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

April 16, 2018

MATERIALS LABORATORY FACTUAL REPORT Report No. 17-095

A. ACCIDENT INFORMATION

Place	:	Minneapolis, MN
Date	:	8/2/2017
Vehicle	:	N/A
NTSB No.	:	DCA17MP007
Investigator	:	Roger Evans

B. COMPONENTS EXAMINED

Walworth model 1700F 3” cast iron plug valve recovered from the accident site with a portion of pipe attached (figure 1) and an exemplar Walworth model 1700F 3” cast iron plug valve removed from natural gas service.

C. DETAILS OF THE EXAMINATION

The accident plug valve was shipped to the laboratory with a portion of the pipeline still attached. The valve handle and valve body had chalk alignment marks indicating the valve handle was found in the position perpendicular to the valve body (figure 1). Examination of the valve bore from the free end revealed that the valve was in the open position. A portion of gasket material was attached to the flange of the free end of the valve. Overall the valve and attached piping exhibited areas of soot covered surface as well as areas of oxidized surface. No paint remained on the valve body. The valve handle also exhibited an overall oxidized appearance.

The valve handle had a square hole and a set screw on one end for engagement with the valve stem (figure 2). The valve stem was a square (1-3/8”) shaft with one of the edges beveled. There were no features in the relationship between the valve handle and valve stem to ensure an alignment between the two components consistent with the state of the valve. In the position that the valve handle was found, perpendicular to the direction of flow, the valve handle set screw would have pressed against valve stem surface #1 as labeled in figure 2. With the valve handle installed parallel to the direction of flow, the handle set screw would have pressed against valve stem surface #2 as labeled in figure 2. Examination of the valve stem surface #1 revealed a faint witness mark consistent with the handle’s set screw (figure 3). Examination of the valve stem surface #2 revealed two distinct witness marks consistent with the handle set screw (figure 4). These witness marks on surface #2 were deep and had made indentations on the valve stem.

The valve stem had a collar attached where it protruded from the top of the valve (figure 5). Examination of the relationship between the valve stem collar and the valve stem revealed that these two components were keyed to each other as shown in figure 5. The valve stem collar had arrows embossed onto the part indicating the state of the valve. After the accident the arrows on the collar were parallel to the direction of flow, consistent with the valve being in the open state. Collar stops on the top of the valve engage with the valve stem collar limiting the valve stem rotation to 90 degrees.

The accident plug valve was separated from the attached piping to facilitate a bench-top measurement of the torque needed to close the valve. An exemplar valve was used for comparison purposes. The exemplar valve had been in natural gas service prior to removal and shipping to NTSB. The exemplar valve body was painted with a silver paint that covered all surfaces. This silver paint also covered the top of the grease fitting at the end of the valve stem. The exemplar valve was received in the open state with blank flange covers bolted to each of the flanges on the valve body. After removal of the blank flange covers and looking through the bore of the exemplar valve a dry rubbery substance was identified at the edges of the tapered valve plug and valve body interface. This dry rubbery substance (figure 6) appeared to be hardened valve lubricant.

Measurements were made to establish the operating torque needed to change the state of the valves. These measurements were done by holding the valve bodies in a bench vise and using a socket wrench with an electronic torque transducer to record the torque (figure 7). Blank flange covers modified with compressed air fittings were installed on the valves to allow for pressurization of the valve bodies during the test. This arrangement worked for the exemplar valve. The accident valve had a higher operating torque that could not be achieved while using the arrangement shown in figure 7. To prevent the valve body from rotation and gain better leverage to apply the operating torque, the accident valve was secured by one of its flanges to the T-slotted work table of a band saw as shown in figure 8. In this arrangement it was not possible to install the modified blank flange covers and the valve body pressurization was omitted from the test protocol. The operating torque to change the state of both the exemplar and accident valves are listed in tables 1 & 2.

Two samples of valve grease material, one removed from the accident valve and the second removed from an exemplar valve, were taken to identify the material. The samples were examined using a Fourier Transform Infrared (FTIR) spectrometer with a diamond attenuated total reflectance (ATR) accessory in accordance to ASTM E1252-98 (American Society for Testing Materials E1252-98: *Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis*). The spectrometer was used to collect and process infrared wavelength absorbance spectra of the unknown material(s).

