National Transportation Safety Board

Washington, D.C. 20594

Pipeline Accident Brief

Accident Number:	DCA99-MP005
Owner/Operator:	Colonial Pipeline Company
Type of System:	Hazardous liquid petroleum products pipeline
Accident Type:	Pipe rupture
Location:	Knoxville, Tennessee
Product Released:	Diesel fuel, high sulfur, 86 Grade
Time:	11:58 p.m. EST
Date:	February 9, 1999
Fatalities/Injuries:	None
Property Damage:	$7 million
Quantity Released:	About 53,550 gallons (1,275 barrels)
Pipeline Pressure:	Approximately 91 psig
Component Affected:	10-inch-diameter, Grade 5L X-42, 0.250-inch wall thickness, electric resistance weld steel pipe

The Accident

On the afternoon of February 9, 1999, Colonial Pipeline Company (Colonial) successfully completed a delivery of diesel fuel to the East Knoxville delivery facility (East Knoxville) in Knoxville, Tennessee, using its Atlanta Junction/Knoxville stubline.[1] To initiate the delivery, an operator at Colonial's Knoxville Terminal began operating valves that directed product into a 10-inch-diameter steel pipeline leading to the East Knoxville facility, about 8 miles away. At about the same time, a valve was opened at the other end of that line to allow the product to flow into the East Knoxville facility tanks. At the completion of the delivery, the valves were closed, which left the pipeline filled with diesel fuel at a pressure of about 91 psig.

About 11:58 p.m. on February 9, the supervisory control and data acquisition (SCADA) system[2] at Colonial's Atlanta control center registered and recorded a sudden drop in pressure from 91 to 72 psig at East Knoxville. After several minutes of oscillation, the pressure stabilized at 73 to 74 psig. The controller on duty in the Atlanta control center at the time of the accident stated that he normally displays the SCADA pressure strip charts[3] across the two CRT screens at the top of his operating console. The SCADA

[1] A Colonial *stubline* is a smaller diameter, lateral pipeline system that emanates from one of the company's larger mainline pipelines that run from Texas to New York.

[2] Pipeline controllers use the SCADA system to remotely control and monitor movement of product through the pipeline. Controllers can monitor flow rates and pressures along the lines and control valves and pipeline pumps to adjust the flow and make product deliveries.

system did not alarm in response to the decrease in pressure, and the controller said he was not aware of the pressure drop. As determined later, the pressure drop occurred when the pipeline leading to East Knoxville ruptured on a Pitner Place residential property near Knoxville's Goose Creek.

On the east side of the Tennessee River, Colonial's pipeline crosses Scottish Pike and then Pitner Place. Between midnight and 12:15 a.m. on February 10, a Scottish Pike resident walking outside his home smelled a kerosene odor, but he said he took no action in regard to the smell. At 1:02 a.m. on February 10, a resident of Pitner Place called 911 to report a very strong diesel or gasoline odor in the area. The Knoxville Fire Department responded and concluded that the reported odors came from an asphalt plant across the river from the community. Thus believing this odor did not pose any further concern but was merely a nuisance odor, the firefighters cancelled the fire call and left the scene.

About 2:05 a.m., another Pitner Place resident closer to the pipe rupture, called 911 to report a very strong petroleum gas odor in the area. The fire department returned to the scene to investigate. Again, the fire company attributed the odor to the nearby asphalt plant. At 2:17 a.m., a Knoxville area resident called 911 to report oil on the Tennessee River.

Meanwhile, the Atlanta controller (still unaware of the drop in the pipeline pressure) called the Knoxville operator to start another product delivery to East Knoxville. About 2:31 a.m., the Knoxville operator began operating valves to send product to the East Knoxville delivery facility. The Atlanta controller observed that the East Knoxville meter indicated no flow rate and that the pressure did not rise as expected at Knoxville. The Knoxville operator said that after waiting 4 to 5 minutes for the flow rate to register on his CRT screen, he called the Atlanta controller about the situation. The Atlanta controller called the senior controller for his shift over to the console to discuss the pipeline data, at which point the senior controller decided to terminate the delivery on the East Knoxville line. About 2:39 a.m., the Knoxville operator began shutting down the East Knoxville pipeline section and resumed using the stubline to make a delivery to another Knoxville terminal.

