National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594

PLD24FR003

MATERIALS LABORATORY

Factual Report 24-023

October 9, 2024

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A. ACCIDENT INFORMATION

Location:	Jackson, Mississippi
Date:	January 24, 2024 (Location 1) January 27, 2024 (Location 2)
Vehicle:	Atmos Energy Corporation Residential Gas Distribution System
Investigator:	Sara Lyons (RPH-21)[1]

B. COMPONENTS EXAMINED

Items were submitted from 2 accident locations in Jackson, MS.[2]

Items from Location 1:

190 Bristol Blvd: Excavated main and tap assembly (2 inch main, Mueller tapping tee, Dresser ¾ inch Style 90 Ell Connector, ¾ inch nipple pipe, Dresser 5 inch Style 90 straight coupling) and separated ¾ inch service pipe, water service pipe from in front of address.

185 Bristol Blvd: Housing and diaphragm from gas meter (these pieces were submitted by field investigators as originating from Location 1).

Items from Location 2:

1147 Shalimar Dr: Excavated main and tap assembly (2 inch main, Mueller tapping tee, Dresser ¾ inch Style 90 Ell Connector, ¾ inch service pipe).

C. EXAMINATION PARTICIPANTS

Materials Engineer	Brian Fuchs, Ph.D. NTSB Washington, D.C.
Sr. Metallurgist	Frank Zakar NTSB Washington, D.C.
Engineering Technician	Ed Komarnicki NTSB Washington, D.C.
Investigator-In-Charge	Sara Lyons NTSB

[1] Ashely Horton (RPH-21) was investigator-in-charge at the on-site phase of the investigation. Sara Lyons was interim investigator-in-charge post on-site phase of the accident investigation.

[2] Accident locations described in detail in the NTSB Pipeline Operations Group Chair's Factual Report.

	Washington, D.C.
Party coordinator	Jennnifer Ries Atmos Energy Dallas, Texas
Technical Expert	Greg Smith Atmos Energy Dallas, Texas
Product Engineer	Michael Zampogna Dresser Utility Solutions Bradford, PA
Party Coordinator	Rickey Cotton Mississippi Public Safety Commission (MS PSC) Jackson, MS

D. DETAILS OF THE EXAMINATION

1.0 INITIAL EXAMINATION

1.1 Location 1

Figures 1 and 2 show photographs of the as-received main, tee, and service pipe from Location 1. The excavated gas line components from 190 Bristol Dr were submitted in two pieces. The larger piece consisted of a 2-inch iron pipe size (IPS) steel main, Mueller service tee, a Dresser ¾-inch Style 90 Ell connector, a short section (less than 6 inch visible) of ¾-inch steel nipple, and a Dresser 5-inch Style 90 straight coupling. The couplings and tee[3] were identified by stamped markings on the pieces. The main was coated by a hard black material. The straight coupling, service pipe, ell, tapping tee, and the main around the tapping tee were covered in a black tape. The tape in some areas was loose and peeling away from the assembly. A black, viscous substance was visible on some areas not covered by tape. Several areas of the service pipe showed evidence of exposed metal. Black and brown corrosion products were visible on areas where the bare metal was exposed. There was no evidence that the corrosion had penetrated through the pipe walls.[4]

At the exposed downstream end of the straight coupling, a rubber gasket was visible inside the end nut (Figure 3), lining the opening. Per instructions from

[3] The base of the tee was welded to the gas main.
[4] The corrosion products for all the parts discussed in this report were superficial (on the surface) regardless of the color and location.

Dresser,[5] the service pipe is inserted into this hole during installation. The nut is then tightened down, forcing the rubber gasket to compress onto the pipe and forming a gastight seal. Dried clay and brown corrosion product were found on the gasket except for one small area that exposed the black surface of the gasket, as shown in Figure 3.

A section of ¾-inch gas service pipe (measured 0.789 inch inner diameter, 1.040 inch outer diameter) was also submitted for examination. The service pipe was originally joined to the straight coupling,[6] but was not attached to the main and tee assembly when received by the NTSB Materials Laboratory. The service pipe piece was approximately 29 inch long. Loose black tape was wrapped around an approximately 4-inch section at one end of the pipe piece. The texture and width of the tape was consistent with that of the tape on the main and tee assembly. The taped end was determined to be the end that had been inserted into the straight coupling prior to the separation.[7] The ends of the pipes will be referred to as "upstream" and "downstream" in accordance with the flow of gas while in use. Most of the remainder of the pipe had a hard black coating approximately 0.06 inch thick, similar to the coating on the main. Sections of this coating were missing, exposing bare metal. The pipe was washed with water and a soft bristle brush and the extent of this coating damage is documented in Table 1. The exposed material was analyzed with a handheld Olympus Vanta, Series C, handheld X-ray fluorescence (XRF) alloy analyzer.[8] The general composition indicated by the alloy analyzer was consistent with a low-carbon steel (in general, 97.6 wt% Fe, 1.6 wt% Si, 0.5 wt% Mn).

[5] Dresser's historic published installation instructions can be seen in Section 4.5 of the NTSB Pipeline Operations Group Chair's Factual Report.
[6] NTSB Pipeline Operations Group Chair's Factual Report, Section 3.1.2.1.
[7] NTSB Pipeline Operations Group Chair's Factual Report, Figures 14-15.
[8] In X-Ray Fluorescence, a surface is irradiated with high-energy x-rays. Atoms in the surface material then emit fluorescent x-rays that are analyzed and used to identify the elements. The relative strength of the fluorescent x-rays gives the relative weight percent (wt%) of elements in the surface.

Table 1. Location of exposed bare metal areas found on the outer surface of the 28-inch cut service pipe to 190 Bristol Blvd.

Distance from upstream end (Coupling Side)	Calculated Length (inch)	Clock Position[9] Looking Downstream	Measured Width (inch)
0.0 – 4.5	4.5	All Around	---
6.3 – 6.6	0.3	4:30 - 5:30	0.2
6.5 – 7.5	1.0	5:30 - 8:00	0.6
9.0 – 11.0	2.0	10:00 - 3:00	1.0
9.0 – 9.3	0.3	5:00 - 5:30	0.4
11.5 – 13.2	1.7	6:30 – 10:00	0.8
14.0 – 19.0	5.0	12:00 - 6:00	1.3
20.0 – 22.0	2.0	8:00 – 11:30	0.9
23.5 – 25.3	1.8	7:00 – 9:00	0.7

The service pipe was bent approximately 13 inches from the upstream end. The upstream end of the pipe was bent up relative to the downstream. The pipe was straight on both sides of the bend, as observed by placing rulers under the straight segments of the pipe (Figure 4). The upstream end was displaced laterally from the straight-line projection of the downstream end by 1.75 inch.

A section of copper water pipes excavated from Location 1 was also submitted (Figure 5). This piece was installed above the gas service pipe. The assembly consisted of three flexible copper pipes (approximately 1 inch outer diameter) connected to a double wye fitting that would have connected to the water main. Generally, these pipes spread outward from the double wye, curved downwards (deeper into the ground, as excavated) to approximately the halfway point, and then curved back upwards and towards a central point approximately in line with the orientation of the double wye. The pipes were arbitrarily labeled “1” through “3” by the NTSB Materials Lab for purpose of orientation. Per the NTSB Pipeline Operations Group report, pipe 1 traversed over the gas service pipe in the vicinity of Area “E” (labeled in Figure 5).[10] The pipes were cleaned with a soft plastic bristle brush and water and surface damages were recorded (Table 2). Several notable areas of damage on pipe 1 are described in the following text, some of which are accompanied by close-up photographs.

A series of diagonal (relative to the cylindrical axis of the pipe) scrapes was noted starting approximately 27 inch from the double wye fitting (Area “B”, close-up in Figure 6). The scrapes were copper-colored and shiny in appearance. This area extended 9 inch along the length of the pipe. Viewed from the fitting towards the cut

[9] Position based on the face of a clock looking downstream, with 12:00 at the top of the pipe.
[10] For more information on the relative positions of the gas and water pipes as excavated, see Section 3.1.2.1 of the NTSB Pipeline Operations Group Chair’s Factual Report

end, the widest point of the scrapes extended from the 5:30 position to the 6:30 position (approximately 0.5 inch wide).

Further downstream, two dents were noted on the top of pipe 1 (Area "D", close-up in Figure 7). The first was located 48 inch from the fitting, and the second was 54.5 inch from the fitting. They were approximately 1 inch long and parallel to each other, angled approximately 45° compared to the axis of the pipe.

The bottom of pipe 1 in the area below the two dents showed a mix of black and green corrosion product (Area "E", close-up in Figure 8).[11] Similar areas of corrosion product were noted at other locations on pipe 1 and on pipe 2.

Table 2. Damage noted on the water pipe assembly. Areas of interest are labelled in Figure 5.

Pipe segment	Area of Interest	Associated close-up image	Approx. start and end distance[12] (inch)	Calculated Length (inch)	Approx. clock position when looking downstream	General observation
1	A	--	23 – 27	4	2:00 – 4:00	Mixed black and green corrosion product
1	B	Fig. 6	27 – 36	9	5:30 – 6:30	Shiny parallel scrapes diagonal to axis of pipe.
1	C	--	35 – 40	5	4:00 – 8:00	Mixed black and green corrosion product
1	D	Fig. 7	48	1	12:00	Shallow dent, linear, 1 inch long
1	D	Fig. 7	54.5	1	12:00	Shallow dent, linear, 1 inch long
1	E	Fig. 8	44 – 54	10	3:00 – 9:00	Mixed black and green corrosion product
2	F	--	21 – 34	13	4:00 – 8:00	Mixed black and green corrosion product
3	G	--	14	1	Whole pipe	Pipe kinked to form ~120° upward angle. Appears pinched, almost reducing the inner diameter to closure. Edges of the deformed areas are shiny.
3	H	--	35 – 37	2	11:00 – 3:00	Dent partially closes off the pipe.

Pieces of the diaphragm and housing for the gas meter from Location 1 are pictured in Figure 9. The bottom half of the housing was missing. The remaining housing showed extensive signs of melting and re-solidification. The remains of the diaphragm mechanism were fused together with a mixture of metallic material and ash. A female-threaded connection on the top of the housing was deformed and

[11] The dent at 48 inch (Area D) and surrounding superficial scratches can be seen in Figures 14 and 15 of the NTSB Pipeline Operations Group Chair's Factual report, where the water pipe traverses over the service line.
[12] Measured from double wye junction.

fractured. Damage to the diaphragm and housing was consistent with exposure to heat for an extended period.