The samples identified as ACCIDENT and EXEMPLAR shared matching spectra indicating that both samples were the same material. The two spectra contained the following combination of spectral peaks corresponding to particular functional groups

found within the molecular structure of the material. The presence of a low, broad peak at ~3450 cm^{-1} is indicative of an oxygen-hydrogen bond (O-H). The presence of a strong doublet peak between ~2920 $cm^{-1}$and ~2850 cm^{-1} is indicative of a carbon-hydrogen (C-H) single stretching bond. The presence of a single peak ~1730 cm^{-1} is indicative of a carbon-oxygen (C=O) double bond. The presence of a single peak ~1460 cm^{-1} is indicative of a carbon-hydrogen$_2$ (C-H_2) bending bond. The presence of a single peak ~1370 cm^{-1} is indicative of a carbon-oxygen (C-O) bond. Peaks at ~1240 cm^{-1}, ~1160 cm^{-1} and 1100 cm^{-1} are indicative of a carbon-oxygen-carbon (C-O-C) stretching bond. The presence of a single peak ~700cm^{-1} is indicative of multiple carbon-hydrogen$_2$ (C-H_2) bending bonds. The spectra were consistent with a fatty acid ester. A spectral library search was performed on the unknown material spectra. There were no strong matches, however, there were some similarities to several fatty acid esters. Fatty acid esters can be found as components in certain types of lubricants.

Joseph Panagiotou
Fire Protection Engineer

Figure 1: As received accident plug valve with handle and portion of piping attached.

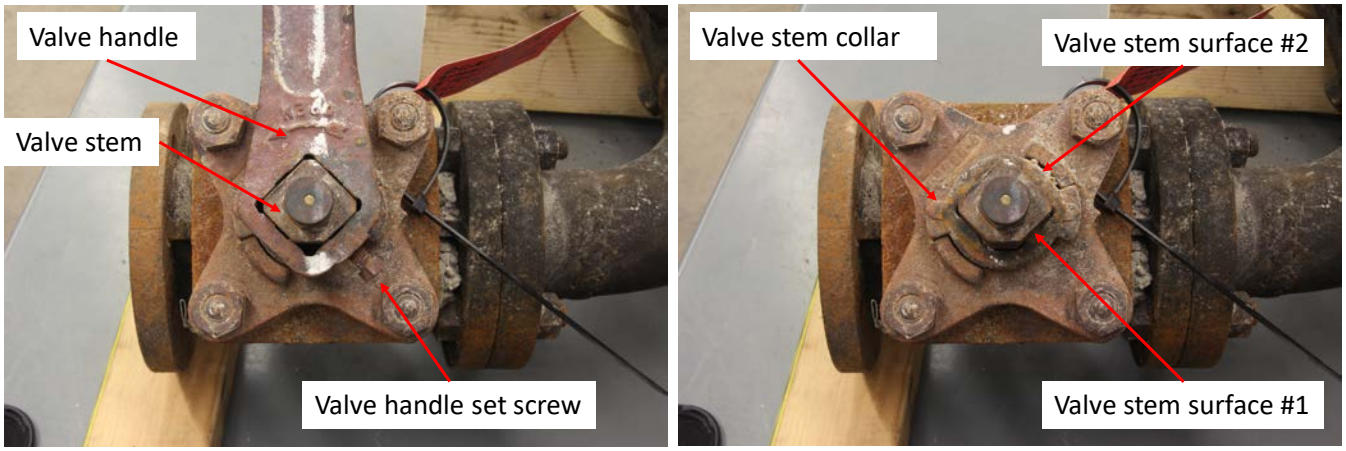

Figure 2: Top view of valve showing valve handle and valve stem engagement.