After shutting down the line, about 2:44 a.m., the Knoxville operator called another Colonial employee at home and asked him to check out the East Knoxville delivery facility. In a discussion with the Knoxville operator at 3:01 a.m., the Atlanta controller suggested that the pipeline might have been in a slack condition (only partially filled with product) when the delivery started, but he added that the pipeline pressure should have increased faster at that time. In that discussion, he also said that the pipeline was 600 to 700 barrels short.

The hourly over/short calculation shown on the controller's log for the line showed a shortage of 725 barrels at 3:00 a.m. After the accident, the Atlanta controller said he considered the shortage "high." He also said that 300 barrels is "getting high," although he believed that 300 barrels could be explained as a characteristic of the opening of a delivery. According to Colonial procedures, a sudden loss of pressure and/or a change in

[3] The SCADA system provides pressure data on a strip chart graphical display on a CRT screen, which displays the pressure history for about the previous hour.

flow rate are to be interpreted as conclusive evidence of a leak. As part of Colonial's leak detection strategy, controllers are to immediately investigate and correct any shortage calculation.

At 3:45 a.m., Knoxville Fire Department responders found fuel running into Goose Creek, which discharges into the Tennessee River about 1/2 mile downstream. Noting a nearby Colonial pipeline marker with contact information, the incident commander directed a Knoxville Fire Department dispatcher trainee to contact Colonial about the leak; however, Colonial was not notified at that time.

Meanwhile, the Colonial employee who had been asked to check the East Knoxville facility had driven by the site where an internal inspection tool had been removed from the pipeline on February 9 (discussed below in the "Pipeline Information" section). About 4:00 a.m., he reported that he saw no evidence of a failure in the pipeline at that location, nor did he find any problem at the East Knoxville facility.

Still unaware of the nature of the problem, the Knoxville operator and the called-out Colonial employee discussed the situation with the Atlanta controller. At the end of the discussion, the Atlanta controller decided that the Knoxville operator should attempt another delivery to East Knoxville. The senior controller was not involved in the decision to restart delivery. This time, the called-out operator would be observing at East Knoxville. About 4:03 a.m., the operator attempted to pressure up the line between Knoxville and East Knoxville, but the pressure did not rise as expected. About 4:20 a.m., he again opened the East Knoxville valve to operate this pipeline section, and initially no flow was noted at East Knoxville. After a few minutes, the pressure began to fluctuate and a lower-than-expected flow rate was indicated. The hourly flow rate was expected to be more than 3,000 barrels per hour (bph); however, it peaked at approximately 2,000 bph.

About 4:30 a.m., the Knoxville Fire Department found diesel fuel spraying from a pipeline onto a Pitner Place residence and running downhill into Goose Creek, which was about 170 feet from the rupture site. The incident commander asked the fire department communications center dispatcher to contact Colonial and have the company shut down the pipeline. The fire department dispatcher, who was talking to Colonial's senior controller in Atlanta at that time, notified him of the leak and asked that the pipeline be shut down. The senior controller immediately ordered that the Knoxville stubline be shut down. The East Knoxville segment shutdown was completed at 4:35 a.m. At 4:46 a.m., the East Knoxville delivery valve was opened, and the pipeline segment was then allowed to drain into the East Knoxville terminal. According to Colonial records, the temperature of the product was approximately 61° F at East Knoxville.

The ruptured pipeline released approximately 53,550 gallons (1,275 barrels) of diesel fuel. Fifteen people were reported to have voluntarily evacuated the immediate area of the leak. During the first 24 hours, the leading edge of the oil slick on the Tennessee River advanced about 6 miles downstream from Goose Creek. For the next several days, the Tennessee River in the Knoxville area was closed to navigation as containment booms were placed downriver. Nine collection points for escaped petroleum product were placed downstream of the accident site. Colonial estimated that 44,016 gallons (1,048 barrels) of product have been recovered. No fire resulted, and no injuries were reported.

