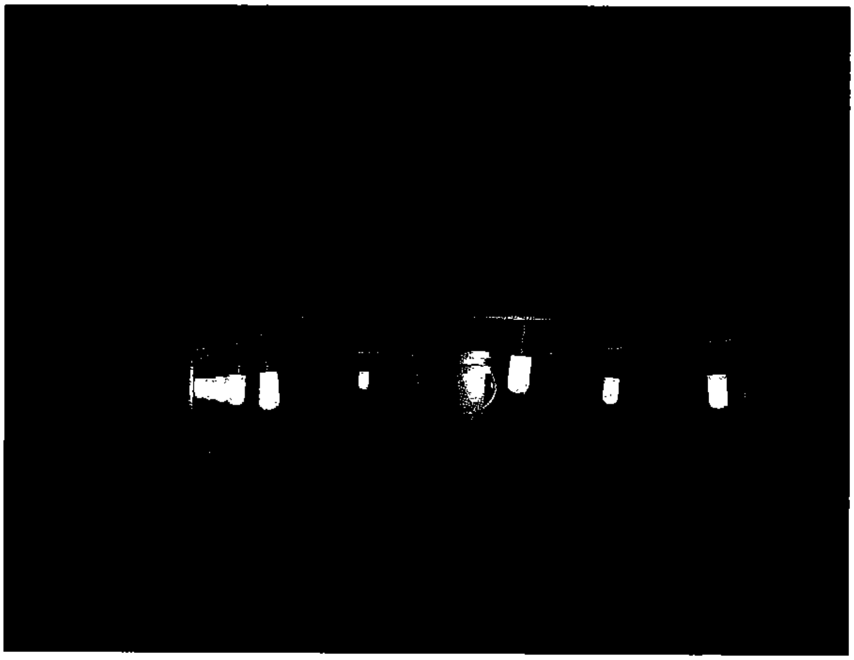
U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

INVESTIGATION REPORT

Report – Draft #3: CBI and Factual Review

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

REPORT NO. 2008-01-I-CO
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U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

INVESTIGATION REPORT

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Acronyms and Abbreviations

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
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
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
psig	pounds per square inch gauge
PSCo	Public Service Company of Colorado
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 west of Denver, Colorado, killed five and injured three workers. Industrial painting contractors were in the initial stages of recoating the 1,530-foot steel portion of a 4,300-foot 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 within the penstock from exiting the single point of egress within the penstock. Fourteen community emergency response teams responded to the incident. The five trapped workers communicated by handheld radios with co-workers and emergency responders for approximately 45 minutes before succumbing to smoke inhalation.

[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

1.2 Scope of the Investigation

It is well-known that catastrophic workplace accidents are not the result of a single error or one piece of faulty equipment. Higher-level safety system deficiencies are often found to exist at facilities where such accidents occur. It is also established that accident prevention is most effective when these systemic causes are understood and learned.[3] As such, the CSB examined both the technical and organizational causes of the fire at Xcel Energy's Cabin Creek penstock.

The investigation found 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 spaced. 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.

[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).

Shortly after the epoxy application process commenced, the sprayer system began malfunctioning, 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), to remove epoxy residue before taking the equipment out of the penstock. During this cleaning operation, MEK vapors inside the base hopper 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 Coating 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. However, five 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 to provide water tightness. Between 1960 and 1980, coal tar epoxies were used for interior lining systems of steel penstocks; these products generally have only a 15-year service life. 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 100 percent solids 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 U.S. Chemical Safety and Hazard Investigation Board (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 of highly flammable methyl ethyl ketone (MEK)[5] 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 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 nor implemented during their pre-job safety planning such as substituting a non-flammable solvent.

[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 and boiling point at or above 100°F. *NIOSH Pocket Guide to Chemical Hazards, 2005.*

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 use of flammables, hot work, and the switch from abrasive blasting to recoating the penstock interior.

4. Both Xcel's and RPI's corporate confined space programs did not adequately address 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. Both Xcel's and RPI's permit-required confined space policies and permit forms did not require or establish a maximum permissible percentage of the lower explosive limit (LEL)[6] for safe entry and occupancy inside a permit space.

5. RPI did not monitor the interior of the permit-required confined space for flammable atmospheres on the day of the incident where flammables were being used. Instead, RPI monitored the atmosphere of the penstock only at its entrance, 1,400 feet from the work activities.

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 and Training

[6] 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.

Committee, established by industrial painting contractors (including RPI) and the International Union of Painters and Allied Trades, 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-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. From 1993 to May 2009, the Chemical Safety Board (CSB) identified 47 serious flammable atmosphere confined space incidents involving fires and explosions; 55 percent of these involved a fatality. These incidents caused 50 injuries and 40 fatalities, and a majority of these fatalities and injuries occurred since 2001. These flammable atmosphere incidents include two investigated by the CSB 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 emergency response plan for rescue services for the penstock reline project was to call 9-1-1 emergency dispatch. No emergency responders with confined space technical rescue certification were at the hydroelectric plant standing outside the penstock and immediately available for rescue on the day of the incident, and the approximate response time of the closest identified certified rescuers was approximately 1 hour and 15 minutes. The trapped workers communicated with co-workers and emergency responders by handheld radio for approximately 45 minutes after the initial fire and eventually died from smoke inhalation.

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

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7 Letter to Mr. 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.

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)].

materials responders but does not offer certification for technical rescue including confined space rescue.

12. Xcel's pre-qualification 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 when its safety record was evaluated, 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 to be the best from a technical and quality perspective, RPI's proposal received the highest ranking in the evaluation process, based primarily on low price.

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:

- OSHA
- The governor of Colorado
- Xcel Energy
- RPI Coating
- The director of the Colorado Division of Fire Safety
- The director of the Division of Emergency Management
- The American Public Power Association
- The Society for Protective Coatings
- The Southern California Painting and Drywall Industries Joint Apprenticeship and Training Committee

Section 12 of this report provides the detailed recommendations.

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[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

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), the U.S. Occupational Safety and Health Administration (OSHA), and the CSB remained onsite and worked with Xcel management to protect and preserve evidence at the Cabin Creek site, including 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 was 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, 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

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financial capacity of the potential contractor.

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 in regard to the involved parties of the investigation, including Xcel and RPI. Several RPI managers asserted their constitutional right against self incrimination and RPI did not respond to numerous interrogatory requests. Xcel also 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 to obtain information relevant to its investigation.

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 Public Service Company of Colorado (PSCo)

The Public Service Company of Colorado (PSCo), a Denver-based company founded in 1869 and a subsidiary of Xcel, 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. This report will refer to PSCo and Xcel Energy collectively as Xcel.

2.1.1 Cabin Creek Hydroelectric Plant

The PSCo-owned 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 elevation) approximately six miles south of the Georgetown, Colorado and 45 miles west of Denver.

Cabin Creek is a pumped storage plant, with upper and lower water reservoirs totaling 1,977 acre-feet, 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 (commonly called the "mushroom" due to its shape), which is connected to a penstock, and 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 four hours.

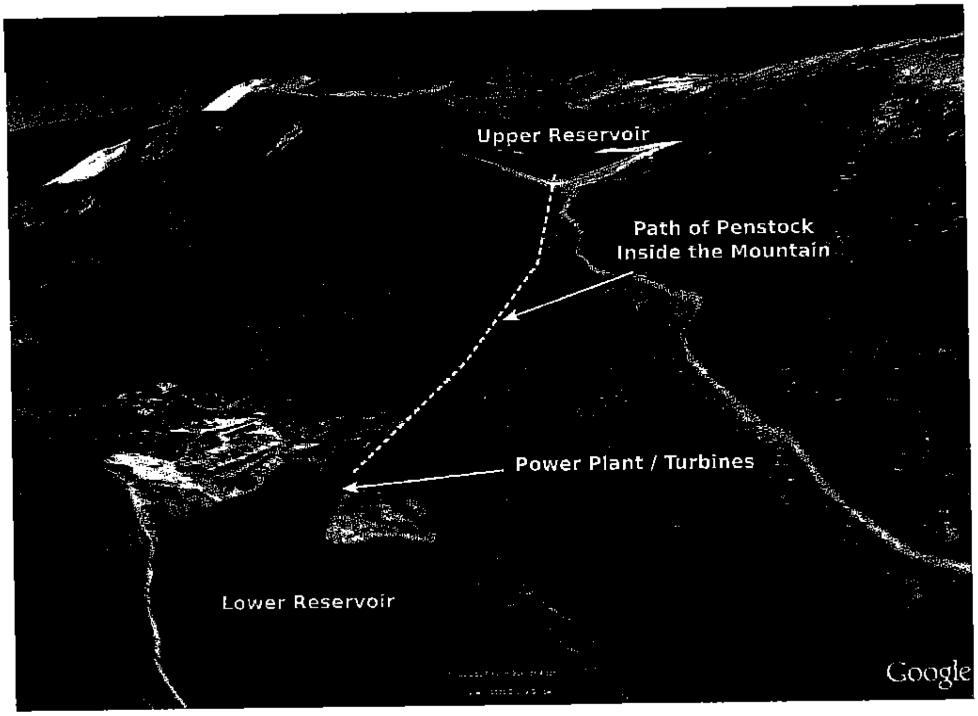

Figure 1. Location of hydroelectric plant, reservoirs, and penstock pathway

2.1.1.1 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 (950 meters) can be traveled by foot. The RPI contractors were hired 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.

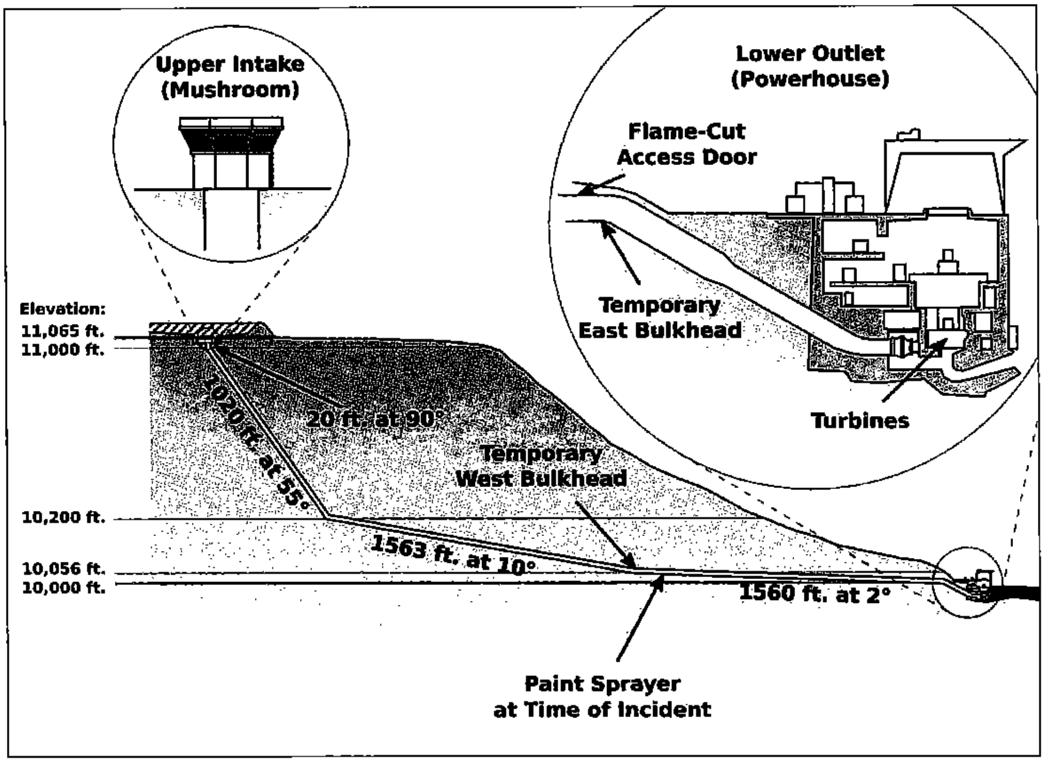

Figure 2. Penstock Configuration

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

2.1.1.2 Deteriorated Penstock Interior Lining Requires Replacement

During the fall 2000 plant outage,[10] a Federal Energy Regulatory Commission[11] (FERC)-mandated internal inspection of the penstock found numerous indications of deterioration of the epoxy coating in the interior of the steel-lined pipe section. The coating was found to be flaking, blistering, and checking, which resulted in areas of 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 old coal-tar based lining and replace it with a new 100 percent solids epoxy lining was scheduled for the fall 2007 outage.

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

[11] 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.