1.2 Location 2

Figures 10 and 11 show the parts as received from Location 2. The gas main, tee[13] and service pipe assembly from 1147 Shalimar Dr. was submitted as a single piece. The assembly consisted of a 2-inch main, Mueller H-17510 service tee, a Dresser ¾-inch Style 90 Ell connector, and a section of ¾-inch service pipe (measured approximately 2.5 feet in length, 1.045 inch outer diameter, 0.790 inch inner diameter). A section of the pipe was cleaned with soapy water and a soft plastic bristle brush to expose bare metal, and that section was subjected to a portable XRF alloy analyzer for analysis. The chemical composition showed in general a high amount of iron (91 wt %) and some silicon (6.9 wt %), with other elements showing less than 1 wt%.[14] The outer surface of the main was covered with a black coating (resembling a hard tar-like material). A greater amount of black coating was present at the tee and the surrounding area, and a mass of coating extended between the main and the ell connector. Sections without the black coating showed brown and black corrosion product with no appreciable wall loss. There was no evidence that the corrosion had penetrated through the pipe walls.

A patch of yellow paint in the rough shape of a cross was visible on the outer surface of the service pipe and the ell connector where the pipe was inserted (visible in Figure 11). Per the Atmos party representatives[15], the yellow paint was added during excavation to mark the relative position and alignment between the service pipe and the ell connector, as the connection was loose. Upon receiving the pipe at the NTSB Materials Laboratory and removal from the shipping crate, the service pipe was able to be moved around in its connection. The assembly was handled carefully to avoid further loosening the joint. All other joints in the assembly were rigid (did not move relative to each other).

2.0 PRESSURE TESTING

Pressure testing was performed on both submitted assemblies using compressed air. The assemblies were tested at nominal pressures of 5 psig,[16] 10 psig, 20 psig, 30 psig, 35 psig (approximate operating pressure at the time of the accidents), and 40 psig (Maximum Allowed Operating Pressure). A shop compressor was used to supply air pressure. The open ends of the pipes were sealed with compression plugs. Pressure, air leak rate, and temperature were measured with a

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[13] The base of the tee was welded to the gas main.
[14] XRF measurements penetrate into the volume of the measurement surface. Thus, a reading on a surface with a thin deposit layer will show a combination of the deposit and the base materials.
[15] The gas main and service was operated by Atmos Energy.
[16] Pounds per square inch gauge

VPFlowScope® electronic in-line flowmeter.[17] The flow rate was measured after holding pressure for approximately one minute.

2.1 Location 1

Pressure tests were performed on the tee assembly and service pipe separately. The nut and gasket at the open end of the straight coupling on the tee assembly were replaced with a Dresser ¾-inch cap adapter (Figure 12).[18] Soapy water was applied to the test articles to aid with leak detection. The pressure test results are summarized in Table 3. No leak flow was measured, and no bubble formation was observed in either the assembly or the service pipe.

Table 3. Pressure test measurements for the pieces from Location 1.

Measured Pressure (psig)	Measured Flow Rate (SCFM[19], Air)	Temperature (°F)	Leak Observed?
Main, Tee Assembly			
5.5	0	77.4	No
11.2	0	77.8	No
20.3	0	78.2	No
30.4	0	78.5	No
35.1	0	78.7	No
40.8	0	79.0	No
Service Pipe			
6.0	0	81.5	No
9.3	0	81.6	No
19.6	0	81.7	No
30.3	0	81.8	No
35.0	0	81.9	No
39.8	0	82.0	No

2.2 Location 2

During setup of the pressure test, it was noted that the service pipe could be moved and turned in its connection to the pipe assembly at the ell joint. Prior to the start of testing, it was noted that the pipe had slipped out of the joint by approximately 1/16 inch during handling of the assembly, based on a gap between the yellow marking paint and the nut. When the main was secured such that the ell was parallel to the ground, the service pipe would droop downwards under its own weight unless it was supported. Thus, two pressure tests were conducted (Figure 13).

[17] Model # VPS.R080.M050
[18] The cap had the Dresser Style 90 seal-only configuration where the hole for the service pipe was instead filled with a hard plug approximately 0.8 inch in length.
[19] Standard Cubic Feet per Minute

For the first pressure test, the service pipe was supported on blocks to minimize the angle between the ell and the service pipe. The measured angle between the axis of the pipe and the axis of the ell was approximately 1°. When tested in this configuration, soap bubble formation was observed at the joint between the service pipe and the ell starting at 5 psig of applied pressure. However, the flow rate was too low to be measured by the flowmeter (<0.13 SCFM, air) at all pressures.

For the second pressure test, the support blocks were removed and the pipe was allowed to droop downwards under its own weight. In this configuration, the measured angle was approximately 8°. Bubbles formed at the service pipe/ell joint starting at 5 psig. Starting at 20.8 psig, the joint made an audible hiss and soap water applied to the joint was expelled before bubbles could form. Starting at 30.2 psig, the flowmeter measured a positive flow rate. Table 4 contains a summary of pressure test results.

Table 4. Pressure test measurements for the pieces from Location 2.

Measured Pressure (psig)	Measured Flow Rate (SCFM, Air)	Calculated Flow Rate of Natural Gas (SCFM)[20]	Temperature (°F)	Leak Observed?
Test 1 (Supported Pipe)				
5.1	0	--	80.3	Yes
9.7	0	--	80.3	Yes
20.0	0	--	80.6	Yes
30.1	0	--	80.6	Yes
36.1	0	--	80.6	Yes
42.0	0	--	80.7	Yes
Test 2 (Unsupported Pipe)				
6.0	0	--	81.1	Yes
11.4	0	--	81.1	Yes
20.8	0	--	81.1	Yes
30.2	0.2	0.26	81.1	Yes
36.0	0.3	0.39	81.1	Yes
39.8	0.4	0.53	81.1	Yes

3.0 DISSASSEMBLY AND POST-DISASSEMBLY INSPECTION

3.1 Location 1

After removal of the black tape from the straight coupling, nipple, and ell, the surfaces were inspected for tool marks and dents. No tool marks or other mechanical

[20] Equivalent flow of natural gas calculated as Flow(gas) = Flow(air)/(Specific Gravity (gas))$^{1/2}$ where the specific gravity of the natural gas (normalized to air) was 0.58.

damage were positively identified on the surfaces. A layer of dark, sticky residue was present where the tape had been removed.

The straight coupling was then disassembled for removal. A schematic cross section of a Dresser Style 90 seal-only coupling is provided in Figure 14. The gasket sits between the body of the coupling and retainer cup. A nut at the end of the coupling is used to provide compression on the gasket. In use, a pipe is inserted into the end of the coupling and then the nut is tightened down, putting a compressive force on the gasket and creating a seal. The depth to which the pipe is inserted is referred to as the 'stab depth.' The toe of the gasket contains a tightly wound coil of metal (made from brass alloy) that runs around the circumference of the gasket.[21] This coil is referred to as 'armor' by Dresser; its purpose is to maintain electrical continuity between the service pipe and metallic joiner pieces as part of the cathodic protection system. An exemplar undamaged gasket (Dresser part number 30380003039) is shown in Figure 15. During disassembly of the service tee assembly, rubber gaskets in the straight coupling and the ell were collected for further examination (detailed in Section 3.3).

The connecting nipple was removed from the ell and straight coupling. The toes of the gaskets were located approximately 1.4 inch away from the ends of the nipple (Figure 16), consistent with a stab depth of 2 inch. Brown rust was present across much of the surface of the pipe, except where the gaskets had been. These regions had developed significantly less rust. In the locations under the toes of each gasket, a series of silver-like, highly reflective marks were visible. These marks were linear, parallel to the axis of the nipple, and evenly-spaced around the circumference of the nipple.

A bench stereoscope was used to examine the upstream end of the service pipe. The end of the service pipe flared outward slightly, creating a lip along the outside edge of the pipe. Evenly-spaced linear marks, similar in size to the marks seen on the nipple pipe, were visible at the edge of the lip, running around the circumference of the pipe (Figure 17). Spacing between the marks was measured to be approximately 0.02 inch. A layer of corrosion product was present on the marks, having a brown or black appearance.

The amount of dark residue on the outside of the pipe at the upstream end increased moving towards downstream (Figure 18). A thin layer of dark residue extended all the way to the upstream end on one side of the pipe. Elsewhere, the thin layer of residue did not start until 0.6 inch from the end. The tape was adhered to the pipe starting approximately 1.2 inch from the upstream end. Thick pieces of sticky residue were visible beginning approximately 1.4 inch from the end. The residue was

[21] The coil portion of all the submitted gaskets were verified by a portable XRF alloy analyzer as having been made from a brass alloy (each coil having content greater than 55% copper and 26% zinc).

resistant to removal using dish soap, ethanol, and an Alconox[22] solution when scrubbed with a soft plastic bristle brush.

3.2 Location 2

The connection between the ell and the service pipe was disassembled with the service pipe in place. Upon removal, it was discovered that the service pipe did not fully extend through the rubber gasket (Figure 19). A layer of brown dirt was visible on the inner wall of the gasket. This layer of dirt extended from the toe to approximately 0.25 inches along the inside wall of the gasket. Patches of green corrosion product were visible on the dirt and on the end of the service pipe. The service pipe was removed from the gasket and the gasket was collected for further examination.

The yellow paint mark was measured to be 0.6 inch from the upstream end of the pipe. At 0.7 inch, a circumferential line of hard black tar-like material adhered to the service pipe (Figure 20). This residue stretched approximately one-third of the way around the circumference of the pipe. A sample of this residue was compared against the hard black residue material found on the end nut using Fourier Transform Infrared Spectroscopy (FTIR). FTIR showed a match between the two specimens, which were consistent with a coal tar epoxy coating material. The residue on the nut extended to the inner rim of the nut where the pipe was inserted (Figure 21). The location of the residue roughly lined up with the location of the residue on the pipe when it was inserted into the nut and aligned with the yellow paint marks, with overlap between the residue on the pipe and the residue on the inner rim of the nut. The end nut, retainer cup, and an exemplar gasket were assembled per the Dresser schematic. The distance from the toe of the gasket to the outer edge of the end nut was measured using calipers and found to be approximately 0.8 inch.

