U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

INVESTIGATION REPORT

XCEL ENERGY HYDROELECTRIC PLANT PENSTOCK FIRE

(Five Dead, Three Injured)

CABIN CREEK

GEORGETOWN,

COLORADO

OCTOBER 2, 2007

KEY ISSUES:

- SAFE LIMITS FOR WORKING IN CONFINED SPACE FLAMMABLE ATMOSPHERES
- PRE-JOB SAFETY PLANNING OF HAZARDOUS MAINTENANCE WORK
- CONTRACTOR SELECTION AND OVERSIGHT
- EMERGENCY RESPONSE AND RESCUE

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Acronyms and Abbreviations

AIHA	American Industrial Hygiene Association
ANSI	American National Standards Institute
API	American Petroleum Institute
APPA	American Public Power Association
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	all-terrain vehicle
BLS	Bureau of Labor Statistics
CBI	Colorado Bureau of Investigation
CCC	Certified Coatings Company
CCFA	Clear Creek County Fire Authority
CDFS	Colorado Division of Fire Safety
CFOI	Census of Fatal Occupational Injuries
CSB	U.S. Chemical Safety and Hazard Investigation Board
CURT	Construction Users Roundtable
EMR	experience modification rate
EPA	Enviornmental Protection Agency
EPRI	Electric Power Research Institute
ESD	Emergency Services District
FACE	Fatality Assessment and Control Evaluation
FERC	Federal Energy Regulatory Commission
FSA	Formal Settlement Agreement
HSEES	Hazardous Substances Emergency Events Surveillance
IChemE	Institution of Chemical Engineers
IDLH	Immediately Dangerous to Life and Health
IIPP	Injury and Illness Prevention Program
IMIS	Integrated Management Information System
LEL	Lower Explosivity Limit
LFL	Lower Flammability Limit
MEK	methyl ethyl ketone
MSDS	Material Safety Data Sheet
MW	megawatt

NACE	National Association of Corrosion Engineers
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
OIICS	Occupational Injury and Illness Classification
OSHA	Occupational Safety and Health Administration
PHA	Process Hazard Analysis
PPE	Personal Protective Equipment
ppm	parts per million
PSCo	Public Service Company of Colorado
psig	pounds per square inch gauge
PSCo	Public Service Company of Colorado
PSM	Process Safety Management
PUC	Colorado Public Utilities Commission
QP 1	Qualification Procedure No. 1
RFP	Request for Proposal
SCBA	Self Contained Breathing Apparatus
SCPDI	Southern California Painting and Drywall Industries
SSPC	Society of Protective Coatings (formally Steel Structures Painting Council)
TRB	Transportation Research Board of the National Academies

1.0 Executive Summary

1.1 Incident Synopsis

On October 2, 2007, a chemical fire inside a permit-required confined space[1] at Xcel Energy's hydroelectric plant in a remote mountain location 45 miles (72 kilometers) west of Denver, Colorado, killed five and injured three workers. Industrial painting contractors were in the initial stages of recoating the 1,530-foot (466-meter) steel portion of a 4,300-foot (1,311-meter) enclosed penstock[2] tunnel with an epoxy coating product when a flash fire occurred. Flammable solvent being used to clean the epoxy application equipment in the open penstock atmosphere ignited, likely from a static spark. The initial fire quickly grew as it ignited additional buckets of solvent and substantial amounts of combustible epoxy material, trapping and preventing five of the 11 workers from exiting the single point of egress within the penstock. Fourteen community emergency response teams responded to the incident. The five trapped workers communicated using handheld radios with co-workers and emergency responders for approximately 45 minutes before succumbing to smoke inhalation.

1.2 Scope of the Investigation

Catastrophic workplace accidents typically are not the result of a single error or one piece of faulty equipment; rather, higher-level safety system deficiencies are often found at facilities where such accidents occur. It has also been established that accident prevention is most effective when these

[1] The US Occupational Safety and Health Administration (OSHA) defines, in its general industry rule, a confined space as having three attributes: (1) large enough to enter and perform work; (2) limited access and egress; and (3) not designed for continuous occupancy. OSHA states that a permit-required confined space has one or more of the following characteristics: "(1) contains or has the potential to contain a hazardous atmosphere; (2) contains material that has the potential for engulfing an entrant; (3) has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section; or (4) contains any other recognized serious safety or health hazard. OSHA has identified one type of hazardous atmosphere as '[f]lammable gas, vapor or mist in excess of 10% of its lower flammable limit (LFL)' [29 CFR 1910.146(b)].

[2] A penstock in hydroelectric service is typically an enclosed conduit such as a tunnel or pipe that delivers a flow of water to a turbine that generates electric power

systemic causes are understood and learned.[3] As such, the U.S. Chemical Safety Board (CSB) examined both the technical and organizational causes of the fire at Xcel Energy's Cabin Creek penstock.

The investigation found that a number of safety issues contributed to the accident, including a lack of planning for hazardous work, inadequate contractor selection and oversight, and insufficient regulatory standards pertaining to the use of flammables within confined spaces. The investigation also examined the technical aspects of recoating a penstock, the work conditions of the unique confined space, and the training the contractors received prior to starting work. Finally, the CSB evaluated aspects of emergency response, including planning for timely and qualified rescue and the need for certified confined space rescue responders in the state of Colorado.

1.3 Incident Description

On October 2, 2007, a work crew of industrial painters employed by RPI Coating, Inc. (RPI) began applying a new epoxy coating to the steel interior section of the penstock[4] at the Cabin Creek hydroelectric plant operated by Xcel Energy, Inc. (Xcel), located south of Georgetown, Colorado.

Shortly after the epoxy application commenced, the work crew experienced problems with the spraying process, resulting in poor coating quality. Spraying was terminated and the crew began cleaning the sprayer system equipment with a flammable solvent, methyl ethyl ketone (MEK),[5] to remove epoxy residue before taking the equipment out of the penstock. During this cleaning operation, MEK vapors

[3] The Center for Chemical Process Safety (CCPS) states that identifying the underlying or root causes of an incident has a greater preventative impact by addressing safety system deficiencies and averting the occurrence of numerous other similar incidents, while addressing the immediate cause only prevents the identical accident from recurring (1992).

[4] The Cabin Creek penstock is a tunnel with a diameter that varies between 12 and 14 feet that runs between two reservoirs; water flows from the upper reservoir to the lower reservoir through the penstock, passing over turbines which produce electricity (see Section 2.1.1.1).

[5] Methyl ethyl ketone (MEK) is an organic chemical compound often used as a solvent in painting activities listed by the National Institute for Safety and Health (NIOSH) as "highly flammable." *NIOSH MEK International Chemical Safety Cards*, 1998. MEK is a Class IB flammable liquid, with a flash point below 73°F (23°C) and boiling point at or above 100°F (38°C). *NIOSH Pocket Guide to Chemical Hazards, 2005*

inside one of the two epoxy hoppers ignited and flashed. The resulting fire grew quickly, consuming several other open containers of MEK and numerous buckets of epoxy material positioned around the sprayer.

Four RPI crew members positioned on the side of the fire nearest the exit evacuated the penstock, although three were later treated for injuries: one received minor burns, one fractured his arm, and another suffered breathing difficulties. Five additional crew members trapped opposite the exit were unable to evacuate due to the fire and narrow configuration of the penstock. The five workers later succumbed to smoke inhalation inside the penstock and died.

1.4 Increasing Need for Penstock Recoating

Many hydroelectric plants have steel penstocks that have not been relined or recoated for many years. In North America, estimates suggest that 3 million feet (1 million meters) of in-service penstocks exist. Interior coatings and linings are required to maintain the structural integrity and serviceability of penstocks to prevent corrosion and provide water tightness. When periodic internal inspections uncover linings that have deteriorated to the extent that rehabilitation is no longer possible, repair projects are initiated to remove the old penstock linings and replace them with newer epoxy coatings that typically have a 20- to 30-year service life (EPRI, 2000, ch. 1-3). Removing the old linings and applying new interior coatings in penstocks present special hazards to workers, including potential flammable and/or toxic atmospheres and limited access and egress within these confined spaces.

Because of the serious nature of this incident and the unique hazards associated with penstock coating work, the CSB launched an investigation to determine root and contributing causes and to make recommendations to help prevent similar incidents.

1.5 Key Findings

1. On the day of the incident, approximately 16 gallons (61 liters) of highly flammable methyl ethyl ketone (MEK) solvent stored in plastic buckets was used in the penstock to clean the epoxy

sprayer and associated equipment. The cleaning involved pouring MEK into the sprayer's two hoppers and circulating it through the sprayer in the open penstock atmosphere. A number of ignition sources present or created by the work activity were not eliminated or controlled. The circulation of MEK through non-conductive hose likely led to static discharge, igniting the MEK in the sprayer hopper and resulting in a flash fire.

2. Xcel and RPI managers were aware of the plan to operate the epoxy sprayer inside the penstock and the need to use solvent to clean the sprayer and associated equipment in the open penstock atmosphere during the epoxy application portion of the project. However, they did not perform a hazard evaluation of the epoxy recoating work; as a result, they failed to identify serious safety hazards involving use of flammable liquids within the confined space. Effective controls were not evaluated or implemented during their pre-job safety planning, such as substituting MEK with a non-flammable solvent.

3. During the recoating project, neither Xcel nor RPI treated the Cabin Creek penstock as a permit-required confined space, nor did they re-evaluate hazards in the space caused by changing work activities. Such activities included the introduction of flammables into the penstock, hot work within the confined space, and the switch from abrasive blasting to recoating of the penstock interior.

4. Neither Xcel's nor RPI's corporate confined space programs adequately addressed the special precautions necessary to safely manage the hazard of potential flammable atmospheres. Their policies and procedures did not address the need for a confined space monitoring plan or the need for continuous monitoring in the work area where flammables were being used. Neither of their permit-required confined space policies or permit forms required or established a maximum

permissible percentage of the lower explosive limit (LEL)[6] for safe entry and occupancy inside a permit space.

5. On the day of the incident, RPI monitored the atmosphere of the penstock, a permit-required confined space, for flammable atmospheres only at is entrance, 1,450 feet (442 meters) from the work activities, rather than where flammables were being used.

6. The majority of RPI employees working at Cabin Creek had not received comprehensive formal safety training; effective training on company policies; or site-specific instruction addressing confined space safety, the safe handling of flammable liquids, the hazard of static discharge, emergency response and rescue, and fire prevention. The Joint Apprenticeship Training Committee and Center, established by the parties to the Painters and Allied Trades District Council 36 Master Labor Agreement (including RPI), provide comprehensive safety training on these topics as part of its apprenticeship program, but most of the painters hired by RPI had not taken these courses nor had they otherwise received documented equivalent safety training.

7. The U.S. Occupational Safety and Health Administration's (OSHA) Permit-Required Confined Spaces Rule for general industry establishes no maximum permissible percentage of the LEL for safe entry and occupancy inside a permit space. OSHA has interpreted its rule to allow working in a permit-required space where the atmosphere is above 10 percent of the LEL.[7] However, the rule defines a flammable concentration above 10 percent of the LEL as a hazardous atmosphere "that may expose employees to the risk of death, incapacitation, impairment of ability to self-

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[6] LEL is defined as "that concentration of combustible material in air below which ignition will not occur" in Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases, NFPA 329 (2005). The terms LEL and lower flammability limit (LFL) have different definitions but are commonly used interchangeably. This report uses LEL except where citing other sources that use LFL in their standard or regulation. The OSHA Permit-Required Confined Space Standard 29 CFR 1910.146 uses the term LFL in its provisions.

7 Letter to Macon Jones, Blasting Cleaning Products LTD, from John B. Miles Jr., Director, dated September 4, 1996, concerning entry into a confined space when the LFL is greater than 10 percent.

rescue…injury, or acute illness" [29CFR 1910.146(b)]. Other OSHA regulations addressing confined and enclosed spaces in the maritime industry and other sectors prohibit entry and work activities above a specific percentage of the LEL (such as 10 percent). The recent trend of consensus safety guidance and regulatory requirements from other jurisdictions has been to establish safe work limits for confined space flammable atmospheres substantially below the LEL.

8. The CSB identified identified 53 serious flammable atmosphere confined space incidents involving fires and explosions from 1993 to April 2010; 57 percent involved a fatality. These incidents caused 54 injuries and 45 fatalities, a majority of which occurred since 2003. These flammable atmosphere incidents include two the CSB investigated in 2009 where confined space explosions resulted in four fatalities.

9. The penstock had only one egress point. Published safety guidance for penstocks discusses the importance of alternative escape routes in the event of an emergency (ASCE, 1998, pp. 2-8). Xcel Energy had identified the sole egress point as a major concern in the penstock planning as had RPI personnel; however, no remedial action was taken. When the flash fire occurred, five RPI workers who were on the side of the sprayer opposite the exit became trapped by the growing fire and restricted egress.

10. The planned use of flammable solvent in the open atmosphere inside the penstock created the potential for an immediately dangerous to life or health (IDLH)[8] flammable atmosphere. Xcel's and RPI's emergency response plan for rescue services for the penstock reline project was to call

[8] IDLH, or Immediately Dangerous to Life or Health, is a personal exposure limit for a chemical substance set forth by the National Institute of Occupational Safety and Health (NIOSH); it is typically expressed in parts per million (ppm). OSHA's Permit-Required Confined Spaces rule for general industry states that IDLH "means any condition that poses an immediate or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an individuals ability to escape unaided from a permit space" [29 CFR 1910.146(b)].

9-1-1 emergency dispatch. No emergency responders with confined space technical rescue certification were at the hydroelectric plant and immediately available for rescue on the day of the incident, and the approximate response time of the closest identified certified community rescue service was approximately 1 hour and 15 minutes. The trapped workers died from smoke inhalation approximately 1 hour before this response service arrived on site.

11. While the Colorado Division of Fire Safety (CDFS) does not track technical rescue certification in the state, available evidence indicates a limited number of Colorado emergency response organizations with personnel certified individually by an accredited program in technical rescue. The CDFS has a voluntary accredited certification program for firefighters and hazardous materials responders but does not offer certification for technical rescue, including confined space rescue.

12. Xcel's prequalification process[9] for determining which potential contractors were allowed to participate in the Cabin Creek bid process considered only the contractors' financial capacity and did not disqualify bidders based on unacceptable past safety performance.

13. Once prequalified, Xcel reviewed and ranked the contractors' proposals, considering factors such as past performance, quality, and safety records in addition to price. RPI received the lowest score, "zero," in the safety category, which, according to Xcel's evaluation form, meant that the proposal should have been automatically rejected. However, RPI was still allowed to compete for the contract. While another contractor's proposal was judged the best from a technical and quality perspective, RPI's proposal received the highest ranking in the evaluation process, based primarily on low price.

[9] When contractors are selected, an initial prequalification process is often used during which each potential contractor must meet basic qualifications. In this case, Xcel's prequalification process considered only the financial capacity of the potential contractor.

14. Due to concerns about RPI's record of injuries and fatalities in past projects, Xcel added a safety addendum to the penstock recoating contract affirming that Xcel would "closely observe" RPI's safety performance during the recoating project. During the initial penstock project activities prior to the incident, Xcel managers became aware of several significant safety problems attributable to RPI, including a recordable injury where an RPI worker was sent to the hospital; the evacuation of the penstock due to high readings of carbon monoxide, a toxic gas; and electrical problems that resulted in the destruction of penstock equipment. These problems did not result in Xcel increasing its scrutiny of RPI's safety performance or taking corrective action.

15. Prior to the incident, Xcel corporate officials had not conducted safety audits examining company adherence to its corporate policies on contractor selection and oversight at each of its power-generating facilities.

1.6 Recommendations

As a result of this investigation, the CSB makes recommendations to the following recipients:

- U.S. Occupational Safety and Health Administration (OSHA)
- Governor of Colorado
- Colorado Public Utilities Commission
- Director of the Colorado Division of Fire Safety
- Director of the Colorado Division of Emergency Management
- Xcel Energy
- RPI Coating
- American Public Power Association
- Society for Protective Coatings

- Southern California Painting and Drywall Industries Joint Apprenticeship and Training Committee

Section 13.0 of this report provides the detailed recommendations.

1.7 Conduct of the Investigation

The CSB investigation team arrived at the incident scene on October 3, 2007, the day after the incident. They joined the Incident Command structure and began on-scene investigation activities. That same day, Incident Command demobilized, and emergency responders disbanded after the five deceased RPI crew members were removed from the penstock. Investigative teams from the Colorado Bureau of Investigation (CBI), OSHA, and the CSB remained onsite and worked with Xcel management to protect and preserve evidence at the Cabin Creek site within the penstock, as well as those areas of the Cabin Creek site relevant to the case, including the upper reservoir.

After careful and extensive pre-entry safety planning with all involved parties, the CSB entered the penstock on two separate occasions (November 6 and 11, 2007) to examine the incident scene, and was present onsite when evidence was removed from the penstock on December 19, 2007. Investigators video-and photo-documented evidence, took numerous size and distance measurements, and physically examined all items within the penstock. Through joint agreements with all involved parties, the equipment and associated evidence within the penstock were removed to a secure site; the evidence was more thoroughly examined on two separate occasions: December 12, 2007, and January 7, 2009.

The team conducted more than 54 interviews throughout the course of its investigation, collecting the testimony of employees from the various companies involved in the penstock project, emergency responders, officials from the sprayer system manufacturer, supervisors from other contractors involved in penstock recoating work, Colorado state officials, and union training center representatives. The CSB examined a variety of company documents, including those pertaining to contractor selection and management, safety policies and practices, and employee training, as well as the contractual agreements between Xcel and the various contractors involved in the penstock project. Samples of material taken from burned buckets and the sprayer hoppers were also tested in a laboratory for identification and composition analysis. This investigative work activity was coordinated with OSHA, the CBI, and the various companies involved in the penstock coating project.

The CSB encountered a number of obstacles and lack of cooperation in regard to the involved parties of the investigation, including Xcel and RPI. Xcel failed to fully respond to a number of CSB requests for both records and interrogatories. The CSB required the assistance of the U.S. Attorney's Office for the District of Colorado, Civil Division, to attempt to obtain information relevant to its investigation from Xcel. RPI did not respond to numerous interrogatory requests and a number of RPI managers asserted their constitutional right against self incrimination.

Near the end of the CSB's investigation in the spring of 2010, Xcel and RPI who faced criminal charges arising from the Cabin Creek fatalities took the unprecedented step of going to federal court to block the publication of the CSB report.[10] Ultimately, the presiding judge squarely rejected Xcel's effort to prohibit publication of the CSB's findings and recommendations:

> Based on the evidence presented at the June 24, 2010 hearing, the arguments, and the applicable law, I find Defendants' arguments to be without merit. Moreover, the Defendants cite no authority in support of their request that I bar the issuance of the CSB's final Cabin Creek report. First, I find the CSB acted as an independent federal agency in conducting its investigation and drafting its report as required by 42 U.S.C. §7412(r)(6)(A)-(S). There is no evidence whatsoever that the CSB acted in concert with the prosecution in investigating this accident or intentionally delayed the issuance of its report.[11]

While CSB's position was supported by a federal district judge, Xcel and RPI's legal action delayed completion of the CSB report for several months, and diverted CSB resources from other ongoing

[10] *United States v. Xcel Energy, Inc., et al.*, No. 09-cr-00389-WYD (District of Colorado).

[11] Id. Order of June 30, 2010 (docket #178).

investigations. Despite the clear findings to the contrary in the judge's ruling, Xcel representatives *continued* to make unsupported claims that the CSB had delayed release of its report to prejudice Xcel in the federal criminal prosecution in which the company is a defendant.

Finally, in early August 2010, an Xcel attorney provided an incomplete *draft* of the CSB report to the media on the eve of the Board's completion of its work. This last Xcel effort caused yet further delays in the process, and has created a risk that Xcel's Directors and shareholders will draw incorrect conclusions about the accident at Cabin Creek. Accordingly, the Board included in this report a formal recommendation that Xcel shareholders be directly notified by management of the significant findings and recommendations of this report, and of the actions Xcel management intends to take to implement needed safety improvements.

2.0 Xcel Energy

Xcel Energy (Xcel) is a Minneapolis, Minnesota-based holding company founded in 1909 with four wholly owned regulated utility subsidiaries that serve electric and natural gas customers in eight western and Midwestern states: Colorado, Michigan, Minnesota, New Mexico, North Dakota, South Dakota, Texas, and Wisconsin. The company employs nearly 12,000; serves 3.3 million electricity and 1.8 million natural gas customers; and exceeds $9 billion in revenues annually (2008).

2.1 Cabin Creek Hydroelectric Plant

The Public Service Company of Colorado[12] (PSCo) Cabin Creek hydroelectric plant, which began operating in 1967, is located off Guanella Pass, a partially paved road that winds through a remote area in the Rocky Mountains [10,018-foot (3053 meters) elevation] approximately 6 miles (10 kilometers) south of the Georgetown, Colorado and 45 miles (72 kilometers) west of Denver. PSCo is a subsidiary of Xcel; this report will refer to PSCo and Xcel Energy collectively as Xcel.

Cabin Creek is a pumped storage plant, with upper and lower water reservoirs totaling 1,977 acre-feet (2439 megaliters), used to generate electricity primarily during peak demand periods. Electricity is generated by releasing water from the upper reservoir where it flows into an intake structure, which is connected to a penstock; the water passes through turbines before being deposited in the lower reservoir (Figure 1). The flowing water rotates the turbines, which turn shafts that power the generators, producing electricity. When electricity use is low, the water is pumped back into the upper reservoir through the penstock to be used again. The plant has two generators capable of producing 150 megawatts (MW) of electricity for 4 hours.

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[12] The Public Service Company of Colorado, a Denver-based company founded in 1869, is a regulated utility company in Colorado that operates seven coal, six hydroelectric, and two natural gas plants, and one wind turbine field, to provide electricity and natural gas utility services to 1.3 million customers located in Denver, other Colorado cities, and some rural areas.

Figure 1. Location of hydroelectric plant, reservoirs, and penstock pathway

2.1.1 Penstock

The penstock is 4,163 feet (1,269 meters) long from the upper reservoir's intake to the point at which the penstock splits into two pipes to feed the turbines in the powerhouse. Of this space, 3,123 feet (952 meters) can be traveled by foot. RPI was hired by Xcel to recoat roughly one-half of this relatively horizontal space (1,560 feet, or 475 meters, at a 2 degree incline). This section of the penstock is 12 feet (3.7 meters) in diameter, welded and steel-lined. The remaining portions of the penstock going up into the mountain vary in length and degree of gradient, with the 55 degree section too steep to traverse (Figure 2). The last 1,040 feet (317 meters) of the penstock requires climbing aids, ropes, or ladder structures to be traversed.

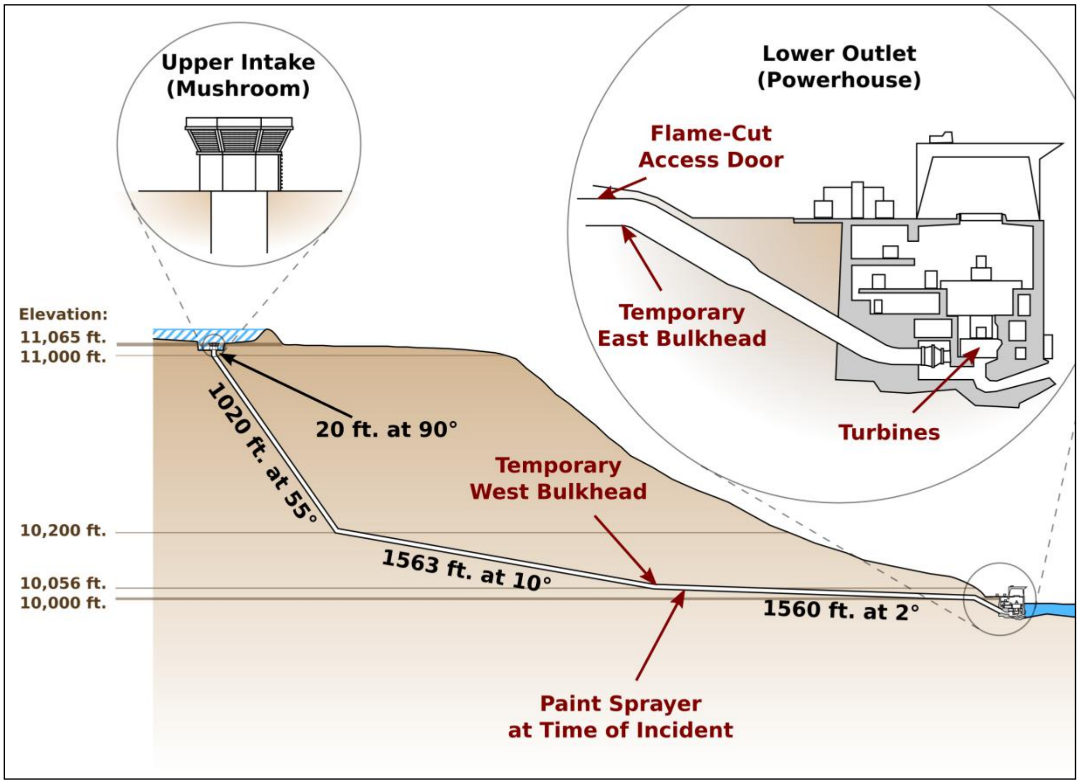

Figure 2. Penstock configuration

At the highest elevation point of the penstock in the upper reservoir is the intake structure known as the "mushroom." The mushroom is a 40-foot (12 meter) tall, cylindrical concrete and steel tower with screened openings near the top that open to the penstock. The mushroom has an access hatch approximately 20 feet (6.1 meters) above grade at a reverse incline position that requires climbing skill and significant physical strength to enter (Figure 3).

Figure 3. Upper reservoir mushroom access hatch

While the penstock runs underground for most of its length, as it exits the mountain rock face near the lower reservoir, a 15-foot (4.6 meter) section is accessible from the powerhouse yard. In this portion of the penstock, a 4 by 6 foot (1.2 by 1.8 meter) opening was flame-cut into the steel penstock pipe to provide access for the recoating project workers and equipment.

2.1.2 Deteriorated Penstock Interior Lining Requires Replacement

During the fall 2000 plant outage,[13] a Federal Energy Regulatory Commission[14] (FERC)-mandated internal inspection of the penstock found numerous indications of deterioration of the epoxy coating (flaking, blistering, and checking) in the interior of the steel-lined pipe section, which resulted in areas of

[13] An outage is a period when a plant, such as this one, is not in normal operation because of maintenance work and/or inspections.

[14] FERC is a self-funded, independent regulatory agency within the U.S. Department of Energy with jurisdiction over electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, and oil pipeline rates. FERC also reviews and authorizes liquefied natural gas (LNG) terminals, interstate natural gas pipelines, and approximately 1,600 non-federal hydropower projects in the U.S.

rusting and pitting corrosion to the steel pipe. Although the structural integrity of the pipe had not been compromised, the inspection report recommended repairs to the coating before more damage resulted. After obtaining an extension for repairs from FERC for several years, a project to remove the lining and replace it with a new epoxy lining was scheduled for the fall 2007 outage.

3.0 Contractors

3.1 RPI Coating, Inc.

Xcel selected RPI Coating, Inc. (RPI), a commercial painting and coating company headquartered in Santa Fe Springs, California, to remove the old liner from the steel portions of the Cabin Creek penstock and apply the new epoxy (for additional information on the selection process, see Sections 4.1.2 and 8.0). RPI, which operated as Robison-Prezioso, Inc. until 2007, was ranked the nation's seventh-largest specialty paint company based on revenues in 2005, according to the *Engineering News-Record* (2005). At the time of the incident, RPI had approximately 275 employees and more than 13.5 million in annual sales.

Prior to this incident, when RPI was still Robison-Prezioso, federal and state OSHA had inspected the company 46 times since 1972. Of these inspections, 31 had been initiated due to a complaint, referral, or accident; 90 violations were issued with fines totaling $135,569. Some violations were issued after accidents that had resulted in serious injuries and/or fatalities to employees (Appendix B).

3.2 KTA-Tator, Inc.

Xcel hired KTA-Tator, Inc. (KTA), a 250-employee consulting/engineering firm, for several work tasks associated with the penstock project. These tasks included writing the technical specifications for the application of the new epoxy coating in the penstock, assisting in the selection of the coatings contractor by reviewing and evaluating submitted bids, helping resolve technical issues arising from application of the coating, and performing periodic quality control checks to ensure proper old coating removal and new coating application.[15]

[15] The first three tasks were completed by a KTA chemical engineer specializing in coatings applications in the water and power industries; the fourth was performed by a KTA coatings inspector certified by the National Association of Corrosion Engineers (NACE).

4.0 Incident Description

The penstock fire occurred on October 2, 2007, but the recoating project had been initiated months earlier.

4.1 Pre-Incident Events

4.1.1 Initial Evaluations of the Penstock Project Hazards

Almost a year before the October 2, 2007, incident, Xcel conducted a hazard assessment of the penstock project, which was later provided to potential contractors during the bidding process. However, this "Safety and Health Hazard Assessment Survey" focused only on the abrasive blasting portion of the recoat project work and did not examine the risks of epoxy recoating associated with the penstock, the use of flammables inside the confined space, or the limited access and egress of the penstock. This was the only hazard assessment Xcel conducted for the entire penstock recoating project.

Later in the penstock project development process, during the spring of 2007, a civil engineer employed by Xcel highlighted a number of difficulties specific to the unique and challenging penstock work that would affect the success of the project in his document, "Cabin Creek Penstock Major Items of Concern."

Within the document, the civil engineer identified the need for an additional point of access, as the penstock's single entryway – a 20-inch (51 centimeters) man hole – was the only existing penstock opening at the start of the project. The civil engineer also discussed the challenges of trying to achieve the necessary temperature conditions within the penstock for successful epoxy application and the significant difficulties of completing the project in the 10 weeks allotted, suggesting that the harsh weather conditions typical of October and November in the Colorado mountains would hinder timely completion. These concerns were given to the Xcel Cabin Creek principal engineer, who later became responsible for preparing for the project with RPI, and a number of other Xcel employees, prior to the start of the recoating work. Yet neither Xcel's submission to the potential bidders for the recoat project, nor RPI's bid response, discussed methods for minimizing or rectifying the concerns raised by the civil engineer.

4.1.2 Contractor Selection

Xcel issued a Request for Proposal (RFP) for a competitive bidding process to several contractors in July 2007. The contractor selected to perform the work was to be chosen based upon the “best value/best overall evaluated offer,” which was supposed to consider factors such as schedule, price, qualifications, and safety performance (TRB, 2006, p.S-3). The Xcel process also included an initial prequalification step that examined the contractors’ financial capacity to carry out the work but did not consider safety performance.

Due to key safety criteria deficits in RPI’s safety record, Xcel rated the company as “zero” in that category, which should have meant its automatic disqualification from the bidding process; however. RPI’s bid was not rejected, and it was eventually awarded the contract despite its poor safety record (Section 8.0).

4.1.3 Planning and Preparing for Penstock Recoating Project

While RPI employees prepped the job site, Xcel held a preconstruction meeting for the penstock recoating project on September 5, 2007, attended by an RPI vice president, the RPI Safety and Quality Control representative, and two RPI project foremen. During this meeting, the Xcel project manager indicated that this was a “high profile project with [the] attention of FERC” and that a high standard toward quality control needed to be maintained. On September 10, at the request of RPI’s safety director, an instructor with the Southern California Painting and Drywall Industries (SCPDI) District 36 Training Center conducted a six-hour safety refresher training session at the Xcel Cabin Creek site for some RPI industrial painters to address gaps that the Xcel safety director had identified in RPI’s contract bid submissions. Only nine of the 14 RPI crew members were on site to attend this general safety training, and no make-up session was offered to those not in attendance (Section 9.0).

4.1.4 Work Preparation Prior to Recoating

Before the old liner could be removed from the steel sections and the new epoxy applied, the plant was shut down and water drained from the penstock. This occurred during the first week of September 2007, as a number of RPI personnel began arriving at the Cabin Creek site to set up for the job.

After the water was drained from the penstock, a 4-foot wide by 6-foot (1.2 by 1.8 meters) tall access opening was flame-cut[16] into the side of the steel penstock pipe for personnel and equipment access. Wooden stairs and a ladder at the access door provided means for personnel to enter and exit the penstock (Figure 4).

Xcel and RPI personnel then entered the penstock to remove standing water, dead fish, mud, and debris. Eyewitnesses reported that the penstock was extremely slippery due to moss buildup, and that personnel often slipped during initial entries. One RPI employee dislocated his shoulder when he slipped and fell.

[16] The access opening was cut by a specialty welding contractor.

Figure 4. Access door cut into penstock for recoating work

To contain the sandblasting debris and control ventilation, RPI built a wooden bulkhead west of the penstock area to be recoated (“west bulkhead”), with a 2 by 2 foot (0.7 by 0.7 meter) access hatch near the bottom, and sealed it against the walls of the penstock with foam. RPI built a second sealed wooden bulkhead about 20 feet east of the penstock’s access door (“east bulkhead”). Two 20-inch (51 centimeters) diameter flexible ventilation ducts, connected to dehumidification, heating, and dust collection equipment located outside the penstock, were brought into the penstock to dry and dehumidify the air and collect dust. The air supply duct was routed along the penstock wall and terminated near the west bulkhead at the steel/concrete transition where the air was discharged; the air return duct terminated near the penstock access door.

Compressed air and 120/240-volt electrical service were brought into the penstock to power equipment and provide lighting. Power cables for the electrical service were connected to a portable transformer located outside the penstock. A 240-volt heavy gauge power cable (6 AWG[17]) ran along the penstock floor from the access door and terminated at power distribution centers (commonly called "spider boxes"), one of which was located about 100 feet (30.5 meters) from the west bulkhead to provide power to the work area; this cable had non-watertight twist lock connector fittings joining sections of cable. The spider box contained 240- and 120-volt GFCI-protected electrical power supply outlets. On the day of the incident, the electric heaters on the sprayer, halogen work lights positioned on top of the sprayer, and explosion-proof lighting mounted on a scaffold immediately adjacent to the bulkhead were plugged into this spider box.

On September 16, 2007, another contractor performing inspection work inside the penstock complained to Xcel about being delayed entry into the penstock for 2 hours due to high carbon monoxide (CO) levels; he also noted a problem with RPI's electrical service inside the penstock when some of the contractor's testing equipment was damaged after it was plugged into an RPI spider box. An RPI foreman later rewired this electrical box, which was located near the sprayer on the day of the incident.

