

**NATIONAL TRANSPORTATION SAFETY BOARD**

Office of Marine Safety

Washington, D.C. 20594

March 28, 2012

**GROUP CHAIRMAN'S FACTUAL REPORT  
HUMAN FACTORS**

**DCA-10-MP-007**

**A. ACCIDENT**

Operator: Enbridge Energy, Inc.

Location: Marshall, Michigan

Date: July 25, 2010

Time: 1758 Eastern Daylight Savings Time (EST)<sup>1</sup>

**B. HUMAN FACTORS GROUP**

Barry Strauch, Co-Chair

National Transportation Safety Board

Washington, D.C.

Matthew Nicholson Co-Chair

National Transportation Safety Board

Washington, D.C.

Jay Johnson

Enbridge Energy

Superior, WI

Karen Butler

PHMSA Central Region

Kansas City, MO

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<sup>1</sup> All times herein are Eastern Daylight Savings Time, in the 24-hour clock, unless otherwise indicated.

## C. SUMMARY

On the evening of Sunday, July 25 2010, at approximately 5:58 p.m.<sup>2</sup>, a 40-foot long pipe segment in Line 6B, located approximately 0.6 of a miles downstream of the Marshall, Michigan pump station, ruptured. The Line 6B is owned and operated by the Enbridge Energy Inc. (Enbridge). The Enbridge control center in Edmonton, Alberta Canada was in the final stages of executing a scheduled shutdown of their 30-inch diameter crude oil pipeline (Line 6B) when the rupture occurred. The initial and subsequent alarms associated with the rupture were not recognized as a line-break through two start-up attempts and over multiple control center shifts. Residents near the rupture site began calling the Marshall City 911 dispatch center to report odors at 9:25 p.m. on Sunday; however, no calls were placed to the Enbridge control center until 11:17 a.m. the following day. Once the Enbridge control center was notified, nearly 17-hours after the initial rupture, remote controlled valves were closed, bracketing the ruptured segment within a three-mile section.

The accident resulted in an Enbridge reported release estimate of 20,082 barrels (843,444 gallons) of crude oil with no injuries or fatalities. The rupture location is in a high consequence area<sup>3</sup> within a mostly rural, wet, and low-lying region. The released oil pooled into a marshy area over the rupture site before flowing 700 feet south into Talmadge creek which ultimately carried it into the Kalamazoo River.

Line 6B was constructed in 1969 as a 293-mile long extension of the Lakehead pipeline system, stretching from Griffith, Indiana to Sarnia, Ontario. The failed segment was a cathodically protected, tape coated pipe manufactured by Italsider s.p.a.<sup>4</sup> per the 1968 API<sup>5</sup> Standard 5LX *Specification for High-Test Line Pipe X52* specification with 0.25-inch thick wall and a double submerged arc welded (DSAW) longitudinal seam. The maximum operating pressure (MOP) for Line 6B was 624 psig; however, at the time of the accident, Marshall Station discharge pressure was limited to 523 psig due to a 2009 Enbridge imposed pressure restriction between Stockbridge and Sarnia. The maximum-recorded discharge pressure at Marshall, prior to the rupture, was 486 psig.

## D. DETAILS OF THE INVESTIGATION

The Human Factors Group was formed November 14, 2011, in Edmonton, Alberta. Group Chairmen were Barry Strauch and Matthew Nicholson, National Transportation Safety Board (NTSB). Other group members were Karen Butler, Pipeline and Hazardous Materials Safety Administration (PHMSA), and Jay Johnson, Enbridge, Inc. From November 14 to November 18, 2011, the group interviewed current and former employees of Enbridge and a PHMSA representative. The group reconvened in Edmonton, AB, on January 30, 2012, when it

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<sup>2</sup> All times are expressed in local accident time, Eastern Daylight Time.

<sup>3</sup> As defined by PHMSA under 49CFR§195.450.

<sup>4</sup> Societa Per Azioni (Italian). The Italsider pipe was purchased from Siderius Inc. of New York.

<sup>5</sup> American Petroleum Institute, New York, New York

interviewed additional current and former Enbridge Pipeline employees. The group also received and reviewed documentation from Enbridge, and reviewed PHMSA regulations and Advisory Bulletins. Also, on March 15, 2012, NTSB investigators interviewed PHMSA headquarters officials at NTSB's Washington, DC, offices. The focus of the human factors group was on PHMSA oversight, Enbridge oversight, and Enbridge control center operations.

## PREVIOUS NTSB ACTION

After a series of earlier pipeline accidents occurred, the NTSB conducted a safety study of supervisory control and data acquisition (SCADA) systems, examining the design and staffing of SCADA centers, and operational issues such as: SCADA screen graphics, alarm philosophy, fatigue management, controller training and selection, and computational pipeline monitoring. The NTSB issued a report on November 29, 2005,<sup>6</sup> which cited the need for additional oversight of pipeline control operations and design, and issued several recommendations as a result of the study, including the following:

Require operators<sup>7</sup> of hazardous liquid pipelines to follow the American Petroleum Institute's Recommended Practice 1165 for the use of graphics on the Supervisory Control and Data Acquisition Screens. (P-05-01)

Require pipeline companies to have a policy for the review/audit of alarms. (P-05-02)

Change the liquid accident reporting form (PHMSA F 7000-1) and require operators to provide data related to controller fatigue. (P-05-04)

Require operators to install computer-based leak detection systems on all lines unless engineering analysis determines that such a system is not necessary. (P-05-05)

Partially in response to the study, Public Law 109-468, the Pipeline Inspection, Protection, Enforcement and Safety (PIPES) Act of 2006, was enacted on December 29, 2006. Pipeline control room management §60137, included within the Act, required the Secretary of Transportation to:

(a)...Issue regulations requiring each operator of a gas or hazardous liquid pipeline to develop, implement, and submit to the Secretary...a human factors management plan designed to reduce risks associated with human factors, including fatigue, in each control center for the pipeline. Each plan must include, among the measures to reduce such risks, a maximum limit on the hours of service established by the operator for individuals employed as controllers in a control center for the pipeline.

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<sup>6</sup>*Supervisory Control and Data Acquisition (SCADA) in Liquid Pipelines*, Safety Study NTSB/SS-05/02 (Washington, DC: National Transportation Safety Board, 2005).

<sup>7</sup> PHMSA refers to pipeline operating companies as "operators" and to pipeline controllers as either "controllers" or "operators." In this report, unless otherwise stated, the terms controllers and operators will be used interchangeably.

Further, Section 19 of the Act, Standards, called on the Secretary of Transportation, no later than June 1, 2008, to implement actions corresponding to those called for in recommendations P-05-01, P-05-02, and P-05-05. The Secretary's response is discussed subsequently in this report.

Shortly after this accident, a gas pipeline in San Bruno, California, operated by Pacific Gas and Electric Company (PG&E), ruptured on September 9, 2010. Eight people were killed, 10 were injured seriously, 48 people sustained minor injuries, and 38 homes were destroyed as a result of the accident. In its investigation of this accident<sup>8</sup> the NTSB noted a breakdown in team performance within PG&E's SCADA operations center after the rupture. As the investigation report noted (p. 98):

... The lack of assigned roles and responsibilities resulted in SCADA staff not allocating their time and attention in the most effective manner. They did not initially notice the dropping pressures at the Martin station after the rupture, but rather were alerted by staff at the Brentwood SCADA facility. Also, there was unnecessary overlap and duplication of their efforts. [Further, after PG&E was asked by the local fire department to shut off the pipeline's gas flow] ...no one had yet been officially dispatched to shut off the valves and isolate the rupture. Further, no one within PG&E was compiling and assessing the information generated from the SCADA system and telephone communications from outside sources or between the SCADA center and dispatch. The NTSB concludes that PG&E lacked detailed and comprehensive procedures for responding to a large-scale emergency such as a transmission line break, including a defined command structure that clearly assigns a single point of leadership and allocates specific duties to SCADA staff and other involved employees.

