National Transportation Safety Board
Office of Research and Engineering
Washington, DC 20594

PLD25FR001

MATERIALS LABORATORY

Factual Report 25-026

June 4, 2025

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A. ACCIDENT INFORMATION

Location: South Jordan, Utah
Date: November 6, 2024
Vehicle: Enbridge Gas Distribution Pipeline System
Investigator: Dane Spillers, RPH-20

B. COMPONENTS EXAMINED

Piece of 4-inch Nominal Pipe Size (NPS/IPS) DuPont Aldyl A gas main, approximately 71.84 inches long.

C. EXAMINATION PARTICIPANTS

Group Chair	Donald Kramer, Ph.D. National Transportation Safety Board Washington, District of Columbia
Group Member	Reid Hess Enbridge Gas Utah Eagle Mountain, Utah
Group Member	Jacob Jorgensen Pipeline and Hazardous Materials Safety Administration Oklahoma City, Oklahoma

D. DETAILS OF THE EXAMINATION

A piece of polyethylene pipe used for natural gas distribution was submitted to the NTSB Materials Laboratory for examination (figure 1a). The pipe contained a through-wall crack that was located at approximately the 6 o'clock (6:00) position (figures 1b, 2a, and 2b). The pipe was 4-inch Nominal Pipe Size (NPS)[1] medium density polyethylene (MDPE) manufactured by E.I. du Pont de Nemours & Co, Inc. (DuPont) and sold under the trade name "Aldyl A". The pipe was marked as follows:

ASTM D 2513 4" IPS SDR 11.5 DUPONT ALDYL ®A PE2306-T0618L 21

The manufacturing date code, T0618L, was decoded as Tulsa, June 18, 1976.

[1] Nominal Pipe Size, also referred to as Iron Pipe Size (IPS), is a standard based on a pipe's outer diameter and wall thickness. A pipe with a "standard" wall thickness will have an inner diameter that is approximately the same as the pipe size. A pipe with a thicker wall will have a smaller inner diameter.

The examination was divided into three phases: 1) Non-destructive geometrical measurements, 2) group examination; and 3) post-examination material testing. The remainder of this report contains findings from each phase of the examination.

1.0 Non-destructive geometrical measurements

The through-wall crack was located at approximately midspan (lengthwise) of the extracted pipe piece. On the outer surface, the crack comprised two smaller through-wall cracks (labelled Crack 1 and Crack 2 for convenience) joined by a ligament of intact material. On the inner surface, the crack comprised one continuous crack, which coincided with visible residues/stains on the inside of the pipe (figures 2a and 2b), consistent with a crack location at the 6:00 position (bottom of the pipe). One end of the pipe piece was arbitrarily designated "end 1" and the other end was designated "end 2". The locations of notable crack features relative to end 1, according to a measuring tape, are shown in table 1.

Table 1. Location of notable features along gas main from "end 1" 6:00 position.

Feature description	Linear distance along pipe, inch
Edge of crack closest to end 1	35.50
Center of impingement	36.50
Edge of crack furthest from end 1	37.88
End 2	71.84

Pipe outer diameter and wall thickness were measured in accordance with ASTM D2122. The outer diameter was measured multiple times between 1 and 2 inches from each end of the segment and near the middle of the segment using diameter tape with a vernier scale. The range of measured values is presented in table 2.[2,3] The wall thickness was measured approximately 0.75 inches to 1 inch from each end and near the middle by ball micrometer (table 3).[4] The wall thickness near the middle of the segment was measured after the group exam but is included here for conciseness.

[2] The location near the middle of the segment was measured multiple times with the same result.
[3] The average diameter of 4-inch IPS pipe is 4.500 inch with a tolerance of ± 0.009 inch.
[4] The minimum wall thickness of 4-inch IPS pipe is 0.395 inch with a tolerance of + 0.040 inch / - 0.000 inch.

Table 2. Pipe outer diameter measurements according to diameter tape. End measurements were taken 1 to 2 inches from each end and represent the high and low measured values.

Location	Diameter, inch
End 1	4.525 to 4.530
Near middle of segment	4.521
End 2	4.522 to 4.529

Table 3. Wall thickness measurements at end 1, middle, and end 2.

Pipe Position, + angle clockwise from TDC, end 1 to end 2, deg	Wall thickness end 1, inch	Wall thickness middle, inch	Wall thickness end 2, inch
0	0.417	0.417	0.418
45	0.422	0.421	0.422
90	0.416	0.414	0.413
135	0.424	0.424	0.423
180	0.423	0.422	0.422
225	0.421	0.419	0.418
270	0.421	0.421	0.420
315	0.417	0.417	0.418

The maximum Standard Dimension Ratio (SDR) at end 1 was 10.89.[5] In the middle it was 10.92. At end 2 it was 10.97. All measured values were better (less) than the SDR of 11.5 that was stamped on the pipe.

The ovalization of the pipe was measured using large-jawed calipers. Pipe outer diameter was measured at the 12:00/6:00 position and the 3:00/9:00 position in 3-inch increments along the pipe segment starting at end 1 (table 4).