4.1.5 Removal of Old Epoxy Liner

Beginning on September 20, 2007, RPI sandblasted and removed the old liner from the the steel section immediately east of the west bulkhead; sandblasting continued until September 28, when the first 500-foot section was completed. On September 22, the Xcel project manager for the penstock recoating work observed RPI conducting abrasive blasting inside the penstock, noting that "[w]ork conditions inside the penstock are highly hazardous on many levels. In the best of conditions, the coating removal is dirty, nasty work." Beginning September 28 and continuing for 4 days, leaks were patched, and the abrasive

[17] AWG (American Wire Gauge) is a U.S. standard set of non-ferrous wire conductor sizes.

blasting medium was vacuumed up and removed from the penstock. An Xcel worker entered the penstock during this period on two occasions to weld weep holes to stop leaks.[18]

4.1.6 Additional Evaluations and Inspections of the Penstock Work Space

On September 22, KTA conducted its own initial pre-job hazard assessment of the penstock. In this assessment, the KTA inspector noted that the Material Safety Data Sheets (MSDSs) for all coatings and solvents to be used in the project were available and would be reviewed relative to personal protective equipment (PPE) and respiratory protection needs, and that the contractor and Xcel project manager were told about this review. In the assessment, the use of solvents was once again identified when the need for eye protection was pinpointed due to the use of "solvents, paints, abrasives, etc." According to the assessment document, the project manager was to be advised on the use of solvent.

In this same inspection, the KTA inspector also indicated that the project would require workers to enter a work area classified as a permit-required confined space. By delineating the space as such, several requirements were outlined to be followed, including review entry procedures and entry permit, verify that air monitoring is performed prior to and during entry, verify that an attendant is present and rescue equipment is onsite, and use respiratory protection in accordance with controlling employer's entry procedures. Despite these requirements, entry procedures were not developed and the required daily permits were incomplete and lacking detail pertaining to the hazards of the day's work activities. Air monitoring was performed almost exclusively at the entrance, about 1,450 feet (442 meters) away from the actual work area within the penstock. Finally, rescue equipment was not available and ready for use onsite throughout the project or on the day of the incident.

Two days later, on September 26, the KTA inspector conducted an inspection of the penstock interior, indicating in his documentation that thinner would be used as part of the coating materials' mixing and

[18] Neither Xcel Energy nor RPI could provide copies of hot work permits for this welding work to the CSB.

pre-application process. Thinner/solvent was required to be run through the sprayer system equipment (including hoses, nozzles, and the sprayer itself) prior to the introduction of the epoxy components. This step ensured that the machine was completely free of all residue or contaminants prior to usage for actual spraying.[19]

On October 1, an Xcel safety consultant inspected RPI employees working in the penstock, but noted no unsatisfactory conditions.

Sandblasting activities, including hand-sanding and grinding of the walls, were completed on the morning of October 2, and 13 RPI crew members[20] began preparing the penstock interior for the new coating. No reevaluation of the safety hazards was held that morning to specifically assess new risks that could be associated with the change in planned work activities from sandblasting to epoxy coating application, nor were special precautions taken within the work environment beyond those put in place prior to the start of the sandblasting operation.

4.1.7 Staging Equipment and Coating Materials

The sprayer, a plural component (two-part) epoxy spraying system manufactured by Graco, is typically used in industrial epoxy application projects (Figure 5).

[19] In the September 26, 2007, KTA Inspection Report, "Task Summary: Coating Observation Hold Points," the inspector indicates that thinner would not be used in any ratio with the paint during either the first or second coat of paint. More traditional types of paint require a thinner or solvent to adjust the viscosity of the paint for proper application. However, the Duromar HPL-2510 two-part epoxy selected as the paint for the penstock interior did not require thinner to be added, as the two parts of the epoxy themselves are mixed according to a specific ratio of hardener to base. While a thinner or solvent was unnecessary for the actual paint mixture to be applied to the penstock interior, the solvent was needed to flush the sprayer system and clean equipment prior to and throughout the spraying process to keep the machine running smoothly for proper application of the two-part epoxy.

[20] One of the 14 contractors left the site prior to October 2nd for personal reasons.

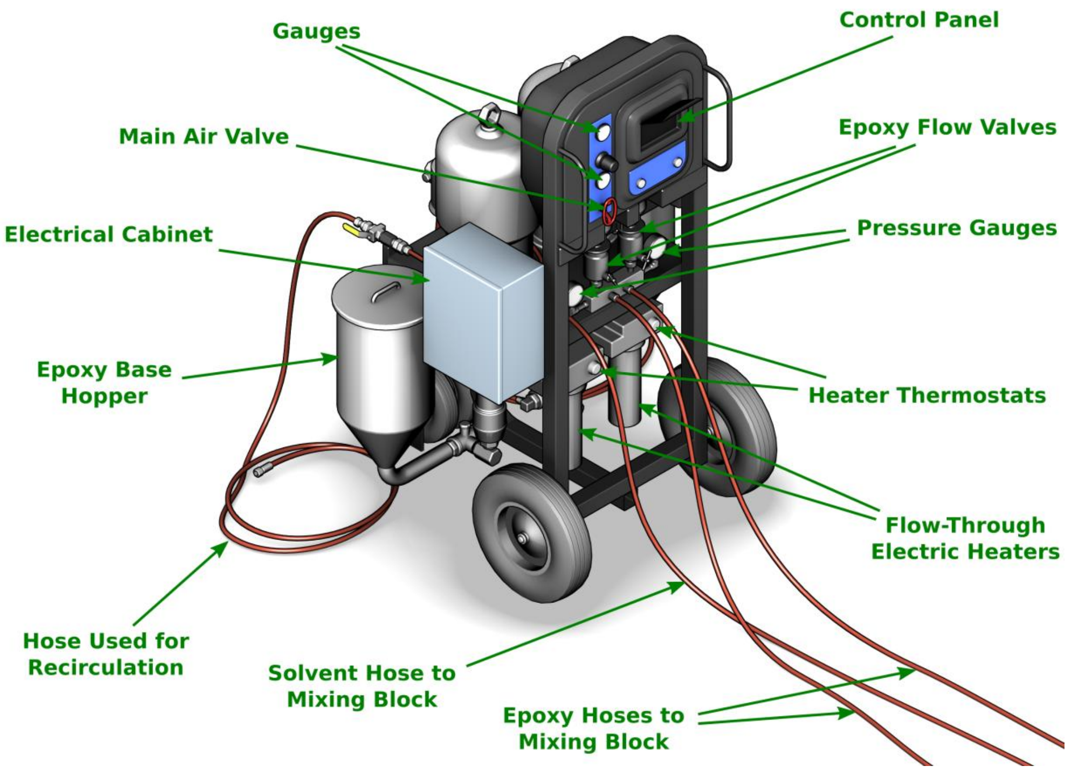

Figure 5. The epoxy sprayer system used within the penstock

Each epoxy component – a base and a hardener – is poured into its respective hopper, and each flows through a heater to achieve the proper application viscosity. Pumps for each component force the heated material through separate hoses to a mixing block, where the hardener and base are homogeneously blended. This separation of heating prior to mixing is necessary because once the two components blend, they begin to "set," forming an epoxy bond that hardens rapidly. The combined epoxy product is then carried through a hose from the mixing block to the spray wand for surface application. Workers stated that the epoxy components used in the Cabin Creek project, once mixed, had a short "pot life"—a period of approximately 20 minutes before they began to permanently harden together.[21]

[21] The epoxy product data sheet gives the "pot life" as 45 minutes at 70 ºF, but the workers described the period before the mixed epoxy began to set up as much shorter in actual working conditions.

Solvent, such as MEK, is needed if problems arise when applying the epoxy mixture. If the combined epoxy product was to set, it would harden within the hoses and spray wands, destroying the equipment. Solvent would be used to flush out the mixing block and hoses to the spray wands to ensure that the epoxy mixture was fully removed from the equipment and would not permanently render it unusable. Solvent would be introduced into these portions of the spray system using a third smaller pump on the back of the machine that would take in solvent from an open bucket placed on the ground at the back of the sprayer (Figure 6). A hose ran directly from this pump to the mixing block.

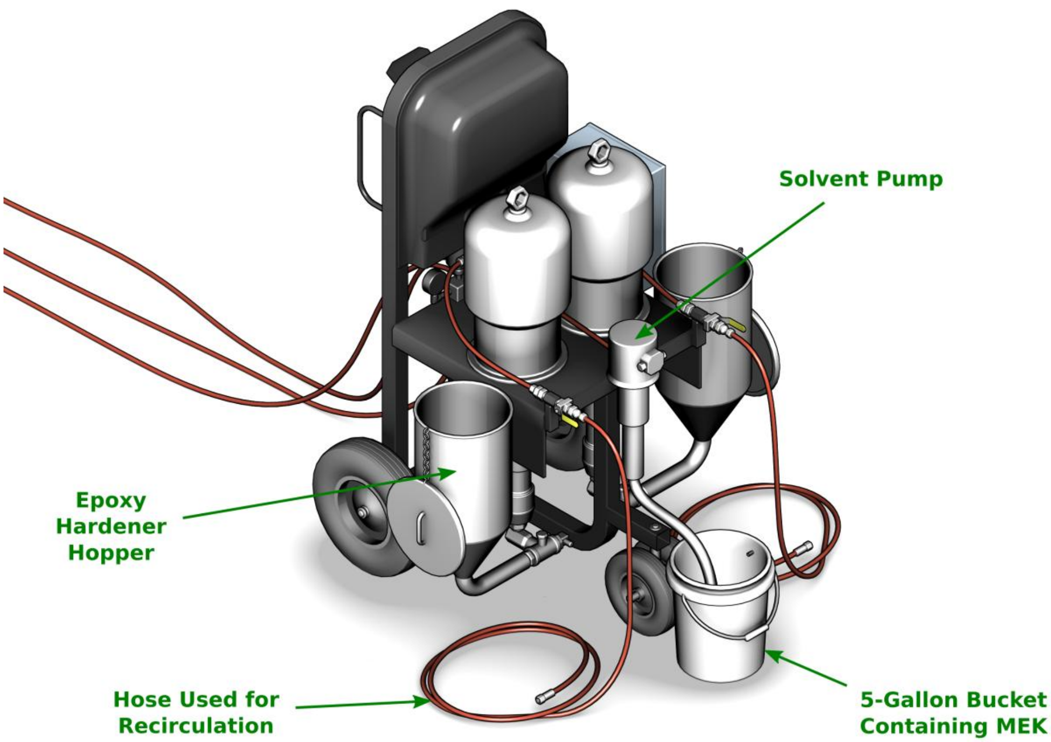

Figure 6. The solvent pump on the back side of the epoxy sprayer

The sprayer was positioned in the penstock on wheeled scaffolding, which the RPI crew called the "stage," about 1,450 feet (442 meters) from the access door and approximately 90 feet from the west bulkhead (Figure 7). The controls for the sprayer faced the west bulkhead, so that when a contractor was in position to manipulate the controls, he was looking in the direction of the access door, with the sprayer between him and that single point of egress.

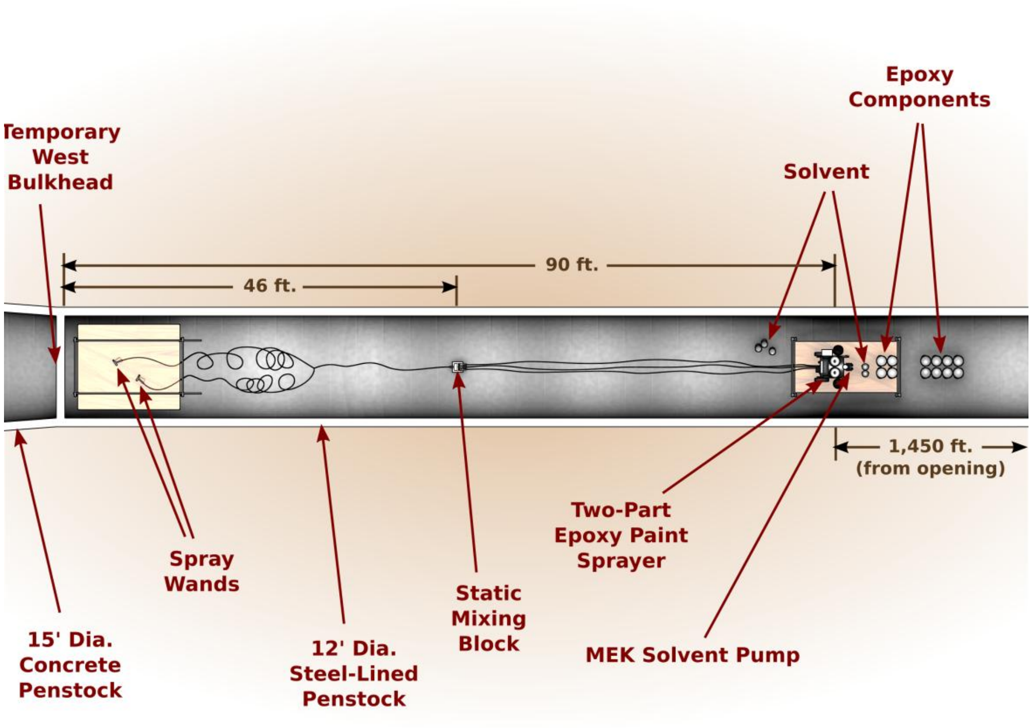

Figure 7. Aerial view of equipment arrangement in work area of the penstock

In the hour leading up to the incident, five of the 13 contractors were working around the sprayer system (Figure 8). Three of these individuals – two of whom were foremen – worked the controls of the sprayer, while two others were stationed on the sides, each responsible for manning a hopper. Four additional contractors were runners, bringing epoxy, solvent, and other equipment to and from the work area to assist the five at the sprayer, and one person was stationed as the "hole watch" attendant at the access door 1,450 feet (442 meters) away.[22]

[22] Among other responsibilities, the assigned "hole watch" is responsible for tracking who enters the confined space and the duration of time each spends within the space.

Figure 8. Depiction of contractors working with the sprayer immediately prior to the flash fire

The last two of the 13 contractors – besides the general foreman – were at the far end of the work area near the temporary west bulkhead, preparing to begin recoating the penstock interior using a wheeled scaffold that had been built for the crew as they used spray wands to recoat the penstock interior (Figure 9).

Figure 9. Depiction of contractors recoating the penstock interior near the temporary west bulkhead

4.1.8 Preparation for Coating Application

In preparation for applying the epoxy, approximately 10 gallons of MEK was brought into the penstock in 5-gallon plastic buckets to flush out the entire sprayer system prior to applying the epoxy. This flushing cleans out the mixing block and combined epoxy product hose lines to the spray wands and involves pouring MEK into each of the hoppers and re-circulating the solvent through the sprayer from the hopper to the discharge of the pump.[23] This full flushing process ensures that all foreign matter, debris, and leftover epoxy products are completely removed from the equipment before new epoxy products are introduced.

MEK is highly flammable and can produce hazardous atmospheres with air and be ignited under almost all ambient temperature conditions (NIOSH, 1998; NFPA 2007b, Table 6.2) (Section 6.5.1 details the hazards of MEK).

On October 2, after this flushing process was completed, the open buckets of used MEK were kept within the sprayer area for future use. Immediately prior to the incident, at least eight buckets of epoxy and three buckets [about 11-12 gallons (42-45 liters)] of MEK were on the stage. One of these buckets was a 5-gallon (19 liters) pail that sat open underneath the solvent pump on the back side of the sprayer. A halogen lamp sat on top of the pumps, projecting light onto the hoppers. In addition, more than 95 plastic buckets of base and hardener epoxy products were distributed throughout the penstock (Appendix C provides an inventory of epoxy and solvent within the penstock at the time of the incident).

The KTA inspector and RPI general foreman examined the penstock work area and determined that the contractors could begin applying epoxy. The inspector and general foreman then left the site for lunch at about 1:10 pm, while the other 12 RPI workers remained at the site, 11 of whom continued working within the penstock.[24]

4.1.9 Epoxy Coating Application Problems

The application process did not go smoothly, and solvent (MEK) had to be used several times to flush out the equipment. Eyewitnesses reported that the sprayer was not flowing accurate hardener-to-base ratios

[23] This preparatory cleaning of the equipment is discussed in the Duromar epoxy application guide and the Graco sprayer manual as normal practice during general commercial or industrial painting prior to introducing epoxy into the sprayer system.

[24] The twelfth contractor was the attendant stationed at the access door.

and that its electronic display continually gave error readings, which automatically shut down the sprayer. Because of "fingering," or uneven application of the epoxy to the surface, the contractors were able to spray only about a 10-foot (3-meter) area of the penstock wall interior. [25]

Each time the sprayer shut down, the contractors ran MEK from the sprayer's solvent pump to the mixing block, through the two hoses of combined epoxy product to the spray wands, where the solvent flushed the epoxy out of the hoses into plastic buckets.

This flushing between attempts of epoxy application occurred approximately four times before one of the RPI foremen decided that the contractors would be unable to apply the epoxy evenly. He instructed the contractors to flush the entire sprayer system by circulating MEK through all the equipment in preparation for removing the sprayer from the penstock.

After flushing the mixing block and the spray wands, the two contractors at the west bulkhead who had been operating the spray wands took the buckets containing a mixture of MEK and epoxy waste to the sprayer area. Other members of the crew began cleaning out the sprayer by removing the epoxy products within each hopper.

Another contractor brought in about 6 more gallons (23 liters) of MEK in several trips using 2-gallon (7.6 liters) plastic buckets that had originally contained the hardener. As a result, about 11-12 gallons (42-45 liters) of pure MEK and another 12 gallons (45 liters) of epoxy/MEK waste product [of which about 5 gallons (19 liters) were MEK] were in close proximity to the sprayer.

At this time, two of the contractors retrieved some of the nearby buckets of MEK to flush out the sprayer system, while two others began walking toward the access door to retrieve even more buckets of the solvent. MEK was poured into the hardener side and circulated through the sprayer system. The

[25] "Fingering" is painting jargon for uneven paint application: when a thick residue of paint is left in long vertical lines, like fingers, up and down a surface.

contractors then poured MEK in the base hopper for circulation. This circulation through the base side of the sprayer was ongoing when the initial flash fire occurred.

4.2 The Incident

At approximately 1:55 p.m., on Tuesday, October 2, 2007, a flash fire ignited at the sprayer in the immediate vicinity of the base hopper while the contractors were flushing the system with MEK. An RPI contractor was circulating the MEK from the base hopper through the pump, discharging the solvent back into the hopper through a nylon hose. At the time of the ignition, the contractor was holding the end of the hose equipped with a metal fitting inside the base hopper; he reported witnessing the initial flash arising from the interior of the hopper. The burning solvent forcefully erupted from the hopper and sprayed onto the contractor and the surrounding area. The flash fire caught the contractor's sleeve on fire and quickly engulfed the buckets of MEK. Another contractor, who left the work area to retrieve portable fans to help dissipate the strong MEK odor, was about 40-50 feet (12-15 meters) from the sprayer when the fire ignited. Two others, on their way out of the penstock to retrieve more MEK, heard a loud rumble; they turned in the direction of the noise and saw a flash of fire that seemed to roll toward them. These eyewitnesses reported that the fire appeared to come from the base hopper.

This rapidly growing fire separated the contractors who were standing on either side of the equipment. The five contractors who were on the far side of the sprayer found their exit blocked by the fire and were unable to escape. The trapped men shouted for fire extinguishers.

4.3 Emergency Response

4.3.1 Fire Extinguishers

No fire extinguishers were staged near the sprayer where the initial fire started. After the initial flash, the fire died down enough for those trapped behind the sprayer to communicate with the survivors on the other side. Those trapped instructed the others to retrieve extinguishers. The contractors on the side of sprayer with access to the entrance ran about 1,450 feet (442 meters) down the penstock to retrieve the fire extinguishers, which were located outside of the penstock.

While they ran for the access door, several flash fires ignited and loud booms reverberated down the penstock as the initial fire ignited the solvent and caused the epoxy buckets surrounding the sprayer to burst. The fire increased in size and intensity and spread to additional epoxy buckets in the vicinity of the sprayer. The trapped men retreated uphill, away from the sprayer and farther up into the penstock.

With extinguishers in hand, two of the crew ran back inside toward the fire and sprayer with the intention of putting out the fire. The thick black smoke reduced their visibility to almost zero and made breathing difficult; as a result, they could not get near enough to the sprayer and burning epoxy products to effectively extinguish the fire. This initial attempt, and all additional re-entries the work crew made to extinguish the fire, failed.

4.3.2 Initial 9-1-1 Call

One of the crew members who retrieved the first two fire extinguishers from outside the penstock handed the extinguishers to his coworkers before running to the nearest phone, located at the Cabin Creek powerhouse entrance east of the penstock. He called the Cabin Creek power house control board, notifying them of the penstock fire and need for 9-1-1 assistance.

Clear Creek County Emergency Dispatch received the first 9-1-1 call from an Xcel control room operator at 2:03 p.m. The caller told the 9-1-1 operator that there was a fire in the penstock, but did not explain that the penstock was a confined space or that specialized rescue personnel and equipment would be required to fight the fire and rescue trapped workers.[26] The 9-1-1 operator immediately broadcast a request to Clear

[26] The caller told the 9-1-1 operator that there was "a fire in our penstock…in our tunnel…outside on our surface deck, outside of the plant…on the surface."

Creek County Emergency Services[27] to respond to the Cabin Creek site, indicating that there was a fire on the "surface deck."

The RPI worker also called the company corporate office to notify management of the emergency. He then went back to the access door of the penstock and found that the RPI general foreman and KTA inspector had arrived.

During this time the trapped workers used a radio to remain in communication with the crew that escaped.[28]

4.3.3 Emergency Responders Arrive

Upon arriving at the Cabin Creek site, emergency responders established an Incident Command structure. At 2:11 p.m., the first Clear Creek County Sheriff's officers arrived on the scene, followed shortly by a volunteer paramedic and firefighter from the Clear Creek County Fire Authority (CCFA). These responders saw no signs of a surface fire when they arrived. Xcel and RPI employees quickly informed them that the fire was inside the penstock and that several workers were trapped. At 2:20 p.m., the 9-1-1 center broadcast an update indicating that the fire was 1,000 feet (305 meters) inside the penstock tunnel and below ground. The message also informed responders that they would need 1,000 feet (305 meters) of hose and the equipment necessary to fight an underground fire.

The CCFA responders lacked the necessary equipment and resources to safely enter the penstock; they were also concerned that they lacked the appropriate training to perform rescue within the confined space.

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[27] Clear Creek Fire Authority (CCFA) is a consolidated fire protection and emergency service agency serving the municipalities of Empire, Georgetown, Idaho Springs, and Silver Plume, and the unincorporated lands of Clear Creek County previously represented by the Clear Creek Emergency Services District (ESD). CCFA's territory includes I-70 (Colorado's primary east-west transportation corridor); Clear Creek (a rafting river); four 14,000-foot (4,300 meters) peaks; two ski areas; several hundred abandoned mines; and residential and business districts. (Colorado Division of Emergency Management, http://dola.colorado.gov/dem/operations/operations.htm, accessed July 30, 2010).

[28] The CSB determined this timeline by correlating events discussed in interviews with security video footage of the area outside the penstock.

4.3.4 Call for Mutual Aid

CCFA personnel en route to the site, based on information broadcast over their radios (i.e., that the fire was located deep inside the penstock and that workers were trapped), contacted Denver's West Metro Fire Protection District (West Metro) to request firefighting and rescue assistance.[29] West Metro Emergency Response personnel are located on the west side of Denver, approximately 1 hour and 15 minutes travel time (about 45 miles or 72 kilometers) from Cabin Creek.

At one point, firefighters requested and received the MSDSs from RPI.

At 2:30 p.m. the Incident Commander contacted Climax Molybdenum Company's (Henderson Mine) mine rescue team to request support in rescuing the stranded workers.

4.3.5 Attempted Entry by Early Rescuers

Approximately 45 minutes after the initial fire, but before West Metro or Henderson Mine emergency personnel arrived, four Clear Creek firefighters entered the penstock to assess the fire and the prospect of rescuing the five trapped RPI employees. Wearing protective fire-fighting clothing and self-contained breathing apparatuses (SCBAs), they used a small gasoline-powered all-terrain vehicle (ATV)[30] to explore the penstock. Because of the smoke and lack of visibility, they were able to move only about 200 feet (61 meters) into the penstock before they stopped and returned to the entrance, concluding that they were unable to extinguish the fire and/or rescue the trapped workers. CCFA did not attempt further entry into the penstock until after Henderson Mine rescue personnel cleared the penstock.

[29] West Metro and CCFA have a Mutual Aid agreement for technical firefighting and confined-space rescue.

[30] The ATV was placed in the penstock at the beginning of the project to transport personnel and supplies throughout the steel portion to be recoated.

4.3.6 Stranded Workers Still Communicating 45 Minutes into Incident

Radio communications between the trapped contractors and those outside the penstock continued for about 45 minutes after the initial flash fire. The trapped workers were instructed to move to the upper end of the penstock, away from the burning sprayer, epoxy, and solvent.

4.3.7 Emergency Responders Evaluate Further Entry into the Penstock

West Metro arrived at the Cabin Creek site around 3:40 p.m., but because they did not know about the conditions inside the penstock—whether explosive hazards existed—they did not enter to fight the fire or attempt rescue. Instead, they joined CCFA and another rescue group, Alpine Rescue, at the top of the penstock (the mushroom). Upon arrival at the mushroom, West Metro was told that breathing air bottles and respirators, a light, and a radio were lowered down into the vertical portion of the penstock in the hopes of reaching the trapped contractors. This activity posed its own difficulties due to the winding pot-holed road leading to the mushroom and the challenges of using the mushroom's access hatch.

4.3.8 Emergency Responders Enter the Penstock

The first of two Henderson Mine rescue teams arrived shortly after 4:00 p.m. and prepared to enter the penstock at the access door.

Sometime between 4:45 p.m.and 5:30 p.m., Xcel operations personnel reversed the penstock ventilation fans to try and reverse the penstock airflow and draw the smoke away from the stranded workers.

Henderson Mine responders entered the penstock at 5:45 p.m. After verifying that the fire had burned out, they continued up the penstock to determine if any of the workers had survived. They found the first body approximately 100 feet (30.5 meters) uphill of the fire. The four remaining were located even further uphill, near the point at which the penstock's incline abruptly steepens. Post incident, it was determined at all five died of asphyxiation shortly after radio communications ceased, at approximately 2:45 p.m.

5.0 Incident Analysis

The CSB found that numerous safety issues collectively contributed to the October 2, 2007, incident.

5.1 Pre-Incident Events

Insufficient ventilation, improper equipment for fire prevention, and a tight schedule created an unsafe work environment even before the epoxy application activities began.

5.1.1 Insufficient Ventilation

Adequate ventilation was an important safety issue of the penstock work environment. The work area being sandblasted and coated was sandwiched between two wooden bulkheads built to confine the sandblasting medium and epoxy coating materials, and to isolate the work area space of the penstock. Ventilation and the control of nuisance dust was to be accomplished using two desiccant-style dehumidifiers that would force air into the space at a rate of approximately 13,000 cubic feet per minute (CFM).[31] Additionally, a 12,000 CFM dust extractor was to be used that would pull air out of the penstock and remove dust particles before discharging the air outside. This ventilation setup, if operating optimally, equated to approximately 4.4 air changes per hour (ACH)[32] in the work area between the two bulkheads.[33] In constrast, the Flammable and Combustible Liquids OSHA standard requires a room that simply stores flammable and combustible liquids be ventilated at a rate of six air changes per hour in order to prevent explosive vapors from accumulating [29 CFR 1910.106(d)(4)(iv)]. None of the

[31] The inlet air was delivered into the work area via a 20-inch (52-centimeter) diameter flexible plastic supply duct magnetically attached near the floor of the metal-walled penstock. The return duct located near the access door directed the air from the penstock through the dust collector before it was discharged to the outside atmosphere. During sandblasting, additional portable blowers and fans moved the dust-laden air down the penstock toward the east bulkhead near the access door. The additional portable blowers or fans were not used while the epoxy coating was being applied.

[32] The number of times air is replaced in an hour.

[33] Volume of Air: 13,000 CFM x 60 min = 780,000 CFH; Volume of Space: $(6\text{ ft})^2 \times 1560\text{ ft} \times \pi = 176{,}432\text{ ft}^3$; Air Changes: 780,000 CFH/176,432ft3 = 4.4 air changes per hour

ventilation design documents obtained by the CSB indicated any analysis of the adequacy of 4.4 air changes per hour in relation to the dissipation of flammable vapors in the work space. The penstock's ventilation setup was designed soley for the purpose of ensuring the penstock ambient conditions were optimal for the sandblasting and epoxy application activities.

After using MEK to clean the spray wands on the scaffold near the west bulkhead, one of the contractors left the work area to get a fan to dissipate the buildup of solvent "fumes" that he smelled through his respirator. He told the CSB that, as he squeezed past the scaffold holding the sprayer, there was "no air movement at all" in the vicinity of the sprayer. Post-incident, OSHA cited RPI for not ensuring ventilation equipment provided acceptable confined space entry conditions [OSHA 21 Mar 2008, inspection 310470034, citation 2(8)]. While adequate ventilation is a necessary component for managing the hazards of confined space work, the CSB has concluded that ventilation alone was insufficient to safely control the risks of using flammables in the open atmosphere of the penstock.

5.1.2 Improper Equipment Choices for Fire Prevention

Penstock recoating equipment choices made by RPI personnel, including management officials, increased the likelihood of a fire.

5.1.2.1 Decision not to Use Heated Hose Lines

The CSB determined that the primary reasons for the epoxy application difficulties were due to the inability to achieve and maintain the necessary temperatures of the epoxy components for application, which likely would have been avoided had heated hose lines been used. Heated hoses are often used in specialized industrial painting projects to overcome the negative impact of temperature, which can affect the viscosity of the epoxy and thus the quality of the coating application. However, a decision was made to use regular spray hoses instead, despite the penstock ambient and surface temperatures being below recommended levels for proper epoxy application.

The product data sheets for the epoxy base and hardener, RPI provided to Xcel as a part of its bid submission package, state that the minimum surface temperature during application must be no colder than 60 ºF (16 ºC). However, in the week leading up the incident, ambient temperatures averaged 58 ºF (14 ºC), and on October 2, the KTA inspector recorded the interior surface temperature of the penstock as 54 ºF (12 ºC). The General Application Guidelines for the epoxy, also included in the bid package, indicate that the base and hardener components be stored in "a warm area where the temperature remains between 60-90 ºF (16-32 ºC). Cold products are very viscous and will be very difficult to mix and apply." While the epoxy components were initially stored in a heated trailer, more than 95 buckets of epoxy were brought into the penstock and staged in groups along 1,450 feet (442 meters) of the penstock's cold steel floor.

The RPI work crew reported that the sprayer was having trouble heating the cold material, particularly the base, due to its thickness and initial cold temperature. When mixing the two epoxy components together, the combined product should have been between 70-80 ºF (21-27 ºC). A RPI contractor taking temperature readings of the unmixed products within the hoppers with a laser gauge immediately prior to application stated that the temperature readings of the base that day reached no greater than "45 º, 47 º."

Furthermore, the sprayer had difficulties maintaining the required epoxy temperature for an extended period. When workers circulated the two epoxy components several times through each side of the sprayer and the attached heaters, the limited quantity of each component within the sprayer system was able to achieve the requisite temperature.[34] However, after the heated components were sent to the mixing block for blending, additional (cold) epoxy had to be added to each hopper to keep the flow of combined product out of the spray wands consistent. But additional time was needed for the cold epoxy to circulate through the heaters to warm up to the appropriate application temperature. The CSB concluded that the 44 feet (13 meters) of hose from the sprayer to the mixing block and the additional 40-60 feet (12-18 meters) of hose from the mixing block to the spray wands was too great a distance to maintain the requiste

[34] Testimony from an RPI crew member stated that the crew had to circulate the material multiple times to get the paint to the requisite temperature.

temperature as cold epoxy was added to the sprayer and then passed through hose that ran along the cold penstock floor to the area being recoated.[35]

The RPI vice president discussed the plan to use in-line heated hose as late as five days prior to the incident, yet they were not incorporated into the equipment setup within the space. The lack of heated hose, in combination with the extensive length of hose required to complete the application work, contributed to the crew's inability to keep the epoxy at the appropriate temperature for proper epoxy application. As a result, the sprayer would not function effectively and the crew was forced to repeatedly flush the hoses from the mixing block to the spray wands with MEK between each failed attempt, which contributed to the buildup of MEK in the atmosphere.

5.1.2.2 Electrical Safety Precautions not Met

Equipment used to handle flammable material must be properly bonded and grounded, and hoses must be electrically conductive. These electrical safety precautions were not met on the day of the incident; specifically, the CSB determined that some of the hose chosen for the penstock job was likely non-conductive.

Non-conductive flexible hoses are not recommended for use with flammable liquids due to their static-accumulation capabilities unless, at a minimum, all conductive couplings (e.g., end fittings or connectors) are bonded and grounded (NFPA 77, 2007a, Section 8.4.3.2).

While most of the hoses around the sprayer were destroyed in the fire, an examination of the equipment post-fire uncovered the remains of the hose used to circulate solvent through the hardener hopper and its associated equipment still attached to the sprayer, including a hose connector (metal swivel) and the inner woven metal sheath. The hose used to circulate solvent through the base side of the sprayer was destroyed

[35] An RPI crew member with experience working with this product recommended that the paint come out of the spray wands at a temperature of 110 ºF for correct application.

in the fire and the inner woven metal sheath was not observed to be attached to the sprayer was not found in the surrounding debris. Due to the lack of an inner metal sheath, the CSB concluded that the base side solvent hose was likely non-conductive and did not establish appropriate bonding to allow for the dissipation of static electricity on the metal hose connector. (Appendix D.1). A static charge likely built up as solvent travelled through this hose; eventually an electrical spark between the hose connector and the metal base-side hopper of the sprayer likely resulted in the initial flash fire (Section 5.2.2 and Appendix D discuss this ignition scenario in detail). To prevent static charge buildup, conductive, rather than non-conductive, hose should have been used with the sprayer.

