NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

May 8, 2018

MATERIALS LABORATORY FACTUAL REPORT Report No. 18-005

A. ACCIDENT INFORMATION

Place	:	Millersville, Pennsylvania
Date	:	July 2, 2017
Vehicle	:	Natural gas mechanical tapping tee
NTSB No.	:	DCA17FP006
Investigator	:	Roger Evans (RPH)

B. COMPONENTS EXAMINED

The mechanical tapping tee assembly was excavated from 2253 Firmstone Street, Wilson Boro, Pennsylvania, by the gas service provider, UGI Utilities, on August 15, 2017, as a result of a natural gas leak. This tee assembly was not involved in an accident.

C. DETAILS OF THE EXAMINATION

As-received

Figures 1 through 4 show photographs of the Permalock® mechanical tapping tee assembly and pipe segment that was submitted to the Safety Board Materials Laboratory.[1] UGI determined natural gas was leaking from the tee assembly that was buried underground. The tee assembly was excavated, cutout, and submitted for examination. Two of the four Nylon bolts fractured at the threaded shank portion. The head portion of the fractured Nylon bolts were not submitted and presumed missing.

The tee assembly was manufactured by Perfection Corporation. The polyethylene tapping tee assembly served as the connection between the 2-inch IPS nominal “Aldyl” polyethylene main and the 0.5-inch CTS nominal polyethylene service pipe.[2] The outlet of the tee assembly was connected (by fusion weld) to the excess flow valve (EFV) which is connected (by fusion weld) to a half-stab 0.5-inch CTS nominal diameter Permasert coupling to which the 0.5-inch CTS nominal diameter service pipe is connected. The tower portion of the tee assembly and base portions were manufactured in February 1997. A representative from UGI indicted that this tee assembly was installed on June 9, 1999, see table 1. The

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[1] Permalock is a tradename for a mechanical tapping tee that was manufactured by Perfection Corporation, later known as Elster-Perfection, and now currently owned by Honeywell.
[2] (a) IPS is the designation for Iron Pipe Standard. (b) Aldyl®” is a trademark name that refers to a finished polyethylene pipeline product manufactured by the DuPont chemical company using Dupont’s proprietary Alathon® polymer resin. The Aldyl product line was acquired from Dupont by the Uponor company in 1991. (c) CTS is the designation for Copper Tube Size.

operating pressure was approximately 54 pounds per square inch gauge (psig). According to UGI, this information was derived from hydraulic modeling analysis.

The bolt was specified as Nylon 6/6 with 43% by weight random oriented short glass fiber reinforcement, according to a manufacturer representative for the tee assembly.[3] For the purpose of this report, the Nylon bolts were arbitrarily assigned a number between “1” and “4”, orientation as shown in table 2. The fractured bolts, bolts “2” and “3”, were located on diametrically opposite sides of the tower. One fractured Nylon bolt was located on the outlet side and the other was located on the nonoutlet side. The head portion of fractured bolts were not submitted.

The mating halves of the tee at the corners that contained the two fractured Nylon bolts showed evidence of a gap. The gap between the mating halves of the tee at the corner that contained fractured Nylon bolt “2” measured in the vertical direction approximately 0.256 inch, and the gap between the mating halves of the tee at the corner that contained fractured Nylon bolt “3” measured 0.213 inch. The mating halves of the tee at the corners that contained the two intact Nylon bolts showed no evidence of a gap.

Bolt Torque Measurements

Prior to disassembly of all the submitted tees, the release and locking torque for the Nylon bolts were measured. For the purpose of this report, a release torque is defined as the greatest measured torque value required to loosen the bolt. The locking torque is defined as the greatest measured torque value that is necessary to re-tighten the Nylon bolt to its original installed position. The results of the measured torque values are shown in table 2. The measured release torque values for all the Nylon bolt ranged between 39 inch-pounds (in-lbs) and 43 in-lbs, whereas, the measured locking torque values for all the Nylon bolts ranged between 35 in-lbs. and 36 in-lbs.

Fractured Nylon Bolt Examination

A saw cut was made at the bottom end of both fractured Nylon bolts, so that it intersected the center of each Nylon bolt. A screw driver was inserted into the cut slot at the bottom of each Nylon bolt, and turned until the remnant of the Nylon bolt was unscrewed from the base portion. The fractured Nylon bolt fragments were ultrasonic cleaned in a solution of detergent and water. The shank and thread portions of fractured Nylon bolt “2” showed no visible evidence of elongation (reduction in diameter cross section) in the general area of the fracture face. Figure 5 shows a photograph of the fracture face from Nylon bolt “2”. The fracture face showed no evidence of a fracture origin or general direction of fracture propagation. The fracture face of Nylon bolt “3” showed fracture features that were similar to those of bolt “2”.

Scanning electron microscope (SEM) examination of Nylon bolt “2” revealed the fracture face contained evidence of fracture features on the polymer matrix (Nylon portion of the bolt) and glass fiber portions (see figure 6 and 7). The fracture face on the Nylon bolt (polymer matrix and individual glass fibers) showed no evidence of a pattern that identified a

[3] Perfection engineering specification E-336, titled “Polyamide (Nylon) Screw Injection Molding Resin”.

general direction of fracture propagation. The origin of the Nylon bolt fracture could not be determined, based on the fracture pattern on the polymer matrix or the glass fibers.