[5] The Standard Dimension Ratio (SDR) is calculated by dividing the average outer diameter of the pipe by the minimum pipe wall thickness. It is a measure of the pressure-carrying capacity of the pipe according to, $\sigma = P \cdot SDR/2$, where σ is the stress in the pipe wall and P is the pressure inside the pipe. A pipe with a lower SDR value means that the stress in the pipe wall will be lower for a given internal pipe pressure. Alternatively, a pipe with a lower SDR can operate at a higher internal pressure before it reaches the allowed stress limit for the pipe material.

Table 4. Ovalization of the pipe piece, measured in 3-inch increments along the length of the pipe segment.

Distance from end 1, inch	12/6 diameter, inch	3/9 diameter, inch
0	4.505	4.508
3	4.523	4.520
6	4.519	4.521
9	4.517	4.522
12	4.519	4.524
15	4.514	4.529
18	4.518	4.525
21	4.522	4.520
24	4.519	4.523
27	4.514	4.526
30	4.507	4.531
33	4.493	4.546
36	4.446	4.573
36.5 (impingement point)	4.437	4.575
39	4.478	4.559
42	4.506	4.534
45	4.520	4.522
48	4.520	4.520
51	4.517	4.521
54	4.514	4.527
57	4.509	4.532
60	4.498	4.540
63	4.503	4.534
66	4.520	4.518
69	4.526	4.511
72	4.502	4.517

2.0 Group examination

A group examination was held at the NTSB Materials Laboratory on February 25, 2025 and February 26, 2025, with representatives from Enbridge Gas Utah and the Pipeline and Hazardous Materials Safety Administration in attendance. During the exam, the following tasks were accomplished:

1) Flow rate testing of the through-wall crack in the pipe.
2) Exposure, examination, and documentation of crack fracture surfaces.
3) Pipe strip flattening/bend back for low-ductility inner wall (LDIW) evaluation.[6]

2.1 Flow rate testing

The pipe piece was prepared for flow rate testing. Electrofusion couplings were fused to each end of the pipe piece by following industry standard procedures. A cap was fabricated for one end (figure 3) that was outfitted with a pressure gage. The other end was connected to a regulated air supply and an in-line flow meter with a maximum flow rate of 50 SCFM. The flow rate was adjusted using the regulator and pressure was read off the pressure gage on the capped end. The flow rate results are shown in table 5.

Table 5. Flow rate testing of through-wall crack in pipe piece.

Pressure, psig	Flow rate, SCFM (air)
25	3.3
30	8.4
32	10.4
40	20.0
43	37.7[7]

2.2 Fracture surface exposure and fractography

Borescope examination of the inner surface indicated that there was some staining and residue on the inside of the pipe on one end of the crack. Several features within the stain/residue region were observed that merited direct visual examination (Subsequent visual examination with the aid of a stereomicroscope

[6] LDIW is a condition that is known to affect a fraction of the Aldyl A pipe manufactured between 1970 and 1972. The condition, if present, increases susceptibility to slow crack growth (brittle-like cracking) fracture.

[7] The flow rate through the crack was measured with the pipe on a workbench without any soil restraint or backpressure on the pipe. The crack could have stretched open/extended some amount as the pressure rose from 40 psig to 43 psig, thereby increasing the size of the opening in the pipe and thus the flow rate. The flow rate into open air may also be higher than into soil surrounding a buried pipe.

found no notable features). The pipe was cut in the transverse plane approximately 4 inches from the impingement point on one side and 12 inches on the other side (the side with the staining) (figures 4a and 4b). The extracted segment was then cut longitudinally at approximately 3:00 and 9:00, revealing the crack opening on the pipe inner surface.

The crack extended through the wall and was visible on both the outer and inner surfaces. On the outer surface, there was an oblong and rough-textured impression in the pipe wall, approximately 0.40 inch x 0.24 inch. There were two cracks on the outer surface, one on either side of the impression, oriented in the longitudinal direction (figure 5a). One crack (Crack 1 in figure 5a) was approximately 0.80 inches long and the other crack (Crack 2 in figure 5a) was approximately 1.20 inches long. The two cracks were separated by an approximately 0.30-inch-long intact ligament, the ligament being approximately coincident with the impression in the pipe. On the inner surface, there was one continuous crack that was approximately 3.35 inches long (measured after flow rate testing and after the pipe was cut open) (figure 5b).

Saws, utility knives, and scalpels were used to back-cut and open the crack. The fracture surfaces were then examined with the aid of an optical microscope. The fracture surfaces exhibited features consistent with crack initiation and progression by slow crack growth (i.e., brittle-like cracking) from a single point origin at the inner diameter surface (figure 6a and 6b).[8] The origin aligned longitudinally with the above-referenced outer surface impression/impingement. The slow crack growth region was comparatively smooth and exhibited fibril features. The crack extended longitudinally in both directions from the origin and from the inner surface toward the outer surface of the pipe. The longitudinal ends of the slow crack growth region bowed outward, away from the origin, such that at approximately 0.222 inches from the inner surface, the crack reached its greatest lengthwise span of approximately 3.50 inches. In the through-thickness direction and approximately 0.035 inches to 0.020 inches from the outer surface, rougher crazing and fine hackle features appeared, consistent with crack acceleration and final fracture (figure 6c). The inner surface of the pipe was examined at the crack point of origin and no notable anomalies were found.

