National Transportation Safety Board

Washington, DC 20594

Safety Recommendation Report

Installation of PermaLock Mechanical Tapping Tee Assemblies

Accident/Incident Number:	DCA17FP006
Operator:	UGI Utilities, Inc.
Accident:	Residential Natural Gas Explosion
Location:	Millersville, Pennsylvania
Date:	July 2, 2017
Recommendation Number:	P-18-1 through -4
Adopted:	June 18, 2018

The National Transportation Safety Board (NTSB) is providing the following information to urge the Pipeline and Hazardous Materials Safety Administration (PHMSA) and Honeywell to take action on safety recommendations intended to prevent the incorrect installation of PermaLock mechanical tapping tee assemblies in gas distribution systems. These recommendations are derived from our ongoing investigation of a fatal accident involving a natural gas explosion and fire in Millersville, Pennsylvania. The NTSB is issuing two recommendations to PHMSA and two recommendations to Honeywell.

Ongoing Investigation

On July 2, 2017, at 12:32 p.m. eastern standard time, a natural gas explosion and fire destroyed a single-family residence at 206 Springdale Lane, in Millersville, Pennsylvania. One person died, and three people were injured. Two nearby residences were severely damaged and condemned for demolition. The NTSB investigation is ongoing, and the cause of the accident has not been determined.

UGI Utilities, Inc. (UGI) supplied natural gas to the Millersville residences through a plastic natural gas pipeline (main) and service lines, which UGI operated at a pressure of 54 pounds per square inch, gauge. The main was 2 inches in diameter and made of Aldyl polyethylene; the 0.50-inch diameter service lines were made of polyethylene. Postaccident, the main and service lines at the accident site were pressure tested, which indicated that a PermaLock mechanical tapping tee assembly was leaking gas at the connection of the tee assembly to the main in front of the destroyed residence. UGI installed the tee assembly in June of 1998; it had been in service for 19 years when the accident occurred. (See figure.)