3.0 Contractors

3.1 RPI Coating, Inc.

RPI Coating, Inc. (RPI), a commercial painting and coating company headquartered in Santa Fe Springs, California, was selected by Xcel to remove the old coal tar-based epoxy from the steel portions of the Cabin Creek penstock and apply the 100 percent solids 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, the company had been inspected 46 times since 1972 by federal and state OSHA. Of these inspections, 31 had been initiated due to a complaint, referral, or accident. Ninety 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. 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. 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 spring 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 man hole – was the only existing penstock opening at the start of the project. Additionally, the civil engineer discussed the challenges they would have trying to achieve the necessary temperature conditions within the penstock for successful epoxy application and the significant difficulties they would have to complete the project in the 10-week period of time 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 interested contractors starting 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.

One of the two top proposals came from RPI; however, the Xcel evaluation team identified key safety criteria deficits in RPI's safety record and consequently rated them as "zero" in that category. The Xcel scoring sheet used for contractor selection stated that a contractor receiving a score of zero signified that the bidder's proposal for that rating criterion "does not meet minimum requirements [and means] automatic rejection." RPI's bid was not rejected, however, and it was allowed to compete in the final selection process. Subsequently, RPI was selected to perform the penstock recoating work primarily as a result of submitting the proposal with the lowest price. In response to RPI's poor safety record, Xcel included a safety addendum to the penstock recoating project contract that required RPI to be "be extra diligent toward safety" and included a commitment by Xcel to "observe closely" RPI's safety performance.

4.1.3 Planning for Penstock Recoating Project

While the job site was being prepped by the RPI employees, Xcel held a preconstruction meeting for the penstock recoating project on September 5, 2007, which was 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 contractors were on site to attend this general safety training, and no make-up session was offered to them (Section 9.0).

4.1.4 Work Preparation Prior to Recoating

Before the old coal tar-based epoxy could be removed from the steel sections and the new epoxy applied, the plant had to be shut down and the 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 tall access door was flame-cut[12] 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/exit the penstock (Figure 3).

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.

[12] The access opening was cut by a specialty welding contractor; Xcel Energy was unable to provide the hot work permit for this work to the CSB.

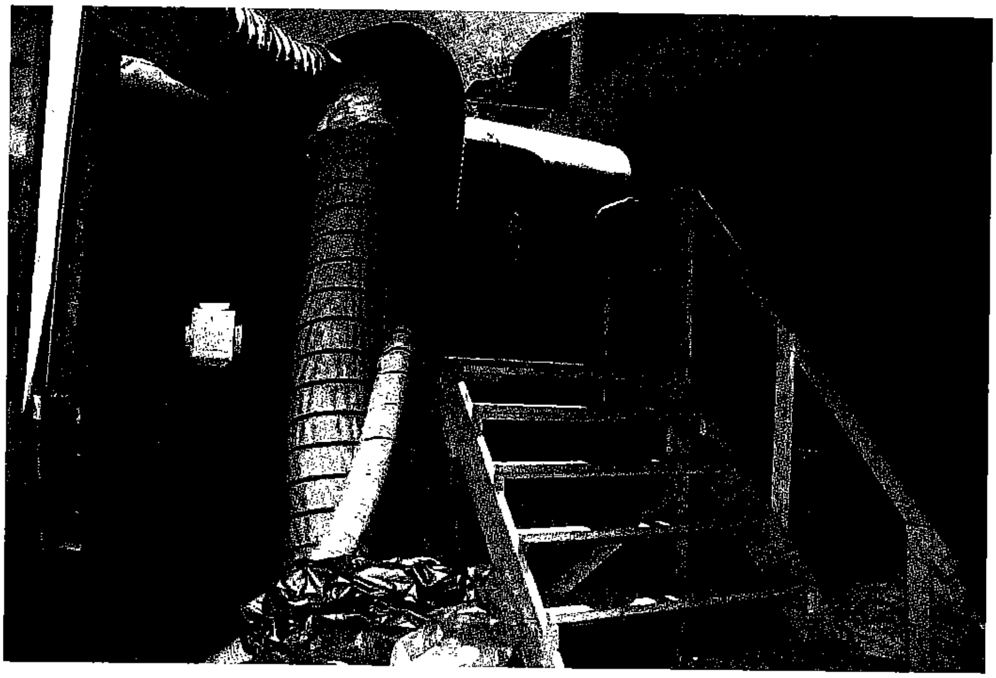

Figure 3. Access door cut into penstock for recoating work

To contain the sand-blasting 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 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[13]) 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 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 malfunctioned 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 Coal Tar-Based Epoxy

Beginning on September 21, 2007, RPI sandblasted and removed the old coal tar-based epoxy coating from the first 500 feet of the steel section east of the west bulkhead; sandblasting continued until September 28, when the entire 1,560 feet portion was completed. On September 22, the Xcel project manager for the penstock recoating work observed RPI conducting abrasive blasting inside the penstock,

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

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 a total of 4 days, leaks were patched, and the abrasive 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.[14]

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

[14] Neither Xcel Energy or RPI could provide copies of hot work permits for this welding work to the CSB.

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 the inspection documentation that thinner would be used as part of the coating materials mixing and 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.[15]

Then, on October 1, an Xcel safety consultant inspected RPI employees working in the penstock. No unsatisfactory conditions were noted.

Sandblasting activities, including hand-sanding and grinding of the walls, were completed on the morning of October 2, and 13 RPI contractors[16] began preparing the penstock interior for the new coating. No safety meeting 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.

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[15] 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 required 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.

At each of these stages within the project, there were opportunities for the project planners from both Xcel and RPI to assess the hazards of introducing flammables into the penstock's confined space, but no such assessment was conducted.

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 4).

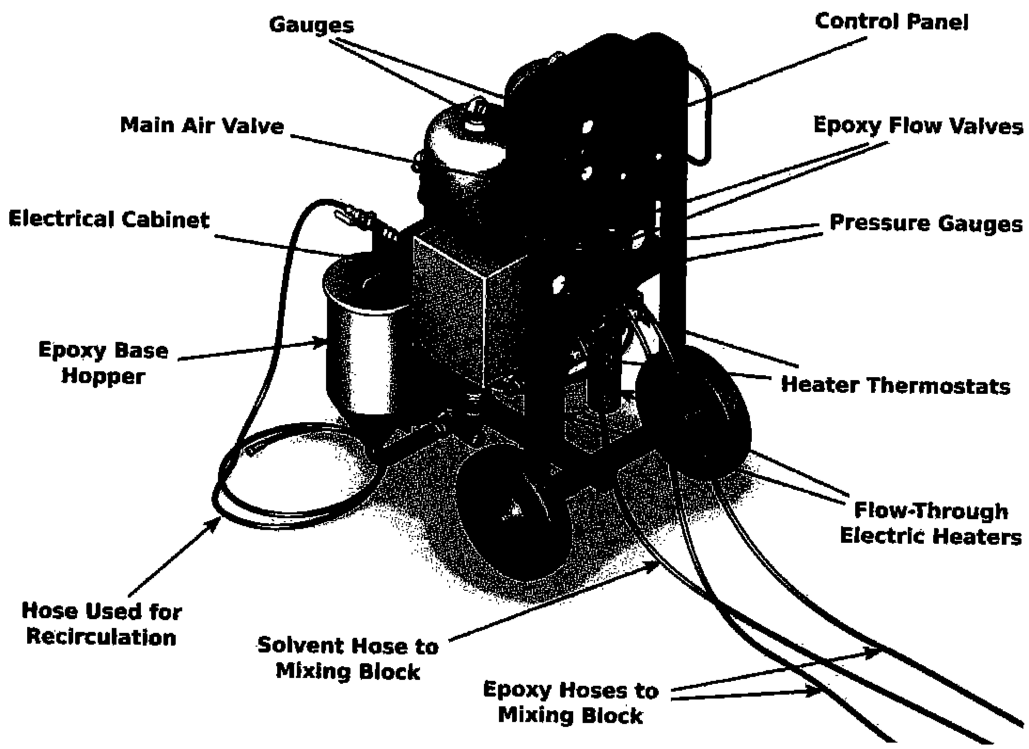

Figure 4 The epoxy sprayer system used within the penstock

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

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.[17]

Solvent, such as methyl ethyl ketone (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, ruining 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 situated at the back of the machine that would take in solvent from a bucket placed on the ground at the back of the sprayer (Figure 5). A hose ran directly from this pump to the mixing block.

[17] The epoxy product data sheet gives the "pot life" as 45 minutes at 70 °F. The workers described the period before the mixed epoxy began to set up as approximately 20 minutes in actual working conditions.

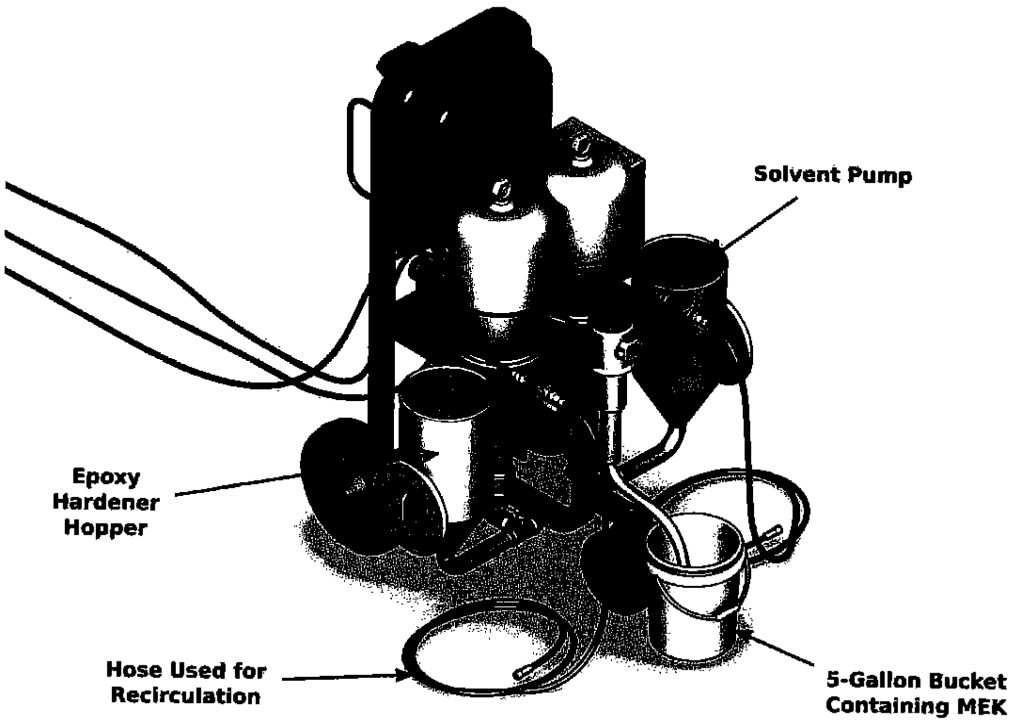

Figure 5. The solvent pump on the back side of the epoxy sprayer

The sprayer was positioned in the penstock on wheeled scaffolding, which the RPI crew called the "stage," about 1,400 feet from the access door and approximately 90 feet from the west bulkhead (Figure 6). 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.

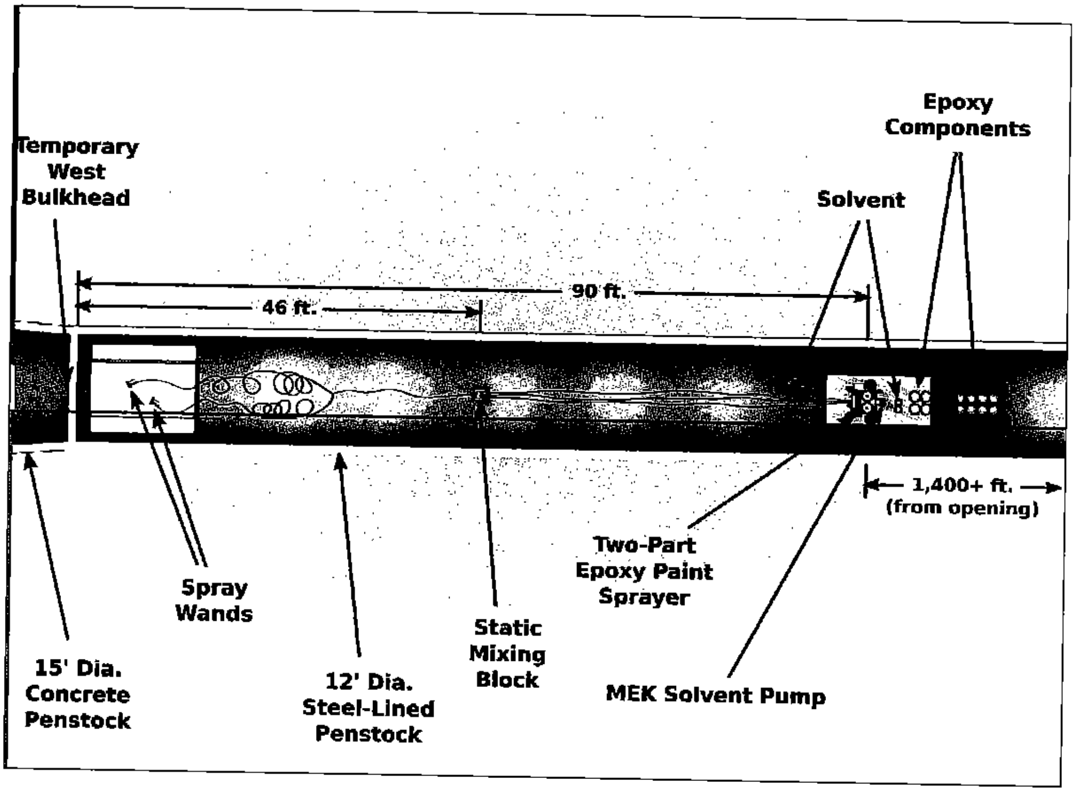

Figure 6. Aerial view of equipment arrangement in work area of the penstock

In the hour leading up to the incident, five of the 13 contractors were working around the sprayer system (Figure 7). Three of these individuals – two of which 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 "hole watch" at the access door 1,450 feet (442 meters) away.