Materials Testing of Nylon Bolts

A sample of Nylon bolt "4" was analyzed by differential scanning calorimetry (DSC) to determine the crystalline melting temperature. The DSC work was contracted to NSL Analytical Services, Cleveland, Ohio. Table A1 in Appendix A shows results of the crystalline melting temperature. The crystalline melting temperature of the Nylon bolt sample measured approximately 261 ºC, consistent with the specified material Nylon 6/6 (256 °C).[4]

A sample of Nylon bolt "4" was analyzed to determine the glass fiber content. The glass fiber content was determined from the ash content of each bolt sample, per ASTM D 3418, titled "Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry". The ash content was determined from the weight of glass fiber portions of a bolt sample that was not consumed by ignition. The testing was contracted to NSL Analytical Services. Table A2 in Appendix A shows the results of the testing. The glass content of the tested Nylon bolt was determined to be 43% by weight, consistent with the specified amount (43% by weight).[5]

A samples of Nylon bolt "4" was analyzed by the Gel Permeation Chromatography (GPC) to determine the molecular size distribution, and this work was contracted to Jordi Labs, Mansfield, Massachusetts. The testing data was collected for information purpose. To describe the molecular weight distribution of a polymer numerically, three different molecular weight averages are commonly used. These are the number average molecular weight (M_n), the weight average molecular weight (M_w), and the Z average molecular weight (M_z). M_n provides information about the lowest molecular weight portion of the sample. M_w is the average closest to the center of the curve and M_z represents the highest molecular weight portion of the sample. Table A3 in Appendix A shows the results of the calculated molecular weight averages (M_N, M_W, M_Z, M_WM_N ratio). Polydispersity index (PDI) is the calculated M_WM_N ratio value. The PDI values of all the samples was 3.50.

Cutter Tool and Locking Sleeve

Figure 8 shows a side view of the tee assembly and the exposed inner wall of the main in the area where the cutter tool made pierced a hole in the wall of the main to gasify the service. The cap was removed from the tower of the tee. The distance between the top of the cutter tool and the top of the tower was measured and the results are shown in table 3. The pierced hole in the main showed no evidence of a locking sleeve, and only showed the bare wall of the main. When looking into the saw cut outlet portion of the tee, the cutter tool extended approximately half way down the bore of the outlet. The bottom half portion of the bore showed no evidence of the locking sleeve (see figure 9).

[4] The crystalline melting temperature for type 66 polyamide resin is specified in Perfection engineering specification E-336, titled "Polyamide (Nylon) Screw Injection Molding Resin".
[5] Specified in Perfection engineering specification E336.

A 5/16-inch hex wrench was inserted into top of the cutter tool and turned counterclockwise. The cutter tool was removed from the tower. The locking sleeve was attached to the cutter tool, see figure 10. The bottom hollow portion of the cutter tool contained a round cut-out coupon from the wall of the main. The cutter tool and locking sleeve were pulled apart from each other by hand with constant and steady force. The two pieces were examined after disassembly. The disassembled cutter tool and locking sleeve showed no evidence of mechanical damage.

The size of the cutter tool and locking sleeve are specified in Perfection Corporation engineering drawing number 53778. Revision D. The specified and measured size of the outer diameter of the cutter tool and inner diameter of the locking sleeve are shown in table 4. The measured outer diameter of the cutter tool and inner diameter of the locking sleeve were within the specified size.

Examination of the cutter tool revealed the outer surface, the slot for the O-ring, and O-ring, were covered with a transparent film, consistent with silicone, and contained no evidence of granular-like particles (such as soil). Portions of the shank was covered with a brown transparent film, similar to a film of silicone (see figure 11). The size of the O-ring for the cutter tool is specified in Perfection Corporation engineering drawing number 53778, Revision D, titled ‘Cutter Assembly Ratchet for 2”, 3”, 4” & 6” PMTT’. The size of the O-ring for the cutter tool was measured and the results are shown in table 5. The size of the cutter tool O-ring was within the specified range. Examination of the locking sleeve revealed the inner surface contained a dry and transparent film that circumferentially oriented relative to the length of the locking sleeve (see figure 12). A sample of the film was removed from the inner surface of the locking sleeve. EDS spectrum of this film contained major elemental peaks of carbon, silicon, oxygen, and minor peaks of zinc, iron, chromium, and titanium (see Appendix B1).

Disassembly of the Tee Assembly

The tee assembly was disassembled from the main (see figure 13). The tee showed no evidence of cracks. The top portion of the main contained longitudinal scratches that intersected the pierced hole in the main. The saddle O-ring was firmly attached to the mating groove that was located at the underside of the tower. The O-ring was peeled off the groove with the assistance of the tip of a screwdriver. The saddle O-ring was found on top of the main. The size of the saddle O-ring is specified in Perfection Corporation engineering drawing number 53942, Revision B, titled ‘Contoured O-ring 2” IPS PMTT’. The size of the saddle O-ring was measured with a caliper and the results are shown in table 6. The inside diameter of the saddle O-ring was slightly less than the specified size (see table 6). The saddle O-ring contained evidence of a parting line and minor squeeze-out from the molding process all around the circumference at the inner and outer diameter surface. The inside diameter of the O-ring included the squeeze-out portion. Although only a thickness is specified for the saddle O-ring, the height and width of the O-ring were measured. The measured height of the saddle O-ring was slightly less than the specified thickness and the measured width of the saddle O-ring was slightly greater than the specified thickness.

Detailed bench binocular microscope examination of the main revealed the pierced hole contained circumferential fine cut marks with no evidence of threads, see figures 14 and 15. The diameter of the pierced hole measured approximately 0.71 inch (see table 7).

Size of Main and Service Pipes

The length of each main segment measured approximately 30 inches. The specified size and measured values for the pipes are shown in tables 8 and 9. The measured size of the main was within the specified size. The tee was placed on a flat table such that the concave side of the main was facing the table. The distance between the outer wall of the main and the table was measured with a ruler. The distance between the outer wall of the main facing the table and the top surface of the table measured approximately 0.5 inch.