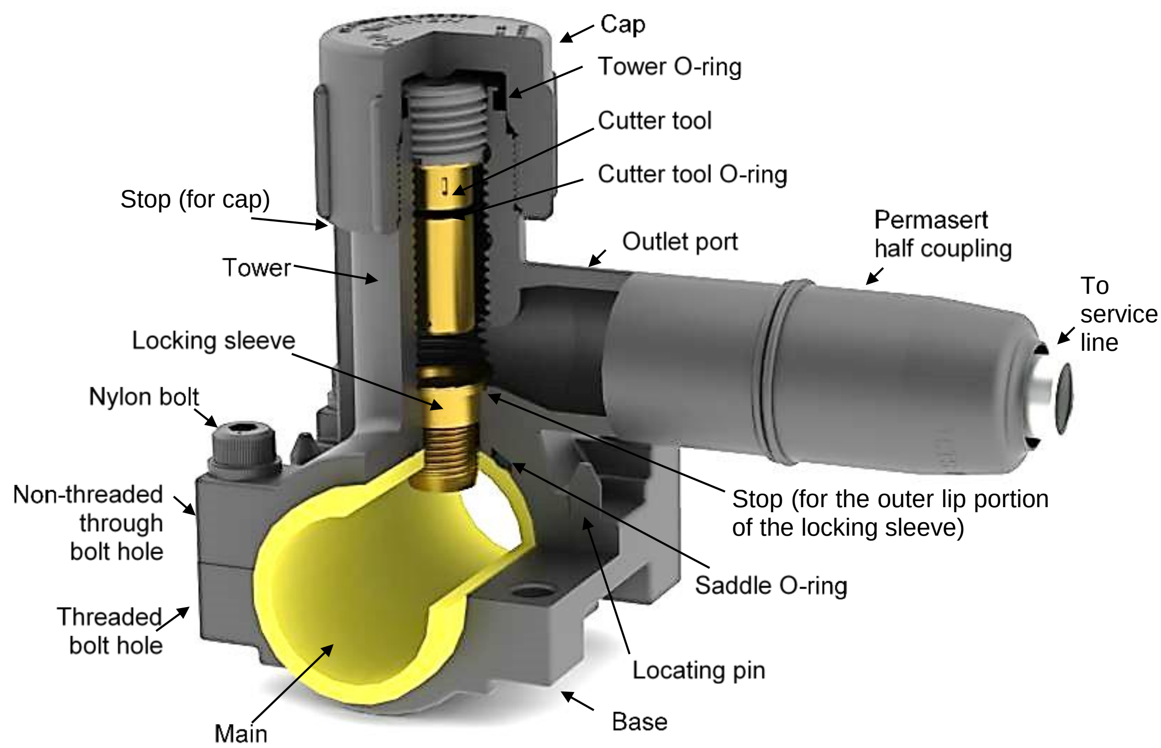

Figure. Cross-section diagram of an exemplar PermaLock mechanical tapping tee assembly, provided by Honeywell.

PermaLock Mechanical Tapping Tee Assembly

Perfection Corporation, later known as Elster Perfection Corporation, which is currently a division of Honeywell, manufactured the PermaLock mechanical tapping tee assembly involved in the accident.[1] Since 1987, three versions of the PermaLock tee assembly have been manufactured, and millions of the tee assemblies have been sold worldwide.[2] Each of the three versions has a different cutter tool design and method of attaching the tower to the main. The tee assembly in this accident was manufactured in 1998; it was the third version. The tee assembly was made of medium density polyethylene and consisted of a tower (upper half) and a base (lower

[1] For simplicity, in this report, the NTSB will use Honeywell as the umbrella company name encompassing the Elster Perfection Corporation and the Perfection Corporation.

[2] The first version of the PermaLock tee assembly had a flat cap and a one-piece cutter design that projected into the main; it was manufactured from 1987 to 1990. The second version had a domed cap and a cutter with a retractable center piece; it was manufactured from 1990 to 1996. The third version has a flat cap, a cutter tool, and a locking sleeve, and it is shipped with a depth tube; manufacturing of this version began in 1995 and continues today, in 2018.

half) joined together around the outer surface of a main by four Nylon 6/6 bolts.[3] The tower contained an internal circular steel cutter tool and a steel locking sleeve.[4]

Honeywell ships the third version of the tee assembly with general written installation instructions and a plastic depth tube.[5] The depth tube is provided so that the person installing the tee assembly can verify that the locking sleeve attaches to the main. According to the written instructions, the cutter tool pierces a hole in the main, and the locking sleeve attaches the tower to the main. The cutter tool is then decoupled (separated) from the locking sleeve and remains stored in the tower for the service life of the tee assembly.

NTSB examination of the PermaLock tee assembly involved in the accident has revealed that the tee assembly was incorrectly installed. Although the cutter tool pierced a hole in the main, the locking sleeve did not progress down far enough into the tower to form threads in that hole. As a result, the locking sleeve was not attached to the main.[6] The NTSB also found that two of the four Nylon bolts on the tee assembly were fractured in a manner consistent with *slow crack growth*.[7] These findings indicate the likelihood of varying tee assembly installation techniques.

Installation Instructions

Honeywell's written installation instructions, which are shipped with the third version of the PermaLock tee assembly, describe the general requirements of the installation, but they do not specify all of the necessary details to properly accomplish the installation and ensure that the locking sleeve attaches to the main.[8] Honeywell also produced an instructional video on the installation of the third version of the PermaLock tee assembly.[9] In the video, the instructor explains that using shorter wrenches allows the person installing the tee assembly to better sense resistance on the wrench handle during the various installation phases. The instructor further explains that using longer wrenches reduces that ability to sense the various installation phases via the wrench handle. However, the instructor does not specify the appropriate size of the wrench that should be used. In reviewing the written instructions and the instructional video for the tee assembly involved in the accident, the NTSB has found that the different formats provided varying

[3] (a) Starting in 2001, the bolt material on the third version was upgraded to Nylon 11. Beginning in 2005, the third version of the tee assembly was upgraded to and made of high density polyethylene. (b) Honeywell also offers accessories for the third version, such as stainless steel bolts and nuts for use in lieu of the Nylon bolts for tee assemblies installed on 1.25-inch diameter and 2-inch diameter mains.

[4] When joined together, the cutter tool and the locking sleeve are referred to as the cutter assembly.