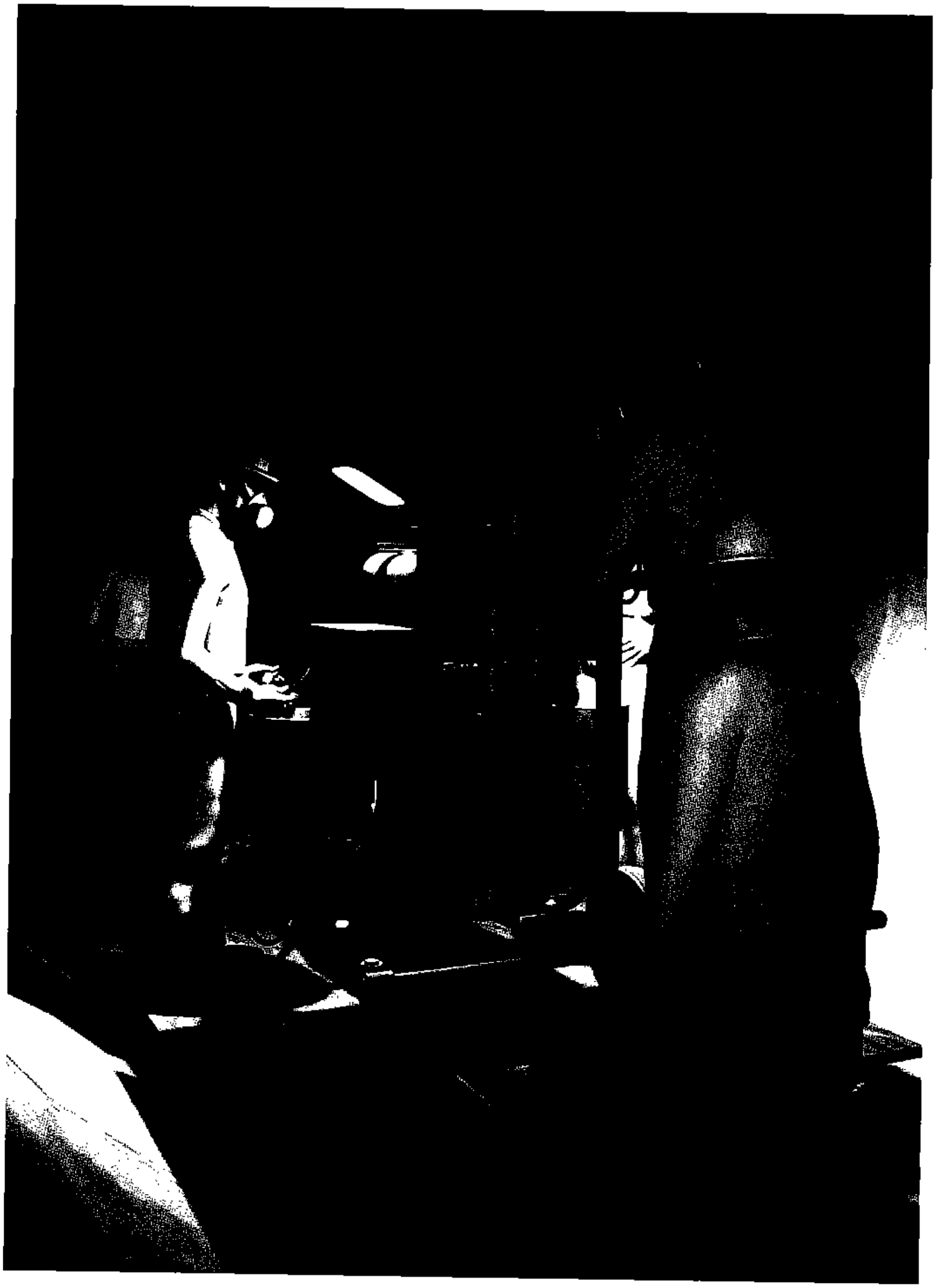

Figure 7. Depiction of contractors working with the sprayer immediately prior to the flash fire

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, attempting 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 8).

Figure 8. 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 were brought into the penstock in 5-gallon plastic buckets to flush out the entire sprayer system prior to applying the epoxy. This flushing not only cleans out the mixing block and combined epoxy product hose lines to the spray wands; it also 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.[18] 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.

On October 2, after this flushing process was completed, the contractors kept the buckets of used MEK 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) of MEK were on the stage. One of these buckets was a 5-gallon 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 containers 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 contractors remained at the site, 11 of whom continued working within the penstock.[19]

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 and that its electronic display continually gave error readings, which automatically shut down the sprayer.

[18] 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, as cleaning ensures smooth discharge of the epoxy products onto the surface.

[19] The twelvth contractor was still stationed at the access door as "hole watch."

Because of "fingering," or uneven application of the epoxy to the surface, the contractors were able to spray only about a 10-foot area of the penstock wall interior.[20]

Each time the sprayer malfunctioned and the epoxy did not evenly adhere to the penstock surface, 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.

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).

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 brought 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 of MEK in several trips using 2-gallon plastic buckets that originally contained the hardener. As a result, about 11-12 gallons of pure MEK and another 12

[20] "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.

gallons of epoxy/MEK waste product (of which about 5 gallons 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 additional buckets of the solvent. MEK was poured into the hardener side and circulated through the sprayer system. The 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 2:00 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, and 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 arm on fire and quickly engulfed the buckets of MEK. The fire rapidly spread to the epoxy material located on the scaffold of the epoxy sprayer. Another contractor, who left the sprayer area to retrieve portable fans to help dissipate the strong MEK odor, was about 40-50 feet from the sprayer when the fire ignited. Two others, already 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 obtain 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 tunnel 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. As the fire intensified, the trapped men retreated uphill, away from the sprayer and farther up into the penstock.

With extinguishers in hand, two of the contractors ran back inside toward the fire and sprayer, but the fire had intensified; 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 made by these contractors to extinguish the fire failed.

4.3.2 Initial 9-1-1 Call

One of the contractors 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 power house 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.[21] The 9-1-1 operator immediately broadcast a request to Clear Creek County Emergency Services[22] to respond to the Cabin Creek site, indicating that there was a fire on the "surface deck."

The RPI contractor also called the RPI corporate office to notify them of the emergency. After the calls were completed, he went back to the access door of the penstock and found that the RPI general foreman and KTA inspector had arrived.

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

[22] 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 world-class rafting river); four 14,000-foot peaks; two ski areas; several hundred abandoned mines; and residential and business districts. http://dola.colorado.gov/dem/operations/operations.htm.

During this time and for approximately 45 minutes after the initial fire, the trapped contractors used a work radio to remain in communication with the crew that escaped.[23]

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 inside. At 2:20 p.m., the 9-1-1 center broadcast an update indicating that the fire was 1,000 feet inside the penstock tunnel and below ground. The message also informed responders that they would need 1,000 feet of hose and the equipment necessary to fight an underground fire.

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

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.[24] West Metro Emergency

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

[24] West Metro and Clear Creek County have a Mutual Aid agreement for technical firefighting and confined-space rescue.

Response personnel are located on the west side of Denver, approximately 1 hour and 15 minutes travel time (about 45 miles) from Cabin Creek.

At one point, firefighters requested the MSDSs from RPI; a contractor went to the RPI storage trailer, retrieved them, and gave the documents to another member of his crew, who subsequently provided the documentation to the firefighters.

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), the four firefighters used a small gasoline-powered all-terrain vehicle (ATV)[25] to explore the penstock. Because of the smoke and lack of visibility, they were able to move only about 200 feet 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 the tunnel was cleared by Henderson Mine rescue personnel.

[25] The ATV was placed in the tunnel at the beginning of the project to transport personnel and supplies up the inclined tunnel.

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, West Metro joined CCFA and another rescue group, Alpine Rescue, at the top of the penstock (the mushroom). Upon arrival at the mushroom, West Metro was informed 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 (Figure 9).

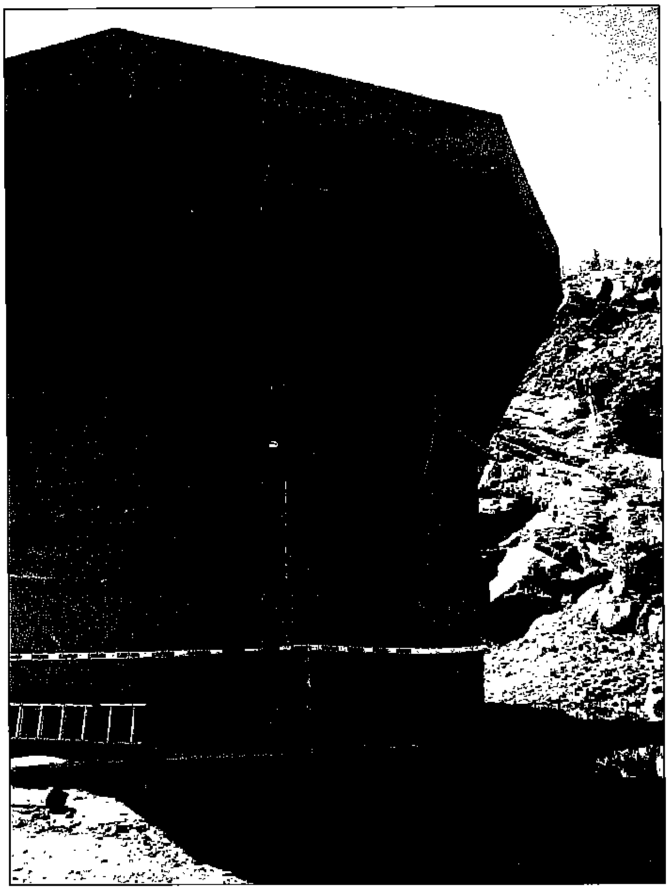

Figure 9. The upper reservoir mushroom and access hatch

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.

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 tunnel to determine if any of the contractors had survived. They found the first individual approximately 100 feet uphill of the fire. The four remaining were located even farther uphill, near the point at which the penstock's incline abruptly steepens. None of the five trapped contractors had survived. 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

Catastrophic incidents like this one are rarely the result of one single cause or one erroneous act. The CSB found that numerous issues had created an unsafe penstock work environment that had collectively contributed to the October 2, 2007, incident.

5.1 Pre-Incident Events

A tight schedule, insufficient ventilation, and improper equipment choices for recoating the penstock created an unsafe work environment even before the epoxy application activities began.

5.1.1 Scheduling and Production Pressures

The Xcel penstock project was under tight schedule constraints. 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, which likely affected the crew's ability to focus on safety. Decisions made in haste can often have deleterious side effects, including inadvertent step deletion, heavy focus on one issue while minimizing the significance of others, and disregard for warning signs that do not match with expected outcomes. Evidence indicates that safety within the penstock was negatively impacted by the rushed work pace at the Cabin Creek site.

The timing of the project was one of the five items emphasized as problematic in the Xcel "Major Items of Concern" penstock project planning document (Sections 4.1.1 and 6.2), where the Xcel civil engineer who wrote this document 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 within the allotted 10-week schedule in the best of conditions. 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."

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. For a power plant like the Xcel Cabin Creek site, the downtime of the penstock would be costly; for the recoating work to be completed in the short time allotted in the scope of work, a short schedule would be needed for successful completion. The contractors working the penstock job confirmed this "short schedule" issue, where they perceived that they were behind schedule before they even began the epoxy application process. The vice president of RPI also noted the very tight schedule in emails during the planning phase of the project. He questioned whether only one coat of epoxy would be needed for the floor of the penstock, as applying just one instead of two coats would accelerate the work pace and decrease curing time of the epoxy. In planning emails with KTA, the Xcel principal engineer also confirmed that the penstock outage would be extremely costly to the company.