Frank Zakar
Senior Metallurgist

Table 1 Tapping Tee Information			
Dwelling	Manufacture Date	Installation Date (month/day/year)	Approximate years in Service
2253	02/1999	6/9/1999	18

Table 2 Measured Torque Values for Bolts (Inch-Pounds)								
Dwelling	Bolt							
	1		2		3		4	
	Release	Locking	Release	Locking	Release	Locking	Release	Locking
2253	39	35	Fractured		Fractured		43	36

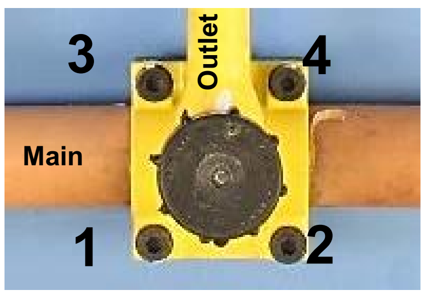


Table 3 Top Surface of Cutter and Locking Sleeve Measured Relative to Top of Tower (Inches)			
Dwelling	Cutter		Locking Sleeve
	Specified	Measured (top of cutter to top of tower)	
2253	Flush to 1/8 inch above the top surface of the tower per manufacturer written instructions	0.14	Cutter tool remained attached to locking sleeve

Table 4 Cutter Assembly Dimensions (Inches)				
Dwelling	Locking Sleeve Inside Diameter		Cutter Tool Outside Diameter	
	Specified	Measured	Specified	Measured
2253	0.7935 - 0.7965	0.7935	0.788 – 0.792	0.790

Table 5 Cutter Tool O-Ring Dimensions (Inches)					
Dwelling	Thickness			Inside Diameter	
	Specified	Measured Width	Measured Height	Specified	Measured
2253	0.067 - 0.073	0.07	0.07	0.605 - 0.684	0.6485

Table 6 Saddle O-Ring Dimensions (Inches)					
Dwelling	Thickness			Inside Diameter	
	Specified	Measured Width	Measured Height	Specified	Measured
2253	0.205 - 0.215	0.22	0.194	1.323 - 1.343	1.319

Table 7 Measured Diameter of Pierced Hole Found in the Main (Inches)	
Dwelling 2253	0.73 – 0.74 Pierced Hole was <u>not</u> threaded

Table 8 PE Tubing Outer Diameter (Inches)			
Pipe	Specified	Method of Measure	Measured
1/2-inch CTS Nominal Tubing Size	0.621 - 0.629	Caliper	0.624
2-inch IPS Nominal Pipe Size	2.369 - 2.381	Pi Tape	2.38

Table 9 PE Tubing Thickness (Inches)			
Pipe	Specified	Method of Measure	Measured
1/2-inch CTS Nominal Tubing Size	0.090-0.099	Caliper	0.095
2-inch IPS Nominal Pipe Size	0.216 - 0.242	Ball-Flat Micrometer	0.225

APPENDIX A

Crystalline Melting Temperature,
Glass Fiber Content,
Molecular Weight Distribution

Table A1
Crystalline Melting Temperature
Using Differential Scanning Calorimeter Method

Bolt Description, Vintage in Month/year	Specified Bolt Material	Typical Crystalline Melting Temp. (°C)	Measured Melting Point 1st Heating Scan (°C)	Consistent With Manufacturer Specification?
Intact Bolt "4" Dwelling 2253 Vintage 2/1999	Nylon 6/6	256	261	Yes

Table A2
Glass Fiber Reinforcement Content
Using Differential Scanning Calorimeter Method

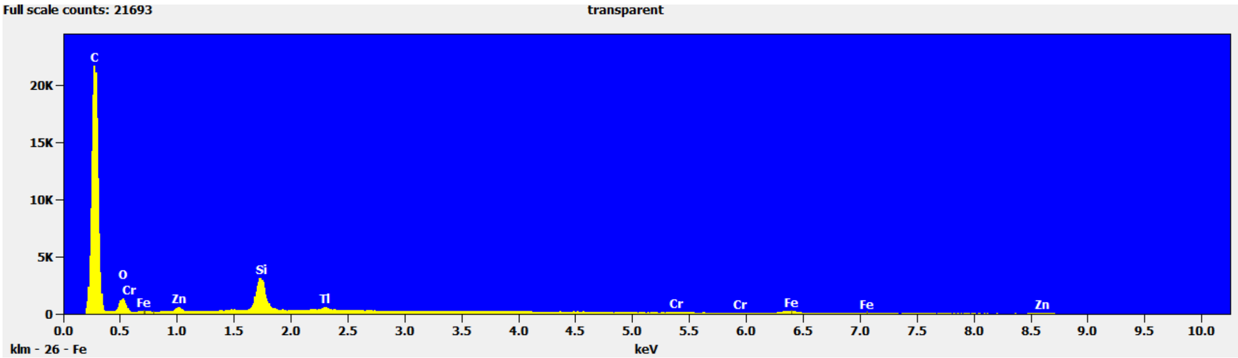
Bolt Description, Vintage in Month/year	Specified Bolt Material	Specified Glass Fiber Reinforcement (Weight %)	Measured Ash Content After Ignition (Weight %)	Consistent With Manufacturer Specification?
Intact Bolt "4" Dwelling 2253 Vintage 2/1999	Nylon 6/6	43	43	Yes

Table A3
Average Molecular Weight (Daltons)
Relative to polystyrene standards

Bolt Description, Vintage in Month/year	M_n	M_w	M_z	M_w/M_n
Intact Bolt "4" Dwelling 2253 Vintage 2/1999	8,971	31,423	80,641	3.50

APPENDIX B

EDS Spectrum



Appendix B1. EDS spectrum of a narrow transparent film that was found on the inner surface of the locking sleeve showing major elemental peaks of carbon, silicon, oxygen, and minor peaks of zinc, iron, chromium, and titanium.

