National Aeronautics and Space Administration

NASA SAFETY CENTER

SYSTEM FAILURE CASE STUDY

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Vapor Trap

The Xcel Energy Confined Space Penstock Fire

October 2, 2007, Cabin Creek, Georgetown, CO: Nine industrial painters were recoating a portion of penstock tunnel that runs 1,530 feet deep into the remote mountainous area surrounding the Xcel Energy Cabin Creek hydroelectric station. Inside the confined area, the workers used a highly flammable solvent to clean their equipment, which filled the tunnel with flammable vapor. The vapor ignited and the resulting explosion separated the nine workers—blocking five of them from the only egress point by a wall of fire. Despite lengthy rescue attempts, the five workers were asphyxiated as smoke slowly filled the tunnel.

PROXIMATE CAUSE

- Flammable vapors inside the penstock ignited and flashed from a spark near the paint sprayer used during a recoating task. RPI workers were trapped by the growing flames and eventually succumbed to smoke inhalation.

UNDERLYING ISSUES

- Permit-required confined space
- Accident Response Planning

AFTERMATH

- The CSB concluded that Xcel did not provide sufficient safety oversight on the job and had there been competent safety and/or industrial hygyiene workers onsight, the hazards of working in the penstock would have been recognized.

Background

The Penstock at Cabin Creek

A penstock is a conduit or pipeline that regulates water flow from the reservoir or water source in hydroelectric power plants and water-operated mills. The steel penstock at the Xcel Energy (Xcel) Cabin Creek facility stretches 4,163 feet from the upper reservoir intake to the powerhouse turbines. The lower, near-level (inclined between 2 and 10 degrees) 3,123-foot section is negotiable on foot. Approximately 15 feet of this near –level portion is exposed above ground where the penstock couples with the powerhouse. The remaining 1,040-feet segment of the penstock has significant gradients of 55 and 90 degrees and requires climbing aids to traverse.

The upper reservoir intake is known as the “mushroom,” a 40-foot tall, steel and concrete structure with screen openings and an access hatch positioned in a reverse incline around the top. Due to this positioning, once the reservoir is drained, individuals require significant physical strength, climbing skills, and equipment to access the mushroom.

The Cabin Creek penstock is a confined space as defined by the Occupational Safety and Health Administration (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. 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 CFR 1910.146(b)).

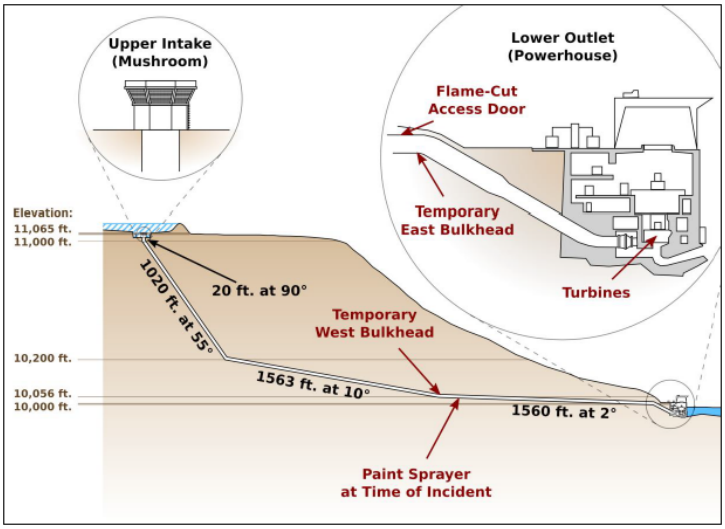

Figure 1. A cutaway view of the penstock at Xcel's Cabin Creek facility. Source: CSB

Figure 2. The upper intake, or "mushroom," sits in the upper resevoir of the Cabin Creek facility. Source: CSB

Contractor Safety Performance

To assist in the selection of a coating contractor, Xcel hired KTA-Tator, Inc. (KTA). KTA, a consulting and engineering firm, to help write the technical specifications for the application of the epoxy coating in the penstock, resolve technical issues with the application process, and perform quality control checks during application.

Xcel selected RPI Coating, Inc. (RPI) to remove the old epoxy and recoat the penstock with a new epoxy lining. RPI was the lowest bidding organization that met technical qualifications, but possessed a low safety rating that technically disqualified the company from consideration. However, RPI contested its low safety rating was a result of a recent on-the-job fatality and convinced Xcel and KTA to overlook the rating.

Since 1972, RPI had been inspected by both state and federal OSHA officials; 31 inspections were initiated due to complaints, referrals, or accidents (some of which were fatal). OSHA had recorded 90 violations from RPI, with issued fines totaling $135,569.

Methyl Ethyl Keytone

Although less hazardous solvents were available, RPI used a highly flammable solvent—methyl ethyl ketone (MEK)—to clean the paint sprayer units involved with the penstock recoating project. MEK is a Class IB flammable liquid and has a flash (ignition) point of 19.4 degrees Fahrenheit.

