NBSIR 77-1292 R

Examination of Failed Six Inch Cast Iron Pipe Natural Gas Main, Public Service Electric and Gas Company, Fairview, New Jersey

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Mechanical Properties Section
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Failure Analysis Report

Prepared for
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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, ***Secretary***

Dr. Sidney Harman, ***Under Secretary***

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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Acting Director***

TABLE OF CONTENTS

SUMMARY

The submitted six inch diameter cast iron pipe in service as a natural gas main had fractured transversely. The transverse fracture and the very low operating pressure in the pipeline, (0.25 psig) indicate that failure was not caused by hoop stresses due to internal gas pressure. Therefore, failure was probably caused by stresses from an unknown external source, although there was no distinct evidence of mechanical damage to the pipe.

Parts of the fracture surfaces at the top and bottom of the pipe were covered with a poorly adherent deposit that had the feel of oily soil. There were jogs in the fracture path at both the top and bottom of the pipe. There was no fractographic evidence to indicate the location of the fracture initiation site.

One region of graphitization of the pipe material was found at the fracture surface near the bottom of the pipe. The maximum penetration of the graphitization was about three-fourths of the pipe wall thickness. It was not possible to draw any conclusions on the relation between the fracture and this graphitized region.

The microstructure of the material appeared to be satisfactory except for a large amount of steadite (iron-iron phosphide eutectic). The chemical composition appeared to be satisfactory except for a rather high phosphorus content.

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1. INTRODUCTION

1.1 Reference

National Transportation Safety Board, Washington, D.C. 20594. This investigation was conducted at the request of Mr. Richard G. Marini, Pipeline Safety Specialist, National Transportation Safety Board (NTSB). The requesting letter was dated April 12, 1977.

1.2 Parts Submitted

Two pieces of the failed six inch diameter cast iron pipe were submitted to the NBS Mechanical Properties Section for examination. The nominal wall thickness was 3/8-inch. Each piece contained one of the two mating fracture faces. The two pieces, designated E and W before being received at NBS, measured approximately 9 1/2 and 9 inches, respectively, in length. The piece designated W was used for most of this examination. The piece designated E was not cleaned or sectioned. Both pieces were marked before being submitted to NBS to indicate the top of the pipe as it had been oriented in service. The parts are shown in figure 1 as they were received at NBS.

It was reported by the NTSB that the operating pressure in the pipeline was 0.25 psig.

2. PURPOSE

The National Transportation Safety Board requested the NBS Mechanical Properties Section to examine the submitted failed pipe and perform a visual examination, chemical analysis, metallographic examination, determination of depth of graphitization, and determination of the location of the fracture origin.

3. RESULTS OF ANALYSES AND EXAMINATIONS

3.1 Visual Examination

The submitted pipe had fractured transversely. The outside surface of the pipe had apparently been cleaned for a length of about six to seven inches on either side of the fracture before being submitted to NBS. About four to five inches of the cleaned surface on either side of and adjacent to the fracture exhibited bare metal with essentially no corrosion product or other deposit. The remainder of the apparently cleaned surfaces were coated with what appeared to be superficial general corrosion with patches of a black, tarry deposit adjacent to the regions of bare metal. Beyond the cleaned regions, the pipe was covered with what appeared to be relatively tightly adhering soil deposits. There was no evidence of mechanical damage.

There was a dark gray deposit on the inside of the pipe at the bottom. Otherwise, the inside of the pipe appeared to be relatively clean with little corrosion.

There were slight jogs in the fracture path at both the top and bottom of the pipe as it reportedly had been oriented in service. The mating fracture surfaces can be seen in figure 1. The jogs are indicated in the figure by arrows.

Similar regions of both of the mating fracture surfaces were covered with what appeared to be an oily soil deposit. The deposit covered about an 80° length of the fracture at the top and about a 60° length at the bottom. The fracture surface on the piece of pipe labeled W was cleaned ultrasonically with detergent and water. Most of the deposit was removed in a short time. Some of the deposit near the top was not removed, but that which remained still appeared to be oily soil.

Cleaning revealed the features over most of the fracture surface. There was, however, no fractographic evidence revealed to indicate the site of fracture initiation.

The fracture surface designated W is shown before and after cleaning in figures 2 and 3, respectively. The cleaning operation revealed one region of graphitization at the fracture near the bottom of the pipe (dark region indicated by the arrow in figure 3). The dark appearing regions near the top of the pipe are areas where the oily deposit had not been removed during the cleaning procedure.