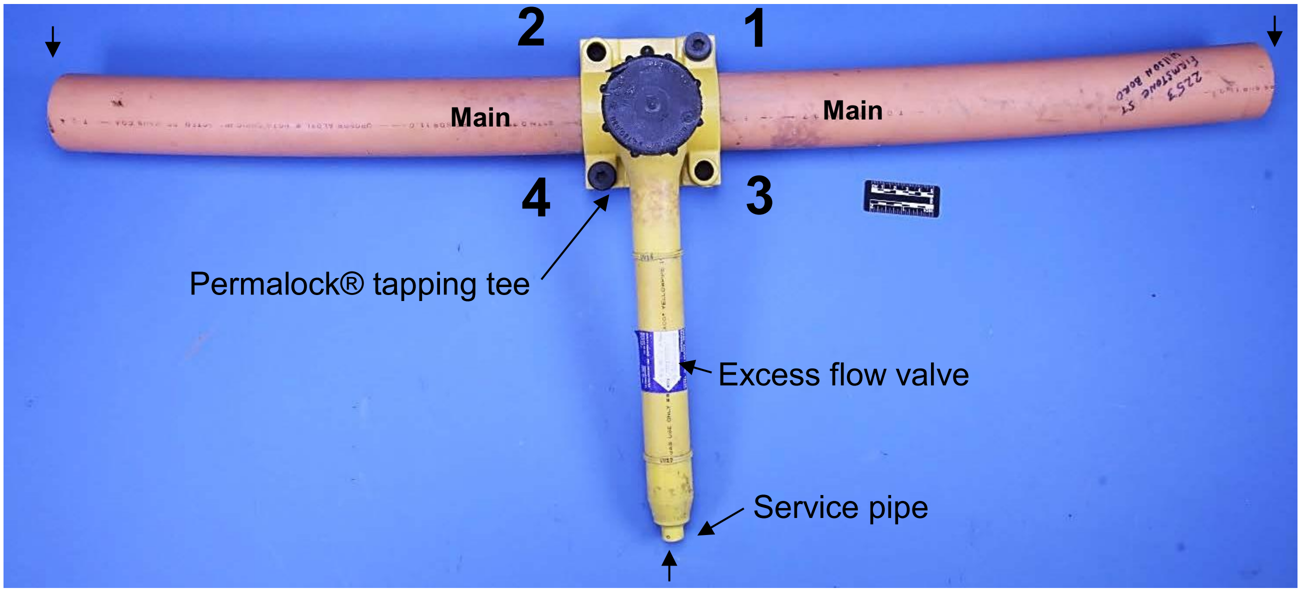


Figure 1. Photograph of the mechanical tapping tee, shown after brush cleaning with water, and identification numbers that were arbitrarily assigned to the Nylon bolts, “1” through “4”. Bolts “2” and “3” fractured at the thread portion. Arrows indicate cut portions of pipes to facilitate transportation and handling.

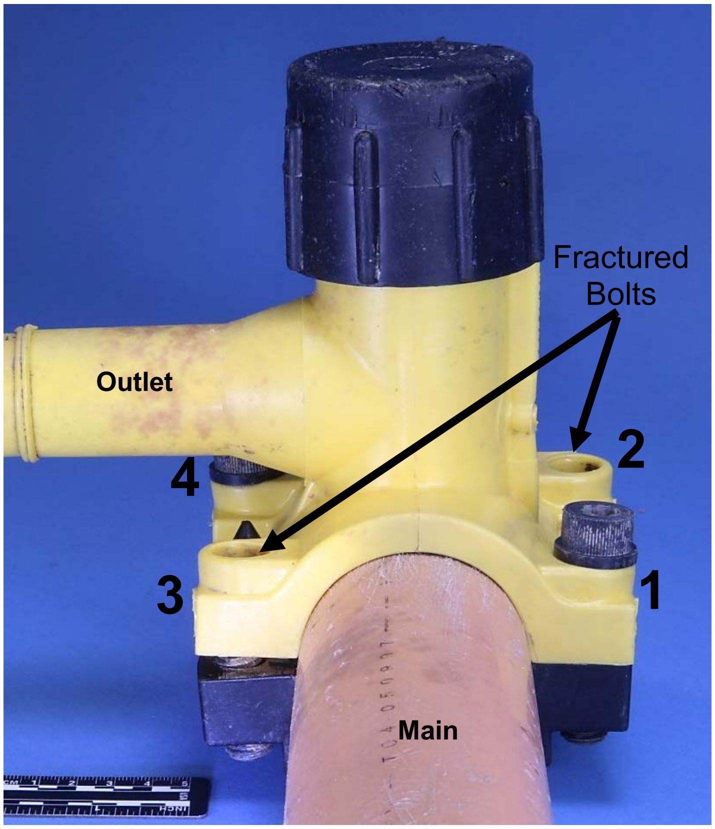


Figure 2. Side view of the tee assembly showing fractured bolts “2” and “3”.