2.3 LDIW evaluation

A bend-back test was performed to evaluate the inner surface for cracking / crazing that would indicate a low-ductility inner wall (LDIW) condition. A strip of pipe material was cut from the rest of the pipe (figure 7a). One end of the strip was clamped in a vice and the other end was gripped using adjustable pliers. The piece

[8] Slow crack growth is a time- and temperature-dependent failure mode that can occur in thermoplastic polymers such as Aldyl A when exposed to sustained long-term stress.

was bent back on itself, and the inner surface was subsequently examined for signs of cracking or crazing (figure 7b). No indications were found (figure 7c).

3.0 Post-examination material testing

Melt flow index and density of the pipe material were evaluated and were found to conform to the known properties of 1976-vintage Aldyl A. Samples of pipe material were submitted to an external laboratory. Melt flow index was evaluated in accordance with ASTM D1238-23a and density was evaluated in accordance with ASTM D792-20. The average melt flow index based on three sample trials was 1.19 g/10 min. The average density based on two trials was 0.943 g/cm^3. Nominal values for melt flow index and density for this vintage of Aldyl A, published by DuPont, were 1.1 g/10 min and 0.937 g/cm^3, respectively. The results were within the tolerance and interlaboratory uncertainty limits for the tests.

E. ATTACHMENTS

Aldyl A Technical Data Bulletin 200, E.I. du Pont de Nemours & Co, Inc., Wilmington, Delaware, 1975.

Submitted by:

Donald Kramer, Ph.D.
Materials Engineer

a)

b)

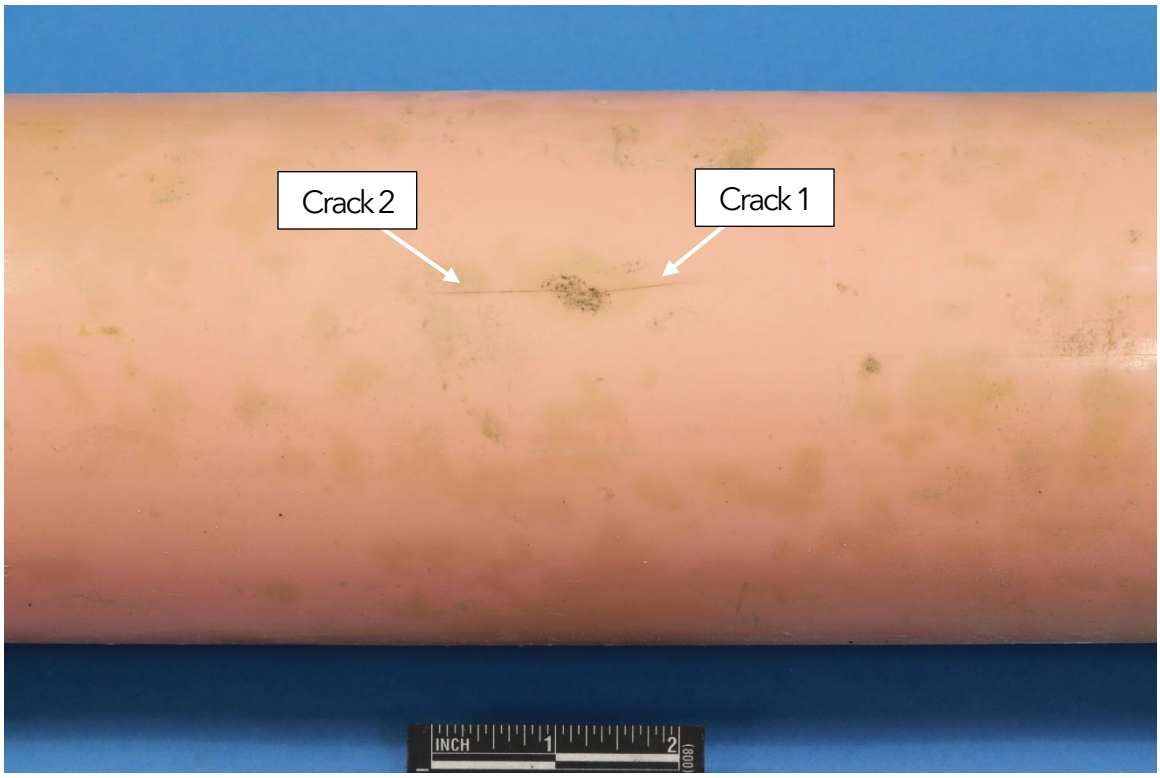
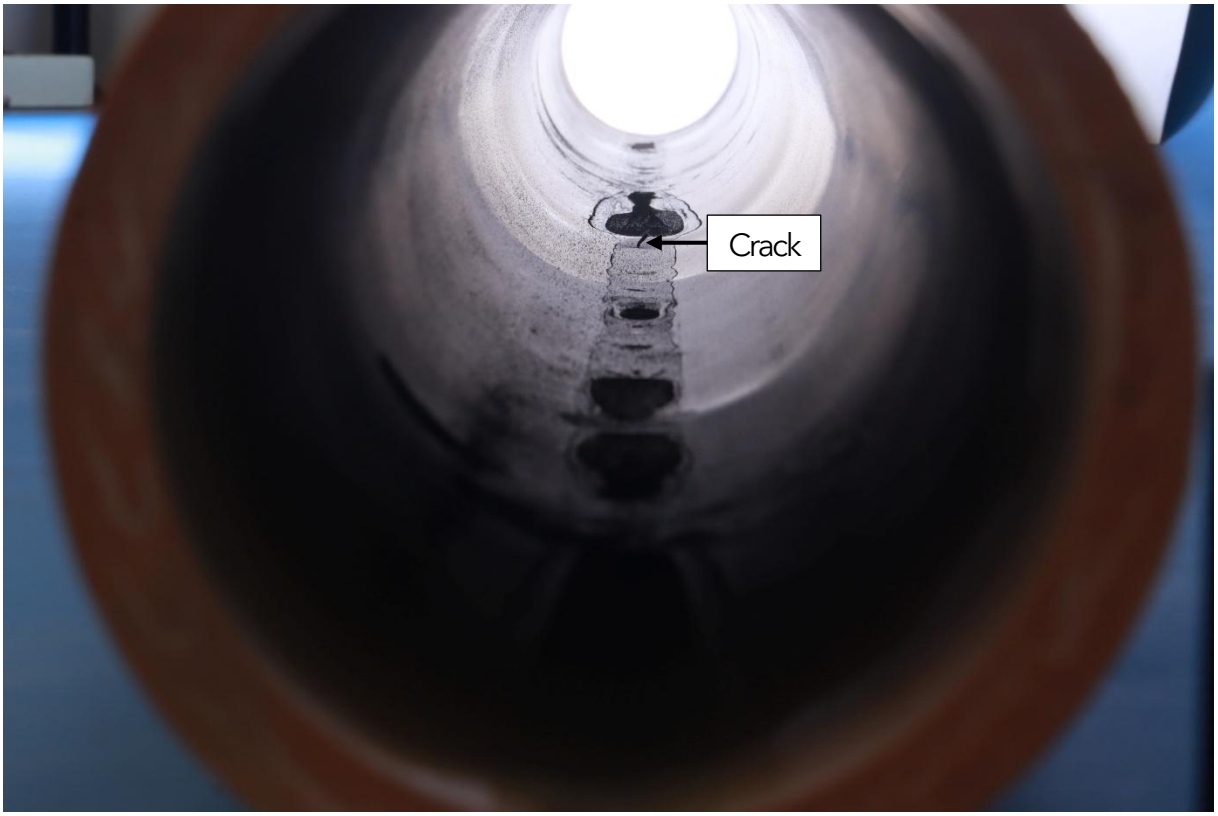