As the project began, several delays in the initial work tasks constrained the already tight schedule. 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. Additionally, the contractors had to spend extra time sandblasting to remove the necessary amount of old liner prior to recoating.

In addition to these work delays, RPI employees reported that the company used unofficial financial incentive programs – both in the past and in this recoating project – to ensure 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.

Scheduling and production pressures likely had jobsite impacts. 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, eye witnesses stated that the general foreman was anxious about the crew's progress and was pushing to get the recoating portion of the project underway.

The crew's rushed pace likely contributed to several decisions that actually hindered work and put employees at risk. The contractors stated that, while they often had daily meetings during the penstock project, the focus of these meetings was on the work to be conducted; there was not a focus on safety issues , such as the hazards of working within the unique confined space of the penstock and the steps they would need to take to minimize those risks or how they should respond in an emergency situation. However, safety meetings were required, as per RPI policy, to "[c]over the safety aspects of each days [sic] work tasks." A safety meeting would have been particularly important the day of the incident because the work conditions were changing within the confined space. Flammables were being brought into the penstock and the epoxy application process was beginning. A reevaluation of the hazards – as required by OSHA's Confined Spaces Rule – should have been conducted as part of this morning meeting. Yet, this safety discussion did not occur.

In addition to the lack of a safety discussion during the brief morning meeting on October 2, necessary equipment was not used inside the penstock. This equipment included: heated hose lines, which should have been incorporated into the sprayer system; safety cans that should have been provided to safely transport solvent into the penstock; portable fans to improve air flow; and fire extinguishers near the sprayer and work activities (Sections 5.1.2 and 5.1.3).

Also problematic was the amount of epoxy and solvent in the penstock prior to the start of the application process. The contractors brought more than 100 buckets of epoxy and solvent into the penstock prior to the start of the application process to speed up the recoating work. (Appendix C). Many of the piles of stacked buckets ignited after the initial flash fire, increasing the thick toxic smoke within the penstock that inhibited the contractors' abilities to fight the fire with extinguishers. A thorough safety meeting the morning of the incident may have highlighted these issues. The crew's tight schedule was likely one reason a reevaluation of the safety hazards was not conducted and the necessary equipment for safe work was not set up prior to the start of the recoating work.

The CSB concludes that these production and scheduling pressures likely contributed to the rushed pace, the poor equipment choices, and the lack of a thorough safety assessment prior to a change in work conditions.

5.1.2 Insufficient Ventilation

Adequate ventilation was a 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; however, these bulkheads interrupted the normal airflow through 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). 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)[26] in the work area between the two

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

bulkheads.[27] 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 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 ventilation setup was designed for the purpose of ensuring the penstock ambient conditions were optimal for the sandblasting and epoxy application activities.

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 precise location of the supply duct outlet is unknown since it was destroyed in the fire, but a picture taken an hour before the accident indicates it was close to the west bulkhead, discharging directly at the west bulkhead wall. 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 were used to move 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.

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

[27] 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

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 (Section 5.3).

5.1.3 Improper Equipment Choices for Fire Prevention

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

5.1.3.1 Choice of Epoxy Hose

Because temperature affects the viscosity of the epoxy and can negatively impact the quality of coating application, specialized industrial painting equipment, such as heated hose line, is available to combat colder weather conditions. However, a decision was made to use regular spray hoses, instead of hoses with in-line heaters, despite the penstock ambient and surface temperatures below recommended levels for proper epoxy application.

The product data sheets for the epoxy base and hardener, provided by RPI to Xcel as a part of its bid submission package, state the minimum surface temperature during application must be no colder than 60 °F (15 °C). However, in the week leading up the incident, ambient temperatures averaged 58 °F (14.4 °C), and on October 2, the interior surface temperature of the penstock was recorded by the KTA inspector as 54 °F (12 °C).

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 °F (15-30 °C). Cold products are very viscous and will be very difficult to mix and apply." While the epoxy

Changes: 780,000 CFH/176,432ft3 = 4.4 air changes per hour.

components were initially stored in a heated trailer, more than 95 buckets 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 the material's thickness and initial cold temperature. When mixing the two epoxy components together, the combined product should have been "between 70-80 °F (20-25 °C)." 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 degrees, 47 degrees [F]."

Furthermore, the sprayer had difficulties maintaining the required epoxy temperature for an extended period. As the two epoxy components circulated several times through each side of the sprayer and the attached heaters, the limited quantity of each within the sprayer was able to achieve the requisite temperature.[28] 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 circulation 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 to great a distance to maintain the requiste 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.[29]

[28] 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.

[29] 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 °F for correct application.

The CSB determined that the primary reasons for the epoxy application difficulties that the work crew experienced arose due to the inability to achieve and maintain the necessary temperatures of the epoxy components for application. These difficulties likely would have been avoided had heated hose lines been used. 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. Consequently, the epoxy did not reach the temperature necessary for proper application, and the crew's repeated flushing of the hoses with MEK between each failed attempt contributed to the build up of MEK in the atmosphere.

5.1.3.2 Electrical Safety

When dealing with flammable material, the equipment being used must be properly bonded and grounded, and made of the proper materials. These electrical safety precautions were not met on the day of the incident.

Some of the hose chosen for the penstock job was likely non-conductive. Most of the hose lines around the sprayer were destroyed in the fire; however, 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. The equipment remains included 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 also destroyed in the fire, yet the inner woven metal sheath was never found. 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 hose connector. (Appendix D.1). 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). 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 5.3 and Appendix D discuss this ignition scenario in detail).

Fire prevention and mitigation issues are discussed in RPI policy documentation. RPI's Injury and Illness Prevention Program (IIPP) section, "Spraying Equipment and Operations," addresses risks of ignition. To prevent explosions and fires from static sparking, the policy requires that all equipment and objects being sprayed are properly grounded, that only non-conductive or grounded air and fluid hoses are used in airless applications, and that spray wands are grounded through hose connections. To prevent static charge buildup, conductive hose should have been used with the sprayer instead.

5.1.3.3 Use of Halogen Lights

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. 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).

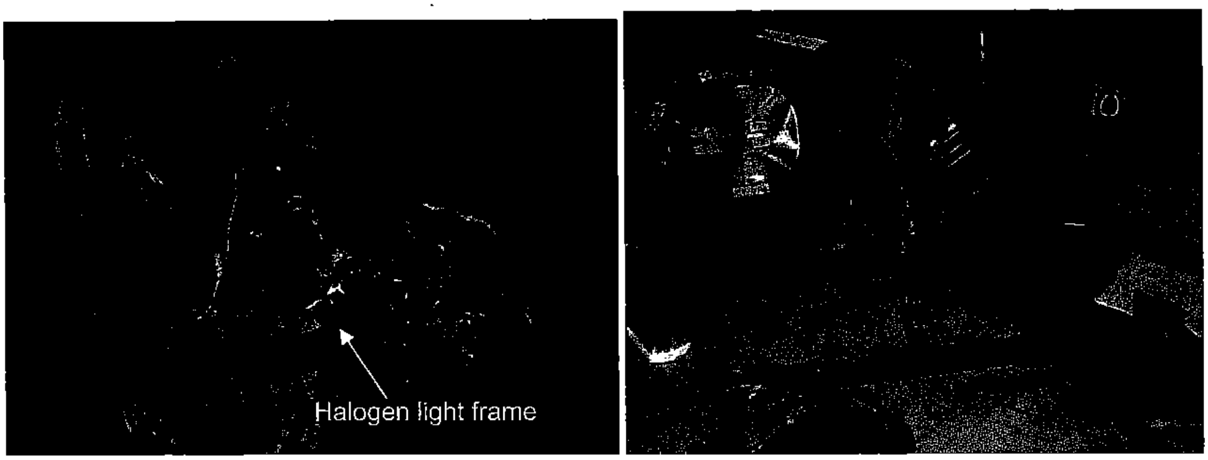

Figure 10 Remains of the halogen light sitting atop the sprayer inside the penstock (left) and the same remains being compared to an exemplar halogen light (right).

Equipment and supplies needed for the penstock project were planned by the onsite foremen, the RPI shop manager, and RPI upper level management. As a result of this planning, halogen lamps were sent to the work site and used during the epoxy application activities. 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 concludes that this unsafe lighting choice provides evidence of a serious deficiency in pre-job safety planning for the work hazards.

5.1.3.4 Fire Extinguisher Placement 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) to the exit of the penstock to retrieve functioning 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).[30] 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 combustible epoxy products.

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 components surrounding the sprayer ignited. The rapid spread of fire and toxic smoke from burning epoxy prevented the contractors 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. This could have been avoided, had the sprayer system been flushed with the solvent outside the penstock.

[30] 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."

The cleaning of the sprayer itself, including the hoppers and associated hoses leading to the mixing block, did not require immediate flushing with a solvent. In fact, all equipment except for the mixing block itself and the hoses going to the spray wands, could have been cleaned with solvent once the equipment was removed from the penstock. As explained in Section 4.1.7, immediate flushing with solvent is only needed once the epoxy components are mixed together at the mixing block; it is when the hardener and base combine that they react with each other and solidify into the epoxy product.

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 and the 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 made it impossible for the CSB to 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 testified 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, based on the evidence, 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[31]: 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[32] to prevent flash fires and explosions. This is especially important in a confined space where the number of air changes can be limited, causing flammable vapors to quickly concentrate. In this incident, a lack of fire safety measures to control 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

Approximately 16 gallons of MEK and more than 95 buckets of epoxy[33] were within the penstock at the time of the fire. All seven buckets of MEK and at least 30 buckets of epoxy 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.

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

[32] 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.

[33] Because the fire burned many of the plastic buckets, leaving only the metal handles, it was impossible to discern if the 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.

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.[34] 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.

[34] 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 understand 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. Additionally, RPI did not re-evaluate the hazards when working conditions changed inside the penstock such as the use of MEK. The lack of sufficient planning and coordination by Xcel and RPI for the recoating work within the confined space was causal to the incident.

6.1 Penstock is a Permit-Required Confined Space

The Cabin Creek penstock was 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 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 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,[35] is an atmosphere 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 LFL. Employers are obliged by OSHA 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)].

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

Most indicative of the companies' understanding that the penstock was a permit-required confined space is the "Safety and Health Hazard Assessment Survey" for abrasive blasting inside the penstock. This document, prepared at the request of the penstock recoating team by an Xcel safety consultant in early 2007, 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. The document was made part of the bid package and sent to potential contractors. Xcel, however, 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.

[35] 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.

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.

Additionally, 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—again an element of a permit-required confined space program.[36]

A 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. 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.

Each of these new hazards should have prompted the application of a permit-required confined space program, yet no such program was initiated.

6.1.3 Permit-Required Confined Space Inadequately Declassified

Neither Xcel, RPI, nor KTA effectively treated the penstock as a permit-required confined space, nor did they take the needed steps to formally declassify the penstock to a non-permit confined space; indeed, the penstock space could not have been safely declassified even if such steps were taken.

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.

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[36] 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.

More important, the penstock's unique size – more than 4,000 feet 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)]. Additionally, the American Public Power Association (APPA), an industry organization of which Xcel is a member, 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).

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 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 prevented it from being treated as anything but 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 all hazards identified were not addressed before work began. Many of these hazards were known to the Xcel recoating project team and RPI management during the planning phase of the project. Section 4.1 discusses opportunities where hazards were identified but not managed.

One such opportunity came in early 2007, when Xcel completed the "Safety and Health Hazard Assessment Survey" for the recoating project. As previously detailed in Section 4.1.1, the assessment was incomplete: it considered only the high pressure abrasive blasting work, not the recoating of the penstock interior. 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 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 not clear; however, the fact 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.

Another opportunity to identify and manage the hazards occurred when a KTA project engineer sent a review of RPI submittals for the penstock recoating project to the Xcel Reline Project Team Leader. 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. 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 the inclusion of eight additions and clarifications to the contract between Xcel and RPI, three of which had safety implications.[37] 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.

An additional opportunity for addressing and managing the hazards associated with using flammables within the confined space occurred during a preconstruction meeting with Xcel, RPI, and KTA on September 5, 2007. Management and safety personnel from Xcel and RPI attended and the need for additional safety precautions for the recoating project were discussed. Handwritten notes on an agenda in the files of the Xcel safety director indicate that both the safety addendum to the contract and the need to enforce Xcel's "Stop Work Authority" policy during the recoating project were part of that discussion. Additionally, the Xcel safety director's handwritten notes indicate his recognition of the need for an external rescue team during the penstock work. While the safety addendum touted Xcel's need to carefully manage the safety of the penstock worksite, post-incident the company asserted that RPI was fully responsible for maintaining safety. Neither Xcel nor RPI took steps to provide rescue services outside the penstock during the hazardous recoating maintenance work.

