the crossing.

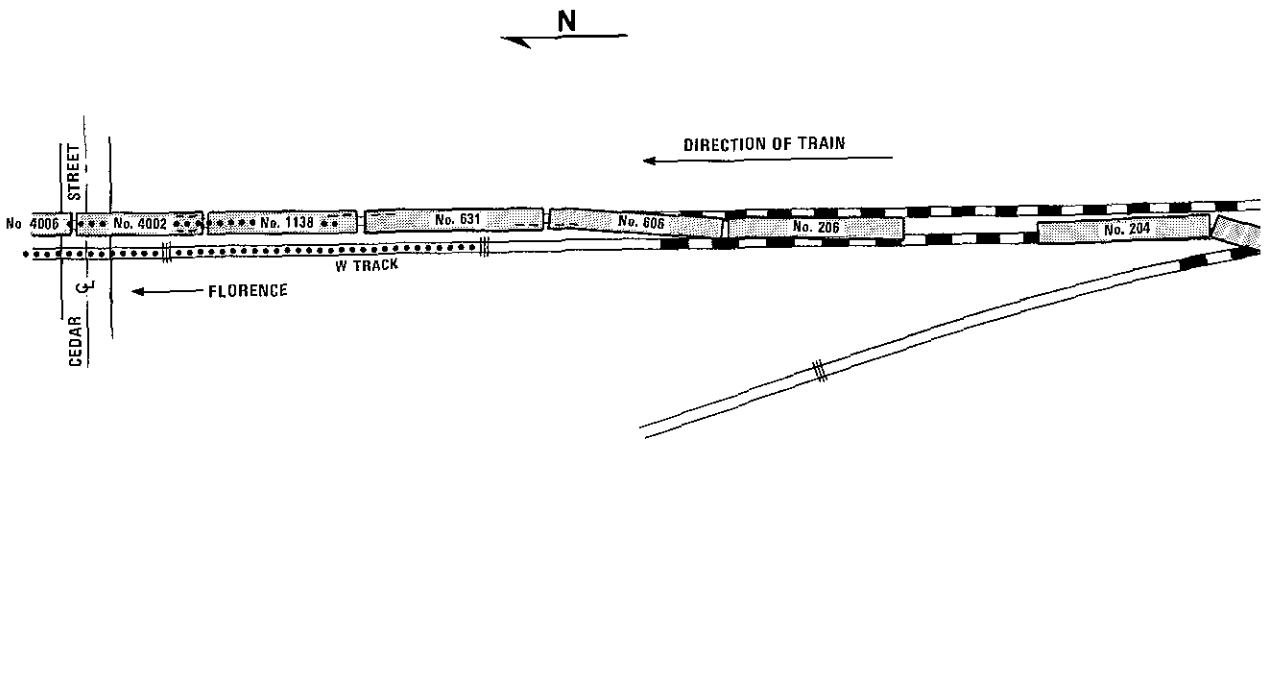
When the locomotive was about 80 feet past the crossing, the fireman looked to the rear, saw fire near the first car, and shouted a warning to the engineer to apply the train brakes in emergency. The engineer responded to this by placing the automatic brake valve in the emergency position and letting the brakes apply on the locomotive. During previous brake applications, the engineer used the independent brake valve to keep the brakes of the locomotive released. The prescribed method of service braking is to keep the locomotive brakes released.

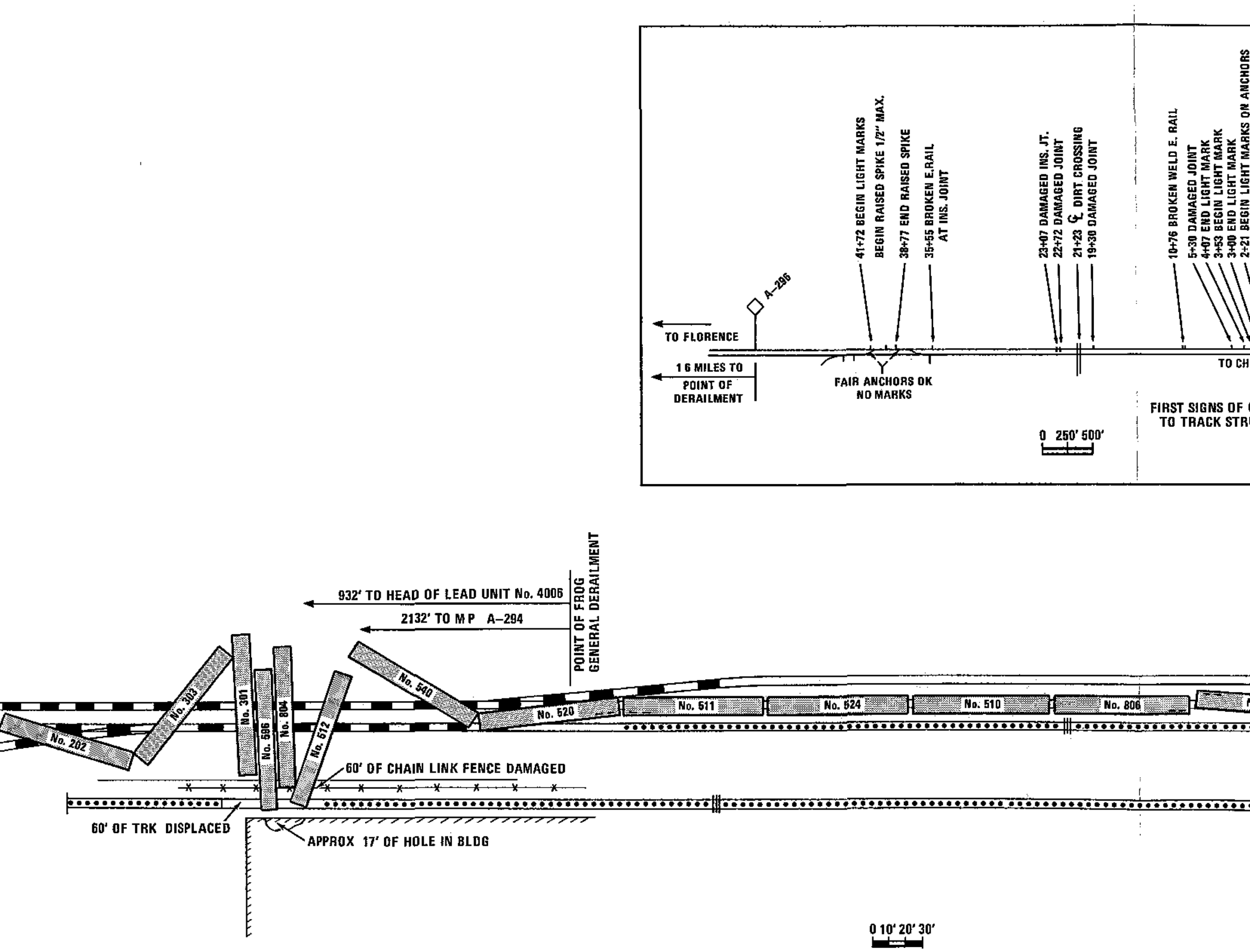
Almost immediately following the emergency brake application at 2:10 a.m., the second locomotive unit and 19 cars derailed. After the locomotive came to rest, the fireman immediately disembarked from the left side of the lead unit. He found the trailing truck of the second unit derailed and saw a fire in the suspension bearing on the gear side of the No. 2 traction motor. As soon as it was determined that emergency forces were coming and no passengers or crewmembers were seriously injured, his attention was directed to extinguishing the fire. Maintenance personnel arrived and removed the axle cap inspection cover. The axle was broken near the midpoint of the bearing area. The truck side frames were grooved at the right and left No. 2 wheel, indicating they had contacted the wheel rim faces. As soon as practical, the portion of the train that did not derail was rerouted northward.

