211

Examination of Failed Four-Inch Diameter Cast Iron Pipe Natural Gas Main, Fort Payne, Alabama

T. Robert Shives

Fracture and Deformation Division
Center for Materials Science
National Measurement Laboratory
U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

September 1980

Issued February 1981

Failure Analysis Report

...d for
...ial Transportation Safety Board
...ngton, DC 20594

NBSIR 81-2211

EXAMINATION OF FAILED FOUR-INCH DIAMETER CAST IRON PIPE NATURAL GAS MAIN, FORT PAYNE, ALABAMA

T. Robert Shives

Fracture and Deformation Division
Center for Materials Science
National Measurement Laboratory
U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

September 1980

Issued February 1981

Failure Analysis Report

Prepared for
National Transportation Safety Board
Washington, DC 20594

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

TABLE OF CONTENTS

SUMMARY

At the request of the National Transportation Safety Board, the Fracture and Deformation Division of the National Bureau of Standards performed an examination of a fractured four-inch diameter cast iron pipe natural gas main from Fort Payne, Alabama. An explosion and fire reportedly occurred in an apartment building at the location of the failure on November 17, 1979.

The pipe had suffered a transverse fracture. Only one of the fracture faces was examined at the National Bureau of Standards. Most of the corrosion product on the fracture surface was rather easily removed indicating the likelihood that most of the fracture was recent. There was some graphitization on the fracture surface in a region near the bottom of the pipe suggesting the existence of at least a part-through crack before the time of the final failure. Failure appeared to be due to the application of a bending load at the location of the apparent pre-existing crack.

In addition to the graphitization observed at the fracture, some graphitization was found in other regions of the submitted pipe. Graphitization, however, does not appear to have been a major contributing factor to the failure.

The chemical composition of the pipe material was typical for gray cast iron. Except for material adjacent to the inside wall surface of the pipe, the hardness was typical for ordinary gray cast iron. Material adjacent to the inside wall surface of the pipe was softer than expected for ordinary gray cast iron. The microstructure of the material varied considerably across the pipe wall thickness.

Examination of Failed Four-Inch Diameter Cast Iron Pipe Natural Gas Main, Fort Payne, Alabama

1. INTRODUCTION

1.1 Reference

National Transportation Safety Board, Washington, DC 20594. This investigation was conducted at the request of Mr. Jerry A. Houck, Metallurgist, National Transportation Safety Board.

1.2 Background Information

Information in this section was furnished by the National Transportation Safety Board.

On November 17, 1979, there was an explosion and fire in a four-unit apartment building in Fort Payne, Alabama attributed to the ignition of natural gas leaking from a four-inch diameter cast iron pipe gas main. Upon exposure, the gas main was found to be cracked circumferentially from about 1:00 to 11:00 o'clock, where 12:00 o'clock is at the top as the pipe lay in the ground. The crack exhibited a maximum width of 0.35 inch at the bottom of the pipe when the pipe was uncovered.

The pipeline had been in service for 26 years. The maximum allowable operating pressure was 25 psig.

1.3 Parts Submitted

Two pieces of the fractured four-inch diameter cast iron pipe, each containing one of the mating fracture surfaces, were submitted to the NBS Fracture and Deformation Division on March 20, 1980. These pieces are shown in figure 1 as received at NBS. It is to be noted that although it was reported that the pipe had cracked circumferentially from about the 1:00 to 11:00 o'clock positions when exposed at the site, complete fracture and separation had occurred before the samples were submitted to NBS. On that same day (March 20, 1980), the smaller piece (on the right in figure 1) was given to Tim G. Dunn of Dunn Laboratories, Inc., as per instructions from Jerry Houck of the National Transportation Safety Board. Therefore, except for some documentary photographs, this examination was limited to the larger piece of pipe (on the left in figure 1).

2. PURPOSE AND PLAN OF THE EXAMINATION

The National Transportation Safety Board requested that the NBS Fracture and Deformation Division perform a failure analysis and material characterization of the fractured pipe. At a meeting at NBS on March 20, 1980 attended by Jerry Houck of the National Transportation Safety Board, Tim G. Dunn of Dunn Laboratories, Inc. and T. Robert Shives of the National Bureau of Standards, it was agreed that the pipe examination would include the following tasks:

1. Photographic documentation

2. Fractographic examination

3. Examination for graphitization

4. Metallographic examination

5. Chemical analysis

6. Hardness measurements

7. Ring tests

8. Talbot tests

3. RESULTS OF THE EXAMINATION

3.1 Photographic Documentation

A documentary photograph of the pieces of pipe containing the mating fracture surfaces is shown in figure 1. The fracture surfaces themselves are shown in figure 2. Documentation of various aspects of the examination is found in other figures throughout the report.

3.2 Fractographic Examination

As indicated in the previous section, the two mating fracture surfaces are shown as-received at NBS in figure 2. The top of the pipe in the figure corresponds to the top of the pipe (12 o'clock position) as it was oriented in service. The fracture surface shown at the left in the figure is the one retained at NBS for examination.

The fracture surface of the pipe was covered with a dark reddish brown corrosion product when submitted to NBS. Two regions, indicated by arrows A and B in figure 2, were somewhat different in appearance from the rest of the fracture surface suggesting the possibility of graphitization.

To facilitate a fractographic examination, the fracture surface was cleaned in an ultrasonic bath with buffered hydrochloric acid. The fracture is shown in figure 3 after cleaning. Most of the reddish brown corrosion product was rather easily removed by the cleaning procedure, indicating that much of the corrosion was of a superficial nature, and therefore that most of the fracture was rather recent. However, some of this corrosion product remained after cleaning, especially in the region near the bottom of the pipe indicated by arrow B in figures 2 and 3. The fact that the corrosion product remained on the fracture surface after cleaning suggests that a crack may have been present near the bottom of the pipe for some time before final failure. Since the corrosion product was concentrated over the outside 2/3 of the fracture in the region indicated by arrow B, the crack probably was only part-through, starting at the outside of the pipe. As compared to most of the rest of the fracture surface, the region indicated by arrow A in figures 2 and 3 remained darker in color after cleaning and appeared to be an area of graphitization.

Regions near the top and bottom of the pipe were examined with the scanning electron microscope (SEM). The locations of these regions are indicated in figure 3. The primary feature of the fracture surface at both top and bottom where it was not masked by corrosion product was cleavage, which is normally observed in gray cast iron fractures. SEM fractographs of two representative areas are shown in figures 4 and 5. A fractograph from the area indicated by arrow A in Figures 2 and 3 is shown in figure 6. Again, this region appears to have been graphitized and shows evidence of separating from the pipe. A fractograph from the area indicated by arrow B in figure 2 is shown in figure 7. Corrosion product on the fracture surface is evident at this location.

3.3 Examination for Graphitization

A cross section ranging from about 1/2 to 2 inches from the fracture was cut from the pipe sample. The polished section is shown in figure 8. Some localized graphitization adjacent to the outside wall surface of the pipe is evident, especially in the region between 12:00 and 2:00 o'clock. At one location in this region, the graphitization penetrates about 1/3 of the pipe wall thickness. Except for this one location, graphitization was rather shallow in this section.