Figure 1. a) Piece of 4-inch Aldyl A pipe as received and b) crack on outer surface of pipe, bottom side as received.

a)



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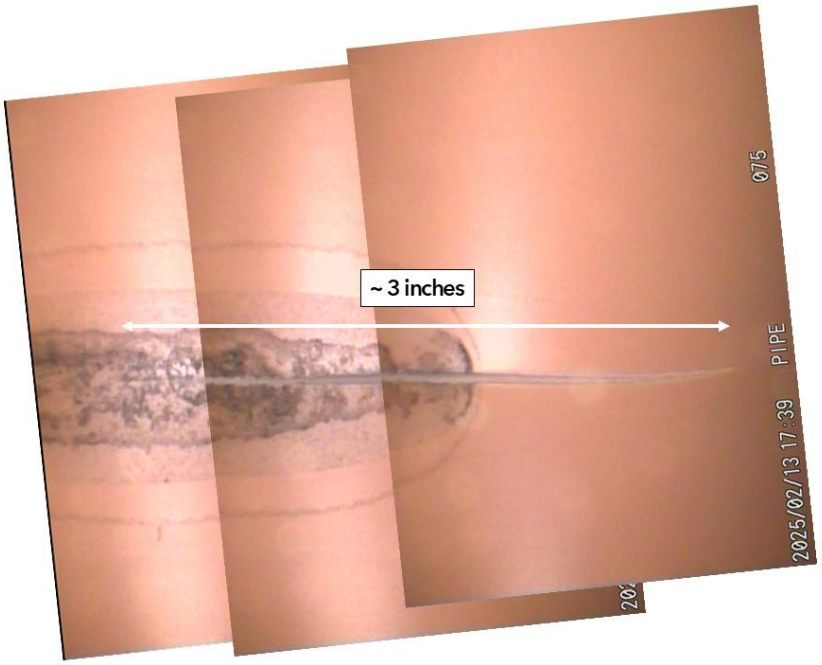


Figure 2. Images of the crack on the inner surface of the pipe, as received: a) looking along the axis of the pipe from end 1 towards end 2 and b) borescope images composited from a probe placed inside the pipe.