The end of the service pipe was flared, similar to the pipe from Location 1. Further, examination of the service pipe under the bench stereoscope revealed evenly spaced axial marks around the lip of the edge (Figure 22). The spacing of these marks measured approximately 0.02 inch. The marks were covered with a layer of corrosion product with a brown-black appearance, similar to the marks on the pipe from Location 1.

3.3 Gasket Examination

Four gaskets extracted from the pipe assemblies were subjected to further examination. Alongside gaskets from the assemblies, an unused gasket was provided by Dresser for comparative purposes.[23] The gaskets were arbitrarily numbered "1"

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[22] Alconox® powdered detergent can be employed to clean metal surfaces.
[23] Manufactured in 2023.

through "5" as detailed in Table 5. None of the gaskets removed from the assemblies had straight outer walls. Rather, the gaskets had a 'shoulder' that ran around the circumference of the gasket (Figure 23). The cross-sectional dimensions of the gaskets were measured with calipers and are recorded in Table 6; dimensions are linked to the schematic in Figure 24. The measured dimensions of the gaskets were consistent with the exemplar gasket for joints of those dimensions. Further, all gaskets showed similar deformation at the inner diameter of the heel, where a small amount of material extruded out of the gap between the outer wall of the service pipes and the retainer cups. All gaskets were pliable under an applied pressure and showed no evidence of dryness or surface cracking when examined under a bench stereoscope. Further, the gaskets had alphanumeric characters molded into the heel. Per input from the Dresser party member, these markings denoted the gasket size, elastomer material type, and the year the gasket was manufactured[24], among other information.

Table 5. Gasket location description.

Gasket No.	Accident Location	Component	Location Description	Associated Figure
1	1	Straight Coupling	Downstream side (open end)	Fig. 25
2	1	Straight Coupling	Upstream side (to nipple)	Fig. 26
3	1	90° Ell	To nipple	Fig. 27
4	2	90° Ell	To service pipe	Fig. 28
5	--	--	Exemplar unused	Fig. 15

Table 6. Dimensions of the gaskets (in inches) measured with calipers. Outer diameter (OD), and inner diameter (ID) were measured at the heel of the gaskets. Figure 24 contains a schematic for these measurements.

Gasket No.	h	w	d_1	d_2	OD	ID
1	0.51	0.29	0.10	0.26	1.63	1.04
2	0.54	0.29	0.08	0.26	1.62	1.03
3	0.51	0.31	0.08	0.22	1.61	1.01
4	0.51	0.30	0.11	0.29	1.63	1.06
5	0.53	0.28	--	--	1.63	1.07

Gasket 1 showed damage resembling a fissure traveling around the circumference of the inner wall below the armor (Figure 25). At its widest, the fissure was approximately 0.15 inch wide (measured from the base of the armor towards the heel of the gasket) with a depth of approximately 0.03 inch, measured in a Keyence VHX-7000 digital microscope.[25] This armor was shaped in a 'tight-wound'

[24] Dresser uses an alphabetical code to mark the year that the gasket was produced, where A = 0, B=1, etc.

[25] The VHX-7000 digital microscope can create a 3D profile of a surface through stitching of images

configuration, per the Dresser party member. Spacing between the windings of the armor was approximately 0.02 inch. The windings on the gasket armor were not continuous around the circumference of the gasket. Four notches were placed in the armor at 90-degree intervals. Per the Dresser party member, these were added to the armor to optimize the electrical bond in the coupling when installed.[26] The armor by the inner wall showed a flat region; this region was visible on windings around the circumference of the gasket. Based on the identification marks found in the heel portion, this gasket was manufactured in 1971.

Gasket 2 showed some damage to the inner wall, especially in the area where the armor abutted the rubber. Like Gasket 1, this damage resembled a fissure traveling around the circumference of the inner wall below the armor (Figure 26). At its widest, the fissure was approximately 0.09 inch wide (measured from the base of the armor towards the heel of the gasket) with a depth of approximately 0.02 inch. This gasket also had a 4-notch type armor configuration. The armor by the inner wall showed a flat region. Based on the identification marks found in the heel portion, this gasket was manufactured in 1971.

Gasket 3 had a different armor configuration from Gaskets 1 and 2 (Figure 27). The gasket used a tight-wound configuration, but it was continuous around the circumference of the gasket with no notches. The inner wall of the gasket was largely intact, with some damage to the rubber at the wall, where some separation existed between the rubber and the armor. The armor along the inner wall also showed damage consistent with contact wear. Per the markings on the heel, it was determined that the gasket was manufactured in 1963.

Gasket 4 was stuck in the metal retainer cup and had to be pried out. A wood wedge was inserted between the heel portion of the gasket and retainer cup at various locations of the joint. The wood wedge did not penetrate the joint. This procedure was repeated with a tool containing a steel wedge and the procedure separated the gasket from the retainer cup. Stamped labeling around the heel of the gasket was obscured in several places. However, the portions of the characters that were visible were consistent with the specified part ("11G0105").[27] The year indicator was partially obscured but indicated that the gasket had been manufactured between 1960 and 1969. Per the Dresser party member, the lack of notches in the armor (as seen in Gaskets 1 and 2) indicates that this gasket would likely have been produced no later than 1963. The inner wall of the gasket was largely intact, with some damage to the rubber on the inner wall where some separation existed between the rubber

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taken at increasing vertical distance from the surface. Software tools can then be used to measure features of the profile.

[26] The Dresser party member noted that gaskets currently produced by Dresser (such as the one shown in Figure 15) use a continuous 'loose-wound' configuration to eliminate the need to add notches in the gasket armors after molding.

[27] This designation defines the geometry of the gasket. It was found on all gaskets examined.

and the armor (Figure 28). The armor along the inner wall also showed a flat region. The armor was continuous around the circumference of the gasket with no notches. Spacing between the windings of the armor was approximately 0.02 inch. At one point along the armor, the armor was deformed, forming a 'bump' in the circle. This bump was approximately 0.12 inch wide and 0.04 inch tall. Damage to the rubber outer wall near this bump was consistent with contact damage on the rubber.

4.0 EXTERNAL LABORATORY MEASUREMENTS

The gaskets listed in Table 5 were submitted to Engineering Systems, incorporated (ESi), Aurora, Illinois, for determination of chemical and mechanical properties. The chemical properties were determined via pyrolysis[28] and Fourier Transform Infrared Spectroscopy (FTIR). All five gaskets were identified as styrene butadiene rubber.

Mechanical properties were tested against Dresser's specifications for the rubber material (Appendix A), which included hardness (durometer) and compression set tests. The hardness was tested with a Shore A durometer per ASTM D2240[29] on the outer wall and heel of the gaskets. Results of the hardness tests are shown in Table 7. Sections of the gaskets were removed for compression set tests, adhering as closely as able to the Dresser specification and ASTM D395[30] Method A. Due to limitations in the dimensions of the gaskets, the samples were smaller than the size called for in the specification. These samples were subjected to 600 psi of compression for 48 hours at room temperature using custom compression fixtures.[31] The pieces were then unloaded and allowed to rest at room temperature. The thicknesses of the pieces were measured after 30 minutes and 3 hours to determine the change in thickness compared to the pre-compressed state. These results are listed in Table 8.

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[28] Pyrolysis is a process to decompose materials at high temperatures for further analysis.
[29] ASTM (2021) Standard Test Method for Rubber Property—Durometer Hardness. doi: 10.1520/D2240-15R21
[30] ASTM (2018) Standard Test Methods for Rubber Property—Compression Set. doi: 10.1520/D0395-18
[31] The fixture consisted of a 10:1 lever arm with compression platens at the short end and weights at the long end. The applied force was measured at the platen end and the weights were adjusted until the force would apply 600 psi on the sample.

Table 7. Shore A Durometer hardness mean measurements and standard deviation at the heel and along the slanted outer wall of the gasket.

Gasket No.	Hardness (Shore A)	
	Heel	Outer Wall
1	81.8 ± 2.5	86.6 ± 1.3
2	83.6 ± 2.6	84.4 ± 2.1
3	78.0 ± 1.2	85.6 ± 1.1
4	79.4 ± 1.3	84.6 ± 1.1
5	75.0 ± 0.7	79.8 ± 0.8
Specification	*75 ± 5*	

Table 8. Compression set results. 600 psi applied at room temperature for 48 hrs.

Gasket No.	Area	Starting Thickness	Thickness after 30 min rest		Thickness after 3 hrs rest	
--	$inch^2$	inch	inch	% change	inch	% change
1	0.063	0.2286	0.2204	3.59	0.2209	3.37
2	0.067	0.2292	0.2250	1.83	0.2256	1.57
3	0.062	0.2498	0.2474	0.96	0.2482	0.64
4	0.081	0.2356	0.2318	1.61	0.2325	1.32
5	0.062	0.2456	0.2433	0.94	0.2436	0.81
Specification	*0.44*	*0.5*	--	*4 max*	--	*3 max*

Submitted by:

Brian Fuchs, Ph.D
Materials Engineer

Frank Zakar
Sr. Metallurgist

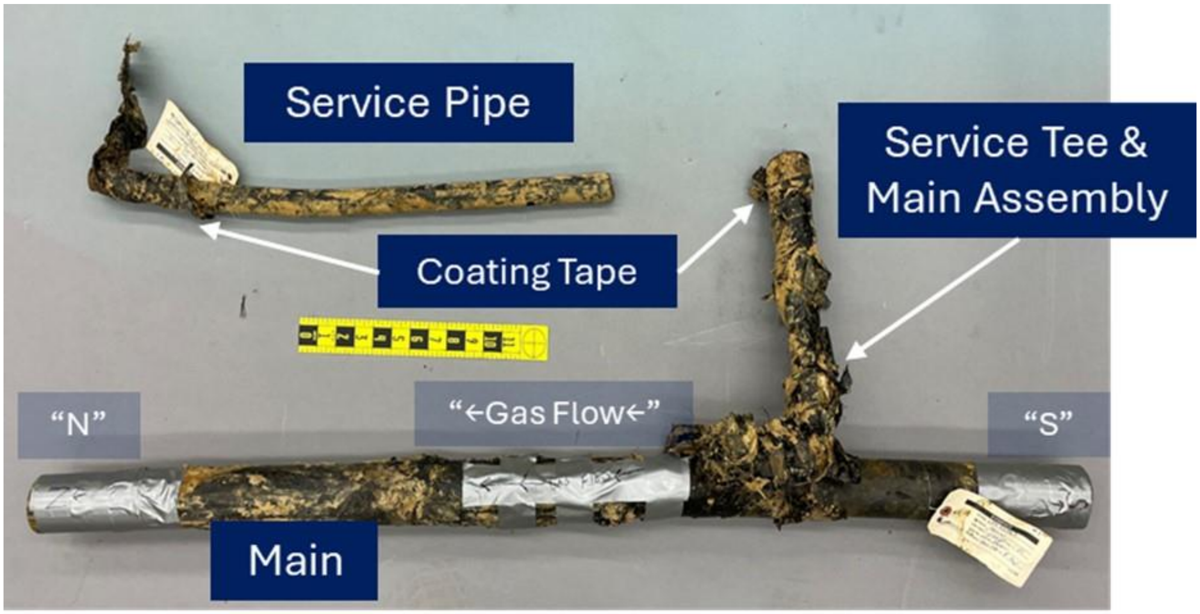

Figure 1. As-received main, tee assembly, service pipe and coupling from 190 Bristol Blvd (Location 1).