## **PHMSA OVERSIGHT**

To conform to these recommendations and the requirements of the PIPES Act of 2006, PHMSA modified existing gas and liquid pipeline regulations contained in 49 Code of Federal Regulations (CFR) 192 and 49 CFR 195, respectively. As a result, the NTSB closed the pertinent recommendations and classified PHMSA's responses, "Acceptable Action." PHMSA's rule modifications,<sup>9</sup> which took effect on February 1, 2011, were similar for liquid and gas pipelines, requiring pipeline operating companies to comply with the requirements by August 1, 2011, and implement the requirements by February 1, 2012. PHMSA regulations do not require pipeline operating companies to have SCADA systems with control rooms. However, if they do, PHMSA's rules would be applicable. As a PHMSA representative explained:

This rule requires pipeline operators to have and follow written control room management procedures. The operators must define the roles and responsibilities of controllers in normal, abnormal, and emergency operating situations. Pipeline operators will be required by this final rule to assure that new SCADA displays and displays for SCADA systems that are expanded or replaced meet the provisions of the consensus standard governing such displays, API RP 1165. Pipeline operators will need to define

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<sup>8</sup> *Pacific Gas and Electric Company Natural Gas Transmission Pipeline Rupture and Fire, San Bruno, California*, Accident Report NTSB/PAR-11/01 (Washington, DC: National Transportation Safety Board, 2002).

<sup>9</sup> 74 FR (*Federal Register*) 231, 63310-63330.

procedures for shift changes and other circumstances in which responsibility for pipeline operation is transferred from one controller to another. The procedures must include the content of information to be exchanged during the turnover. Pipeline operators must implement measures to prevent fatigue that could influence a controller's ability to perform as needed. Operators will need to schedule their shifts in a manner that allows each controller enough off-duty time to achieve eight hours of continuous sleep. Operators must train controllers and their supervisors to recognize the effects of fatigue and in fatigue mitigation strategies. Finally, each operator's procedures must establish a maximum limit on the number of hours that a controller can work. All pipeline operators are subject to the fatigue management requirement, even those whose operations do not involve multiple shifts...and the PIPES Act requires that all pipeline operators have a plan that addresses fatigue.

The modified regulations pertaining to liquid pipelines were incorporated into 49 CFR 195.446, Control Room Management. These rules include the following, with regard to fatigue management:

(d) *Fatigue mitigation.* Each [liquid pipeline] operator must implement the following methods to reduce the risk associated with controller fatigue that could inhibit a controller's ability to carry out the roles and responsibilities the operator has defined:

- (1) Establish shift lengths and schedule rotations that provide controllers off-duty time sufficient to achieve eight hours of continuous sleep;
- (2) Educate controllers and supervisors in fatigue mitigation strategies and how off-duty activities contribute to fatigue;
- (3) Train controllers and supervisors to recognize the effects of fatigue; and
- (4) Establish a maximum limit on controller hours-of-service, which may provide for an emergency deviation from the maximum limit if necessary for the safe operation of a pipeline facility.

According to PHMSA's supervisor of accident investigations for its Central Regional Office in Kansas City, its representatives met with United States Department of Transportation (DOT) personnel involved in overseeing aviation and rail operations, as well as representatives from the Coast Guard, and the Nuclear Regulatory Commission, during the approximate period between 2004 and 2007, before PHMSA developed rules governing control room management. This was done to learn about best practices in the oversight programs of federal regulators. The visits also included the Federal Aviation Administration's Civil Aeromedical Institute to review human factors oversight issues. As the PHMSA supervisor noted:

...We tried to talk to every single [transportation] mode that we could think of to gain our experience. Our specific discussions were along one concept and that was whatever they had done and had success with, we gained that benefit, but also if they'd had trouble with it. And I might add, we...went to hydraulic specialists that modeled pipelines and asked them specifics and we went to SCADA vendors and asked them specifics.

The PHMSA supervisor noted that the agency had just begun audits or inspections of control rooms in accordance with 49 CFR 192 and 49 CFR 195 in late 2011. She anticipated that once PHMSA had audited each control room it would establish a standard inspection interval, which she estimated would be between once every three and five years. She believed that since the new rules were implemented, which coincided with the accident at Marshall, MI, a PHMSA control room audit would examine the following items, which had not been assessed beforehand:

- Color use in control room displays
- Alarm assessment
- Operator training
- Operator experience requirements
- Control room personnel roles and responsibilities, and
- Shift change procedures

PHMSA headquarters officials indicated that it had no in-house human factors expertise. Instead, it contracted with a consultant to obtain the expertise in the development of its control room management regulations.

With regard to alarm design, 49 CFR 195 requires operators to do the following:

(e) Alarm management. Each operator using a SCADA system must have a written alarm management plan to provide for effective controller response to alarms. An operator's plan must include provisions to:

- (1) Review SCADA safety-related alarm operations using a process that ensures alarms are accurate and support safe pipeline operations;
- (2) Identify at least once each calendar month points affecting safety that have been taken off scan in the SCADA host, have had alarms inhibited, generated false alarms, or that have had forced or manual values for periods of time exceeding that required for associated maintenance or operating activities;
- (3) Verify the correct safety-related alarm set-point values and alarm descriptions when associated field instruments are calibrated or changed and at least once each calendar year, but at intervals not to exceed 15 months;
- (4) Review the alarm management plan required by this paragraph at least once each calendar year, but at intervals not exceeding 15 months, to determine the effectiveness of the plan;
- (5) Monitor the content and volume of general activity being directed to and required of each controller at least once each calendar year, but at intervals not

exceeding 15 months, that will assure controllers have sufficient time to analyze and react to incoming alarms; and

(6) Address deficiencies identified through the implementation of paragraphs (e)(1) through (e)(5) of this section.

PHMSA headquarters personnel noted that the agency intended to review the results of audits of the control rooms of pipeline operating companies conducted in 2011 and 2012. They completed 10 audits in 2011 and expected to conduct 40 in 2012. Based on the results of the audits in the two years, they intended to review the audit requirements and modify them, as they considered necessary. They also indicated that the agency was willing to modify its control room management rules if the data warranted, such as the results of this investigation, or if additional control room issues were to be identified.

In addition to its regulations, PHMSA issued several Advisory Bulletins (ADB) governing control rooms and SCADA systems. ADB 03-09, issued on December 23, 2003, was issued in response to NTSB recommendation P-02-05, which urged the DOT's Office of Pipeline Safety, within the then Research and Special Projects Administration, the predecessor of PHMSA to:

Issue an advisory bulletin to all pipeline operators who use supervisory control and data acquisition (SCADA) systems advising them to implement an off-line workstation that can be used to modify their SCADA system database or to perform developmental and testing work independent of their on-line systems. Advise operators to use the off-line system before any modifications are implemented to ensure that those modifications are error-free and that they create no ancillary problems for controllers responsible for operating the pipeline.

In response to PHMSA's actions, the NTSB classified these recommendations as "Closed—Acceptable Action."

ADB 04-05, issued on November 26, 2006, explained the parts of 49 CFR 192 and 195 that required gas and liquid pipeline operating companies to establish and maintain operator qualification programs. The ADB advised pipeline operating companies to include periodic requalifications for operators at intervals that "reflect the relevant factors including the complexity, criticality, and frequency of the performance of the task."

ADB 05-06 responded to NTSB safety recommendation P-98-30, which called upon PHMSA's predecessor agency to "assess the potential safety risks associated with rotating pipeline controller shifts and establish industry guidelines for the development and implementation of pipeline controller work schedules that reduce the likelihood of accidents attributable to controller fatigue." The Advisory Bulletin advised pipeline operating companies to develop shift rotation schedules that would minimize the effects of fatigue, limit work schedules to no more than 12 hours in any 24-hour period, provide a minimum of 10 hours of break between work periods, develop guidelines for operators and supervisors during emergency situations that take controller fatigue into account, establish work relief periods during controller shifts, modify control room environments to minimize environmental fatiguing elements, and train controllers

and supervisors on both factors that affect fatigue and ways to recognize the effects of fatigue on controllers.

ADB 10-01, issued on January 26, 2010, advised pipeline operating companies of the importance of including in their operating plans and procedures, in compliance with existing regulations, an engineering analysis that determines if computer-based leak detection systems are necessary to improve pipeline leak detection performance and line balance processes.

ADB 10-06, issued on August 3, 2010, advised pipeline operating companies of the risks associated with operator use of personal electric devices, such as cell phones, for non-operational purposes, when involved in pipeline control tasks.