A transverse section was taken through the length of pipe designated W about one inch from the fracture. As shown in figure 4, no evidence of graphitization was found at that section location. There was, however, a small amount of porosity in that section in the region indicated by the arrow.

3.2 Metallographic Examination

A longitudinal section intersecting the fracture at the location of the deepest penetration of graphitization was taken through the pipe. This section is shown in figure 5. The fracture profile is vertical at the right in the figure. At the location of maximum depth, graphitization had penetrated about 75% of the wall thickness of the pipe. A gradient of graphitization was found across the pipe wall, with the most severe graphitization at the outside.

The unetched microstructure in a partially graphitized region is shown in figure 6. The very dark areas have become graphitized, whereas the light regions have not. The dark gray thin particles are graphite flakes.

A photomicrograph showing the representative etched microstructure of the pipe material away from the region of graphitization appears in figure 7. The microstructure consists of graphite flakes (thin dark particles), pearlite (fingerprint and gray regions), cementite (light areas), and steadite -- iron-iron phosphide eutectic (small rounded particles).

3.3 Chemical Analysis

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

Element	Weight Percent
Total carbon	3.79
Combined carbon	1.29
Manganese	0.77
Phosphorus	0.960
Sulfur	0.074
Silicon	1.63
Nickel	<0.01
Chromium	0.04
Molybdenum	0.01
Copper	0.07

4. DISCUSSION

The submitted six inch diameter cast iron pipe had completely fractured transversely. Because of the low operating pressure of the pipeline (0.25 psig) it would appear likely that failure occurred as a result of stresses from an external source and not from stresses generated internally. There was one region of graphitization at the fracture near the bottom of the pipe. Maximum penetration of graphitization was about 75% of the approximately 3/8 inch wall thickness. The graphitization was most severe at the outside surface of the pipe and became less severe with distance from the outside surface.

There was no fractographic evidence to indicate the probable initiation site of the fracture.

The chemical composition of the pipe material appears to be satisfactory except for a high phosphorus content. A phosphorus content above about 0.50% is undesirable since it may lead to the formation of excessive steadite, a brittle phase consisting of iron-iron phosphide eutectic[1]. Indeed, the microstructure appeared to be satisfactory where there was no graphitization.

5. CONCLUSIONS

1. The transverse fracture and the low operating pressure in the pipe indicated that failure probably occurred as a result of stresses from an external source.

2. The fracture initiation site could not be determined from the available evidence.

3. There was one region of graphitization at the fracture location. Maximum penetration of graphitization from the outside wall was about 75% of the pipe wall thickness. It was not possible to draw any conclusions on the relation between the fracture and the graphitized region.

4. The pipe material had a high phosphorus content; otherwise, the chemical composition appeared to be satisfactory.

5. The microstructure of the pipe material was satisfactory except for an excessive amount of steadite.

6. ACKNOWLEDGEMENT

The metallographic work was performed by Leonard C. Smith of the NBS Mechanical Properties Section. The photographic work was performed by Mr. Smith and Todd Eudy, also of the NBS Mechanical Properties Section.

REFERENCE

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

Figure 1. The two pieces of pipe showing the fracture surfaces as received at NBS from the NTSB. The piece labeled E is at the left and the piece labeled W is at the right. Arrows indicate jogs in the fracture path near the top and bottom of the pipe. X 1/2

Figure 2. Fracture surface designated W as received at NBS. The top of the pipe, as marked before the pipe was sent to NBS, is at the top in the photograph. X 1