[37] 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 spots.

Another missed opportunity came in the months prior to the incident, when 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 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 these orientation sessions, the Xcel employee providing the orientation to one of the RPI foremen and a few of the other RPI crew members did not review the items listed in Xcel's confined space entry program as they pertain to contractors, nor did he request proof that the crew had received training on confined space entry. During this orientation, the Xcel employee 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 ever 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 the evaluation of 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 air in the penstock was not monitored continuously. Instead, readings were taken only two to three times per day at the penstock entrance by the "hole watch," an RPI employee assigned permit-required confined space attendant duties. The CSB found no evidence that work activities inside the penstock had been monitored on the day of the incident. As stated, the OSHA Permit-Required Confined Spaces Rule requires 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. 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.[38]

[38] At the time of publication of this report, all three companies had contested the OSHA citations.

6.4 No Evaluation of Hazards When Conditions Changed

Had Xcel or RPI been able to appropriately declassify the penstock to a non-permit confined space for the abrasive blasting portion of the work, the companies would still have had to re-examine the space for new hazards when the work conditions inside the penstock changed from blasting to recoating. The OSHA Permit-Required Confined Spaces 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)]. The CSB determined that neither RPI nor Xcel attempted or documented a reclassification of the confined space, even though work conditions and hazards changed as the recoating project progressed inside the penstock.[39] As listed in 6.1.2, the CSB noted that RPI workers experienced a number of potential hazardous atmospheric 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 a new hazard 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 the reassessment of hazards was not conducted and hazards went unmanaged.

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

6.5 Choice of Solvent

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 Methyl Ethyl Ketone

6.5.1.1 Recommended Usage

MEK is an organic chemical compound often used as a solvent in painting and industrial recoating activities. The chemical is specifically referenced in the epoxy manufacturer's application instructions as one of a number of possible solvents for cleaning prior to and during application of the epoxy products; other suggested solvents included acetone and 1,1,1-trichloroethane.

As explained in Section 4.1, the epoxy application procedure states that a solvent is needed during the recoating process. Flushing the epoxy sprayer required pouring MEK into the hoppers that were open to the atmosphere. RPI's planned use of solvent to flush the hose lines involved the use of a separate pump with a hose inserted into an open 5-gallon bucket of MEK. 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.

6.5.1.2 Hazards of MEK

MEK is listed by the National Institute for Safety and Health (NIOSH) as "highly flammable" (NIOSH, 1998). MEK is a Class IB Flammable Liquid, with a flash point below 73 °F and boiling point at or above 100 °F (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, stating in capital bold letters that MSDSs should be consulted and "proper fire and ventilation procedures should be followed." The MSDS provided by Xcel states, "DANGER! EXTREMELY FLAMMABLE LIQUID AND VAPOR. VAPOR MAY CAUSE FLASH FIRE" (emphasis in original). 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).[40]

As part of its investigation, the CSB conducted a brief review of available MSDSs on MEK and found warnings that the product should not be used in confined spaces. The MEK MSDSs – including the MSDS Xcel provided to the CSB – 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. The MSDSs instruct the user to "prevent buildup of vapors or gases to explosive concentrations." 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.

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[40] 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.

RPI's safety policies within its IIPP are similar to the warnings found within the MSDSs. The company's "Fire Protection and Prevention" policy states that liquids should be transferred from a drum to a safety can[41] by gravity through an approved self-closing valve or an approved pump. This policy, as well as several others within the IIPP, requires all flammable liquids to be stored and handled in safety cans. The "Electrical Safety" policy within the IIPP states that containers must be electrically grounded to each other and warns that static electricity can cause fire.

Despite the warnings within the MSDS and RPI's own safety policies, 2- and 5-gallon plastic buckets were used to transport and store MEK solvent in the penstock. One open 5-gallon plastic bucket of MEK was placed under the solvent pump of the sprayer. After using MEK to clean out the spray wands, the 5-gallon plastic buckets of used solvent were left adjacent to the sprayer system instead of removed from the work area. Approximately 6 additional gallons of MEK were brought into the penstock in 2-gallon 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 drum in the storage trailer, transported 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.

6.5.1.3 Evidence that Xcel and RPI had Knowledge of MEK Usage

Both Xcel and RPI had knowledge that the highly flammable MEK solvent was being used within the penstock as part of the recoating activities.

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

[41] RPI Coating's Fire Protection and Prevention policy defines a safety can as "an approved container of not more than 5 gallons capacity, having a flash arresting screen, spring closing lid and spout cover."

employees involved in the penstock project planning, that states that a solvent would be used within the 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 a 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 discuss the use of solvents in the recoating process. It 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." The Application Procedures also include information that solvent would be used with the epoxy product during the application process.

Once RPI was onsite, the planned use of MEK within the penstock was witnessed by workers and supervisors from both companies. On September 12, 2007, 110 gallons of MEK (two 55-gallon drums) were 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.

While Xcel has disputed its knowledge of the use of MEK in the penstock recoating project, from the totality of the 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 solvents in the penstock. Both companies were aware that MEK solvent was being used during the epoxy application process, yet the flammability hazards MEK posed were not addressed prior to starting work inside the penstock.

6.5.2 Safer Alternatives

When planning for this recoating project, neither company 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 citrus-based solvent products are available for industrial purposes; these products are often biodegradable, non-toxic, and have significantly higher flash-points than flammable solvents like MEK.[42] The manufacturer of the two-part

[42] 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.

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. Good practice guidelines such as ANSI Z117.1, "Safety Requirements for Confined Spaces," recommend that the hierarchy of controls be followed to control confined space hazards (ANSI Z117, 2009, p.17). In the hierarchy of controls, primary consideration is given to eliminating the hazard or using engineering controls such as substitution. Here, less hazardous, non-flammable substitute solvents are available to substitute for the highly flammable MEK. Another more effective safety approach is the engineering control of conducting the work outside the confined space.[43] 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 warnings to prohibit entry or occupancy based upon a specified flammable atmosphere limit. Xcel's confined space permit form allowed entry even where "atmospheric and/or serious hazards in the space that cannot be controlled or eliminated" existed, if certain unspecified precautions were being utilized. 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

[43] 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.

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 clearly 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 upon managers and workers if no limits are specified. This safety gap can also lead to a failure to understand the serious hazards of flammable atmospheres, as was the case in the Cabin Creek penstock.

7.0 Emergency Response and Rescue

Xcel and RPI managers were aware of the planned use of MEK solvent in the Cabin Creek project to clean the sprayer, hoses, and associated equipment in the open atmosphere of the penstock, which created a potential for an IDLH[44] atmosphere in the penstock work area. Yet, no qualified confined space technical rescuers were available for immediate action outside the penstock on the day of the incident, when solvent was brought into the confined space.

7.1 OSHA Requirements for 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 its employees can perform rescue and emergency services competently when its employees are working within a permit-required confined space. The only planning that RPI and Xcel did in the event of an emergency inside the penstock was to inform the contractors that 9-1-1 would be called to summon appropriate community emergency services. Neither company contacted emergency service providers to evaluate their competency in permit-required confined space rescue as required by the OSHA Rule, or arranged for emergency response support to be onsite prior to begining work inside the penstock.

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[44] 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)].

7.2 Lack of Qualified Responders Delayed Rescue

The first and closest emergency responders arriving to the Cabin Creek site were not prepared for entry into the penstock's confined space. Approximately eleven minutes after the 9-1-1 call was made, 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 did not have the necessary equipment or training to extinguish the fire in the penstock or initiate a rescue of the trapped RPI personnel.[45]

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.

None of the volunteer fire fighters from the CCFA who responded to the Cabin Creek penstock fire held technical rescue qualifications or had received up-to-date workplace confined space training. 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[46];

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[45] 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."

[46] 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

however, only a small number of Colorado firefighters have been individually certified to perform technical rescue.[47] 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.

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,[48] located in Denver (45 miles, approximately 1 hour 15 minutes travel time), and the Henderson Mine,[49] located near Empire, Colorado (21 miles, approximately 35 minutes travel time). Both were contacted and requested to support the incident by the CCFA.

7.3 OSHA Requirements for Timely Rescue

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 may pose an immediate threat to life and health, the rescue team must be stationed outside the confined space and ready for immediate entry. The use of a flammable liquid inside the penstock created the potential for a

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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.

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

[48] 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

[49] 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

flammable atmosphere and life-threatening conditions in the event of an ignition, especially when coupled with a single exit for evacuation. While RPI and Xcel were aware that a flammable liquid would be used during the epoxy application process inside the penstock, both companies relied on calling 9-1-1 and hoping for a timely response by community emergency services in the event of any emergency inside the penstock.

7.4 Lack of Timely Response Delayed Rescue

The location of the Cabin Creek hydroelectric plant made timely emergency response extremely difficult. Therefore, the CSB concluded that an onsite technically qualified confined space rescue service should have been made immediately available at the penstock access door.

Depending on the road conditions, vehicle type, and speed, it takes between 10 and 30 minutes to drive the 5.5 miles (8.9 kilometers) from the Georgetown fire station – the closest community emergency response facility – to the Cabin Creek hydroelectric plant site. 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 its many hairpin turns made it hazardous to drive at higher speeds.[50]

characteristics and hazards as an underground mine. This rescue team is a private entity and not a public emergency response organization.

[50] 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.

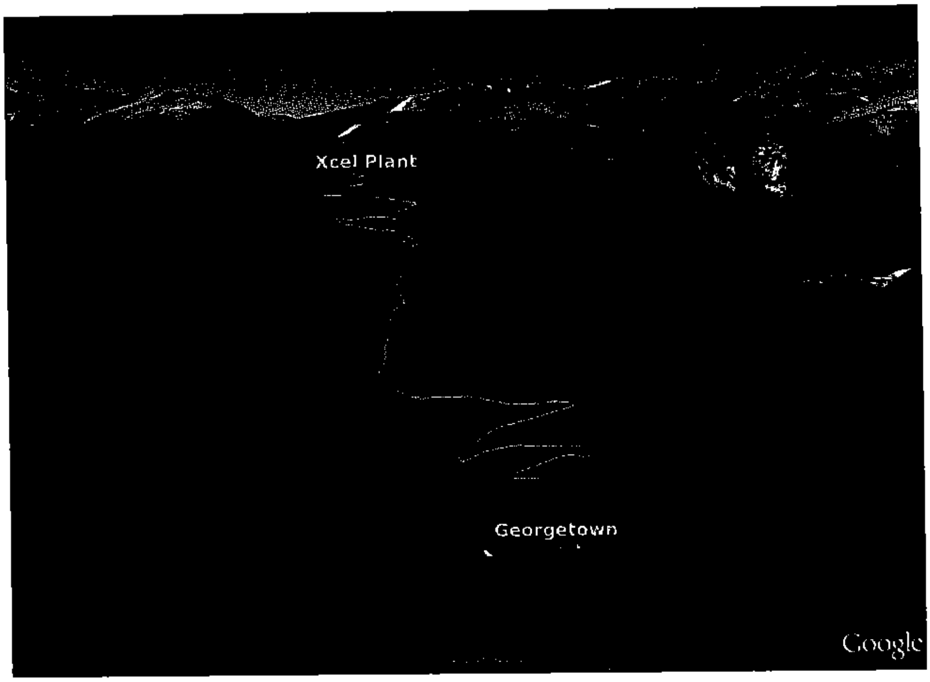

Figure 11. The winding, steep and narrow road from Georgetown to the Xcel hydroelectric plant

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. Within forty minutes after the Clear Creek County Sheriff's officers arrived at the scene and established Incident Command, they were joined by several CCFA volunteer responder units. The closest community emergency responder capable of performing a confined space rescue operation, West Metro Fire Rescue, arrived at the site at 3:40 p.m., more than an hour and a half after the fire started, and the Henderson Mine rescue team arrived shortly thereafter at 4:10 p.m. The community rescue services, who were the 9-1-1 responders in the local area, were not capable of providing a timely response to such a remote mountain location even if they had been qualified in confined space technical rescue. The local fire service officials told the CSB that any attempted rescue of the trapped RPI workers could have been successfully conducted only with sufficient numbers of responders and appropriate equipment immediately available onsite to fight a fire and rescue workers more than 1,400 feet inside the penstock tunnel with difficult access and egress. Additionally, the fire service organizations had no pre-knowledge of the hazards of the chemicals onsite, their quantities, or locations. Any successful rescue would have been possible only if RPI and Xcel had planned and coordinated to have appropriate rescue services stationed immediately outside the penstock in case a life-threatening emergency developed.

7.5 Limited Access and Egress from the Penstock

The penstock is a 4,150-foot (1265-meter) long sloping, underground permit-required confined space (Section 6.1.2). At the outset of the penstock recoating project, an access door in the side of the penstock was cut near the lower reservoir end, uphill of the point where the penstock turned downward to the turbines. After the temporary bulkheads were constructed, this access opening was effectively the only way in or out of the penstock for RPI workers.