5.1.2.3 Use of Unsafe Lighting

Unsafe lighting was also used within the penstock when flammables were present. RPI's "Spraying Equipment and Operations" policy within its IIPP states: "Explosion proof [sic] portable lamps must be used to illuminate the spray areas." However, the penstock spray area, including where the sprayer system was setup, was illuminated with a variety of lighting, not all of which was explosion-proof. Specifically, several halogen lamps were placed around the sprayer, with one resting on top of the sprayer pumps at the time of the incident (Figure 10).

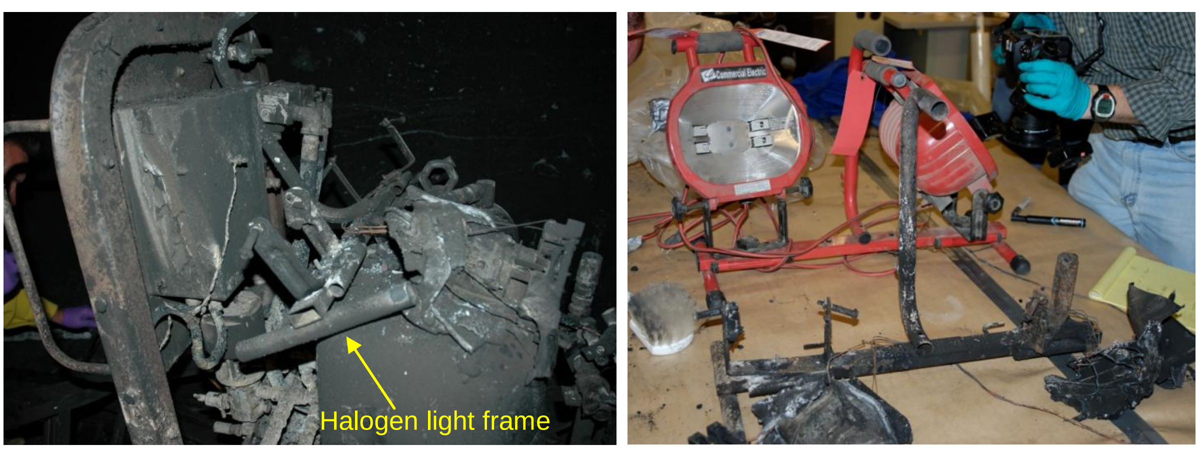

Figure 10. Remains of the halogen light sitting atop the sprayer inside the penstock (left); the same remains being compared to an exemplar halogen light (right).

Equipment and supplies needed for the penstock project were planned by the onsite foremen, the RPI shop manager, and RPI upper level management in advance of the work crew's activities inside the penstock. While the ignition of MEK vapor from the heat of a halogen light was determined to be a less likely ignition scenario (Appendix D), the CSB concluded that this unsafe lighting choice was a serious safety risk when used in conjunction with the introduction of flammables within a confined space.

5.1.2.4 No Fire Extinguishers Within the Work Area

Fire extinguishers were not immediately available to the contractors after the initial flash fire because they were not situated by the sprayer and within the work area. Contractors had to go approximately 1,450 feet (442 meters) – a length of over four football fields – to the exit of the penstock and retrieve extinguishers after the initial fire. RPI's "Fire Protection and Prevention" policy, within the IIPP, states that fire extinguishers "must be in close proximity to all painting operations." While "close proximity" is not defined, it is reasonable to conclude that 1,450 feet (442 meters) does not meet the definition. Additionally, NFPA 851, Recommended Practice for Fire Protection for Hydroelectric Generating Plants (2005), states that fire suppression equipment should be "provided where risk of fire exists" and "located for easy access" (NFPA 851, section 8.8.1). It goes on to state "Portable fire extinguishers of suitable capacity should be provided where…flammable liquids are stored or handled" (NFPA 851, section 8.8.2).[36] Had extinguishers been present at the location of the sprayer work activities, the solvent flash fire likely could have been suppressed or extinguished at the time of initial ignition prior to the combustion of the larger quantities of the epoxy products.

[36] Section 1.3.2 of NFPA 851 states that the recommendations within the Recommended Practice are intended for new installations, but notes that "the recommendations contained in this document represent good industry practice and should be considered for existing installations."

5.1.3 Scheduling and Production Pressures

A tight 10-week project completion schedule, severe weather concerns, several unplanned work delays, and perceived production requirements placed RPI employees under intense pressure to complete the recoating work. These stressors contributed to a rushed work pace on the day of the incident, which likely affected the crew's ability to focus on safety. Decisions made in haste and under stress can often have deleterious side effects, including inadvertent step deletion or heavy focus on one issue while minimizing the significance of others (Dismukes, Berman, & Loukopoulos, 2007, p.261). Evidence indicates that the RPI workers experienced a rushed work pace the morning of the incident, and safety was likely negatively impacted as a result.

For a power plant like the Xcel Cabin Creek site, the downtime of the penstock would be costly. An RPI foreman involved in the initial planning of the recoating project confirmed that the project was set on a "short schedule," where work would be conducted on a 24-hour/7-days-a-week schedule until completed in order to be able to accomplish the recoating project in shortest time period possible. In addition, the vice president of RPI noted the very tight schedule in emails during the planning phase of the project, questioning if only one coat of epoxy, rather than two, could be applied to the floor of the penstock to accelerate the work pace and decrease curing time of the epoxy.

The project's timing was also one of five items emphasized as problematic in the Xcel "Major Items of Concern" penstock project planning document (Section 4.1.1), written by an Xcel civil engineer who noted that the time it would take to drain the penstock, coat the interior lining, allow the epoxy to cure, and refill the penstock for hydroelectric power would be difficult to accomplish, even in the best conditions, within the allotted 10-week schedule. He added that the weather during the time of year the penstock would be recoated – September through November – would "not lend itself to the best of conditions."

As the project began, several delays in the initial work tasks constrained the already tight schedule significantly from the initial timeline RPI submitted to Xcel with its bid submission documentation. A compressor was blown out during the sandblasting portion of the work. The RPI crew experienced electrical problems, blowing out a few of the electrical “spider” boxes and lighting, which required repair and replacement; and the contractors had to spend extra time sandblasting to remove the necessary amount of old liner prior to recoating. Specifically, the submitted schedule stated that the first quarter of the 1,560 feet (475 meters) of the penstock being recoated would be sandblasted and coated by the first of October; but the crew was just making its initial application attempts on October 2, over one week behind schedule.

In interviews with the CSB, the RPI employees confirmed that they were behind schedule before they even began the epoxy application process. Penstock crew personnel stated that they heard the general foreman report to RPI headquarters that a number of work tasks were completed before they actually were. The day of the incident, eyewitnesses stated that the general foreman was anxious about the crew’s progress and was pushing to get the recoating portion of the project underway. A number of the employees stated that with past projects they typically had regular safety meetings to review work tasks and safety concerns, but that the penstock job was different in that such safety discussions were not held as often, nor were they as focused on safety, as in previous jobs. According to the workers, any discussions held the morning of the incident focused on preparing equipment within the penstock for the recoating work, not on any safety risks inherent with the work, such as with using a flammable within a confined space, nor on any steps taken to mitigate those risks, such as ensuring fire extinguishers are located within close proximity to the sprayer system. Instead, the employees reported that the focus that day was solely on getting the epoxy on the walls.

In addition to the work delays and schedule pressures, RPI employees reported that the company used unofficial financial incentive programs – both in the past and in this recoating project – to ensure that work was completed in a timely manner. A number of the survivors asserted that if the crew finished the project on time or earlier than scheduled, the general foreman would receive a financial bonus. Some contractors stated that the general foreman would share the bonus with the hardest working members of the crew. Employees testified that this incentive was based purely on the timeliness of work completion. Incentive programs like these are common in many workplaces; however, attention must be given to ensure that such rewards do not have unintended negative consequences, such as a decline in work quality or safety in order to ensure on-time work progress (Hopkins, 2005, p.51 – 60; Hopkins, 1999, p.13 and 94).

5.2 Incident Events

The use of solvent within the confined space of the penstock to clean the sprayer created a flammable atmosphere. A static spark most likely ignited the flammable atmosphere within the sprayer hopper, resulting in a flash fire that quickly intensified as additional solvent and the combustible epoxy surrounding the sprayer ignited. The rapid spread of fire and toxic smoke from burning epoxy prevented the workers uphill of the sprayer from exiting through the penstock's only egress point, resulting in their deaths.

5.2.1 Unsafe Sprayer Flushing Method Contributed to a Flammable Atmosphere

On October 2, the contractors flushed the entire sprayer system with MEK while it was still within the penstock's confined space, creating a flammable atmosphere within the work area. Flushing the sprayer system with solvent outside the penstock could have avoided creating this flammable atmosphere, as none of the equipment, with the exception of the mixing block itself and the hoses going to the spray wands, required immediate flushing with a solvent. It is only when the hardener and base epoxy components are combined that they react with each other and solidify (Section 4.1.7). The potential for a flammable atmosphere to develop would have been greatly reduced, had the solvent only been used to flush the mixed epoxy material from the hoses extending from the mixing block to the spray wands.

5.2.2 Most Probable Ignition Source

The CSB concluded that the fire inside the penstock was most likely ignited by a static spark that originated from the electrically isolated (ungrounded) metal swivel connector attached to one end of the non-conductive hose being handheld inside the base hopper of the sprayer as MEK was being flushed through (Appendix D.1). The CSB calculated that the MEK concentration in the vapor surrounding the metal swivel connector was between 7.6 and 9.1 volume percent, which is well within the flammable limits of 1.8 and 11 volume percent, based on the MEK vapor-liquid equilibrium concentration adjusted for penstock environmental conditions (Appendix E). The CSB determined that the MEK circulation flow through the sprayer was likely capable of developing a charging current, accumulating stored energy on the electrically isolated metal swivel connector and producing incendiary sparks of sufficient magnitude to ignite the flammable MEK vapor (Appendix F).

While the CSB determined that a static spark was the most probable ignition source, two other potential ignition sources could not be completely ruled out:

- An electrical arc produced inside the base hopper by a stray current inside the sprayer system (Appendix D.2), or
- Autoignition of flammable MEK vapor by the hot bulb of the portable halogen lights positioned above the sprayer (Appendix D.3)

Fire damage to the sprayer and associated equipment precluded the CSB from completely dismissing a stray current arc as the ignition source. The two electrical discharge ignition scenarios (static spark and stray current arc) are similar with respect to the location of the spark (metal swivel connector attached at the end of the hose) and vapor composition constraints limited to the base hopper. However, since a static spark requires a non-conductive hose and a stray current arc requires a conductive hose, these two electrical discharge mechanisms are mutually exclusive. Available evidence indicates that the base hardener hose was constructed from a non-conductive (nylon) material and the end connector was attached without any internal electrical bonding.

Conflicting testimony and fire damage to the sprayer's heaters and control panel also meant that the CSB could not conclusively verify whether the MEK was being heated as it circulated through the sprayer at the time the fire occurred. Thus, the CSB could not totally eliminate the possibility that the MEK temperature was hot enough to develop a flammable atmosphere above the sprayer, where the hot bulb surface from the portable halogen lights could have caused autoignition of the flammable MEK vapor. However, witnesses stated that the fire originated inside the base hopper and the CSB considered it unlikely for the fire to have been ignited at the halogen lights with a flame front traveling back to the hopper without being observed.

Three additional ignition scenarios were evaluated and eliminated as probable ignition sources: hot surface ignition by the sprayer heater(s) (Appendix D.4); compression ignition inside one of the sprayer piston pumps (Appendix D.5); or electrical spark from the heater control box (Appendix D.6). In summary, although either autoignition by the halogen bulb or a stray current arc were both possible ignition sources, evidence suggests that the most likely ignition source was a static spark between the metallic end connector on the non-conductive hose and the wall of the hopper.

To reduce the risk of fire or explosion, fire safety measures should employ protections aimed at eliminating at least two legs of the fire triangle [37]: oxygen, fuel, and ignition source (Scarbrough, 1984, pp.521-552). Potential ignition sources are often difficult to identify and control in situations where flammable liquids are being used. Because oxygen is normally present and difficult to remove, especially when people need to employ or interact with equipment that uses flammable liquid, fire safety measures stress the need to keep concentrations of flammable vapors well below the LEL[38] to prevent flash fires and explosions. This is especially important in a confined space where the number of air changes can be

[37] The fire triangle is a concept used to explain the three conditions – heat, fuel, and oxygen – that must be present for combustion.

[38] LEL is defined as "that concentration of combustible material in air below which ignition will not occur." "Recommended Practice for Handling Releases of Flammable and Combustible Liquids and Gases, NFPA 329 (2005). The terms lower explosive limit (LEL) and lower flammability limit (LFL) have different definitions but are commonly used interchangeably. This report will use LEL except where citing other sources that use LFL in their standard or regulation. The OSHA Permit-Required Confined Space Standard 29 CFR 1910.146 uses the term LFL in its provisions.

limited, causing flammable vapors to quickly concentrate. In this incident, a lack of fire safety measures to control or eliminate the concentrations of flammable vapors being generated during the flushing operation resulted in the penstock fire igniting when a suitably energetic ignition source appeared.

5.2.3 Flash Fire Becomes Sustained Toxic Fire, Trapping Workers

Approximately 16 gallons (61 liters) of MEK and at least 30 of the 95 buckets of epoxy[39] were destroyed in the fire. The initial flash fire involved only the solvent being used directly within the hopper; however, the large amount of solvent surrounding the sprayer, as well as numerous buckets of epoxy hardener and base, caused the flash fire to grow into a sustained, intense toxic fire.

Neither the MEK nor the epoxy components needed to be in the penstock in such large quantities. The amount of solvent required to flush the lines from the mixing block to the spray wands was significantly less than what was needed to clean out the entire sprayer system.

Had the decision been made to remove the sprayer from the penstock prior to flushing – a decision that should have been made by management prior to any onsite activities related to the penstock recoating project – the creation of a flammable atmosphere likely would have been avoided. And, had there not been additional MEK in buckets surrounding the sprayer, the initial flash fire likely would not have intensified. Finally, the subsequent ignition of the combustible epoxy components turned the growing fire into a toxic one.[40] This sustained fire prevented the trapped contractors from climbing around the sprayer. They had no choice but to run up the penstock, away from the burning products and their only exit.

[39] Because the fire burned many of the plastic buckets, leaving only the metal handles, it was impossible to discern if these melted buckets were 2-gallon hardener or 5-gallon base buckets. Therefore, a more precise quantity (in gallons) of epoxy burned in the fire could not be determined.

[40] The MSDS for the epoxy hardener states that “heat and fire can generate toxic or irritating decomposition products that may cause a health hazard. Sudden reaction wand [sic] fire may result if product is mixed with an oxidizing agent” (Duromar HPL-2510 Hardener, 7/2/2007). The MSDS for the epoxy base states that “heat from fire can generate flammable vapor and decomposition products that may cause a health hazard.” The base is also noted as a “known human carcinogen” (Duromar HPL-2510 Base, 3/21/2007).

6.0 Confined Space

The penstock recoating project was hazardous in that introducing and using flammable and toxic chemicals within a confined space presents numerous safety risks. The unique features of the penstock, including its extensive size and lack of a secondary point of egress, amplified the danger. Extensive and detailed pre-job safety planning was needed to evaluate and address the hazards inherent in this maintenance work.

The CSB concluded that Xcel, RPI, and KTA initially recognized the Cabin Creek penstock as a permit-required confined space, but did not treat it as such during the penstock project. As a result, the companies did not effectively coordinate and plan to control the hazards inherent in the recoating work. Nor did RPI re-evaluate the hazards when working conditions changed inside the penstock, such as the introduction of flammable MEK into the work area. Xcel's and RPI's lack of sufficient planning and coordination for the hazardous recoating work within the confined space was causal to the incident.

6.1 Penstock is a Permit-Required Confined Space

The Cabin Creek penstock is a permit-required confined space, as defined by OSHA: it is large enough and so configured that an employee can bodily enter and perform assigned work, it has limited or restricted means for entry or exit, and it is not designed for continuous human occupancy [29 CRF 1910.146(b)]. The penstock's 12-foot (4-meter) diameter space is large enough for workers to enter and work inside; entry and exit are feasible only through the temporary 4 by 4-foot (1.2 by 1.2-meter) opening cut at the lower end and, when generating hydroelectric power, the penstock is full of flowing water. The penstock also meets an additional criterion: it "contains or has the potential to contain a hazardous atmosphere," making it not just a confined space, but a *permit-required* confined space [29 CRF 1910.146(b)]. A hazardous atmosphere, as defined by the OSHA Permit-Required Confined Spaces

Rule,[41] is one that may expose employees to the risk of death; incapacitation; impairment of ability to self-rescue; injury; or acute illness from flammable gas, vapor, or mist in excess of 10 percent of its lower flammability limit (LFL).[42] OSHA requires employers to evaluate their workplace to determine if any confined spaces meet the criteria for a permit-required confined space [29 CFR 1910.146(c)(1)]. Despite initial recognition that the penstock was a permit-required confined space, neither Xcel nor RPI treated the penstock as a permit-required confined space while the recoating work was being conducted.

6.1.1 Initial Evaluation of the Confined Space Indicated a Permit-Required Program was Necessary

In early 2007, an Xcel safety consultant, at the request of the penstock recoating team, prepared the "Safety and Health Hazard Assessment Survey" for abrasive blasting inside the penstock, which lists confined space entry as one of the potential health hazards associated with the recoating work, in conjunction with applying epoxy or other surface coatings. The survey states that "a confined space air monitor is required," which is a key safety requisite in a permit-required confined space program. While this document was made part of the bid package and sent to potential contractors, Xcel did not implement a permit-required confined space program or issue permits for its personnel who entered the penstock on numerous occasions for inspection and maintenance.

In addition, a KTA inspector completed a separate "Initial Pre-Job Hazard Assessment," which it submitted to Xcel on September 24, 2007, for abrasive blasting inside the penstock, explicitly indicating that the penstock was a permit-required confined space.

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[41] In addition, the OSHA Permit-Required Confined Space rule states that these risks follow from one or more of the following causes: (1) flammable gas, vapor, or mist in excess of 10 percent of its LFL; (2) airborne combustible dust in a concentration that meets or exceeds its LFL; (3) atmospheric oxygen concentration below 19.5 percent or above 23.5 percent; and/or (4) atmospheric concentration that could result in employee exposure in excess of its dose or permissible exposure limit.

[42] The terms LEL and lower flammability limit (LFL) have different definitions but are commonly used interchangeably. This report uses LEL except where citing other sources that use LFL in their standard or regulation. The OSHA Permit-Required Confined Space Standard 29 CFR 1910.146 uses the term LFL in its provisions.

RPI wrote a number of partially completed confined space permits with air monitoring logs between September 11 and October 2, 2007, where the crew indicated that continuous air monitoring was required inside the penstock—another element of a permit-required confined space program.[43,44]

Although Xcel, RPI, and KTA acknowledged that elements of a permit-required space were necessary for the penstock work, the companies did not take the steps necessary – and required by OSHA – to manage the risks inherent in the space.

6.1.2 The Known Work Activities in the Penstock Necessitated a Permit-Required Confined Space Program

The potential atmospheric hazards related to future work activities in the penstock known to Xcel and RPI during the early stages of the penstock recoating project should have triggered the application of a permit-required confined space program. These potential atmospheric hazards in the confined space included

- High carbon monoxide (CO) levels that caused air monitors to alarm and required the penstock to be briefly evacuated;
- Fumes created from welding conducted inside the penstock by an Xcel employee on two occasions;
- Irritating dust and breathing hazards created by abrasive blasting; and
- Flammable vapors generated while using MEK to flush and clean the sprayer.

[43] The logs typically listed only the gas detector readings for oxygen written on a page taken from RPI's multipage confined space permit form. No other pages of the permit form were completed

[44] Even number of the unsuccessful bidders for the penstock recoating project identified the penstock as a permit-required confined space in their submissions to Xcel. A proposal from a prospective bidder on the recoating project stated that the penstock would be considered a permit-required confined space when certain activities were undertaken, such as abrasive blasting, abrasive cleanup, and epoxy application.

6.1.3 Permit-Required Confined Space Inadequately Declassified

Once work began at Cabin Creek, Xcel, RPI, and KTA treated the penstock as a *non*-permit-required space; however, the companies did not take the OSHA-required steps to formally declassify the penstock to a non-permit confined space. Indeed, had they taken the requisite steps to attempt to declassify the penstock, they would have determined that the penstock space could not have been safely declassified.

OSHA's Permit-Required Confined Spaces Rule states that if an employer wishes to reclassify a permit-required confined space as a non-permit confined space, the employer must develop monitoring and inspection data demonstrating that the space poses no actual or potential atmospheric hazards, and this data must be documented by the employer [29 CFR 1910.146(c)(7), 1910.146(c)(7)(i), 1910.146(c)(5)(i)(F)]. Additionally, the employer is required to "document the basis for determining that all hazards in a permit space have been eliminated, through a certification that contains the date, the location of the space, and the signature of the person making the determination" [29 CFR 1910.146(c)(7)(iii)]. Neither RPI nor Xcel provided the CSB with a documented basis for declassifying the penstock space as non-permit required.

More important, the penstock's unique size – more than 4,000 feet (1200 meters) long – makes it an exception in the Permit-Required Confined Spaces Rule for declassifying a space. The rule states that "if isolation of the space is infeasible because the space is large or part of a continuous system (such as a sewer), pre-entry testing shall be performed to the extent feasible before entry is authorized and, if entry is authorized, entry conditions shall be continuously monitored in the areas where authorized entrants are working" [29 CFR 1910.146(d)(5)(i)]. The American Public Power Association (APPA), an industry organization for public utilities – of which Xcel is not – instructs its member organizations as follows: "If a hazard increasing work activity is to take place in a confined space (i.e., welding, painting, working with solvents and epoxy), the air in the space shall be continuously tested for the presence of flammable or toxic gases and vapors or insufficient oxygen" (APPA, 2007).[45]

The expansive size of the penstock required continuous monitoring at the location of the work, which at the time of the incident was 1,450 feet (442 meters) from the access door; this continuous monitoring within the penstock was not being performed by the RPI crew, the KTA inspector, or any Xcel personnel. The penstock's large size and the companies' lack of documented basis for declassifying the space require it to be treated as a permit-required confined space.

6.2 Lack of Pre-Job Safety Planning for Hazards

Despite a lengthy period of over one year devoted to pre-job safety planning for the recoating project of the Cabin Creek penstock, the CSB noted that serious hazards identified by the Xcel recoating project team and RPI management were not addressed before work began (Section 4.1).

In early 2007, Xcel completed the "Safety and Health Hazard Assessment Survey" for the recoating project; however, this assessment was incomplete, as it considered only the high pressure abrasive blasting work, not the recoating of the penstock interior (Section 4.1.1). As a result, the fire potential due to the use of solvents within the confined space of the penstock was not evaluated.

As an experienced contractor and the seventh-largest specialty paint company in 2005, RPI would be reasonably expected to understand the need for safety during relining operations in confined spaces (Engineering News-Record, 2005). Indeed, documents from the RPI bid and safety program reveal that the company was aware of the potential hazards posed by the penstock itself and those created when performing spraying operations inside it. The RPI bid contained several references to prior projects where similar safety issues to that of the penstock were encountered, including limited access in confined spaces

[45] Although APPA is an industry association for public utilities, which Xcel is not, the good practice guidance APPA publishes is useful to both public and private utility groups.

that created "inherent risks." RPI stated in its bid submission to Xcel that it handled these risks by providing training; confined space watch personnel; and emergency equipment, such as breathing apparatus and extraction devices. Whether these safety actions were actually implemented in the prior projects is unclear; however, that RPI listed them as precautionary steps taken in previous projects speaks to the company's familiarity with managing the hazards. Yet, training was less than adequate (Section 9.0), and no emergency breathing apparatuses were provided to the work crew at the penstock.

A KTA project engineer sent a review of RPI submittals[46] for the penstock recoating project to the Xcel Reline Project Team Leader. The RPI coating application plan clearly states that the sprayer would be brought inside the penstock. The product-specific application procedures for the epoxy describe the short working time after the base and hardener are mixed and the need to flush the sprayer with a solvent before introducing the epoxy into the system and to clear any blockages as necessary in the spraying equipment during use. Based on his review, the KTA project engineer recommended including eight additions and clarifications to the contract between Xcel and RPI, three of which had safety implications.[47] Yet the project engineer made no recommendations to Xcel concerning safeguards that would need to be employed if flammable solvents were used to flush the sprayer inside the penstock (such as ventilation and explosion-proof lights), nor did he provide recommendations for use of safer (e.g., nonflammable) solvents for flushing the sprayer. Xcel also had its own employees review the RPI bid submission documentation, but no actions were taken to manage the hazards associated with using flammables within a confined space.

[46] KTA reviewed a number of RPI's bid documents, including a surface preparation and coating application plan, a project schedule, product-specific application procedures, and product data sheets for the two-part epoxy material.

[47] The three additions that had potential safety implications were the need (1) for adequate heating inside the penstock, (2) to ensure the bulkheads were fitted with manways, and (3) to install strung lighting supplemented with spotlights.

In the September 5, 2007, preconstruction meeting, Xcel and RPI management and safety personnel discussed the need for additional safety precautions for the recoating project. Handwritten notes on an agenda in the files of the Xcel safety director indicate that both a safety addendum to the contract (Section 8.2.1) and the need to enforce Xcel's "Stop Work Authority" policy during the recoating project were discussed. Additionally, the Xcel safety director's handwritten notes indicate his recognition of the need for an external rescue team during the penstock work.

Months prior to the incident, the Xcel penstock recoat project leader emailed a power plant engineer and the Xcel plant manager stating that the contractors involved in the penstock work were requesting information concerning the site's confined space entry procedures, whether the air was being monitored, and who was responsible for the monitoring. The project leader received a reply email from the Xcel plant manager that this information would be covered in contractor orientation. This brief orientation – consisting of a 30-60-minute checklist review of potential hazards – was held on three separate occasions, led by different Xcel personnel and attended by various members of the crew. During one of the sessions, the Xcel employee leading the orientation did learn that RPI would be using a "ketone" solvent to clean the sprayer inside the penstock, but even after the incident he stated he was unaware if Xcel had received a copy of the solvent MSDS before epoxy application began.

6.3 No Monitoring Plan Established

Neither Xcel nor RPI had a monitoring plan established for safe entry and work inside the penstock. The OSHA Permit-Required Confined Spaces Rule discusses appropriate procedures for atmospheric testing to include evaluating the atmospheric hazards of the permit space that may exist or arise so that both entry procedures and safe entry conditions are clearly stipulated in advance of conducting work [29 CFR 1910.146] (Appendix B). Recommended practices for monitoring potential flammable atmospheres suggest that any company performing atmospheric monitoring should implement a "written, established protocol that describes the sampling procedures, sampling locations, and required sample collection time" (Levine, 2004, pp.35). Because hazardous gases or vapors may be stratified within the atmosphere, the location of air monitoring can significantly impact a worker's ability to determine if a flammable atmosphere exists. Additionally, the sampling procedures should address if continuous atmospheric testing is necessary. Criteria for determining this need includes work spaces with the potential for changes in work activities that "may affect the composition, concentration, flow rate or volume, pressure and/or temperature of flammable liquids, vapors or gases" or changes in "ambient conditions such as temperature, wind direction and wind speed" (Levine, 2004, p.36). Both of these factors were present in the penstock recoating work environment the day of the incident.

However, interviews with surviving RPI employees revealed that the atmosphere was not monitored continuously in the work area inside the penstock. Instead, readings were taken only two to three times per day at the penstock entrance by the RPI attendant, which did not meet the OSHA Permit-Required Confined Spaces Rule requirement for continuous monitoring of entry conditions in the areas where authorized entrants are working if the permit space is large, or part of a continuous system, and where isolating the space is infeasible [29 CFR 1910.146(d)(5)(i)]. While this monitoring requirement is related to the size of the space and not to the specific hazard of using a flammable solvent in the confined space, RPI was nonetheless required to continuously monitor the work area in the penstock.[48]

6.4 No Evaluation of Hazards When Conditions Changed

When work conditions inside the penstock changed from blasting to recoating, Xcel or RPI should have re-examined the space for new hazards, as per the OSHA Permit-Required Confined Spaces Rule.[49] As listed in 6.1.2, the CSB noted that RPI workers experienced a number of potential hazardous atmospheric

[48] Post-incident, OSHA issued a willful violation to RPI Coating ($63,000 proposed penalty) [OSHA, March 21, 2008, inspection 310470034, citation 2(9)] and serious violations to both Xcel and KTA ($4,500 proposed penalties, each) [OSHA, March 21, 2008, inspection 310470059, citation 1(9) and inspection 310470083, citation 1(6), respectively] for not continuously monitoring the air during the penstock recoating project.

[49] The Rule states: "When there are changes in the use or configuration of a non-permit confined space that might increase the hazards to entrants, the employer shall reevaluate that space and, if necessary, reclassify it as a permit-required confined space" [29 CFR 1910.146(c)(6)] and certify it through the required documentation [29 CFR 1910.146(c)(7)(iii)].

conditions within the penstock, including dust from abrasive blasting, flammable atmospheres from the use of solvents, welding fumes from hot work, and accumulation of toxic carbon monoxide from the use of an ATV with an internal combustion engine. Each time one of these hazards was introduced or encountered in the confined space, the permit should have been updated to accurately reflect the hazard(s) and the appropriate safeguards to protect the entrants and ensure that acceptable entry conditions were maintained. But neither RPI nor Xcel reassessed the hazards as conditions changed, thus these hazards were unmanaged.[50]

6.5 Safer Solvent Not Chosen

As the application procedures supplied to both Xcel and RPI made clear, the use of the sprayer inside the confined space required the use of a solvent to flush and clean the sprayer, which would occur in the open atmosphere of the penstock at least daily, given the project work schedule. Flammable MEK was chosen as the solvent for the penstock recoating project.

Bringing a flammable into a confined space to use in the open atmosphere increases the likelihood of a potential fire because it adds the second of the three conditions required for combustion: fuel, oxygen, and an ignition source – oxygen was already present in the penstock. Fire risk is significantly heightened because ignition sources can be difficult to identify and control where flammable liquids are being used. These hazards were not adequately assessed when MEK was chosen as the penstock recoating project solvent.

6.5.1 The Hazards of MEK

MEK is an organic chemical compound often used as a solvent in painting and industrial recoating activities. MEK is listed by the National Institute for Safety and Health (NIOSH) as "highly flammable"

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[50] The CSB also noted that none of the forms were filled out completely and only portions of forms were retained for some dates.

(NIOSH, 1998). MEK is a Class IB Flammable Liquid, with a flash point below 73 °F (23 °C) and boiling point at or above 100 °F (38 °C) (NFPA 704, 2007b, Table 6.2; NIOSH, 1998).

As a highly flammable liquid, MEK poses significant hazards if used in a work area and the safety risk potential increases dramatically when the location of work is within a confined space. The epoxy application procedure specifically highlights the flammability risk involved with the use of MEK,[51] as do the MSDSs Xcel and RPI provided to the CSB.[52],[53]

As part of its investigation, the CSB conducted a brief review of available MSDSs on MEK and found a number of MSDSs with warnings that the product should not be used in confined spaces.[54] The MEK MSDSs – including the MSDS Xcel provided to the CSB[55] – warn that MEK vapors may cause a flash fire or ignite explosively, and that the solvent's vapors may travel considerable distance to a source of ignition and flash back.[56] The MSDSs instruct the user to "prevent buildup of vapors or gases to explosive concentrations."[57] The various MSDSs also warn that MEK is sensitive to static discharge, so containers of the solvent should be bonded and grounded for transfer to avoid static spark.[58]

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[51] The procedures states in capital bold letters that MSDSs should be consulted and "proper fire and ventilation procedures should be followed.

[52] The MSDS provided by Xcel states, "DANGER! EXTREMELY FLAMMABLE LIQUID AND VAPOR. VAPOR MAY CAUSE FLASH FIRE" (emphasis in original), and the MSDS RPI provided to the CSB also states that MEK is "EXTREMELY FLAMMABLE…vapors will accumulate readily and may ignite explosively" (emphasis in original).

[53] According to RPI, this MSDS was sent via fax to the Cabin Creek site by the company post-incident; it was provided to the CSB upon subpoena request in July 2008.

[54] Carboclor MSDS on MEK, June 2008; Sunnyside Corporation MSDS on MEK, 1/12/06; RAW Chemical Distribution Limited MSDS on MEK, 11/11/02; Linchem, Ltd. MSDS on MEK, 9/10/02.

[55] Mallinckrodt Baker, Inc. MSDS on MEK, 8/17/05 (retrieved online by Xcel Energy on 10/12/07 from www.jtbaker.com/msds/englishhtml/M4628.htm).

[56] Sunnyside Corp. MSDS on MEK, 1/12/06; RAW Chemical Distribution Limited MSDS on MEK, 11/11/02; Linchem, Ltd. MSDS on MEK, 9/10/02.

[57] Sunnyside Corp. MSDS on MEK, 1/12/06; RAW Chemical Distribution Limited MSDS on MEK, 11/11/02.

[58] Mallinckrodt Baker, Inc. MSDS on MEK, 8/17/05; Sherwin-Williams Co. MSDS on MEK, 10/2/07; Sunnyside Corporation MSDS on MEK, 1/12/06.

Despite the warnings within the MSDSs about MEK's extreme flammability and RPI's own safety policies that require flammable liquids to be stored and handled in safety cans,[59] 2- and 5-gallon (7.6 and 19 liters) plastic buckets were used to transport and store MEK solvent in the penstock. One open 5-gallon (19 liter) plastic bucket of MEK was placed under the solvent pump of the sprayer to supply solvent to the mixing block. After using MEK to clean out the spray wands, the 5-gallon (19 liters) plastic buckets of used solvent were left opened adjacent to the sprayer system instead of removed from the work area. Approximately 6 additional gallons (23 liters) of MEK were brought into the penstock in 2-gallon (7.6 liter) plastic buckets specifically to flush and clean the sprayer system immediately prior to the incident. Additionally, the MEK solvent was transferred from a 55-gallon (208 liter) drum in the storage trailer, hand-carried into the penstock, and stored in plastic buckets around the work area; these buckets were reportedly not covered when inside the penstock prior to and during the solvent cleaning process.

6.5.1.1 Evidence that Xcel and RPI Knew that MEK would be Used

While Xcel has disputed its knowledge of the use of MEK in the penstock recoating project, from the totality of evidence – including the fact that the Xcel project scheduler stated he was made aware that RPI would be using a "ketone" during the recoating work – the CSB has concluded that Xcel was aware of the use of flammable solvent in the penstock, and that both companies were aware that MEK solvent would be used during the epoxy application process.