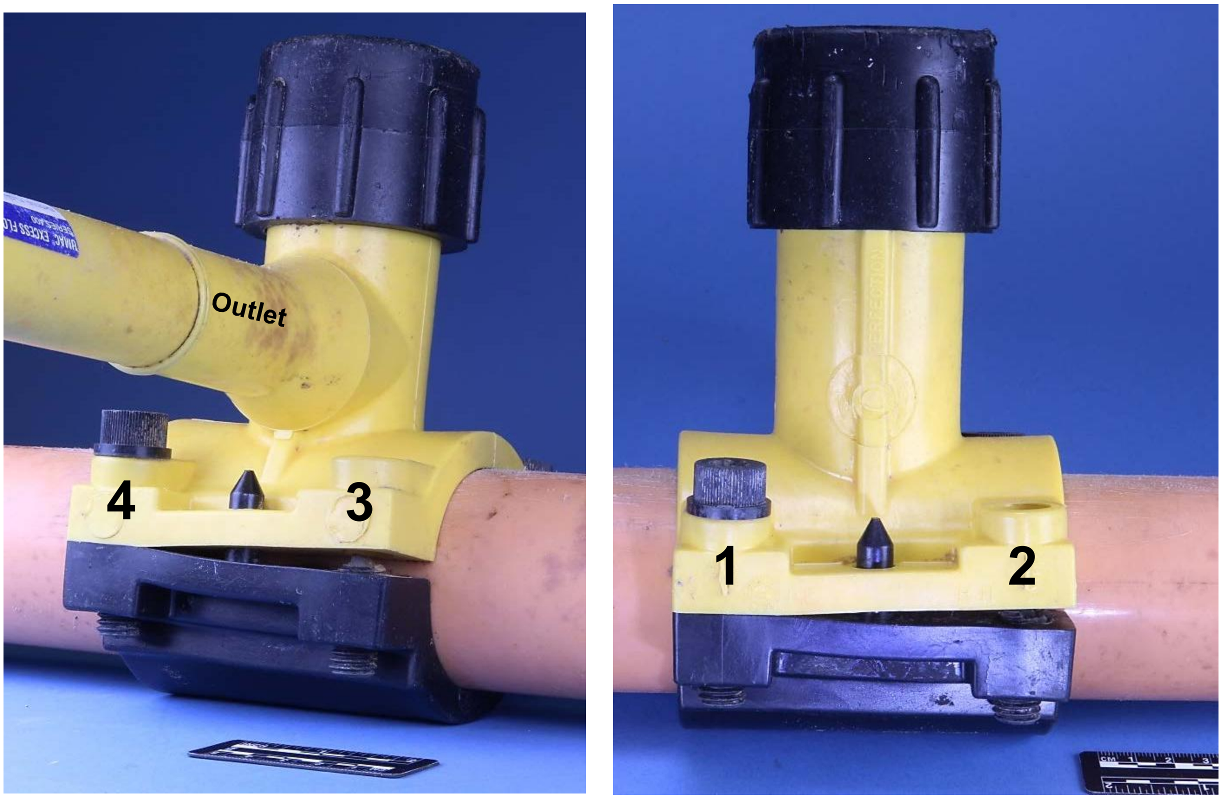


Figure 3. Other views of the tee assembly showing fractured bolts “2” and “3”.

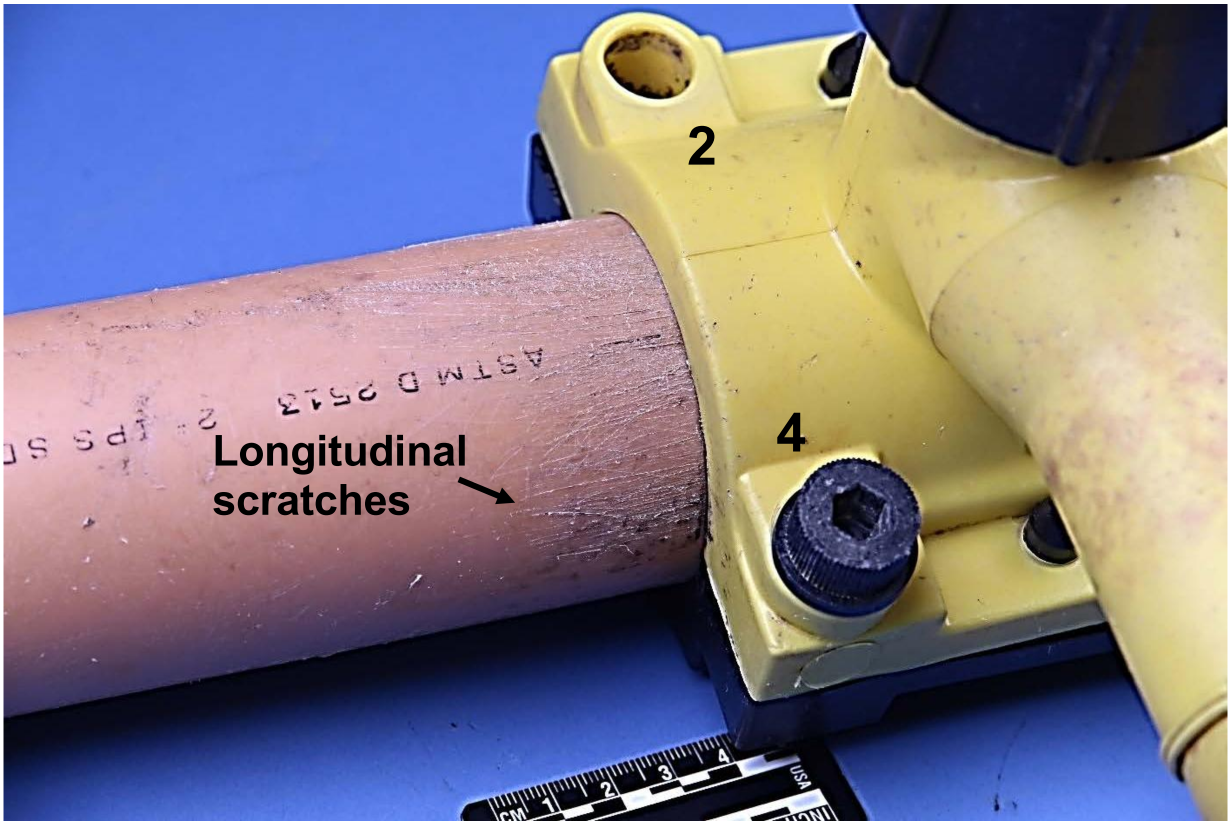


Figure 4. Close-up view of the top portion of the main showing longitudinal scratches that extend out of the tee assembly.

Figure 5. Fracture face of bolt “2” after ultrasonic cleaning.