In order to check for graphitization at the fracture surface, longitudinal sections intersecting the fracture were taken in regions near the top and bottom of the pipe in locations indicated by arrows A, G, H, and B in figure 3. These sections were taken through the specimens used for the fractographic examination. Low magnification photographs of each of these sections are shown in figures 9 through 12. There was some graphitization at the outside wall surface in each section, and in one section from the top of the pipe (figure 9), the graphitization had penetrated about 40% of the pipe wall thickness adjacent to the fracture. This section was taken through the pipe at the location indicated by arrow A in figure 3 and was through the area of apparent graphitization shown in the fractograph of figure 6. When the SEM sample was sectioned for the metallographic examination, this area of graphitization separated from the pipe. There was, however, very little graphitization along the fracture surface. There was very little graphitization on the fracture surface of the other section from the top of the pipe (figure 10), but there appears to be a substantial secondary crack leading from and parallel to the fracture at the location indicated by the arrow.

In the sections from the bottom of the pipe, graphitization at the outer wall surface in the vicinity of the fracture was not nearly as severe as in the one region near the top shown in figure 9, but graphitization on the fracture surface itself extended across about 2/3 of the pipe wall thickness in both sections. The layer of graphitization on the fracture surface is strong evidence that at least a part-through crack had existed at the bottom of the pipe at the location of the fracture for some time before final failure of the pipe.

3.4 Metallographic Examination

The longitudinal sections that were examined for graphitization were also examined metallographically in order to characterize the

microstructure of the pipe material. There was considerable variation in the microstructure across the pipe wall thickness. The microstructure near the outside wall surface not in a region of graphitization is shown in figure 13. It consisted essentially of type B graphite flakes in a matrix of ferrite with a small amount of steadite (iron-iron phosphide eutectic) in rounded particles[1]. Near the center of the wall thickness, shown in figure 14, the microstructure consisted primarily of type E graphite flakes in a ferrite matrix with steadite at the boundaries of the solidification cells. Adjacent to the inside wall surface, the microstructure consisted primarily of type A graphite flakes in a ferrite matrix with some apparent steadite. A representative example of the microstructure in this region is shown in figure 15. Note that the graphite flake size is much larger near the inside wall surface than in the rest of the material. A representative region of essentially complete graphitization is shown in figure 16.

Unetched fields exhibiting parts of the fracture profile in the sections taken at arrows H and B in figure 3 are shown in figures 17 and 18, respectively. Graphitization at the fracture surface is evident.

3.5 Chemical Analysis

A sample of the pipe material was submitted to a commercial laboratory for chemical analysis. The results of that analysis are as follows:

Element	Weight Percent
Total carbon	3.60
Graphitic carbon	3.25
Manganese	0.39
Phosphorus	0.775
Sulfur	0.080
Silicon	1.86
Nickel	<0.01
Chromium	0.05
Molybdenum	<0.01
Copper	0.19

The chemical composition requirements of proposed ANSI Standard A21.9-1970 for cast iron pipe centrifugally cast in sand lined molds for gas service limit the phosphorus and sulfur contents to 0.90 and 0.12% maximum, respectively. These are the only chemical requirements of this standard, and this cast iron material satisfies them. The standard or specification under which the pipe was produced is not known; ANSI Standard A21.9-70 is quoted only for comparison of the pipe material with that produced in accordance with today's practices. The composition of the material appears to be typical for gray cast iron.

The carbon equivalent [% total carbon + 1/3 (% silicon + % phosphorus)][2] is equal to about 4.5, which indicates that this cast iron is hyper-eutectic. Hypereutectic cast irons usually contain coarse graphite flakes, although this does not appear to be true for this material except near the inside wall surface. These cast irons are generally of lower strength than hypoeutectic cast irons, but they are good for vibration damping applications.

3.6 Hardness Measurements

Hardness measurements were made on the cross section through the pipe shown in figure 8. Brinell measurements were attempted, but the material cracked rather badly when the load was applied. Therefore, Rockwell B (HRB) hardness measurements were made. The material adjacent to the inside wall surface of the pipe was considerably softer than either the material at the center or the material adjacent to the outside wall surface. The hardness near the inside wall surface averaged about HRB 64, whereas the hardness at the center and near the outside wall surface was HRB 84 and 86, respectively. Approximate Brinell equivalent hardness values are 114, 162, and 169, respectively, for material adjacent to the inside wall surface, material at the center, and material adjacent to the outside wall surface. Brinell hardness values of 162 and 169 are typical for ordinary gray cast iron, whereas a Brinell hardness value of 114 is low for ordinary gray cast iron and is more typical for soft gray iron[2].

3.7 Ring Tests

Three ring specimens, each about 2 1/2 inches wide, were machined from the pipe sample. The modulus of rupture was calculated in accordance with ANSI A21.9-1970 from the results of ring tests performed on these specimens. The modulus of rupture values are as follows:

Specimen No.	Modulus of Rupture, psi
1	71,900
2	62,900
3	74,100

The standard requires a minimum of 40,000 psi for the modulus of rupture and is quoted for comparison of the pipe material with today's requirements. Therefore, the results from all three specimens satisfy the requirement of the standard.

3.8 Talbot Tests

Both the modulus of rupture and the secant modulus of elasticity were determined from the results of Talbot tests in accordance with ANSI Standard A21.9-70. Tests were performed on four specimens - one from the top, one from the bottom, and one from each side of the pipe sample as the pipe had been oriented in service. The modulus of rupture and the secant modulus of elasticity results are as follows:

Specimen	Modulus of Rupture, psi	Secant Modulus of Elasticity, psi
Side 1	63,600	7,380,000
Side 2	47,400	12,975,000
Top	61,800	8,790,000
Bottom	34,600	13,875,000

The standard requires a minimum value of 40,000 psi for the modulus of rupture as calculated from the results of the Talbot tests. Therefore, the results from the specimens from both sides and the top satisfy the standard, but the results from the specimen from the bottom failed to meet the minimum requirement of the standard.

Further, the standard states that the secant modulus of elasticity must not exceed 250 times the actual value of the modulus of rupture for any given specimen. The results from the top and side 1 are satisfactory, but the results from side 2 and the bottom exceed the maximum permissible value. Again, the standard is quoted only for comparison of the pipe material with today's requirements.

4. DISCUSSION

This four-inch diameter gray cast iron pipe natural gas main fractured transversely while in service. When the pipe was uncovered, it was found to be cracked from about 1:00 o'clock to 11:00 o'clock, although the fracture was complete when the pipe samples were received at NBS.

When the pipe was received at NBS for examination, there was a considerable amount of corrosion product on the fracture surfaces. Most of the corrosion product was easily removed indicating that corrosion was primarily superficial, and therefore that most of the fracture was rather recent. In a region near the bottom, however, all of the corrosion product was not removed by the cleaning procedure. This region consisted of a thin layer of reddish brown corrosion product over a relatively thin layer of graphitization on the fracture surface. The graphitization extended in about 2/3 of the pipe wall thickness starting at the outside wall surface. Its presence as a thin layer on the fracture surface strongly suggests the existence of at least a part-through crack for some time before final failure of the pipe. A small region at the top was found to be a patch of graphitization.