Enbridge operates pipelines in both Canada and the United States, from its Edmonton, Alberta, operations center. Pipelines in the United States are subject to United States oversight by PHMSA, and those in Canada are subject to Canadian oversight by the Canadian National Energy Board (NEB). Pipelines that originate in Canada and terminate in the United States are subject to the requirements of both PHMSA and NEB. According to Enbridge's Manager United States/Canadian compliance, Enbridge does not find conflicts in meeting the requirements of the two regulators. Rather, where reporting requirements of the two regulators are different, the company either meets the requirements of the applicable regulator, or the regulator with more rigorous standards. For example, NEB does not require operator qualifications (OQs) testing at regular intervals, but PHMSA does. Therefore, Enbridge requires regular OQ testing on all of its control room operators, irrespective of the location of the lines they operate. The Enbridge compliance manager described the requirements of PHMSA as being "somewhat more prescriptive" than those of NEB while those of NEB are "more on a performance based type of standard regulation."

NEB inspections have tended to focus on somewhat broader areas than PHMSA, although both focus on pipeline integrity. In addition to regulating pipeline safety, NEB oversees Enbridge tariffs, a task performed in the United States by the Federal Energy Regulatory Commission (FERC). PHMSA has conducted more frequent comprehensive inspections than has NEB, partly because, according to a PHMSA representative, several of the states in which Enbridge pipelines traverse are authorized to conduct audits on behalf of PHMSA, and thus can accomplish the audits without impacting PHMSA workload. Neither United States nor Canadian regulators have implemented a medical oversight system of control room operators.

## **ENBRIDGE**

### **CONTROL ROOM STAFFING**

At the time of the accident, the control room was staffed by 22 pipeline controllers or operators, two shift leads, and a materials balance system (MBS) analyst, who worked in 12-hour shifts. Pipeline controllers were grouped in two, sitting side by side or across from each other, and worked on two or three pipelines within a particular geographic area of Enbridge's pipeline system. In addition, a senior management representative was available, either in person during regular work hours or on call at nights and on weekends, in the event higher level authority was needed or questions were raised regarding pipeline operations.

Pipeline controllers were given assignments directing certain amounts of hydrocarbon liquid product, to be shipped from various collection points to destinations within the Enbridge system. Depending on parameters related to product characteristics, scheduled volumes, injection and delivery locations, available pumps, flow rates, etc., line operators would plan and carry out the necessary controls to meet the shipping objectives by adjusting power and flow rates.

MBS analysts were located in the control room with the operators and shift leads at the time of the accident. Because pipelines followed terrain undulations, column separations, in which gravitational or other forces created breaks or separations of the liquid product within the pipeline, could occur. In that event MBS alarms could be activated. Enbridge required MBS analysts to be consulted when an MBS alarm activated to analyze the MBS system and determine the validity of the alarm. According to one of the shift leads on duty during the accident sequence, MBS analysts were expected to be able to explain, "...what the cause [of an MBS alarm] is..."

According to Enbridge's control center supervisor, the amount of information that MBS analysts provided in response to MBS alarms changed after the accident. He noted that "the request to minimize the amount of information coming from the MBS analyst, whether the model is working or not, were implemented post 6B," that is, after the accident.

Shift leads, who before becoming supervisors had served as either pipeline operators or terminal operators, were expected to serve as liaisons between controllers and others involved in pipeline operations, to facilitate pipeline controllers' ability to operate the pipelines. In this way, the supervisors were expected to serve as "people persons" and to provide technical support. They were given training in interpersonal skills, leadership, and management to that effect. One operator noted that when terminal operators became shift leads, in addition to former pipeline operators, they had lost some pipeline operating expertise that the pipeline operators could rely on because shift leads with terminal operating background did not have the pipeline operations knowledge as had shift leads with pipeline operating background. As she explained,

...when we had a problem we had someone we could talk to about it and help us make decisions. Whereas now ...sometimes the supervisor we're talking to is a terminal supervisor and he's only worked on terminals, he hasn't, you know, he doesn't know what we know about the line and so it's not -- we don't have that second person we can discuss the problem with.

Shift leads were no longer required to qualify through operator qualifications or OQs, as PHMSA required of operators, on a triennial basis. Shift leads worked similar shifts as the operators, and were responsible for helping to guide operators' careers at Enbridge by completing performance evaluations according to Enbridge performance appraisal system, and to mentor or counsel operators as needed. Shift leads also were responsible for documenting operator errors and determining and communicating follow up actions, as needed.

Shift leads were expected to contact the on call supervisor for management support and approvals specific situations arose as outlined in the emergency procedures. The on-call supervisor who was contacted during the night of July 25/26 was Enbridge's supervisor, terminal services. He told investigators that when he was discussing the situation with the shift leads on

the night of the accident, because of his background in terminal operations rather than pipeline operations, he was,

...trusting the shift leads to make sure that -- to ensure they knew what was going on. So I mean my trust was within them, within the shift leads.

He said that he discussed the situation on the night of the accident with the shift leads and MBS analyst. He was aware that the shift leads were "there as people leaders" leaders" but that they also had technical and operating backgrounds as well. As he told investigators, "So when I ask them a question, they're not going to say I don't know, I'd have to go ask the operator. They have some technical expertise."

As one of the night July 25/26 shift leads described his role, "...I'm there to first and foremost be a people leader to the operators in the room and then also provide support where needed, whether that's technical support, whether that's, I guess support as a leader with personal issues or anything that is involved in the control center." The shift lead also expressed uncertainty about his role, as he told investigators, that he had wanted, "... more of a defined role. I really find that it was, and to this day is still clouded to some extent as to what our actual position is." The other shift lead on duty that night described his role this way, "We're the guys they come to when they have problems, and we try to help them." In terms of emergency response, he characterized the role of the shift leads this way:

We're the operators' performance manager and we're there for emergency response. You got emergency one call response, and then we're the one that write any emails and letting everybody know about what's happening, like shipper services, our manager group. So, we're kind of liaison between the control center and outside departments."

According to Enbridge's vice president, customer service, who oversaw the control room and its operations at the time of the accident, the emphasis on interpersonal relationships and leadership skills in shift leads came about because of an increase in the number of control room personnel. She noted that with more pipeline operators, the company wanted more consistency in managing the performance of operators than had been experienced before. According to Enbridge's senior vice president of operations, who after Enbridge reorganized its management structure after this accident oversaw the control room in place of the vice president, customer service, the decision to emphasize interpersonal skills in its shift leads was influenced by the desire to increase the retention among control room operators. As he noted, "...we were losing too many of those people, so we were always in the backfill mode and we were never quite getting up to the full compliment [of control room operators that] we wanted."

Enbridge reported that in 2005 it lost 10 control room personnel to termination, retirement, transfer or promotion. In 2006, 2007, 2008, 2009, and 2010, the number of employees who left the control room for these reasons were 12, 8, 17, 12, and 14, respectively. On January 1, 2007, Enbridge employed 89 control room operators and 15 control room support staff. On July 15, 2010, these numbers were 117 and 37, respectively.

In follow up interviews with current and former control room personnel, several interviewees complained about the effects of insufficient staffing on control room morale. A former shift lead

told interviewers that on occasion, shift leads would compel operators who had called in sick to report to work because the shift leads were unable to find replacements for the operators. When that occurred, he said that "...you have to call ... the rest of the group that basically is in that pod and you basically have to force them to come to work and fill that position."

The director, control center operations (who was appointed to the position 6 months after the accident), was aware of reports of insufficient control room personnel and noted that Enbridge was addressing the issue. He said that, "I think that over the past 3 years, we've struggled to a certain degree in relation to our staffing levels and we are really working hard to get our staffing levels to where we need them to be to allow that work-life balance, to allow that flexibility and so forth, to ensure coverage."

Current and former controllers also commented on a general decline in the overall control room experience level. One of the night, July 25/26 shift leads told NTSB investigators that he would "... characterize it as a whole to be inexperienced, yeah. Yeah, I guess I don't have the number in my head, but like 1 or 2 years experience..." A shift lead said that "the experience level is diminishing now." The day, July 25 line 6B controller, who had retired from Enbridge over a year after the accident, told investigators that there were no effects on the quality of the control room's performance from possible declines in control room experience levels, "because there was always enough senior people there to help out."