On March 3, 1999, Colonial submitted a *Corrective Action Plan for Impacted Soils and Groundwater at the Goose Creek Knoxville, Tennessee, Release Site* to the Tennessee Division of Solid Waste Management and Tennessee Division of Water Pollution Control. The intent of the action plan was to determine the extent of the underground diesel fuel plume and the further action needed to ensure site remediation acceptable to the State. The corrective action plan called for the excavation of all contaminated soils at the leak site that exceeded 500 parts per million, in accordance with Tennessee underground storage tank guidance cleanup guidelines.

Approximately 18,000 tons of contaminated soil were excavated at the leak site area during March and April 1999. The excavated soil was transported to Waste Management's Chestnut Ridge Landfill for disposal under the approval of the Tennessee Division of Solid Waste Management. A well survey conducted shortly after the release found no residential wells in the leak site area. The limited amount of affected groundwater encountered was treated on site. The March 3 plan stated that because the affected groundwater immediately discharges to Goose Creek, it would not contaminate other portions of the shallow groundwater system and would not affect deeper groundwater. It was therefore determined that it was not necessary to install monitoring wells at the leak site.

Community Awareness

At the time of the spill, Colonial had in place a 14-point public education program that it had designed to meet the requirements of 49 *Code of Federal Regulations* (CFR) Part 195.440, which requires oil pipelines to conduct public educational programs.[4] Colonial's public education program included mailing safety flyers to a targeted audience, including apartment dwellers, living within 1/8 mile of a pipeline. The company also provided direct mail pieces to those individuals who owned property where Colonial held easements. These materials included an annual wall calendar and a Colonial road atlas with a companion booklet that contained general information about the company. The atlas and booklet were distributed every 5 years.

In areas where Colonial deemed excavator risk particularly high, company representatives participated in meetings to educate public officials, emergency responders, and excavators. Additionally, the company distributed its atlas and companion booklet to some public officials and contractors. In both 1997 and 1998, Colonial had pipeline maps available for review at its tank farm during the emergency response coordination drills it held with the Knoxville Fire Department.

A review conducted in the immediate area of the pipeline failure disclosed that Colonial pipeline easements crossed five residential properties. Colonial records indicate that various public education items were mailed to two of these residences in November and December 1997. These items addressed questions such as how to detect a pipeline accident, what to do in case of an accident, and how to report an accident. Thirteen

[4] Under 49 CFR 195.440, each operator shall establish a continuing education program to enable the public, appropriate government organizations, and persons engaged in excavation-related activities to recognize a hazardous liquid pipeline emergency and to report it to the operator or the fire, police, or other appropriate public officials.

residents were interviewed. Of those, residents from two households stated that they were aware of a pipeline in the immediate area. One resident recalled receiving a pamphlet explaining Colonial's brush-clearing operation; however, no one was aware of any specific reporting action or personal protection measures to take in the event of a pipeline release, nor could they recall any safety awareness mailings from Colonial.

The Knoxville Fire Department hazardous materials emergency response procedures were last revised and approved in January 1999 by the Knoxville County Emergency Management Agency. Fire department personnel have received training in hazardous materials team operations provided by the Tennessee Emergency Management Agency. These training courses cover hazardous materials incident response (incident command system, hazardous material identification, notification, protective equipment, etc.) at the responder, operations specialist, and technician levels.