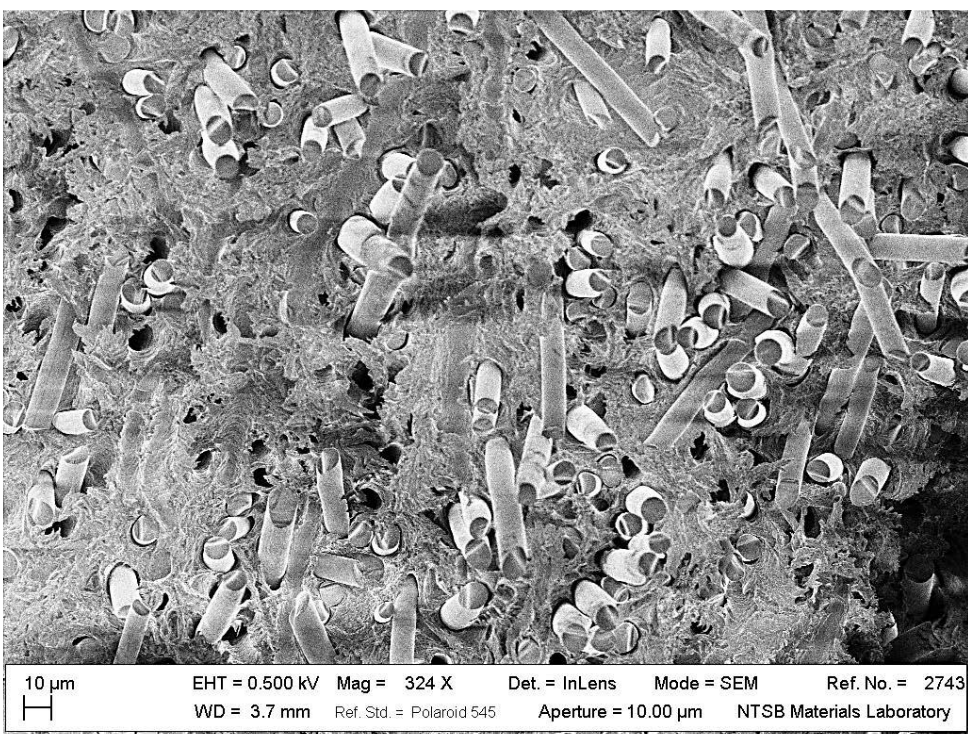


Figure 6. Scanning electron microscope (SEM) photograph of a portion of the fracture face from Nylon bolt “2” showing the matrix (Nylon) and the end of several fractured glass fibers.

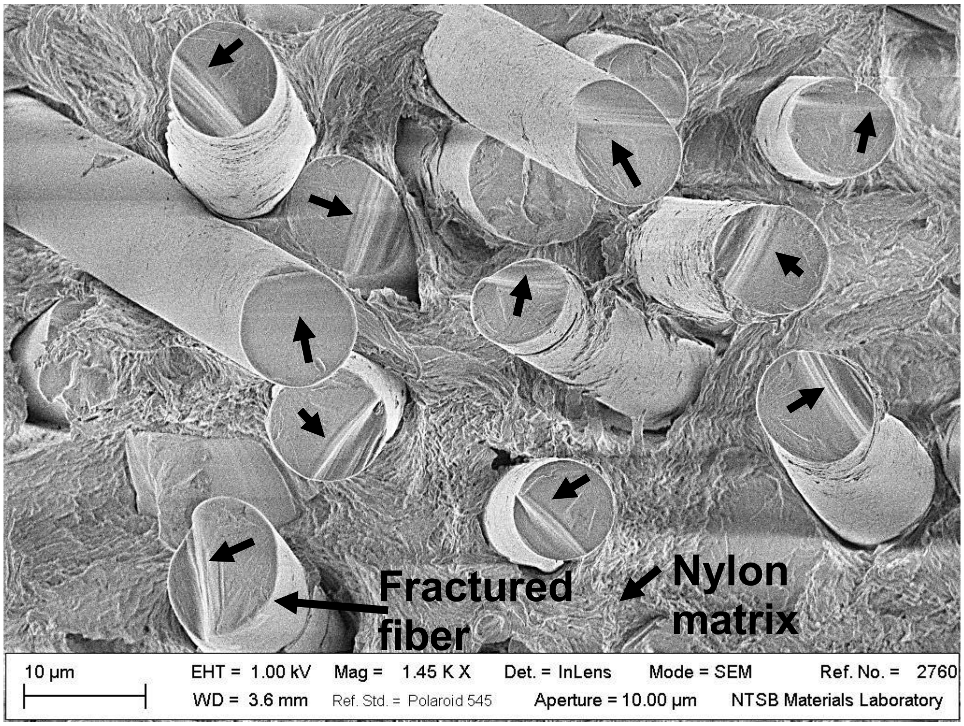


Figure 7. Scanning electron microscope (SEM) photograph of a portion of the fracture face from Nylon bolt “2” showing the matrix (Nylon) and the end of several fractured glass fibers. Arrows indicate general direction of fracture propagation on each fractured glass fiber.

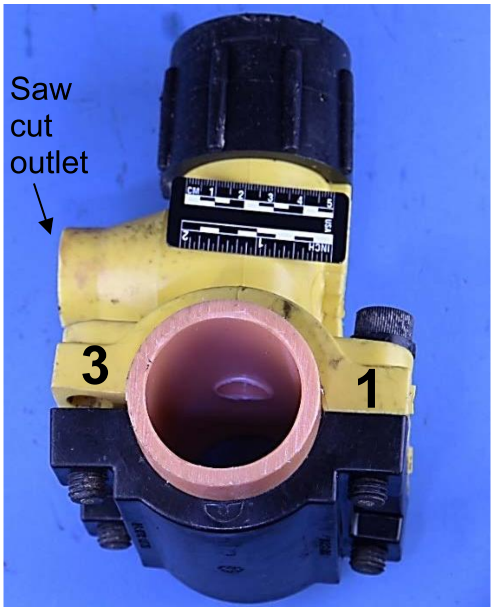


Figure 8. Photograph of the tee assembly showing the exposed inner wall of the main in the area where the cutter tool pierced a hole in the wall of the main to gasify the service. The wall of the pierced hole was bare and showed no evidence of a locking sleeve.