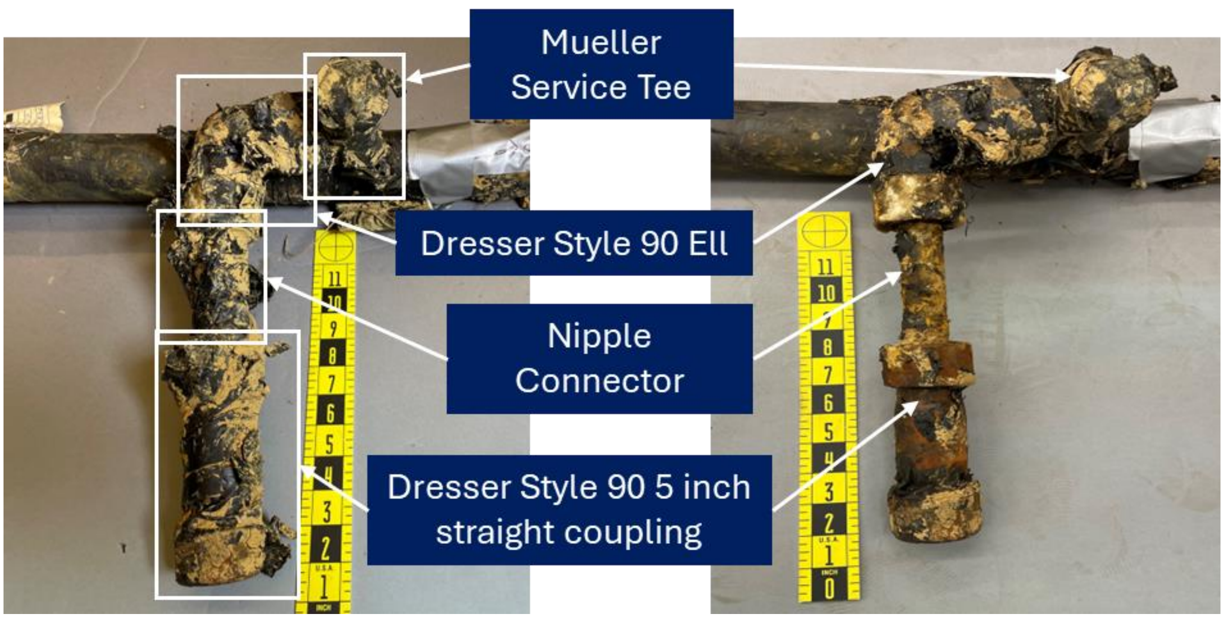

Figure 2. (Left) Top view of as-received main and tee assembly at Location 1 with coating tape. (Right) Similar view with coating tape removed.

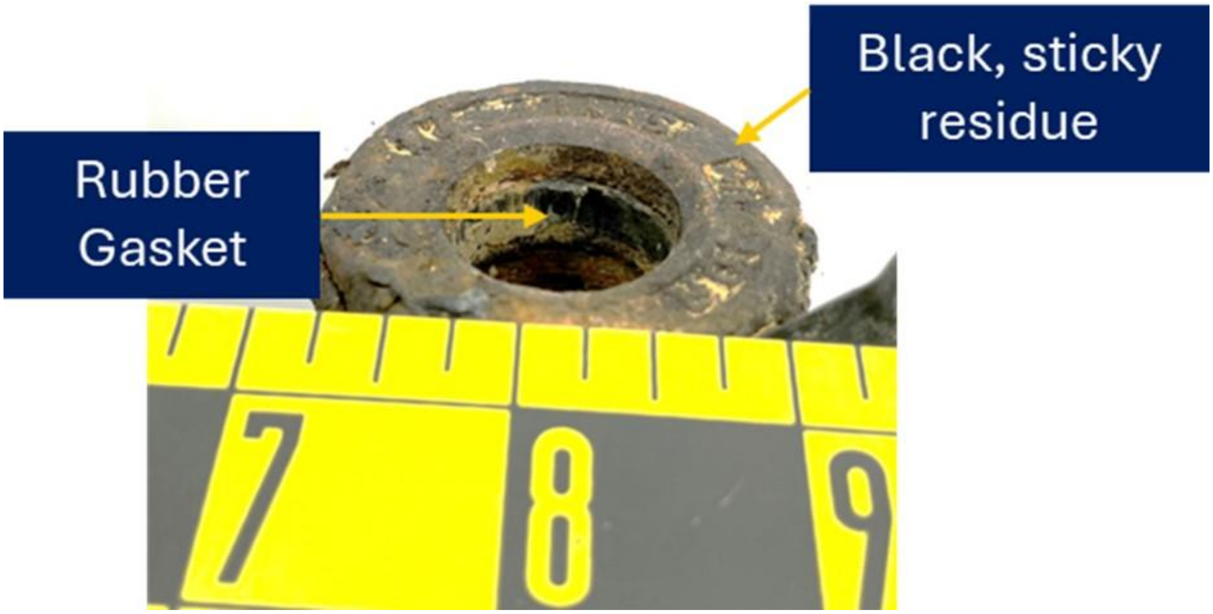

Figure 3. Open downstream end of the straight coupling on the tee and main assembly, at Location 1. A rubber gasket was visible inside the open end.

Figure 4. The service pipe at Location 1 was bent approximately 13 inch from the upstream end with straight segments on either side of the bend.

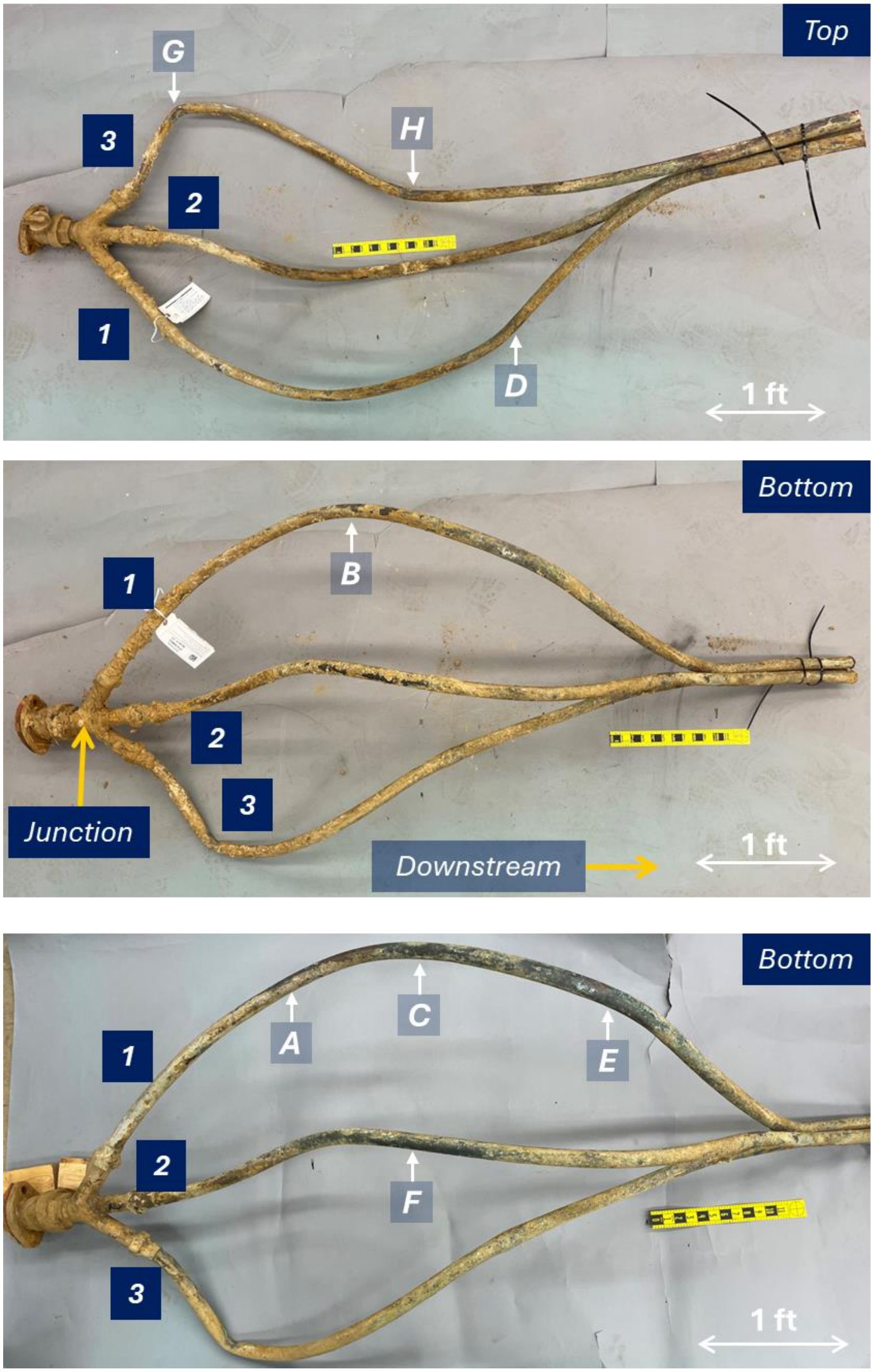

Figure 5. (Top) Top surface of the copper water pipes as received. (Middle) Bottom surface of the pipes as received. (Bottom) Bottom surface of the pipes after cleaning with water, revealing areas of black and green corrosion product. The right side of the pipes were held together by tie straps to facilitate shipping and transportation. Areas marked with letters are associated with damage noted in Table 2.