Xcel sent all potential bidders for the penstock recoating project the document "Surface Preparation and Repainting of Interior of the Cabin Creek Penstock" prepared by KTA and reviewed by a number of Xcel employees involved in the penstock project planning, which states that a solvent would be used within the

[59] RPI's "Fire Protection and Prevention" policywithin its IIPP, as well as several others requires all flammable liquids to be stored and handled in safety cans. A safety can, as defined in the IIPP, is an approved container of not more than 5 gallons capacity, having a flash arresting screen, spring closing lid and spout cover.

penstock for initial cleaning of the surface, and instructs the bidders on appropriate storage methods for solvents and thinners during the project.

As part of its bid submission package to Xcel, RPI provided the three-page “Surface Preparation and Application Guide” from the manufacturer of the two-part epoxy product, that also referenced the need for a solvent for cleaning purposes. During the bid evaluation and selection process, this contractual documentation was reviewed by numerous management and safety personnel from both companies.

In August 2007, RPI’s vice president provided the Xcel Cabin Creek project manager with the more detailed epoxy “Specification and Application Procedures,” which discusses the use of solvents in the recoating process several times.[60]

Once RPI was onsite, evidence of the planned use of MEK within the penstock was witnessed by workers and supervisors from both companies. On September 12, 2007, 110 gallons (416 liters) of MEK [two 55-gallon (208 liters) drums] was delivered to the Cabin Creek site and signed for by an RPI crew member. According to testimony of the crew, the Xcel principle engineer and project scheduler witnessed the delivery of the MEK and confirmed with the crew that it was the solvent being delivered.

That same day, RPI conducted a test spray with the epoxy products and solvent on the Xcel Cabin Creek site. Five gallons of MEK were purchased for the test spray and used afterward to clean the equipment. The Xcel principle engineer was present during these activities and signed off on the invoice for the solvent and epoxy.

[60] The procedure document instructs that, upon initial setup, “solvent should be flushed through the line to check for any foreign matter, leakages, or blockages.” These procedures state that if blockages or other stoppages occur, “immediately shut off the heater, and place a clean bucket of solvent underneath the pump and flush the lines.” It goes on to state that merely spraying the material will build pressure and cause the epoxy product to begin to set; as a result, the user is instructed to “flush solvent through the system” and “re-circulate solvent until the pump and lines are clear.” Finally, the procedures provide guidance about cleanup: “Any mixing and application tools should be immediately wiped or scraped clean. Any residue can be removed with a solvent, such as 1,1,1-trichloroethane, MEK or an appropriate blend.”

6.5.2 Safer Alternatives

None of the companies considered safer alternatives to the flammable MEK, nor did they identify work tasks involving the solvent that could have been performed outside the penstock.

One significantly less hazardous option is a citrus-based solvent, a variety of which are available for industrial purposes and are often biodegradable, non-toxic, and have significantly higher flash-points than flammable solvents like MEK.[61] ANSI Z117.1, "Safety Requirements for Confined Spaces" recommends that the hierarchy of controls be followed to address confined space hazards [ANSI Z117, 2009, p.17]. Using this method of hazard control, primary consideration is given to eliminating the hazard or using engineering controls such as substitution; for instance, using less hazardous, non-flammable substitute solvents for the highly flammable MEK.

Another more effective safety approach within the hierarchy of controls would have been to conduct the work outside the confined space.[62] In the Cabin Creek penstock incident, while the hoses from the mixing block to the spray wands required immediate flushing due to the mixing the two-part epoxy, the sprayer itself did not need to be cleaned inside the confined space.

6.6 Xcel's and RPI's Confined Space Policies

Xcel's and RPI's corporate confined space policies in effect prior to the incident did not effectively establish safe limits for flammable atmospheres that would prohibit entry or occupancy when the limits were exceeded. Xcel's corporate confined space policies did not effectively establish acceptable entry conditions for flammable atmospheres as a specific percentage of the LEL, nor did they provide explicit

[61] A less flammable, but still hazardous, option is 1,1,1-trichloroethane. This organic compound has a history of use as a solvent within the industrial painting industry; however, its use has lessened due to its toxicity. The manufacturer of the two-part epoxy used in the penstock recoating project has communicated that several non-flammable solvents would be effective for cleanup activities, including n-Propyl Bromide and citrus-based products.

[62] The United Kingdom Confined Spaces Regulation [Statutory Instrument 1997, No. 1713] imposes the duty of first avoiding entry into the confined space by conducting the work outside the space, unless entry is unavoidable.

warnings to prohibit entry or occupancy based upon a specified flammable atmosphere limit. Xcel's confined space permit form allowed entry even when "atmospheric and/or serious hazards in the space that cannot be controlled or eliminated" were present, if certain unspecified precautions were being implemented. The confined space entry policy in effect at the time of the incident of Northern States Power Company, a subsidiary of Xcel, however, provides effective specific entry and occupancy limits for flammable atmospheres. The policy establishes 10 percent of the LEL as an alarm point and states: "If the air monitor alarms all entrants shall immediately evacuate the space." After the Cabin Creek incident, Xcel revised its confined space policy with improvements that designated greater than 10 percent of the LEL as an "alarm limit." However, the new policy does not explicitly prohibit entry or occupancy based upon the alarm limit, unlike the Northern States' policy.

RPI's confined space entry policy and permit provided to Xcel as part of the contractor selection process did not provide for safe entry and occupancy limits or effectively prohibit entry when those limits were exceeded. Neither the policy nor the permit defined a hazardous atmosphere or provided for acceptable confined space entry conditions.

The failure of Xcel's and RPI's confined space policies to establish safe flammable limits undermines the importance of monitoring in permit-required confined spaces; the need for periodic or continuous monitoring will not be effectively communicated to managers and workers if no limits are specified. This safety gap can also lead to a failure to address the serious hazards of flammable atmospheres, as was the case in the Cabin Creek penstock.

7.0 Emergency Response and Rescue

The CSB determined that the flash fire inside the penstock occurred at approximately 1:55 p.m. and the 9-1-1 call was placed at 2:03 p.m.. While the initial emergency responders arrived at the Cabin Creek site in less than 10 minutes from the dispatch notification, the first community emergency responder capable of performing a confined space rescue operation, West Metro Fire Rescue, did not enter the property for more than an hour and a half after the fire started due to their distant location. The trapped workers likely succumbed to smoke inhalation about one hour prior to West Metro's arrival. An immediately available qualified confined space technical rescue provider likely would have been able to effectively control the fire and prevent the worker fatalities. However, no such rescuers were immediately available outside the penstock on the day of the incident.

The lack of competent technical rescue services at Cabin Creek was the result of:

- Xcel's and RPI's lack of a competency evaluation of available confined spaces rescue services, as required by the OSHA Permit-Required Confined Spaces Rule;
- The failure of Xcel and RPI to identify the life-threatening hazards of using flammable solvents in the penstock and arrange for immediately available emergency response services onsite prior to the start of the epoxy application.

As a result of not evaluating the competency of available emergency service providers to perform permit-required confined space rescue, nor arranging for emergency response support to be onsite prior to the start of the penstock work activities, neither Xcel nor RPI were prepared to handle a confined spaces emergency such as they experienced on October 2, 2007. And because the first responders to the incident were voluntary firefighters without the training or qualifications to peform permit-required confined space rescue, no one was immediately available and capable to successfully enter the penstock to rescue the trapped workers. The CSB also notes that alternative egress and/or safety chambers were not provided in the penstock and the State of Colorado lacked a training and certification program for technical rescuers including confined space technical rescue.

7.1 Lack of Preparation by Xcel and RPI to Ensure Availability of Qualified Rescue Personnel

The OSHA Permit-Required Confined Spaces Rule [29 CFR 1910.146(k)] requires the employer to either arrange for a competent outside rescue and emergency services provider, or ensure that its employees can perform rescue and emergency services competently when they are working within a permit-required confined space. However, RPI and Xcel did neither.

The emergency response and rescue preparation conducted by Xcel and RPI ineffectively consisted of instructing RPI personnel that, in the event of an emergency inside the penstock, 9-1-1 would be called by Xcel personnel. On October 2, 2007, this was the emergency response step taken. Unfortunately, the first and closest emergency responders arriving at the Cabin Creek site were not prepared for entry into the penstock's confined space. Approximately less than 10 minutes after the 9-1-1 call, the first community emergency responder to arrive onsite was the Clear Creek County Sheriff's office, who established the Incident Command. Several volunteer Clear Creek County Fire Authority (CCFA) emergency medical and firefighters arrived next, but none of these responders had the necessary equipment or training to extinguish the fire in the penstock or initiate a rescue of the trapped RPI personnel.[63] Additionally, the fire service organizations had no pre-knowledge of the hazards of the chemicals onsite, their quantities, or locations. The site was not pre-equiped with appropriate firefighting equipment specific to the unique hazards of the penstock. Such planning and communication should have been implemented with designated emergency responders in advance of any recoating work being conducted withtin the penstock.

[63] This was noted by the Xcel control room operator, who added the following entry in the control room logbook: "14:20 Emergency services w/out confined space fire training – they have summoned a Denver team."

When an employer chooses to rely on an outside rescue and emergency service, the OSHA Confined Spaces Rule requires the employer to evaluate the service's ability, in terms of proficiency with rescue-related tasks and equipment, to function appropriately while rescuing entrants from the particular permit space or types of permit spaces identified [29 CFR 1910.146(k)(1)(ii)]. However, neither Xcel nor RPI evaluated CCFA's or other nearby responders technical capabilities.

Had Xcel and RPI arranged for a competent outside rescue and emergency services provider prior to beginning work inside the penstock and supplied the provider with pertinent information about the chemicals being used within the confined space, the first responders to the incident would likely have been prepared for entry, firefighting, and rescue activities.

7.2 Failure by Xcel and RPI to Arrange for Timely Rescue

Local fire service officials told the CSB that any attempted rescue of the trapped RPI workers could have been successful only with sufficient numbers of responders and the appropriate equipment immediately available onsite to fight a fire that was more than 1,450 feet (442 meters) inside the penstock.

The OSHA Permit-Required Confined Spaces Rule requires that emergency response be timely, based on the specific hazards involved in the entry. According to a December 9, 2003, settlement agreement between OSHA and the American Petroleum Institute (API), a "timely" response to a confined space emergency depends on the hazards the entrants may face. If entrants encounter hazards that are deemed potentially Immediately Dangerous to Life and Health (IDLH), [64] a rescue team must be stationed outside the confined space and ready for immediate entry. The use of MEK inside the penstock created the

[64] IDLH or Immediately Dangerous to Life or Health, is a personal exposure limit for a chemical substance set forth by the National Institute of Occupational Safety and Health (NIOSH); it is typically expressed in parts per million (ppm). OSHA's Permit-Required Confined Spaces rule for general industry states that IDLH "means any condition that poses an immediate or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an individuals ability to escape unaided from a permit space" [29 CFR 1910.146(b)].

potential for a flammable atmosphere and life-threatening conditions in the event of an ignition, especially when coupled with a single exit for evacuation.

An immediately available rescue and response team is especially important for a worksite like Cabin Creek, which is situated in a remote mountainous location where timely response would be extremely difficult.

Depending on the road conditions, vehicle type, and speed, driving the 5.5 miles (8.9 kilometers) from the Georgetown fire station – the closest community emergency response facility – to the Cabin Creek hydroelectric plant takes between 10 and 30 minutes. At the time of the incident, the only improved road to the site, Guanella Pass, was steep, narrow, and winding (Figure 11). This road had no guardrails, was partially unpaved with loose gravel and potholes, and has many hairpin turns that made it hazardous to drive at speeds above 20 miles an hour (32 kilometers per hour).[65]

[65] CCFA personnel told the CSB investigators that the turns were so tight that one of their fire support vehicles had to completely stop and back up several times to navigate through the turns.

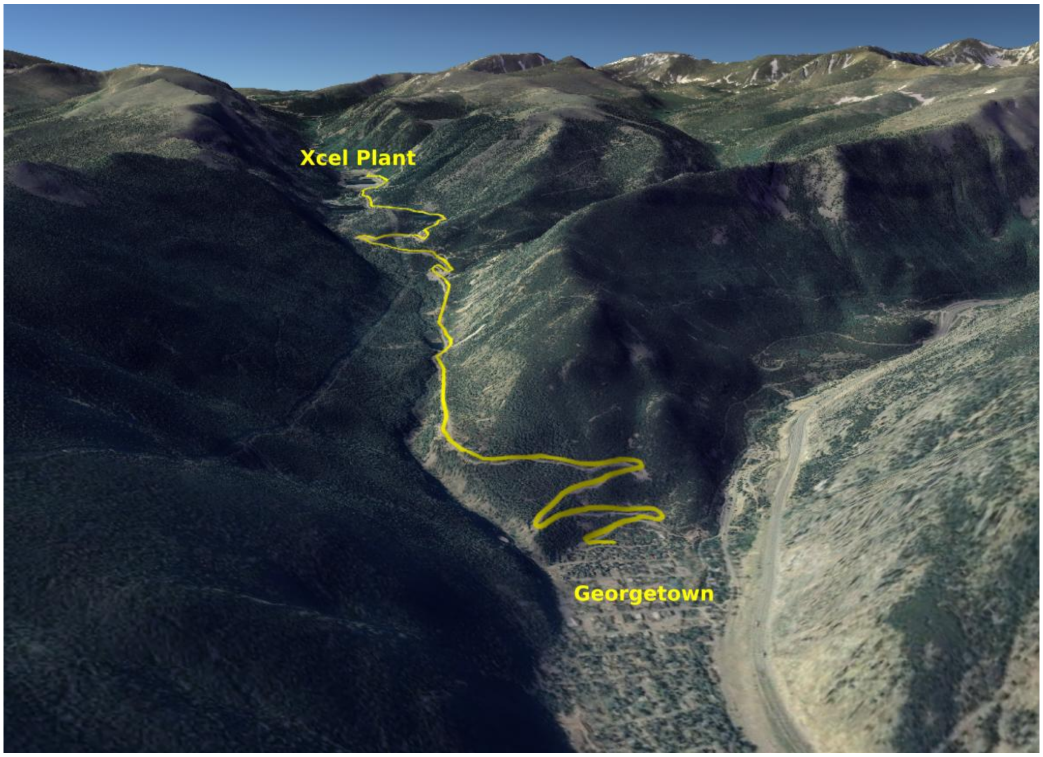

Figure 11. The winding, steep and narrow road from Georgetown to the Xcel hydroelectric plant

7.2.1 Requirements and Recommendations for Alternate Escape Routes or Safety Chambers

While the need for immediately available qualified technical rescue services was critical given the hazards in the penstock, another safety precaution that should have been taken by Xcel and RPI was to plan for an alternative escape route out of the penstock or a safety chamber within it. However, there was no plan for an alternate escape route out of the penstock if the primary route were to be blocked in an emergency.[66]

The penstock is a 4,163-foot (1269-meter) long sloping, underground confined space that required an access door in the side of the penstock to be cut for the recoating work crew to enter; this access opening

[66] Bid documents indicate that one of the unsuccessful bidders contemplated building a stairway to an egress opening in the mushroom.

was effectively the only way in or out of the penstock for RPI workers. Once the penstock starts its 55 degree incline, it is physically impossible to traverse the penstock without climbing paraphernalia setup in advance from the mushroom[67] and individual skill and qualifications in rigging and rope climbing, which none of the contractors were prepared or trained to do from inside the penstock. All of the deceased RPI workers were found beyond the west bulkhead with most near the start of the 55 degree incline.

The need for secondary escape routes from penstocks is identified in the American Society of Civil Engineering (ASCE) Task Committee's "Guidelines for Inspection and Monitoring of In-Service Penstocks" (ASCE, 1998, Section 2.3.6.1).

Alternatively, a safety/rescue chamber[68] inside the penstock could have housed fresh air, water, and reliable communication equipment for the trapped workers. The CSB notes that a useful guidance document was published in 2009 by the National Institute for Occupational Safety and Health (NIOSH) addressing instructional materials on refuge chamber setup, use, and maintenance (2009). At a minimum, self-contained breathing apparatuses could have been placed west of the west bulkhead, so that potentially trapped workers would have access to fresh air until rescue could be performed.[69]

Addressing the lack of secondary egress hazard by creating an alternative/emergency exit or installing a rescue chamber,[70] and staging qualified emergency rescuers near the penstock entrance would have likely have prevented the fatalities in this incident.

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[67] In September 2007, Xcel employees used climbing equipment to enter the penstock from the mushroom's vertical shaft entrance to inspect the interior for potential wear and damage of the concrete portion of the penstock.

[68] A safety/rescue chamber is an airtight chamber stocked with food, water, and oxygen, and typically used in underground mines. Such a chamber recently saved 72 miners who were trapped underground for 30 hours at the Mosaic Potash Mine in Saskatchewan, Canada.

[69] Three people survived a Bunker, Missouri, mine fire in January 2010 although their escape route was blocked by burning equipment; the mine had a rescue chamber with compressed air supplies that kept them alive until rescue teams were able to save them six-and-a-half hours later.

[70] This list also is not intended to be all inclusive, as other solutions could include actions such as increasing the ventilation and installing fire suppression.

7.3 Lack of a Technical/Confined Space Rescue Certification Progarm for Volunteer Firefighters

The first responders to the Cabin Creek penstock fire were local voluntary firefighters from the CCFA; none of these individuals held technical rescue qualifications or had received up-to-date workplace confined space training. The significant hazards inherent with confined spaces require specialized training and certification.

The Colorado Department of Public Safety, Division of Fire Safety, administers the firefighter voluntary certification program [8 CCR 1507] in the state. The purpose of this program is to measure the level of knowledge, skills, and abilities of firefighters and to attest that they meet nationally recognized standards. At the time of the incident, the state had certifications for various levels of firefighters and fire officials, fire inspectors, fire instructors, hazardous materials responders, fire apparatus drivers, and emergency medical first responders, but no certification program for technical and/or confined space rescue.

Interviews with Division of Fire Safety personnel revealed that the state does not track how many firefighters in the state are trained or certified in technical rescue because there is no certification program for this specialty. Interviews with various state fire officials revealed that several fire service and response organizations have achieved the operational capacity to conduct technical rescue, including confined space rescue[71]; however, only a small number of Colorado firefighters have been individually certified to perform technical rescue.[72]

[71] NFPA 1670: Standard on Operations and Training for Technical Search and Rescue Incidents (2009) issued by the National Fire Protection Association (NFPA), establishes levels of functional capability for conducting technical rescue operations. Several Colorado fire service and responder organizations have been deemed to have established functional capability under this standard, including organizations affiliated with the Colorado Urban Rescue Task Force. NFPA 1670 does not, however, address individual technical rescuer qualifications.

[72] NFPA 1006: Technical Rescuer Professional Qualification (2008) establishes job performance requirements for rescue technicians.

At the time of the penstock incident, only two entities in the region were identified to have the organizational experience and training to handle the technical rescue issues this incident presented: West Metro Fire Rescue,[73] located in Denver (45 miles or 72 kilometers, approximately 1 hour 15 minutes travel time); and the Henderson Mine,[74] located near Empire, Colorado (21 miles or 34 kilometers, approximately 35 minutes travel time). The CCFA contacted and requested both to support the incident; due to the time each required to assemble a rescue team and travel to the Cabin Creek site, neither arrived at the penstock until approximately an hour after the trapped workers succumbed to smoke inhalation.

State fire officials informed the CSB that the availability of state voluntary certification for technical rescue, including confined space rescue, would improve the capabilities and capacity of Colorado fire service personnel to respond to events similar to the Cabin Creek incident.

[73] Members of the West Metro Fire Rescue have been trained in technical rescue in confined spaces as part of their duties as members of a regional FEMA Urban Search and Rescue Team, but were unfamiliar with the configuration of the Cabin Creek penstock

[74] Although the rescue team at the Henderson Mine is not trained in confined space rescue, the team has specialized training in underground mine rescue. As the penstock was bored through solid granite, it has many of the same characteristics and hazards as an underground mine. This rescue team is a private entity and not a public emergency response organization.

8.0 Contractor Selection and Oversight

Having both a strong contractor selection methodology and contractor oversight policy ensures that the owner receives both quality work from its contractors and worker safety is maintained for its own employees and those of the contractor. However, neither the methodology nor the oversight Xcel employed for the Cabin Creek penstock project adequately ensured that the recoating work would be conducted safely.

8.1 Contractor Selection

Xcel's contractor selection methodology did not disqualify contractors with substandard safety records from bidding on the penstock project.

8.1.1 Contractor Selection Process for the Penstock Project Request for Proposal

In April 2007, Xcel initiated the competitive bidding process to select a coating contractor for the Cabin Creek penstock recoating project. The company issued an RFP[75] to several contractors who were to be selected based upon the "best value/best overall evaluated offer"[76] rather than price alone. The Xcel RFP stated that the contractor would be evaluated, scored, and chosen using weighted rating factors, such as pricing (15%), safety experience modification rate (EMR)[77] (5%), historical quality of services and equipment (10%), operating history (10%), completeness of proposal (5%), and key personnel experience

[75] Xcel used the RFP procurement method for selecting suppliers of goods and services in more substantial acquisitions or projects.

[76] The "best value" procurement method considers a variety of factors in selecting contractors in addition to price, such as experience with similar projects, on-time completion, employee training, and safety record (TRB, 2006, p.S-3).

[77] EMR is used by the U.S. insurance industry "to determine premiums for workers' compensation insurance. An EMR less than 1 indicates above-average injury and illness performance, and an EMR greater than 1 indicates below-average performance. An owner can get some indication of a contractor's past safety performance by reviewing the contractor's EMR. A comparison of the EMRs of contractors bidding on a project may improve the selection process" (API RP 2220, 2005a, p.13). The RFP called for reporting the interstate EMR.

and continued availability (5%).[78] The RFP also established minimum qualifications and experience, including the need for at least five years of successful similar recoating experience and a QP 1 certification from the Society for Protective Coatings (SSPC), an industrial protective coatings trade association.[79] The Xcel contractor selection process for larger projects, such as the Cabin Creek penstock recoat, also included a prequalification[80] step that examined the contractor's financial capacity to successfully perform the work; however, the prequalification step did not consider safety performance.

Xcel's first attempt to select a contractor was unsuccessful. Of the three bidders submitting proposals, only one bid, from Certified Coatings Company (CCC), was evaluated as technically and commercially complete; however, its proposal was $450,000 above the budgetary allotment. Rather than increase the capital budget, Xcel re-bid the penstock project to find additional interested contractors. In late July 2007, an Xcel team that included the Cabin Creek plant manager and the penstock recoat project manager evaluated and scored the second group of proposals from four bidders.

[78] Other rating factors were exceptions to terms and conditions (10%), compliance with performance guarantees (15%), technical exceptions (5%), creative proposal options (10%), and QP 1 Certification/Experience (10%).

[79] SSPC certifies coating contractors based on demonstrated competence in areas such as technical capabilities, safety and environmental compliance, quality control, and management procedures. The certification process requires an evaluation of submittals to SSPC and an onsite audit of an active job site to verify that the stated programs are implemented. SSPC has established a QP 1 disciplinary action system with criterion for issuing warnings and placing contractors on probation or suspension based upon the severity of critical faults or violations in the areas of competence. (SSPC, http://www.sspc.org/certification/PCCP/QP1main.html , http://www.sspc.org/certification/PCCP/DAC.html, accessed March 8, 2009.)

[80] Contractor selection processes often have an initial prequalification during which each potential contractor must meet basic qualifications, including safety. A prequalification process is typically pass/fail; owners evaluate contractors and craft workers to determine if they meet the identified criteria and only firms that meet or exceed those requirements are allowed to bid in the final selection process. In this case, Xcel's prequalification process considered only the financial capacity of the potential contractor.

8.1.2 RPI Safety Record "Not Acceptable," but Allowed to Bid

The top two evaluated proposals from the second round of bidding were from CCC and RPI.[81] Xcel's project manager summarized the results of the proposal evaluations stating "from a technical and quality perspective, Certified Coatings (CCC) is the best evaluated proposal. They are at least $500 k over budget. The second best evaluated proposal is Robinson-Prezioso (RPI). Their safety EMR is high[,] although their OSHA incident rate does not reflect a safety problem. Their proposal is very close to budgetary requirements." The KTA consultant assisting Xcel stated that RPI's high EMR may have been the result of fatalities from their work on the "recent Golden Gate bridge project."[82] The RPI EMR was trending upward from 1.03 in 2005 to 1.28 in 2006; the contractor evaluation team was aware that under Xcel's policies, an EMR rate of 1.0 or above was unacceptable. In fact, the Xcel team gave RPI's proposal a safety rating of "zero" in the evaluation process. The RFP evaluation form the team used states that the rating of zero signifies that the bidder's proposal for that rating criterion "does not meet minimum requirements [and means] automatic rejection."[83]

RPI's penstock recoating proposal, however, was not rejected. The Cabin Creek plant manager concurred with the project manager: "I agree with you that RPI be the one selected due to cost and the fact that they are qualified." He recommended that the Xcel Colorado safety supervisor evaluate RPI's safety record and contact the contractor to discuss its EMR number. The project team asked the safety supervisor to investigate "whether a pattern of negligence is evident for this company [RPI]." When the Xcel safety

[81] RPI's total score of the weighted rating elements was 4.3 with a technical ranking of 2.9; CCC's total score was 4.25 with a technical ranking of 2.95. RPI's bid was slightly over $1.3 million and CCC's was $1.7 million, a difference of less than $400,000.

[82] RPI had two fatality incidents during the Golden Gate retrofitting project. In September 2001, a passing motorist was killed by a falling scaffold. Then, in January 2002, an employee was crushed and four co-workers were injured when a platform buckled as it was being lowered onto a truck (Bjelland, S., et al., 11 Oct 2007).

[83] The Cabin Creek recoating proposals were rated with a scoring system that ranged from 0-5, with "0" representing the lowest score and defined on the scoring sheet as "does not meet minimum requirements, automatic rejection." The rating score of "5" was defined as "exceeds all requirements."

supervisor inquired, the RPI safety director stated that the company's EMR was high due to the Golden Gate Bridge job and that the company's EMR was trending down in 2007.[84]

8.1.3 Contractor Selection and Safety: Historical Background

An influential Business Roundtable report published in 1982, "Improving Construction Safety Performance," found that construction was one of the "most hazardous occupations" in the U.S. with a 54 percent higher injury and fatality rate based upon data from that period.[85] The report determined that contractors with a history of positive safety performance are more likely to perform safely in the future than those with a poor safety record. The report recommends that safety be considered when selecting construction contractors and that factors such as past safety performance and present safety capabilities be evaluated. The report includes a model safety prequalification form for use in selecting contractors.

A 2008 comprehensive report on contractor safety prequalification, "Contractor Safety Prequalification," (Phillips and Waitzman, 2008) refers to a 1991 John Gray Institute report, "Managing Workplace Safety and Health: the Case of Contract Labor in the U.S. Petrochemical Industry," as a "bellwether" for subsequent industry interventions addressing contractor safety, including the issue of contractor safety

[84] This information is not completely accurate. OSHA's "300 Log of Work-Related Injuries and Illnesses for 2006," the year that RPI experienced an EMR of 1.28, listed no injuries or illnesses that occurred in the area of the Golden Gate Bridge or the Bay Bridge in California. Robison-Prezioso, Inc. was cited by OSHA for a fatality incident on a Bay Bridge on January 4, 2002, and another fatality incident on the Bay Bridge on September 25, 2001, where a motorist was killed. Both of these cases are still listed as "open" on the OSHA website. The reference to the "Golden Gate Bridge" and RPI's high EMR rate was made by the Colorado Safety Supervisor in the Safety Addendum to the penstock contract signed by both parties. http://www.osha.gov/pls/imis/establishment.inspection_detail?id=300890555 , http://www.osha.gov/pls/imis/establishment.inspection_detail?id=300890100 , accessed June 4, 2009.

[85] The Business Roundtable represents the CEOs of some of the largest corporations in the U.S. The association develops policy and advocates positions on diverse issues such as workforce development, sustainable growth, and corporate leadership. CURT is an independent offshoot of the Construction Committee of the Business Roundtable and represents the viewpoints of member construction owners seeking to improve construction industry practices including safety performance [CURT, 1990].

prequalification.[86] The report found an association between rigorous screening in the selection of contractors and positive safety performance (Phillips and Waitzman, 2008, pp.49-50).[87]

8.1.4 Contractor Selection and Safety: Current Industry Guidelines

Recent studies note a modern trend of alternative procurement methodologies that use factors other than low price to select construction contractors, such as quality, past performance, and safety[88] (TRB, 2006, pp.40). Several organizations and industry associations, including the Construction Users Roundtable (CURT),[89] the American National Standards Institute (ANSI), the American Industrial Hygene Association (AIHA), and FM Global, have developed guidelines and recommended practices addressing the use of safety criteria for selecting contractors. One common method is prequalification, typically a pass/fail system that ensures that only contractors who meet specific requirements, including safety, are allowed to compete (CURT, 2004, pp. 1, 5). Another common alternative construction procurement

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[86] While the John Gray Institute report addresses contractor safety issues in the petrochemical industry, recent reports note the applicability of the conclusions from the 1991 report to general industry construction safety (Phillips and Waitzman,2008, pp.49-50). A case study examining the protection of contract workers at the Department of Energy's facilities found the John Gray Institute report to be the "most comprehensive study of safety related to contract labor" (Gochfeld and Mohr, 2007, pp.1607-1613).

[87] In 1989, an explosion and fire at the Phillips Chemical Complex in Pasadena, Texas, killed 23 and injured 232 workers. In the wake of the Phillips' incident, OSHA released a report to the President of the United States that identified multiple safety system failures that led to the incident including contractor safety issues (1990, pp.25-26). As a result, OSHA commissioned a major study to examine the health and safety issues related to the use of contractors in the U.S. petrochemical industry. OSHA specifically directed that the study examine the "the role of safety and health in the selection of contractors" (1990, p.64). Consequently, the John Gray Institute report used industry national surveys and case studies to understand the extent to which safety performance was considered in the selection of contractors (2006, pp.85-91). Partly in response to the John Gray report, OSHA's contractor safety requirements in the Process Safety Management Standard, C.F.R. 1910.119, include a requirement that employers when selecting a contractor "shall obtain and evaluate information regarding the contract employer's safety performance and programs," 1910.119(h)(2)(ii).

[88] The TRB (Transportation Research Board) report addresses highway procurement; however, the discussion of procurement methodologies more generally references industry or public sector procurement trends.

[89] CURT is an industry organization that promotes advocacy by users of construction services on national issues that includes "developing industry standards and owner expectations with respect to safety, training and worker qualifications" http://www.curt.org/2_0_about_curt.html, accessed 10/27/09. CURT is composed of 66 member companies, organizations, and government entities that represent some of the largest industrial corporations and users of construction services in the U.S. including DuPont, ExxonMobil, Dow Chemical, Intel, Proctor & Gamble, Duke Energy, General Motors, Shell, the U.S. General Services Administrations, and the U.S. Army Corp of Engineers.

method is referred to as "best value" contracting where, in addition to price, other key factors such as safety can be considered in evaluating the bid package—this method typically involves a rating system where bidders are scored and the highest evaluated bidder is selected (TRB, 2006, pp. S-2 – S-8). A third common procurement method combines prequalification and best value practices: only prequalified bidders are allowed to compete in the final selection process and the evaluation and rating of the bidders is based on best value parameters (CURT, 2005, pp.6-9; TRB, 2006, p.1). Xcel used both prequalification and best value components in its selection of the Cabin Creek penstock recoating contractor.

Industry guidelines addressing contractor selection support using a prequalification process that includes safety criteria. CURT has developed user practices addressing safety and contractor selection that are intended to educate CURT members and industry. The CURT User Practice, "Construction Safety: The Owner's Role," states that "[c]ontractors must be prequalified by the owner to participate in the final contractor selection process. Demonstrated safety performance is a critical criterion used in the prequalification process" (CURT, 2004b, p.6). CURT guidance lists a variety of typical criteria for safety prequalification: staff qualifications, accident history, EMR, a contractor's safety program, and an owner's previous experience.[90] Safety guidelines published by the AIHA, "Health and Safety Requirements in Construction Contract Documents" identify a number of specific prequalification criteria including EMR, OSHA injury and illness logs, OSHA citations, and training certifications. ANSI Standard Z-10, "Occupational Health and Safety Management Systems" also recommends that the

[90] The CSB noted in its BP Texas City investigation report (2007) that particular attention must be given by companies in developing effective safety performance metrics, which should include leading and lagging indicators (pp.184-185). Additionally, performance metrics that are commonly utilized may be inappropriate in some circumstances. For example, one contractor safety standard noted that the use of EMRs may not always be effective (API Standard 2220, 2005a, p.13).

contractor prequalification process include consideration of safety criteria for successful contractor safety performance management[91] (ANSI/AIHA Z-10, 2005, p.20).

8.1.5 Xcel Corporate Policies on Contractor Selection

Xcel had corporate policies in place prior to the incident that addressed contractor safety and the role of safety in selecting contractors. However, while these policies allowed a prequalification process to be used, and a rating and ranking RFP competitive bid process that awarded the contract to the "lowest evaluated bidder," using a prequalification process was not mandatory and the minimum specified requirements were left to the procurement representative. Thus, the use of safety criteria in the prequalification process was not required, nor was it considered in the prequalification step at the Cabin Creek project.

In addition to the score of zero that RPI received, the Xcel evaluation team was also aware of RPI's accident history that involved fatalities. Had Xcel examined RPI's OSHA inspection database and other sources publically available, they would have discovered a lengthy history of serious OSHA citations, including a number of violations specifically involving the unsafe handling of flammable liquids (Appendix B). Although the terms of the RFP relied on contractors to self-report accident histories, RPI did not provide Xcel with records related to several other serious relevant regulatory actions. [92, 93]

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[91] API Recommended Practice (RP) 2221, "Contractor and Owner Safety Program Implementation" also recommends contractor prequalification using a variety of safety criteria. The recommended practice states that "[t]he selection of a qualified contractor is the first step toward obtaining safe contractor performance" (API RP 2221, 2005b). API's RP 2221 provides a comprehensive prequalification form that includes 48 questions and data requests. While the API publication addresses refining and petrochemical industry facility owners, it is persuasive guidance for general industry to improve contractor safety performance, particularly in performing hazardous repair, maintenance, and construction as in the Xcel penstock recoating project.