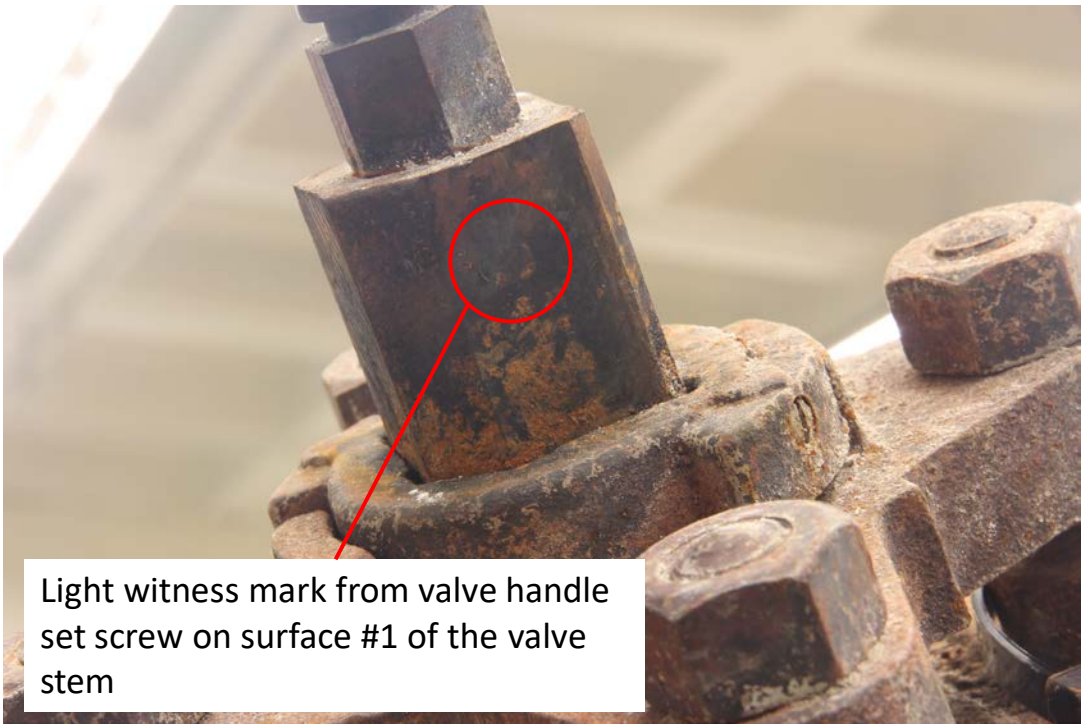

Figure 3: Witness mark on valve stem surface #1 (consistent with as found handle position)