Failure of the pipe due to the application of bending stresses at a location in the pipe weakened by the presence of the apparent part-through crack, and probably to a much lesser degree by graphitization, is consistent with the observations of this examination. The pipe failed in a brittle manner with cleavage being the primary fracture mode. Although the origin of the fracture crack was not definitely established, it appears very likely that fracture initiated at the apparent pre-existing crack at the bottom of the pipe.

In addition to the graphitization at the fracture, there was some localized graphitization in a cross section slightly removed from the fracture. Also, graphitization appears to have contributed to the rather poor performance of two of the Talbot specimens which will be

discussed later. Although there was graphitization present in the pipe sample, there was a relatively small amount at the outside wall surface at the fracture. Therefore, graphitization does not appear to have been a major factor in the failure of the pipe.

The chemical composition of the pipe material appeared to be typical for gray cast iron. The microstructure of the pipe material varied considerably across the wall thickness - possibly due to a cooling rate gradation across the thickness during the casting process. Hardness was typical for ordinary gray cast iron except adjacent to the inside wall surface where the material was softer than expected for ordinary cast iron.

The modulus of rupture as calculated from the results of ring tests easily satisfied the requirement of the present day standard, ANSI Standard A21.9-70. The modulus of rupture calculated from the Talbot test results satisfied the standard in three out of four cases, and the secant modulus of elasticity satisfied the standard in two out of four cases. An examination of the Talbot specimens after testing indicated that there was significant graphitization at the fractures of the specimens that resulted in values that failed to satisfy the standard.

5. CONCLUSIONS

1. This failed gray cast iron gas main pipe had fractured transversely around about 5/6 of the circumference while in service. (The fracture had been completed before the pipe was submitted to NBS for examination.)

2. There was an apparent part-through transverse crack near the bottom of the pipe in existence before final failure through which the fracture passed.

3. The fracture origin was not definitely established, but is probably associated with the apparent pre-existing crack near the bottom of the pipe.

4. Failure appeared to be due to a bending load applied to the pipe.

5. Except for a small region near the top and a somewhat larger region near the bottom of the pipe, corrosion product on the fracture surface was rather easily removed indicating that most of the fracture was probably recent.

6. The fracture mode was primarily cleavage, which is normal for overload fractures in cast iron.

7. There was some graphitization at the fracture and in other regions of the pipe that were examined, but graphitization does not appear severe enough to have been a major factor in the failure.

8. The chemical composition of the material appeared to be typical for gray cast iron.

9. Except for material adjacent to the inside wall surface of the pipe, hardness was typical for ordinary cast iron. Hardness adjacent to the inside wall surface was lower than expected for ordinary cast iron and is more typical of soft gray iron.

10. There was a considerable variation in microstructure across the wall thickness of the pipe.

11. The modulus of rupture based on the results of ring tests satisfies ANSI Standard A21.9-70.

12. One of four modulus of rupture values and two of four secant modulus of elasticity values based on the results of Talbot tests did not meet today's requirements of ANSI Standard A21.9-70. (ANSI A21.9-70 is quoted for comparison of this pipe with present day requirements.)

6. ACKNOWLEDGEMENT

Leonard C. Smith of the NBS Fracture and Deformation Division performed the metallographic work, prepared the SEM specimens, made the hardness measurements, and assisted in performing the ring and Talbot tests. Joel C. Sauter, also of the NBS Fracture and Deformation Division, and Mr. Smith performed the photographic work.

REFERENCES

1. Metals Handbook, 8th Edition, Volume 7, American Society for Metals, 1972.

2. Gray and Ductile Iron Castings Handbook, Charles F. Walton, Editor, Gray and Ductile Iron Founders' Society, Inc., 1971.

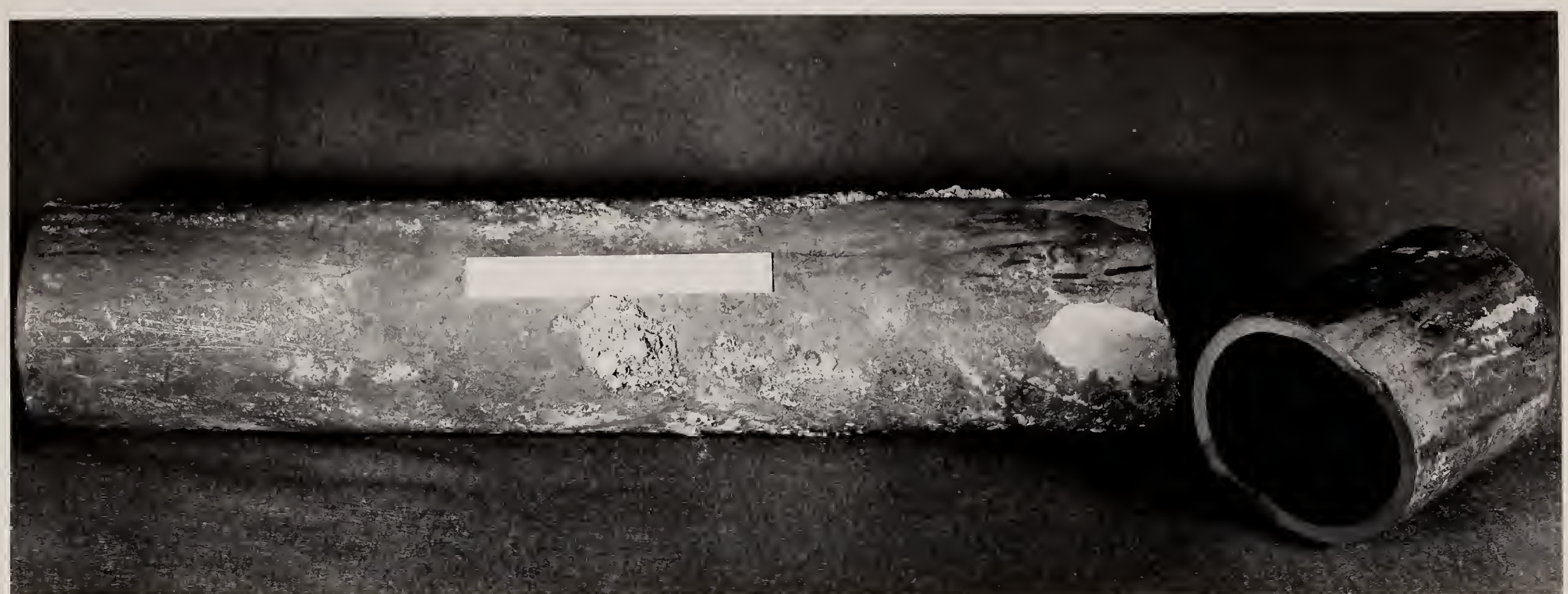

Figure 1. The two pieces of the fractured four-inch diameter cast iron pipe as received at NBS. After documentary photographs were taken, the smaller piece was given to Tim Dunn of Dunn Laboratories, Inc., on March 20, 1980, the same day both pieces were received. The larger piece on the left was retained at NBS for examination.