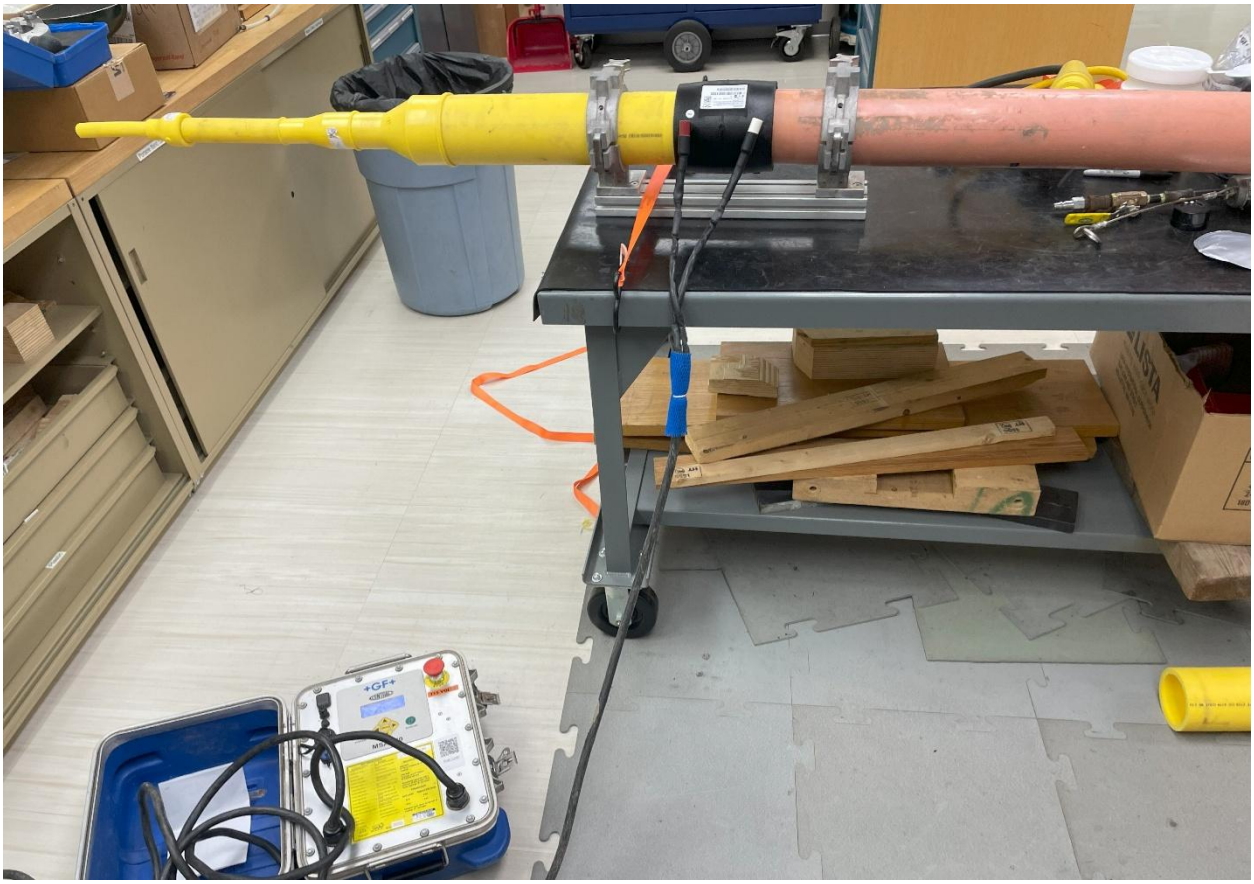
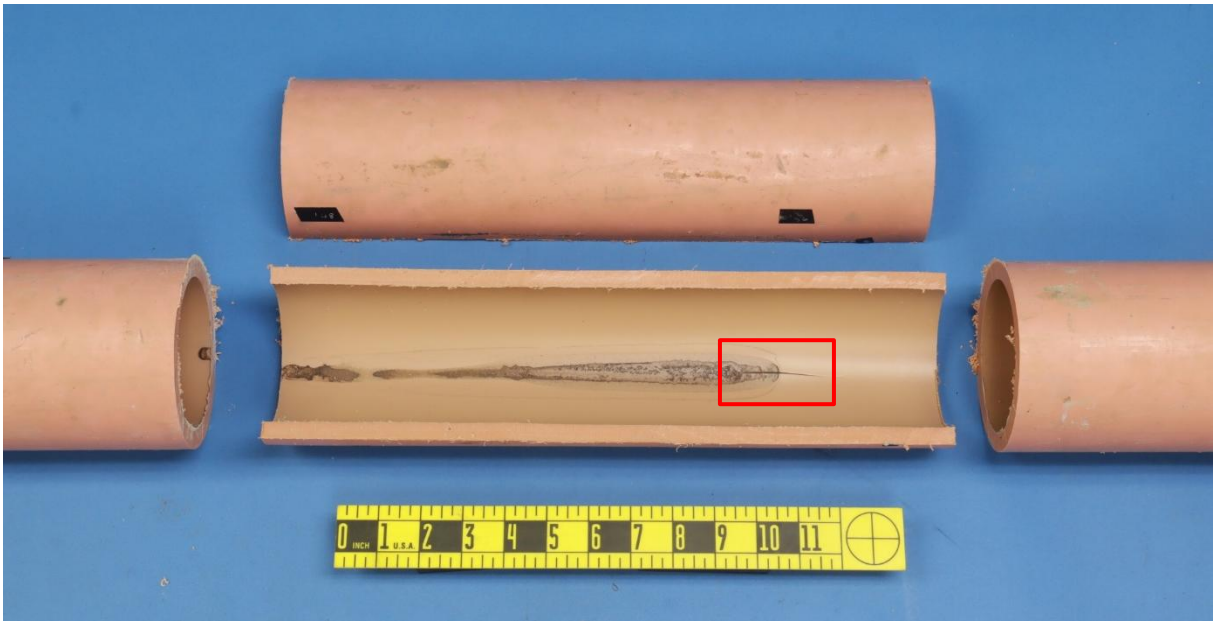