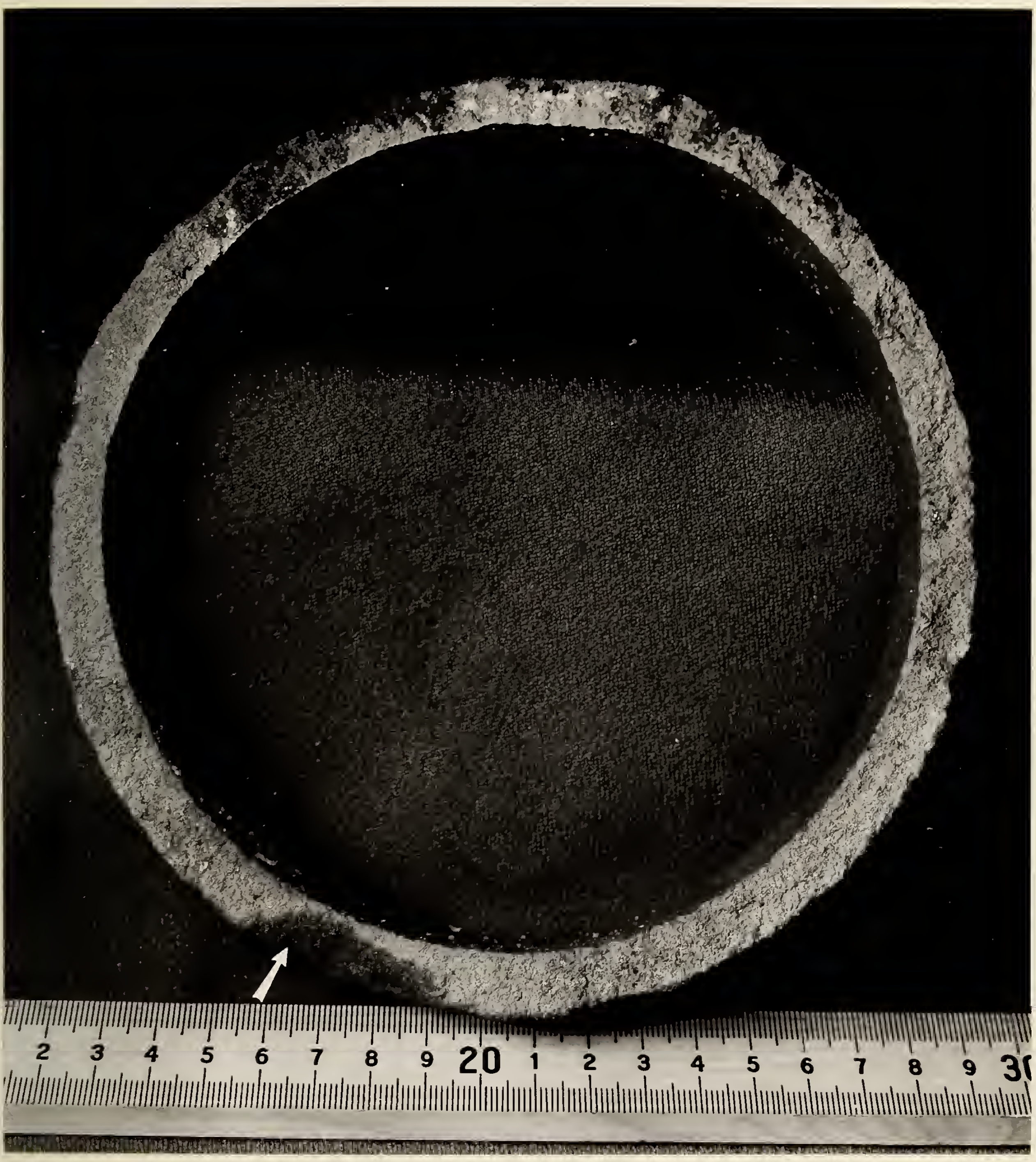

Figure 3. Fracture surface designated W after ultrasonic cleaning. The designated top of the pipe is at the top in the photograph. The arrow indicates the region of graphitization near the bottom of the fracture. The dark regions near the top are deposits that were not removed by the cleaning procedure. X 1

