of pipe was not loaded in this position, it was to be rotated as necessary to attain one of these positions. Except for the loading diagram, there were no written procedures for loading pipe, nor did U.S. Steel use checklists or other methods to confirm that the pipe was loaded according to specifications.

U.S. Steel does not currently manufacture DSAW or SAW pipe. U.S. Steel Tubular Products does produce seamless and electric resistance weld pipe, and the current loading procedures for the pipe are described in the company's *Pack, Mark, and Load Manual.* The procedures to be used for each order are entered into the order entry system from the purchase order and are designated on the mill order sent to the production mill. All pipe manufactured to API standards and destined for railroad transportation from the pipe mill is to be loaded to the requirements of the Association of American Railroads' *Open Top Loading Rules Manual*[18] and the supplementary recommended practices in API RP 5L1. Any additional transportation requirements are referenced in the mill order for the shipping department personnel and, if applicable, are attached to the mill order. A preproduction meeting is held at the mill to review the order and shipment requirements.

At pipe mills currently producing tubular products for U.S. Steel, shipping department workers are trained in the department's standard operating procedures. The group leader in the loading area discusses the loading requirements for each order with the crew. A load tally sheet is created that shows the length of each pipe joint with the referenced heat number for the material. The yard foreman checks the railcars periodically to confirm that the pipe is loaded according to the written requirements.

Before 1991, Enbridge specified that the manner of loading pipe for rail transportation should be provided in the pipe manufacturer's quotation, which was subject to Enbridge's approval. Currently Enbridge includes the use of API RP 5L1 in its specification for purchase of pipe transported by rail from a pipe mill. Enbridge also inspects the pipe during loading at the pipe mill to confirm that the requirements of API RP 5L1 are being met.

Safety Board Materials Laboratory Study

The Safety Board performed a finite element study of the U.S. Steel 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

[18] The Association of American Railroads' *Open Top Loading Rules Manual* includes Section 1, General Rules Manual for Loading all Commodities, and Section 2, Loading Metal Products Including Pipe.