Figure 3. Image of a fusion coupling joined to one end of the pipe segment and one of the end caps. The end was capped by a pressure gage.

a)



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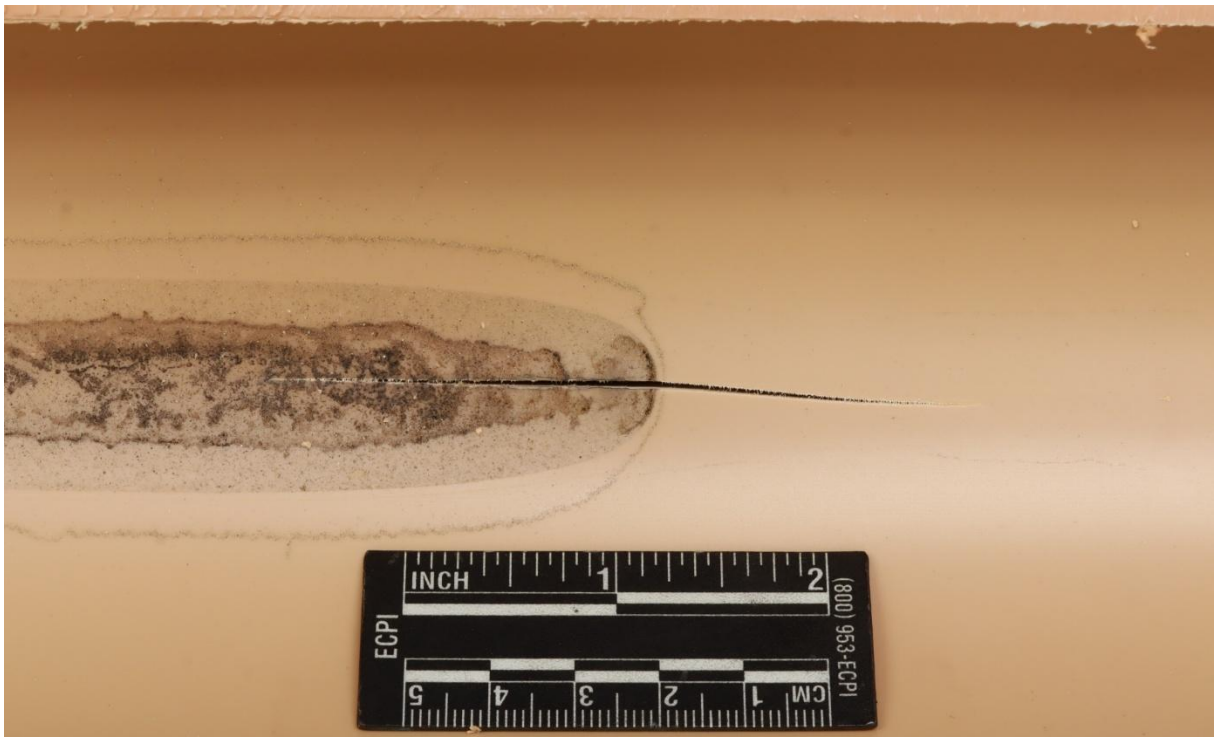
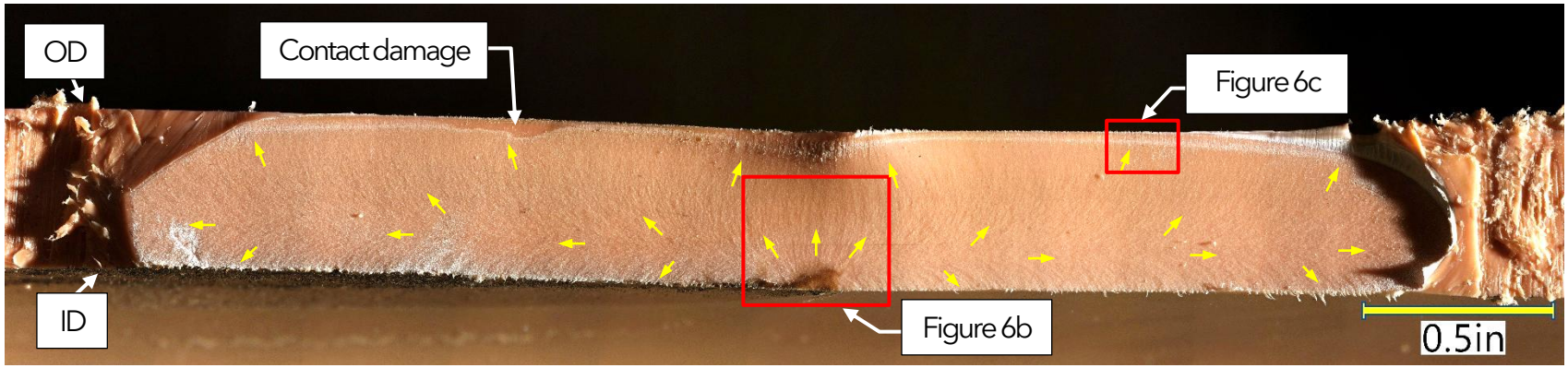


Figure 4. Pipe cut open after the flow rate test, revealing crack on inside surface of pipe: a) overview image and b) image of the crack on the inner surface.