At the accident site, the northbound track was paralleled on the west by the southbound track and on the east by a stub-ended industrial siding. (See Figure 1.) The switch to the siding was located at its north end. Approaching the accident point from the south, the grade ascends 0.56 percent, and the track alignment is straight.

Injuries to Persons

Injuries	Crewmembers	Passengers	Other
Fatal	0	0	0
Nonfatal	1	24	0
None	30	479	0


N
DIRECTION OF TRAIN
CEDAR
STREET
No 4006
No. 4002
No. 1138
No. 631
No. 606
No. 206
No. 204
W TRACK
FLORENCE



TO FLORENCE
A-296
1 6 MILES TO
POINT OF
DERAILMENT
41+72 BEGIN LIGHT MARKS
BEGIN RAISED SPIKE 1/2" MAX.
38+77 END RAISED SPIKE
35+55 BROKEN E.RAIL
AT INS. JOINT
FAIR ANCHORS OK
NO MARKS
23+07 DAMAGED INS. JT.
22+72 DAMAGED JOINT
21+23 ℄ DIRT CROSSING
19+30 DAMAGED JOINT
10+76 BROKEN WELD E. RAIL
5+30 DAMAGED JOINT
4+07 END LIGHT MARK
3+53 BEGIN LIGHT MARK
3+00 END LIGHT MARK
0 250' 500'
932' TO HEAD OF LEAD UNIT No. 4006
2132' TO M P A-294
POINT OF FROG
GENERAL DERAILMENT
No. 202
No. 303
No. 301
No. 596
No. 804
No. 612
No. 540
No. 520
No. 511
No. 524
No. 510
No. 806
60' OF CHAIN LINK FENCE DAMAGED
60' OF TRK DISPLACED
APPROX 17' OF HOLE IN BLDG
0 10' 20' 30'