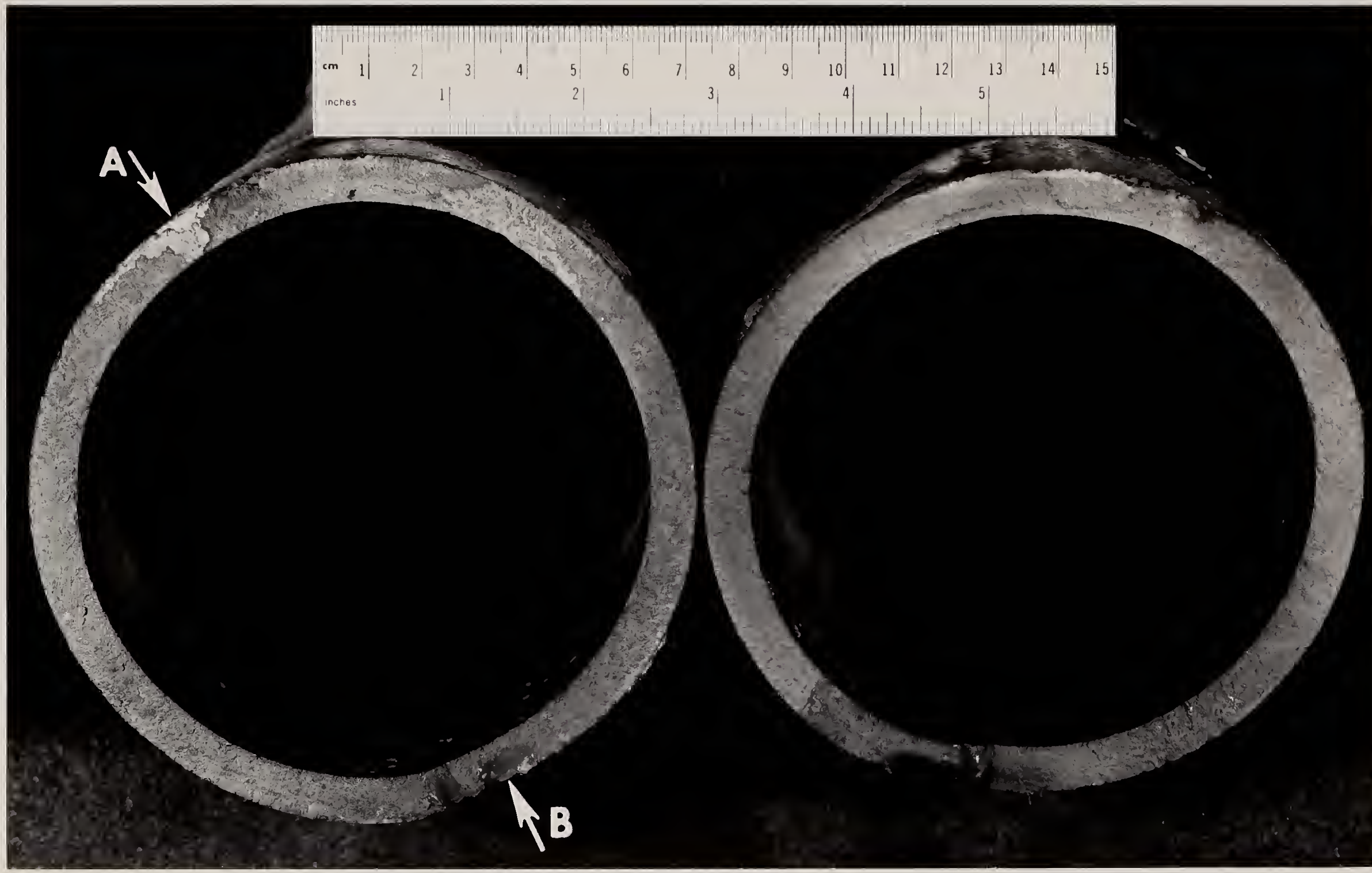

Figure 2. Mating fracture surfaces of the failed pipe as received at NBS. The piece of pipe on the left was retained at NBS for examination. The top of the pipe in the figure corresponds to the top of the pipe as it was oriented in service. The arrows indicate regions of the fracture surface where there is possible graphitization or more severe corrosion than on the rest of the fracture surface.