According to fire department officials, the department conducts disaster drills annually. The most recent disaster drill before the accident was on September 9, 1998. The scenario involved a joint multiagency response to an aircraft crash at the Knoxville Airport. The last chemical transportation accident drill was conducted in November 1998. This simulated an accident that involved a highway cargo tank containing acid and the release of a toxic cloud that caused two injuries. In November 1997, the Knoxville Fire Department and Colonial conducted a joint training drill at a petroleum products terminal in Knoxville. The scenario involved a pipeline rupture at a storage tank and a 1,000-gallon gasoline spill. During a tour of its facility during December 1998, Colonial discussed with Knoxville Fire Department personnel its pipeline delivery system, spill response procedures, and pipeline location maps for the city of Knoxville. In its review of this accident, the Knoxville Fire Department identified internal operations problems in its response, including the use of trainees and the fact that some of the communications channels monitored by the fire department were not recorded. Also, fire department officials identified an issue regarding the lack of pipeline location maps during the early stage of the emergency, which might have helped them locate pipelines in the complaint area.

Pipeline Information

The pipeline was constructed in 1962 and put into service in early 1963. The pipe installed was 10-inch-diameter, Grade 5L X-42, 0.250-inch wall thickness, electric resistance weld (ERW) steel pipe. At the rupture site, the pipeline was installed on a slope and had a slight side bend to the left below the rupture (figure 1) in the downstream flow direction. Colonial records indicate that the pipe had asphalt enamel coating. A coating defect (wrinkled coating) was also evident 2 to 3 feet upstream of the rupture (figure 2). Safety Board investigators and Colonial personnel observed no visible damage to the pipe coating that remained immediately adjacent to the rupture area before the pipe was removed for examination. Colonial did not have a toughness requirement[5] for pipe when it was purchased for this pipeline, and no pipeline industry standards had been established at that time. Since July 13, 1990, Colonial's line pipe purchasing specifications have had minimum toughness requirements that include, among other factors, a minimum acceptance criteria of 25 ft/lbs of absorbed energy at 32° F for Charpy V-Notch (Charpy) impact tests.[6]