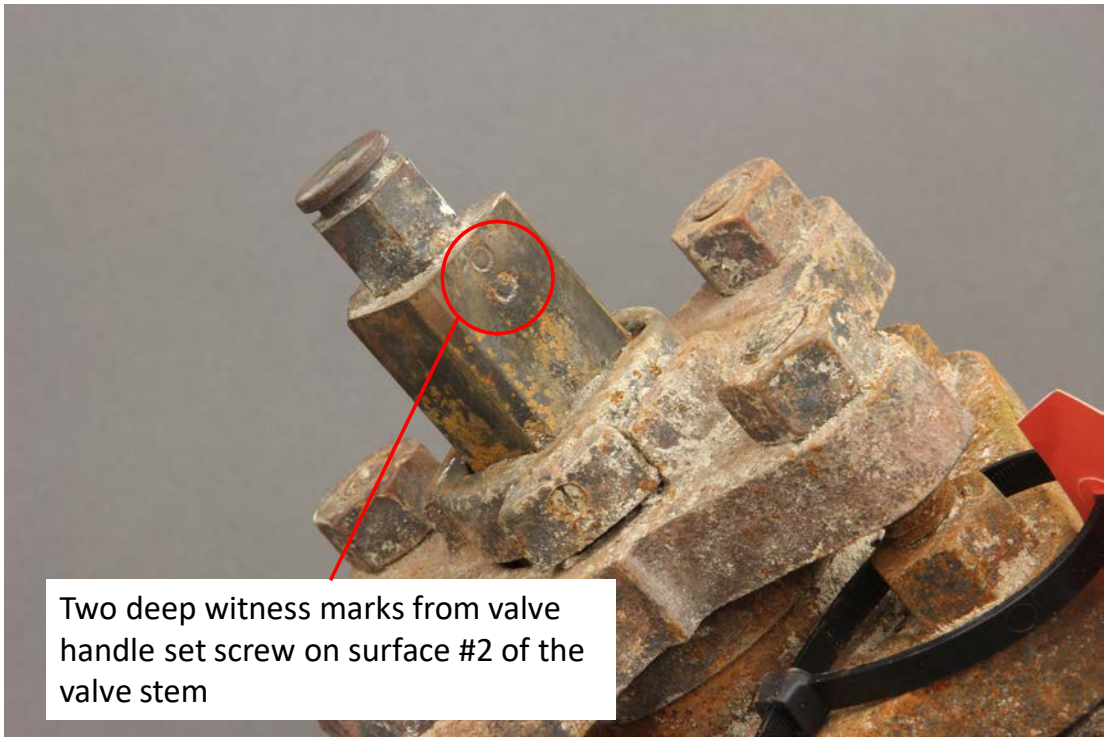

Figure 4: Witness marks on valve stem surface #2 (correct position of handle with regard to the state of the valve)

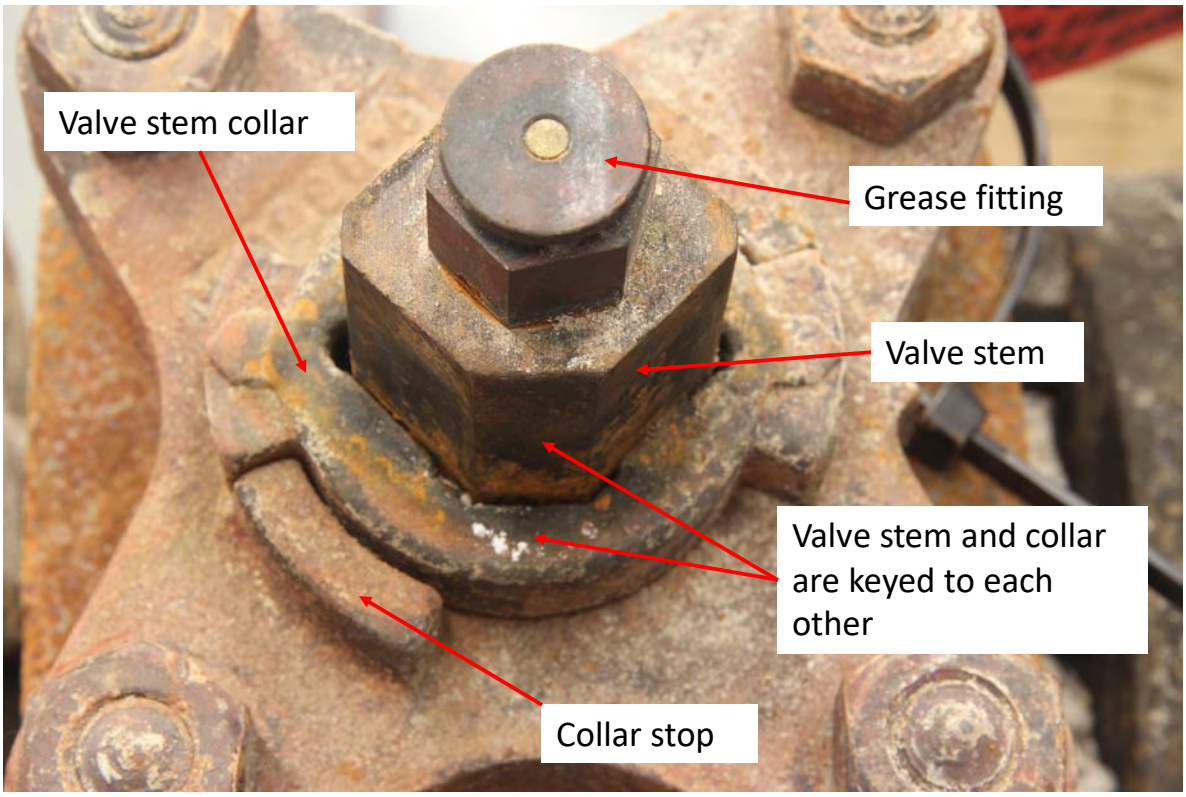

Figure 5: Valve collar and valve stem relationship.

Figure 6: Material recovered from exemplar plug valve bore.