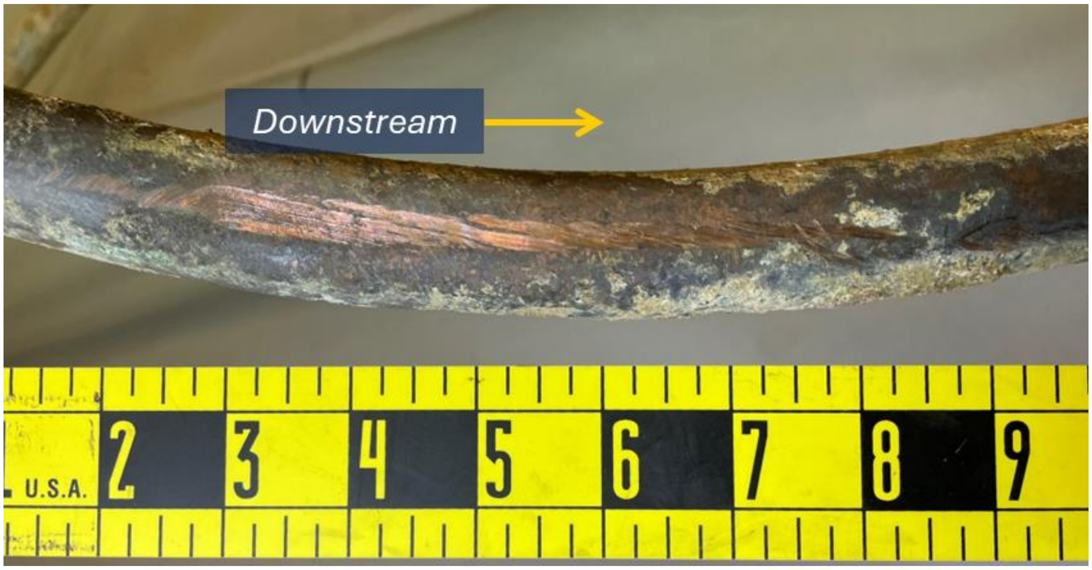

Figure 6. Series of surface scratches located on the bottom of pipe 1 (Area "B" in Figure 5).

Figure 7. Two dents located on the top of pipe 1 (Area "D" in Figure 5).

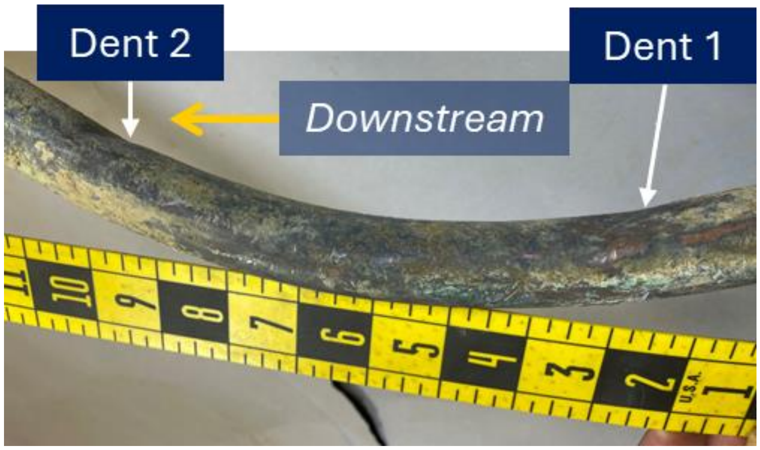

Figure 8. Area "E" in Figure 5 showing pipe 1 from the side. Black and green corrosion product was visible on the bottom of the pipe near where the two topside dents were located. The two dents from Area D (Figure 7) are visible in this image

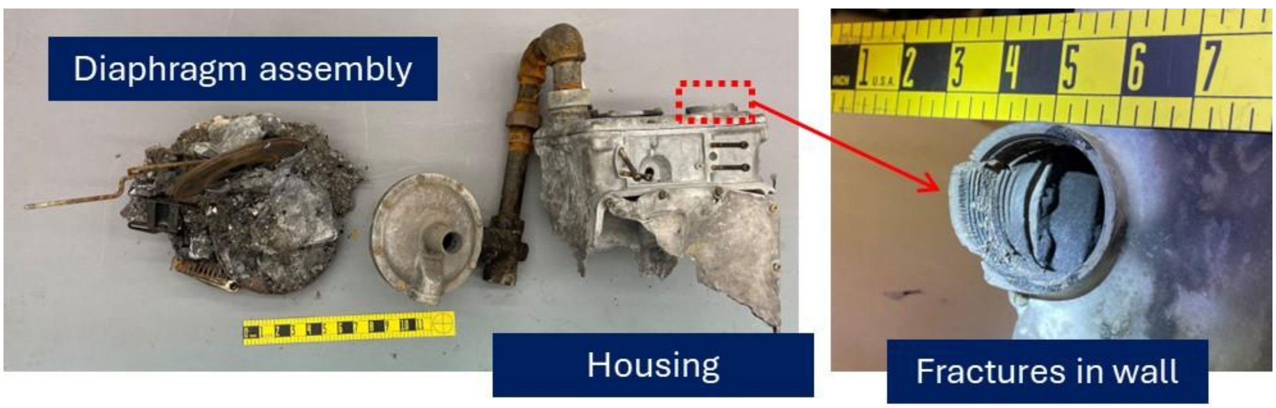

Figure 9. (Left) Remains of gas meter housing and diaphragm assembly. (Right) Fractures seen in wall of the outlet connection threading.

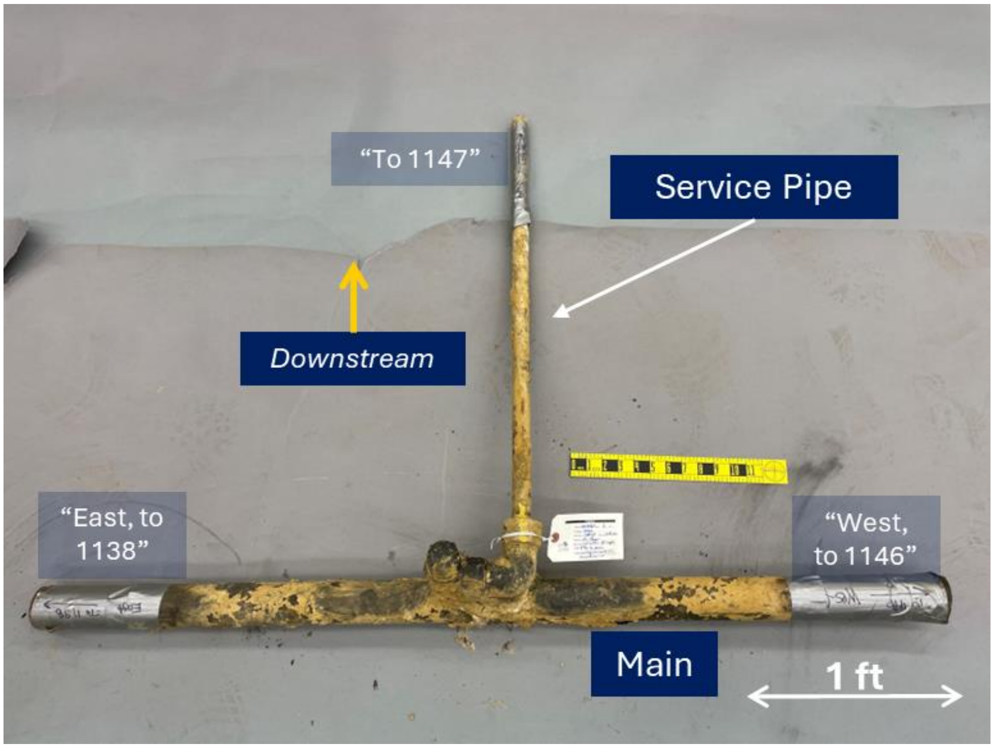

Figure 10. Main, tee, and service pipe as-received from 1147 Shalimar Dr (Location 2). Text in quotes are the notes written on the pipes as-received.

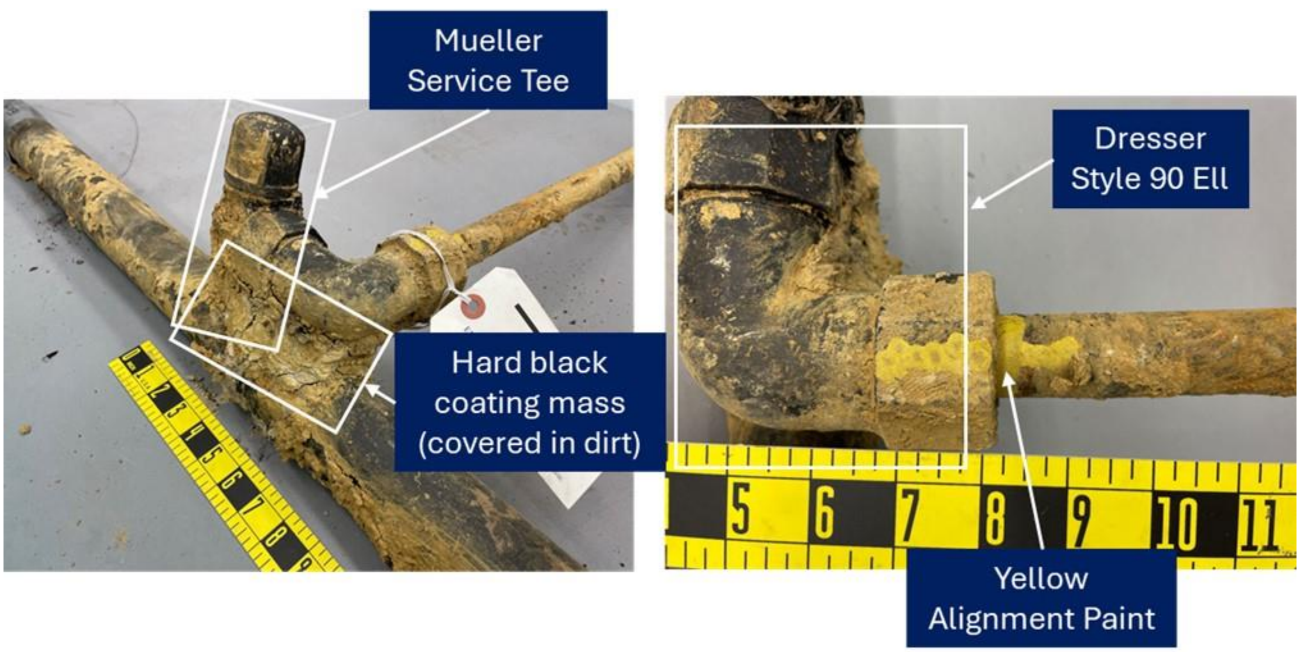

Figure 11. (Left) Oblique and (right) top views of the tee, ell, and service pipe joint from Location 2. Yellow paint marks the alignment of the service pipe as-received.