[92] In 2006 RPI agreed to pay a penalty of $145,000 to a division of the California Environmental Protection Agency to settle violations that included illegally disposing of hazardous waste and making false statements to government officials.

[93] Xcel's "Contractor Safety, Health and Environmental Questionnaire," attached to the Cabin Creek penstock recoating RFP, required submission of any citations received from a regulatory agency during the past three years. RPI did not disclose to OSHA a 2005 serious OSHA violation in Arizona that occurred within the 3-year time period.

Moreover, Xcel's policies addressing contractor selection do not require that the records be verified and, in fact, Xcel confirmed to the CSB that it had not verified RPI's submissions or researched its background.

Xcel's "Contractor Safety" corporate policy provided for a health and safety evaluation of the contractor bids and recommended a review of the contractor's EMR. The policy stated that an EMR above 1 "would normally be considered unacceptable for the construction industry," but did not explicitly require a rejection of a bid proposal based upon the EMR. Xcel's policies allowed a contractor with "unacceptable" safety performance to further compete in the contractor selection process. CURT guidance on contractor selection prequalification illustrates an approach that more effectively ensures safety:

> Any contractors that do not meet base criteria fail and are not included on the potential list. An example of this type of pass/fail criteria might be: only contractors with an Experience Modification Rate less than 1.0 are acceptable (CURT, 2004a, p.5).

A prequalification policy consistent with industry guidelines would have disqualified RPI and prevented the firm from being considered in the final selection process.

8.2 Contractor Oversight

Xcel did not provide sufficient oversight to ensure that safe practices were upheld during the hazardous recoating work within the penstock.

8.2.1 Safety Addendum Added to Contract

In response to negative information about RPI's safety record, the Xcel safety supervisor proposed additional safety requirements for the penstock project. The agreement between Xcel and RPI included a safety addendum that required a number of additional safety measures. It reads as follows:

1. RPI will be extra diligent toward safety, ensuring [that] they are carefully following their safety policies and procedures.[94]
2. RPI will respond to safety questions and concerns from Xcel Supply in a timely manner.
3. Xcel Supply will observe closely the work and report any concerns immediately to RPI's on site supervision (daily by on site personnel and randomly by Energy Safety).
4. Xcel Supply will provide our Stop Work Policy to RPI and that all understand that any Xcel Supply employee can stop a job. This is routine and covered in our contractor orientation at the start of all jobs.

Xcel concluded that if it kept a "close watch" on RPI, the penstock recoating project would be safe and successful.

8.2.2 Xcel Cabin Creek Site Contractor Oversight Activities and RPI Safety Performance

Xcel did not increase its oversight of RPI nor did it implement corrective actions even though, during the penstock recoating project site activities prior to the incident, Xcel managers had identified serious safety hazards associated with the work and were aware of several significant safety problems attributable to RPI:

- An RPI worker slipped and fell inside the penstock due to the wet, slippery interior surface conditions. The worker suffered a dislocated shoulder and was treated at the hospital.
- The penstock was evacuated on several occasions prior to the incident due to high readings of CO, a toxic gas.

[94] RPI provided its entire "Injury and Illness Prevention Program" safety manual to Xcel as part of its bid package submission; therefore, Xcel was aware of RPI's safety policies and procedures and could ensure that they were followed.

- Electrical problems that destroyed of penstock lighting, electrical junction boxes, and other equipment.
- Xcel welded a "weep hole" inside the penstock on the day of the incident without issuing a hot work permit. Xcel's entry into the confined space lacked a confined space permit; that welding fumes could create a potential hazardous atmosphere was not analyzed.
- The Xcel penstock project manager identified serious hazards in the penstock work, stating in an email that "work conditions inside the penstock are highly hazardous on many levels."

Despite Xcel's knowledge of these serious safety problems, Xcel managers conducted safety observations of RPI's penstock activities on only two documented occasions: September 20, 2007 and October 1, 2007. The project manger completed an inspection checklist, noting the "extremely slick surfaces" inside the penstock. The penstock inspection form also stated "environment continuously monitored," but employee interviews and documentation indicate that the penstock was only periodically monitored at the access door entrance for hazardous atmospheres.[95] An Xcel safety representative visited the penstock for a safety observation the day before the incident, during sandblasting operations. The completed safety observation form listed a number of worker protection categories that were marked off as satisfactory, unsatisfactory, or not applicable. The safety representative had marked the worker protection category of "confined space entry permit" as "satisfactory." The comments section noted that an RPI worker was at the penstock entrance accounting for the personnel inside. However, as discussed, RPI and Xcel had not effectively implemented important elements of a permit-required confined space program. For example, the confined space permits were only partially completed and RPI had not established acceptable entry

[95] A few witnesses stated that the RPI supervisor also occasionally monitored the air farther inside the penstock, but not on the day of the accident. There is, however, no documentation of these readings.

conditions for the penstock. The form the project manager completed during the September 20 safety inspection similarly checked "OK" under the category of confined space safety practices.

8.2.3 Xcel Corporate Policies and Other Requirements Addressing Contractor Oversight

While Xcel's corporate policies and contracting documentation place primary responsibility for safety on the contractor for work under its control, Xcel policies also contain specific contractor safety oversight requirements. In the wake of the Cabin Creek incident, Xcel spokespersons stated that safety was RPI's responsibility and the contractors are "experts in the field and that's why we hired them" (Lipsher, Mitchell, and McPhee, 2007). However, Xcel's "Construction and Contractor Management" policy states: "[c]ontractor oversight or project control shall be established by both parties for all contracts with regard to health and safety standards." Xcel's "Contractor Safety" policy provides several contractor oversight requirements including the establishment of effective daily communication addressing safety issues between Xcel and the contractor, periodic jobsite visits by Xcel personnel to verify safety performance, and prompt notification and correction of deficiencies where violations of health and safety standards or regulations are discovered. Xcel's corporate policy is consistent with industry safety guidelines for owner oversight of contractor safety. CURT user practices recognize that "[t]he owner must monitor contractor behavior to ensure effective implementation," which includes auditing, measuring, and analyzing safety results, participating in incident investigation, and participating in contractor safety training (CURT, 2004b, pp.7-9).

However, Xcel ineffectively implemented its program for contractor safety oversight in a number of key areas identified by its contractor safety policy:

- Xcel and RPI managers did not establish effective daily communication concerning the hazards associated with the penstock recoating project. Xcel did not effectively plan and coordinate with RPI to identify and control serious hazards in the recoating project, including the use of a flammable solvent within the penstock confined space.

- The Xcel project manager or safety staff made documented safety observations only on two occasions at the penstock; these safety observations were ineffectively performed and failed to identify the serious confined space hazards.
- Violations of Xcel safety standards and OSHA regulations were not promptly communicated and corrected. The serious safety issues that were known to Xcel during the penstock work did not lead to increased scrutiny of RPI or effective corrective action.

Xcel acknowledged to the CSB that it had not audited the performance of its corporate contractor selection and safety oversight program prior to the incident. Periodic corporate audits play an important role in ensuring that safety policies and procedures are applied and effectively implemented so that safety hazards can be controlled or eliminated (ANSI/AIHA Z-10, 2005, p.25).

Xcel did not follow an effective contractor selection methodology that would ensure that contractors with a known unacceptable safety record would be disqualified from the bidding process. The company also failed to provide sufficient oversight to ensure that its contractors maintained a safe work environment while performing hazardous maintenance work at its Cabin Creek site.

9.0 EMPLOYEE SAFETY TRAINING

Employee safety training is integral to the success of a company's safety and health program. First and foremost, the company is responsible for ensuring that its employees are trained and capable of conducting work safely.[96]

Three broad types of training were available to RPI employees: 1) company-specific training provided by RPI; 2) general continuing education training provided through a union and the company partnership committee's Training Center; and 3) work-site specific training provided by RPI and Xcel. However, all of these modes of training were deficient in providing appropriate safety information to the penstock work crew, either by the administration of the training or the content of the material.

Specifically, the RPI employees were ill-prepared to safely conduct work inside the penstock because

- RPI did not provide adequate training to its employees on its safety policies and procedures
- RPI relied primarily on the partnership committee's Training Center to provide training to its employees, but the Training Center is not responsible for providing company- or site-specific training to its members;
- Only individuals hired as an apprentice or those specifically referred to the Training Center for enrollment in the apprenticeship program's semester-long courses receive the comprehensive and in-depth safety training the Training Center provides; consequently, just

[96] The American National Standard, "Occupational Health and Safety Management Systems (OHSMS), ANSI/AIHA Z10-2005," provides good practice guidance on training and competency. It states that the employer will "establish processes to ensure through appropriate education, training or other methods that employees and contractors are aware of applicable OHSMS requirements and are competent to carry out their responsibilities as defined in the OHSMS" (ANSI/AIHA, 2005).

two of the 14 contractors[97] on the penstock project who had gone through portions of the program received some of this in-depth training.

- Employees referred to the Training Center for evaluation are assessed only on their technical painting skills, not their safety knowledge.[98] And because the two RPI employees referred by RPI to the Training Center had skill levels at or above a mid-level apprentice, they were not required to take the basic painting level courses that included much of the in-depth safety training.
- Only nine of the 14 RPI employees received onsite training at Cabin Creek prior to the start of the recoating project, and that training was both abbreviated and did not effectively address the hazards inherent to the penstock recoating work.

As a result, the RPI work crew received inadequate training on the specific and unique hazards of the penstock, including the safe handling of flammables, proper and safe use of spray equipment in a confined space, fire prevention and mitigation, and emergency response and rescue awareness. Had the existing apprenticeship safety training been provided to all journeyman painters, the RPI work crew would likely have been better prepared to manage the unique hazards of the penstock.

9.1 Company-Specific Safety Training

Employers are responsible for providing appropriate and effective safety training to its employees. RPI's IIPP manual describes safe work practices and procedures on a wide array of safety issues, and while many are deficient (Section 6.6), a number address specific hazards that were associated with the penstock project, including the safe handling of flammables, proper confined space entry, and fire

[97] RPI had 14 employees working at the Cabin Creek site for the penstock recoating project; however, one left prior to the day of the incident for personal reasons. Twelve contractors and a general foreman remained on site.

[98] The only safety issue individuals are evaluated on is their knowledge of proper PPE

prevention. Training on the safety information within the IIPP manual likely would have mitigated some of the risks inherent with the recoating work.

Unfortunately, the company's method to ensure that newly hired individuals understood the IIPP information was simply to have them sign off on a Certificate of Compliance, which states that the employee received the *IIPP Manual* and the *Employee Safety Handbook* and agrees to comply with the rules and practices of these documents. At the time of the incident, RPI did not test or otherwise verify comprehension of the IIPP and its contents on an ongoing basis throughout an employee's career with the company. In fact, a 2006 audit of RPI by the SSPC found that RPI had "[n]o documentation of craft-worker assessment." In response to this finding, RPI stated that it was "currently implementing a training and documentation plan that will meet the requirements…" outlined in the audit. RPI went on to state that "[o]ur training[,] which will now be more stringently documented, will consist of; [sic] Ongoing Safety Training, Specialized Material Application Training, New Equipment Training, Site Specific Training…etc…)." Available evidence indicates that this training did not occur.

9.2 Training Center Safety Training

A Master Labor Agreement between the Painters and Allied Trades Union, District Council 36, and several participating multi-employer associations created the Southern California Painting and Drywall Industries (SCPDI) Joint Apprenticeship Training Committee and Center.[99] The SCPDI Training Center is charged with providing an apprenticeship training program for beginners in the industrial painting trade. Integrated within this apprenticeship training program are a number of critical safety components. Those who fully complete the program have the opportunity to build a solid foundation of technical painting skill and safety awareness.

[99] This Committee, and its Training Center, is maintained through a Master Labor Agreement between the Painters and Allied Trades Union (District Council 36) and several contractor associations, of which RPI is a member.

However, the number of individuals who benefit from the apprenticeship program training courses is limited, in that the SCPDI Training Center is responsible for providing in-depth safety training only to individuals who are either just entering the industrial/commercial painting field or those referred to the Training Center by their employer for a skills evaluation and are subsequently found to be lacking in painting skills and abilities. None of the 14 RPI employees working on the penstock project were graduates of the apprenticeship program; only two were referred to the Training Center by RPI for skills evaluation. And because the two RPI employees referred to the Training Center had skill levels at or above a mid-level apprentice, they were not required to take the basic painting level courses that included much of the in-depth safety training.

Additionally, those referred to the Training Center are evaluated solely on technical painting skill and expertise; safety knowledge is not assessed as part of the evaluation process. An individual could qualify at the fourth stage within the seven-stage Apprenticeship Program based on his/her demonstrated knowledge of proper painting techniques and abilities, without having to demonstrate that he/she has the *safety* knowledge necessary to perform work at that painting skills level within the program. Indeed, the evaluation procedure utilized by the Training Center does not include an assessment of safety knowledge. Individuals that enter midway into the Apprenticeship Program miss out on multiple opportunities for in-depth safety training, and those hired by the company and deemed sufficiently skilled in the trade are not sent to attend the semester-long Apprenticeship courses, and consequently are not exposed to the in-depth safety training.

These training gaps are compounded because the Training Center does not, and is not expected or required to, provide instruction on company-specific policies or site-specific hazards.

The SCPDI Training Center does offer general OSHA-required continuing education training opportunities[100] to its union members; however, this training is not worksite-specific.

9.3 Generic Onsite Training Provided at Cabin Creek

The RPI work crew did not receive comprehensive safety training specifically pertaining to the penstock work environment from either their employer (RPI) or the host company (Xcel).

An Xcel safety supervisor, after reviewing RPI's penstock project bid submittal, noted that a number of the RPI employees lacked several training courses pertinent to the penstock work, including confined space entry and electrical safety. He communicated this lapse in training to the RPI safety manager, who asserted that all RPI employees involved in the project would receive onsite training to cover these and other safety topics prior to starting work. The RPI safety manger asked a trainer at the SCDPI Training Center to come to the Cabin Creek site to provide basic OSHA-required continuing education/refresher training to the work crew.

Only nine of the 14 RPI employees on the penstock project received this onsite training on September 10, 2007. This training consisted of 6 hours of refresher-level safety review on six topics (each lasting about an hour). The contractors watched a safety video on each topic and were tested through multiple-choice exams. Those who had not arrived onsite until after September 10 were not provided an opportunity to take a make-up session.

In testimony to the CSB, the trainer stated that the review of safety topics was kept "pretty brief" because the contractors had attended the refresher courses multiple times. While repetition may seem burdensome, the real challenge in preparing for safe work is to ask: What about this job and these planned activities are

[100] CPR, Respirator Use and Fit Test, and Lead Worker Refresher is required annually; First Aid is required every three years; and the following courses are reviewed at least once per year in the Apprenticeship program but journeymen are required to take the training only once: Fall Protection, Scaffold/Swing Stage, Confined Space Awareness, Hazard Communication, Hearing Protection, Asbestos Awareness, Aerial Mobile Power Lifts, Forklift & Drywall.

different from what we've done before? What are the hazards of those different activities? How can that risk be eliminated or controlled?[101] Approaching hazards this way focuses attention on the risks that may not be readily apparent when reviewing generic training materials before the start of work.

The onsite training for the RPI employees was brief and generic and included only a basic review of confined space awareness. It included an overview of the definition of a confined space, but not how to evaluate a confined space for potential hazards, how to properly complete confined space entry forms, or how to prepare and arrange methods for evacuation. The onsite training also included a basic review of electrical safety, the material provided focused on the importance of using grounded equipment and following lockout/tagout procedures, but not on the need to use conductive hoses to prevent static discharge, nor did it explicitly instruct the crew about how to wire and ground equipment properly for safe use.

The hazardous communication training on September 10 did not include a site-specific discussion of safe use of flammable solvents in confined spaces, despite plans by both companies to use a solvent within the penstock during the recoating process[102] (Section 6.5). Nor were flammable and explosive atmospheres, fire prevention, and fire extinguisher use within the penstock incorporated in any onsite training for the contractors; also excluded was a discussion of procedures for emergency evacuation of the penstock. Neither Xcel nor RPI discussed the lack of a secondary egress with the work crew during the onsite training, and specific emergency response and rescue training did not extend beyond the instruction to the crew to call the Xcel control room for 9-1-1 services if an emergency should arise.[103]

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[101] A U.S. aircraft commander, who is also a human performance specialist, often prepares his crews by asking, "What is dumb, different, and dangerous about this specific mission?" to provoke their collective thinking about the specific and potentially unique risks of a given mission.

[102] The hazardous communication training on September 10 consisted of an employee's right to know the chemicals onsite, how to read an MSDS, and proper PPE.

[103] One likely reason for the lack of pertinent training on the issues inherent with the penstock project work was the trainer's lack of penstock experience. The trainer relied on a more experienced contractor within the RPI crew to

The RPI employees also received a brief onsite safety overview from Xcel as they arrived at Cabin Creek and began preparing for work inside the penstock.[104] This brief orientation – consisting of a checklist review of potential hazards – was held on three separate occasions, led by different Xcel personnel and attended by various crew members.[105] The orientation provider addressed confined space by asking the RPI crew if they had been trained on the safety topic, but the provider did not verify this training, nor were MSDSs of chemicals to be used within the penstock discussed or requested. The orientation did not cover a number of safety issues related to the penstock work, including emergency response and evacuation plans or safeguards for minimizing fire hazards within the confined space.

9.4 Safety Training Needs Specific to the Penstock

The unique characteristics of the penstock and the recoating work require knowledge and skill on a number of safety topics, including the safe handling and use of flammables, confined space entry and monitoring, fire prevention, and emergency preparedness. Many of these safety topics are covered effectively in the SCPDI apprenticeship program; others are covered within the safety policies of the host and contractor companies. Through interview testimony and training records, the CSB found that the necessary safety information pertaining to the penstock project was not, in most cases, effectively administered to the RPI workforce, nor did either company uphold and reinforce safe work practices at the work site. This section identifies where safety training and information existed but was not incorporated into the work activities at Cabin Creek.

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inform the others of the penstock's hazards; however, according to witness testimony, the experienced contractor focused on slip, trip and fall hazards, not on the major confined space hazards of the penstock or the risks of working in flammable atmospheres.

[104] This orientation was meant to focus on Xcel policies and procedures; topics covered included lockout/tagout, forklift use, slipping hazards, and waste removal from the site.

[105] Each member attended the orientation once.

9.4.1 Substituting Non-flammables for Flammable Solvents

The use of potentially safer alternatives to MEK is discussed in the SCPDI apprenticeship program's training course, "Solvent and Hazardous Materials." The training materials state: "Whenever possible, organic solvents should be replaced with either water-based solvents or another less harmful organic solvent." The importance of exploring opportunities to exchange flammable solvents for non-flammable substitutes is reiterated throughout the training materials, which provide a substitution example dealing explicitly with MEK: "a citrus based [sic] cleaner could be used in place of MEK for tool clean up." Only one RPI crew member attended the "Solvent and Hazardous Materials" course (as part of his training through the Apprenticeship program). The use of a non-flammable solvent would have prevented the Cabin Creek fire.

9.4.2 Safe Handling and Use of Flammables

Training on the safe handling and use of flammables is offered only to employees who are going through the apprenticeship program or when specifically requested by a company. The IIPP safety policies concerning the safe handling and use of flammables were not provided to employees through in-house company-provided training, nor were employees' comprehension of these polices assessed.[106] As a result, RPI employees were not sufficiently trained on the safe use of flammables.

The proper and safe handling of flammables is covered in the "Basics of Solvents and Thinners" and "Solvent and Hazardous Materials" training courses the SCPDI Training Center offers. However, records going back five years prior to the incident show that none of the RPI employees working inside the penstock took the "Basics of Solvents and Thinners" course and, as stated, only one of the crew took the "Solvent and Hazardous Materials" training course.

[106] When subpoenaed for all training materials, RPI did not provide any documentation that employees were tested on the IIPP safety information.

The “Basics of Solvents and Thinners” course materials provide many warnings about the risks of using flammables, and the “Solvents and Hazardous Materials” course goes further, stating: “NEVER leave solvent products open when not in use” (emphasis in original) and “Place solvent soaked rags or materials in all-metal containers with tight sealing tops” to prevent dangerous vapor accumulation in the work area. The training materials also warn: “Transport and store solvents ONLY in approved, properly labeled and marked containers” (emphasis in original). By following these safety rules, the training material asserts, the chance for a fire or explosion is reduced.

Some RPI employees stated they knew how to safely transfer flammables, but as metal safety cans for MEK transfer were not made available for use at Cabin Creek, adhering to this safety policy was impossible.

9.4.3 Flammable Atmospheres and Confined Space Entry

SCPDI Training Center training materials for “Confined Space Entry” state: “If the atmosphere contains flammable gas, vapor or mist in excess of 10 percent of its lower flammable limit (LFL), that atmosphere is not acceptable for entry.” Yet on October 2, 2007, the Cabin Creek confined space work did not prohibit entry or occupancy of the penstock where the LFL was in excess of 10 percent, nor did Xcel or RPI’s policies require this safeguard. The attendant was conducting atmospheric monitoring at the access door, more than 1,450 feet (442 meters) away from the crew using the solvent to flush the hoses, wands, and sprayer system with MEK, which was too far away to get an accurate measurement. MEK vapor produced with the flushing activities resulted in the accumulation of solvent vapors to levels above the maximum allowable for entry around the equipment and work crew.

9.4.4 Fire Prevention and Mitigation

Both the SCPDI fire prevention training course material and RPI’s IIPP section, “Fire Protection and Prevention,” stress the importance of both clear access to emergency response equipment and its placement close to the actual painting operation. Yet RPI provided only six of the 14 contractors with a general course on proper fire extinguisher placement within the worksite; this training occurred approximately two months prior to the incident.

The SCPDI fire prevention training also included instructions that there should be more than one exit in the area of work and that all workers keep their backs to an exit in case a fire necessitated escape. Despite these fire safety recommendations, the arrangement of spray equipment within the narrow confines of the penstock kept contractors separated from the work area's only exit. No remedial action was taken to address the lack of a secondary exit, although a number of RPI employees expressed concern about having only one egress point. The positive affects of training are significantly diminished when the good practices promoted in the training cannot be adhered to. Interestingly, a penstock project contract addendum, which both Xcel and RPI agreed to, empowered Xcel employees with "stop work authority" during the project, allowing Xcel employees to order RPI to cease work within the penstock if they observed unsafe work practices. This stop work authority was given specifically to Xcel employees, not the RPI work crew.

9.4.5 Proper and Safe Use of the Sprayer and Associated Equipment

RPI employees were not trained on the proper and safe use of the Graco epoxy sprayer system. The SCPDI Training Center does not train on Graco spray equipment exclusively, but a plural component (two-part) spray system is a topic within the apprentice spray painting course curriculum. However, only two of the 14 contractors went through the apprenticeship semester course that covers this information. This training, which was provided by a third party in agreement with RPI, had taken place two years prior to the penstock project. Working with unfamiliar equipment likely contributed to the operational problems the crew was experiencing during their application attempts.

The RPI crew working inside the penstock lacked the in-depth safety training and knowledge necessary to work safely within this unique and challenging confined space environment. RPI did not provide adequate training addressing the safety risks of the penstock recoating work to its employees. The Training Center

Apprenticeship Program does provide comprehensive safety training; however, few RPI employees received this in-depth safety training.

10.0 Regulatory and Industry Standards Analysis

RPI's and Xcel's policies and permits failed to established safe limits that prohibit entry or occupancy of a confined space with a hazardous flammable atmosphere. However, existing federal regulations for general industry do not require that employers establish such safety limits. Specifically, the current OSHA Permit-Required Confined Spaces Rule does not prohibit entry or occupancy in a confined space above a maximum permissible percentage of the LFL nor does it require continuous monitoring throughout the duration of the work[107] to ensure the concentration of flammable gases does not exceed that percentage.

The CSB determined that, even if combustible gas monitoring had been performed on the day of the incident in the area where flammable solvent was being used, this monitoring would likely not have been enough to prevent the initial flash fire in the penstock; with no set limit for flammable atmospheres, the RPI crew had no evaluation and action level in which to use to determine when it was safe to work and when cessation and/or evacuation was necessary.

10.1 Hazards of Confined Space Work in Potentially Flammable Atmospheres Inadequately Covered in Existing Standards

OSHA's Permit-Required Confined Spaces Rule for general industry states that a confined space must be permit-required when the space has a potential to contain a hazardous atmosphere, which is defined for flammables as an atmosphere that exceeds 10 percent of the LFL [29 CFR 1910.146(b)] (Section 6.1). A permit-required confined space program mandates that employers specify acceptable entry conditions and take actions such as purging or ventilating the space to eliminate or control atmospheric hazards such as a flammable atmosphere [29 CFR 1910.146(d)(3)(i), (iv)]. However, the rule does not define acceptable

[107] In this incident, the penstock space was "large or…part of a continuous system," which would require continuous monitoring (See Sections 6.1.3 and 11.2.2.2, which discuss 29 CFR 1910.146 (d)(5)(i)). However, the fact alone that a flammable was being used within a confined space would not have triggered the requirement for continuous monitoring.

entry conditions or specify what additional precautions must be taken for working in a permit-required confined space with a potential flammable atmosphere, nor does it limit entry based upon measureable critieria such as a specific maximum percentage of the LFL, even though OSHA defines an atmosphere as hazardous when it exceeds 10 percent of the LFL. Appendix C of the rule gives examples of permit-required programs, including a scenario where interior coatings/linings are applied in portable tanks. This scenario describes an approach to control the hazards by establishing forced air ventilation to keep the potentially flammable atmosphere below 10 percent of the LFL [29 CFR 1910.146 Appendix C, Example 3]. However, Appendix C provides only examples of permit-required programs; it does not establish enforceable requirements.

In 1996, OSHA issued a letter of interpretation that allows work to be performed in atmospheres in excess of 10 percent of the LFL, stating that when the atmosphere is above 10 percent, “all of the requirements of the rule must be met”; however, it provides no specific safety guidance (OSHA, 1996). The letter concludes that because the Permit-Required Confined Spaces Rule for general industry is a performance standard, “it does not specify procedures for conditions where the permit-required space has a hazardous flammable atmosphere” (OSHA, 1996). Rather, the employer must implement control measures based upon a hazard analysis of the “the means, procedures, and practices necessary for safe permit space entry operations” [29 CFR 1910.146(d)(3)]. In fact, the letter does not suggest any limits on entry based on measurements of the flammable atmosphere or even that safe entry conditions need be defined in terms of the LFL, which directly contradicts the more recent OSHA shipyard standards and recent NFPA guidance, as discussed below.

The Permit-Required Confined Spaces Rule requires “purging, inerting, flushing or ventilating the permit space as necessary to eliminate or control atmospheric hazards” [29 CFR 1910.146(d)(3)(iv)]. Under the rule, a hazardous atmosphere is one “that may expose employees to the risk of death, incapacitation, impairment of ability to self-rescue…injury, or acute illness” [29 CFR 1910.146(b)]. The logic of the provisions would appear to demand that for safe entry, the confined space flammable atmosphere would need to be reduced to 10 percent or less of the LFL or inerted to prevent the formation of a flammable mixture inside the permit space and the possibility of death or injury; however, the Rule has no such explicit requirement.

The following support the need for effective requirements or limits for working in flammable atmospheres in terms of confined space entry and occupancy:

1. Establishing safe flammable limits as a percentage of the LFL, with the effective use of appropriate monitoring devices (e.g., combustible gas detectors), is an accurate method for obtaining quantitative data to evaluate the potential degree of hazard and protect personnel (McManus, 1999, p.748).

2. Safe flammable atmosphere limits are needed because no adequate PPE is available that can protect workers from an explosion within a confined space (NFPA 1006, 2008).

3. Sources of ignition for a fire or explosion are typically plentiful and difficult to eliminate entirely, as illustrated in the number of possible ignition sources available in the Cabin Creek penstock; as such "there is no ready assurance that all sources of ignition could be eliminated" (McManus, 1999, p.746).

4. Lacking specific regulatory requirements based upon measureable parameters, employers may fail to establish adequately protective limits for working in potentially flammable atmospheres. In this incident, neither Xcel nor RPI had established safe entry conditions for flammable atmospheres based upon a percentage of the LFL in their procedures and permits.

5. Failure to establish safe flammable limits undermines the importance of monitoring in permit-required confined spaces; the need for periodic or continuous monitoring will not be understood by employers and personnel if no limits are specified. This safety gap can lead to a failure to conduct critical combustible gas testing in appropriate locations and with the needed frequency, as was the case in the Cabin Creek penstock.

6. Unlike flammable atmospheres, other atmospheric hazards have explicit and measureable requirements elsewhere in the OSHA regulatory scheme to confirm compliance with the Permit-Required Confined Spaces Rule. For example, OSHA standards for toxic substances establish quantitative permissible exposure limits and other standards require quantitative monitoring of potentially oxygen-deficient atmospheres.[108]

7. Confined space entry is a frequent activity in U.S. workplaces-OSHA estimates that more than 4.7 million permit-required confined spaces are entered by workers annually (OSHA, September 2008).

8. A flammable atmosphere is a serious confined space hazard. According to noted confined space expert McManus (1999), fires and explosions are a "major cause" of deaths and injuries in confined spaces and have led to a relatively "large portion of fatalities per incident compared to other situations" (p. 112). The CSB concluded that serious confined space incidents involving flammable atmospheres are still a significant problem and that adequate combustible gas monitoring, clearly defined limits for working safely in potentially flammable atmospheres, and other control measures such as eliminating the hazard or adequate ventilation of the space can prevent these accidents (Section 11.0).

10.2 Other Regulations and Safety Guidelines Set Protective LEL Limits for Work in Potentially Flammable Atmospheres

The approach in the Confined Spaces Rule sharply contrasts with more stringent, recently promulgated OSHA standards, such as those for confined spaces in shipyard employment [29 CFR 1915, Subpart B], which limit work activities that can be conducted in atmospheres that exceed 10 percent of the LEL. The shipyard standard requires that confined spaces containing a flammable concentration of 10 percent of the

[108] For example, see OSHA's Table Z-1, "Limits for Air Contaminants"; 29 CFR 1910.1000; and the Respiratory Protection Standard, 29 CFR 1910.134.

LEL or higher be labeled as “Not Safe for Workers” [29 CFR 1915.12(b)(2)]. In the discussion related to the final rule for confined spaces in shipyard employment, OSHA argued that adopting 10 percent of the LEL limit for safe occupancy was more appropriate than other proposed levels: “The Agency believes that a compartment in which any portion is above 10% of the LEL is unsafe” [59 FR 37816-37863].

Yet the general industry Permit-Required Confined Spaces Rule allows employers to adopt limits higher than 10 percent of the LEL as an acceptable entry condition. McManus, in *Safety and Health in Confined Spaces* (1999), defends the use of lower LEL limits, noting that conducting a confined space hazard analysis can be difficult and uncertain because of several factors: 1) the accurate detection of ignitable atmospheres depends on the position of the intake of the instrument relative to the source, 2) the relative response of the sensor based the on substance(s) being sampled to the substance(s) used to calibrate the sampler, and 3) the timing of the samples (pp. 745-752).[109]

A number of organizations, standard-setting bodies, and other government regulatory agencies have also adopted guidelines that prohibit or limit work activities in confined spaces in atmospheres above 10 percent of the LEL (Appendix G). McManus (1999) suggests that “[t]he consensus expressed through more recent standards indicates decreased tolerance” for hazardous flammable atmospheres (p. 745). An important example of this trend can be found in the 2008 edition of NFPA 1006, Standard for Technical Rescuer Professional Qualifications. This consensus standard addresses acceptable entry conditions for confined space rescue and states in its explanatory material that “[r]escuers should not enter confined spaces containing atmospheres greater than 10 percent of a material’s LEL, regardless of the personnel protective equipment worn. There is no adequate protection for an explosion within a confined space” [NFPA 1006, 2008, Annex A.7.1.1].

[109] Webber (2007) summarizes relevant research showing conditions where flammable vapors can be ignited even when concentrations are below the LEL that result in localized flash fires.

A number of other confined space consensus safety standards and industry guidelines recommend special precautions to detect and control flammable atmospheres and explicitly establish safe work limits for confined spaces that are substantially below the LFL, such as 10 percent of the LFL [ANSI Z117.1, 2009, p.24; ASTM D4276-02, 2007, p.3; NFPA 326, 2005; API 2015, 2001a, p.28; API 2016, 2001b, pp.43, 60; IChemE, 2005, p.66].

NFPA 326, Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair, requires that "[a]ll work in or around the tank or container shall be stopped immediately when the flammable vapors in the atmosphere exceed 10% of the lower flammability limit (LFL). The source of the vapors shall be located and eliminated or controlled" [NFPA 326, 2005, p.9]. A number of countries including Australia, New Zealand, and nearly all Canadian provinces prohibit confined space entry above a defined safe flammable atmosphere limit that is substantially below the LEL (Appendix G).

Therefore, in light of the existing consensus of confined space codes and regulations establishing lower LEL limits for safe entry and the improved understanding of the increased hazards of working in permit spaces in atmospheres above 10% of the LEL, the CSB recommends that OSHA limit confined space work activities in the presence of flammables in the same manner and to the same degree as the agency has done in shipyards and as many other consensus standards recommend.

10.3 Colorado Public Utilities Commission

The Colorado Public Utilities Commission (PUC) is a state regulatory agency that oversees a wide variety of electric power and other utilities. Xcel is one of two investor-owned electric utilities operating in Colorado that are regulated by the PUC. The stated mission of the PUC is to serve the public interest "by effectively regulating utilities and facilities so that the people of Colorado receive safe, reliable, and reasonably priced services consistent with the economic, environmental and social values of our state."[110] The PUC has promulgated the Rules Regulating Electric Utilities (4 Code of Colorado Regulations 723-3, Part 3) that address a range of subjects including safety; construction, maintenance, and operation of electric utility facilities; and competitive bidding processes related to areas such as the acquisition of new utility resources.

The PUC rules require that the construction, maintenance, and operation of a utility be "in accordance with accepted engineering practice in the electric industry to assure continuity of service, uniformity in the quality of service, and the safety of persons and property."[111] The PUC rules provide that in the event of an incident resulting in death, serious injury, or significant property damage, the regulated utility shall inform the Commission within two hours of learning of the incident and submit a written report within 30 days.[112] The only content requirements of the written report are the date, time, place, location, and type of the incident; names of persons involved; and nature and extent of injury and damage. For the Cabin Creek incident Xcel sent a one-page letter to the PUC on November 1, 2007, briefly describing the incident and the number of people killed and injured. PUC rules state that if a utility conducts an internal investigation of an incident that any report developed shall be made available to the Commission upon request.[113] The PUC Commission was not notified of the availability of any internal investigation report by Xcel nor did the Commission receive any report. Xcel did not inform the Commission of the root causes of the Cabin Creek incident, recommendations for prevention, or any subsequent preventative measures taken by Xcel.

