National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: July 1, 2004

In reply refer to: P-04-01 through -03

Mr. Samuel G. Bonasso
Acting Administrator
Research and Special Programs Administration
400 Seventh Street, S.W.
Washington, D.C. 20590

About 2:12 a.m., central daylight time, on July 4, 2002, a 34-inch-diameter steel pipeline owned and operated by Enbridge Pipelines, LLC ruptured in a marsh west of Cohasset, Minnesota.[1] Approximately 6,000 barrels (252,000 gallons) of crude oil were released from the pipeline as a result of the rupture. No deaths or injuries resulted from the release. The cost of the accident was approximately $5.6 million, which includes the cost of cleanup and recovery, value of lost product, and damage to the property of the pipeline operator and others. The National Transportation Safety Board determines that the probable cause of the July 4, 2002, pipeline rupture near Cohasset, Minnesota, was inadequate loading of the pipe for transportation that allowed a fatigue crack to initiate along the seam of the longitudinal weld during transit. After the pipe was installed, the fatigue crack grew with pressure cycle stresses until the crack reached a critical size and the pipe ruptured.

At the time Enbridge purchased the pipe that ruptured in this accident, the pipeline industry was aware that thin-wall, large-diameter pipe (such as the 109:1 diameter to wall thickness ratio pipe that ruptured in this accident) was particularly susceptible to cyclic stresses encountered during transportation, especially by rail, and that such stresses could lead to the initiation of fatigue cracking in the pipe unless the pipe was properly loaded and transported. Welded areas were also known to be the areas most susceptible to fatigue crack initiation during transportation.

The metallurgical testing and examination of the fatigue crack and ruptured area of the accident pipe found no material or manufacturing defect in the steel or in the welded longitudinal seam. In the absence of manufacturing or material defects, the creation of a fatigue crack would be unlikely to result from normal operational pressure cycles. However, once a fatigue crack has been created it may grow with the repetitive stresses from normal operational pressure cycles.

[1] For additional information, see National Transportation Safety Board, *Rupture of Enbridge Pipeline and Release of Crude Oil near Cohasset, Minnesota, July 4, 2002.* NTSB/PAR-04/01 (Washington, DC: NTSB, 2004).

The fracture surfaces of the fatigue crack in the accident pipe had multiple arrest lines and other indications of progressive cracking starting from the inside surface of the pipe wall. There were two regions paralleling the inside surface; the region next to the pipe wall was darkened and oxidized and contained multiple crack initiation sites. The adjacent region where the crack extended further into the pipe wall was lighter and cleaner, exhibiting little or no oxidation. The oxidation found in the darkened region most likely occurred while the faces of the fatigue crack were exposed to the atmosphere before the pipe was placed in service. The lighter region indicates that the fatigue crack grew while oil was protecting the crack surfaces from oxidation.

The Safety Board's finite element analysis revealed that the length of the fatigue crack was consistent with the high stress region predicted on the inside surface of the pipe at a bearing or separator strip. Documents show that Enbridge used an engineering company for the specific purpose of inspecting the U.S. Steel pipe until it was stored near the mill. Further, the pipe was transported only a few miles before storage, whereas it was transported about 1,000 miles by rail and truck from storage to construction sites in Minnesota, suggesting a greater likelihood that the pipe was damaged after it was removed from storage. Further, there is no documentation to substantiate that instructions for loading pipe on railroad cars were followed after storage, and no evidence was found to indicate whether pipe loading instructions existed for transportation by truck. Therefore, the stress levels necessary for the initiation and initial growth of the fatigue crack were most likely caused by cyclic forces acting on the pipe during transportation after storage. The finite element analysis for the accident pipe shipment showed that following the rail loading standard, which prescribes size and placement of bearing/separator strips and alignment of the welded seams at 45° to the vertical, would not have resulted in stress levels high enough to initiate fatigue cracking during transportation. Therefore, the Safety Board concluded that, after storage, the accident pipe was likely inadequately loaded for transportation, which led to the initiation of fatigue cracking along a longitudinal seam weld before the pipe was placed in service. The Safety Board further concluded that after installation the preexisting fatigue crack grew with pressure cycle stresses until the crack reached a critical size and the pipe ruptured.