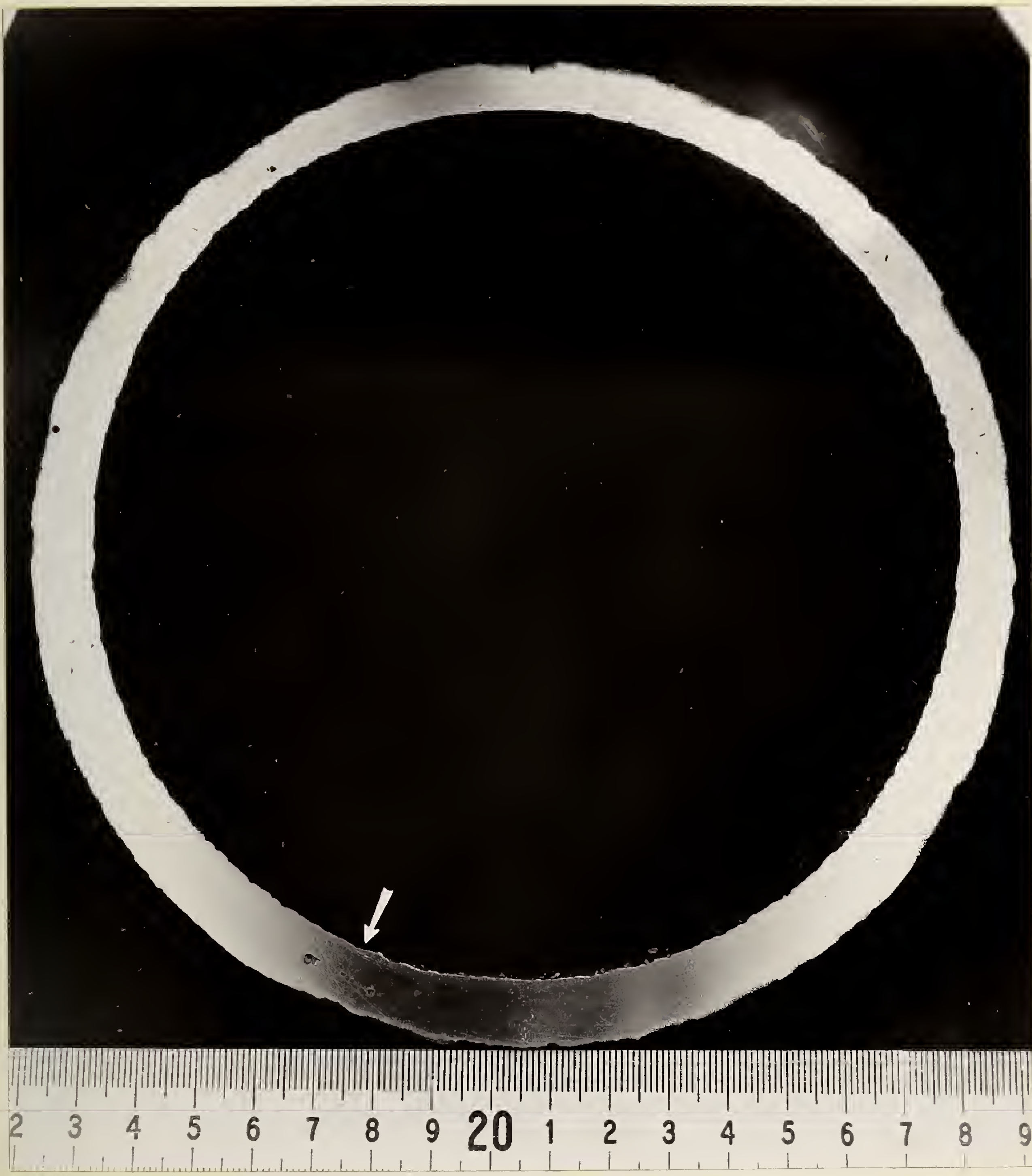

Figure 4. Transverse section through the piece of pipe designated W one inch from the fracture. The top of the pipe is at the top of the photograph. (The notch appearing at the top was put in with a file in order to identify the orientation.) The arrow indicates a region of porosity. X 1