A control room operator characterized the effects of inexperience this way,

...the loss of experience is kind of like having a -- making a tape of a tape. Every time you train somebody you lose a little bit and you train -- that person trains another person and you lose a little bit.

Enbridge's director, control center operations, acknowledged the challenges that relatively inexperienced personnel presented. As he said,

... We've got a very young leadership group there, right. Some of our shift leads or shift supervisors are new. You know, from that perspective, they've been, you know, through quite a bit of training, like corporate training, like frontline leadership, everyday coaching, those types of things, but they need to gain more experience and they need to be worked with and coached along and mentored...

## PERSONNEL

NTSB investigators examined the work history and schedules of seven control room personnel on duty during the event, each of whom was directly involved in the critical decisions regarding the operation of line 6B. These were the line 6B operator/mentor, the line 6B operator trainee, and the MBS analyst on duty during the day of July 25, 2010, and the line 6B operator, MBS analyst, and the two shift leads on duty during the night of July 25/26, 2010. All maintained a schedule that either began or ended at 0600 and 1800 local time.

Day line 6B operator trainee-The day, July 25, line 6B operator trainee was 52 at the time of the accident. He was off on July 21, and had worked an extra shift on July 22, and the day shift on July 23, 24, and 25. He graduated high school in 1975, served in the Canadian Armed Forces for

three years, and then worked as a mechanic and then a driver for two companies from January 1979 to August 1979, before joining Enbridge as a utility person on August 20, 1979.

He became a pipeline controller with Enbridge on April 20, 1981, and on November 19, 1985, became a senior control center operator. On October 1, 2000, he became a level III operator.<sup>10</sup> On October 26, 2009, he commenced an approximate 6-month period of medically-caused absence from pipeline operational duties. He returned to the Enbridge control room on a part-time basis on April 12, 2010. On June 30, 2010, he was medically-cleared to work full time and he began working a regular shift schedule on July 14, 2010.

His personnel record included a commendation that noted, in part, his "...quick decisive action on January 1 [, 2007,] for the L-14 leak was instrumental in mitigating environmental damage and reducing oil losses. ... [He] received recognition from [an Enbridge supervisor] ... for his quick response to the leak."

Because of his prolonged absence from operator duties his operator qualification or OQ was no longer valid, and he was reclassified as a trainee upon his return. He then worked under the mentorship of an operator who had about the same amount of pipeline operating experience as he had. Both reported to NTSB investigators that, while considered to be a trainee, he required little oversight. He told investigators that he remained familiar with pipeline operations but was unfamiliar with procedural changes that had taken place in his absence.

The 53-year old operator/mentor, who served as the mentor for the line 6B day time operator, began her employment at Enbridge as a clerk on June 2, 1980. She became a technical assistant on May 1, 1981, and later entered training to become a control center operator. She qualified as a control center "swing operator" on March 1, 1982, and became a control center operator on March 1, 1985. On June 1, 1987, she was promoted to senior control center operator. On June 1, 1990, she was reassigned to the position of control center operator, in response to an April 26, 1990, request she had made to her supervisors to return to the operator position. On October 1, 2000, she was promoted to control center operator III. She had been off duty for four days before working on day shifts on July 23, July 24, and July 25. She was to have worked on the night shifts beginning on July 26 and 27<sup>th</sup>.

Before joining Enbridge she had earned two certificates from Conestoga College, one in 1980 for "Product Planning and Inventory Control," and the other in 1979, for "Introduction to Non-Traditional Occupations." During the time she was earning the certificates until joining Enbridge she was employed in several companies in Ontario performing inventory control duties.

The day line 6B operator/mentor had two letters in her file regarding errors in her performance as operator. One, dated November 2, 1994, concerned two errors committed in October 1994 in line operation. One of the errors was "Failure to follow the 'Ten Minute Rule.'" She received a second letter, on May 11, 2010, also for two errors in line operations committed a week earlier.

Night line 6B operator-The night, July 25/26 line 6B operator was 26 at the time of the accident. He worked on the day shift on July 21 and 22, and then worked on the night shifts of July 23, 24,

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<sup>10</sup> At the time of the accident control center operators were classified into one of three levels based on their experience and performance. Level III was the highest of the pipeline operator categories.

and 25. He had completed his day and night rotation schedule was off duty beginning on July 26. He told investigators that he does not sleep well during the period when he is serving as a pipeline controller.

At the time of the accident the night line 6B July 25/26 operator was wearing dark glasses at all times, including while on duty in the control room because, for the six months or so before the accident, he had become sensitive to light and if he didn't wear them he would "get hot and sweaty and dizzy, and if it goes long enough, I feel like I'll -- I'm going to throw up kind of thing." He told investigators that he believed that this condition did not interfere with his pipeline operating duties as long as he wore the dark glasses.

The operator received a diploma in mechanical engineering technology from the Northern Alberta Institute of Technology (NAIT) in April 2005. Between 1993 and 2006 he was a custom fertilizer specialist with a petroleum company and a line service technician with an aviation fueling company. He then became a field specialist with a company providing cement services in Alberta and Saskatchewan before joining Enbridge as a control center operator on October 25, 2006. He became a level II operator in October 2007 and a level III operator in November 2008. No commendations or reprimands were noted in his personnel record.

Day MBS analyst-The July 25 and July 26<sup>th</sup> daytime MBS analyst was 31 at the time of the accident. He had been off duty on July 21-24. On July 25 and 26 he worked a day shift schedule. He earned a diploma in information technology and systems management in 2004 from Grant MacEwan College. Before that he had attended three different colleges from 1998 to 2003, studying power engineering in the first, computer engineering technology in the second, and computer information systems in the third, without obtaining a degree or diploma.

He was self employed as a webmaster from 1996 to 2005. For part of that period, 2003 to 2005, he served as a webmaster for a building products company. Before that he had served as a webmaster as a coop while a student from 2002-2003, and from 2000 to 2001, as a systems analyst for the Alberta provincial government. He joined Enbridge on January 5, 2009, as an MBS support analyst level II.<sup>11</sup> No commendations or reprimands were noted in his personnel record.

Night MBS analyst-The night July 25/26 analyst was 56 at the time of the accident. He had worked the night shift on each of the nights beginning on July 21 to the night beginning on July 26 (which ended on the morning of July 27). He graduated high school in 1981 and attended one year of college in 1982. He then worked for four years for an oil service company in Canada's Northwest Territories (NWT). He joined Enbridge on October 17, 1989, as a pipeline operator in Norman Wells, NWT. He became a senior pipeline operator on October 17, 1991, and on December 1, 1993, transferred to Enbridge's Edmonton control center. On October 1, 2000, he became a level III pipeline operator and remained in that position until March 15, 2008, when he became a level III MBS analyst. His personnel records contained a January 19, 1999, letter commending him for his assistance on a project involving Enbridge Technology-Mexico.

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<sup>11</sup> At the time of the accident MBS analysts were classified into one of three levels based on their experience and performance. Level III was the highest of the MBS analyst categories.

Night shift lead-The first of the two shift leads on the July 25/26 night shift was 37 at the time of the accident. He had worked on the day shifts of July 21 and 22 then worked the nights beginning on July 23, 24 and 25. He was off on the night beginning on July 26. He had earned a diploma in April 1996 in mechanical engineering technology from NAIT. He served as a project engineer for an oil services company from June 1997 to October 1998. Before that he served as an engineer in training for a company from May 1996 to June 1997. No commendations or reprimands were noted in his personnel record.

He joined Enbridge on March 22, 1999, as a control center operator II, and became a level III operator on October 1, 2000. On January 1, 2008, he became a control room shift lead.

Night shift lead-The second of the two night shift leads on duty during the night of July 25/26, was 37 at the time of the accident. Because shift leads and line operators typically worked similar schedules, he worked on the same day/night shift schedule as the other shift lead. No commendations or reprimands were noted in his personnel record.

The second shift lead earned a bachelor's degree in history in 1994 from the University of Regina. He was a self employed contractor from June 1996 to June 1999, performing pipeline maintenance. During the summers of 1992, 1993, 1994, and 1995, he worked as a student employee for Enbridge, performing pipeline maintenance-related duties in Kerrobert and Regina, Canada.