[5] The specified length of the depth tube varies in accordance with the various tee assembly sizes.

[6] NTSB x-ray computed tomography images and post disassembly inspection of the tee assembly confirmed this condition.

[7] *Slow crack growth*, also known as stress rupture, occurs when sustained tensile stresses in parts made from polymeric materials enable a network of fine craze cracks that coalesce and propagate with time, ultimately resulting in fracture of the part. See K. G. Budinski and M. K. Budinski, *Engineering Materials: Properties and Selection*, 9th ed. (Upper Saddle River, New Jersey: Prentice Hall, 2010: 275-278).

[8] A copy of these instructions is available in the docket for the Millersville accident investigation; see the NTSB Docket Management System and search for accident ID DCA17FP006.

[9] The video was produced in 1996, about 1 year after Honeywell began manufacturing the third version of the tee assembly. A copy of the video is available in the docket for the Millersville accident investigation; see the NTSB Docket Management System and search for accident ID DCA17FP006.

amounts of critical information about the installation process, which likely affected the installation outcomes.

UGI Training Program

Title 49 *Code of Federal Regulations* (*CFR*), Part 192, Subpart N, effective October 2002, requires that personnel installing mechanical tapping tee assemblies must have received qualification training prior to installing a tee assembly. UGI instituted a certification program for employees who install mechanical tapping tee assemblies, which included a written examination and a practical test. However, when the tee assembly involved in the accident was installed in 1998, federal regulations concerning operator qualification training standards for installation of tee assemblies did not exist, and UGI did not have a training program for installing them. At that time, UGI was relying solely on the written installation instructions shipped with the tee assembly.

NTSB Tee Assembly Installation Testing

The NTSB experimented with installing several exemplar PermaLock tee assemblies and found the following.

Locking Sleeve

The NTSB found that certain techniques can alter the tee assembly installation, particularly affecting whether the locking sleeve attaches to the main. For example, when the NTSB used 4.5-inch and 7-inch length wrenches, the level of resistance was felt in the wrench handles as the cutter assembly was driven down the tower. Specifically, it was possible to feel the following installation stages:

- the cutter tool piercing the main;
- the cutter tool being driven through the wall of the main;
- the locking sleeve forming threads into the main;
- the outer lip portion of the locking sleeve making contact with a manufactured stop near the bottom of the tower; and
- the cutter tool separating from the locking sleeve, which was also audible.

However, when using a 19-inch length wrench, changes in resistance were difficult to feel via the wrench handle during the installation stages. NTSB testing demonstrated that as the cutter assembly was driven down the tower with the longer wrench, the outer lip portion of the locking sleeve was easily driven below the stop, leading to an incorrectly installed locking sleeve and potential damage to the threads in the main.

Sensing resistance on the handle of a wrench indicates the correct positioning of a PermaLock tee assembly during the installation stages. In particular, sensing that the locking sleeve is resting against the stop near the bottom of the tower is critical to knowing that a locking sleeve is properly attached to a main. Therefore, knowing which wrench length will best facilitate the ability to feel increasing resistance is safety-critical information necessary to correctly installing a PermaLock tee assembly.

Using the supplied depth tube is also essential to correctly installing a PermaLock tee assembly. The depth tube is inserted into the tower, on top of the cutter assembly. The depth tube provides the installer a visual indication of the vertical travel distance of the cutter assembly, thereby, allowing the installer to visually verify the point at which the locking sleeve attaches to the main. When the locking sleeve attaches to the main, the depth tube will be flush to 0.125 inch above the top of the tower. Knowing to use the depth tube and how to use it are also critical to reliably ensuring the correct and safe installation of a PermaLock tee assembly.

Detailed installation instructions for each specific tee assembly version are necessary to eliminate confusion or misinterpretation during installation. For tee assemblies with a locking sleeve, such instructions must specify (1) the exact tools that are most effective for attaching a locking sleeve to a main and (2) the use of a depth tube to verify that attachment. Therefore, the NTSB concludes that more detailed installation instructions for PermaLock mechanical tapping tee assemblies that specify the exact tools to be used and emphasize what should be sensed while using those tools are necessary to ensure correct installation and prevent gas leaks. The NTSB recommends that Honeywell update its PermaLock mechanical tapping tee assembly installation instructions to specify the exact tools that should be used during installation and explain what an installer should sense while using those tools throughout the installation process. For example, specify which size wrench to use when installing a PermaLock tee assembly, and explain what should be sensed via the wrench handle when the locking sleeve reaches the stop at the bottom of the tower indicating the locking sleeve is attached to the main.