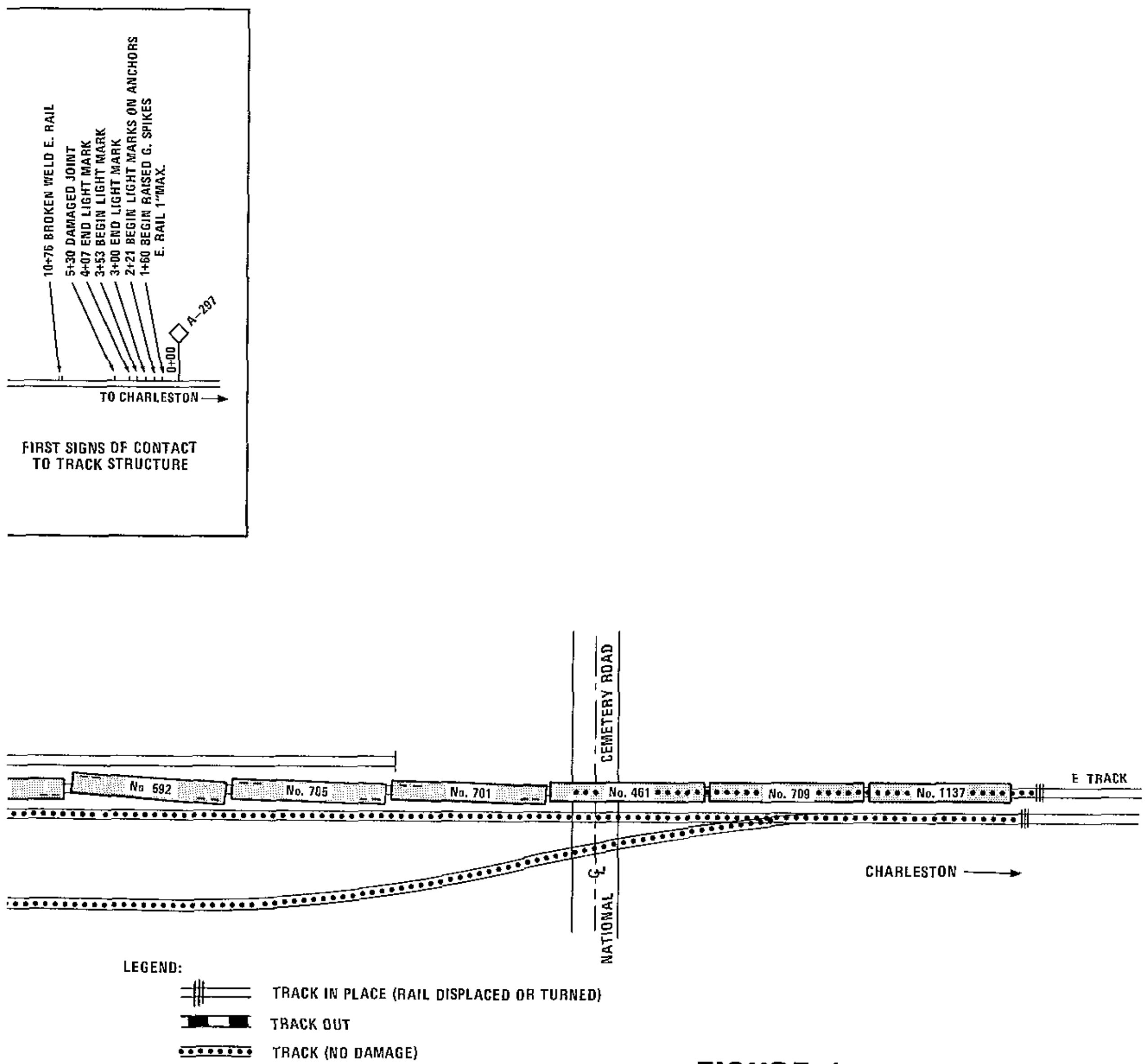


FIGURE 1

SEABOARD COAST LINE RAILROAD
FLORENCE DIVISION

AUTO—TRAIN DERAILMENT
ON FEB 24, 1978
FLORENCE, S.C

Damage

One passenger car was destroyed; two were heavily damaged; six were moderately damaged, and the other derailed cars were slightly damaged. About 1,380 feet of track, including one turnout, were destroyed.

The lead locomotive unit did not derail. The trailing (No. 1) truck on the second unit derailed. The 1st through the 14th cars, including the steam car, dormitory car, six sleepers, two diners, three coaches, and one nightclub car, were derailed. The 14th car, a coach, was derailed on the north end. The next two cars, both coaches, were not derailed. The 17th car, a diner, and the following three coaches were completely derailed. Only the lead west wheel of the lead truck of the 21st car, a coach, derailed. The first five derailed cars stayed in line with the track; the 6th through the 11th cars derailed to the west and stopped perpendicular to the track. The 6th and 7th cars, the 8th and 9th cars, and the 11th and 12th cars jacknifed. The other derailed cars stayed in line with the track. Some of the derailed cars were deformed severely; however, this did not hinder passenger evacuation.

The cost of the derailment damages was estimated to be:

Track	$ 95,000
Signal and Appurtenances	15,000
Nonrailroad	4,000
Equipment	660,029
Total	$774,029

Train Information

The two class U36B diesel-electric locomotive units were manufactured to Auto-Train specifications in 1971 and 1972 by the General Electric Company (GE). They were equipped with dynamic brakes and a 26L-type air airbrake. Instead of the GE-designed truck, Auto-Train requested a truck manufactured by the Electro-Motive Division (EMD) of the General Motors Corporation. GE modified the EMD truck to accept a GE No. 752 traction motor. Each locomotive unit had two trucks, each of which contained two traction motor-wheel-axle assemblies. The traction motor mounted on each axle was supported on the axle by two friction-type motor-suspension bearings and on the truck frame by a nose support. Oil for each axle bearing was conducted to the axle and suspension bearings through a felt-wick lubricator. A pinion gear on the traction motor armature shaft meshed with the axle ring gear for propulsion. The axle ring gear had 79 teeth, and the pinion gear had 24 teeth.

GE first mounted the axle, wheels, and traction motor on the EMD truck in January 1973. The truck initially was placed in service on another locomotive unit--one not involved in this derailment. In

April 1975, the axle was removed to have new wheels applied and was returned to service on the same unit. In November 1976, the wheel assembly was removed to have the wheels turned, and in December 1976, the assembly was installed in the No. 2 position of the locomotive unit that derailed at Florence. At the time of the failure, the axle, traction motor and traction motor suspension bearing had been in service more than 298,000 miles.

Since June 1972, Auto-Train had experienced 14 suspension bearing failures, some of which resulted in axle failures on locomotive units, and had instituted new maintenance procedures to combat the problem. These measures included a new style suspension bearing, sealing of the dust guard with silicone, changing the suspension bearing oil every 90 days, and checking the wicks every 90 days. Suspension bearings and wicks were replaced each time the traction motors were removed for servicing.

When this assembly, which subsequently failed, was placed in the second locomotive unit, new journal boxes were installed, and new suspension bearings and wicks were applied in accordance with the new instructions. In January 1978, the traction motor brushes were changed, and new pedestal liners and rubber thrust absorbers were applied. In February 1978, new swing-hanger bushings and pins were applied. The wheel work done in 1975 and 1976 was performed by the SCL maintenance shop in Rocky Mount, North Carolina, and both times the axle was checked for visible defects. The axle was tested by the magnetic particle method prescribed by the Association of American Railroads (AAR). This type of test is prescribed for an axle to be reconditioned or reworked. The axle was found to be in condition to be returned to service.