He joined Enbridge as a temporary utility employee on February 28, 2000. On February 1, 2001, his employment with Enbridge became permanent, in the same position as before. He became a control center operator level II on May 1, 2002. On September 1, 2003, he became a control center operator III at the same facility. He transferred to the Edmonton control center, in the same position, on January 1, 2007. On May 16, 2008, he became a shift lead.

## CONTROL ROOM PERSONNEL-TOXICOLOGY

As required by 49 CFR 195 (b),<sup>12</sup> and 49 CFR 199.221,<sup>13</sup> Enbridge obtained drug and alcohol tests from the shift leads and line 6B controllers on duty during the day and night shifts on July 25 and July 26 to determine the presence of alcohol and five classes of illegal drugs (marijuana, cocaine, opiates, amphetamines, and phencyclidine (PCP), see 49 CFR 199.3). The samples of the day July 25 and July 25/26 and night line controllers were collected on July 28, around 1000 local time. The remaining samples were obtained on July 27, around 2050, local time. Because

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<sup>12</sup> The regulation states: (b) Post-accident testing. As soon as possible but no later than 32 hours after an accident, an operator shall drug test each employee whose performance either contributed to the accident or cannot be completely discounted as a contributing factor to the accident. An operator may decide not to test under this paragraph but such a decision must be based on the best information available immediately after the accident that the employee's performance could not have contributed to the accident or that, because of the time between that performance and the accident, it is not likely that a drug test would reveal whether the performance was affected by drug use.

<sup>13</sup> Each operator shall prohibit a covered employee who has actual knowledge of an accident in which his or her performance of covered functions has not been discounted by the operator as a contributing factor to the accident from using alcohol for eight hours following the accident, unless he or she has been given a post-accident test under §199.225(a), or the operator has determined that the employee's performance could not have contributed to the accident.

the maximum time after the accident required by regulation for alcohol testing had been exceeded, the results were not considered to have been valid. The results of the drug tests were negative.

Enbridge provided information on drug and alcohol testing in Part F of the Form 7000-1 accident report form it filed with PHMSA. Enbridge did not provide PHMSA with an explanation of why alcohol testing was not carried out within 8 hours of the accident, as required by 49 CFR 199.221. It provided this explanation to the NTSB for the delay in alcohol testing:

[The two day shift leads and the line 6b mentor and operator] ... completed their shift at approximately 6 pm July 25, 2010. The leak at Marshall was confirmed the morning of July 26, 2010. These individuals would have been away from work for more than 12 hours at the time that the leak was discovered on July 26th. Additionally, both ... [line 6B operator and mentor] were given paid leave for July 26 and 27. [The line 6B mentor]...was called in on July 27th at 8:00 pm to go for testing, which was past the 8 hour timeframe to conduct the testing. She admitted prior to the test that she had been golfing all day and had consumed alcohol.

[The two night shift leads and the night line 6B operator] ... completed their shift at approximately 6 am July 26, 2010. The leak was not confirmed until later that morning and these people had already left shift and were at home.

[The two night shift leads and the day line 6B operator] started their shift at approximately 6 am July 26, 2012. They had all been on scheduled days off prior to July 25.

Once Enbridge discovered the leak and realized the magnitude of the event, it was determined that testing would still be completed for these individuals even though more than 8 hours had transpired since they were on shift.

The control center supervisor told investigators that the delay in testing was due to the delay in confirming the leak, and the fact that many of the personnel who had been on duty during the accident sequence had gone home by the time the leak had been identified. He explained that the decision to request toxicological samples was made on July 27, in the belief that it was better to obtain the samples at that date than to not obtain them and “wish we’d had,” despite his knowledge that “...the alcohol testing wouldn't apply but the drug would.”

#### TRAINING-CONTROL ROOM PERSONNEL

Enbridge's control room training is the responsibility of their supervisor of training and compliance for control center operations. In addition to training, he also oversaw the OQ process for controllers. He told NTSB investigators that control room training sought to meet both Canadian and United States requirements, and when one exceeded the other, the company followed the more stringent of the two.

As he described it, Enbridge's training program for new hires involved five phases. The aim of the training was to develop student knowledge and proficiency sufficient to operate pipelines

effectively. As Enbridge's training supervisor noted, "...the goal is for the operator to operate independently, but also with the support of the team members." While classroom training was given to groups of trainees, all other training, such as on the job training and operating simulator scenarios was conducted with the operators individually. No formal team training involving shift leads, operators and MBS analysts was conducted, nor did PHMSA or NEB require such training.

The first training phase featured classroom- and web-based instruction that took about two weeks. It included an orientation and an overview of the controller operations including material on pipeline product properties such as viscosity, vapor pressure, hydraulics, and specific gravity. During this phase as with the other phases, students were given written tests. Upon passing these tests and other assessments they began the subsequent phase.

The second phase, usually a month in length, was based in the control room. It featured on-the-job training under a dedicated mentor, and the teaching of additional material about pipeline operations such as pump stations and pressure control valves. Knowledge-based topics that were addressed in this section included displays, commands and alarms, trending, and standard operating procedures. As with the previous phase, some of the material was taught through web-based instruction. Students were considered ready to proceed to the third phase after successfully passing examinations and assessments by the training instructors.

The third phase, which typically lasted two months, focused on pipeline operations. It consisted largely on structured on-the-job-training, with some classroom instruction as well. Specific topics included line protection software, problem solving, flow gradients, and commodity movement track (CMT) batch track analysis.

The fourth phase, which also lasted about two months, included on-the-job-instruction, classroom time, and simulator time. In this phase, students were to become increasingly proficient in normal operations, and recognize and respond to abnormal operating conditions. These included column separations, leak scenarios, and emergency alarms such as fire and gas. In this phase students were also taught to use the systems facilities management or FACMAN system to report abnormal operating conditions.

In the fifth and final phase, which also took students about two months to complete, students continued on-the-job instruction, and were expected to increasingly demonstrate proficiency in pipeline operations. Students completed this section when they demonstrated intervention-free pipeline operation for ten shifts. Students also had to successfully complete additional supplemental classroom type training, a written and oral examination by a trained OQ evaluator, and the intervention-free performance. Finally, students were evaluated on their overall performance and on additional traits considered necessary for an operator. After review and approval by the student's instructor, mentor, and a shift lead, a student was then qualified to serve as an operator. Students completing this section were considered to have passed their OQs to become qualified operators.

Although Enbridge did not conduct formal team training programs, pipeline operators were introduced to team aspects of the control center during initial training and were expected to use available control room personnel resources to accomplish training objectives. During the latter

phases of controller initial training, when operators were introduced to simulator scenarios, instructors and other course participants used role playing to assist or distract the operator trainees, portraying, for example, on-site or on-call field personnel. Part of the evaluation of student performance at the conclusion of the latter phases was based on the quality of the student's teamwork.

After qualifying, operators and shift leads participated annually in simulator training where they were presented with leak and column separation scenarios, as well as other abnormal operating conditions. Many of the operators that NTSB investigators interviewed indicated that the emergency scenarios were the only occasion they had to observe a leak scenario after completing their initial training. One operator described the emergency scenarios that they practiced in the following manner, "They have some pre-configured programs that we run and some of them have station lockouts and some of them have leaks and some of them have just com [communications devices] fails and different scenarios that we go through to help us to understand what we're seeing." The operator added that they practice leak scenarios on the simulator, but because the simulators do not have MBS alarms, they recognize leaks by line pressure variations.

Simulator modeled pipelines did not always match the pipelines the controllers operated and there is no evidence that line 6B was modeled in its simulator. In addition, operator training did not include historical trend training covering time frames suitable for operator or shift lead review. Finally, operator training did not include operating pipelines in restricted pressure conditions.

In accordance with PHMSA requirements, operators were required to successfully complete examinations to test their qualifications, which were referred to as operator qualifications or OQs. These were conducted at three-year intervals, a frequency not specified by PHMSA, but within its acceptable limits. Shift leads administered the OQs to the operators, either by observing on-line performance and/or by observing their performance in simulated scenario, and testing their knowledge of abnormal operating procedures. Shift leads and MBS analysts were not required to be reexamined. Qualified operators could lose their OQs after an absence of three months or more from the pipeline operations (e.g., for, medical reasons), not passing a simulator evaluation, improperly performing a covered task, or incorrectly responding to an abnormal operating condition.