Exposure to high concentrations of MEK impairs the central nervous system resulting in dizziness and drowsiness. This could happen at levels below the LEL.

What Happened

In preparation for the penstock project, Xcel performed a Safety and Health Hazard Assessment Survey limited to the abrasive blasting removal of the old penstock liner. The survey did not cover the hazards of epoxy recoating, flammable material usage, or entry and egress limitations. In spring 2007, an Xcel civil engineer submitted "Cabin Creek Penstock Major Items of Concern," a document calling for a point of access to the penstock besides the single 20-inch manhole, citing epoxy application temperature constraints, and significant challenges to completing the project in the ten weeks scheduled. Xcel's principal engineer for the project received the document, but neither the company submission to potential bidders nor RPI's bid response addressed single point of entry, epoxy flammability, or scheduling. Later, an access hatch was cut into one side of penstock for blasting and painting crew access: the only available exit on the day of the incident.

KTA performed its own hazard assessment of the penstock on September 22. A KTA inspector identified the tunnel as a permit-required confined space and listed the requirements, including entry procedures, entry permit, air monitoring prior to and during entry, an attendant present at the entry point, rescue assets present, and respiratory protection. But no entry procedures were developed, hazards were incompletely detailed on the permit, air monitoring was only done at the entry point, and no rescue team or equipment were put in place throughout the project or on the day of the incident.

During the first week of September 2007, the plant was shut down and the penstock was drained of water. A 6-foot access point was cut into the side of the 15-foot exposed portion of the penstock. RPI began sandblasting the old epoxy liner on September 20, 2007 and continued through September 28, when the first 500-foot section was completed.

On October 2, 2007, the RPI painters began applying a new coat of epoxy to the interior of the penstock; however, the spray application process the workers were using produced unacceptable results. The workers stopped the coating process and cleaned the sprayer system several times with MEK. At 1:55 p.m. Mountain Daylight Time (MDT), during equipment cleaning, MEK vapors inside the penstock ignited and flashed, likely from a static spark near the sprayer hopper containing the base portion of the two part epoxy (according to the Chemical Safety Bureau (CSB) investigation). The explosion separated the workers by fire.

Four of the nine painters were located on the side of the fire nearest the access point. The remaining five workers were blocked from the exit and trapped by the fire in the narrow penstock. As the fire abated enough to allow communication between the two groups, the trapped workers called out for fire extinguishers. The four ran approximately 1,450 feet to the access point while several flash fires ignited and loud booms reverberated down the penstock and the initial fire ignited more buckets of solvent and epoxy. The trapped group moved deeper into the penstock, retreating from the smoke.

Two of the four escaped workers ran back into the penstock to put the fire out; however, the thick black smoke reduced their visibility and made breathing difficult. They were unable to get close enough to the sprayer and burning epoxy to extinguish the fire. The escaped workers were eventually treated for minor burns, fractures, and breathing difficulties.

The escaped workers notified the Cabin Creek power house control board and requested 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., but the operator failed to inform the dispatcher that the penstock was a confined space or that specialized rescue personnel and equipment would be required to fight the fire and rescue the trapped workers. The CSB final investigation report does not give answer to why the operator neglected to initially inform the dispatcher.

Beginning at 2:11 p.m., Clear Creek County Sheriffs arrived, followed by volunteer paramedic and firefighting units from Clear Creek County Fire Authority (CCFA). After realizing the fire was deep in a confined area and trapping workers, CCFA contacted mutual aid partner Denver West Metro Fire Protection District (West Metro) (arriving at approximately 3:40 p.m.) and a mine rescue team from a nearby Molybdenum mine (arriving shortly after 4:00 p.m.), who were qualified and equipped for confined space and technical rescue.

Despite their lack of specialized equipment and training, CCFA attempted an unsuccessful rescue while waiting for mutual aid to arrive. Radio communication with the trapped workers continued 45 minutes after the initial fire. As mutual aid arrived the trapped workers were instructed to move as deep into the penstock as possible.

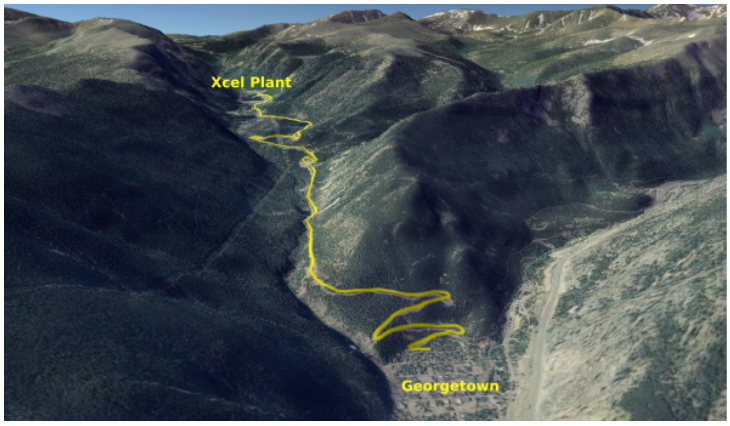

Figure 3. Georgetown, CO, is a 15-minute drive away, not including the off-road, up-hill path to the upper resevoir. Source: CSB

West Metro did not attempt to rescue the workers or fight the fire because they did not know if explosive hazards remained in the penstock, opting to join CCFA and other rescue groups at the top of the penstock mushroom in lowering air bottles, respirators, a light, and another radio to workers through the vertical portion of the penstock.