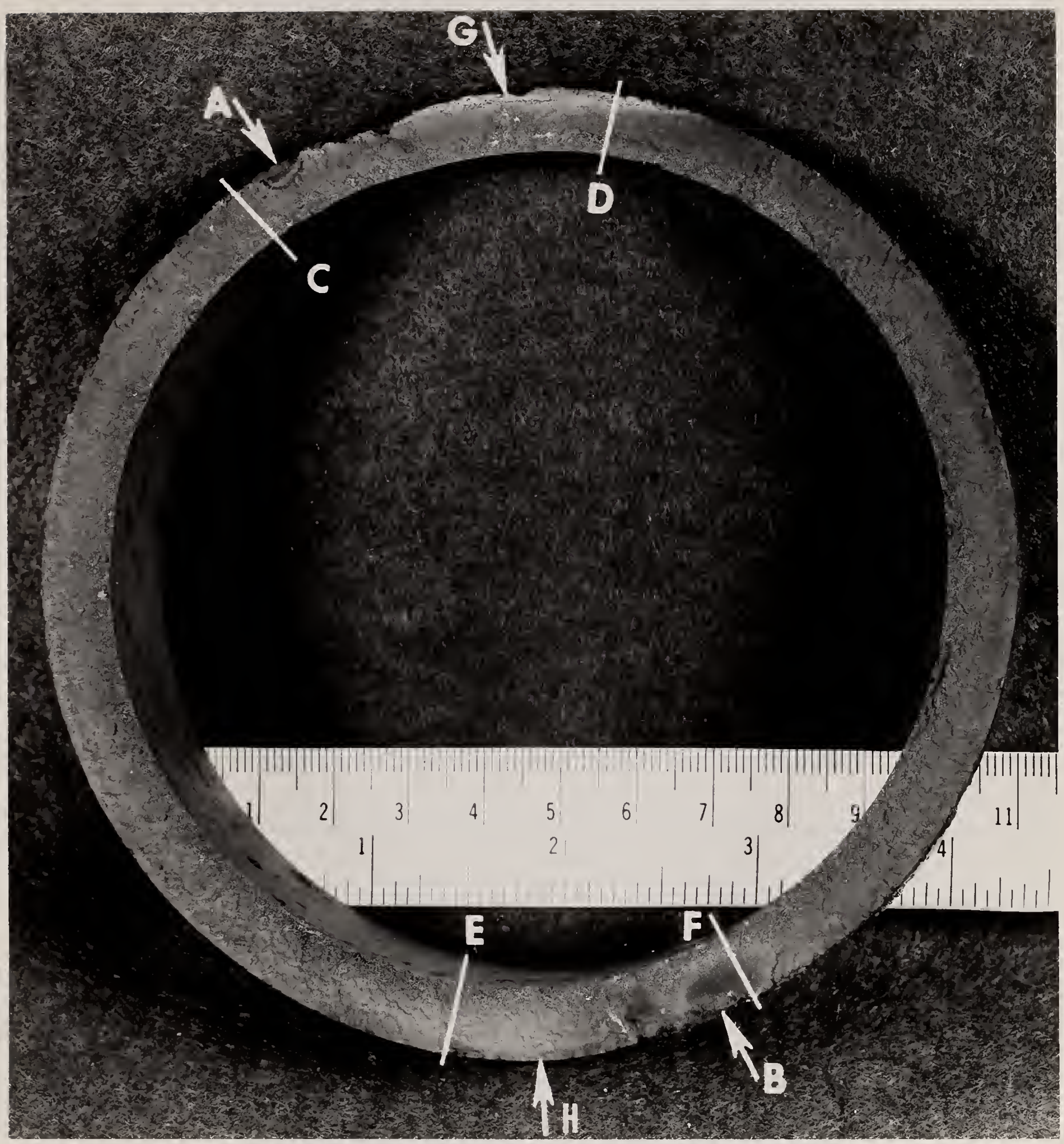

Figure 3. Fracture surface after cleaning with buffered hydrochloric acid. Arrows A and B indicate the same regions as arrows A and B, respectively, in figure 2. The regions between lines C and D and between lines E and F were examined with the SEM. Longitudinal sections for metallographic examination were taken at arrows A, G, H, and B.

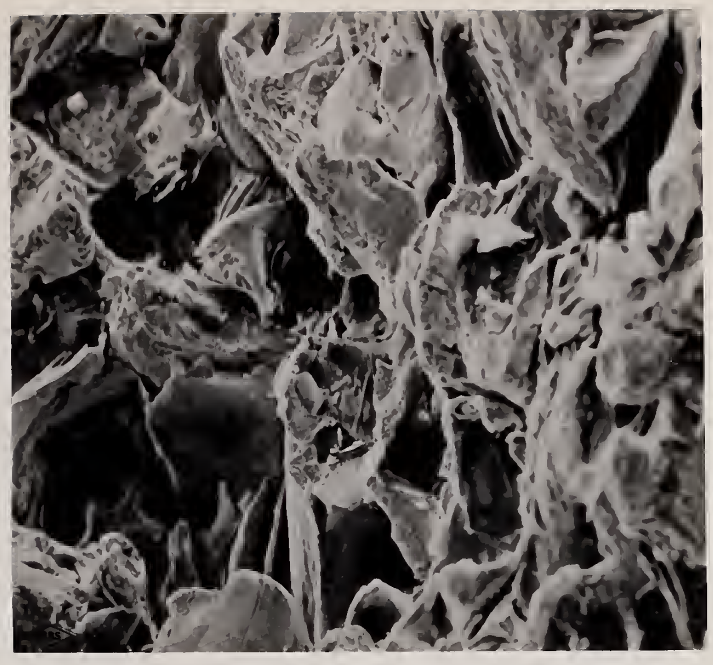

Figure 4. SEM fractograph from the region indicated by arrow B in figure 3 near the inside edge of the fracture. The primary fracture mode is cleavage. X 550

Figure 5. SEM fractograph from the region indicated by arrow G in figure 3. The primary fracture mode is cleavage. X 475

Figure 6. Low magnification SEM fractograph from the region indicated by arrow A in figure 3. A region of graphitization can be seen about to separate from the pipe. X 20

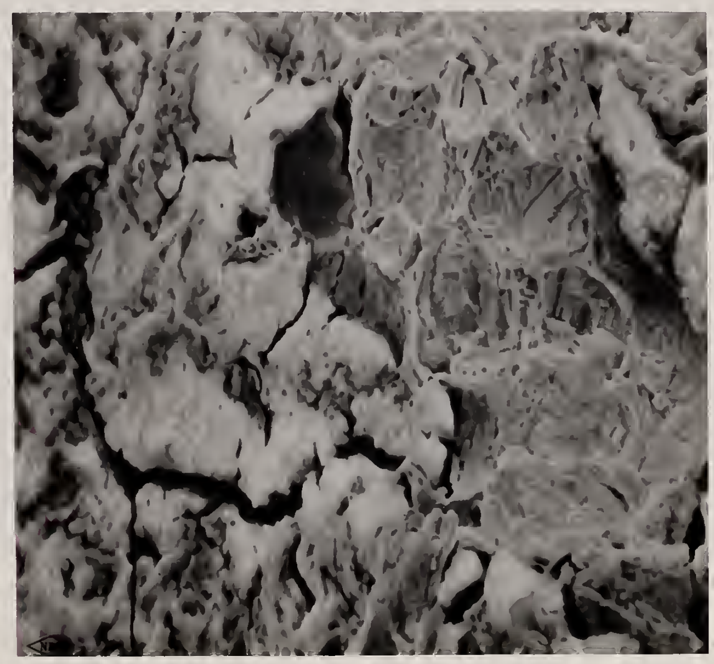

Figure 7. SEM fractograph from the region indicated by arrow B in figure 3 near the outside edge of the pipe. Corrosion product is covering the fracture surface. X 950