Nylon Bolts

According to a Honeywell representative, the locking sleeve is the primary means of securing a PermaLock tee assembly tower to a main. A saddle O-ring, made from an elastomer, is located under the tower of the tee assembly (see figure). When the tower is attached to the main, the saddle O-ring forms a seal between the tower and the main that prevents gas from escaping out of the tee assembly. If the locking sleeve within the tower is not attached to the main, additional tensile stress is placed on the four Nylon bolts, which are used to join the tower and the base together around the outer surface of the main. The four Nylon bolts then become the fail-safe feature holding the tee assembly in place. When the locking sleeve is not attached to the main, fracture of one or more of the Nylon bolts can be sufficient to allow a gap to open in the saddle O-ring area between the tower and the main where gas can escape out of the tee assembly.

The mechanical behavior of bolts fabricated from polymers, such as Nylon, is different than metallic materials, such as stainless steel. Nylon bolts have lower tensile strength and creep resistance, and they are susceptible to failure by slow crack growth, a failure mode not encountered in traditional metal alloys (such as in the case of the bolt-joint design of the tee assembly involved in the Millersville accident).[10] Honeywell tee assembly installation instructions do not warn about the consequences of slow crack growth and stress relaxation due to creep, which can result from overtightening the Nylon bolts.[11] The NTSB concludes that Nylon bolts are susceptible to slow

[10] (a) *Tensile strength* refers to the amount of stress a material can endure before fracturing. (b) *Creep* is the deformation of a material when exposed to constant stress for an extended period of time. *Creep resistance* refers to the ability of a material to resist deformation when subjected to constant stress for an extended period of time.

[11] *Stress relaxation* is the reduction in stress in plastic material when subjected to constant strain. Deformation can progress until eventual fracture of the material.

crack growth when overtightened. Therefore, the NTSB recommends that Honeywell specify in its PermaLock mechanical tapping tee assembly installation instructions a not-to-exceed torque limit for Nylon bolts and have that value checked and adjusted with a torque wrench immediately after installation.

UGI Remediation Program

The UGI remediation program refers to repairing or replacing PermaLock tee assemblies.[12] Specifically, the UGI Gas Operations Manual, Section 70.40.20, "Remediation of Perfection Plastic Mechanical Tapping Tees," states that the tee assembly Nylon bolts are subject to breaking, and the locking sleeve may not have attached to the main during installation.[13] UGI remediation includes replacing the Nylon bolts, checking the attachment of the locking sleeve to the main, gathering information on the tee assembly installation and site conditions, and handling any leaks that have occurred.[14]

When a tee assembly is excavated and found with one or more fractured Nylon bolts but shows no evidence of a gas leak, UGI replaces all of the Nylon bolts with type 316 stainless steel bolts, flat and lock washers, and nuts. When a tee assembly is found leaking gas at its base, UGI cuts out the segment of the main with the tee assembly and replaces it with a new main segment and a new approved tee assembly.

Since 2007, UGI has remediated or replaced about 4,000 PermaLock tee assemblies, more than a 1,000 of which have been remediated or replaced since the July 2, 2017, Millersville accident. UGI also stopped installing PermaLock tee assemblies about 10 years ago, choosing instead to install electrofusion tee assemblies in their place.[15]

Related Incidents and Investigations

Out of concern that incorrectly installed PermaLock tee assemblies may be a widespread safety issue, the NTSB reviewed related incidents and investigations and found the following.