GE provided Auto-Train with its specifications for maintaining the locomotive and its appurtenances. Auto-Train indicated that it complied with these specifications and requirements. Auto-Train had performed the periodic inspections on the locomotive unit required by the Federal Railroad Administration (FRA). The last daily examination was on February 23, 1978, and the last 30-day inspection was on February 17, 1978. No exceptions were taken during either of these inspections. The last annual examination was made on August 24, 1977.

The fracture in the axle was located 30 1/4 inches from the left end, at a point where the axle diameter was 8 7/8 inches. The fracture was about midway under the bearing on the drive side of the axle. The fractured axle had a journal size of 6 1/2 by 12 inches, was of grade F steel, and was manufactured by the Bethlehem Steel Corporation (Bethlehem) in May 1972. Specifications listed in the AAR Manual of Standards and Recommended Practices were used in the manufacturing process. Specification M-101 prescribes manufacturing procedures, chemical requirements, and mechanical properties and tests. Bethlehem certified to GE that the axle complied with the requirements of M-101, including ultrasonic inspection. (See Appendix A.)

Method of Operation

Trains operating in the accident territory are governed by a traffic control system. The maximum authorized speeds between Savannah and Florence are 79 mph for passenger trains and 70 mph for Auto-Trains. Normal northbound daily traffic consists of eight trains, including one Auto-Train and two passenger trains.

Meteorological Information

At the time of the accident, the temperature was 31° F, and surface visibility was 7 miles. The sky was clear with a northeast wind of about 7 mph. There had been no precipitation.

Survival Aspects

Even though many of the passenger cars were badly deformed in the derailment, only 24 of the 503 passengers and 1 of the 31 crewmembers received minor injuries. One passenger was hospitalized. A significant factor in the relatively low number of injuries was the time of the accident -- 2:10 a.m. Most of the passengers were in berths or seated.

Tests and Research

An inspection of the northbound track disclosed flange marks on the flange boards of a highway grade crossing located 17.5 miles south of the accident site. Markings were found at each road crossing from this point to the point of derailment. Wheel markings were found on the flared portion of the guardrail of a facing point left-hand turnout, adjacent to the east rail, and on the frog 1/ point on the west rail at Coward, South Carolina, 15 miles from the accident point.

Marks on the heel of the frog of the turnout to the siding at the accident site indicated that the derailed left No. 2 wheel of the trailing truck on the second locomotive unit struck the frog and was diverted to the west. The left wheels on the following cars struck the frog and derailed.

The failed wheel axle assembly with its traction motor was shipped to the Sanford shop of Auto-Train, where it was disassembled for inspection on March 3, 1978. All components were examined as they were separated from the assembly. However, since the surfaces of the failed area had been subjected to severe heat and friction, it was not possible to visually determine the sequence of events that led to the axle/bearing failure. Selected sections of the failed surface were forwarded to a laboratory for analysis.

1/ A track structure used at the intersection of two running rails to provide support for wheels and passageways for their flanges, thus permitting wheels on either rail to cross the other.

Much of the bearing had been melted and fused to the outer surface of the turning axle due to the intense heat generated in this area. The heat and pressure between the broken sections of the axle were so intense that the contour of the axle was changed. Differences in the surface color of the axle steel from the drive side to the differential side indicated that the heat originated from the swagging and rubbing actions between the broken faces of the axle. The axle color spectrum ranged from black to yellow (500° - 800°F).

Metallurgical, mechanical, and chemical tests indicated that the axle contained preexistent cracks and voids. (See Appendix B.) Several cracks extending to the axle surface appeared to have initiated in the voids in the axle core. Scanning electron microscope examination of the void surfaces disclosed features which develop when axles are manufactured. Also the failed axle material did not meet the chemical requirements.

Chemical analysis below the axle surface disclosed no evidence of diffusion of the bronze bearing material into the steel axle, which likely would have occurred if a bearing had failed before the axle failed. When a bearing is in the process of failing, frictional forces generate heat at the interface of the two dissimilar materials. This heat can diffuse the bearing metal into the steel.

The engineering evaluation tests were based on the AAR specifications for axles manufactured at the time that the failed axle was made. The felt-wick lubricators of the other axle suspension bearings were inspected and found to be satisfactory. The wheel-slip control circuitry on the two locomotive units was tested and found to perform as intended.

Other Information

The FRA does not have regulations pertaining to the manufacture of locomotive unit axles; however, FRA does have rules for the removal of in-service axles. (See Appendix C.)

ANALYSIS

The flange markings on the highway grade crossings indicated that the axle broke about 17 miles south of the derailment site. The wheel-slip control system did not indicate the failure because the gears still meshed and no voltage differential between the wheels of the unit was established. The broken axle permitted the wheels to move inward sufficiently for the flanges to strike the paved surface of the highway crossings, but not enough to derail. The broken ends of the axle were kept in line by the suspension bearing, and the wheels were kept upright by the truck sides and other parts of the track. The rubbing of the wheels on the truck sides caused the grooving on the locomotive truck frame. This action continued until the wheel struck the frog of the turnout to the siding at the accident site and caused the frog to become misaligned. As other wheels struck the frog, the cars derailed.

The metallurgical examination of the broken axle indicated that the axle probably broke before the bearing failed. Further examination disclosed several voids within the axle. Cracks extended from the voids toward the outer surfaces of the axle. The surfaces of the broken axle had been distorted by rubbing against each other for 17 miles and by the heat produced by this friction. Although this distortion prevented precise determination of the cause of the failure, it is possible that one of the cracks from the voids extended far enough toward the outer surface of the axle to weaken the axle structure, causing it to fail.

Some of the voids in the axle produced when the axle was manufactured. Discontinuities of this type usually can be detected by ultrasonic testing equipment, especially when progressive fractures begin to radiate from the voids. The AAR requires ultrasonic testing of new locomotive axles only. Magnetic particle testing of used axles, as required by AAR, will detect only those cracks that appear on the surface of the axle and will not detect voids below the surface, such as those found in this failed axle. By the time a crack from a void surfaces so that it can be detected by the magnetic particle method, the axle already has failed.