PUC electric utility contracting rules describe procedural requirements and criteria other than price to consider in the competitive bidding process but the provisions do not include any safety considerations.

[110] Mission of the Public Utilities Commission, http://www.dora.state.co.us/puc/about/AboutMission.htm accessed 7-13-10.
[111] Colorado Department of Regulatory Agencies, 4 Code of Colorado Regulations (CCR) 723-3, Part 3, Rules Regulating Electric Utilities, Rule 3200(a), Construction, Installation, Maintenance, and Operation.
[112] Id. Section 3204(a) and (b).
[113] Id. Section 3204(c).

The rules contain provisions that regulate resource planning such as those resources that provide electrical capacity and renewable energy. The acquisition of utility resources can include new construction, maintenance, and repairs that significantly impact capacity or prevent service interuption. PUC rules favor competitive bidding for the acquisition of new resources and address requirements for the competitive bidding processes, requests for proposals (RPFs) and bid evaluation criteria. In 2010, the Colorado General Assembly approved renewable energy legislation that requires the Colorado Public utilities Commission to implement new "best value" contracting bid criteria for electric resource acquisition[114]. The additional criteria that need to be considered in the competitive bidding process include workforce training certifications, long-term career opportunities, and industry standard health care benefits. However, neither the existing PUC rules nor the new mandated criteria require that past safety performance be considered as a factor in the competitive bidding process, nor do they include safety prequalification or disqualification procedures.

[114] The 2010 Colorado General Assembly amended Colorado Revised Statutes 40-2-124 by House Bill 10-1001, http://www.dora.state.co.us/PUC/rulemaking/HB10-1001/HB10-1001_enr.pdf , accessed 7-13-10.

11.0 Flammables Used in Confined Spaces: Other Incidents

As part of its investigation of the Xcel penstock case, the CSB collected and compiled confined space incident data from the past 17 years to ascertain the prevalence of confined space flammable incidents and determine if the rate has been impacted by the promulgation of the Permit-Required Confined Spaces Rule. The CSB has determined that the hazard of flammable atmospheres in confined spaces has been a significant workplace safety issue since the promulgation of OSHA's Permit-Required Confined Space Rule on April 15, 1993.

The CSB compiled and researched incident data on 105 previous confined space incidents; of these, 53 were determined to be the result of a flammable atmosphere in a confined space. (Appendix I describes CSB's incident data collection methodology used to obtain this data.) The CSB also found that the number of confined space flammable incidents has increased the past nine years, as a majority of the 53 incidents from 1993 until April 2010 occurred since 2003. These flammable atmosphere confined space incidents include two the CSB investigated in 2009 that resulted in four fatalities (Appendix J).

The 53 identified confined space flammable incidents caused 45 fatalities and 54 injuries from 1993 to April 2010; approximately 57 percent included a fatality. The number of fatalities and injuries increased in the 17 years, with 49 percent of the total fatalities and approximately 57 percent of total injuries occurring since 2003. In the past 14 months, from February 2009 to April 2010, the CSB identified seven additional confined space incidents that resulted in six fatalities and four injuries.

The CSB analysis shows that a flammable atmosphere was present in the confined space prior to entry in 60 percent of the incidents sampled. Flammables were brought into the confined space for activities like painting/recoating, cleaning, or welding in the remaining approximately 40 percent. This data underscores the importance of monitoring the confined space both before entry and continuously in the work area where the confined space work activity includes the use of flammables. Continuous monitoring under these circumstances combined with flammable atmosphere limits established in procedures and permits are likely to alert workers to the importance of rapid changes that can lead to a flammable atmosphere so that workers can evacuate.[115]

The data suggest that, even after the promulgation of the Permit-Required Confined Space Rule, a significant number of confined space incidents with fatalities and serious injuries were attributed to flammable atmospheres. Furthermore, the increasing numbers of fatalities and injuries post-promulgation of the Permit-Required Confined Spaces Rule suggests the need for more protective requirements for work in potential flammable atmospheres in confined spaces.

[115] An example of how continuous monitoring can prevent worker fatality or injury is evident from a confined space incident that occurred on January 7, 2010 in Amsterdam, NY. Two telephone workers were conducting repair work in a telephone vault (similar to a manhole) when their combustible gas meter alarmed. They were able to evacuate the confined space prior to a small fire breaking out.

12.0 ROOT AND CONTRIBUTING CAUSES

12.1 Root Causes

1. Xcel and RPI management did not ensure effective planning and coordination of the Cabin Creek penstock recoating project to control or eliminate the serious confined space hazards that were present.

    - An effective hazard evaluation of the penstock confined space was not performed; the work required the use of a solvent to clean the epoxy sprayer and associated equipment in the open penstock atmosphere, yet the serious safety hazards of using a flammable solvent inside the confined space were not identified or addressed.
    - Substituting a non-flammable solvent was not considered.
    - Important safety precautions when using a flammable in a confined space, such as continuous monitoring in the work area, providing adequate ventilation, and eliminating or controlling ignition sources, were not implemented.

2. Xcel's and RPI's corporate safety policies and permits did not effectively establish safe limits for flammable atmospheres in permit-required confined spaces that would prohibit entry or occupancy when those limits were exceeded.

3. Early in the planning process, Xcel identified the Cabin Creek penstock's single point of egress in the event of an emergency as a major concern; RPI personnel also raised safety issues about a single exit. However, neither Xcel nor RPI management took remedial action.

    - American Society of Civil Engineering (ASCE) published safety guidance addressing penstock inspections advises on the importance of alternative escape routes in the event of an emergency (ASCE, 1998, p.2-8).

- As a result of the flash fire, five RPI workers, who were located on the side of the sprayer opposite the sole exit, were trapped by the growing flames and eventually succumbed to smoke inhalation.

4. Xcel management did not provide effective oversight of RPI to ensure the penstock recoating work was safely conducted.

- Due to concerns about RPI's record of injuries and fatalities in past projects, Xcel added a "Safety Addendum" to the penstock recoating contract affirming that Xcel would closely observe RPI's safety performance. However, Xcel managers conducted safety observations of RPI on only two documented occasions in the 29 days that RPI personnel were on the job. During the penstock recoating work prior to the incident, Xcel managers were aware of several significant safety problems attributable to RPI, yet Xcel did not increase scrutiny of RPI's safety performance or implement corrective actions.

12.2 Contributing Causes

1. Xcel's corporate policies and practices addressing contractor selection did not adequately ensure contractor safety performance for the penstock recoating project.

- During the contractor selection process, Xcel managers graded RPI safety performance as a zero, the lowest possible score; however, Xcel's contractor selection practices typically provided only for disqualification from the bidding process based upon financial capacity, not safety criteria.
- The evaluation rating form stated that the score of zero did not met Xcel's minimum requirements and required automatic rejection; however, RPI was still allowed to compete for the penstock recoating contract. RPI's proposal was ranked as the best overall based primarily on its low price.

- RPI did not disclose to Xcel regulatory violations resolved within the requested three-year period as part of the RFP evaluation process. Xcel's corporate policies addressing contractor selection relied upon self-reporting and did not include specific procedures to verify the contractor's submissions.

2. Xcel and RPI managers did not plan and coordinate the immediate availability of qualified confined space technical rescuers outside the penstock, although the use of flammable solvent in the open atmoshere of the permit space created the need for immediate rescue due to the potential for IDLH conditions.

    - Neither company ensured that emergency response organizations or personnel with confined space technical rescue qualifications were immediately available with the necessary fire-fighting equipment outside the penstock.
    - The approximate travel time of the closest identified public emergency response organization with confined space technical rescue qualifications was approximately 1 hour and 15 minutes.
    - After the penstock fire erupted, firefighting and rescue activities likely would have been sucessfully provided to prevent the fatalities had qualified personnel and equipment been immediately available; the trapped RPI workers were in radio communication with coworkers and emergency responders for 45 minutes after the initial 9-1-1 call.

3. RPI did not ensure that the majority of its workforce at Cabin Creek had received comprehensive formal safety training, effective training on company safety policies, or site-specific instruction addressing confined space safety, the safe handling of flammable liquids, the hazard of static discharge, emergency response and rescue awareness, and fire prevention.

13.0 RECOMMENDATIONS

Occupational Safety and Health Administration (OSHA)

2008-01-I-CO-R1 Amend the OSHA Permit-Required Confined Spaces Rule for general industry (29 CFR 1910.146) to establish a maximum permissible percentage substantially below the lower explosive limit (LEL) for safe entry and occupancy in permit-required confined spaces.

2008-01-I-CO-R2 Publish a “Safety and Health Information Bulletin” addressing the hazards and controls when using flammable materials in confined spaces that includes actionable guidance regarding:

a. The importance of implementing a hierarchy of controls to address hazards in a confined space that first seeks to eliminate hazards or substitute with a less hazardous material(s) or method(s). Examples include performing work outside of a confined space where reasonably practicable or substituting a flammable material with a non-flammable one.

b. The necessity of establishing a maximum permissible percentage substantially below the lower explosive limit (LEL) for safe entry and occupancy of permit required confined spaces.

c. The need to comprehensively control all potential ignition sources and continuously monitor the confined space at appropriate locations and elevations when work activities involve the use of flammable materials or where flammable atmospheres may be created.

d. The importance of treating confined spaces with the potential for flammable atmospheres above 10 percent of the LEL as a hazard immediately dangerous to life or health (IDLH) that requires rescuers to be stationed directly outside the permit space and available for immediate rescue with appropriate fire-extinguishing and rescue equipment.

e. The requirement that confined spaces such as penstocks be managed as permit-required that are so large or part of a continuous system that they cannot be fully characterized from the entry point. Such spaces need to be monitored for hazardous atmospheres both prior to entry and continuously in areas where entrants are working.

The Governor of the State of Colorado

2008-01-I-CO-R3 Implement, through the Division of Fire Safety, an accredited firefighter certification program for technical rescue that encompasses appropriate specialty areas including confined space rescue.

The Colorado Public Utilities Commission

Revise your rules regulating electric utilities, 4 Code of Colorado Regulations 723-3, to:

2008-01-I-CO-R4

a. Require regulated utilities to investigate the facts, conditions, and circumstances of all incidents resulting in death, serious injury or significant property damage as defined in Section 3204

b. Require utilities to submit a written investigation report to the Commission within one year of the incident that contains the investigation findings, root causes and recommendations for preventing future incidents that focus on needed changes to utility safety systems. All reports shall be made public.

c. Authorize the commission to issue orders addressing needed corrective actions to be taken as a result of the incident.

d. Require utilities to submit periodic reports to the Commission detailing action taken on the incident report recommendations and Commission orders. All reports shall be made the public.

2008-01-I-CO-R5

Require all regulated utilities to fully cooperate with all government safety investigations including facilitating access to witnesses, facilities, and equipment; providing copies of requested records; and responding to interrogatories and other investigative requests for information as expeditiously as possible.

2008-01-I-CO-R6

Require that competitive bidding and contractor selection rules for construction, maintenance or repair of regulated utilities include procedures for prequalifying or disqualifying contractors based on specific safety performance measures and qualifications.

Director of the Division of Fire Safety and the Director the Division of Emergency Management for the State of Colorado

2008-01-I-CO-R7 Publish a safety communication that will inform fire service and emergency planning organizations in the state about the confined space safety lessons learned from the Cabin Creek incident including

a. The need to train and certify emergency response personnel who perform technical, including confined space, rescue.

b. The importance of a written confined space rescue plan for each designated permit space that includes

i. Methods of rescue and determination of whether a rescue team is required to standby outside the space.

ii. Rescue equipment requirements and plan of action.

c. The importance of treating confined spaces with the potential for flammable atmospheres above 10 percent of the LEL as a hazard immediately dangerous to life or health that requires rescuers to be stationed directly outside the permit space and available for immediate rescue with appropriate fire-extinguishing and rescue equipment.

d. The need for confined space rescue procedures to instruct emergency responders to not enter or occupy a confined space containing a flammable atmosphere 10 percent of the LEL or greater. Personal protective equipment (PPE) will not protect rescuers from an explosion in a confined space.

Xcel Energy, Inc.

2008-01-I-CO-R8 Revise your policies for solicitation and procurement of construction services to

a. Ensure that requests for proposals (RFPs) and selection processes include criteria and procedures for prequalifying or disqualifying contractors based on specific safety performance measures and qualifications.

b. Implement written verification procedures for the safety information and documentation submitted by contractors during the bidding and selection process.

2008-01-I-CO-R9 Revise your contractor safety policies to require a comprehensive review and evaluation of contractor safety policies and procedures such as the permit-required confined space program and safety performance of contractors working in confined spaces to ensure that any bidding contractor meets or exceeds Xcel Energy safety requirements.

2008-01-I-CO-R10 Conduct periodic safety audits of contractor selection and oversight at your power-generating facilities to ensure adherence to corporate contractor procurement and safety policies.

2008-01-I-CO-R11 Report key findings, causes and recommendations of the CSB report to Xcel shareholders so that the owners of Xcel are fully informed of the report contents and how Xcel intends to prevent a similar accident in the future.

Xcel Energy, Inc. **2008-01-I-CO-R12**

See below for recommendation text.

RPI Coating Inc. **2008-01-I-CO-R13**

Revise your confined space entry program and practices. At a minimum

a. Require continuous monitoring for flammable atmospheres at appropriate locations and elevations within a confined space where work activities involve the use of flammables or where flammable atmospheres may be created.

b. Prohibit entry or require evacuation of a confined space if the atmospheric concentration of flammable vapors is 10 percent of the LEL or higher.

c. Ensure that confined spaces such as penstocks be managed as permit-required that are so large or part of a continuous system that they cannot be fully characterized from the entry point. Ensure that such spaces are monitored for hazardous atmospheres both prior to entry and continuously in areas where entrants are working.

d. Ensure that evacuation plans for penstocks that have only one egress point provide for alternative escape routes and/or refuge chambers.

e. Ensure the implementation of a written confined space rescue preplan for each designated permit space. Address staging and methods of rescue for each designated permit space including whether a rescue team is required to standby outside the space. Require that confined space rescue teams be standing by at the permit spaces where the hazards pose an immediate threat to life or health including the hazard of a potential flammable atmosphere.

RPI Coating, Inc.

2008-01-I-CO-R14 Based on the findings and conclusions of this report, hire a certified safety professional to conduct periodic safety audits at your worksites. At a minimum, assess safety training, confined space safety, safe handling of flammables, emergency response, rescue, and fire prevention.

2008-01-I-CO-R15 Ensure that all journeyman painters have received safety training equivalent in content to that covered in the Joint Apprenticeship program. At a minimum, address confined space safety, safe handling of flammables, emergency response and rescue, and fire prevention.

The Society for Protective Coatings (SSPC) **2008-01-I-CO-R16**

See below for recommendations text.

American Public Power Association (APPA) **2008-01-I-CO-R17**

Publish safety guidance addressing the hazards and controls for using hazardous materials including flammables in confined spaces and the unique hazards of penstocks. At a minimum

a. In controlling hazards in confined spaces, implement a hierarchy of controls by first attempting to eliminate hazards or substitute with a less hazardous material(s) or method(s). Examples include performing work outside of a confined space where reasonably practicable or substituting a flammable material with a non-flammable one.

b. Establish a maximum permissible percentage substantially below the LEL for safe entry and occupancy of permit-required confined spaces.

c. Recommend that confined spaces that are large, or part of a continuous system such as a penstock, always be managed as permit-required as defined in the OSHA Confined Space Standard, and that such spaces always be monitored for hazardous atmospheres both prior to entry and continuously in areas where work is being performed.

d. Ensure that evacuation plans for penstocks that have only one egress point provide for alternative escape routes or refuge chambers.

e. Provide guidance for implementing a written confined space rescue plan. Address staging and methods of rescue for each designated permit space including whether a rescue team is required to stand by outside the space. Require that confined space rescue teams be standing by at the permit spaces where the hazards pose an immediate threat to life or health, including the hazard of a potential flammable atmosphere.

Southern California Painting and Drywall Industries Joint Apprenticeship and Training Committee

2008-01-I-CO-R18 Require that all journeyman painters who are employees and/or members have received safety training equivalent in content to that covered in the Joint Apprenticeship program. At a minimum, address confined space safety, safe handling of flammables, emergency response and rescue, and fire prevention.

2008-01-I-CO-R19 Include a safety knowledge and skills component to your journeyman and apprentice evaluation criteria.

BY THE

U.S. Chemical Safety and Hazard Investigation Board

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Date of Approval August 25, 2010

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APPENDIX A: INCIDENT TIMELINE

Date	Time	Detail
Summer 1964		Construction of upper dam and reservoir underway, as part of the Cabin Creek Pumped Storage Hydroelectric Project.
1967		Original coal tar-based epoxy coating applied in penstock.
September 20, 2000 - December 9, 2000		Initial inspection and evaluation of the penstock determines that the internal epoxy coating of the steel-lined section shows signs of deterioration, including blistering and cracking.
June 4, 2001		Xcel internal report on the 2000 inspection states that corrective action to repair the areas of deterioration must be implemented to prevent continued corrosion and unacceptable pitting damage.
September 25, 2001		Robison-Prezioso Bay Bridge project incident kills a private citizen.
January 4, 2002		Robison-Prezioso Bay Bridge project employee fatality incident.
2004		Xcel hires a contractor to explore the possibility of creating a permanent access to penstock, but the project is rejected due to insufficient time to obtain FERC approval. RPI interstate Experience Modification Rate (EMR) is 0.93.
~ October 2004		A decision is made to recoat the penstock during the 2004 outage as a result of a metallurgist's inspection, which notes that the interior liner is peeling up to the concrete section.
2005		RPI interstate EMR is 1.03
2006		2006 SSPC audit finds that RPI has "No documentation of craft-worker assessment." RPI interstate EMR is 1.28.
January 3, 2006		The KTA-Tator Coating inspection contractor submits proposal for the penstock recoating project to Xcel.
November 1, 2006		Xcel reviews the existing penstock recoating plan.
October 1, 2006		Xcel conducts "Safety and Health Hazard Assessment Survey," focusing on the abrasive blasting portion of the recoating project work, but not the risks of epoxy recoating work associated with using a solvent in a confined space.
2007		Robison-Prezioso, Inc. is renamed RPI Coating; the company is ranked the nation's seventh-largest specialty paint company based on revenues in 2005, according to Engineering News-Record.

January 16, 2007		The KTA-Tator coating assessment contractor contracts with Xcel to inspect and report on the quality of RPI's penstock re-coating work for 2007 penstock recoating project.
January 17, 2007		Xcel's internal hazard assessment of the penstock re-lining project identifies the penstock as having a confined space hazard.
Spring 2007		An Xcel civil engineer identifies "major items of concern" with the penstock recoating project, including a lack of an alternative exit.
April 2007		Xcel issues an RFP to multiple vendors to recoat the penstock. Proposal asserts that an Xcel project manager will be fully integrated into the contractor's safety program. Only one vendor meets criteria for successful completion of the job, but the vendor's cost estimate exceeds Xcel's anticipated budget.
June 2007		First bid submissions evaluated; one company meets criteria but cost estimate is $450,000 over Xcel's estimated budget; Xcel resubmits the project for additional bids.
July 11, 2007		Clear Creek County Fire Authority conducts an emergency drill at the Cabin Creek facility, rehearsing a fire response to the power production office facility; this drill does not involve the penstock or a confined space rescue.
Late July 2007		RPI and one other company meet the criteria for consideration as the potential recoating contractor; although the competing bidder is more technically qualified and RPI Coating's safety record is poor, RPI is selected due to cost.
August 27, 2007		RPI requests a copy of Xcel's Cabin Creek site confined space procedures from the penstock recoating project team leader and the Xcel Cabin Creek plant manager. Plant manager states information will be covered in contractor orientation.
Late August – mid September 2007		RPI contractors begin arriving at the Xcel Cabin Creek site.
September 4, 2007		KTA-Tator project engineer sends review of RPI coating application plan, project schedule, coating application procedures, and product data sheets for epoxy materials to the Xcel recoating project team leader. The Xcel project scheduler provides contractor orientation with an RPI foreman and five contractors (of the 14 RPI employees involved in the penstock work).The orientation form indicates that all contractors are trained for confined space entry and that MSDSs have been provided to Xcel plant management. RPI notifies the Xcel scheduler that the contractors will be using a "ketone" solvent to clean the sprayer inside the penstock.
September 5, 2007		Xcel and RPI Coating hold a "Preconstruction Meeting" where project-specific safety concerns are to be identified; however, the use of flammables within a confined space and the need for emergency response and rescue plans are not discussed. Xcel identifies RPI's high EMR rate during the meeting and requires RPI to take extra precautions and informs RPI that Xcel's Stop Work Policy will be enforced during the penstock recoating project.
September 4-9, 2007		The upper reservoir is dewatered.

September 10, 2007		An instructor from Southern California Painting and Drywall Industries (SCPDI) District 36 Training Center conducts a six-hour safety refresher training session pertaining to OSHA-required topics at the Xcel Cabin Creek site for nine of the 14 RPI industrial painters at the request of RPI's safety director. This training consists of watching safety videos on each topic and multiple-choice exams on the information; the training is general in nature and not tailored to all site-specific safety risks of the penstock work.
September 11-October 2, 2007		A number of confined space entry permits and air monitoring logs are completed by RPI that indicate that continuous air monitoring is required inside the penstock. Logs reveal that KTA-Tator and Xcel employees entered the penstock on several occasions to inspect and/or review RPI Coating's work progress.
September 12, 2007		110 gallons of MEK (two 55-gallon drums) delivered to Cabin Creek site. RPI conducted a test spray with the epoxy and MEK at Cabin Creek site; the Xcel principle engineer was present during this test spray.
September 15, 2007		RPI reports trouble with 480 volt power feed to equipment in the penstock. Xcel employees enter the penstock to troubleshoot the electrical equipment. Incorrect wiring is modified.
September 16, 2007		Entry into the penstock is delayed 2 hours due to high carbon monoxide (CO) levels. RPI experiences additional electrical service problems inside penstock. Foreman rewires an electrical spider box in the penstock for RPI Coating.
September 19, 2007		Xcel Cabin Creek personnel leave high bay fans on to ventilate errant CO from coming down penstock to hydroelectric plant's substation lower level.
September 21, 2007		RPI Coating begins sandblasting inside the penstock; the company is 5 days behind its tight 10-week schedule.
September 22, 2007		The Xcel Penstock Reline Project Manager observes RPI Coating conducting abrasive blasting inside the penstock and notes: "Work conditions inside the penstock are highly hazardous on many levels. In the best of conditions, the coating removal is dirty, nasty work." KTA-Tator conducts an initial pre-job hazard assessment of the penstock, noting that the MSDSs for all coatings and solvents used in the project are available. Inspector also notes that RPI and the Xcel penstock recoating project manager were advised on the MSDSs.
September 26, 2007		Xcel employees enter the penstock to perform welding on weep holes to stop leaks. The KTA-Tator inspector conducts a "Task Summary: Coating Observation Hold Points" inspection of the penstock interior. Inspection identifies the use of thinner as part of the coating materials mixing and pre-application process, and documents the necessity of using thinner/solvent to flush the sprayer system equipment (including hoses, nozzles, and the sprayer itself).

October 1, 2007	8:00 AM	Xcel personnel conduct a safety evaluation of RPI's sandblasting work inside penstock; no unsatisfactory items are noted.
	~12:00 PM	An Xcel welder enters with the RPI Coating foreman to begin welding around the leaking seep hole/cap in the penstock. The welder does not sign into the log book at the penstock's entrance.
October 2, 2007	Morning of	Sand-blasting activities, including hand sanding and grinding of the walls, are completed. RPI employees began the preparatory steps for applying the new coating onto the penstock interior. No special precautions are taken beyond those in place prior to starting the sandblasting operation.
	8:00 AM	Xcel welder completes welding job around the leaking seep hole/cap in the penstock.
	1:10 PM	RPI project supervisor and KTA-Tator inspector leave for lunch. RPI employees continue attempts to apply epoxy to the first 12-15 feet of the penstock's interior, but difficulties with the sprayer and epoxy mixture prevent satisfactory application.
	~1:55 PM	**A flash fire ignites at the sprayer in the immediate vicinity of the base hopper while the contractors flush the system with MEK solvent. This rapid fire catches one contractor's sleeve on fire and quickly engulfs a number of buckets of solvent located on and around the scaffold of the epoxy sprayer.**
	1:59 PM	A worker rapidly exits from the penstock access door and runs to notify the Xcel control board operator about the fire in the penstock.
	~2:00 PM	The Xcel employees at upper reservoir mushroom hear a "whoosh," followed by yelling, but what is being said is unintelligible.
	2:03 PM	Clear Creek County dispatch receives a 9-1-1 call from the Xcel control board operator regarding the fire and initiates emergency response.
	2:11 PM	The Clear Creek County Sheriff's officers' response vehicle arrives at the Cabin Creek site.
	2:20 PM	Xcel operator log book documents: "Emergency services w/o confined space fire training arrived. They have summoned a Denver team."
	2:22 PM	Additional emergency responders from various districts/units arrive at Cabin Creek site.
	2:25 PM	West Metro Rescue asked to respond to Cabin Creek site.
	2:30 PM	An RPI contractor retrieves and gives the MSDSs to the Georgetown Police Department. Henderson Mine Rescue team asked to respond to Cabin Creek site.
	~2:45 PM	Final radio communication from the trapped workers is received by emergency responders and co-workers.

	2:47 PM	A small group of responders and an RPI employee enter the penstock through the access door, travel up the penstock, but exit shortly thereafter due to the thick black smoke conditions.
	~3:00-3:15 pm	Xcel employees at the upper reservoir mushroom intake report seeing ash and flecks of burned material come out of the penstock.
	3:15 PM	SCBA oxygen tanks are dropped into mushroom upper end of penstock.
	3:25 PM	Residual smoke evident from penstock access door.
	3:30:37 PM	A growing smoke cloud is evident around the penstock access door.
	3:40 PM	West Metro Fire Rescue arrives at Cabin Creek.
	3:54 PM	A cloud of smoke remains evident in front of the penstock access door.
	4:10 PM	Henderson Mine Rescue arrives at Cabin Creek
	4:45 PM	Emergency responders wearing SCBA enter the penstock
	5:35 PM	Emergency responders on site receive the first order from Incident Command to fight/extinguish the fire; Henderson Mine team to enter.
	5:45 PM	Henderson Mine team enters the penstock through the access door to check air quality, size up the fire, and locate/rescue the trapped contractors.
	~9:00 PM	Xcel personnel allowed back into the Cabin Creek substation building, as air monitoring results are found to be at safe levels.
October 3, 2007	2:00 PM	Fatally injured workers are removed from the penstock.
	8:00 PM	The incident scene is released back to Xcel.

APPENDIX B: REGULATORY HISTORY OF RPI COATING, INC.

OSHA Inspection and Citation History
Robison-Prezioso Inc. (RPI Coating, Inc.)
5/27/88 - 12/31/2008

Date	Inspection Number	Location	State	Inspection Type	Emphasis Program	Citation Summary	Initial Penalty	Final Penalty	Resolution
10/7/2008	312279870	Overton	NV	Planned - Safety		OSHA 300 log errors	$0	$0	Closed
5/14/2008	311643977	Jean	NV	Referral - Health		None			Closed
11/5/2007	311634307	Las Vegas	NV	Compliant - Health	Special - Construction	None	$0	$0	Closed
10/2/2007	310470034	Georgetown	CO	Accident - Safety; 5 fatalities	National - Lead; Special - Electrical; Special - Fall from Height; Special - Lead; Special - Powered Industrial	Working surfaces; flammable liquids; respirators; confined space; welding; electrical wiring; hazard communication	$845,100		Contested
12/29/2005	125529636	Santa Rosa	CA	Planned - Safety	Special - Construction	No ROPS or seatbelt installed on equipment	$150	$150	Closed
10/13/2005	110569803	Davis Monthan AFB	AZ	Program Related[1] - Safety		No body belt worn on vehicle-mounted rotating work platform	$1,375	$1,375	Formal Settlement Agreement (FSA); Closed

[1] A Program Related inspection is one where OSHA conducted an unannounced programmed inspection at an establishment and also inspected RPI, who was working at the establishment as a contractor.

OSHA Inspection and Citation History
Robison-Prezioso Inc. (RPI Coating, Inc.)
5/27/88 - 12/31/2008

Date	Inspection Number	Location	State	Inspection Type	Emphasis Program	Citation Summary	Initial Penalty	Final Penalty	Resolution
10/5/2005	125529289	Santa Rosa	CA	Planned - Safety	Special - Construction	Flaggers not used at a construction site when warning signs and barricades could not be used to control traffic	$150	$150	Closed
9/27/2002	305639262	Vantage Bridge I-90	WA	Complaint - Health		None	$0	$0	Closed
9/23/2002	305551491	Vantage Bridge I-90	WA	Planned - Safety	Local - Construction	No written fall protection work plan; No fall restraints/fall arrest systems;	$600	$600	State Decision
5/10/2002	300891090	San Francisco	CA	Complaint - Health	National - Lead; Special - Construction	Cadmium - Improper removal and storage practices	$13,500	$280	FSA; 24 citations deleted; closed
1/4/2002	300890555	San Francisco	CA	Accident - Safety; 1 fatal; 4 hospitalized		Improper scaffold design; Rated load capacity exceeded on suspended scaffold; Platform on suspended scaffold not wide scaffold not wide enough or missing a guardrail; Improper erection or dismantling of scaffolds; Scaffold overloaded	$41,400	$41,400	Open
9/25/2001	300890100	San Francisco	CA	Accident - Safety	Special - Construction	Framed panels not securely anchored, guyed, or braced; Machinery and equipment components not designed, secured, or covered to minimize hazards caused by breakage, release of mechanical energy (e.g., broken	$18,000	$18,000	Open

OSHA Inspection and Citation History Robison-Prezioso Inc. (RPI Coating, Inc.) 5/27/88 - 12/31/2008									
Date	**Inspection Number**	**Location**	**State**	**Inspection Type**	**Emphasis Program**	**Citation Summary**	**Initial Penalty**	**Final Penalty**	**Resolution**
						springs), or loosening and falling			
6/19/2001	304706450	Cape Canaveral AFS	FL	Program Related - Safety	Local - Fall, FLCare; Special - Construction, Construction Fatalities	No medical services/first aid available; Unsafe abrasive blasting respirators; **Flammable liquid dispensing units not protected against collision damage; "No smoking" signs were not posted in flammable liquid areas**; Spinner knobs were attached on steering wheels of equipment; Industrial truck did not meet ANSI standard requirements	$9,375	$5,250	FSA; Closed
4/23/2001	304422132	Henderson	NV	Planned - Safety	Special - Construction	None	$0	$0	Closed
4/23/2001	304425416	Henderson	NV	Planned - Health	Special - Construction	None	$0	$0	Closed
3/20/2001	126030634	Coalinga	CA	Accident - Safety; 1 hospitalized		Injury not immediately reported to Cal-OSHA; Forklift operating rules not enforced	$935	$935	Closed

OSHA Inspection and Citation History
Robison-Prezioso Inc. (RPI Coating, Inc.)
5/27/88 - 12/31/2008

Date	Inspection Number	Location	State	Inspection Type	Emphasis Program	Citation Summary	Initial Penalty	Final Penalty	Resolution
3/7/2001	125637058	San Francisco	CA	Planned - Health	National - Lead; Special - Construction	Cadmium - No regulated area or demarcation, no monitoring, prohibited activities conducted, no medical for respirator use, torn PPE not replaced; Machinery not maintained in safe condition; Separate shower facilities not available for females; Safety glasses interfere with respirator; Compressed gas cylinder not secured while being transported; Pinch points on machinery not guarded	$83,925	$20,250	FSA; 19 violations deleted; open
2/27/2001	125619239	San Francisco	CA	Accident - Safety; 1 hospitalized		Ramps/Runways not 20-inches wide; Metal scaffolds - Railings and planks not secured; Improper anchorages for personal fall protection equipment	$26,100	$18,000	FSA; One item deleted; Closed
10/11/2000	300888401	Bay Bridge - Lower Deck, San Francisco	CA	Accident - Safety		None	$0	$0	Closed
12/17/1999	120266846	Pasadena	CA	Complaint - Health	Local – Regulated carcingen	None	$0	$0	Closed
5/28/1999	302528437	Spring Mountain Overpass, Las Vegas	NV	Complaint - Safety		None	$0	$0	Closed

OSHA Inspection and Citation History Robison-Prezioso Inc. (RPI Coating, Inc.) 5/27/88 - 12/31/2008									
Date	**Inspection Number**	**Location**	**State**	**Inspection Type**	**Emphasis Program**	**Citation Summary**	**Initial Penalty**	**Final Penalty**	**Resolution**
3/2/1999	119737997	Yeruba Buena Island, San Francisco	CA	Planned - Safety	Local - Regionp1[2]	None	$0	$0	Closed
12/28/1998	11967461	Yeruba Buena Island, San Francisco	CA	Planned - Health		Cadmium - No initial monitoring; Respirators not worn; Torn PPE not replaced; Fall protection - Positioning systems not used	$2,495	$1,685	FSA; Closed
10/13/1998	302524384	Las Vegas	NV	Planned - Safety		**More than 25 gallons of flammable or combustible liquids stored in a room outside of an approved storage cabinet; No portable fire extinguisher, having a rating of not less than 20-B units, located outside of, but not more than 10 feet from, the door opening into any room used for storage of more than 60 gallons of flammable or combustible liquids; Flammable liquids were used where there were open flames or other sources of ignition within 50 feet of the operation**	$375	$375	Review Commission Decision

[2] This is a code for a state of California local emphasis program.