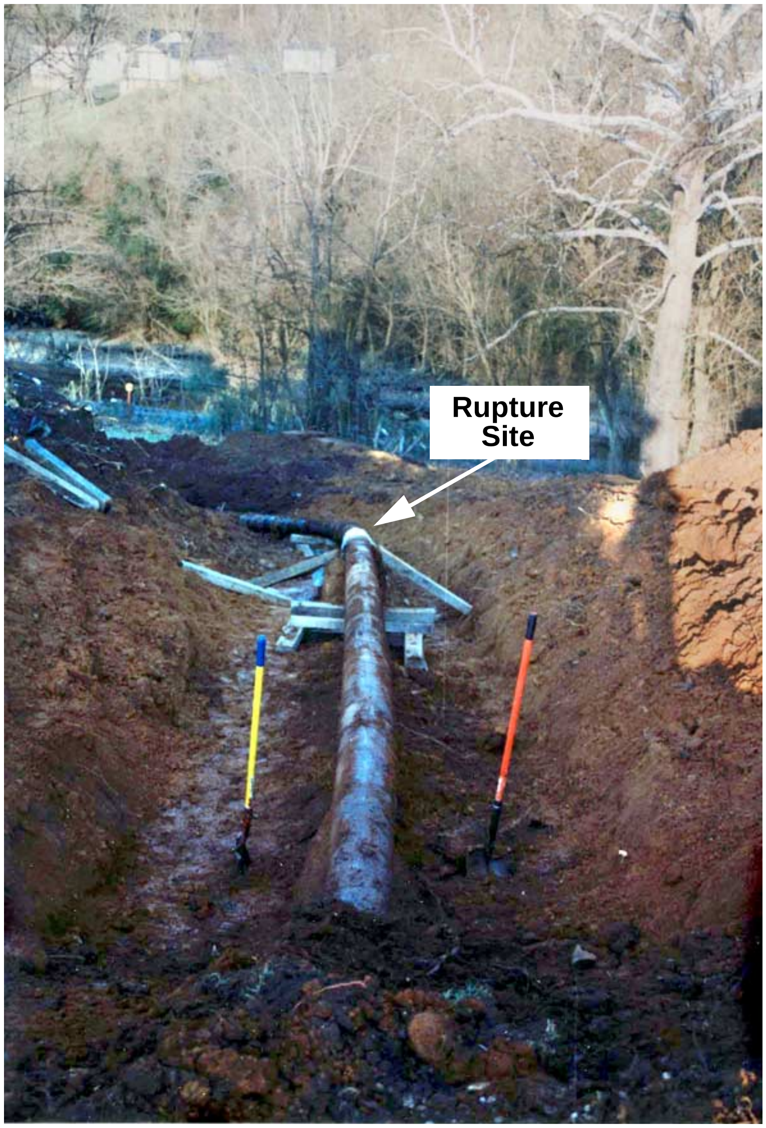

Figure 1. Pipeline on slope showing side bend to the left beyond the rupture.

[5] As a result of its investigation of a March 23, 1994, pipeline accident in Edison, New Jersey, the Safety Board issued the following safety recommendation to the U.S. Department of Transportation's Research and Special Programs Administration (RSPA):

> P-95-2
> Develop toughness standards for new pipe installed in gas and hazardous liquid pipelines, especially in urban areas.

In June 1995, in response to a request from RSPA, the American Petroleum Institute (API) organized a task group to revise the specification for line pipe, API Specification 5L, to include minimum toughness requirements. In January 2000, the revised 42nd Edition of API Specification 5L was published. It contains two pipe product specification levels with Product Specification Level 2 (PSL-2) having a required minimum fracture toughness level for new pipe. Safety Recommendation P-95-2 remains "Open-Acceptable Response."

[6] Charpy V-Notch impact tests that measure the energy absorbed by a given thickness of material at a given temperature were used to evaluate the fracture toughness of materials.

Figure 2. Wrinkled coating 2 to 3 feet upstream of the circumferential crack that terminates at the 9 o'clock position.

A hydrostatic pressure test to 649 psig was completed on February 4, 1995, on the East Knoxville pipeline segment. The maximum operating pressure (MOP) for the pipeline was determined to be 519 psig at the Knoxville station, which calculates to 552 psig at the rupture location. The allowable surge pressure, based on pipeline Federal safety regulations (1.1 x MOP), is 571 psig at the Knoxville station and 607 psig at the rupture location. Colonial records indicate that the typical operating pressure at the rupture location ranges between 72 and 250 psig, and the number of operating cycles for that range is at least 144 per year for the East Knoxville section of the pipeline.

Internal inspections with different types of "smart pigs" were performed in 1989 and 1999. The 1989 inspection was done using a conventional magnetic flux internal inspection tool. The internal inspection company graded the inspection log, and no defects were indicated at the rupture point. Colonial reported that repairs were made to other areas of the pipeline as a result of the 1989 inspection.

The pipeline was internally inspected again using a high-resolution magnetic flux inspection tool on February 8, 1999. The inspection tool became stuck at one of several dents about 4,000 feet upstream of the East Knoxville station (about 1.7 miles downstream of the rupture site). The pipeline was pressurized a number of times to dislodge the inspection tool and push it ahead. SCADA logs indicate that the pressure on the pipeline reached 546 psig at the Knoxville station, which calculates to approximately 580 psig at the rupture location. The effort to dislodge the tool using pressure was unsuccessful, and on the afternoon before the rupture, the section of pipe containing the tool was cut from the pipeline and replaced with new pipe. Product was transported through the line after the repair. The high-resolution magnetic flux inspection indicated no defects such as dents, gouges, or significant corrosion at the failure location.