As briefly mentioned in Section 2.1.1.1, the gradient of the penstock, from the cut access door, through the area where the incident occurred, to the west bulkhead is at a two degree incline. The gradient then increases to 10 degrees for another 1,563 feet (476 meters), and 55 degrees for an additional 1,020 feet (311 meters). The final 20 feet (6.1 meters) of the penstock is completely vertical, with no stairs or ladder. At the top of this vertical section of the penstock in the upper reservoir is the intake structure known as the "mushroom." The mushroom is a 40-foot (12.2-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) at a reverse incline position, requiring climbing skill and significant physical strength to enter (Figure 12).

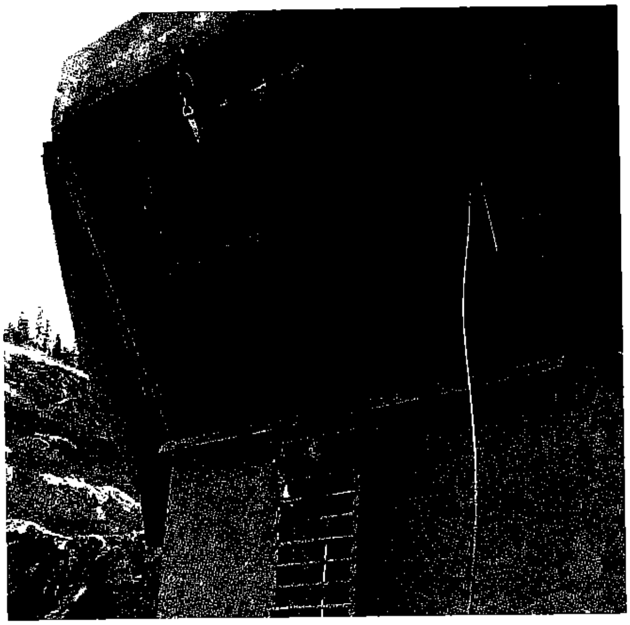

Figure 12. The upper reservoir mushroom access hatch

While walking in the lower sections of the penstock is relatively easy, walking (or climbing) beyond the point where the penstock starts its 55 degree incline is physically impossible. The final vertical section of the penstock cannot be traversed without climbing paraphernalia setup in advance from the mushroom[51] 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 near the start of the 55 degree incline.

[51] 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.

7.6 Requirements and Recommendations for Alternate Escape Routes or Safety Chambers

The decision to use a flammable solvent in a confined space with a single means of egress inhibited self-rescue in the event of a fire or other emergency. This significant hazard was not addressed during the planning phase of the recoating project. There was no plan for an alternate escape route out of the penstock if the primary route were to be blocked in an emergency.[52]

The need for secondary escape routes from penstocks is advocated by a guideline published by the American Society of Civil Engineering (ASCE) Task Committee. Section 2.3.6.1 of "Guidelines for Inspection and Monitoring of In-Service Penstocks," identifies the need to have alternative escape routes from penstocks when the normal entrance is unavailable as an exit.

Alternatively, provisions could have been made for a safety/rescue chamber[53] inside the penstock wherein the RPI workers could have found fresh air, water, and reliable communication equipment. The National Institute for Occupational Safety and Health (NIOSH) has issued guidance 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.[54]

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

[53] 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.

[54] 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.

Addressing the hazard by creating an alternative/emergency exit or installing a rescue chamber,[55] and staging emergency rescuers near the penstock entrance could have prevented the fatalities in this incident. In addition, such planning could have afforded the opportunity to weigh the costs and benefits and the various risks, which could have resulted in a safer solution, such as using a less flammable solvent or modifying the equipment so as to eliminate or significantly minimize the need to use a flammable solvent inside the penstock.

7.7 Lack of Emergency Response Planning

Xcel's and RPI's approach to rely on community emergency services to provide adequate response when these services were unfamiliar with the unique characteristics of the penstock space and not forewarned about the inherent hazards of the recoating work could not ensure the safety of the workers inside the penstock. Better emergency response planning would have revealed the shortcomings of using flammable liquids inside an egress-impaired permit-required confined space located at a remote mountain location.

7.7.1 Xcel's Role in Planning for Emergency Response

Xcel did not participate in any emergency response planning for the penstock, even though its employees and managers routinely entered the interior of the penstock to inspect project progress and perform other tasks. As stated in Section 7.1, no penstock-specific or confined space rescue emergency drills were conducted with the CCFA or other response entity at the Cabin Creek facility.[56] Xcel did not plan or

[55] 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.

[56] On July 11, 2007, about two months before the start of the penstock job and several months after Xcel began planning for the project, the CCFA conducted an emergency drill at the Cabin Creek facility. However, this drill rehearsed a fire response to the power production office facility, and did not involve the penstock or a confined space rescue.

coordinate with RPI to ensure the contractor's confined space program met Xcel's expectations, including consideration for responding to an emergency inside the penstock.

7.7.2 RPI's Role in Planning for Emergency Response

When the fire ignited it intensified rapidly, and by the time RPI workers returned with fire extinguishers the fire had grown too large to extinguish. RPI immediately told Xcel operations personnel to call 9-1-1. The RPI crew at Cabin Creek did not have the equipment or training to respond to this emergency, and RPI had not arranged for an emergency service to provide timely support.

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)]. As no such evaluation of CCFA by RPI occurred, the emergency response was severely handicapped. The trapped RPI workers were communicating with outside personnel up to 45 minutes after the fire started. Had a properly equipped and trained rescue service been standing by, it is likely that the fire could have been extinguished and the workers rescued.

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 both 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 [57] to several contractors who were to be selected based upon the "best value/best overall evaluated offer"[58] rather than price alone. The Xcel RFP stated that the contractor would be evaluated, scored, and chosen using weighted rating factors (percentage of weighting in parenthesis) such as their pricing (15%), safety experience modification rate

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

[58] 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).

(EMR)[59] (5%), historical quality of services and equipment (10%), operating history (10%), completeness of proposal (5%), and key personnel experience and continued availability (5%).[60] 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),[61] an industrial protective coatings trade association. The Xcel contractor selection process for larger projects, such as the Cabin Creek penstock recoat, also included a prequalification[62] step that examined the contractors' financial capacity to successfully perform the work; however, the prequalification step did not consider safety performance.

Xcel's first attempt at selecting 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,

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[59] 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 one indicates below-average performance. An owner can get an 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, 2005, p.13). The RFP called for reporting the interstate EMR.

[60] 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%).

[61] SSPC QP 1 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. http://www.sspc.org/certification/PCCP/QP1main.html , http://www.sspc.org/certification/PCCP/DAC html, accessed March 8, 2009.

[62] Contractor selection processes often have an initial pre-qualification process during which each potential contractor must meet basic qualifications, including safety. A pre-qualification 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 pre-qualification process considered only the financial capacity of the potential contractor.

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.

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[63] 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 be the result of fatalities from their work on the "recent Golden Gate bridge project."[64] The RPI EMR was trending upward from 1.03 in 2005 to 1.28 in 2006; the RPI team was aware that under Xcel's policies, an EMR rate of 1.0 or above was not acceptable. In fact, the Xcel team gave RPI's proposal a safety rating of "zero" in the evaluation process. The RFP evaluation form used by the team stated that the rating of zero signifies that the bidder's proposal for that rating criterion "does not meet minimum requirements, automatic rejection."

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

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[63] 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 $1,328,250 and CCC's bid $1,702,105, a difference of $373,855.

[64] 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).

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 supervisor inquired, the RPI safety director stated that the company's EMR was high due to the Golden Gate Bridge job and the company's EMR was trending down in 2007.[65]

8.1.3 Contractor Selection and Safety: Historical Background

An influential 1982 report by the Business Roundtable, "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.[66] 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 included a model safety pre-qualification form for use in selecting contractors.

A 2008 comprehensive report on contractor safety prequalification, "Contractor Safety Prequalification," (Phillips and Waitzman, 2008) has referred to the 1991 report by the John Gray Institute, "Managing Workplace Safety and Health: the Case of Contract Labor in the U.S. Petrochemical Industry," as a

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[65] 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.

[66] 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

"bellwether" for subsequent industry interventions addressing contractor safety, including the issue of contractor safety pre-qualification.[67] 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 [68] (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). The report found an association between rigorous screening in the selection of contractors and positive safety performance (Phillips and Waitzman, 2008, pp.49-50).

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 in the selection of construction contractors, such as quality, past performance, and safety[69] (TRB, 2006, pp.40). Several organizations and industry associations have developed guidelines and recommended practices addressing the use of safety criteria for the selection of contractors including the

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and represents the viewpoints of member construction owners seeking to improve construction industry practices including safety performance [CURT, 1990].

[67] While the John Gray Institute report addressed 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).

[68] OSHA determined that a contracting crew was involved in working on the equipment where a massive release of flammable gas occurred that resulted in an explosion. The contractor, who had been involved in a fatal accident at the same facility three months earlier, was fined $724,000 for multiple willful and serious violations (OSHA, 1990, pp 26-27, 63).

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

Construction Users Roundtable (CURT),[70] the American National Standards Institute (ANSI), and FM Global. One common method using criteria other than low price in contractor selection is a pre-qualification process. Pre-qualification is typically a pass/fail system that ensures that only contractors who meet specific requirements, including safety, are allowed to compete further in the selection process (CURT, 2004, pp. 1, 5). Another common alternative construction procurement 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 the bidders are scored and the highest evaluated bidder is selected (TRB, 2006, pp. S-2 – S-8). A third common procurement method uses a combination of pre-qualification and best value practices where only pre-qualified bidders are allowed to compete in the final selection process, whereby an evaluation and rating of the bidders is based upon best value parameters (CURT, 2005, pp.6-9; TRB, 2006, p.1). Xcel's approach used both pre-qualification and best value components in its selection of the Cabin Creek penstock recoating contractor.

Industry guidelines addressing contractor selection support using a pre-qualification 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

[70] CURT is an industry organization that promotes owner company advocacy on national construction 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 &

owner's previous experience.[71] ANSI Standard Z-10, "Occupational Health and Safety Management Systems" also recommends that the contractor pre-qualification process include consideration of safety criteria for successful contractor safety performance management[72] (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 for the sourcing of goods and services. These policies allowed a pre-qualification process to be used, and a rating and ranking RFP competitive bid process that awarded the contract to the "lowest evaluated bidder." The use of a pre-qualification process was not mandatory and the minimum specified requirements were left to the procurement representative; therefore, the use of safety criteria in the prequalification process was not required. In the Xcel penstock recoating contractor selection process, a pre-qualification step was implemented but only the financial capacity of the bidders was considered – not safety.

In the penstock bid evaluation process, RPI received a score of zero in the safety category, a score that the evaluation form indicates means that the bidder's rating "does not meet minimum requirements [and means] automatic rejection." The evaluation team was also aware of RPI's accident history that involved

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Gamble, Duke Energy, General Motors, Shell, the U.S. General Services Administrations, and the U.S. Army Corp of Engineers.

[71] 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, 2005, p.13).

[72] API Recommended Practice (RP) 2221, "Contractor and Owner Safety Program Implementation" also recommends contractor pre-qualification 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, 2005). 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.

fatalities several years earlier. Had Xcel examined RPI's public OSHA inspection database and other sources publically available on the Internet, a lengthy history of serious OSHA citations would have been revealed, including a 2001 fatality incident involving a member of the public, a 2005 serious OSHA violation in Arizona, and a number of violations specifically involving the unsafe handling of flammable liquids (Appendix B). 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. Records related to the 2005 and 2006 regulatory actions were not provided to Xcel although required by the terms of the RFP.[73] Xcel's policies addressing contractor selection rely on the contractors to self-report their accident histories, but do not require verification of the submissions. Xcel confirmed to the CSB that it had not verified RPI's RFP submissions or researched RPI's background as part of its contractor evaluation process.

Despite the wording on Xcel's contractor evaluation form, RPI's bid was not rejected nor did Xcel's policies require it to be. 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:

[73] 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.

> 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.[74]
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).

[74] 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.

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

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. However, Xcel did not increase its oversight of RPI nor did it implement corrective actions. These serious safety issues include

- 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 sent to the hospital for treatment. The worker was on light duty for the remainder of the project.
- The penstock was evacuated on several occasions prior to the incident due to high readings of CO, a toxic gas.
- Electrical problems that resulted in the destruction 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. In the best of conditions, the coating removal is dirty, nasty work."