Figure 12. (Top) Cap used to seal the open end of the assembly from Location 1. (Bottom) assembly and tee during pressure test. No bubble formation was observed on any surface during the test.

Figure 13. (Left) Bubbles formed at the joint between the ell and the service pipe at Location 2 when the service pipe was supported. (Right) Air escaping at higher pressures forced the soapy water out of the joint before significant bubbling could occur.

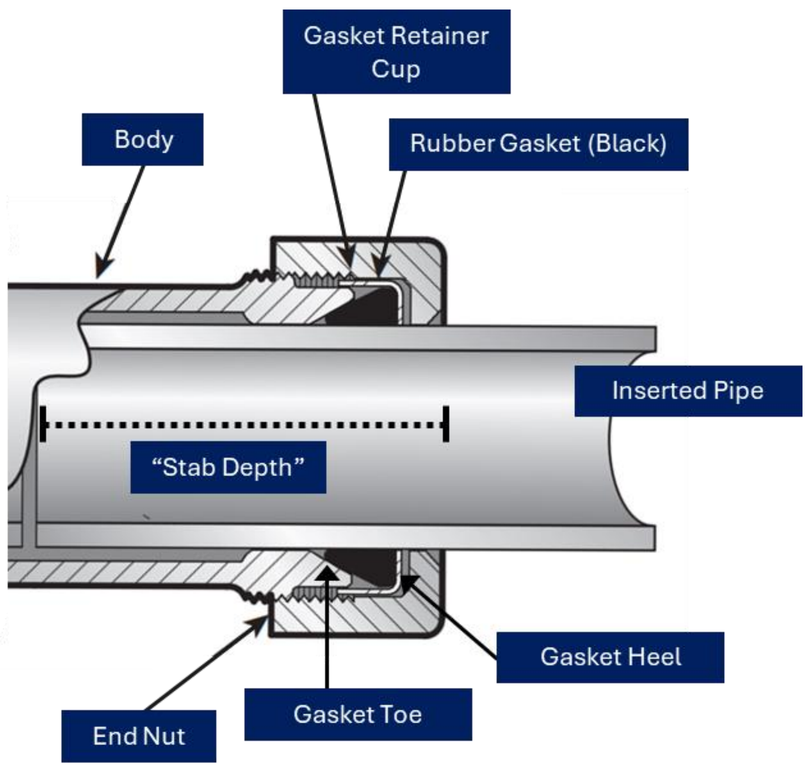

Figure 14. Cross-section drawing of a Dresser "Seal Only" Style 90 gas service fitting. Adapted from recent Dresser marketing materials.[32]

[32] Dresser Utility Solutions, "Style 90 SEAL-ONLY Gas Service Fittings." Retrieved 09/2024 from https://dresserutility.com/wp-content/uploads/style-90-seal-only-gas-service-fitting-brochure.pdf

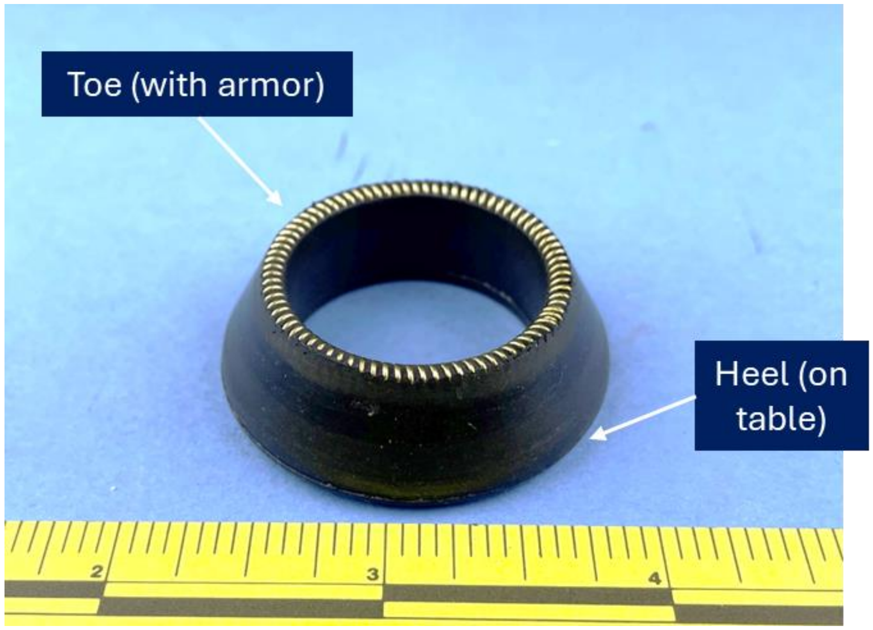

Figure 15. Exemplar unused contemporary ¾ inch Grade 27 Style 90 gasket.

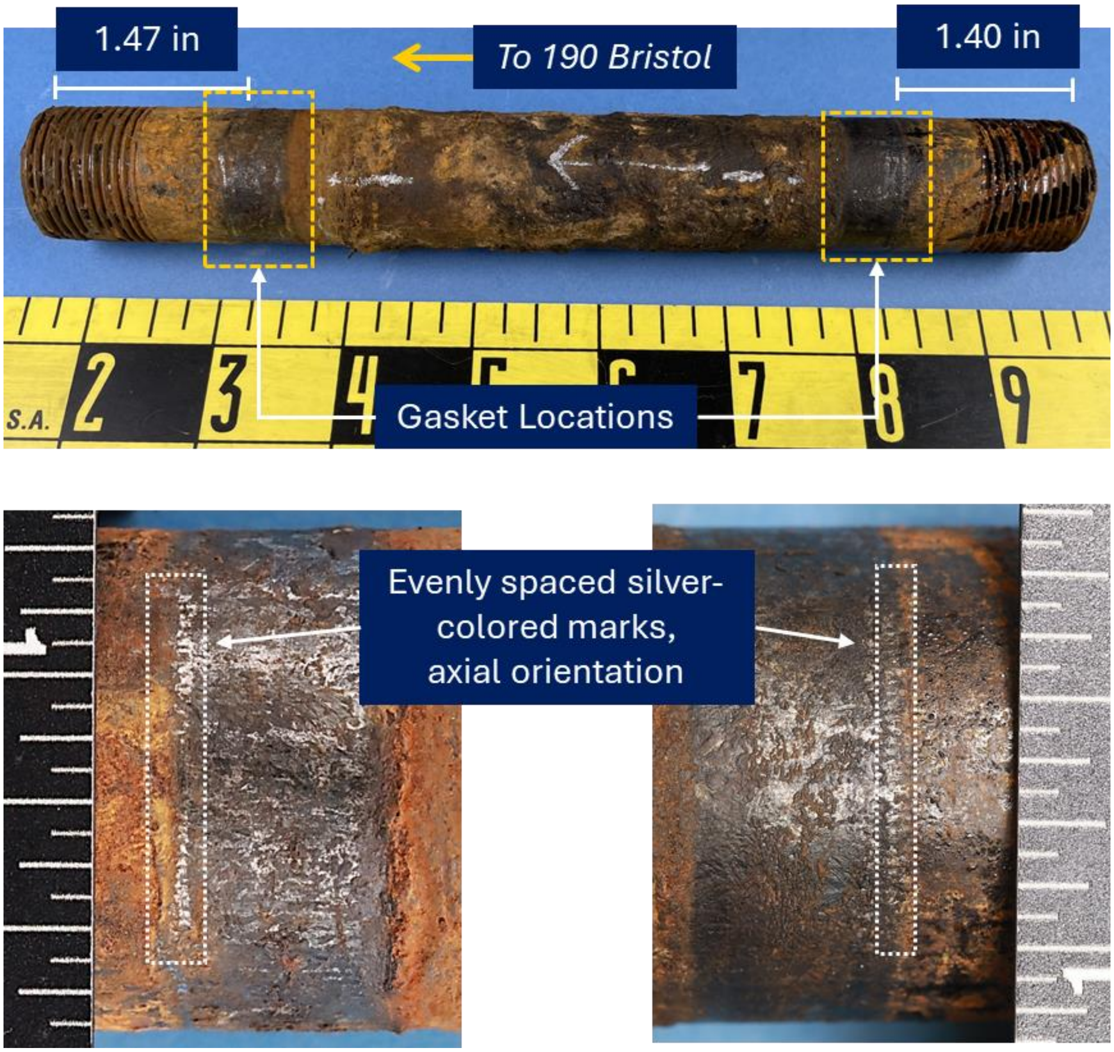

Figure 16. (Top) Nipple between the straight coupling and the ell from Location 1. Yellow boxes mark the location of gaskets prior to removal. (Bottom Left) Gasket location on the downstream end of the nipple. (Bottom Right) Gasket location from the upstream end of the nipple. Silver-like reflective marks were seen around the circumference of the nipple under where the toes of the gaskets had been located.

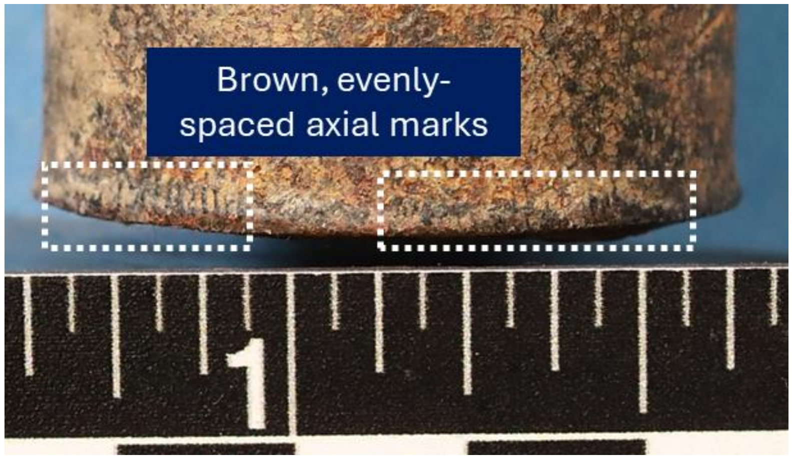

Figure 17. Evenly spaced axial marks seen at the flared upstream end of the service pipe from Location 1.