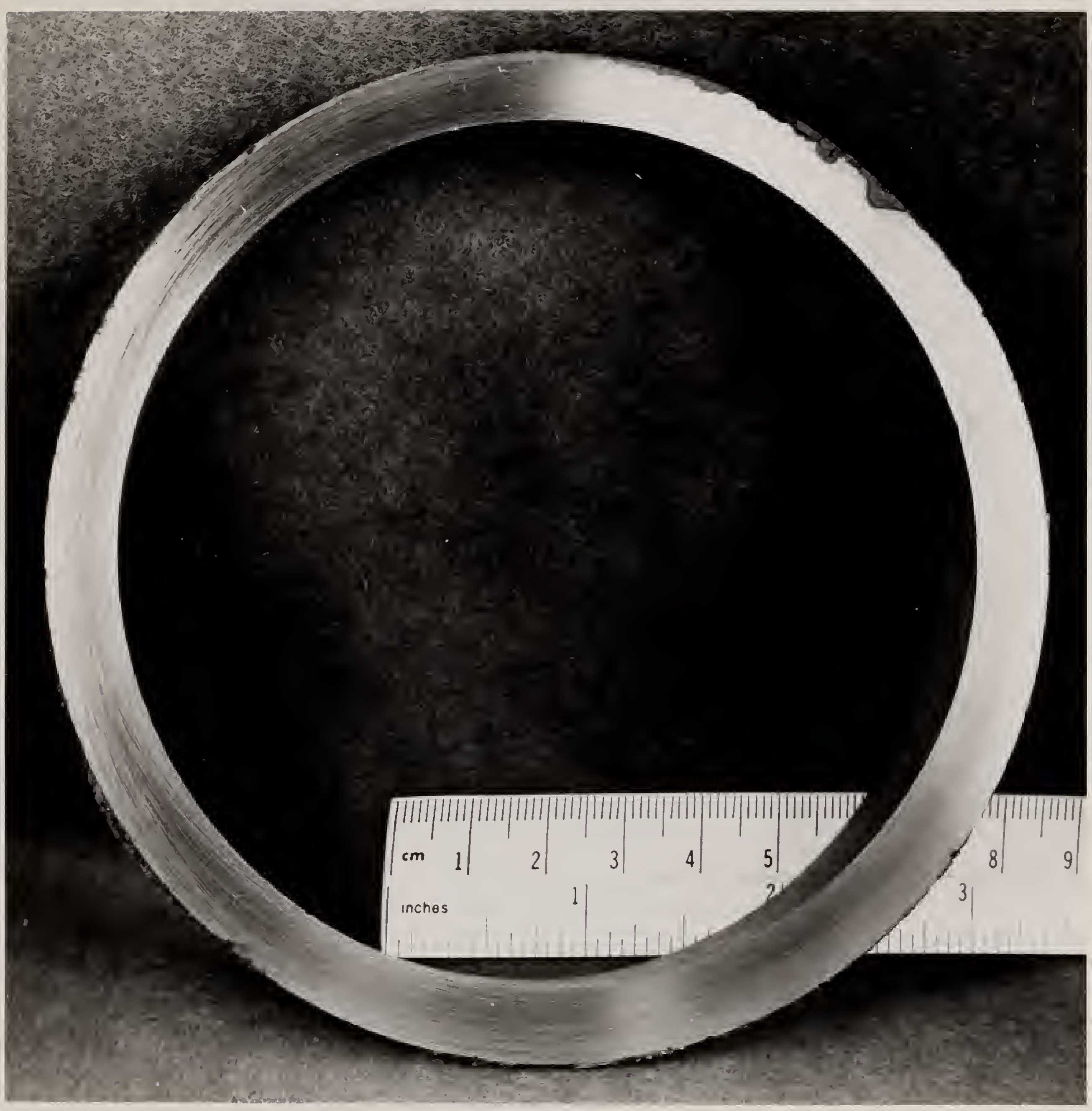

Figure 8. Polished cross section through the pipe sample ranging from about 1/2 to 2 inches from the fracture. Some localized graphitization is evident, especially between 12:00 and 2:00 o'clock. The top of the pipe in the figure corresponds to the top of the pipe as it was oriented in service.

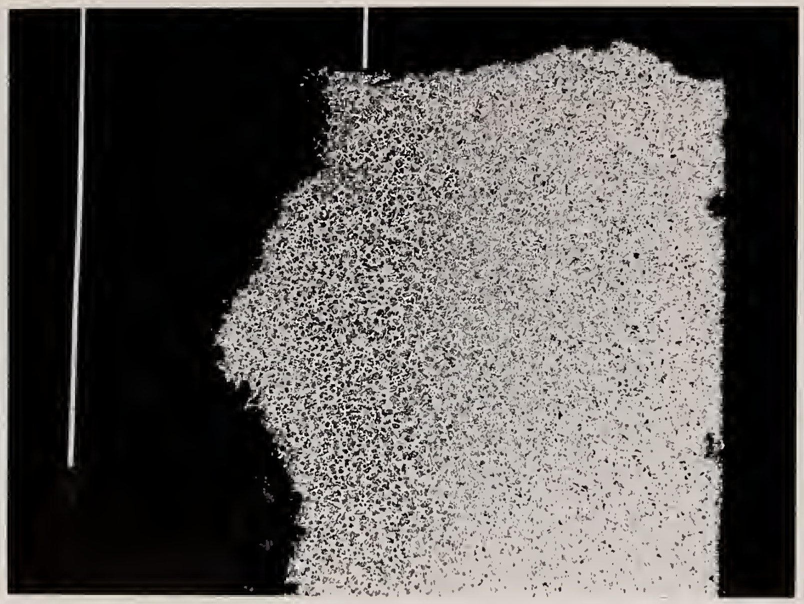

Figure 9. Longitudinal section through the pipe at arrow A, figure 3, showing the fracture profile horizontally at the top. Graphitization at the outside wall surface (vertical at the left) is evident. The inside wall surface is vertical at the right. The vertical line at the far left represents the original outside wall surface. The other vertical line represents the approximate extent of graphitization at the fracture.
Etchant: 1% nital X 10

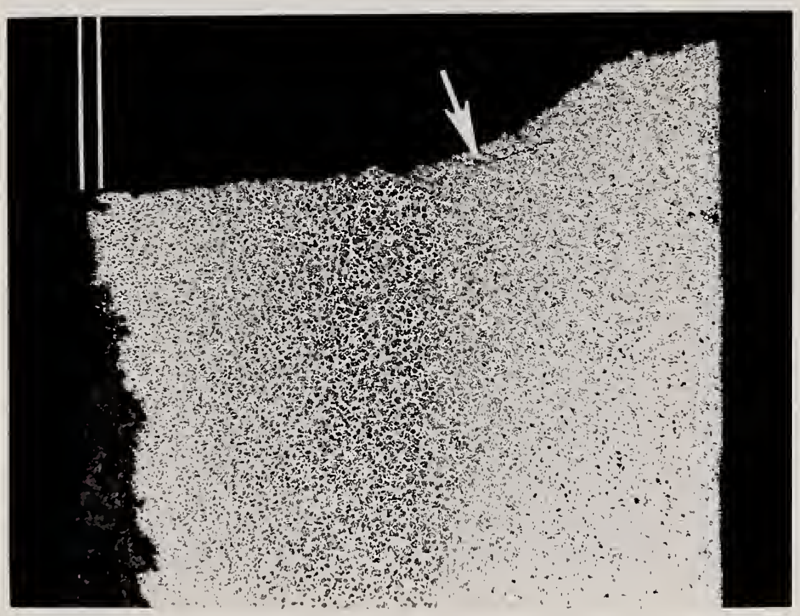

Figure 10. Longitudinal section through the pipe at arrow G, figure 3, showing the fracture profile horizontally at the top. Graphitization at the outside wall surface (vertical at the left) away from the fracture can be seen. The inside wall surface is vertical at the right. The vertical line at the far left represents an extension of the original outside wall surface. The other vertical line represents the approximate depth of graphitization at the fracture. The arrow indicates a secondary crack.
Etchant: 1% nital X 10

Figure 11. Longitudinal section through the pipe at arrow H, figure 3, showing the fracture profile horizontally at the top. The outside wall surface is vertical at the left and the inside wall surface is vertical at the right. Graphitization at the fracture surface is evident. The vertical line at the far left represents an extension of the original outside wall surface. The other vertical line represents the approximate depth of graphitization at the fracture.
Etchant: 1% nital X 10

Figure 12. Longitudinal section through the pipe at arrow B, figure 3, showing the fracture profile horizontally at the top. Graphitization is evident both on part of the fracture surface and at the outside wall surface (vertical at the left). The inside wall surface is vertical at the right. The vertical line at the far left represents an extension of the original outside wall surface. The other vertical line represents the approximate depth of graphitization at the fracture.
Etchant: 1% nital X 10