Despite these serious safety problems known to Xcel, RPI's safety performance in the penstock work was only minimally monitored. Xcel managers conducted safety observations of RPI's penstock activities on only two documented occasions. The project manger completed an inspection checklist on September 20, 2007, that noted the "extremely slick surfaces" inside the penstock. The penstock inspection form also stated "environment continuously monitored." However, the CSB knows from employee interviews and documentation that the penstock was only periodically monitored for hazardous atmospheres at the entrance.[75] An Xcel safety representative visited the penstock for a safety observation on October 1, 2007, 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 conditions for the penstock. The form completed during the September 20 safety inspection by the project manager similarly checked "OK" under the category of confined space safety practices.

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[75] 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.

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, in reference to the relationship between Xcel and its contractors, 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).

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).

The CSB concluded that Xcel did not use 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 CONTRACTOR SAFETY TRAINING

Employee 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.[76]

Three broad types of training were available to RPI Coating employees: 1) company-specific training provided by RPI Coating; 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 contractors 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

[76] 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

comprehensive and in-depth safety training the Training Center provides; consequently, just two of the 14 contractors[77] on the penstock project who had gone through portions of the program received some of this in-depth training.

- Contractors referred to the Training Center for evaluation are assessed only on their technical painting skills, not their safety knowledge.[78] Because the two RPI contractors 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 contractors received onsite training at Cabin Creek prior to the start of the recoating project, and that training was both abbreviated in nature and did not effectively address the hazards inherent to the penstock recoating work.

As a result, the RPI contractors 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. This section of the report discusses these inadequacies and demonstrates that, had the existing apprenticeship safety training been provided to all journeyman painters, the RPI work crew would have been better prepared to manage the unique hazards of the penstock.

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contractors are aware of applicable OHSMS requirements and are competent to carry out their responsibilities as defined in the OHSMS" (ANSI/AIHA, 2005).

[77] 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.

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

9.1 Company-Specific Safety Training

Contractors, such as RPI, 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. As noted, many of the policies within the IIPP are deficient (Section 6.6); however, a number of RPI's documented safety policies do address specific hazards that were associated with the penstock project, including the safe handling of flammables, proper confined space entry, and fire prevention. Training on the safety information within the IIPP manual likely would have mitigated some of the risks inherent with the recoating work.

However, the company's method for ensuring employee knowledge of the IIPP information consisted of having newly hired individuals 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 contained therein. Assessments or tests of comprehension of the IIPP and its contents are not conducted by RPI on an ongoing basis throughout an employee's career with the company. In fact, a 2006 audit of RPI by the Society for Protective Coatings (SSPC), an industry association that qualifies industrial painting companies based on a number of criteria, 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…)." However, no documentation exists that shows that this training occurred. As further evidence that the SSPC audit finding was not acted on by RPI, the company responded to a CSB information request about eight months following the incident, asserting that its employees receive training knowledge from the information contained within the IIPP and through the partnership committee's Training Center.[79] RPI had not implemented additional training or documentation. Section 9.2 demonstrates that the company's purported reliance on the Training Center for training on company safety policies was ill-placed.

9.2 Training Center Safety Training

A Master Labor Agreement between the Painters and Allied Trades Union and several participating companies created the Southern California Painting and Drywall Industries (SCPDI) Joint Apprenticeship and Training Committee Center. 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 are provided the opportunity to build a solid foundation of technical painting skill and safety awareness.

However, the numbers of individuals who benefit from the apprenticeship program training courses are limited. 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 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 contractors 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.

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[79] This Committee, and its Training Center, is maintained through a Master Labor Agreement between the Painters

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 by the fact that the Training Center is not intended to provide instruction on company-specific policies or site-specific hazards.

The SCPDI Training Center does offer general OSHA-required continuing education training opportunities[80] to its union members; however, this training is not worksite-specific Section 9.3 describes how this OSHA-required training was not specific enough for the safety hazards of the penstock, while section 9.4 discusses how the in-depth safety training provided as part of the Appenticeship Program is comprehensive and would have addressed most of the specific safety hazards present in the penstock recoating work had the contractors received the Program's training.

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and Allied Trades Union (District Council 36) and several contractor associations, of which RPI is a member.

[80] CPR (annual), First Aid (every three years), Fall Protection, Scaffold/Swing Stage, Confined Space Awareness, Hazard Communication, Respirator Use & Fit Test (annual), Hearing Protection, Asbestos Awareness, Aerial Mobile Power Lifts, Forklift & Drywall, and Lead (annual refresher).

9.3 Generic Onsite Training

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

Upon review of RPI's penstock project bid submittal, an Xcel safety supervisor noted that a number of the RPI contractors were lacking in 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 contractors on the penstock project received this onsite training, held September 10, 2007. This training consisted of six 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 on the information. Those who had not arrived onsite until after September 10 were not provided with an opportunity to take a make-up session.

It is imperative that onsite safety training focus on work activities that may be new and potentially dangerous to contractors. 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 before. 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 different from what we've done before? From those different activities, what is dangerous? How can that risk be eliminated or controlled?[81] Approaching hazards in this manner focuses attention on the risks that may not be readily apparent when reviewing generic training materials before the start of work.

However, the onsite training for the RPI contractors was brief and generic and included only a basic review of confined space awareness. This training consisted only of an overview of the definition of a confined space, but not how to evaluate a confined space for potential hazards, how to properly fill out 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 used during this training focused on the importance of using grounded equipment and following lockout/tagout procedures, but did not cover 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.

Other topics covered during the onsite training included respirator training with fit testing, fall protection, lockout/tagout, and hazardous communication. 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. It 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 (Section 6.0).

Flammable and explosive atmospheres, fire prevention, and fire extinguisher use within the penstock were not incorporated in any onsite training for the contractors. Also left out was a discussion of procedures for emergency evacuation of the penstock. The lack of a secondary egress was not discussed by either Xcel or RPI with the work crew during the onsite training, and specific emergency response and

[81] 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

rescue training did not extend beyond the instruction to contractors to call the Xcel control room for 9-1-1 services if an emergency should arise.

Part of the reason for the lack of pertinent training on the issues inherent with the penstock project work may be because the trainer had no experience working within a penstock. The trainer relied on a more experienced contractor within the RPI crew to 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.

The RPI work crew also received a brief onsite safety overview from Xcel as they arrived at Cabin Creek and began preparing for work inside the penstock. 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.[82] 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. Confined space was covered by the orientation provider in terms of asking the RPI crew if they had been trained on the safety topic; this training was not verified by the orientation provider, 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 Penstock-Specific Safety Issues

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

the specific and potentially unique risks of a given mission.

[82] Each member attended the orientation once.

monitoring, fire prevention, and emergency preparedness. Several of these safety topics are covered effectively in the Painters 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, in most cases, not administered to or understood by the RPI workforce, nor were safe work practices upheld and reinforced by either company at the work site.

9.4.1 Substituting Non-flammables for Flammable Solvents

Section 6.5 dicusses Xcel's and RPI's decision to use MEK inside the penstock instead of other potentially safer alternatives. However, it is relevant to note that the SCPDI apprenticeship program's training course, "Solvent and Hazardous Materials," covers the use of potentially safer alternatives. 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.[83] As a result, RPI contractors 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 offered by the SCPDI Training Center. 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" and, as stated, only one of the crew took the "Solvent and Hazardous Materials" training course.

The "Basics of Solvents and Thinners" course materials provide many warnings about the risks of using flammables, including "Do not carry flammable liquids in containers larger than one gallon size unless they are tightly sealed in approved metal safety cans. This is an OSHA requirement." 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.

In post-incident testimony, some contractors revealed knowledge of proper transfer methods of flammables, which they learned through SCPDI training; however, metal safety cans for the solvents were not made available for use at Cabin Creek. Because employees were not provided with the safety cans for MEK transfer, adherence to this safety policy was thwarted.

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

9.4.3 Flammable Atmospheres and Confined Space Entry

Training materials for "Confined Space Entry" used by the SCPDI Training Center 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 LEL was in excess of 10 percent, nor did Xcel or RPI's policies require this safeguard. The contractors were not monitoring the atmosphere of the immediate work area while they were flushing the hoses, wands, and sprayer system with MEK. The monitoring was conducted primarily by the standby person (hole watch) at the access door, more than 1,450 feet (442 meters) from the crew using the solvent. 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 placement of it within close proximity to the actual painting operation. Yet only six of the 14 contractors were provided a general course on proper fire extinguisher placement within the work site by RPI; 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 should 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 additional steps were taken to address the lack of a secondary exit, although a number of RPI contractors 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 agreed to by both Xcel and RPI empowered Xcel employees with "stop work authority" during the project, whereby Xcel employees were allowed 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; the addendum did not give the RPI work crew the same authority to cease work they deemed unsafe.

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 been 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. While the Training Center Apprenticeship Program does provide comprehensive safety training, because none of the contractors went through the entire Apprenticeship Program, they did not receive this in-depth safety training. The hazards related to the recoating portion of the penstock project were not adequately assessed and managed by either Xcel or RPI, and the crew was instructed to work in unsafe conditions without the proper precautions in place. The combination of these inadequacies resulted in a workforce incapable of recognizing and minimizing the potential dangers of the penstock project.

12.0 ROOT AND CONTRIBUTING CAUSES

12.1 Root Causes

1. Xcel and RPI management did not ensure effective preplanning 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, no remedial action was taken by Xcel or RPI management.

- Published safety guidance by the American Society of Civil Engineering (ASCE) 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 safe conduct of the penstock recoating work.

   - 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 action.

12.2 Contributing Causes

1. Xcel's corporate policies and practices addressing the selection of contractors 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 only provided 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 permit space created the need for immediate rescue due to the potential for an IDLH atmosphere.

- Xcel's emergency response plan for rescue services for the penstock project was to call 9-1-1 emergency dispatch. No 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 one hour and 15 minutes.

- After the penstock fire erupted, there was an opportunity for fire fighting and rescue activities 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, and fire prevention.

BY THE

U.S. Chemical Safety and Hazard Investigation Board

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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 exhibits indications 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 fatality incident involving 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 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 noted that the interior liner was peeling up to the concrete section.
2005		RPI interstate Experience Modification Rate is 1.03
2006		2006 SSPC audit finds that RPI has "No documentation of craft-worker assessment." RPI interstate Experience Modification Rate 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 holds a meeting to review 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 signs a contract 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 interested in recoating the penstock. Proposal asserts that an Xcel project manager will be fully integrated into the contractors 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 Ccontractors 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 supposed 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 low EMR rate during the meeting and requires RPI to take extra precaution 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 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 for two hours due to high carbon monoxide (CO) levels. RPI experiences additional electrical service problems inside penstock. Xcel 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 five 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 in order 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. He 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 contractors 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 contractors 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 epoxy and 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 requested 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 is requested 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
	~4:45 - 5:30 PM	Air flow through penstock is reversed by changing the flow of air through the Cabin Creek plant's exhaust fans. Soon after this reversal, high carbon monoxide levels (900ppm) are recorded on the first floor of the plant.
	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

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
10/13/2005	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
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] 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
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 springs), or loosening and falling	$18,000	$18,000	Open
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

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
3/20/2001	126030634	Coalinga	CA	Accident - Safety; 1 hospitalized		Injury not immediately reported to Cal-OSHA; Forklift operating rules not enforced	$935	$935	Closed
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

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
5/28/1999	302528437	Spring Mountain Overpass, Las Vegas	NV	Complaint - Safety		None	$0	$0	Closed
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

[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
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, was 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
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

[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
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			
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

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
3/10/1994	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 temporary wiring; unapproved forklift	$125	$125	State Decision; Closed
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

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
7/7/1992	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			
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

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
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 storage rooms	$0	$0	Closed
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[93]
One (2-gal) bucket with MEK, heavily melted at scaffolding[94]	Between 79 ft and 91 ft	1
Three five-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; and 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+

93 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.

94 The exact location of this bucket is unknown because it was moved during the removal of the victims; distance estimate is based on CBI initial entry report that buckets were located on and under scaffolding, and knowledge that scaffolding was 12 feet in length, 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 conducted 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 and, 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 observed 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[95] 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-centimeters) depth of MEK, or about one-half gallon (2 liters). The MEK was being circulated from the base hopper through

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

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.

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[96] (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 observed 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

[96] 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.

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 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 resistance from the JIC swivel connector to ground, via the column of MEK inside the hose, is governed by Ohm's Law. Thus, 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 itself 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.[97]
- 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.

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

- The resistance to ground ("R") via the column of conductive MEK contained within the hose is determined by the formula R = ρL/A, where ρ is the resistivity of MEK (approximately 1 x 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 x 10^{-5} m^2). If these values are substituted, the resistance to ground via the hose is approximately 6.6 x 10^9 ohms (or on the order of 10^{10} ohms).

- 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 x 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 x 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 for 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[98] 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,[99] 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

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

[99] 200 pF is frequently used as an average value for the capacitance of a person (Britton, 1999, p. 44).