OSHA Inspection and Citation History Robison-Prezioso Inc. (RPI Coating, Inc.) 5/27/88 - 12/31/2008									
Date	**Inspection Number**	**Location**	**State**	**Inspection Type**	**Emphasis Program**	**Citation Summary**	**Initial Penalty**	**Final Penalty**	**Resolution**
7/15/1998	126141324	Oxnard	CA	UnProgrammed Related[3] - Health		Cadmium	$185	$185	FSA; Closed
1/8/1998	115218703	Highway 17N, Soap Lake	WA	Complaint - Health		None	$0	$0	Closed
5/28/1997	125658047	Los Vacqueros Dam, Brentwood	CA	Planned - No Inspection	Local-Tunnel	None			
5/27/1997	126207984	Santa Maria	CA	Accident - Safety; 1 hospitalized		Improper portable wooden ladders; Injuries not immediately reported; no Injury and Illness Prevention Program	$150	$150	Closed
5/23/1997	126053537	Los Angeles	CA	Complaint - Health		No Injury and Illness Prevention Program	$185	$185	Closed
1/17/1997	115236564	Highway 17N, Soap Lake	WA	Complaint - No Inspection/Process Inactive		None			

[3] An UnProgrammed Related inspection is one where OSHA was conducting a fatality, compliant, or referral inspection at an establishment and also inspected RPI, who was working at the establishment as a contractor.

OSHA Inspection and Citation History Robison-Prezioso Inc. (RPI Coating, Inc.) 5/27/88 - 12/31/2008									
Date	**Inspection Number**	**Location**	**State**	**Inspection Type**	**Emphasis Program**	**Citation Summary**	**Initial Penalty**	**Final Penalty**	**Resolution**
10/11/1996	119772846	Los Vacqueros Dam, Brentwood	CA	Planned - No Inspection	Local-Tunnel	None			
2/5/1996	119874667	Los Angeles	CA	UnProgrammed Related - Health		None	$0	$0	Closed
9/26/1995	11966949	Rodeo	CA	UnProgrammed Related - Health		None			
5/9/1995	112130059	Carson	CA	Accident; 1 hospitalized		No training on aerial lifts; Foundation soil not maintained in safe condition	$5,525	$600	FSA; 1 citation deleted
3/10/1994	123834228	Tracey	NV	Planned - Safety		Hazard communication - improper labeling, MSDS, training; no respirators	$3,000	$3,000	FSA; Closed
12/1/1993	112173331	Calabasas	CA	UnProgrammed Related - Health		No monitoring for hazardous substances (deleted); No eyewash	$900	$225	Administrative Law Judge (ALJ) Decision; 1 citation deleted; Closed
4/8/1993	12386675	Las Vegas	NV	Planned - Safety		**No bonding/grounding when transferring flammable liquids between containers**; Containers not provided for waste rags; Improper	$125	$125	State Decision; Closed

OSHA Inspection and Citation History Robison-Prezioso Inc. (RPI Coating, Inc.) 5/27/88 - 12/31/2008									
Date	**Inspection Number**	**Location**	**State**	**Inspection Type**	**Emphasis Program**	**Citation Summary**	**Initial Penalty**	**Final Penalty**	**Resolution**
						temporary wiring; Unapproved forklift			
9/24/1992	119989457	Cardiff	CA	Complaint - Health		Improper temporary wiring, ladders, floor openings	$2,770	$2,475	ALJ Decision; Closed
9/23/1992	119988425	Carlsbad	CA	Complaint - Health - No Inspection		None			
8/7/1992	107108474	Alyeska Pipeline Marine Terminal, Valdez	AK	Compliant - Safety		Improper air compressors for abrasive blasting; HAZCOM labeling and MSDSs; No first aid training; No washing facilities; No respirators; Temporary heaters too close to combustibles; Improper electrical wiring; No fall protection	$14,300	$4,054	Informal Settlement; 4 citations deleted; Closed
7/7/1992	114570963	Henderson	NV	Planned - Safety		Smoking not prohibited where flammable liquids are present; Hazard communication; **Flammable liquids stored or transferred in unapproved containers**; Respirators; Air powered tools	$4,650	$2,325	Informal Settlement; Citation Amendments; Closed
6/9/1992	11566424	Phoenix	AZ	Complaint - Health		None			
6/9/1992	115561169	Phoenix	AZ	Complaint - Safety		None			

OSHA Inspection and Citation History Robison-Prezioso Inc. (RPI Coating, Inc.) 5/27/88 - 12/31/2008									
Date	**Inspection Number**	**Location**	**State**	**Inspection Type**	**Emphasis Program**	**Citation Summary**	**Initial Penalty**	**Final Penalty**	**Resolution**
5/5/1992	112051784	Lancaster	CA	Accident; 2 hospitalized		No head protection; Improper rolling platform scaffold planks and construction	$2,250	$2,250	Closed
4/3/1992	111872867	Playa Del Ray	CA	Accident - 1 Hospitalized		Portable ladders not secured	$0	$0	ALJ Decision; Closed
1/10/1992	11199040	Playa Del Ray	CA	UnProgrammed Related - Safety		Personal Fall Protection not used	$600	$600	ALJ Decision; Closed
10/30/1991	112088117	Carson	CA	Program Related - Safety	Local - Refinery	Respiratory protection not used	$0	$0	Closed
8/8/1991	111994851	Oakley	CA	UnProgrammed Related - Safety		Safe Code of Practices not posted	$0	$0	Closed
5/16/1991	112223318	Goleta	CA	UnProgrammed Related - Health		Respiratory protection no used	$0	$0	Closed
4/24/1991	111979316	Fountain Valley	CA	UnProgrammed Related - Safety		None			
4/5/1991	111869483	Playa Del Ray	CA	UnProgrammed Related -Safety		None			
1/7/1991	112113501	Playa Del Ray	CA	UnProgrammed Related - Safety		**Flammable vapors were not controlled**; Flammable liquid containers not marked; No portable fire extinguisher outside flammable storage room; Open flames not prohibited in flammable liquid	$0	$0	Closed

OSHA Inspection and Citation History Robison-Prezioso Inc. (RPI Coating, Inc.) 5/27/88 - 12/31/2008									
Date	**Inspection Number**	**Location**	**State**	**Inspection Type**	**Emphasis Program**	**Citation Summary**	**Initial Penalty**	**Final Penalty**	**Resolution**
						storage rooms			
12/4/1990	112117767	Playa Del Ray	CA	UnProgrammed Related - Safety		Improper temporary stairs	$0	$0	Closed
10/26/1990	112082862	Wilmington	CA	Program Related - Safety	Local - Refinery	Lack of suitable eye and face protection; Hazard communication	$0	$0	Closed
5/27/1988	106775455	New Hall	CA	UnProgrammed Related - Safety		Respirators; PPE; **Flammable liquids in unapproved containers**	$540	$540	Closed

APPENDIX C: INVENTORY OF FLAMMABLE AND COMBUSTIBLE MATERIAL IN PENSTOCK

Flammable and Combustible Material in Penstock	Distance from Sprayer	Number of buckets[119]
One (2-gal) bucket with MEK, heavily melted at scaffolding[120]	Between 79 ft and 91 ft	1
Three 5-gallon buckets of epoxy/MEK mixture (~12 gallons, of which ~5 gallons were MEK) on penstock floor, adjacent to sprayer stage	On floor, adjacent to sprayer	3
Three buckets of MEK (~11-12 gallons) and at least eight buckets of epoxy (epoxy buckets completely melted and, therefore, unable to determine if base or hardener; only handles survived fire)	On stage with sprayer	11
Eight (5-gal) buckets of base; three (5-gal) additional melted buckets of base; one (2-gal) bucket of hardener; and indeterminate number of completely melted buckets	13 ft, 9 3/8 in	12+
Twelve (2-gal) buckets of hardener; indeterminate number of completely melted buckets	101 ft, 1 in	12+
Ten (5-gal) buckets of base; 20 (2-gal) buckets of hardener	172 ft, 11 7/8 in	30
Four (2-gal) buckets of hardener	228 ft, 3 ¾ in	4
Ten (5-gal) buckets of base at 500' mark in penstock	380 ft, 3 5/16 in	10
Nineteen (5-gal) buckets of base	532 ft, 2 7/8 in	19
TOTAL NUMBER OF BUCKETS INSIDE PENSTOCK		**102+**

[119] The number of buckets, instead of actual volumetric quantity, of the epoxy and MEK are provided here because a number of the buckets were destroyed in the fire; only the wire handles of these buckets remained post-incident. As a result, the CSB could not determine if the handles belongs to 2-gallon or 5-gallon buckets.

[120] The exact location of this bucket is unknown because it was moved while victims were being removed; distance estimate is based on CBI initial entry report that buckets were located on and under scaffolding, and knowledge that scaffolding was 12 feet long, adjacent to the west bulkhead.

APPENDIX D: EVALUATION OF IGNITION SOURCES

As Section 5.2.2 explains, numerous potential ignition sources existed in the immediate area of the sprayer at the time of the fire. Below is a detailed analysis of each potential ignition source the CSB considered. Supporting evidence for each analysis is based on examination of physical evidence, interviews with witnesses, tests on equipment preserved from the scene as evidence, and the physical and chemical properties of the materials involved at the time of the incident based on local environmental conditions inside the penstock. In certain cases, conflicting witness statements and extensive fire damage to the equipment made it impossible for the CSB to determine events and/or exact equipment configurations just before the fire; as a result, the CSB could not positively rule out several potential ignition sources due to lack of evidence.

D.1 Static Ignition of Explosive MEK Vapor-Air Mixture inside Sprayer Base Hopper

The CSB concluded that static electricity generated while flushing MEK in the base hopper was the most likely source of ignition. One worker testified that he was looking into the base hopper and saw the initial flash of MEK near the bottom of the hopper. The worker stated that he was holding a 3/8-inch diameter braided nylon, non-metal reinforced, hose with a metal JIC[121] swivel connector at the end, close to the inside wall of the metal hopper. This was about 6 inches (15 centimeters) from the top and about 1foot (30 centimeters) above the MEK surface. The hopper contained a 3-inch (8-centimeter) depth of MEK, or about one-half gallon (2 liters). The MEK was being circulated from the base hopper through the sprayer's air-driven piston pump, electric heater, piping, and hose, back into the base hopper to flush remaining epoxy particles from the sprayer.

[121] JIC stands for Joint Industrial Council, which revised specifications for these types of connectors in the 1960s.

Assuming that the electric heater for the base hopper on the sprayer was not operating and the temperature of the MEK was the same temperature as the penstock[122] (approximately 47-53 °F or 8-12 °C), the CSB determined that the hydrocarbon-air mixture in the region where the journeyman painter was holding the swivel connector was likely near its most easily ignitable composition (Appendix E). Once ignited, the brightest flame would have appeared in the bottom of the base hopper where the hydrocarbon-air mixture was optimal for combustion. Ignition inside the base hopper would have produced a rapid deflagration with an outwardly directed pressure wave, thus producing a "fireball." This scenario matches descriptions given by the workers who saw the initial flash.

After the incident, the JIC swivel and the base hopper hose could not be located. However, the fitting on the other end of the base hopper hose was still attached to the valve on the sprayer. This fitting had an internal diameter of 0.117 inches (0.297 centimeters). In addition, remnants were found of an inner woven metal sheath that had belonged to the hose used to circulate MEK in the hardener hopper. The lack of a similar metal sheath on the base hopper hose led the CSB to conclude that the base hopper hose was most likely constructed from a non-conductive material, which was likely consumed by the fire.

Based on testimonial evidence that the pump was being operated with an air supply pressure of 10-15 psig (0.7-1.0 barg) and using the performance curves for the 56:1 King piston pump supplied by the sprayer manufacturer, the CSB estimated a maximum liquid flow rate of 4-5 gallons (15-19 liters) per minute during circulation. The maximum flow velocity of MEK through the JIC swivel was then estimated to be 12-16 feet (3.7-4.9 meters) per second. This estimate neglects the pressure drop from the King Pump to the JIC swivel connector outlet by extrapolating the pump curves to ambient pressure. Frictional losses would have occurred in the heater, the quarter-turn valve, piping, hoses, and the JIC swivel connector

[122] The air temperature inside the penstock was fairly constant, as demonstrated by daily temperature readings taken by the KTA-Tator inspector from the beginning of the project.

itself. Since the MEK was being used to clean residual epoxy base resin from the system, it is plausible that the narrowest parts of the system (i.e., the quarter-turn valve and JIC swivel connector) could have, at least periodically, become partly blocked with resin. Therefore, a range of different flow velocities, up to a maximum of 16 feet (4.9 meters) per second, was possible during circulation, accompanied by a range of different pressures at the JIC swivel connector, depending on its orientation and any additional restrictions created by resin blockage.

The JIC swivel connector operated as a spray nozzle with pulsed flow produced by the King piston pump. Consequently, MEK liquid flowing through the JIC swivel connector would have broken up into droplets. This shearing action would have resulted in electrical charge separation with respect to the metal connector, leaving a net charge on the spray and an equal but opposite charge on the ungrounded JIC swivel connector.

The potential for static charges to accumulate on the isolated JIC swivel connector increases as the length of the hose increases and as the hose diameter decreases. The electrical resistance is proportional to hose length and inversely proportional to the hose cross-sectional area. Static charge accumulation in the swivel also becomes more likely as the MEK velocity through the swivel end connector increases, as the rate of charge separation increases, and as the operation more closely resembles a spray nozzle. Provided the liquid breaks up into a spray, the only continuous electrical path from the JIC swivel connector to ground is through the column of MEK liquid in the hose. Since circulation was carried out using a King piston pump, pulsation spraying increases the probability of a non-continuous outlet jet. Charging may have been further increased if suspended epoxy particles were present in the MEK, especially if these particles created flow restrictions at narrow points in the valve and/or JIC swivel.

The following analysis estimates the potential “spark energy” that could be stored by an isolated JIC end connector and demonstrates that the spark energy was sufficient to ignite the MEK vapor-air mixture inside the base hopper. This discussion assumes that the resistance of the hose is infinite (i.e., constructed of a non-conductive material) compared to that of the column of conductive MEK contained within it; that the MEK was ejected as a pulsating spray jet offering no continuous conductive path to ground; and that the JIC swivel connector was held close to the hopper wall creating a potential spark gap of a few millimeters:

- The CSB calculated that the Minimum Ignition Energy (MIE) of an optimum MEK vapor-air mixture under penstock conditions to be about 0.5 mJ (Appendix E).
- Although the capacitance of the isolated JIC swivel end connector might be only 3-5 pico Farads (pF), which is typical for a small metal object, this would have increased several-fold by coupled capacitance with both the hopper wall and journeyman painter's gloved hand. The estimated range of capacitance ("C") is 7-15 pF, although larger values are possible.[123]
- Using the formula $W = ½(CV^2)$ to describe the energy of charged capacitors, where W is the stored energy (Joules), C is the estimated capacitance (Farads), and V is the spark voltage (Volts), the voltage required to yield an incendiary spark of 0.5 mJ is in the range 8,160-12,000 volts.
- The resistance to ground (R) via the column of conductive MEK contained within the hose is determined by the formula $R = \rho L/A$, where ρ is the resistivity of MEK (approximately 1×10^5 ohm-meters); L is the length of the hose (7.0 feet or 2.1 meters); and A is the internal cross sectional area of the hose (approximately 31.7 mm^2 or 3.17×10^{-5} m^2). If these values are substituted, the resistance to ground via the hose is approximately 6.6×10^9 ohms (or on the order of 10^{10} ohms).

[123] An experimental simulation would be needed to obtain a more accurate value.

- Using Ohm's Law (I = V/R), where I is the charging current (Ampere); V is the required voltage of the isolated end connector (V = 8,160-12,000 volts); and R is the ground resistance through the MEK in the hose (6.6×10^9 ohms), the required charging current is in the range of 1.2-1.8 microamperes (µA). This is the charging current needed to support a voltage of 8,160-12,000 volts on the swivel connector given the leakage resistance of 6.6×10^9 ohms back to ground through the MEK in the hose.

- The estimated voltage of 8,160-12,000 volts could have produced a spark several millimeters long. Spark energies of 0.5 mJ are very small (roughly 1 percent of an automobile spark plug) and unlikely to be observed, even if a succession of such sparks were to occur.

- A circuit containing a resistor and capacitor is called an "RC" circuit. In this type of a circuit, current varies with time. The RC time constant of the JIC swivel is about 0.1 seconds—this is the product of resistance to ground (on the order of 10^{10} ohm) and capacitance (on the order of 10^{-11} F). The connector would be capable of charging to its maximum voltage in about five time constants, or one-half second. Sparks could therefore have occurred on a frequency of about two per second given these assumptions. Incendiary sparking would have been prevented by gaps much larger than a few millimeters or by a continuous stream of liquid from the swivel to the wall. The worst case (most frequent sparking) is for the liquid to continuously break up into spray and the swivel to be held about 0.12 inches (3 millimeters) from the hopper wall and spraying downwards. This is consistent with journeyman painter's testimony of how the hose was positioned to minimize splashing the MEK inside the base hopper.

High-velocity MEK spraying through an isolated JIC swivel connector (i.e., "nozzle") with a charging current of 1.2-1.8 µA could have accumulated sufficient stored energy to produce a series of incendiary sparks capable of igniting the MEK vapor-air mixture (i.e., having at least 0.5 mJ energy). The ignition probability would have been greatly increased by the large number of sparks possible during circulation, plus the variety of charging conditions, spark gap geometries, and mixture compositions involved.

Although the journeyman painter was not electrically grounded, the CSB considers it unlikely that static ignition occurred from a "doorknob type" spark between the journeyman painter and the sprayer. The CSB also considers it unlikely that electrical charging of the journeyman painter's Tyvek® coveralls[124] could have resulted in brush static discharges because evidence indicates that he was essentially stationary on the sprayer platform during the circulation operation. However, the painter might have become charged while holding the circulation swivel nozzle, which is considered a variation of this ignition source scenario. Had the painter's glove had a hole, notably in the thumb or index finger holding the nozzle, he could have become charged to many kilovolts while the nozzle was not contacting the hopper wall. This would have allowed a spark to subsequently occur once the nozzle approached the hopper wall. Assuming his capacitance was 200 pF,[125] an incendiary spark would require a voltage of 2.2 kV and a charging current of about 0.33 µA. Accordingly, there is less than an order-of-magnitude reduction in the charging current requirement to give an incendiary static spark and this variation has little practical importance.

Lundquist et al. (1975) observed charging currents up to about 6 µA during airless paint spraying of conductive liquids. Although the MEK circulation operation was being carried out at much lower pressures and with a larger nozzle diameter than those used for airless paint spraying, the Lundquist et al. work shows that conductive liquids such as alcohols produce higher charging currents than less conductive liquids and that larger diameter nozzles and higher pressures (i.e., higher liquid velocities) produce higher charging currents. Their article implies that charging currents vary widely with conditions,

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[124] The manufacturer of Tyvek coveralls cautions users against wearing this type of protective clothing in flammable or explosive atmospheres as doing so can generate static.

[125] 200 pF is frequently used as an average value for the capacitance of a person (Britton, 1999, p. 44).

and overall, supports the static charging scenario, although the magnitude of the charging current would need to be resolved experimentally. The need for proper grounding of paint spray nozzles is stressed in the Lundquist article. In addition, NFPA 77 (2007), the operating manual for the sprayer, and even RPI's safety program, contain safety warnings about proper grounding of equipment and the need to use conductive hoses.

D.2 Stray Current Ignition of Explosive MEK Vapor-Air Mixture inside the Sprayer Base Hopper

Some RPI workers' statements reveal that a dimming of the lights at the work area inside the penstock nearly coincided with the initial flash of the fire. These lights were powered from PDC 3, the power distribution center closest to the sprayer. PDC 3 also powered the 240-volt heaters on the pump outlets. During interviews with the CSB, these workers associated the dimming lights with the base heater coming on, but the CSB found no other evidence to support this. It can be inferred only that the voltage supplying the lights suddenly dropping was caused by increased power load as a result of the base heater turning on. The dimming lights could equally well have been caused by events outside the penstock. Power distribution center PDC 3 was preserved as evidence and examined closely by the CSB and other parties at an offsite location; no evidence of internal ignition (such as shorting) was found inside. However, the examination did reveal that the 240-volt power supply for the heaters was wired with a three, rather than a four, -prong connector. Thus, there was no ground connection in the circuit and the sprayer was operated with a floating neutral.[126] Although the sprayer was equipped with an independent

[126] A floating neutral means no neutral-to-ground bond in the electrical distribution system, which causes the neutral conductor to "float," or lose its reference to ground. Should the loading become unbalanced or an electrical short occur, the phase voltages fluctuate severely. This spider box had been damaged as a result of electrical problems early in the recoating project and repaired by an RPI employee. This individual was not a licensed electrician and lacked training certifications to perform electrical work.

grounding wire, the ground wire was not connected to any ground point when it was examined after the incident.

At the time of the flash, two spray hoses (one containing the base, the other the hardener) were attached to the sprayer, each going out to the metal mixing block. While preparing the spraying equipment inside the penstock, an apprentice painter stated that he saw a series of “sparks” jumping from the sprayer unit to one of the spray hoses when he connected it with a crescent wrench, implying faulty bonding in the spray hose. The CSB physically examined the spray hoses after the fire. Both hoses were metal-reinforced and thus, should have had electrical continuity to the mixing block, although no continuity measurements could be made due to fire damage. These sparks may have been caused by a stray current arc between the floating neutral of the sprayer chassis and the grounded metal hose connector. A ground path was likely provided, via the metal reinforcement sheath inside the hose, to the metal mixing block lying on the steel tunnel floor.

Grounding via the spray hoses to the mixing block is likely, but required the mixing block to have been in good electrical contact with the floor of the steel tunnel. The CSB noted that the position of the box on the drain pipe may have produced only intermittent contact grounding. Similarly, grounding via a spray wand requires electrical continuity through the mixing block out to the spray wand, which would also need to be in electrical contact with the steel tunnel. After the incident, the spray wands were found laying on the wood deck platform of the sprayer scaffold, so they were not grounded. The CSB concluded that at the time of the flash, the sprayer may have been grounded, but it is unlikely that the sprayer was reliably grounded.

Assuming that current was flowing to ground from the floating neutral connection, different metal components of the sprayer would have been at slightly different voltages, depending on the impedances between the components. Thus, a change in load on the 240-volt supply, caused by a sudden voltage drop at PDC 3 (resulting in the observed dimming of the lights), may have produced a change in the floating neutral voltage on the sprayer chassis. The outcome may have been an electrical arc caused by a high voltage transient between the base hopper and the metal nozzle on the circulation hose physically held inside the base hopper by the journeyman painter. An arc could have occurred during contact/separation between the nozzle and the hopper wall. However, the use of a non-conductive hose (Section D.1) rules out a stray current arc as the ignition source.

D.3 Ignition of Explosive MEK Vapor-Air Mixture by Halogen Lights atop the Sprayer

The sprayer unit was mounted on a wheeled cart sitting on a wheeled portable tube and coupler scaffold positioned about 100 feet (30 meters) from a plywood bulkhead that had been erected to block off the steel section of penstock. The only source of illumination for the workers on the scaffold[127] on which the sprayer was sitting was a dual fixture halogen light assembly. Based on examination of physical evidence[128] and employee statements, the CSB determined that the halogen light assembly was placed on top of the sprayer pumps. Each halogen light fixture contained two 300-watt halogen bulbs. The CSB concluded that neither light had been equipped with a glass lens; witness testimony substaintiated the lack of glass lenses and insufficient glass residue was found in the area after the fire to account for them.[129] The lamps were swivel-mounted on an assembly and could be oriented to point down. The base and hardener hoppers were situated below and to either side of the sprayer, with the top of each hopper approximately 25 inches (64 centimeters) from the nearest bulb, depending on the lamp orientation.

As worker statements (Section D.1) place the initial flash of the MEK vapor-air mixture inside the base hopper, ignition of a flammable (i.e., greater than LEL) MEK vapor-air mixture in the atmosphere by hot

[127] A second scaffold, positioned near the west bulkhead, had explosion-proof lights mounted to it to provide illumination for the two painters applying the epoxy to the penstock walls.

[128] The charred and melted remains of the halogen light were found on top of the sprayer pumps after the incident.

[129] The only remains of glass found in the fire debris were identified as coming from the sprayer control panel.

halogen lights, followed by an unobserved flashback into the base hopper, is possible, but considered unlikely. One of the experienced painting contractors told the CSB that the explosion-proof light on the scaffold dimmed, which he caught out of the corner of his eye while looking down primarily into the base hopper to ensure that the MEK being dispensed from the hose was not splashing – and then he saw the flash inside the base hopper. During this short period of distraction, it may not have been possible for the contractor to discern flashback from an ignition source outside the hopper. Flashback of a lean flame would have occurred in just a few seconds, and the flame would likely have been bluish. However, the CSB considers it unlikely that the contractor would not have seen the flashback from the location of the halogen lamps.

As discussed in Section D.1, it is also unlikely that an optimum vapor-air mixture (approximately 5.5 volume percent MEK) would have existed at the elevation of the halogen lights unless the base heater was operating. It is possible that a flammable mixture (>1.8 volume percent MEK) migrated by convection to the location of the halogen lights, if air ventilation was minimal, but a mixture near the LEL would have been more difficult to ignite. The work area was provided with forced, clean air ventilation conveyed through a 20-inch (51-centimeter) diameter plastic duct, magnetically attached to the metal wall of the penstock near the floor. It is unknown whether there was any appreciable air movement in the zone between the hoppers and halogen lights. The lights were located approximately at the axis of the 12-foot (3.7-meter) diameter tunnel. Assuming the air flow from the duct was directed toward the bulkhead at the time of the incident, the flow velocity back toward the tunnel entry would have been slow; the average upstream velocity in the penstock would be reduced by a factor of approximately 52 relative to the duct outlet velocity. Air velocity would have been highly variable across the tunnel at the location of the sprayer unit, and additional evidence suggests that a stagnation region may have existed on the upstream side of the unit. After using MEK to clean the spray wands on the scaffold near the west bulkhead, one of the two contractors at the bulkhead left the work area to get a fan due to the buildup of MEK “fumes.” He told the CSB that, as he squeezed past the scaffold holding the sprayer, there was “no air movement at all” in the vicinity of the sprayer.

Since the MEK was being sprayed into the hopper at about 12-16 feet (3.7-4.9 meters) per second, it is possible that some liquid mist would have migrated toward the lamps by convection, increasing the overall fuel concentration and/or that some splashing of coarse droplets occurred (Section D.3.3). However, ignition of the MEK vapor-air mixture at the halogen lamps would have produced an unconfined flash fire centered at the contractor’s head, rather than a deflagration inside the base hopper that propagated toward him.

While an eyewitness statement indicates that the base heater was turned off, this would not rule out the possibility of a sudden catastrophic failure of the base heater thermostat. If the 3.4 kW electric heater did come on, causing the observed dimming of the lights, the MEK temperature could have increased very rapidly. A malfunctioning thermostat may have led to unregulated heating; the set point of 95 ºF (35 °C) for the base epoxy corresponded to a level of 5.5 on the thermostat dial, which had a scale of 1-9. Under penstock conditions, MEK boils at 154 ºF (68 °C). Only a small volume of MEK was in the lines between the heater and the end of the hose. It is plausible that this volume was heated sufficiently to convect “easily ignitable” concentrations of vapor up to the halogen lights. For this to occur, the entire volume of MEK in the hopper would not have had to have been heated to the same temperature, since heated liquid would have been sprayed over a large area inside the hopper, creating a large surface for evaporation. However, this scenario represents a great deal of inference from the fact that the lights dimmed just before the flash and is inconsistent with eyewitness accounts that the initial flash was inside the base hopper. Since the thermostat was destroyed by the fire, the CSB cannot rule out the possibility that the thermostat failed catastrophically.

D.3.1 Ignition Caused by Halogen Lamps

The CSB also evaluated four distinct sub-cases involving ignition by halogen lamps.

D.3.1.1 Ignition Caused by Halogen Bulb Breakage

Halogen bulbs can break spontaneously and explode, due to the pressurized gas inside. Bulb breakage can be caused by contamination of the quartz surface, such as by a fingerprint, or via halide migration (Babrauskas, 2003). The internal filament of a halogen bulb can operate at 5,072 °F (2,800 ºC) with somewhat lower temperatures on the support. The inside bulb wall temperature may be around 1,382 °F (750 ºC) (Cayless & Marsden, 1983). These temperatures certainly would have been capable of igniting an explosive MEK vapor-air mixture. In the current case, bulb breakage might have been attributed to excessive vibration from the pumps or impact of MEK droplets sprayed from the hoppers. A portion of a hot filament from a bulb could have even fallen into the base hopper. However, the CSB ruled out halogen bulb breakage as a potential ignition source, when intact bulbs from both halogen lamp fixtures were found still mounted in their ceramic housings on top of the sprayer after the fire. All the bulbs were covered in soot, but that can be attributed to rich combustion of MEK during the fire.

D.3.1.2 Ignition by Bulb Terminal Arcing

In this scenario, a loose electrical connection at one end of a halogen bulb would periodically arc at the spring contact fitting. This arcing could be exacerbated by vibration from the pump fixture on which the lamps were positioned. It is unlikely a standard torque was applied to the mounting plates, so these might also have been subject to excessive vibration.

If the lamp prongs were made from hard tungsten or tungsten alloy, evidence of arcing (local melting or pitting) is more likely to be found on the spring contacts in the ceramic connectors. The spring contacts have a much lower melting point than the lamp prongs, assuming they are made of brass or steel. While arcing at the bulb terminals was not specifically investigated, visual inspection of these terminals did not reveal arcing patterns.

D.3.1.3 Ignition by Hotspot on Bulb

In a published account describing a vapor ignition by a 300-watt halogen bulb involving gasoline vapor (Babrauskas, 2003), violent impact caused the filament to move, which created an external hotspot on the quartz envelope without bulb breakage. In the absence of hotspots, gasoline vapor ignition did not occur. Most gasoline listed in NFPA 325 (NFPA, (out of print)) have roughly the same autoignition temperature as MEK. No violent impact occurred in the penstock; however, a hotspot could have developed via impact of coarse droplets from the base hopper.

If a droplet of MEK containing dissolved “base” resin were splashed onto the hot bulb region, the result could have been formation of a transient hotspot on or near the bulb. The nominal 1,832 °F (1,000 ºC) hotspot would be created as residual epoxy resin decomposed and combusted either as a glowing ember or small flame.

Upon impact of an MEK-based mixture on a hot surface at approximately 932 °F (500 ºC) or more, the MEK solvent will immediately evaporate. If the MEK vapor does not ignite first, the residual base might decompose and combust either as a glowing hotspot or small flame, which would create very high local temperatures commensurate with MEK’s lower limit flame temperature of about 2,192 °F (1,200 ºC). It is well known that the hotspot ignition temperature of ignitable gas mixtures is a strong function of hotspot size and contact time, although the ignition phenomenon is complex. At temperatures close to the lower limit flame temperature, hotspots on the order of 1 millimeter in diameter can cause almost immediate ignition of optimum vapor-air mixtures. As the halogen bulbs were covered by soot during the fire, the CSB cannot determine if a hotspot occurred on one or more of the bulbs.

D.3.1.4 Autoignition of Heated MEK Vapor Volume

A review of the literature shows that the surface temperature of individual 300-watt halogen bulbs in torchiere lamps is about 968 ºF (520 ºC) (CPSC, 1996); higher values approaching 1,100 ºF (593 ºC) have also been reported. The temperature varies with bulb diameter, design, and degree of confinement. The halogen lights had top reflectors and should have achieved higher temperatures than torchiere lamps, which are open at the top and lose heat by free convection.

The halogen lamp fixtures used in the penstock each contained two closely spaced 300-watt bulbs, so the bulb surface temperatures would have been greater than for single bulbs, especially on the adjacent hot quartz surfaces. To the CSB's knowledge, no relevant tests have been done on the type of halogen lamp fixtures involved in the MEK fire. Bulb surface temperatures could, in principle, be measured by two-color pyrometry or other means, but no such testing was performed.

An experiment would need to be devised and run to determine whether an MEK vapor-air mixture could be ignited by a hot halogen bulb fixture at optimum concentration; if not, it would rule out autoignition at all concentrations. Standard autoignition temperature (AIT) tests hold the vapor-air mixture for several minutes in a glass vessel at the test temperature; they are conservative relative to transient heating by a hot halogen bulb surface. The lack of confinement (i.e., lenses not present) means that transitioning from cool to hot flames could not have occurred via pressure increase.[130] The CSB found various published values for the AIT of MEK, but the most reliable is reported to be 887 ºF (475 ºC) at one atmosphere (760 mmHg) (Brandes, et al., 2005, pp.1-5); this corresponds to the minimum temperature for spontaneous ignition of the optimum MEK-air mixture in a 200 milliliter (ml) glass flask using the IEC 60079-4 test method. However, the low atmospheric pressure in the penstock may have elevated the MEK AIT.

The CSB concluded that the halogen bulb surface temperatures would likely need to be significantly higher than the AIT of MEK (at least 125-212 °F (52-100 ºC) above the standard AIT) for MEK vapor ignition. Ignition is far more likely had a hotspot (or small flame) been created on a bulb or an adjacent hot surface.

[130] MEK is subject to forming cool flames, a phenomenon that can result in a range of reported AITs.

D.4 Hot Surface Ignition by the Sprayer Heater(s)

The CSB determined that even if the sprayer base heater had been operating at full output, its surface temperature would be too low to create MEK vapor-air ignition. The heater was rated for a Class 1, Division 2 atmosphere, with a T2 (482 °F/250 ºC) rating; the standard AIT of MEK is 887 °F (475 ºC).

In addition, both heaters (base and hardener) were radiographed, electrically tested, and physically examined after the fire by an independent consultant hired by OSHA. The consultant determined that the heaters did not provide an ignition source for the fire, nor did they contribute to the spread of the fire.

D.5. Compression Ignition inside One of the Sprayer Piston Pumps

In theory, if an air-operated piston pump runs "dry," adiabatic compression of air plus residual vapor could lead to temperatures that exceed the MEK AIT. The CSB was able to rule out this potential ignition source, as both hoses were reportedly circulating MEK at the time of the fire. The journeyman painter also reported a level of about 3 inches (8 centimeters) of MEK in the base hopper where the initial flash was observed.[131] Thus, neither piston pump could likely have been running "dry" at the time of ignition.

D.6 Electrical Spark from Heater Control Box

Electrical power for the two heaters was supplied by the heater control panel. Unlike the sprayer control panel, which used low voltage electronics supplied from a pneumatic generator and was approved for use in flammable atmospheres, the heater control box was an aftermarket addition and was not rated for use in flammable atmospheres. Although the heater control box was severely damaged by the fire and its internal components were charred,[132] visual examination by the CSB revealed that the incoming power to

[131] The CSB could not determine the amount of MEK inside the hardener hopper at the time of the incident, but survivor statements indicate that MEK was also being circulated in this hopper at the time of the incident.