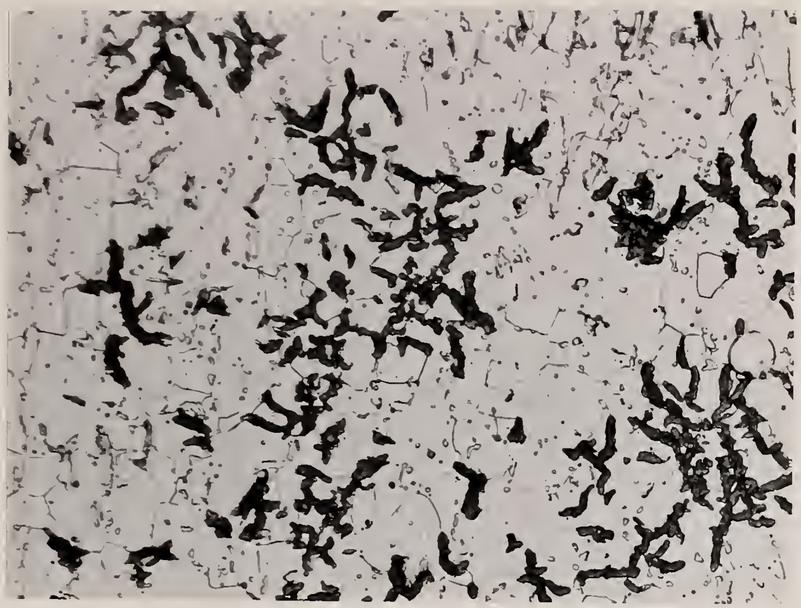

Figure 13. Longitudinal section through the pipe wall showing the representative microstructure of the material near the outside wall surface. The microstructure consists primarily of type B graphite flakes in the ferrite matrix. There are some rounded particles of apparent steadite (iron-iron phosphide eutectic).
Etchant: 1% nital X 500

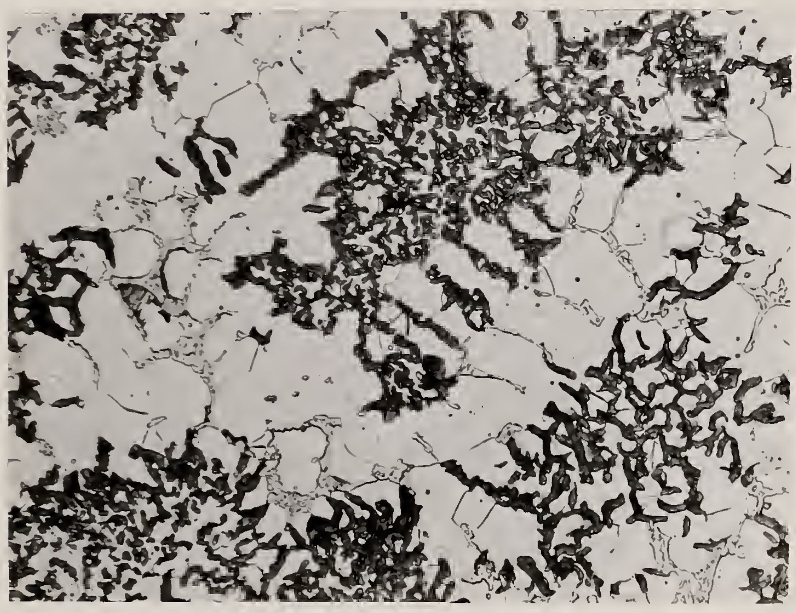

Figure 14. Longitudinal section through the pipe wall showing the representative microstructure of the material near the midthickness of the wall. The microstructure consists primarily of type E graphite flakes in a ferrite matrix. There is a small amount of what appears to be steadite (iron-iron phosphide eutectic) present in interdendritic patches.
Etchant: 1% nital X 500

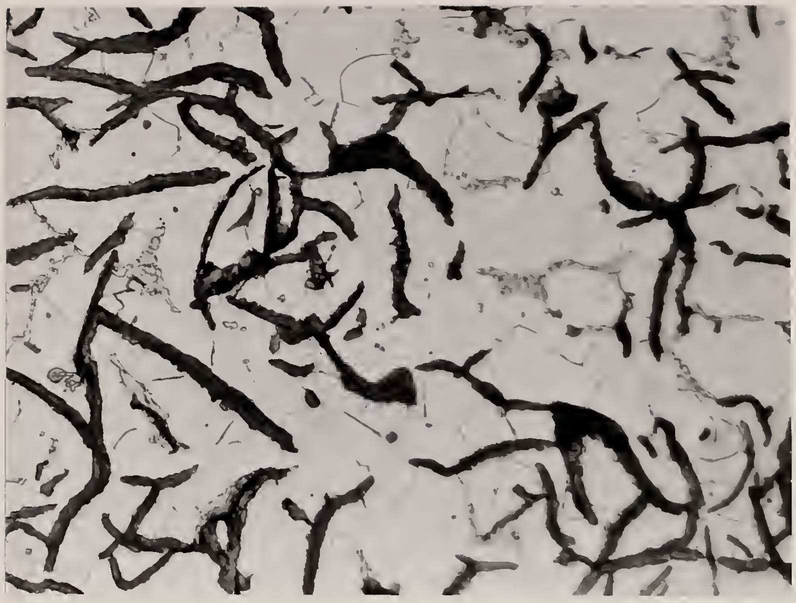

Figure 15. Longitudinal section through the pipe wall showing the representative microstructure of the material near the inside wall surface. The microstructure consists primarily of type A graphite flakes in a ferrite matrix. There are some patches which appear to be steadite (iron-iron phosphide eutectic).
Etchant: 1% nital X 500

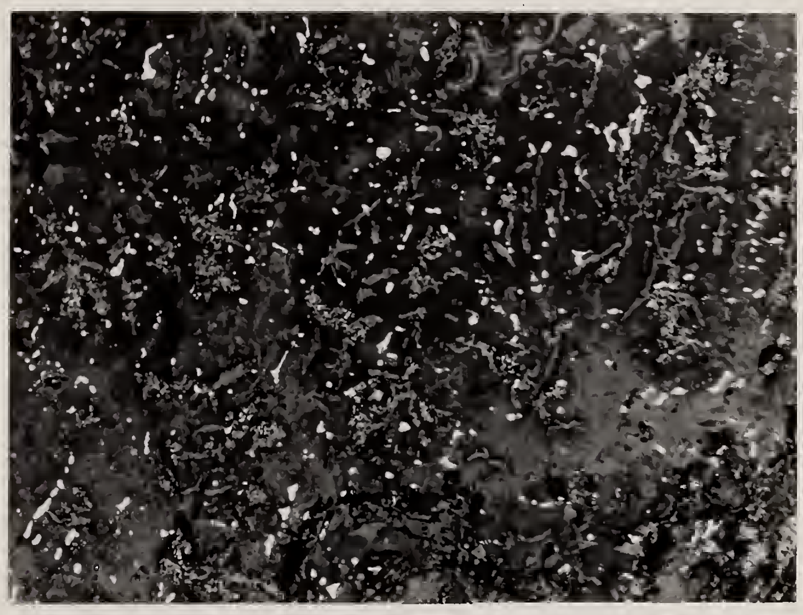

Figure 16. Longitudinal section through the pipe wall showing a representative field of essentially total graphitization.
Etchant: 1% nital X 500