Additional examinations beyond the required magnetic particle method should be required for all axles when new wheels are applied, or when wheels are turned. These examinations should be able to detect internal defects. This accident investigation disclosed that Auto-Train had had other axle failures caused by bearing failures and so had changed its maintenance practices accordingly. However, without some internal examination system, in addition to the improved maintenance practices, defects below the surface of an axle will not be detected. Auto-Train should incorporate some type of internal axle testing as part of its periodic examination of locomotives.

The results of this accident suggest that the FRA should extend its regulations to include the inspection of locomotive axles during the manufacturing processes and to the tests performed by the manufacturer. At present, the only mandatory AAR requirement for ultrasonic axle inspection is at the time of manufacture. Since the state-of-the-art is capable of detecting voids of the type disclosed in the postaccident metallurgical tests, it appears that the testing requirements are not stringent enough and that the present monitoring program is not sufficient.

The lack of serious injuries was probably due to the time of the accident, because most passengers were in their seats or berths. If the accident had occurred at mealtime when passengers were moving from their cars to the dining cars, or at a time when the entertainment car was open, the probability of deaths or serious injuries would have been greater. Even though many of the passenger-carrying cars sustained considerable damage, passenger evacuation was not impeded.

The Auto-Train locomotive units were not provided with rearview mirrors to assist the crewmembers in observing their train en route. Intermittent sparking was produced during the axle failure prior to the derailment, and the use of a rearview mirror might have alerted a crewmember who could have taken preventive action to avoid the general derailment. The crew had observed the train for defects; however, the sparking might not have been discernible where their observations were made.

CONCLUSIONS

Findings

1. The No. 2 axle of the second Auto-Train locomotive failed before the traction motor support bearing failed.

2. The axle failed at least 17 miles before the train derailed.

3. The crewmembers did not perceive the failed axle in time to avoid the accident.

4. The No. 2 wheel and axle assembly had been used more than 298,000 miles before it failed.

5. Metallurgical tests and chemical analysis were necessary to reveal the axle's internal defects and to determine the failure sequence.

6. The wear pattern of the wheel rim on the truck frame indicated that the back-to-back wheel measurement was out of gage.

7. The ultrasonic inspection by the manufacturer did not detect any internal axle defects which were present when it was manufactured.

8. At the time the axle was remounted, SCL employees using AAR specifications for remounting used axles, did not detect any defects.

9. The FRA should have minimum specifications or testing requirements for the manufacture of locomotive axles.

10. The AAR should have mandatory requirements or specifications for locomotive axles.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was a locomotive unit axle fracture that originated in an undetected void that developed during the manufacture of the axle. Contributing to the cause of the accident was the lack of a system for detecting an axle failure independent of crewmembers' inspection.

RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board made the following recommendations:

.....to the Association of American Railroads:

> "Amend the procedures for testing and inspecting used locomotive unit axles before they are remounted to insure that internal defects can be detected. (Class II, Priority Action) (R-78-53)"

.....to the Federal Railroad Administration:

> "Revise 49 CFR 230.213, Axles, to establish specifications for the manufacturing and testing of locomotive axles to insure the discovery of internal defects before they are placed in service. (Class II, Priority Action) (R-78-54)
>
> "Revise 49 CFR 230.213, Axles, to establish procedures and methods to test in-service locomotive axles to insure the detection of internal defects so they may be removed from service. (Class II, Priority Action) (R-78-55)
>
> "Develop a method that will automatically detect the failure of a locomotive unit truck or any of its components, independent of crew observation. (Class II, Priority Action) (R-78-56)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

/s/ ELWOOD T. DRIVER
Member

September 21, 1978

APPENDIX A

Report of Physical Tests and/or Chemical Analysis by Bethlehem Steel Corporation

BETHLEHEM, PA 18016

3-103160-1 10/18/71 — 603-2035-1/2

45325-00 | 301 | 9 | 24 | 3725 | 430 | | | X2 | TF 91940 X576

Q | 3GS | H | 6 | COLLECT

SOLD TO: 0576
GENERAL ELECTRIC CO
TRANSPORTATION SYSTEMS DIV
2901 EAST LAKE ROAD
ERIE PA 16501

SHIP TO: GENERAL ELECTRIC CO
TRANSPORTATION SYSTEMS DIV
3410 MAIN AVE FOR ECY 10
ERIE PA 16501

DATE SHPD 9/1/72 SHPD FROM JOHNSTOWN PA

ROUTE W C MCQUAIDE

CAR OR VEHICLE NO	NO PCS OR PKGS	KIND OF PACKAGE, DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS	WEIGHT POUNDS
TRL TC61495	22	AXLES W/O BRGS GEARS KNUCKLES OR POWER ATCHMTS	34300

CUSTOMER & BSC ORDER NOS.	UNITS	DESCRIPTION AND SIZE	WEIGHT
20-0792	PCS		

INSP: 3 CERT TESTS TO LOCO QUAL CONTROL SUPVR BLDG
14-3 2901 E LAKE RD ERIE PA 16501
SPEC: AAR M101-68 GRADE F DN&T MICRO TEST REQUIRED
RTAO STD 60 DEG CENTERS ULTRASONICALLY INSPECTED
TO AAR SPEC M101A-70 LOCO AXLES DWG 41C612095-P3
REV 8

(2353-155-481)

20 32200

HT	SER							
3-662H534	25	30	64					
6-654H497	6	32	34	66	67	68		
11-658H505	8	20	21	23	35	36	38	39
	43	53	58					

	Yield	Tensile	El. 2"	Red.A.	Micro	C	Mn	P	S	Si
662H534	53920	97850	25.0	47.2	OK	51	84	012	039	23
	54420	99350	23.5	46.3	OK					
654H497	54420	100850	25.0	45.4	OK	55	80	010	027	21
	54920	100850	24.0	44.0	OK					
658H505	51630	99000	26.0	46.1	OK	56	79	010	023	20
	51920	97850	25.0	46.0	OK					

REPORT OF PHYSICAL TESTS AND/OR CHEMICAL ANALYSES

I CERTIFY THE ABOVE RESULTS OF TESTS AND/OR ANALYSES TO BE CORRECT AS CONTAINED IN THE RECORDS OF THE BETHLEHEM STEEL CORPORATION.