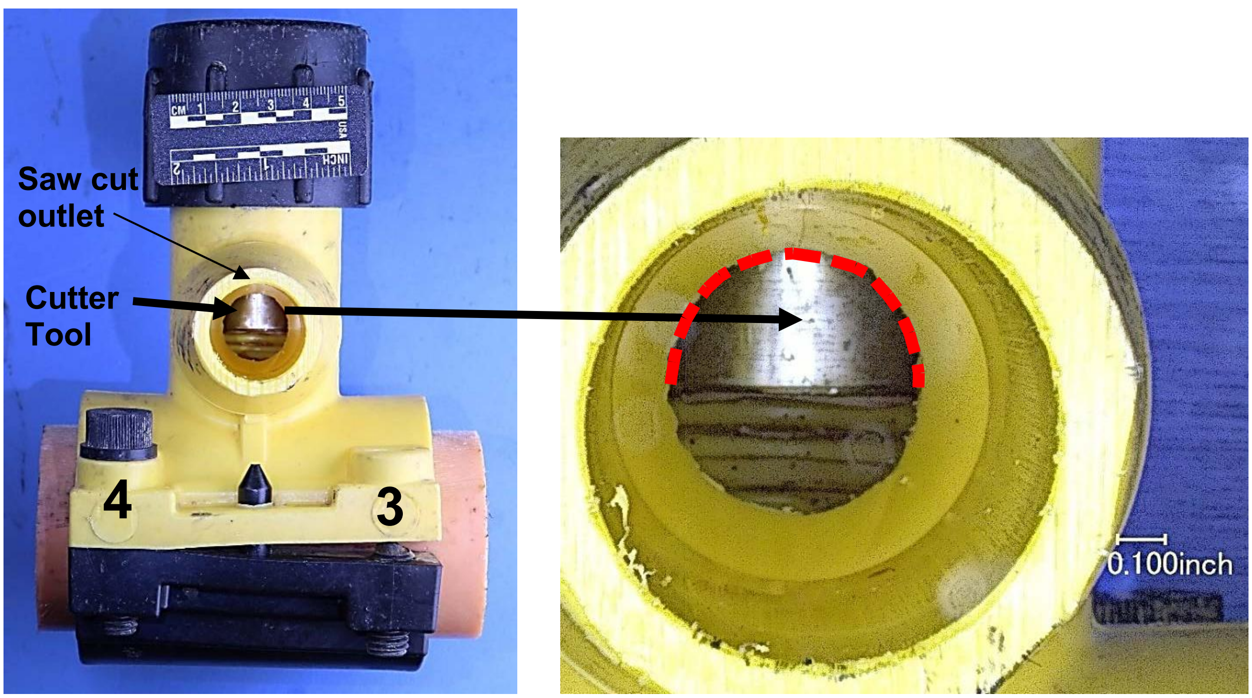


Figure 9. Photograph of a portion of the tapping tee assembly looking in the saw cut outlet showing the bottom end of the cutter tool that extended approximately half way down the outlet (left side of page). A close-up photograph of the same cutter tool (right side of page) shows the portion of the cutter tool that was exposed through to the outlet highlighted by the red dashed line.

Figure 10. Photograph of the extracted cutter assembly. The area enclosed by a red dashed line represents the portion of the cutter tool that was exposed in the outlet (see figure 9).

Figure 11. Photograph of a portion of the cutter tool after disassembly showing the outer shank surface adjacent and below the cutter O-ring.

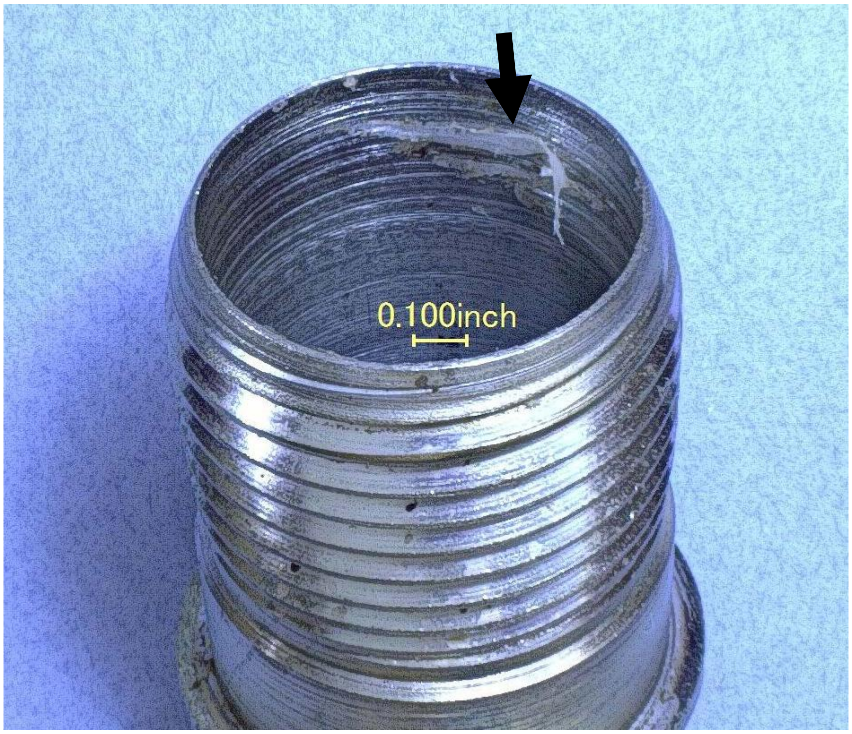


Figure 12. Photograph of the disassembled locking sleeve showing the inner surface and a transparent particle (film) that was circumferentially oriented, indicated by an arrow.