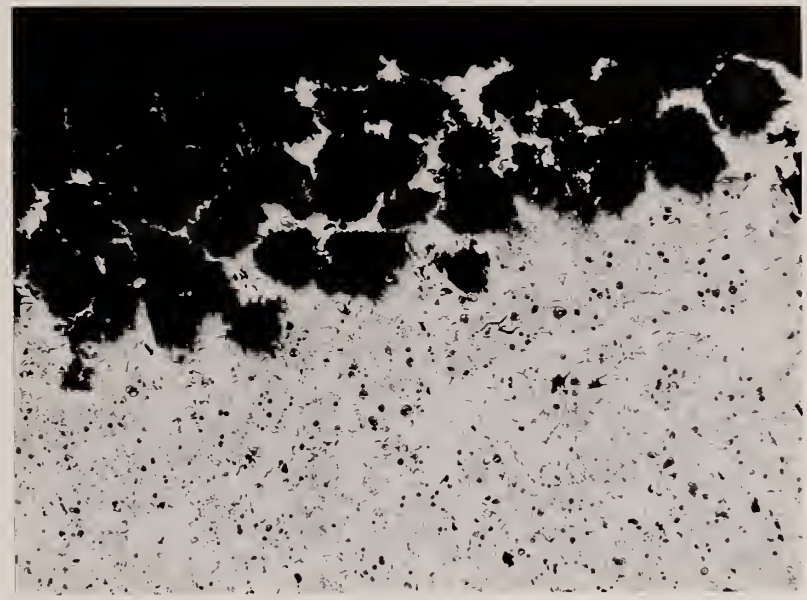

Figure 17. Longitudinal section through the pipe wall at arrow H, figure 3, showing the fracture profile horizontally at the top. Graphitization at the fracture surface can be seen.
As polished X 100

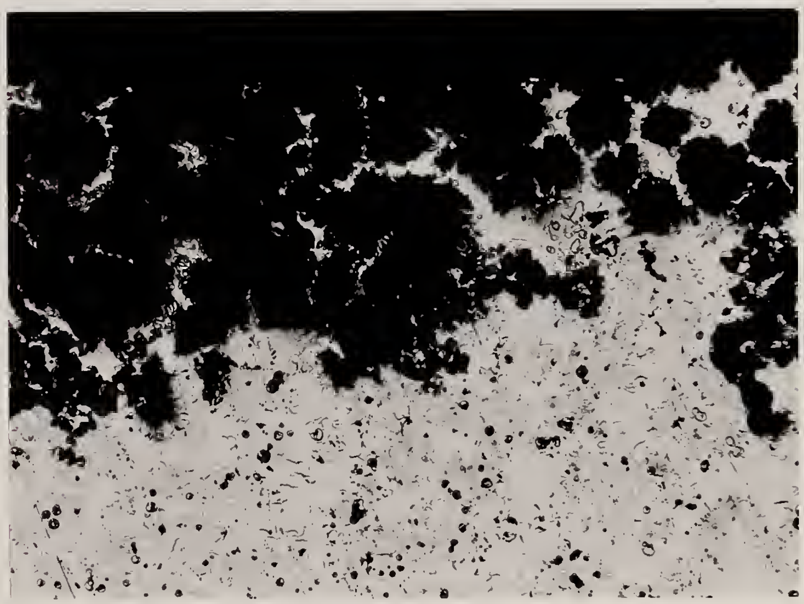

Figure 18. Longitudinal section through the pipe wall at arrow B, figure 3, showing the fracture profile horizontally at the top. Graphitization at the fracture can be seen.
As polished X 100

FAILURE ANALYSIS REPORT REVIEW ROUTING SLIP

Title: Examination of Failed Four-Inch Diameter Cast Iron Pipe Natural Gas Main, Fort Payne, Alabama

Author: T. Robert Shives

Sponsoring Agency: NTSB

FROM:	INITIAL & DATE SENT	TO:	INITIAL & DATE REC'D
T. R. Shives	[illegible]	J. H. Smith	
[illegible]	[illegible]	[illegible]	[illegible] 9-18-80
J. G. Early	JG	T. R. Shives	[illegible] 10/3
[illegible]		B. W. Christ [illegible]	

APPROVAL	DATE AND INITIAL
SECTION CHIEF	JGE [illegible]
DIVISION CHIEF	
LEGAL OFFICE	[illegible]

OCT 3 0 1980

NATIONAL BUREAU OF STANDARDS

February 4, 1981

Memorandum to Author : T. Robert Shives
(Through Center Office)

From: R.F. Blunt, Executive Secretary
Washington Editorial Review Board

Subject: WERB Approval of NBSIR Manuscript

Your manuscript

Shives, T.R.
Examination of Failed Four-Inch Diameter Cast Iron Pipe Natural
Gas Main, Fort Payne, Alabama
NBSIR 80- (NTSB)(R)

NBSIR number & sponsor: NBSIR 81-2211 (NTSB)(R)

has been approved and/or noted by the Washington Editorial Review Board for issuance as an NBS Interagency/Internal Report. (See the January 16, 1973 revision of Section 5 of the NBS Manual for Scientific and Technical Communications.)

Any required security or sponsoring agency release should be obtained by your division in advance of reproduction.

If this report is to be reproduced by NBS, arrangements are to be made by the originating organization directly with Printing and Duplicating. Printing and Duplicating will supply the Technical Information and Publication Division (TIPD) with required number of copies for appropriate internal NBS distribution. If the report is for unlimited distribution TIPD will arrange for input to NTIS.

NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO.	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE	5. Publication Date
EXAMINATION OF FAILED FOUR-INCH DIAMETER CAST IRON PIPE NATURAL GAS MAIN, FORT PAYNE, ALABAMA	6. Performing Organization Code
7. AUTHOR(S) T. Robert Shives	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, DC 20234	10. Project/Task/Work Unit No. 11. Contract/Grant No. No. 5640-42
12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)* National Transportation Safety Board Washington, D.C. 20594	13. Type of Report & Period Covered Failure Analysis 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

At the request of the National Transportation Safety Board, the Fracture and Deformation Division of the National Bureau of Standards performed an examination of a fractured four-inch diameter cast iron pipe natural gas main from Fort Payne, Alabama. An explosion and fire reportedly occurred in an apartment building at the location of the failure on November 17, 1979.

The pipe had suffered a transverse fracture. Only one of the fracture faces was examined at the National Bureau of Standards. Most of the corrosion product on the fracture surface was rather easily removed indicating the likelihood that most of the fracture was recent. There was some graphitization on the fracture surface in a region near the bottom of the pipe suggesting the existence of at least a part-through crack before the time of the final failure. Failure appeared to be due to the application of a bending load at the location of the apparent pre-existing crack.

In addition to the graphitization observed at the fracture, some graphitization was found in other regions of the submitted pipe. Graphitization, however, does not appear to have been a major contributing factor to the failure.

The chemical composition of the pipe material was typical for gray cast iron. Except for material adjacent to the inside wall surface of the pipe, the hardness was typical for ordinary gray cast iron.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Brittle fracture; cast iron; cast iron gas pipe; cleavage; graphitization

18. AVAILABILITY ☐ Unlimited	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PRINTED PAGES
☒ For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	
☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003-	20. SECURITY CLASS (THIS PAGE)	22. Price
☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161	UNCLASSIFIED	

USCOMM-DC