Chief Metallurgist

APPENDIX B
EXCERPTS FROM THE ENGINEERING COMPANY EVALUATION OF LOCOMOTIVE AXLE SEGMENTS

April 10, 1978

Grain Size Determinations: The saw cut faces of pieces A-1-1, B-W-1, B-2-3 and CCC-4 were ground smooth, polished in six stages and etched in 2 percent nital. High contrast film was used to obtain typical pictures of the grain at approximately 120X.

Comparisons of grain sizes were made with figure 3b, A-1969 M-126-68 which represents the maximum grain structure acceptable Figures 43, 44, 45 and 46 show a grain size much larger than acceptable in pieces A-1-1, B-W-1, and B-2-3 due most likely to the heat generated.

In figure 47 and 48, the grain structure in piece CCC-4 appears to comply with the maximum acceptable size. Piece CCC-4 was taken from the segment not in the overheated portion of the axle.

Cleanliness Ratings & Discontinuities: Cleanliness ratings were obtained for pieces of axle material from the overheated region (B-W-3) as well as from the CCC slice which was not in the overheated portion The method as described in SAE J422a was used, and the results show that the cleanliness of the steel in the B-W-3 piece (figures 57 through 59) was somewhat less than the CCC-4 piece (figures 52 through 56).

The B-W-3 piece was located several inches from the fracture face of the axle

When the slices of axle were saw-cut from the three segments as described above several voids in the metal were evident. The voids were generally of two different shapes. Figures 49 through 51 show the void in piece B-W-1 at from 7X to 25X magnification Cracks appeared to be connected from the void to the outside edge. This type of gap appeared to have pre-existed in the metal volume.

Figure 60 is a composite of a different type of void as seen in piece A-1-1 at 7X This type of void appears to have been due to the hot swaging of the metal brought about by the rubbing of the broken faces of the axle Figures 61 through 68 are additional photographs at from 15 to 25X of different views of the discontinutities. The clean separation of the faces surrounding the openings is to be noted.

Auto Train Corporation   April 10, 1978

Diffusion Studies: A small piece was cut from slice A to include the surface of the axle in contact with the bearing This edge was ground, polished and etched Figure 69, 70 and 71 made in the SEM at 26X, 260X, and 1300X, respectively show the thin layer in contact with the axle

The diffusion of the bearing alloy by the axle was not observed Chemical analyses SEM scans of this area were made for lead, zinc and copper and the results were negative in each case This indicates that the bearing was probably operational until the axle failed because of a lack of diffusion of bearing elements in the steel

Surface Studies in Void Walls: An additional void was observed in slice C-W-3, located several inches away from the fracture surface Figures 72 through 74 are SEM photographs taken at 22X and show clearly the outline of the void At higher magnification to 220X the surface of metal in the void appeared to be as a "free" surface as seen in figures 76 and 77 The absence of sharp tears and/or dimples indicates that the free surface or the void was probably present before axle failure.

Figures 78 through 80 are SEM micrographs of the "free" surface at from 1000X through 2100X. The presence of numerous pits in the "free" surface is to be noted

Mechanical Properties: A slice was taken from the unheated segment at about one-half the distance between the center and the surface Tensile test specimens and charpy V notch specimens were machined with the material oriented in the longitudinal direction or axial direction of the axle

Strength data are summarized in Table I and show that the axle material does not meet the requirements for AAR-M-101-76 Grade F (Double nomalized and tempered) material for the offset yield strength

Rockwell B Scale: Hardness tests were also run on samples from CCC and B-W pieces and results showed that the B-W material was slightly harder.

Charpy V-notch specimens were tested at room temperature and at 0°F. Data are summarized in Table II and show a transition in the material between these temperatures from a more ductile to a brittle failure. This means that the axle material would be more susceptible to failure when a combination of notches or discontinuitites existed at low temperatures under fatigue-impact loads

APPENDIX B

Auto Train Corporation April 10, 1978

Chemical Analyses: The chemical analyses of axle material in samples A-5 and CW-3 were determined and the results are shown in Table III. Data show that the amount of manganese was excessive in sample CW-3 when compared with the requirements of AAR-M-101-68

CONCLUSIONS & DISCUSSION

Based on the results of extensive metallurgical, chemical and mechanical properties testing the most probable cause for the axle failure appears to be due to the presence of a growing discontinuity or void within the axle

The failure of the bearing appears to have taken place after axle failure based on the lack of diffused bearing elements in the axle matrix.

Voids of two types were discovered One type of void appears to have been caused by the movement of metal due to high temperature and pressure as evidenced by grain growth and profile. The other type was characterized by a "free" surface which indicated existance before axle failure

The failure of the axle material to meet the yield strength and chemical requirements of AAR-M-101-76 for Grade F double nomalized and tempered steel is to be noted.

The low transition temperature of the axle material as evidenced by the low values of impact strength at 0°F is significant in a discussion of the toughness of the axle.

