National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: July 1, 2004

In reply refer to: P-04-06

Mr. Red Cavaney
President
American Petroleum Institute
1220 L Street, NW
Washington, DC 20005-4070

The National Transportation Safety Board is an independent Federal agency charged by Congress with investigating transportation accidents, determining their probable cause, and making recommendations to prevent similar accidents from occurring. We are providing the following information to urge your organization to take action on the safety recommendation in this letter. The Safety Board is vitally interested in this recommendation because it is designed to prevent accidents and save lives.

This recommendation is derived from the Safety Board's investigation of the rupture of a pipeline owned and operated by Enbridge Pipelines, LLC near Cohasset, Minnesota, on July 4, 2002, and is consistent with the evidence we found and the analysis we performed.[1] As a result of this investigation, the Safety Board has issued six safety recommendations, one of which is addressed to the American Petroleum Institute. The Safety Board would appreciate a response from you within 90 days addressing the actions you have taken or intend to take to implement our recommendation.

About 2:12 a.m., central daylight time, on July 4, 2002, an Enbridge 34-inch-diameter steel pipeline ruptured in a marsh west of Cohasset, Minnesota. 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.

[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).

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.

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 performed a finite element study of the United States Steel[2] loading practice to determine the static stresses in pipe loaded for rail transportation. The study showed that the peak circumferential tensile stresses would have been highly localized to the areas in contact with the bearing and separator strips and that the stresses would have occurred at the inner surface of the pipe.

The length of the fatigue crack in this accident was similar to the length over which the peak circumferential tensile stress was predicted in the finite element model, and the fatigue crack initiated at the inner surface of the pipe. The finite element model indicated that the circumferential tensile stresses decreased rapidly away from the bearing or separator strips. Aligning the welded seams at 45° to the vertical results in very small levels of circumferential tensile stress at the welds during transport. The results of the finite element model also indicate that aligning the welds at the 2, 4, 8, or 10 o'clock positions instead of exactly 45° from vertical does not increase the stress levels significantly.

[2] United States Steel manufactured the pipe that ruptured in this accident.

The Safety Board also studied API loading practices for rail transportation to determine the static stresses in pipe loaded for transportation. API recommended practice RP 5L1, *Recommended Practice for Railroad Transportation of Line Pipe,* provides an equation for calculating the peak circumferential tensile stress in a pipe at a bearing strip as a function of the geometry of the loading. API RP 5L1 does not indicate the source of the equation. The purpose of this equation is to calculate the number of flat bearing strips needed to keep the stress below a specified level. The stress determined from the finite element model was compared to the stress calculated by the equation from API RP 5L1 under the same conditions. For a 40-foot-long, 34-inch-diameter, 0.300-inch-wall thickness pipe, the comparison indicates that the equation from API RP 5L1 underestimates the peak circumferential tensile stress by a factor of approximately 2. However, the Safety Board's analysis indicates that the effectiveness of API RP 5L1 to prevent fatigue crack initiation can be explained by the emphasis on leveling the bearing strips and the proper alignment of welded seams at 45° to the vertical, leading to a significant reduction in stress at the welds, which are the areas most susceptible to the initiation of fatigue cracking. Although implementation of the recommended practice has resulted in a reduction of railroad transportation fatigue crack initiation, the Safety Board concludes that API RP 5L1 may significantly underestimate the stresses in the pipe at the bearing or separator strips. In the case of the accident pipe shipment, regardless of whether the stress levels were underestimated in the rail loading standard, as noted previously, following the rail loading standard would not have resulted in stress levels high enough to initiate fatigue cracking.

API RP 5LW, *Recommended Practice for Transportation of Line Pipe on Barges and Marine Vessels*, also provides an equation for calculating the static load stress in a stack of pipe for shipment, but this equation is significantly different from the equation in API RP 5L1. When the Safety Board compared the stresses calculated using the equation in API RP 5LW to those determined by the finite element analysis for 34-inch-diameter, 0.300-inch-wall thickness pipe, it found that the equation in API RP 5LW also underestimates the stresses in pipe loaded for transport by a factor of approximately 2. The Safety Board, therefore, concludes that API RP 5LW may significantly underestimate the stresses in the pipe at the bearing or separator strips.

Based on the foregoing information, the National Transportation Safety Board makes the following safety recommendation to the American Petroleum Institute:

> Review the equations in American Petroleum Institute RP 5L1, *Recommended Practice for Railroad Transportation of Line Pipe*, and American Petroleum Institute RP 5LW, *Recommended Practice for Transportation of Line Pipe on Barges and Marine Vessels*, for calculating the static load stresses at the bearing or separator strips and revise the recommended practices based on that review. (P-04-06)

The Safety Board also issued safety recommendations to the Research and Special Programs Administration and the American Society of Mechanical Engineers. In your response to this letter, please refer to Safety Recommendation P-04-06. 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