UGI Excavation, 2006

On September 2, 2006, a natural gas explosion destroyed a residence at 39 Apple Blossom Drive, in West Lampeter Township, Pennsylvania. UGI excavated a PermaLock tee assembly that was leaking gas from the main in front of the residence. The tee assembly had two fractured bolts. UGI contracted JANA Laboratories, Incorporated (JANA), to examine the tee assembly; JANA

[12] The remediation program applies to all three versions of the PermaLock tee assemblies. Because the first two versions of the tee assembly do not contain a locking sleeve, the position of the internal cutter tool is not checked. For all versions, the Nylon bolts are replaced.

[13] The UGI Gas Operations Manual became effective February 16, 2015.

[14] According to the UGI Gas Operations Manual, to determine the depth of a locking sleeve and whether it is attached to a main, an installer should attach a wrench to the cutter tool and count the number of turns and measure the torque value as the cutter tool is driven down the tower. The number of turns made on the wrench and measured torque values can then be compared to those specified in the UGI manual.

[15] *Electrofusion tee assemblies* have built-in electric heating elements. They are used for welding a plastic tee assembly to a plastic pipe.

issued its examination results in report 07-4063, dated July 2008.[16] The report does not indicate the reason for the bolt fractures. However, X-ray inspection results in the JANA report showed that the locking sleeve did not appear to be attached to the main. These findings are similar to those in the Millersville accident.

NTSB Delegated Investigation

On December 9, 2009, a natural gas explosion occurred at 9140 Grey Pointe Drive, in Knoxville, Tennessee.[17] The resulting fire destroyed the brick three-story residence, causing more than $1 million in damages, including about $55,000 of damage to the Knoxville Utilities Board (KUB) gas utility system. One person died, and two people sustained serious injuries. Three nearby houses were also damaged and later condemned.

The NTSB delegated the Tennessee Regulatory Authority (TRA), Gas Pipeline Safety Division, to investigate the accident and submit its findings to the NTSB.[18] The TRA investigation revealed that the gas leak stemmed from a PermaLock tee assembly, and two of its four Nylon bolts were fractured.

In 2014, the NTSB determined that "the probable cause of the Knoxville, Tennessee, accident was natural gas leaking from an incorrectly installed, bolt-on service tee. The natural gas migrated into the single-family structure where it accumulated and ignited." The NTSB further stated that—

> because PHMSA had taken significant action to address plastic pipe issues before the accident, and the KUB took significant corrective actions to identify and correct plastic pipe installation deficiencies in its system, no safety recommendations were proposed, and no further action [was] taken on this accident.

To ensure public safety, the KUB decided to remove all PermaLock tee assemblies from service throughout its distribution system. The KUB initiated a replacement program, which involved locating and replacing about 1,875 tee assemblies that KUB had purchased and installed between 1997 and 2001. The KUB excavated about 12,000 service connections to find and replace the tee assemblies.[19] The replacement program cost about $4 million, not including KUB employees' salaries and benefits.

Wilson Boro, Pennsylvania, 2017

On August 15, 2017, as a result of a natural gas leak, UGI excavated a PermaLock tee assembly in front of a single-family residence at 2253 Firmstone Street, in Wilson Boro, Pennsylvania. The tee assembly was the third version. Although the NTSB is not investigating the

[16] JANA is located in Aurora, Ontario, Canada.

[17] NTSB Director, Office of Railroad, Pipeline and Hazardous Materials Investigations letter to the Public Docket regarding the "Delegated Pipeline Accident Report, Knoxville, Tennessee," dated June 19, 2014. A copy of the letter is available in the NTSB Docket Management System, search for accident ID DCA10FP001.

[18] In 2017, the TRA was renamed the Tennessee Public Utility Commission.

[19] See the Report of Natural Gas Safety Inspection Report #11-211, issued by the Gas Pipeline Safety Division, Tennessee Regulatory Authority, which is available in the NTSB Docket Management System, search for accident ID DCA10FP001.

Wilson Boro incident, UGI provided the tee assembly to the NTSB for examination. The NTSB determined that the locking sleeve was not attached to the main, and two of the four Nylon bolts were fractured. The findings about the condition of the tee assembly are similar to those of the tee assembly involved in the Millersville accident.