Although the surface finish was difficult to assess due to the numerous abrasion marks applied during the attempt to remove, cut and transport the axle segments, the basic original surface finish appeared to be very good and between an 8 Ground - 16 Ground finish as seen in figure 81

APPENDIX B

TABLE I

SUMMARY OF AXIAL STRENGTH DATA ON AXLE MATERIAL

SAMPLE NO.	*TENSILE STRENGTH (PSI)	0 2 PERCENT OFFSET YIELD STRENGTH(PSI)	PERCENT ELONGATION	PERCENT REDUCTION AREA
CCC-1	92,900	45,500	26 5	46
CCC-2	93,400	44,400	28 0	49
CCC-3	92,500	45,200	25.0	47
AVERAGE	92,900	45,030	27 0	47
AAR-M-101-76 REQUIREMENTS GRADE F (DOUBLE NORMALIZED AND TEMPERED)	86,000 MIN	48,000 MIN	21 0 MIN	35 MIN

* ROCKWELL SCALE HARDNESS TRAVERSES MADE ON SAMPLES OF AXLE MATERIAL, CCC AND B-2 PIECES, RANGED FROM R_B OF 88 - 91 (86 - 91 KSI) AND R_B OF 90 - 102 (89 - 102 KSI), RESPECTIVELY.

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TABLE II

SUMMARY OF CVN IMPACT DATA (TRANSVERSE NOTCH)
AXLE MATERIAL AT ROOM TEMPERATURE AND 0°F

SAMPLE NO.	TEST TEMPERATURE(°F)		IMPACT STRENGTH (FT/LBS)	LATERAL EXPANSION	PERCENT SHEAR
1	RT		18		
2	RT		16		
3	RT		17		
		AVERAGE	17		
4	0°F		5		
5	0°F		6		
6	0°F		4		
		AVERAGE	5		

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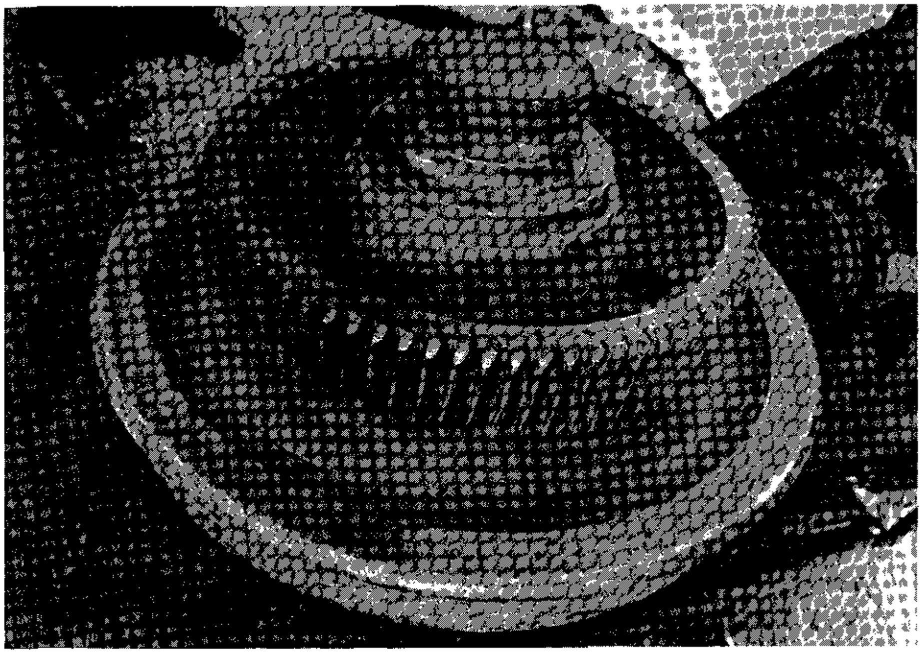
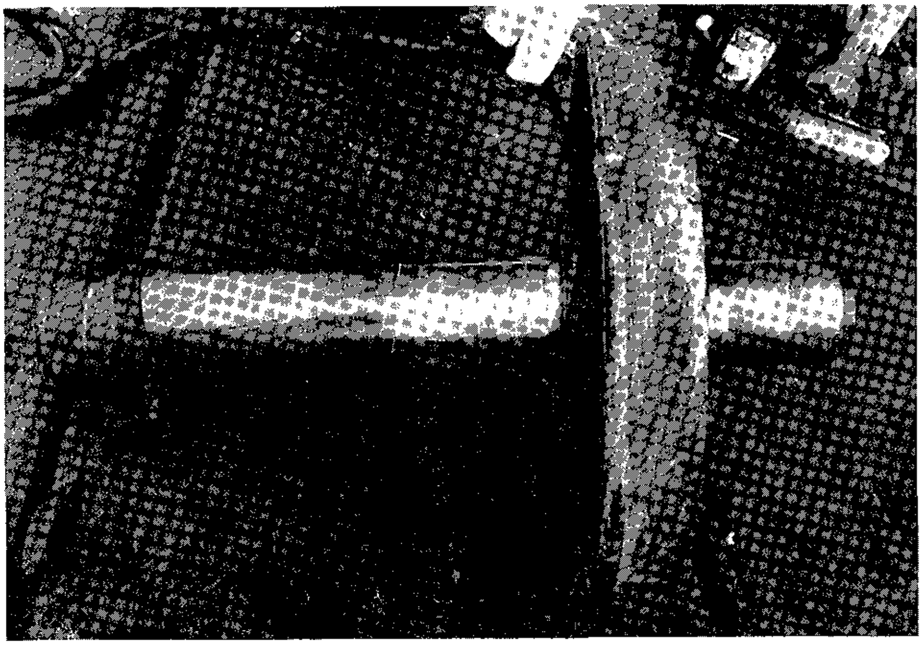
TABLE III

CHEMICAL ANALYSES
PERCENTAGE BY WEIGHT

ELEMENT	SAMPLE A-5	SAMPLE CW-E	AAR M-101-68
CARBON	.51	.57	.45 - .59
PHOSPHORUS	.02	.03	.045 - ±0.008
SULFUR	.02	.04	.050 - ±0 008
MANGANESE	.82	1 04	.60 - .90 ±0.03
SILICON	.29	.25	.15 MIN ±0 02
COPPER	.07	.04	--
NICKEL	.04	.06	--
CHROMIUM	.03	.02	--
MOLYBDENUM	.02	.10	--



Drive side of failed axle (marked for cutting).