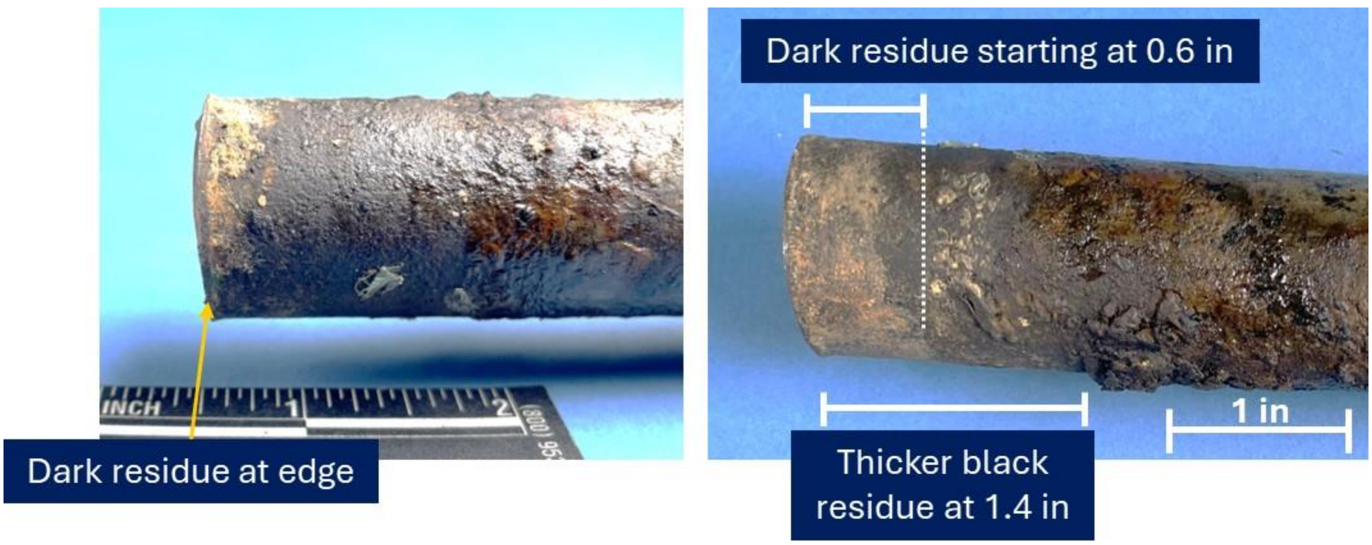

Figure 18. Dark residue progression from the upstream end of service pipe from Location 1 (left) viewed at the top of the pipe (right) viewed from the side of the pipe.

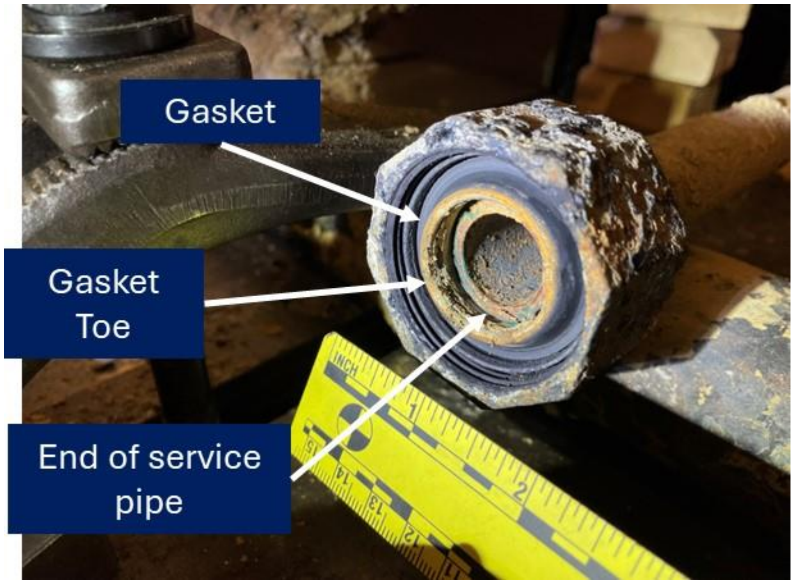

Figure 19. Service pipe, gasket, and end nut from Location 2 after disconnection from the assembly. The service pipe did not feed fully through the gasket, with an approximately 0.25 inch space between the toe of the gasket and the end of the pipe.

Figure 20. Black residue visible on the upstream end of the service pipe from Location 2 close to the yellow paint marking.

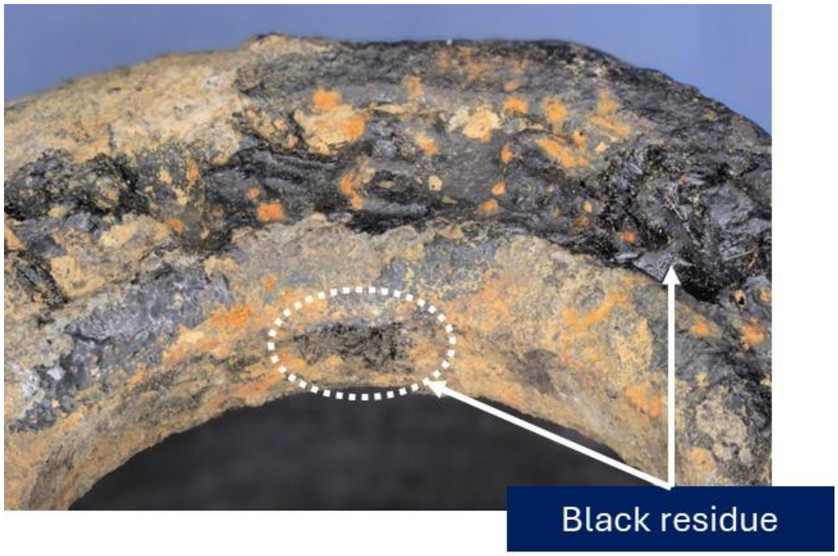

Figure 21. The end nut from the ell at Location 2. Hard black residue was seen on the stamped surface of the nut and on the wall where the nut would have been in contact/near contact with the service pipe when it was inserted (white circle).

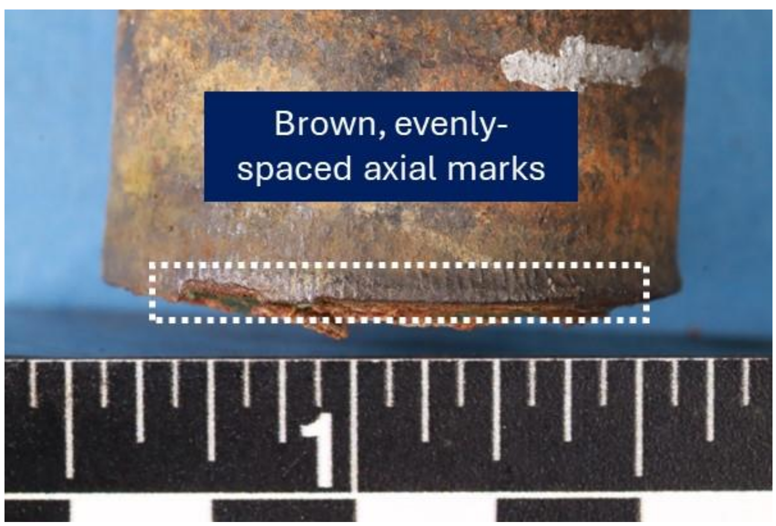

Figure 22. Evenly-spaced axial marks seen at the flared upstream end of the service pipe from Location 2.

Figure 23. Gaskets taken out of the couplings in service had an angled 'shoulder' that ran around the circumference of the outer wall of the gasket. Example: gasket from Location 1 (for comparison, see the exemplar in Figure 15).

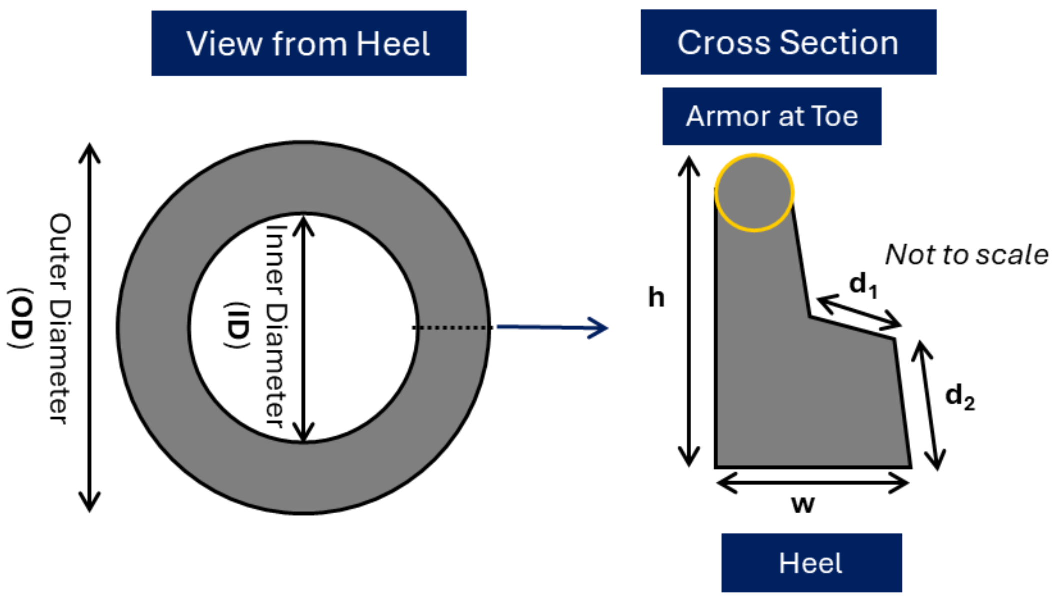

Figure 24. Schematic of the measurements taken on the deformed gaskets using calipers.