To prevent the formation of fatigue cracks during railroad transportation of pipe that is to be used in natural gas service, 49 C*ode of Federal Regulations* (CFR) Part 192.65 (effective November 12, 1970) required shippers to follow the requirements of the American Petroleum Institute's (API's) recommended practice RP 5L1[2] when transporting pipe for which the expected hoop stress during service was equal to or greater than 20 percent of the specified minimum yield strength. When the regulation became effective, pipeline operators were prohibited from using an estimated $13 million of stockpiled pipe that had been transported by rail because operators were unable to verify that the pipe had been transported in accordance with API RP 5L1. The Research and Special Programs Administration granted an exemption in February 1973 that allowed the installation of this pipe if it were pressure tested to higher pressures than normally required. However, transportation fatigue cracks can grow to failure in service after the pipeline has been pressure tested. Therefore, the Safety Board concluded that hydrostatic pressure testing of a pipeline is insufficient to expose all transportation fatigue cracks

[2] API RP 5L1, *Railroad Transportation of Line Pipe*, applies to 24-inch- to 42-inch-diameter pipe and includes recommendations on the design of bearing strips, banding, separator strips, and longitudinal weld placement during pipe loading.

that may eventually cause pipe failure. Although the amount of pipe still in stock that was transported before November 12, 1970, without documentation that API RP 5L1 was followed is likely not significant, such pipe could be placed in service.

Pipe shipped by marine transportation has also exhibited transportation-related failures, but the pipeline safety regulations have no requirement that a standard be followed when pipe is transported on a marine vessel. The API recommended practice for transportation of pipe on marine vessels, API RP 5LW, was first issued in 1975 as API RP 5L5. In addition to 9 fatigue failures attributed to rail transportation in a 1988 metallurgical study,[3] 17 fatigue failures were attributed to pipe transported by ship that failed during hydrostatic testing between 1976 and 1987 while the recommended practice was available to the pipeline industry. The Safety Board concludes that there is a potential risk of pipe damage due to fatigue crack initiation during marine vessel transportation of pipe, similar to the risk during rail transportation, for both hazardous liquid and natural gas pipelines.

Rail transportation has generally been considered to be the most likely source of transit fatigue cracking because of the larger number of pipe rows and high loads, long distances, and long travel times involved. A number of previous pipeline failures have been attributed to rail transportation fatigue, but the pipe also was transported in the field by truck following rail transit. Since no information was available regarding truck loading and transport conditions for the pipe that ruptured, the possibility of fatigue crack initiation during truck transportation can not be ruled out.

It is reasonable to assume that, in addition to incurring abrasions or dents, pipe could incur fatigue damage during truck transportation. A pipeline industry standard does not exist for the loading requirements for transportation of steel pipe on trucks. Although the Safety Board does not have any data with which to determine the extent of fatigue crack initiation that may occur as a result of highway transportation induced stresses, the Safety Board concludes that the absence of industry loading standards for truck transportation of pipe might create risks to the integrity of both natural gas and hazardous liquid pipelines.

Therefore, the National Transportation Safety Board makes the following safety recommendations to the Research and Special Programs Administration:

> Remove the exemption in 49 *Code of Federal Regulations* 192.65 (b) that permits pipe to be placed in natural gas service after pressure testing when the pipe can not be verified to have been transported in accordance with the American Petroleum Institute's recommended practice RP 5L1. (P-04-01)

> Amend 49 *Code of Federal Regulations* to require that natural gas pipeline operators (Part 192) and hazardous liquid pipeline operators (Part 195) follow the American Petroleum Institute's recommended practice RP 5LW for transportation of pipe on marine vessels. (P-04-02)

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[3] Bruno, T.V., "Transit Fatigue of Tubular Goods," *Pipe Line Industry*, July 1988, pp. 31–34.

> Evaluate the need for a truck transportation standard to prevent damage to pipe, and, if needed, develop the standard and incorporate it in 49 *Code of Federal Regulations* Parts 192 and 195 for both natural gas and hazardous liquid line pipe. (P-04-03)

The Safety Board also issued safety recommendations to the American Society of Mechanical Engineers and the American Petroleum Institute. In your response to this letter, please refer to Safety Recommendations P-04-01 through -03. If you need additional information, you may call (202) 314-6177.

Vice Chairman ROSENKER, and Members GOGLIA, CARMODY, and HEALING concurred in this recommendation. Chairman ENGLEMAN CONNERS did not participate.

Original Signed

By: Mark V. Rosenker
Vice Chairman