Commutator side of failed axle (marked for cutting).

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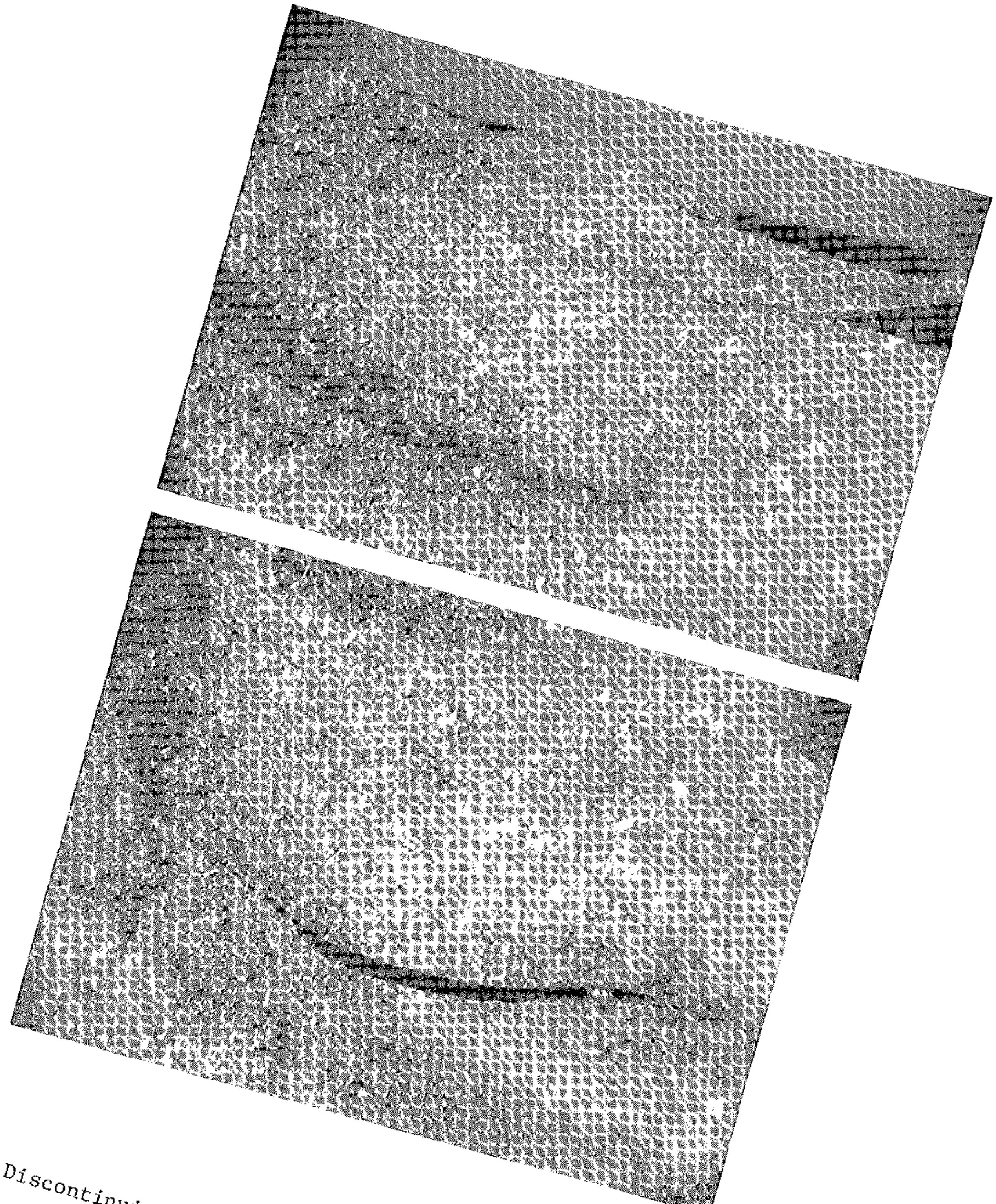

Discontinuities in failed axle, magnified 15 times.

APPENDIX C

Excerpts from Code of Federal Regulations

§ 230 200a Responsibility for design, construction, inspection, and repair

The railroad company is held responsible for the general design construction, inspection, and repair of all locomotives used or permitted to be used on its line It must know that all inspections, tests, and repairs are made and reports made and filed as required, and that all parts and appurtenances of every locomotive used are maintained in condition to meet the requirements of the law and the rules and instructions in this subpart Nothing contained in the rules and instructions in this subpart, however, shall be construed as prohibiting any carrier from enforcing additional rules and instructions not inconsistent with those in this subpart contained, tending to a greater degree of precaution against accidents.

RUNNING GEAR

§ 230.213 Axles

(a) *Defects* Driving and truck axles with any of the following defects shall not be continued in service Cracked or bent axles, cut journals that cannot be made to run cool without turning; seamy journals in steel axles; transverse seams in iron axles, or any seams in iron axles causing journals to run hot, unsafe on account of usage, accident, or derailment; nor driving or truck axles more than one-half inch under original diameter, except for locomotives having all driving axles of the same diameter, when other than main driving axles, may be worn three-fourths inch below the original diameter.

(b) *Stamping* The date applied, the original diameter of the journal, and the kind of material, shall be legibly stamped on each driving axle and truck axle applied after January 1, 1926

(c) *Abbreviations* The following abbreviations shall be used in stamping "kind of material" on driving axles, truck axles, and crank pins I.—iron; S.—steel, H T. S —heat-treated steel; Chr —chrome; Van —vanadium; Nkl —nickel; Nik.—nikrome, Cof Proc.—Coffin process, Cam Spec —Cambria special, Tay I —Taylor iron