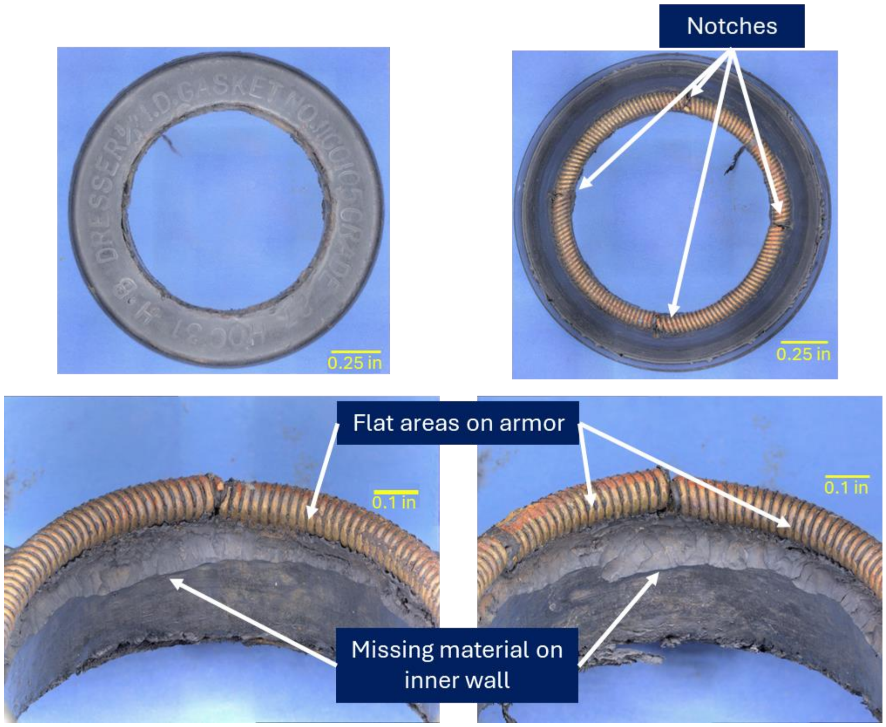

Figure 25. Condition of Gasket 1 (Location 1, straight coupling, downstream side) after cleaning in ultrasound bath with soapy water.

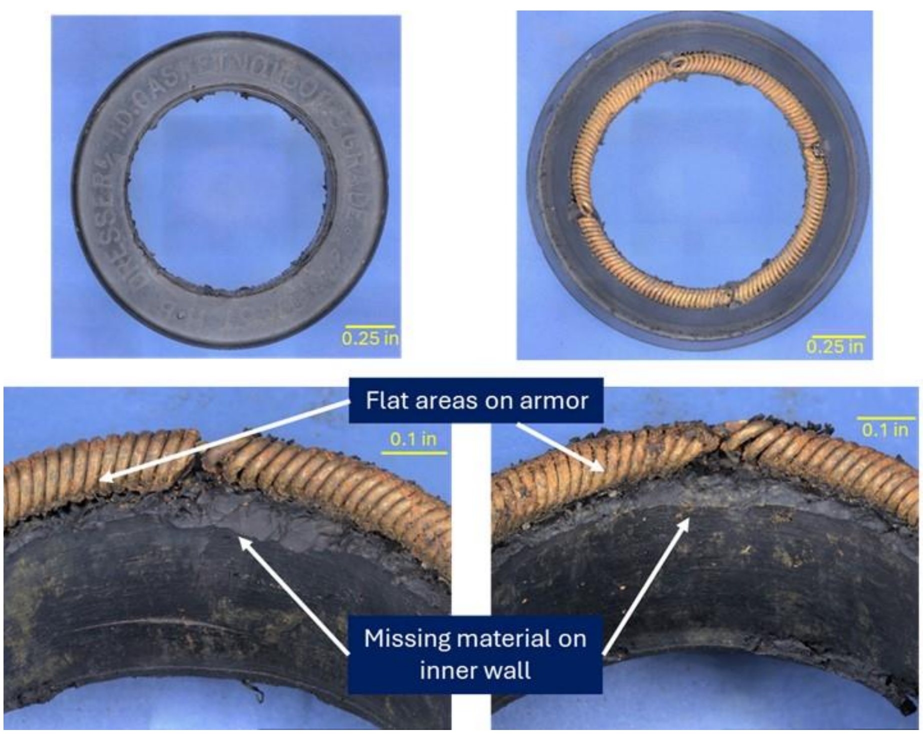

Figure 26. Condition of Gasket 2 (Location 1, straight coupling, upstream side) after cleaning in ultrasound bath with soapy water.

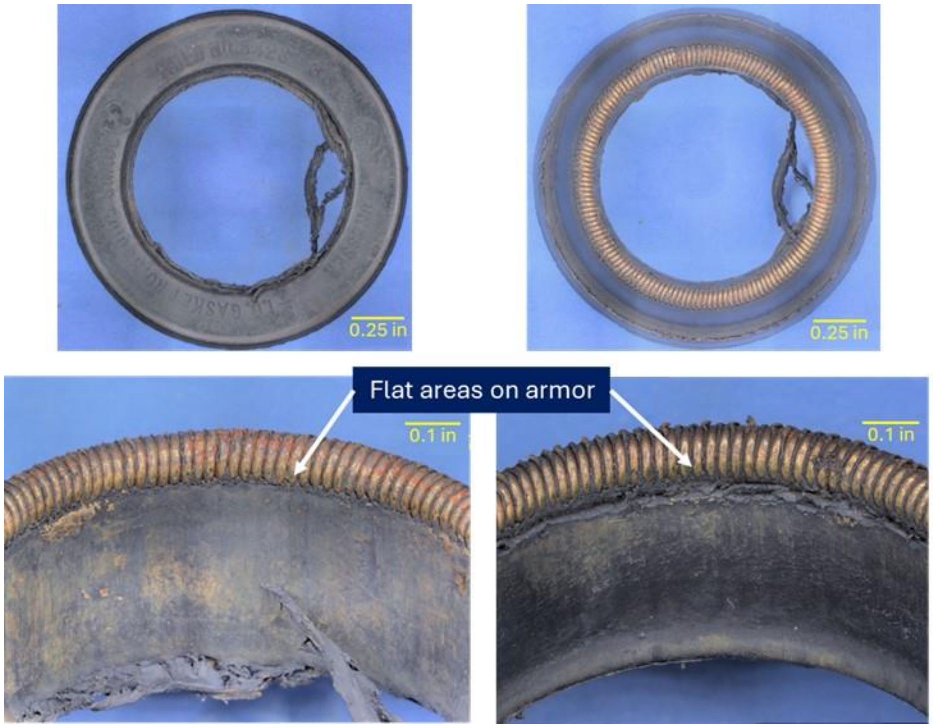

Figure 27. Condition of Gasket 3 (Location 1, ell) after cleaning in ultrasound bath with soapy water.

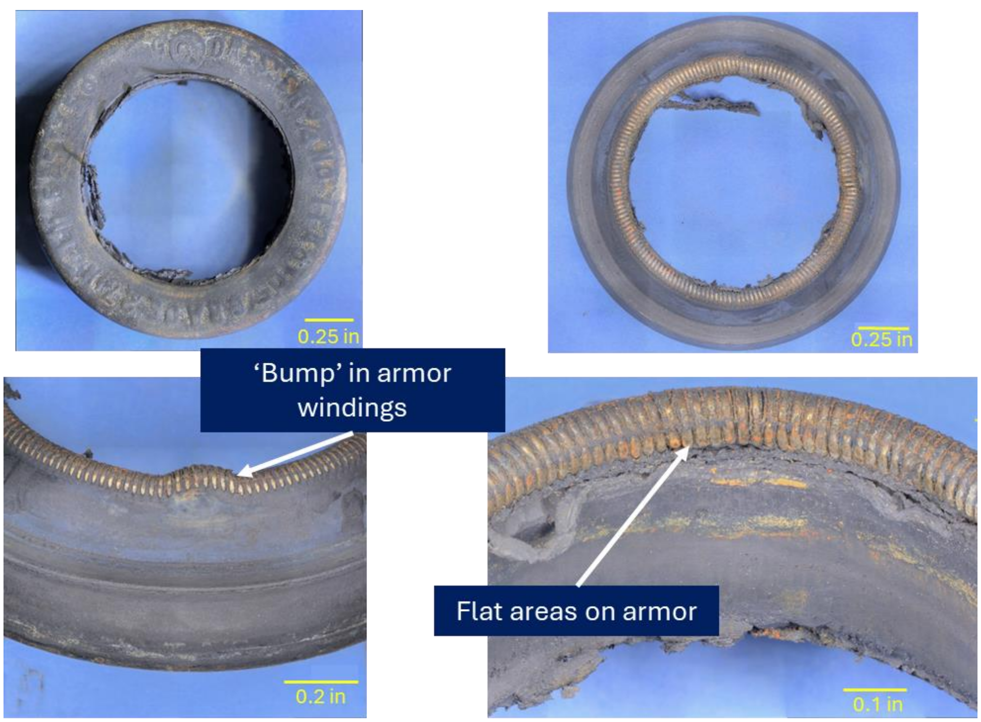

Figure 28. Condition of Gasket 4 (Location 2, ell) after cleaning in ultrasound bath with soapy water.

E. APPENDICES

1.0 APPENDIX A: Dresser Specification for Grade 27 Rubber

5/27/68
8/6/68
8/20/75
*11/30/88

DRESSER MANUFACTURING DIVISION
Dresser Industries, Inc.
Bradford, Pennsylvania

DRESSER GRADE 27 GASKET SPECIFICATION

The gaskets shall have cross sections as approved and shall be made of new rubber, compounded to give maximum durability. The compounded rubber of the completed gaskets shall conform to the following physical properties:

Tensile Strength, Minimum - 1500 PSI (10.35 MN/m^2)
Elongation, Minimum - 150%
Hardness, Shore A Durometer 75 plus or minus 5
Compression Set - 4% Maximum 30 Minutes
3% Maximum 3 Hours

Tensile strength and elongation shall be determined in accordance with ASTM Specification D412. Hardness shall be determined as specified by the ASTM Designation D2240. Compression set shall be determined upon 3/4" diameter x 1/2" thick disc, cut from 3" diameter plaque, subjected to 600 PSI for 48 hours at room temperature. In other respects, the procedure shall conform to the requirements of ASTM D395 Method A, using the external loading device. In addition, a specimen is subjected to a compression of 20% of the original deflection, for 22 hours at 158°F. Results are in accordance with ASTM D395 Method B.

The deterioration of the physical properties of the rubber shall not exceed minus 25% in tensile strength, minus 35% in elongation, and an increase in durometer not to exceed 10 points in aging tests conducted at a temperature of 158°F (70°C) for a duration of 96 hours and made in accordance to the Standard Specifications for Accelerated Aging of Vulcanized Rubber by the Oven Method, Serial Designation D573 of the American Society for Testing Materials.