Following the accident, Enbridge increased the number of emergency response simulator sessions that operators encountered, from one session per year to two per year, and increased the number of annual training sessions to include two additional sessions, one addressing human factors (which included fatigue), and one hydraulics. The additional human factors training was administered in response to PHMSA's new rules addressing control room management.

MBS analyst training typically took 3 months to complete, according to Enbridge's supervisor, pipeline modeling group at the time of the accident. She indicated that the curriculum contained both instructional segments, in which students learned basic hydraulic information and the Enbridge MBS system, and on-the-job training, where they sat with, and observed and worked under the supervision of qualified MBS analysts. In addition, students practiced scenarios on a simulator and determined whether the validity of the MBS alarms. Upon successful completion

of both a written examination and assessment of performance on a simulator-presented scenario, students were considered qualified as MBS analysts. MBS analysts did not meet PHMSA OQ or testing requirements and were not required, at the time of the accident, to be retested to retain their qualification.

## FATIGUE MANAGEMENT

In accordance with 49 CFR 195.446 (d),<sup>14</sup> Enbridge developed and implemented a fatigue risk management plan, as described in its Fatigue Risk Management Handbook, which took effect on July 30, 2011. The handbook specified a Control Center fatigue manager who was “responsible for reporting areas of concern to ... management, reporting statistical analyses of actual hours of service and the potential contribution of fatigue to operational close calls, and making recommendations for improvements and enhancements to fatigue risk management strategies.” In addition, a fatigue risk management working group was formed, consisting of personnel from “a cross section of Control Centre functional areas” to meet quarterly to review control center personnel’s actual hours worked as well as review policies to mitigate the effects of fatigue.

Enbridge provided training, and required all supervisors and control center operators to be trained in fatigue recognition and management. Supervisors also were required to complete “Circadian Fatigue Training for Supervisors” and both supervisors and operators were to complete web-based fatigue management training. As part of their training, supervisors were trained to “recognize signs of fatigue,” and given guidelines to use to assess an individual’s risk for fatigue based on shift rotation schedule. Operators who self-reported to supervisors that they were “unfit for duty due to fatigue” were to be supported by supervisors before the shift by reallocating personnel or other means, or during the shift by “close monitoring” and by “individual on-shift fatigue mitigation strategies.”

In November 2011 Enbridge opened a dedicated facility for control room operations and moved its control center to the new facility. The new facility included features designed to address fatigue such as a “rest and recovery room” with a sleep chair, an exercise room with “sufficient equipment in working order to accommodate use by at least three people at a time,” and a leisure activity with “sufficient amenities to provide an environment conducive to stimulating activities and social interaction.” In addition, lighting levels in the control room were designed to change according to time of day to enhance the effects of natural illumination cycles on operator alertness.

PHMSA’s requirements governing hours of service required pipeline control center operators to receive at least 8 hours of rest between shifts. Enbridge followed PHMSA requirements to provide operators with “off-duty time sufficient to achieve eight hours of continuous sleep,” and limited emergency coverage to seven 12-hour shifts in succession. According to Enbridge’s control center supervisor, control room shifts were 12 hours in length, from 0600 to 1800 and 1800 to 0600 the next day, although operators worked overtime beyond those 12 hours on occasion. Shifts were typically three days followed by two nights (e.g., Monday and Tuesday),

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<sup>14</sup> As noted, this rule, as all PHMSA control room management rules, was not in effect at the time of the accident. Pipeline operating companies were required to comply with the requirements of the rule by August 1, 2011, and implement the requirements by February 1, 2012.

followed by four/five days off. Operators would then return for shifts of two days followed by two nights, and the four/five days off. Thus, a typical pipeline operator schedule would begin at 0600 on Friday, Saturday, and Sunday, ending at 1800 each day, followed by Monday and Tuesday nights in which the schedule was reverse, followed by four to five days off. The operator would then work during the days of Monday and Tuesday, and work Wednesday and Thursday during the night. Classroom training was conducted during daylight hours.

## TEAM CONCEPT

The control room was arranged so that two operators, who shared the same shift schedule and were qualified on the same consoles, worked side by side or across from each other in “pods.” These controllers, or “pod mates,” were expected to assist each other when needed, for example, when one had questions or needed a break. Enbridge supervisors referred to a “team concept” in the control room in which control room personnel were expected to work together as a team in support of the common goal of facilitating pipeline operators. As one of the nighttime, July 25/26 controllers explained, in referring to the control room environment, “I’d characterize it as a team environment that everyone helps each other and we get -- everyone gets along pretty well.” Another shift lead noted,

...we try to promote team concept in the room. So if operators have different various questions on their operation, depending on the experience level, the lesser experienced might ask the more experienced an opinion on what they’re seeing. And so, like we do try to promote teamwork in the room, so -- with all the terminals and pipelines that they interact with.

## CONTROL ROOM ENVIRONMENT

In the November 2011 interviews that were conducted in Edmonton, a former Enbridge controller who was paired with the night shift July 25/26 line 6B pipeline operator, made allegations regarding the control room environment that existed at the time of the accident. She charged that:

- Supervisors openly criticized some employees
- Supervisors used errors as a way to discipline employees whom they did not like
- Supervisors created an atmosphere of intimidation and hostility
- The supervisor, control room operations, violated the confidentiality of Enbridge’s internal post-accident investigation the day after the interview and rebuked her for what she had told interviewers, and
- A hostile atmosphere towards women existed.

As a result of her allegations, NTSB interviewers conducted additional interviews in Edmonton, in January/February 2012, of 19 current and former Enbridge employees. All but one of the interviews was conducted in person, while one was conducted telephonically. All interviews were on the record, and conducted in the presence of NTSB, PHMSA, and Enbridge personnel.

One interviewee asked and was granted right to have the Enbridge representative leave the room during his interview.

The night, July 25/26 controller, who was the former controller's pod mate at the time of the accident told NTSB investigators about not liking that pod mate. The former controller said that this controller never liked her to begin with. As she described his behavior towards her:

Whenever I asked for help, it was very degrading, the tone he talked to me. Whenever I offered to help him, his response was, no thank you; I can do it myself.

That particular controller later told investigators that, "most of the other controllers were happy to get help or that I would help them and, for her, it didn't seem like she appreciated the help that I was trying to give her."

Each of these two controllers, independently, discussed with a supervisor at a level above the shift leads, reassignment to a different pod mate. As the controller who left Enbridge noted, Enbridge's control center supervisor was aware of the conflict between her and her pod mate "from day one." As she told investigators, rather than change her pod mate, she was told,

If we do it for you, we have to do it for everybody else, too. You need to get along with everybody.

The day, July 25 line 6B controller told investigators that he asked his shift lead for a different pod mate. He was also told that such a request could not be granted, and that he "stuck with the person ... [he] was with."

Enbridge's supervisor control center operations told investigators that he was unaware that the two operators had asked for different pod mates. He was not aware of a company policy in response to such requests. He added,

There's an approach where we try to maintain the -- I'll call it stability ... of the team as far as, you know, 22 individuals on the team. Had I been asked, I'm of the opinion they should work through those things.

Current and former Enbridge employees differed on reporting instances of unfair treatment. The July 25 daytime controller, who had retired from Enbridge before he was interviewed again in 2012, said that the control room environment was good. He described the control room as "...a good place to work. ...people get along." Others echoed his characterization of the control room environment. Another controller said about the control room and the company,

...it treats everybody good and it's a good company to work for. The people make it good. I think for -- you know, for -- I came from a small town so in a small town working for Enbridge was a good job, good paying job.

Several current and former controllers reported having been the victim of or witnessed supervisors treating controllers differently. One controller said, with regard the former controller who had made the initial allegations, that she wasn't

...the only one that's been treated unfairly. I would have to say there's others as well that have been treated unfairly, and I've seen it over my ... years with Enbridge, and I really can't answer what the reason behind it. It may be some people are more outspoken than others.

A former Enbridge shift lead, who had left the company before he was interviewed, believed that the employee who had made the initial allegations was “treated badly by supervision” and that “they didn’t respect her.” He also noted that the day July 25 controller and his mentor were also singled out for criticism. As he told investigators:

... The biggest thing with them two people are they're 30-year employees and they voiced their concerns. They knew there was issues there and management didn't ... like people that basically voice their concerns. If you voice your concerns, you're singled out.