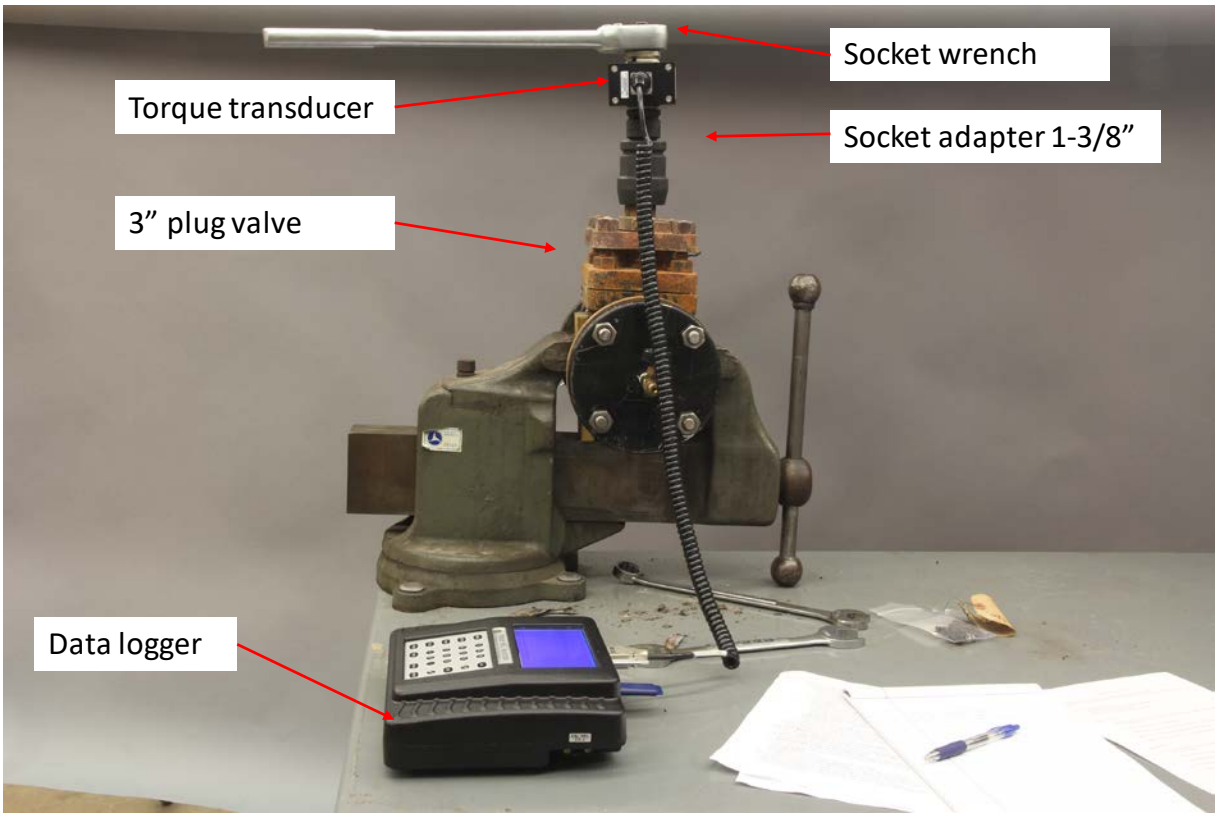

Figure 7: Arrangement for measuring the operating torque needed to change the state of the valve.

Figure 8: Alternate arrangement for measuring the valve operating torque.

Exemplar valve: Peak torque measured during opening and closing		
Action	Torque (lb-ft)	Tool used
1st Closing	344	valve wrench
1st Opening	199	valve wrench
2nd Closing	222	valve wrench
2nd Opening	152	valve wrench

Table 1: Peak torque measured during the operation of the exemplar valve.

Accident valve: Peak torque measured during opening and closing		
Action	Torque (lb-ft)	Tool used
1st Closing attempt - no movement	430	Valve wrench
2nd Closing attempt - no movement	409	Valve wrench
3rd Closing attempt - no movement	721	Valve wrench with 4' extension
The valve was attached to the band saw table for better leverage and the torque transducer was not used to close and open the valve once using the 4' extension		
1st Closing (after valve was opened and closed once)	243	Valve wrench with 4' extension
1st Opening (after valve was opened and closed once)	185	Valve wrench with 4' extension

Table 2: Peak torque measured during the operation of the accident valve.