Figure 5. Digital microscope images of the through-wall crack: a) outer surface, taken prior to the flow rate test and b) inner surface, taken after the flow rate test.

a)



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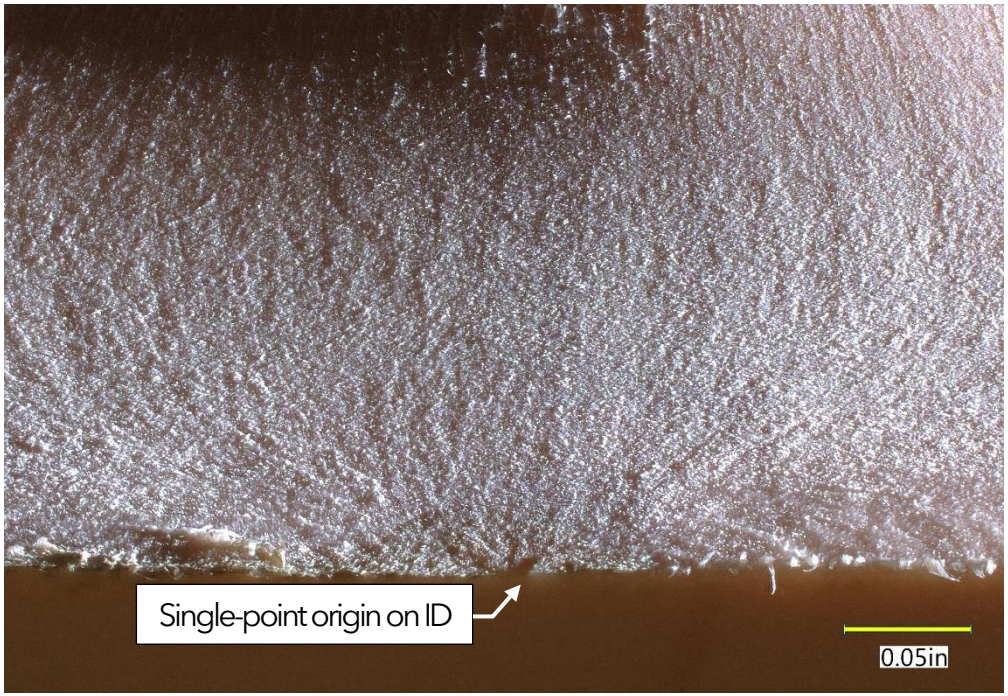


Figure 6. a) Overview image of fracture surface with origin and crack propagation direction annotations and b) closer image of origin.

c)

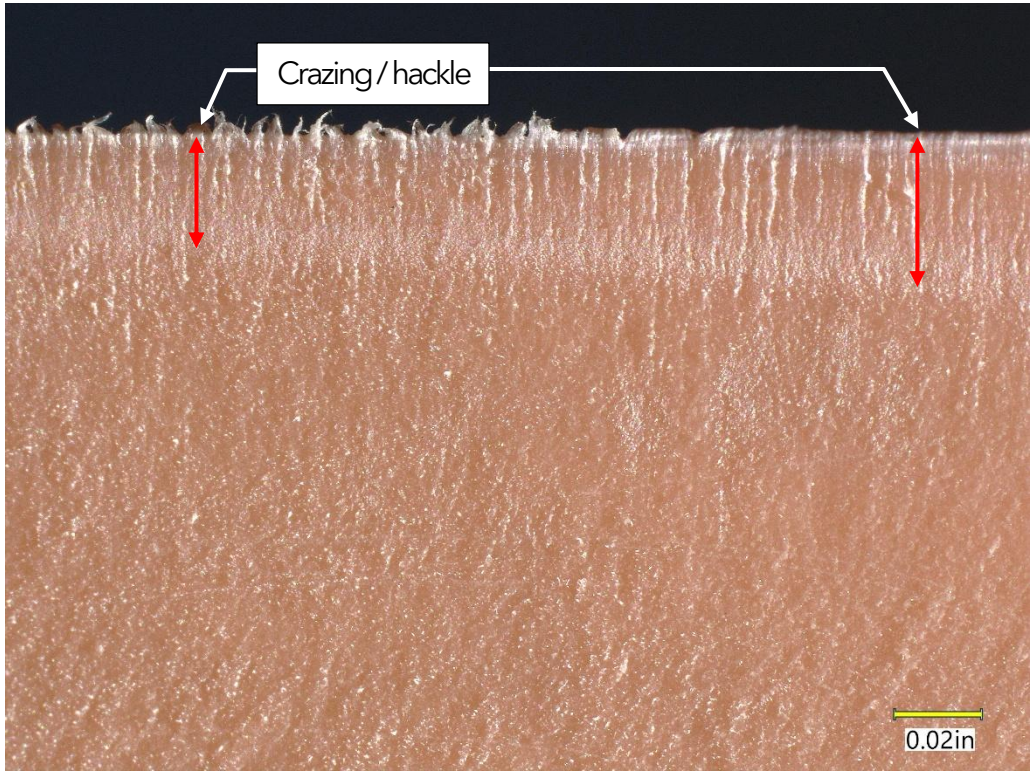
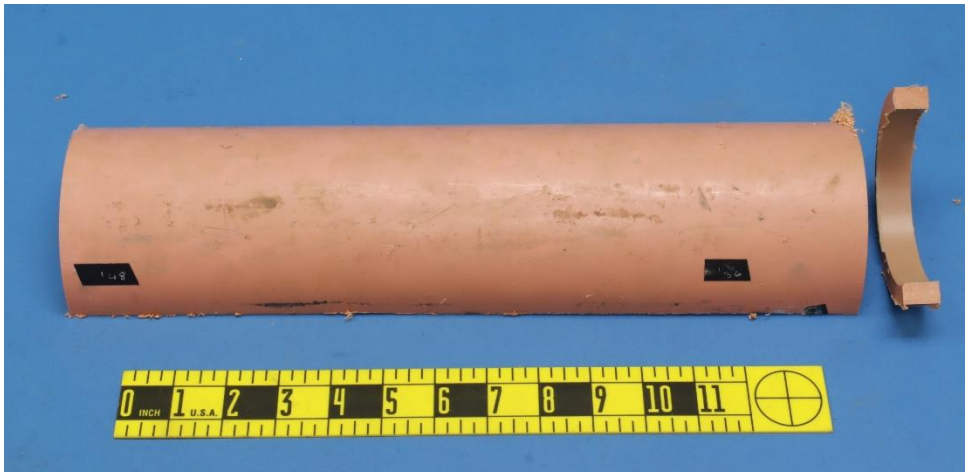