Several interviewees noted that some supervisors used the error reporting system as a way of attempting to intimidate controllers. Pipeline operators’ errors were tracked and an operator who had committed a sufficient number of errors could lose his or her OQs, and if errors continued, his or her employment. The former operator who had made the initial allegations had been cited for the number of errors that she had made. She and others told interviewers that supervisors can and did classify as errors mistakes committed by some controllers, but would not classify as errors the same mistakes that had been committed by others.

The director, control center operations, who, as noted, was appointed to this position after the accident, was aware of perceptions of favoritism by some operators and some operators’ concerns with the use of the error tracking process. As he told NTSB investigators,

I'm aware that there was a perception of favoritism, and that's something that we're really trying to move away from, or that there could have been a perception of favoritism. I'm aware of an error program that's been -- that was run, you know, for a period of time within the control center that our operators did not like. We have changed that error program. We've gone to more of an incident reporting format.

Most interviewees did not observe differences between the way Enbridge management treated male as compared to female personnel. A former female controller, the pod mate of the July 25 day line 6B operator, who retired from Enbridge after the accident, told NTSB interviewers, “I was the second woman that ever worked in that control room, so when I first started there, there was a definite difference, but over the years, it's changed a lot and we were pretty well all treated the same.”

One controller noted that the former controller “personally had some issues with some of the shift leads that were a little bit prejudiced towards women.” Another Enbridge controller told interviewers,

And it's more than one occurrence I've had a young, female operator come to me and wonder about gender discrimination. Now, as far as witnessing it, I can't specify incidents. Once that's brought to my attention I look for it, but that's a problem, that now I'm looking for it. So it's -- but it has been told to me by more than one.

All current and former Enbridge control room personnel agreed that pipeline operators had the authority to shut down a line, regardless of the opinions of the shift leads. The pod mate of the July 25 day, line 6B controller, who retired from the company over a year after the accident, said,

If we didn't feel something was right, we had the choice to shut it down, and then we would take it to our supervisor and say okay, this is what I see, this is why I shut it down, that kind of thing. They basically would -- they would honor our decision to do that.

A former Enbridge pipeline operator told investigators, "I never once felt that I couldn't shut down a pipeline."

Interviewees disagreed on whether pipeline operators felt that they were pressured to restart pipeline operations or maintain flow, in spite of the requirement to shut down lines if MBS alarms were unexplained. A former shift lead said that, while there was no pressure per se, more effort was needed to shut a line down than in continuing operations.

Because once you start shutting down lines, now all of a sudden you have to start shutting in shippers; now you have to start calling scheduling; now you have to start calling ...[supervisors in the] middle of the night or whenever it is, and there's a lot of paperwork that goes with it. So -- and then you affect so many other terminals and so many other pipelines depending how full the tanks are, depending on -- it's just a whole bunch of things that you have to look at.

A control room pipeline operator believed that the July 25 day, line 6B operator perceived pressure to restart the line. He told investigators,

I think what happened was the shift leads -- I don't want to say bullied, but influenced ... [his] decision to start up. He should not have allowed himself to be influenced by the shift leads if he wasn't comfortable himself.

Another controller provided a similar insight with regard the actions of that line 6B operator,

He was still on a learning curve and very conscious of what he was doing, but also wanted to please, so he might have been a little naïve [in] believing that what he was told by his supervisors to start the line up...

Enbridge's accident director, control room operations, indicated that the management style of some of the control center leaders may have contributed to the perceptions described by some current and former control room personnel. As he told investigators,

I think the shipper services group, to a certain degree, they've had a couple of consultants that were a part of that group that had a little bit different management style in relation to, you know, results orientated... And the control center was a part of that group in the past.... And I think that may have had an impact on the approach and stuff like that by [control room] leaders...

## CONTROL ROOM PROCEDURES

Control room operators were required to follow operating procedures according to the particular situation encountered. One rule, considered to be part of many procedures, was commonly referred to as the “ten-minute rule.” This required operators to shut down a line if a column separation cannot be resolved with 10 minutes. One operator noted that all operators were aware of the rule, and they “talk about the 10-minute rule in our training all the time...”

During the Marshall, MI, event a draft procedure was used by the July 25/26 night line 6B pipeline operator and a shift lead to exceed the 10-minute rule. The operator’s pod mate, who had accessed the draft procedure from the company’s intranet, indicated that about two to three weeks before the Marshall, MI, accident a shift lead had suggested she use that draft procedure during a column separation that she had encountered. As she told investigators, referring to the shift lead:

... He said there's this procedure [is] in review and we know for a fact we did drain on purpose. I said that's true. So he said how long will it take? And we -- and I pulled up my CMT and we calculated it together. We said minutes, and I said that's going to go over 10 minutes. He said that's okay. We've done the calculations. We know it's going to take minutes. I give you approval to start up. I'll watch. I said okay, and I started up with his -- him watching and my other pod mate watching as well.

She mentioned this draft procedure to the shift lead on duty at the time. She noted that he returned to her about an hour later and asked her about how many cubic meters of product she estimated it would take to “pack the line,” or pump to reengage the columns and end the separation. She did the calculation and reported the number to him. She believes that this interaction occurred about 0600, before the second attempt to restart operations on the line.

Both current and former control room personnel told NTSB interviewers that they had witnessed occasions when the 10-minute restriction was not adhered to. A former shift lead told investigators, “...I know a few times we have bypassed the 10-minute rule because, like I said, it takes 20, upwards of 20 minutes, if not longer, to bring that column back together.” The former Enbridge controller who worked the line 6B July 25 day shift said that he witnessed the rule violated “probably half a dozen” times, usually after major pipeline work had been completed.

Enbridge informed the NTSB that following major pipeline repairs or modifications that involved the installation of new pipeline, during start-ups, more than 10 minutes may be needed to fill the newly installed or modified pipeline. The amount of time depended on the length and diameter of the pipe installed. Operators accounted for this known column separation in their line fill and restart plans.

The Enbridge director of control center operations in response to a question regarding support from the company for efforts to change the “culture” of the control room, , told NTSB investigators, “I think Marshall was a wake-up call for a lot of people within our organization and, you know, maybe we needed that. We're on a path of growth and that type of thing and, you know, we -- it was a bit of a wake-up call.”

## SHIFT CHANGE COMMUNICATIONS

At the time of the accident Enbridge did not require written or formal documentation of information communicated between controllers, shift leads, and MBS analysts ending their shifts and those replacing them on the new shifts. Operators and shift leads would communicate the information they thought most critical to the persons relieving them on the subsequent shifts. One control room operator told investigators that during the handoff he would discuss maneuvers that were expected to be performed, and problems, including MBS alarms that had not cleared. He considered MBS alarms that did clear sufficiently frequent that they were not worth mentioning during the handoffs. Enbridge informed the NTSB that this operator believed that the MBS alarm clearing indicated that the condition that caused the alarm was no longer present and therefore not worth mentioning to the pipeline operator b of the subsequent shift.

According to Enbridge's control center supervisor, at the time of the accident communication of information between shifts was, "...best practice. And it was assumed that abnormal operating conditions like that would get passed on then. This particular one [involving Line 6b at the time of the accident], it was just dismissed at the time."

According to the day July 25<sup>th</sup> line 6B controller/trainee, he conveyed information about the 16:59 MBS alarm to the operator taking over control of the line on the next shift. As he told investigators:

I would tell them [the relieving operator] what I had done during the day, that's a shut down due to scheduling, that the pigs were upstream of Minden, the station was set up on bypass for the pig run. There was a five minute MBS alarm -- due to column separation. When he started back up, he started up from Griffith to Marysville, downstream -- of Stockbridge, upstream of Sarnia.

The line 6B operator added that he did not inform the relieving operator of the low pressure alarm, and that the information communicated during the handover was not in writing.