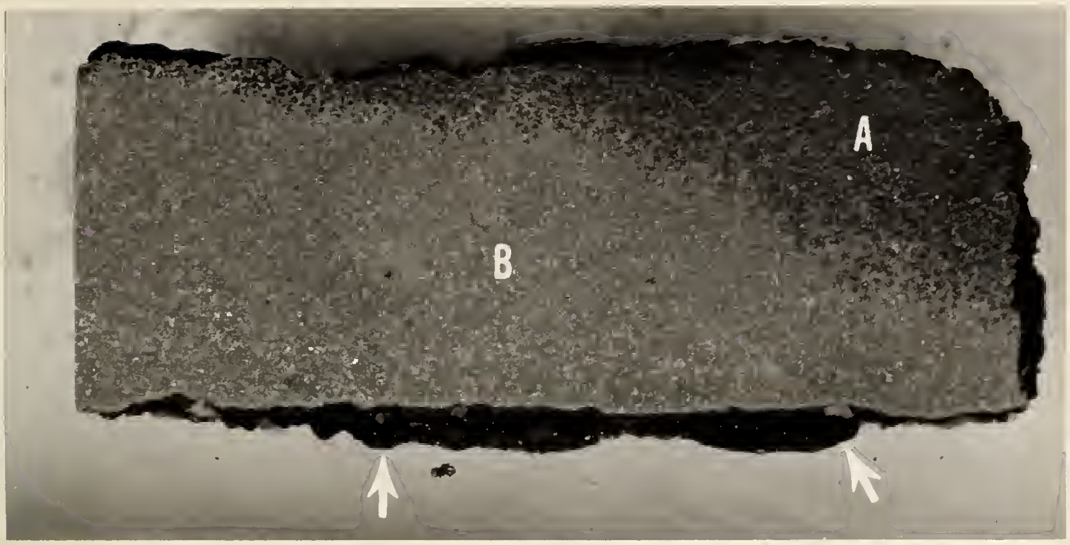

Figure 5. Longitudinal section through pipe intersecting fracture at location of deepest penetration of graphitization. Fracture profile is vertical at the right. The outside surface of the pipe is horizontal at the top. Region A has been graphitized, whereas region B has not. The very dark areas indicated by arrows are deposits on the inside surface of the pipe.
Etchant: 1% nital X 4

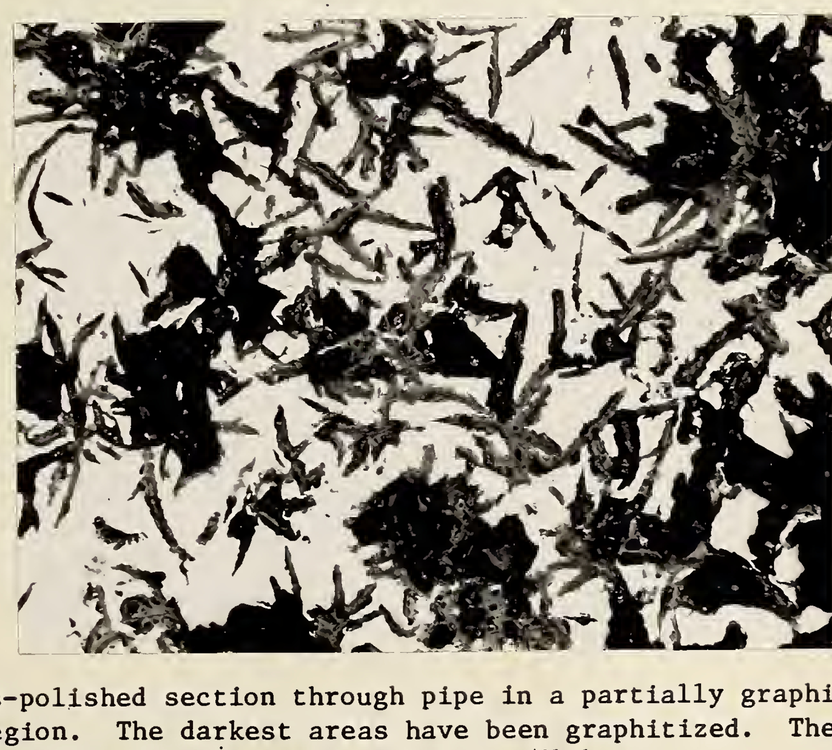

Figure 6. As-polished section through pipe in a partially graphitized region. The darkest areas have been graphitized. The light gray thin areas are graphite flakes.
Unetched X 100

Figure 7. Representative microstructure of the pipe material in an area that has not been graphitized. The thin, dark particles are graphite flakes. White areas are cementite. Fingerprint areas and gray areas are pearlite. Small rounded particles are steadite (iron-iron phosphied eutectic).
Etchant: 1% nital X 500

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15. SUPPLEMENTARY NOTES

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.)*

The submitted six inch diameter cast iron pipe in service as a natural gas main had fractured transversely. The transverse fracture and the very low operating pressure in the pipeline, (0.25 psig) indicate that failure was not caused by hoop stresses due to internal gas pressure. Therefore, failure was probably caused by stresses from an unknown external source, although there was no distinct evidence of mechanical damage to the pipe.

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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 pipe; graphitization.

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Analysis of Housing Data Collected in A Lead-Based Paint Survey in Pittsburgh, Pennsylvania -- Part II

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