Colonial uses an impressed current cathodic protection[7] system to protect its pipelines. Company records indicate that the rectifier system was operating properly before the accident. Annual corrosion survey records for 3 years prior to the accident indicate the pipe-to-soil potential levels[8] were –0.85 volt or more negative with reference to a copper-copper sulfate reference electrode.[9]

Materials Laboratory Examination

When the pipe was exposed, a circumferential crack was found around the top half of the pipe's diameter (figure 3), and no pipe coating remained in the area of the crack. The crack was not located in a girth weld, visible dent, or gouge; however, the crack ran through an area of surface corrosion. Close examination of the fracture surface established that the crack initiated at an area with at least nine separate darkly colored thumbnail-shaped corroded regions (thumbnails). The failure initiation region was centered at the 3 o'clock position (looking downstream, toward East Knoxville) in the area of the external surface corrosion. The thumbnail shape, dark coloration, and fracture surface features were consistent with corroded preexisting cracks that initiated on the external surface of the pipe and propagated radially inward. None of these preexisting cracks penetrated through the pipe wall, with 0.120-inch being the deepest penetration observed, which was 48 percent of the nominal pipe wall thickness. Similar corroded preexisting cracks were noted nearby in the surface corrosion area.

The crack ran in both directions from its initiation point. The crack propagated clockwise past the longitudinal weld seam. In the clockwise direction, the brittle fracture extended less than 0.5 inch before changing to a ductile fracture. In the counterclockwise direction, the brittle fracture extended over the top of the pipe to approximately the 9 o'clock position, where it also terminated in a ductile fracture. (Refer to figure 2.)

Scanning electron microscope examination of the fracture face revealed heavy oxide deposits on the thumbnails that obscured some and obliterated other fracture details; however, sufficient detail was visible to indicate that the thumbnails originated at shallow corrosion pits on the external surface. Each of the thumbnail regions was associated with surface corrosion damage and typically had one or two crack origin sites. In some

---

[7] *Cathodic protection* is a corrosion mitigation method used by the pipeline industry to protect underground metal pipes. The system uses rectifier stations along the pipeline to supply protective electrical current. Cathodic protection current is forced to flow in the opposite direction of currents produced by corrosion cells. A rectifier converts alternating current from the utility service to direct current and supplies it to a ground bed that typically contains a string of suitable anodes, with soil as an electrolyte, to provide a path for the current from the rectifier to the pipeline. A cable connected to the pipeline provides the return path to complete the circuit.

[8] The *pipe-to-soil potential* is defined as "the voltage difference between a buried metallic structure [pipe] and the electrolyte [soil], measured with a reference electrode in contact with the soil." From H.L. Gordon, *Cathodic Protection*, Power Plant Electrical Reference Series, Project 2334, Electric Power Research Institute, Palo Alto, California, 1991, vol. 11, p. 11.2.

[9] Pipeline companies perform pipe-to-soil potential surveys by measuring and recording the voltages and currents at test stations along the pipeline and at rectifiers. Measurement intervals vary widely from less than 100 feet in some locations to several miles in others.

Figure 3. Circumferential crack on top half of pipe with failure initiation region at the 3 o'clock position.

instances, crack arrest marks were visible within the thumbnail regions. The preexisting crack features in the failure initiating area were consistent with environment-induced cracking.[10]

After the accident, Colonial had an independent lab perform Charpy tests on specimens prepared from the failed pipe joint. Longitudinal pipe specimens were tested at temperatures ranging between 25° and 170° F. The full-size energy values[11] for absorbed energy in the longitudinal direction were from 3.4 to 21.8 ft/lbs between 25° and 65° F, and 40.2 ft/lbs at 85° F. The results between 105° and 170° F were from 62 to 77.1 ft/lbs.

The Safety Board also had Charpy testing performed on test specimens taken in proximity to the rupture. The tests were conducted in both the longitudinal and circumferential direction at a range of temperatures between 0° and 85° F. The test results in the longitudinal direction indicate absorbed energy values from 4.2 to 15 ft/lbs between 0° and 65° F, and 54 ft/lbs at 85° F. The results in the circumferential direction indicate values from 4.6 to 22 ft/lbs between 0° and 85° F.

[10] *Environment-induced cracking* occurs due to the combined effects of tensile stress and a corrosive environment. If a susceptible material under static tensile stress is exposed to a specific corrosive medium, the failure is defined as stress corrosion cracking. If the material is exposed to cyclic tensile stresses in a corrosive environment, the failure is defined as corrosion fatigue.