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, 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 this 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 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, the contractors 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-prong, rather than a four-prong, connector. Thus, there was no ground connection in the circuit and the sprayer was operated with a floating neutral.[100] Although the sprayer was equipped with an independent 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 lying on the wood deck platform of the sprayer scaffold, so they were not grounded. The CSB concluded that at the

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[100] 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.

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 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[101] on which the sprayer was sitting was a dual fixture halogen light assembly. Based on examination of physical evidence[102] 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

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[101] 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.

lenses and insufficient glass residue was found in the area after the fire to account for them.[103] 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 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, provided 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

[102] The charred and melted remains of the halogen light were found on top of the sprayer pumps after the incident.
[103] The only remains of glass found in the fire debris were identified as coming from the sprayer control panel.

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." As he squeezed past the scaffold holding the sprayer, he told CSB that 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 in fact 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 °F (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 °F (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. It is not necessary for the entire volume of MEK in the hopper to have been heated to the same temperature for this to occur, 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 °C) with somewhat lower temperatures on the support. The inside bulb wall temperature may be around 1,382 °F (750 °C) (Cayless, 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 observation of these terminals did not reveal arcing patterns.

D.3.1.3 Ignition by Hot Spot 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 hot spot on the quartz envelope without bulb breakage. In the absence of hot spots, 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 hot spot 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 hot spot on or near the bulb. The nominal 1,832 °F (1,000 °C) 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 °C) 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 hot spot 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 °C). It is well known that the hot spot ignition temperature of ignitable gas mixtures is a strong function of hot spot size and contact time, although the ignition phenomenon is complex. At temperatures close to the lower limit flame temperature, hot spots 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 hot spot 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 °F (520 °C) (CPSC, 1996); higher values approaching 1,100 °F (593 °C) 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 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.[104] The CSB found various published values for the AIT of MEK, but the most reliable is reported to be 887 °F (475 °C) 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 concludes 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 °C) above the standard AIT) for MEK vapor ignition. Ignition is far more likely had a hot spot (or small flame) been created on a bulb or an adjacent hot surface.

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 °C) rating; the standard AIT of MEK is 887 °F (475 °C).

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

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

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.[105] Thus, neither piston pump could likely have been running "dry" at the time 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,[106] visual examination by the CSB revealed that the incoming power to 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

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

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

(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,[107] the boiling point of MEK at 523 mmHg was calculated to be 154 °F (67.8 °C). This compares with the "normal" value of 175 °F (79.4 °C) at 760 mmHg (standard atmospheric pressure).

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 °F (-16 to 15 °C). 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 °F (2.4 °C).

[107] 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.

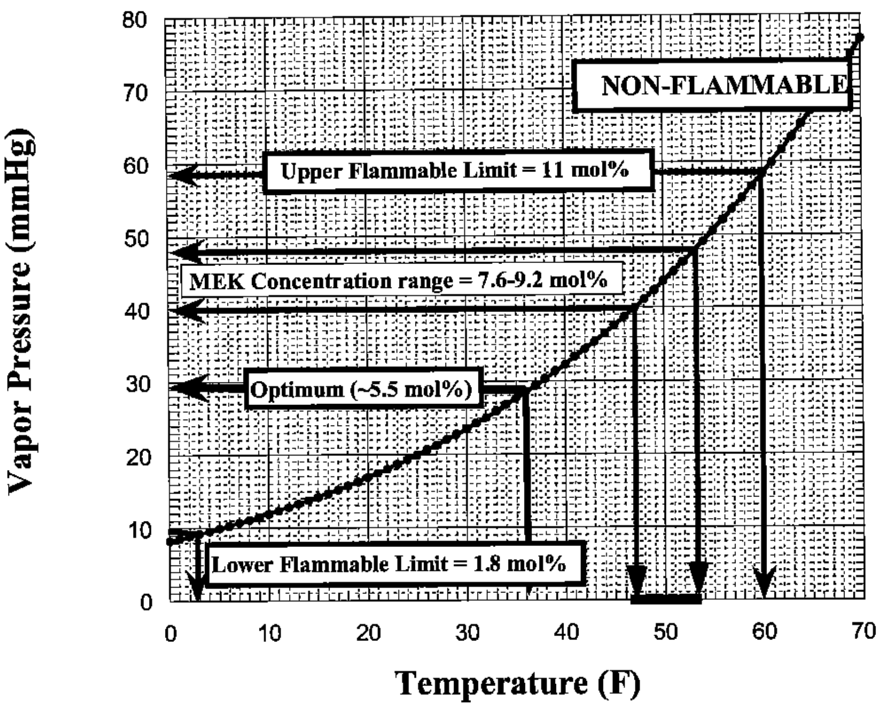

Figure E- 1 Equilibrium vapor pressure of MEK near liquid surface in base hopper

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 °C (3.4 °F). For ignition in the base hopper, this TLF should be more accurate than a measured flash point because of (1 the ambient pressure, and (2 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" 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 °C (60 °F). This result shows that MEK in the penstock could be within the flammable range (ignitable) at all times inside a pail or hopper.

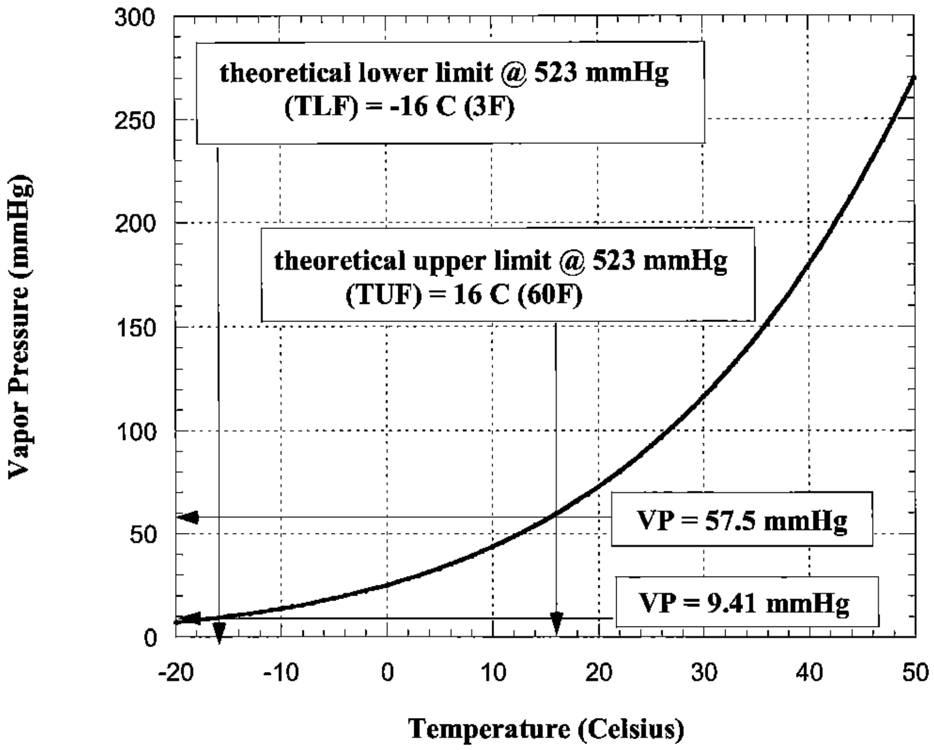

Figure E- 2 Theoretical MEK flammability limits at penstock conditions

With the base side pump heater not operating, the CSB determined that the circulated MEK would have been at 50 ± 3 °F (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. With respect to faulty electrical equipment, it is unimportant since electrical arcs should be sufficiently energetic to ignite MEK vapor over the entire flammable range.

Calcote (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. 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 (Britton, 2002) uses the heat of oxidation to estimate the LMIE of CH and CHO organic compounds:

LMIE (mJ) = 4.0056 – 0.06231 $(-\Delta H_C/S)$ + 0.00024333 $(-\Delta H_C/S)^2$

Where $(\Delta H_C/S)$ = 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 (see Figure F-1), the LMIE of MEK at 0.69 atmospheres (523 mmHg) should be approximately 0.5 mJ. (Britton, 1999):

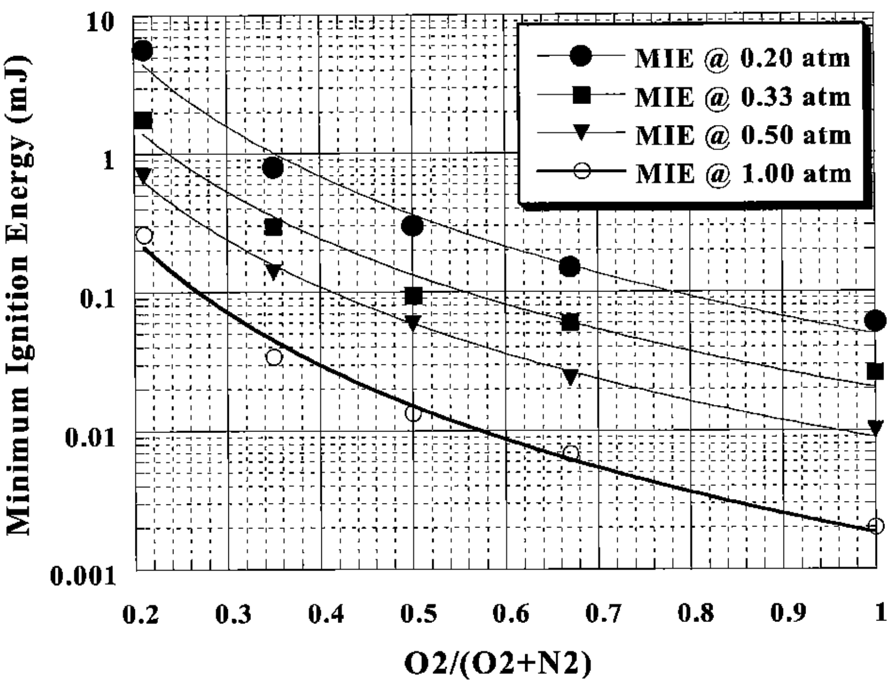

Figure F-1 Effect of pressure on MIE of propane in various oxygen-nitrogen mixtures

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, there is also the risk 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.

Source	Industry/Personnel	Citation/Reference	Requirement
		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. Once the atmosphere is above 10% of the LFL, all of the requirements of the standard must be met. The employer must identify and evaluate each hazard to which the 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.
	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 percent of the LEL. Exception: An employee may enter for emergency rescue or for a short duration for installation of 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 precaution 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 percent of the lower flammable limit of the gas.

Source	Industry/Personnel	Citation/Reference	Requirement
	Underground construction (tunneling)	1926.800	When air monitoring shows, for 3 consecutive days, 10 percent 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 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.
		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 percent or 20 percent) should be adopted.

Source	Industry/Personnel	Citation/Reference	Requirement
MSHA	Underground Coal Mines	75 CFR 323	When 1.0 percent 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 percent; and No other work shall be permitted in the affected area until the methane concentration is less than 1.0 percent. When 1.5 percent 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 percent (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 percent (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 percent, 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 percent (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 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 percent (40% of LEL) in the mine atmosphere, all

Source	Industry/Personnel	Citation/Reference	Requirement
			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) percent.
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 is provided whenever atmospheric testing indicates flammable levels are greater than 10% of thee 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, unless 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 only be entered with appropriate personal protective equipment 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 one of the methods described in this standard, as specified by the qualified person, prior to the issuance of a hot work permit.

Source	Industry/Personnel	Citation/Reference	Requirement
			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 percent of the LFL, entry can be made to located 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 lower explosive limit (LEL) or LFL. Rescuers should not enter confined spaces containing atmospheres greater than 10 percent of a material's LEL, regardless of the personal protective equipment 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 contains flammable gas, vapor, or mist in excess of 10 percent of its lower flammable limit (LFL), that atmosphere is not acceptable for entry.
Pipeline	Fire fighters, law enforcement officers,	Appendix B	Natural Gas Escaping Inside a Building

Source	Industry/Personnel	Citation/Reference	Requirement
Association for Public Awareness	emergency medical technicians and all other emergency responders responding to pipeline incidents		EMERGENCY RESPONSE 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 only be approached 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	Work site 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 f flammable or explosive gas or vapor is less than 10% of LEL. Inspection permitted if concentration f flammable or explosive gas or vapor is less than 25% of LEL.

Source	Industry/Personnel	Citation/Reference	Requirement
			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 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 employing construction practices (e.g., sandblasting and coating) to make physical changes to the power plant, the penstock was existing equipment (constructed in 1967) that was being refurbished by removing of 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 2.1.1, 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 under 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, "Regulatory and Industry Standards Analysis."

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

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 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 did not contain 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 concludes 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 99 incidents compiled by the CSB, 47 were subsequently categorized as A and determined to be a result of a flammable atmosphere in a confined space.