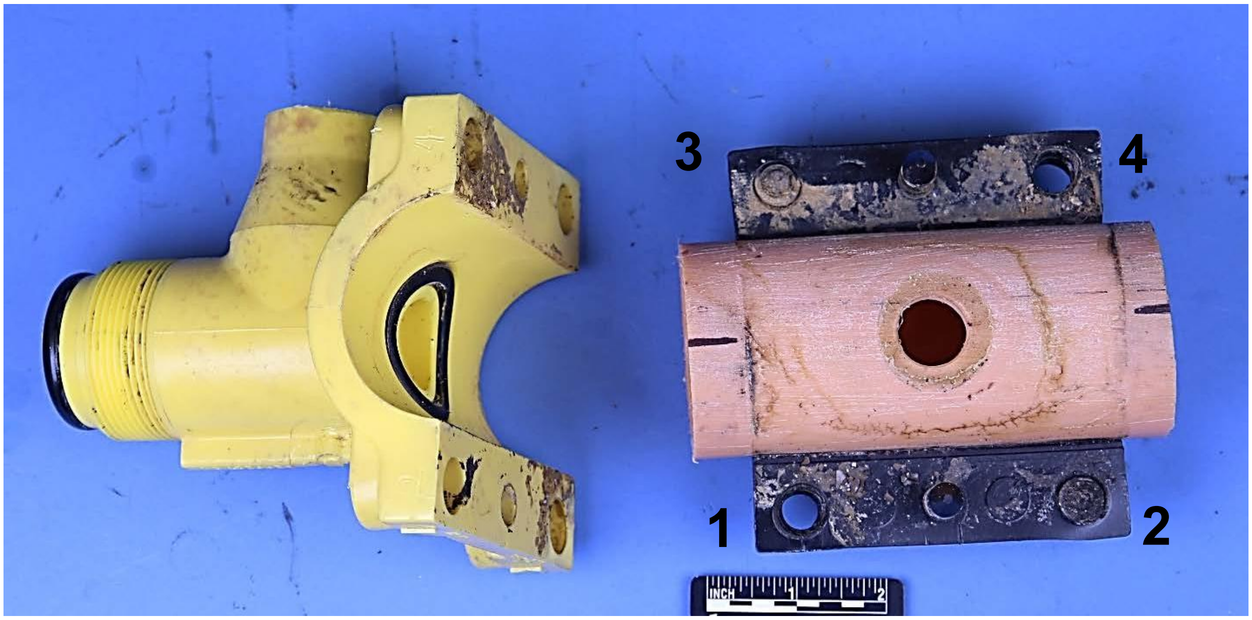


Figure 13. Photograph of the disassembled tee showing the top exposed surface of the main and pierced hole. The top portion of the main contained longitudinal scratches that intersected the pierced hole in the main.

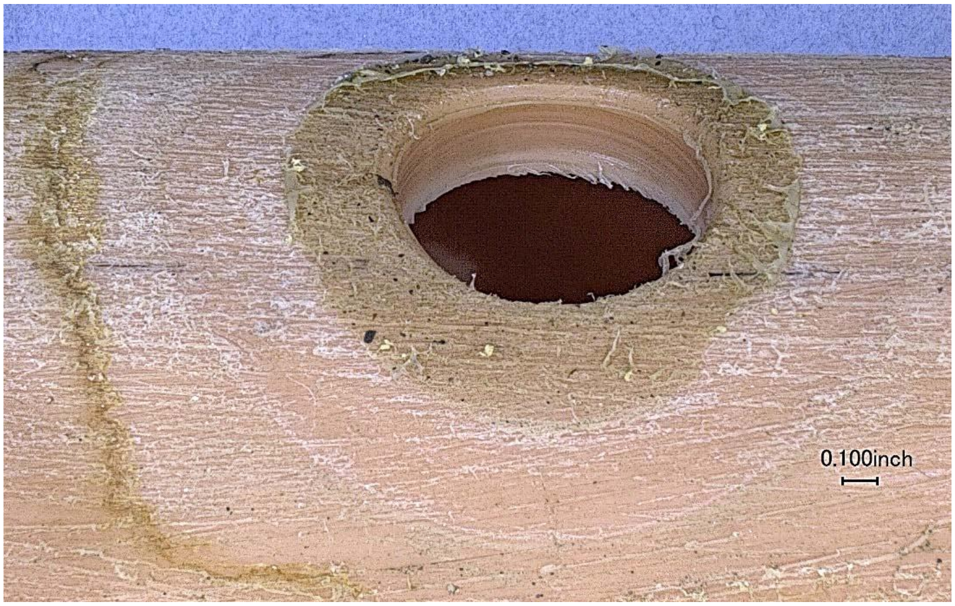


Figure 14. Photograph of the exposed outer top surface of the main after disassembly of the tee showing the pierced hole made by the cutter tool. Note the fine circular cut marks within the pierced hole and the absence of threads.

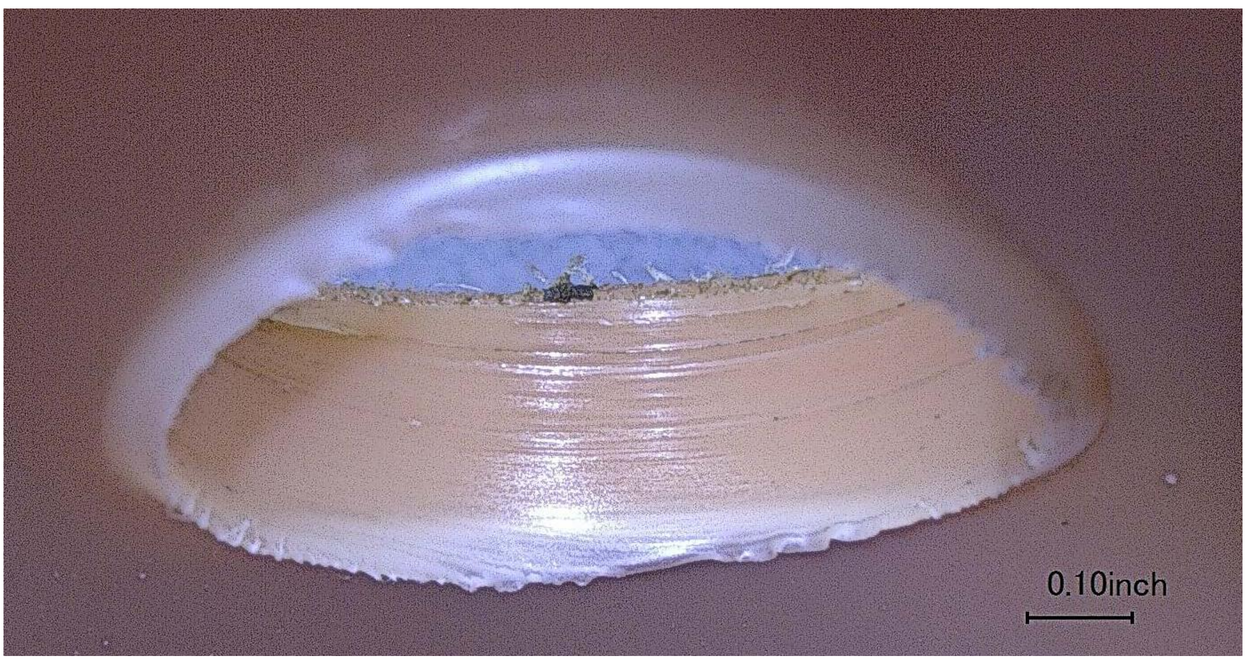


Figure 15. Photograph of the exposed inner surface of the main after disassembly of the tee showing the pierced hole made by the cutter tool. Note the fine circular cut marks within the pierced hole and the absence of threads.