The mine rescue team entered the penstock at 5:45 p.m., after Xcel operators reversed the penstock ventilation fans attempting to send the smoke away from the stranded workers.

After verifying that the fire had burned out, the mine rescue team continued farther down the penstock to search for survivors. They found the first body approximately 100 feet uphill of the fire. The four remaining bodies were located farther up where the penstock begins a 55-degree incline. It was determined that the trapped workers had died of asphyxiation shortly after radio contact ceased at 2:45 p.m.

Proximate Cause

MEK vapors inside the penstock ignited and flashed from a static spark near the base hopper of the paint sprayer used during the recoating task. 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.

Underlying Issues

Permit-Required Confined Space

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 classified the penstock as a permit-required confined space. Many of the unsuccessful bidders for the penstock recoating project identified the penstock as a permit-required confined space in their submissions to Xcel.

Xcel's Safety and Health Hazard Assessment Survey that listed confined space entry as one of the potential health hazards associated with abrasive removal of the old penstock lining, requiring a confined space air monitor was required (a key safety requisite in a permit-required confined space program). In addition, KTA's Initial Pre-Job Hazard Assessment explicitly indicated that the project would require workers to enter a work area classified as a permit-required confined space and outlining several requirements to be followed.

Although Xcel and RPI recognized the penstock as a permit-required confined space, neither treated it as such during the recoating work. 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.

Entry procedures were not developed and the required daily permits were incomplete and lacking detail pertaining to the hazards of the day's work activities. Air monitoring was performed almost exclusively at the entrance, about 1,450 feet away from the actual work area within the penstock. Neither RPI nor Xcel provided the CSB with a documented basis for declassifying the penstock space as non-permit required.

In addition, a number of ignition sources involved in the recoating activity were not controlled. The power distributor inside the tunnel that powered the sprayer components in addition to both explosion-proof and non-explosion-proof lighting (unsafe for penstock conditions) had non-watertight twist locking connectors fittings at cable connections.

Accident Response Planning

The OSHA Permit-Required Confined Spaces Rule 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 they are working within a permit-required confined space.

Xcel and RPI managers did not plan or coordinate the immediate availability of qualified confined space technical rescuers and equipment outside the penstock, although the use of flammable solvent in the open atmosphere of the permit space created the need for immediate rescue because of the potential for Immediately Dangerous to Life and Health (IDLH) conditions.

Xcel and RPI ineffectively conducted the emergency response and rescue preparation instructing RPI personnel that Xcel personnel would call 9-1-1 in an emergency at the penstock. On October 2, 2007, RPI personnel made the initial call for support to Xcel. The first and closest emergency responders at the site were not prepared for entry into the penstock's confined space.

Additionally, the fire service organizations had no pre-knowledge of the hazards of the chemicals onsite, or their quantities, hours of work, or locations. The site was not pre-equipped with appropriate fire-fighting equipment specific to the unique hazards of the penstock. Such planning and communication should have been implemented with designated emergency responders in advance of any recoating work conducted withtin the penstock.

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

Aftermath

The CSB concluded that Xcel did not provide sufficient safety oversight on the job and had there been competent safety or industrial hygiene workers onsight, the hazards of working in the penstock would have been recognized early in the project. Xcel's and RPI's lack of sufficient planning and coordination for the hazardous recoating work within the confined space was causal to the incident.

RPI was later found guilty of violating five OSHA regulations causal to the mishap.

Relevance to NASA

In all projects, project managers always juggle at least four kinds of risk—cost, schedule, quantity of products or services, and performance (technical, quality, and safety margin). Where the former two are rigidly fixed by the customer, project managers may feel forced to shave margins of protection from how technical operations are performed. When clear identification of critical safety requirements does not happen, the risks of cutting performance safety controls become invisible to the real risk owners: project managers and operators physically exposed to hazards. The discussion fails to occur at the right level, where real risk mitigation can occur and going forward by cutting performance margin can be seen as being efficient from a cost/schedule/quantity risk viewpoint.

The phrase, "it seemed like a good idea at the time" signals blindness to risks that lay in wait as inevitable chemical reactions and physical laws. NASA Safety NPR 8715.3C requires that Centers develop and implement confined space operations plans, identify all confined spaces and document the confined space permit process. NASA procurement teams are wise to learn and weigh each bidders' past safety performance and adherence to technical requirements.

Safety professionals must be fearless communicators when safety hazards are identified and speak up to risk owners. "What are the mitigation options and how do we implement controls and monitor them for effectiveness?" Without such conversations, cost and schedule risks can compete and divert attention away from safety or technical risk.

References

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