## ALARMS

Enbridge's control center used one auditory alert to signal alarms to pipeline operators. Operators were then directed to their visual displays, computer screens, to determine the nature and severity of the condition generating the alarm. Alarms were of four severity levels, S8, considered critical, included such types of incidents as a fire or gas alarm, S6, considered severe, included incidents considered important but not emergencies, such as unit lockouts that indicating a condition that may affect pipeline flow, S4, considered "warning" alarms and S2 alarms, which were informational. Enbridge required operators acknowledge S8, S6 and S4 alarms, and to inform shift leads when S8 or S6 alarms alerted. In addition, operators filed FACMAN reports for S6, S8, and MBS alarms. The FACMAN system interfaces with the maintenance management system used by maintenance personnel in the field, and generates repair orders directing maintenance personnel to take diagnostic or corrective action to address the condition. Operators were required to report all S8 and some S6 alarms to supervisors.

MBS alarms fell into three types, 5-minute, 20-minute, or 2-hour. MBS alarms were often generated during transient conditions such as pipeline startup and shutdown, when an imbalance exceeded a defined threshold, and when some instrumentation necessary for mass balance

detection failed or was taken out of service. Enbridge’s leak detection system relied on MBS alarms to signal operator attention to the possibility of a leak. Operators were expected to contact MBS specialists, who worked in the control room with the operators at the time of the accident, to determine the nature of the alarm. The operator on daytime duty on July 25 said that he would recognize a leak after an MBS alarm had alerted when a line was running and there was a sudden pressure drop.

Operators and supervisors consistently described the frequency of MBS alarms, and their primary cause, column separations, or gaps within a pipeline of the liquid product. According to the control center supervisor, “ninety nine percent of the time these columns come back together.” An MBS analyst noted that column separation is “fairly common,” occurring he would say, “out of five calls, it’s probably three of them.” An operator of line 6B at the time of the accident noted that she was “pretty well be guaranteed on line 3 to get an MBS alarm on a startup.” Another operator noted that “startups and shutdowns are the worst times to have a leak ...because of the transients.” A shift lead asked:

In January 2010, 210 MBS alarms alerted in the control room, for an average of 3.39 alarms per shift. The total number of alarms, the types of alarms, and the average number of alarms per shift for the period of January 2010 to the time of the accident were:

I mean why do we have redundant MBS alarms on a startup and shutdown every time. Obviously, there has to be something there, but why do we get them every time. Why are we receiving the same alarm and if you startup and shutdown a small little line that feeds one of your terminals and you get an MBS alarm every time you do it and you do it five times a day and five times a shift and so you get it 10 times a day it becomes redundant, and you're just kind of, oh, that's normal.

	Total	Average Alarms per Shift	5 Minute	20 Minute	2 Hour
January	210	3.39	114	75	21
February	161	2.88	79	60	22
March	194	3.13	86	74	34
April	140	2.33	69	62	9
May	106	1.71	45	53	8
June	219	3.65	110	85	24
July	279	4.50	136	107	36

Operators could silence the alarms by several methods, 1) acknowledging the alarm, 2) taking action to correct the condition causing the alarm, 3) taking no action but allowing the condition correct itself, or 4) shutting the line during the alarm thereby temporarily clearing the condition that created the alarm. At the time of the accident, the MBS alarm caused by the line 6B rupture cleared because the line had been shut down at 2:58, as scheduled.

## POST ACCIDENT CHANGES

After the accident Enbridge instituted a number of changes to its operations. The two night July 25/26 shift leads, line 6B operator and MBS analyst, and July 25 day line operator mentor and trainee, were reassigned to duties outside of the control room. As noted, the operator mentor and operator trainee have since retired from Enbridge. The others have remained in Enbridge's employment, awaiting its determination of their assignment within the company. Enbridge indicated that its decision regarding them would be made after the NTSB adopted its probable cause and report on this accident.

Oversight of the control room was reorganized as noted, and transferred from the vice president, customer service to senior vice president, operations. A new vice president of pipeline control and a new control room director were named. Control center operations were divided into a terminal side and a pipeline side, with technical advisors added to each side. The advisors were to support the shift lead and operator when technical issues arose. Three operators (the operator/mentor and the operator/trainee from the July 25 day shift, and the night July 25/26 operator), the MBS analyst from the night July 25/26 shift, and two shift leaders (during the night July 25/26 shift) were temporarily reassigned to positions outside of the control room. The two daytime July 25<sup>th</sup> operators retired from the company, one in September 2011 and the other in November 2011.

All operators, shift leads, and MBS analysts were given additional training technical training, including information on hydraulics, control center roles and responsibilities, procedure compliance, column separation analysis, and the 10-minute rule.

After the accident MBS analysts were required to note, in response to an MBS alarm, only whether the MBS model supporting the alerting of the MBS alarm was "valid" for that alarm, "invalid," or whether their "analysis was not complete." They were not permitted to identify the cause of the alarm. Operators were given an additional simulated emergency scenario annually and additional training on human factors to include fatigue and lessons learned from previous incidents and accidents. In addition, a formal written procedure governing information communication during shift changes was developed and implemented.

Enbridge reemphasized the 10-minute rule, requiring operators to shut down a line after 10-minutes if a problem was unresolved. Operators and supervisors were prohibited from overriding approved control room procedures. On call procedures were revised to make available additional personnel, including the control room director and the vice president of pipeline control when control room personnel needed assistance, and on-call individuals were given specific procedures to be followed and questions to be asked in response to the particular circumstance.

## MEDICAL

PHMSA did not require operating room personnel to be subject to medical oversight after being hired. Enbridge required newly hired control room personnel to be examined by a physician. According to Enbridge's control center supervisor, Enbridge had no unique medical requirements for operators, other than one requiring a demonstration, upon being hired, of color vision acuity. According to Enbridge's senior vice president of operations, operators were also

required to report to their supervisors when they were taking medications that the operators considered to be impairing. Neither Enbridge nor PHMSA required pipeline controllers to report potentially impairing medical conditions to their employer or have such medical conditions be evaluated by medical practitioners for their effects on operating performance.

## ENBRIDGE HEALTH AND SAFETY MANAGEMENT SYSTEM

In May 2010 Enbridge created the position of director of safety culture, after three pipeline employees were killed in two on-site accidents, in a five-month interval, between November 2007 and March 2008. The position, which reported to the senior vice president of operations, was given to Enbridge's director of construction, safety and services, within its major project group. The director had no support staff.

The focus of the safety culture director's activities was primarily on on-site safety, within three areas: workplace safety, process safety management, and contractor safety. Within these three major foci, the company concentrated on five general safety areas: driving safety, confined space entry, ground disturbance, isolation of energized systems, and reporting of safety-related incidents.

The company retained the services of an outside contractor to develop a health and safety management system (HSMS) to address on site safety issues. The company then reassessed the program in 2005 and again in 2008, in what it termed "benchmarks." In addition, the company, at the contractor's request, carried out its own internal audits of the system.

The HSMS program retained many of the elements of a safety management system. The company's designated safety person was its director, safety culture. The program, which focused exclusively on on-site safety, called for, among other things, a management commitment to safety, written procedures, safety initiatives, documenting incidents and accidents, safety rewards and recognition, and a quality management system procedure. The 2008 benchmark, the company's most recent, found improvements since the preceding assessment in 2005. Its findings included, "safety is a high priority throughout the organization; there is rarely pressure to subordinate safety to operational needs," and "senior management demonstrates a strong personal belief in safety." It also found that "improvement initiatives tend to be driven solely by the mid-level managers and below who have value but insufficient authority to effect change," and "with significant personnel changes underway, there is no organizational management of change system to manage the effect on the safety culture from so many new-hires and changes in position." To provide background to its findings, the contractor noted, "In 2008, the company [Enbridge] is undergoing tremendous expansion with capital projects on the order of \$12 billion over the next 5 years, which is straining its current management systems and culture."

The HSMS program was developed even though PHMSA had no requirement for pipeline operating companies to implement a safety management system (SMS).

The company's director, safety culture, indicated that Enbridge was implementing many of the consultant's recommendations, but the company's emphasis on safety activities changed after the Marshall accident. As he told investigators:

I think that what we realized after the Marshall incident was that safety was much larger than workplace safety, individual safety, and I think that that's when we started to develop a better understanding of, number one, the need for process safety and also the need to make sure that control center operations was included within the scope of our safety culture effort.

**BARRY STRAUCH**

**Office of Marine Safety** (on loan to the Office of Railroad, Pipeline, and Hazardous Materials Safety)