Figure 6 (cont.). c) rougher crazing and hackle features near outer surface.

a)



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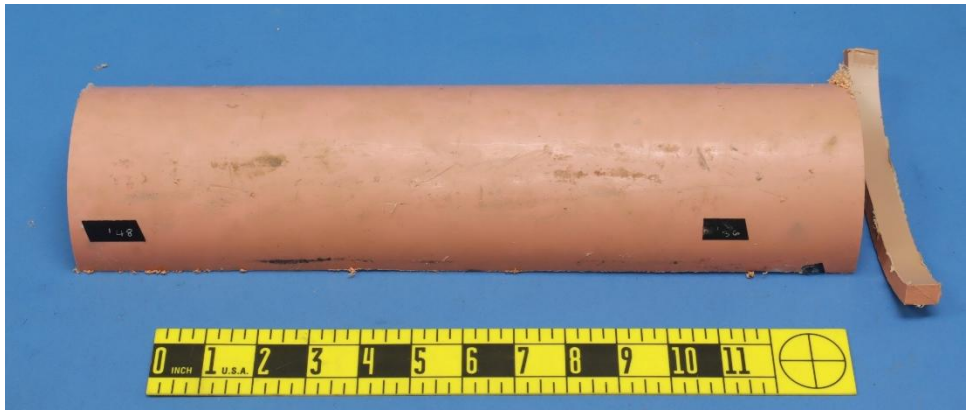

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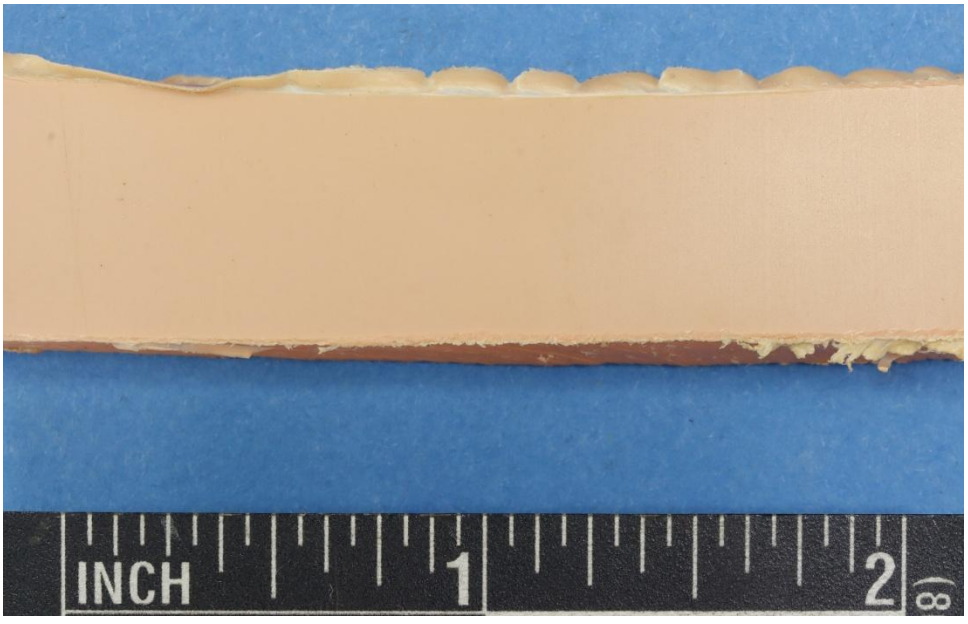

Figure 7. Images showing results of bend-back test: a) strip cut out in before-test condition; b) strip in the after-test condition; and c) closer image of inner surface. No notable features were found.