[11] Sub-size specimens were tested and full-size energy values were calculated in accordance with ASTM E23 for all Charpy absorbed energy data.

Actions Taken Since the Accident

Since the accident, Colonial has updated its public education program to reach a target audience within a minimum of 1/4 mile of its pipeline operating area, regardless of whether the property is traversed by a pipeline easement. Colonial has also updated the educational information in its safety pamphlet and upgraded the method by which the safety information is communicated to the target audience. Colonial has also updated its public education program mailings to better reach its target audience. The first paragraph of each educational mailing now encourages the initial reader to share the information with all members of the household.

In addition, Colonial has upgraded its written procedures for establishing and maintaining liaison with fire, police, and other agencies that might respond to a hazardous liquid pipeline emergency. The procedures identify the methods to be used, the information to be shared, and the frequency of the contacts.

Since the Knoxville accident, Colonial's control center operations manual for abnormal and emergency operations has been amended to include the following: "Any time an unscheduled shutdown occurs, the line will only be re-started with the concurrence of a Senior Controller." At the time of the accident, Colonial's control center operations manual directed that for continuous minor hourly shortages, the controller would investigate by having all active facilities "prove" (verify the accuracy of) the meters. If proving meters did not correct the shortages, controllers were to contact the senior controller for a decision to possibly pressure-test the line or shut it down for inspection. Colonial's control center operations manual for emergency operations involving leaks or suspected leaks has been amended to include the following:

> Any time a line is shut down to investigate a continuous minor hourly shortage, the line will only be re-started with the concurrence of a representative from the Engineering Services Team.

Colonial is using the details surrounding this event in various training scenarios and has added the Knoxville accident scenario to its maximum critical event training. Colonial uses simulator training as part of its controller training.

Colonial is continuing its efforts to install an automated leak detection system. Colonial is currently installing a batch tracking system on a Colonial stubline system similar to the one involved in this accident. This new system is expected to aid the pipeline controller in identifying variances in the amount of product shipped versus the amount of product delivered. Any discrepancies identified above a predetermined threshold will be investigated as a possible leak. Colonial has experienced some difficulty in completing the installation of this system but anticipates completion in the first half of 2001. Once the first system is successfully installed, Colonial anticipates installing the batch tracking system on other stublines. When all the stublines are addressed, Colonial anticipates attempting to apply the same batch tracking system to the company's mainlines, although the company expressed some concern about the effect that the size and the complexity of the mainlines will have on the performance of the batch tracking system.

Colonial is developing a formal, documented strategic plan on how to approach the identification, evaluation, and application of technology to leak detection on Colonial's system. This plan is scheduled to be fully developed in 2001. The objective of the plan is to find and implement effective means of leak detection and to comply with the new Office of Pipeline Safety regulations on integrity management of pipelines that affect high-consequences areas.

The Knoxville Fire Department incident commander held a postaccident debriefing with Knoxville communication center personnel, established new procedures for the communications center, and requested that Colonial provide maps for fire department use. Because of the delay in notifying Colonial that occurred in this accident, procedures have been changed so that (1) the communications center will not rely solely on dispatcher trainees during periods of heavy workload; (2) the supervisors will assist the dispatcher during periods of heavy workload; and (3) the communications center will record all communications channels to create a record of emergency response conversations.

Also at the request of the Knoxville Fire Department, Colonial provided the department with pipeline location maps to be carried by fire department units responding to calls involving the possible release of hazardous materials. The department also uses the maps during annual fire department training sessions at the Colonial terminal facility.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was pipe rupture initiated by environment-induced cracking in an area of pipe coating failure. A contributing factor to the failure was the relatively low fracture toughness of the pipe. Contributing to the severity of the accident was Colonial Pipeline Company's failure to determine from the supervisory control and data acquisition system that a leak had occurred, with the result that the pipeline controller started and restarted the pipeline, thereby increasing the amount of diesel fuel that was released.

Approved: March 28, 2001