[132] The CSB found no evidence that an internal deflagration had occurred inside the box.

the box was 240-volts and fuses. The heater control box was found to contain open circuits, relays, and other solid-state components. Consequently, the CSB determined that it was possible for an electrical spark generated inside this box to ignite an explosive MEK vapor-air mixture, but for the same reasons described in Section D.2, this ignition source is unlikely because the heater controls were not likely being used at the time of the incident; an explosive MEK vapor-air mixture probably did not exist outside the base hopper, and a spark, if it did occur, would have had to flash back into the base hopper unobserved.

APPENDIX E: MEK FLAMMABILITY PROPERTIES AT PENSTOCK CONDITIONS

Flammability data, such as flashpoints and lower and upper explosive limits are typically measured at standard atmospheric conditions. As this incident occurred inside a penstock at an elevation of 10,050 feet (3,063 meters) above sea level, the CSB needed to recalculate this data to account for the effects of the elevation.

Using data showing changes in atmospheric pressure at various site elevations (UIG, 2004), the CSB calculated the atmospheric pressure at the penstock fire location to be 523 mmHg.

Next, the equilibrium vapor pressure equation is given by

$$EVP = \exp(A + B/T + C\ln T + DT^{E})$$

Obtaining constants A-E from the Design Institute for Physical Properties Research (DIPPR) database,[133] the boiling point of MEK at 523 mmHg was calculated to be 154 ºF (67.8 ºC). This compares with the "normal" value of 175 ºF (79.4 ºC) at 760 mmHg (standard atmospheric pressure).

[133] The DIPPR database stores thermophysical properties and parameters for correlations of temperature-dependent property models of over 1,900 components. It has been under development since 1980 and is continuously updated and enhanced. DIPPR is an industrial consortium, operating as part of AIChE.

At 523 mmHg, the vapor-liquid equilibrium curve (Figure E-1) shows that the lower and upper flammable limits of MEK in air (1.8-11 volume percent) are attained at respective equilibrium temperatures of 3 to 60 ºF (-16 to 15 ºC). Between these temperatures, MEK vapor in equilibrium with liquid, such as deep inside the liquid hoppers on the sprayer, is ignitable. MEK vapor becomes most easily ignitable at an "optimum" concentration of about 5.5 volume percent, attained at an equilibrium temperature of about 36 ºF (2.4 ºC).

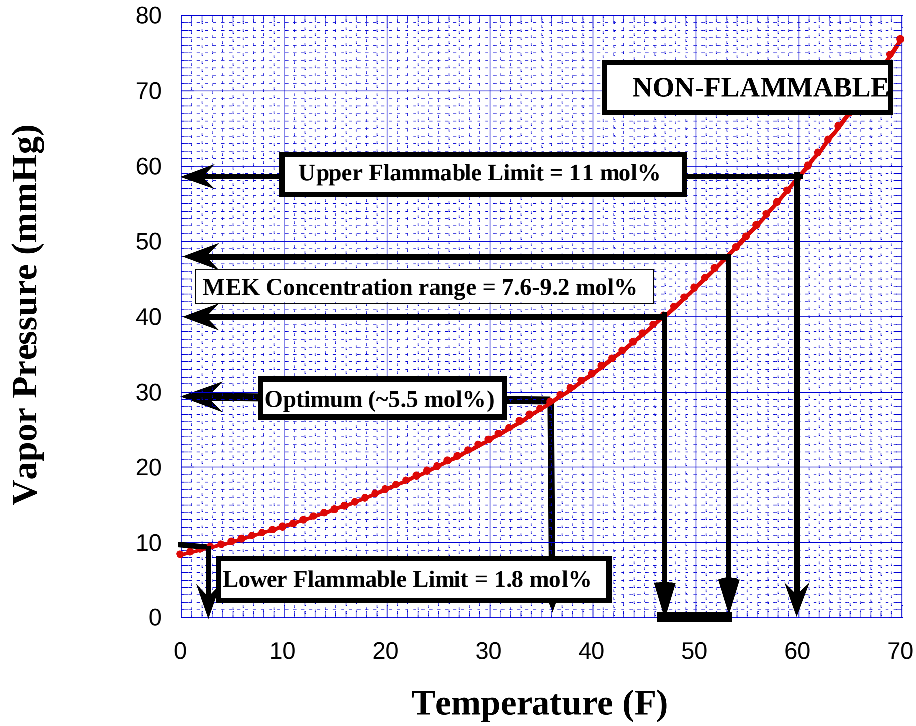

Figure E- 1. Equilibrium vapor pressure of MEK near liquid surface in base hopper

Although the low atmospheric pressure in the penstock (523 mmHg) has negligible effect on the flammable limits, it significantly increases the mole fraction of vapor in air at any given temperature; consequently the flash point is decreased (Figure E-2). The calculated lower theoretical flash point, temperature limit of flammability (TLF), is -16 ºC (3.4 ºF). For ignition in the base hopper, this TLF should be more accurate than a measured flash point because of the ambient pressure and upwards flame propagation, which occurs at lower vapor concentrations than in a standard flash point test apparatus (where flame propagation is downward).

Similarly, the "upper temperature limit of flammability" (UFL) can be calculated. The UFL is generally not sensitive to pressure in the range being considered, so the corresponding MEK vapor pressure is 57.5 mmHg to achieve 11 mole percent MEK in the vapor and the theoretical upper flammability limit (TUF) is found to be 15 ºC (60 ºF). This result shows that MEK in the penstock could be within the flammable range (ignitable) at all times inside a pail or hopper.

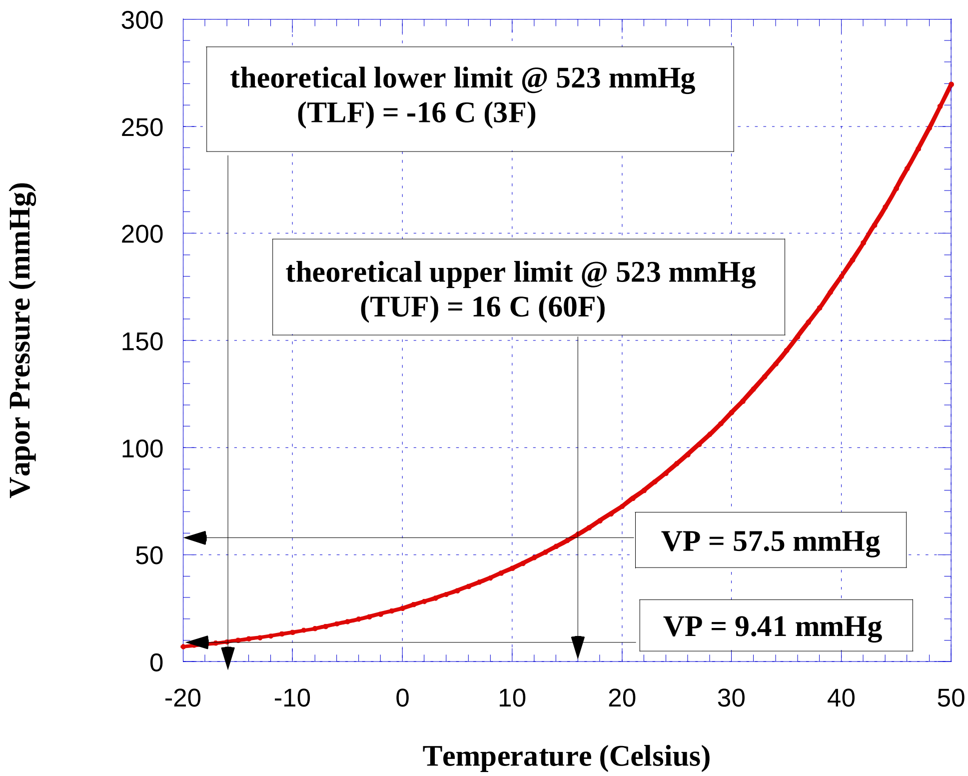

Figure E- 2. Theoretical MEK flammability limits at penstock conditions

With the base side pump heater not operating, the CSB determined that the circulated MEK would have been at 50 ± 3 ºF (10 ± 2 °C). This range compares favorably with the unheated base resin temperature of

47 °F (8.3 °C) measured by the journeyman painter with a laser temperature indicator, and the air temperature of 53 °F (12 °C) inside the penstock measured earlier that day by the KTA inspector. Hence, near the liquid surface in the bottom of the hopper (i.e., where the vapor-liquid equilibrium assumption is most applicable), the MEK vapor concentration should have been in the range of 7.6-9.1 mole percent. This is slightly greater than optimum concentration (approximately 5.5 mole percent), but less than the upper flammable limit (UFL) of 11 mole percent. To summarize, with the heater not operating, the entire volume of the hopper should have been within the ignitable range and capable of deflagration (i.e., rapid burning with the creation of an upward pressure wave).

APPENDIX F: LOWEST MINIMUM IGNITION ENERGY AT PENSTOCK CONDITIONS

Calculation of this parameter is significant with respect to static ignition sources having very small energies. Faulty electrical equipment is unimportant since electrical arcs should be sufficiently energetic to ignite MEK vapor over the entire flammable range.

Calcote, et al. (1952) reported the Lowest Minimum Ignition Energy (LMIE) of MEK as slightly below 0.3 mJ. However, they reported the LMIE of n-pentane at about the same value, 0.28 mJ. This is higher than the approximately 0.24 mJ published for similar paraffin hydrocarbons such as butane and hexane (Lewis & von Elbe, 1961). The latter authors also reported a significantly lower value for cyclopropane, 0.17 mJ versus the 0.22 mJ found by Calcote et al. The CSB noted that the data of Calcote et al. tend to be high compared with other LMIE values. Indeed, most of the Calcote et al. data were measured at stoichiometric composition, and only a few compounds such as MEK were tested at optimum composition (approximately 1.5 times stoichiometric in the case of MEK). The test method used by Calcote et al. usually involved electrodes with 1/8-inch hemispherical tips versus the 1/16-inch tips used by Lewis & von Elbe. Quenching effects presumably caused the measured values of Calcote et al. to be somewhat high. It has been observed that the lowest LMIEs are found with pointed electrodes at very low circuit capacitance. Since Calcote et al. used various test procedures, it is not clear exactly which procedure was used for the MEK tests. It is possible that lower values would have been found by optimizing the circuit capacitance. In conclusion, the LMIE of MEK was found to be about the same as n-pentane, whose LMIE is about 0.24 mJ. No MEK tests have been reported under truly “optimum” conditions of spark gap geometry and circuit capacitance.

Britton’s method (2002) uses the heat of oxidation to estimate the LMIE of CH and CHO organic compounds:

$$\text{LMIE (mJ)} = 4.0056 - 0.06231\,(-\Delta H_C/S) + 0.00024333\,(-\Delta H_C/S)^2$$

Where (ΔH_C /S) = Heat of Oxidation (-100.07 kcal/mol for MEK)

Hence LMIE = 0.21 mJ

From the preceding discussion, the most easily ignitable composition should be about 1.5 times stoichiometric or 5.50 mol%.

Lowest MIE = 0.21 mJ (5.50 mol % MEK in dry air at 298 K, 1 atm)

However, the LMIE generally increases as pressure decreases. In the penstock, the ambient pressure was about 523 mmHg (0.69 atmospheres). By analogy with data for propane (Figure F-1), the LMIE of MEK at 0.69 atmospheres (523 mmHg) should be approximately 0.5 mJ. (Britton, 1999):

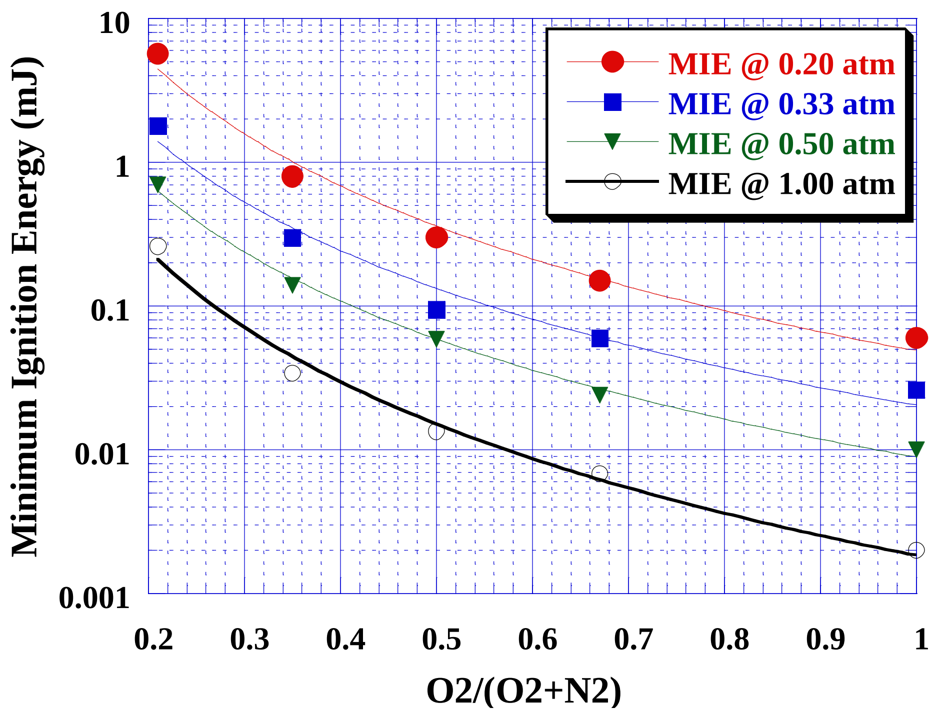

Figure F-1. Effect of pressure on MIE of propane in various oxygen-nitrogen mixtures

Hence, the lowest MIE for MEK is approximately 0.5 mJ (5.50 mole percent MEK in dry air at 298 K, 0.69 atm).

APPENDIX G: WORK ACTIVITIES ALLOWED IN POTENTIALLY EXPLOSIVE ATMOSPHERES

Source	Industry/Personnel	Citation/Reference	Requirement
OSHA	Permit-required confined spaces in general industry	1910.146(d)	Entry into permit-required confined spaces above 10% of the LFL is allowed provided that acceptable entry conditions for flammable vapors listed on the permit are followed.
		Appendix C Examples of Permit-Required Confined Space Programs	**Example 3. Workplace.** Workplaces where tank cars, trucks, and trailers, dry bulk tanks and trailers, railroad tank cars, and similar portable tanks are fabricated or serviced. **Sources of hazards.** In addition to the mechanical hazards arising from the risks that an entrant would be injured due to contact with components of the tank or the tools being used, the risk also exists that a worker could be injured by breathing fumes from welding materials or mists or vapors from materials used to coat the tank interior. In addition, many of these vapors and mists are flammable, so failure to properly ventilate a tank could lead to fire or explosion. **Application of interior coatings/linings.** Atmospheric hazards shall be controlled by forced air ventilation sufficient to keep the atmospheric concentration of flammable materials below 10% of the lower flammable limit (LFL) (or lower explosive limit (LEL)), whichever term is used locally). The appropriate respirators are provided and shall be used in addition to providing forced ventilation if the forced ventilation does not maintain acceptable respiratory conditions.
		Std Interpretation letter, 9/4/96	The permit-required confined spaces standard [29 CFR 1910.146] does not prohibit working in a permit-required space where the atmosphere is above 10% of the LFL. However, once the atmosphere is above 10% of the LFL, all requirements of the standard must be met. The employer must identify and evaluate each hazard to which entering employees will be exposed. Based on the hazard analysis, the employer must develop and implement the means, procedures, and practices necessary for safe permit space entry operations. If the flammable atmosphere is the result of a process involving equipment, there may be precautions with regard to the equipment that an employer would be required to follow.

Source	Industry/Personnel	Citation/Reference	Requirement
	Confined spaces using alternative entry provisions in general industry	1910.146(c)(5) OSHA Directive 2.100, page 19. 58 FR 4488	In confined spaces using alternative entry procedures, entry is permitted provided the concentration of the flammable substance does not exceed 50% of what would constitute a "hazardous atmosphere" (e.g., 5% of the LFL).
	Confined and enclosed spaces and other dangerous atmospheres in shipyard employment	1915.13(b)(3)	An employee may not enter a space where the concentration of flammable vapors or gases is equal to or greater than 10% of the LEL. Exception: An employee may enter for emergency rescue or for a short duration to install ventilation equipment necessary to start work, provided no ignition sources are present, the atmosphere in the space is monitored continuously, atmospheres at or above the upper explosive limit are maintained, and respiratory and other appropriate PPE and clothing are provided.
	Excavations	1926.651(g)(1)(iii)	In excavation and trenches, adequate precautions shall be taken, such as providing ventilation, to prevent employee exposure to an atmosphere containing a concentration of a flammable gas in excess of 20% of the lower flammable limit (LFL) of the gas.
	Underground construction (tunneling)	1926.800	When air monitoring shows, for 3 consecutive days, 10% or more of the LEL for methane or other flammable gases measured at 12 inches from the roof, face, floor, or walls in any underground work area, additional safety precautions are required. These include using more stringent ventilation requirements, using diesel equipment only if it is approved for use in gassy operations, posting each entrance with warning signs, prohibiting smoking and personal sources of ignition, maintaining a fire watch when hot work is performed, and suspending all operations in the affected area until all special requirements are met or the operation is declassified. Additional air monitoring is also required.
	Confined spaces in construction, except for diving, non-sewer excavations, and underground construction	1926.1028 (proposed)	Entry into permit-required confined spaces (PRCS) above 10% of the LFL is allowed provided conditions under which the authorized entrants can work safely are defined, including hazard levels and methods of employee protection. Monitoring procedures must also be in place to detect an increase in atmospheric hazard levels in sufficient time for the entrants to safely exit the PRCS in the event the ventilation system stops working.

Source	Industry/Personnel	Citation/Reference	Requirement
		72 FR 67391	OSHA requests comment on the advisability of reconciling the difference in LFLs between the excavation standard in subpart P and this proposed standard, including which LFL (that is, 10% or 20%) should be adopted.
MSHA	Underground Coal Mines	75 CFR 323	When 1.0% or more methane (20% of LEL) is present in a working place or an intake air course, including an air course in which a belt conveyor is located, or in an area where mechanized mining equipment is being installed or removed--except intrinsically safe atmospheric monitoring systems (AMS), electrically powered equipment in the affected area shall be de-energized, and other mechanized equipment shall be shut off; changes or adjustments shall be made at once to the ventilation system to reduce the concentration of methane to less than 1.0%; and no other work shall be permitted in the affected area until the methane concentration is less than 1.0%. When 1.5% or more methane (30% of LEL) is present in a working place or an intake air course, including an air course in which a belt conveyor is located, or in an area where mechanized mining equipment is being installed or removed--everyone except those persons referred to in §104(c) of the Act shall be withdrawn from the affected area and, except for intrinsically safe AMS, electrically powered equipment in the affected area shall be disconnected at the power source.
	Underground Metal Non-Metal Mines	57 CFR 22231- 22238	If methane reaches 0.25% (5% of LEL) in the mine atmosphere, changes shall be made to improve ventilation, and MSHA shall be notified immediately. If methane reaches 0.5% (10% of LEL) in the mine atmosphere, ventilation changes shall be made to reduce the level of methane. Until methane is reduced to less than 0.5%, electrical power shall be de-energized in affected areas, except power to monitoring equipment determined by MSHA to be intrinsically safe under 30 CFR part 18. Diesel equipment shall be shut off or immediately removed from the area and no other work shall be permitted in affected areas. If methane reaches 1.0% (20% of LEL) in the mine atmosphere, ventilation changes shall be made to reduce the methane. Until such changes are achieved--all persons other than competent persons necessary to make the ventilation changes shall be withdrawn from affected areas; electrical power shall be de-energized in affected areas, except power to monitoring equipment

Source	Industry/Personnel	Citation/Reference	Requirement
			determined by MSHA to be intrinsically safe under 30 CFR part 18; and diesel equipment shall be shut off or immediately removed from the area. If methane reaches 2.0% (40% of LEL) in the mine atmosphere, all persons other than competent persons necessary to make ventilation changes shall be withdrawn from the mine until methane is reduced to less than 0.5% (10% of LEL).
Environmental Protection Agency (EPA)	Personnel activities at hazardous waste sites	*Standard Operating Guides,* EPA, December 1984	Less than 10% of LEL, continue investigation; 10 to 25% of LEL, continue onsite monitoring with extreme caution as higher levels are encountered; Above 25% of LEL, explosion hazard. Withdraw from area immediately.
ANSI	Confined spaces at normal atmospheric pressure. Not applicable to underground mining, tunneling, caisson work, or intentionally inert confined spaces	Z117.1-2003 Section 6.3.2	Entry into confined space prohibited until appropriate controls are implemented or appropriate personal protective equipment (PPE) is provided whenever atmospheric testing indicates flammable levels are greater than 10% of the LEL/LFL.
API	Personnel cleaning stationary, aboveground atmospheric and low pressure petroleum storage tanks	Standard 2015-2001 Section 8.3.3.2.	Entry into tanks is prohibited when the flammable vapor-air levels are above 10% LEL, <u>unless</u> there are extraordinary circumstances requiring such entries and employers (owners/operators and contractors) have established and implemented appropriate precautions and safeguards for permit required confined space entry.
NFPA	Vessels that carry, or burn as a fuel, flammable or combustible liquids and vessel that carry compressed gases, chemicals in bulk, or other products capable of creating a hazardous condition	Standard 306 – 2003 Section 4	Compartments where flammable vapor-air levels are less than 10% of the LEL are marked as “Safe for Workers” or “Safe for Hot Work”. Compartments with vapor-air levels that exceed 10% of the LEL are marked “Enter With Restrictions” and can be entered only with appropriate PPE to install ventilation or perform emergency rescue.
	Tanks or containers operating at normal atmospheric pressure that contain or have contained flammable or combustible liquids or other hazardous substances and related vapors and residues that are to be entered or cleaned	Standard 326 – 2005 Sections 6.3.2, 6.3.8, 6.3.9	All work in and around the tank or container shall be stopped immediately when flammable vapors in the atmosphere exceed 10% of the LFL. Source of the vapors located and eliminated or controlled. When a tank or container is tested prior to the start of hot work, any indication of flammable gas or vapor in excess of the established allowable limits shall require additional ventilation, purging, re-cleaning, or further safeguarding by

Source	Industry/Personnel	Citation/Reference	Requirement
			one of the methods described in this standard, as specified by the qualified person, prior to the issuance of a hot work permit. When testing a tank or container during hot work, any indication of flammable gas or vapor in excess of the established allowable limits shall require the immediate cancellation of the hot work permit.
	Emergency/fire personnel responding to releases of flammable or combustible liquid, gas, or vapor that can migrate to a subsurface structure	RP 329 – 2005 Sections 5.4.5.1 – 5.4.5.3	During initial response to a reported leak, the affected area should be evacuated when gas or vapor concentrations are above 50% of the LFL. The affected area should be ventilated to remove or reduce the flammable gas or vapor concentration and thus reduce the fire or explosion hazard. As soon as the flammable gas or vapor has been reduced below 50% of the LFL, entry can be made to locate and eliminate the source.
	Emergency/fire personnel performing rescue from confined spaces	Standard 1006 – 2008 Section A.7.1.1.(2)	Flammability is measured as a percentage of a material's LEL or LFL. Rescuers should not enter confined spaces containing atmospheres greater than 10% of a material's LEL, regardless of the PPE worn. There is no adequate protection for an explosion within a confined space.
NIOSH	Criteria for a Recommended Standard – Working in Confined Spaces	Publication No. 80-106 – 1987	Less than 10% of the LFL, no modification of work processes; between 10-19% of LFL, ventilation and protective measures; 20% of LFL or above, ventilation and protective measures.
International Union of Painters and Allied Trades, Joint Apprenticeship and Training Fund	Apprentice and Journeymen Painters	Confined Space Entry, Employee Handbook and Facilitator Guide (Summit Training Source, Inc.)	Permit Space Hazards Flammable Gas, Vapor, or Mist If the atmospheres contain flammable gas, vapor, or mist in excess of 10% of its LFL, that atmosphere is unacceptable for entry.
Pipeline Association for Public Awareness	Firefighters, law enforcement officers, emergency Medical technicians and all other emergency	Appendix B	Natural Gas Escaping Inside a Building EMERGENCY RESPONSE

Source	Industry/Personnel	Citation/Reference	Requirement
	responders responding to pipeline incidents		Monitor the atmosphere, using multiple monitors where possible ♦ Action Criteria: 0 to 10% of the LEL - Use Extreme Caution ♦ Action Criteria: 10% of the LEL or greater - DO NOT ENTER THE BUILDING TACTICAL CONSIDERATIONS ♦ Natural gas released inside buildings presents one of the greatest flammable hazards to emergency responders. ♦ Building full of natural gas should be approached only when needed with extreme caution and with a minimum number of personnel. CGI reading s in excess of 10% LEL require evacuation of the building.
Alberta	Worksite or work area	Handling and Storage of Flammable Materials at the Work Site (May 2007) OHS Code, Part 10	Work is prohibited in areas greater than 20% of the LEL, except for competent workers responding to emergencies
British Columbia	Confined Spaces	Confined Space Entrance Reference Manual (2007) Section 9.5, OH&SR	Workers not allowed entry into confined spaces under any circumstances when the flammability is greater than 20% of the LEL. Good practice to prohibit hot work in atmospheres providing a reading on the flammable gas meter above 1%. Any untested confined space is considered IDLH.
Ontario	Confined Spaces	Confined Spaces Guideline (1996)	Hot work permitted if concentration of flammable or explosive gas or vapor is less than 5% of LEL. Cold work permitted if concentration of flammable or explosive gas or vapor is less than 10% of LEL. Inspection permitted if concentration of flammable or explosive gas or vapor is less than 25% of LEL. No entry permitted if concentration of flammable or explosive gas or vapor exceeds 25% of LEL.
Australia	Confined Spaces	AS 2865 – 1995	No entry into a confined space permitted if the concentration of the flammable

Source	Industry/Personnel	Citation/Reference	Requirement
			contaminant in the atmosphere exceeds 5% of the LEL. When persons have entered a confined space and are using continuous monitoring, they may remain in the confined space at concentrations of flammable contaminant in the atmosphere of less than 10% of the LEL before evacuation of the confined space is necessary.
New Zealand	Confined Spaces	Safe Working in a Confined Space (no date)	Concentration of flammable contaminant in the atmosphere is 0% of the LEL if hot work is to be carried out, or 10% if cold work is to be varied out.
United Kingdom	Shipping Industry	IACS Confined Space Safe Practice Section 6.3 April 2007	A space with an atmosphere with more than 1% of the LFL or LEL on a combustible gas indicator should not be entered.

APPENDIX H: APPLICABLE OSHA CONFINED SPACE STANDARDS

H.1 OSHA General Industry Standards (29 CFR 1910)

The CSB reviewed OSHA safety and health regulations addressing confined space requirements applicable to general industry as well as those for construction. The CSB determined that OSHA general industry standards codified at 29 CFR 1910 apply to the penstock recoating project at the Xcel Cabin Creek facility based on OSHA definitions of construction versus maintenance [29 CFR 1910.12(b), 29 CFR 1926.13(a) and 1926.32(g)]. Although the contractor (RPI) was using construction practices (e.g., sandblasting and coating) to physically change the power plant, the penstock was existing equipment (constructed in 1967) that was being refurbished by removing the old coating and applying new. Consequently, this work activity is classified as maintenance rather than new construction and falls under the OSHA general industry standards.

H.2 Electrical Power Generation (29 CFR 1910.269)

Although the CSB found that OSHA's electrical power generation standards apply to the Xcel Cabin Creek hydroelectric power plant, these standards contain no specific regulations pertaining to penstocks, and the penstock does not meet the definition of an "enclosed space" as outlined in this standard. As discussed in Section 2.1, the Xcel Cabin Creek facility is a pumped hydroelectric power plant that supplies electricity to residential customers during peak demand periods. As its purpose is to generate electrical power, the Xcel Cabin Creek facility is subject to the regulations of OSHA's general industry standard that apply only to electrical power generation, transmission, and distribution codified at 29 CFR 1910.269. In fact, 29 CFR 1910.269(a)(i)(B)(2) specifically states that "water and steam installations, such as penstocks, pipelines, and tanks providing a source of energy for electric generators" are subject to these standards. A review of the 1910.269 standard reveals that it contains no specific requirements for penstocks, but does contain specific requirements for "enclosed spaces." Subparagraph (e) outlines safe work practices, evaluation of potential hazards, atmospheric testing, ventilation, attendants, and rescue provisions that are applicable to "enclosed spaces." However, the definition of an "enclosed space" at 29 CFR 1910.269(x) states that these spaces are "designed for periodic employee entry under normal operating conditions"; thus, the penstock cannot be classified as an "enclosed space" under the 1910.269 standard because under normal operating conditions the penstock is filled with water and employees do not enter. A note beneath the "enclosed space" definition states that if the space meets the criteria for a permit-required confined space then the provisions of 29 CFR 1910.146 apply.

H.3 Permit-Required Confined Spaces (29 CFR 1910.146)

See Section 10.0, "Regulatory and Industry Standards Analysis."

APPENDIX I: CSB CONFINED SPACE INCIDENTS DATA INCLUSION CRITERION AND LIMITATIONS

To determine the prevalence of confined space incidents attributable to a flammable atmosphere, the CSB researched and identified a number of confined space incidents from various sources.[1] Incidents were included in the CSB database if they occurred in a confined space and resulted from a fire or explosion where monitoring of the atmosphere and establishing safe flammable limits could have played a role in preventing entry or requiring exit from the space. The CSB search included only incidents that occurred in what was determined to be an OSHA defined confined space. Incidents were selected if they occurred after April 15, 1993, and if work was being performed inside the confined space where a flammable atmosphere was either created by the work being conducted or present prior to entry resulted in an explosion or fire.

The CSB obtained a majority of these incidents by using specific search terms to query OSHA's IMIS database where inspection records of OSHA investigations are recorded and categorized. The CSB's data search retrieved incidents containing the words ”confined space” in the summary words, incident summary description, or title of the inspection report. If an incident occurred in a confined space, but the words ”confined space” did not appear on that inspection report as a descriptor, it was not initially identified as an incident of interest. Only after subsequent queries into the IMIS system to identify incidents that contained a "flammable atmosphere," "explosion," or "chemical fire," among others, were additional confined space incidents identified. For example, a few of our incidents did not contain the

[1] Sources included the NIOSH Fatality Assessment and Control Evaluation (FACE) Program reports, the OSHA Inspection Data from OSHA's Integrated Management Information System (IMIS) from 1993 to the present, media reports and inquiry into the Agency of Toxic Substance and Disease Registry (ATSDR), and the Hazardous Substances Emergency Events Surveillance (HSEES) system to determine the prevalence of incidents attributed to a flammable atmosphere.

words ”confined space” but were retrieved under these search terms and found to contain OSHA confined space citations.

Additionally, a few of the incidents included in the CSB dataset were obtained through Internet media searches. These incidents were then checked in the OSHA IMIS database and matched with their correlating OSHA inspection number. If these media incidents contained OSHA confined space citations under the standard 1910.146, they were included into the CSB database. However, some incidents found through the media search had an OSHA inspection number but not an OSHA inspection report description or confined space citations indicating that the incident occurred in a confined space; thus, they were not included in the CSB dataset. Other OSHA IMIS incidents contained OSHA confined space citations but no incident summary indicating that the accident occurred in a confined space and were therefore excluded from the dataset. Incidents were included only in the CSB dataset if the OSHA confined space citations were connected to the explosion or fire. As a result of incomplete or inconsistent reporting of confined space incidents in the OSHA IMIS system, the voluntary nature of incidents reported to NIOSH to generate the NIOSH Fatality Assessment and Control Evaluation (FACE) reports and the lack of specific confined space data in ATSDR HSEES, the CSB concluded that there is a likely undercount in confined space incidents that occurred in a flammable atmosphere in our data.

Confined space incidents obtained from OSHA’s IMIS, the NIOSH FACE reports, ATSDR, and the media were categorized into two subgroups. Subgroup A contained incidents that matched our inclusion criterion, and subgroup B contained incidents that did not fully meet our inclusion criterion. Of the 105 incidents compiled by the CSB, 53 were subsequently categorized as A and determined to be a result of a flammable atmosphere in a confined space.

APPENDIX J: SIMILAR RECENT CONFINED SPACE INCIDENTS INVOLVING FLAMMABLES INVESTIGATED BY THE CSB

Since the Xcel penstock incident, the CSB has investigated two additional confined space incidents involving workers who were injured or fatally wounded by an explosion or fire involving flammables in a confined space.

13.1.1 ConAgra Foods Processing Plant Explosion

On February 16, 2009, a North West Metal Fabricators contractor was killed while attempting welding repair to a 1¼ by ½ inch (3.2 by 1.3 centimeters) crack on a clarifier tank at a ConAgra facility in Boardman, Oregon. The 23-foot (7-meter) tall, 12-foot (3.7-meter) diameter tank had an open top structure and cone-shaped bottom covered by a metal skirt. The tank, used in a potato-washing process for separating dirt and debris from waste water, was classified as a permit-required confined space.

The CSB investigators found an accumulation of approximately 14 inches (36 centimeters) of bacteria-rich debris and water under the tank's skirting as a result of the material leaking through the crack. Through sample analysis, the CSB determined that bacteria in this debris and waste water likely produced flammable gas. When the contractor started welding, the arc generated acted as the source of ignition, resulting in a confined vapor explosion. Air monitors were used to detect flammable vapors near the entrance of the tank but were not used in the vicinity where the hot work was conducted.

13.1.2 TEPPCO Terminal Explosion

Three contractors from C&C Welding, Inc. were fatally injured on May 12, 2009, in an explosion at the TEPPCO Partners LP McRae Terminal in Garner, Arkansas. The workers were using a cutting torch above the floating roof inside a 67,000-barrel (10,700 cubic meters) capacity gasoline storage tank when an internal explosion blew both the floating roof and the fixed roof off the tank. The contractors were preparing for the installation of a gauge pole, and at the time of the explosion were using an oxygen acetylene cutting torch to cut into the secondary roof of the internal floating roof of the tank. The contractors were issued both a hot work permit and confined space permit to flame-cut the roof and enter the tank. However, an evaluation of both the hot work and confined space entry permit and policies of TEPPCO Partners LP and C&C Welding Inc. reveals no maximum or minimum LEL limits for work within confined spaces. The flame-cutting activity most likely ignited flammable vapors inside the tank.