Ongoing UGI Gas Leak Survey Incidents

After the Millersville accident, UGI instituted an accelerated gas leak survey to more quickly identify gas leaks resulting from incorrectly installed PermaLock tee assemblies throughout its distribution system. As of June 12, 2018, UGI had found 19 tee assemblies leaking gas in its distribution system, many of which were discovered during the excavation process. All of the leaks were associated with fractured Nylon bolts.[20] An incorrectly installed tee assembly can leak gas several months, years, or decades after installation. Thus far, none of these recent gas leak incidents identified by UGI's leak survey have caused any personal injuries or property damage.

PHMSA

Advisory Bulletin, 2008

Because of ongoing concerns about mechanical couplings and related appurtenances failures, PHMSA issued advisory bulletin ADB-08-02 in 2008. It advised owners and operators of gas pipelines to consider the potential failure modes for mechanical couplings used for joining two pipes together. The bulletin cautioned that "failures can occur when there is inadequate restraint for the potential stresses on the two pipes, when the couplings are incorrectly installed or supported, or when the coupling components such as elastomers degrade over time." Further the bulletin warned operators to precisely follow manufacturer installation instructions to prevent future accidents.

Distribution Integrity Management Program

Title 49 *CFR* Part 192, Subpart P, requires gas distribution pipeline operators to have a distribution integrity management program (DIMP).[21] Specifically, operators are required to develop a DIMP that identifies threats, actions to mitigate the hazards associated with those threats, and measures to reduce risk as well as their frequency. A DIMP should include an engineering evaluation of any reinforcement or remediation of a PermaLock tee assembly to ensure its longevity and leak-free service.

As part of a DIMP, an operator should have an understanding of the design of and best practices for installing a mechanical tapping tee assembly. Because UGI is not the only operator to have detected gas leaks stemming from PermaLock tee assemblies due to incorrect installation, additional action is needed to ensure that such tee assemblies are installed correctly. Manufacturer installation instructions for tee assemblies must precisely convey best practices, and operators must clearly explain those best practices to their employees installing the tee assemblies. The NTSB

[20] UGI did not conduct examinations to determine whether the locking sleeve was attached to the main in these 19 instances.

[21] Operators had until August 2, 2011, to establish their DIMPs.

concludes that Honeywell's installation instructions, on which UGI relied, are too brief and imprecise to ensure the correct installation of the PermaLock mechanical tapping tee assembly. Therefore, the NTSB recommends that PHMSA work with state pipeline regulators to incorporate into their inspection programs, a review to ensure that gas distribution pipeline operators are using best practices recommended by the manufacturer in their DIMPs, including using the specified tools and methods, to correctly install PermaLock mechanical tapping tee assemblies.

Frequently Asked Questions

PHMSA provides written clarification of the pipeline safety regulations (49 *CFR* Parts 190-199) in the form of frequently asked questions (FAQs). The FAQs help clarify, explain, and promote better understanding of how to comply with the regulations. The NTSB notes that the FAQs for preparation of DIMPs focus primarily on system information that the operators maintain; the FAQs do not reference external sources of information for threat identification, such as advisory bulletins, safety alerts, or NTSB investigation reports. The NTSB concludes that referencing the use of external sources of information for threat identification in the FAQs for preparation of DIMPs would help gas distribution pipeline operators recognize and better understand how to reduce potential incidents or accidents. Therefore, the NTSB recommends that PHMSA reference the use of external sources of information for threat identification in its FAQs for preparation of DIMPs.

Recommendations

To the Pipeline and Hazardous Materials Safety Administration:

> Work with state pipeline regulators to incorporate into their inspection programs, a review to ensure that gas distribution pipeline operators are using best practices recommended by the manufacturer in their distribution integrity management programs, including using the specified tools and methods, to correctly install PermaLock mechanical tapping tee assemblies. (P-18-1)
>
> Reference the use of external sources of information for threat identification in your frequently asked questions for preparation of distribution integrity management programs. (P-18-2)

To Honeywell:

> Update your PermaLock mechanical tapping tee assembly installation instructions to specify the exact tools that should be used during installation and explain what an installer should sense while using those tools throughout the installation process. (P-18-3)
>
> Specify in your PermaLock mechanical tapping tee assembly installation instructions a not-to-exceed torque limit for Nylon bolts and have that value checked and adjusted with a torque wrench immediately after installation. (P-18-4)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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