Idaho Cleanup Project CPP-603A Basin Deactivation Waste Management 2007

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ABSTRACT

The CPP-603A basin facility is located at the Idaho Nuclear Technology and Engineering Center (INTEC) at the U.S. Department of Energy’s (DOE) Idaho National Laboratory (INL). CPP-603A operations are part of the Idaho Cleanup Project (ICP) that is managed by CH2M-WG Idaho, LLC (CWI). Once the inventoried fuel was removed from the basins, they were no longer needed for fuel storage. However, they were still filled with water to provide shielding from high activity debris and contamination, and had to either be maintained so the basins did not present a threat to public or worker health and safety, or be isolated from the environment.

The CPP-603A basins contained an estimated 50,000 kg (110,200 lbs) of sludge. The sludge was composed of desert sand, dust, precipitated corrosion products, and metal particles from past cutting operations. The sediment also contained hazardous constituents and radioactive contamination, including cadmium, lead, and U-235. An Engineering Evaluation/Cost Analysis (EE/CA), conducted pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), evaluated the risks associated with deactivation of the basins and the alternatives for addressing those risks. The recommended action identified in the Action Memorandum was to perform interim stabilization of the basins. The sludge in the basins was removed and treated in accordance with the Hazardous Waste Management Act/Resource Conservation and Recovery Act (HWMA/RCRA) and disposed at the INL Radioactive Waste Management Complex (RWMC). A Non-Time Critical Removal Action (NTCRA) was conducted under CERCLA to reduce or eliminate other hazards associated with maintaining the facility. The CERCLA NTCRA included removing a small high-activity debris object (SHADO 1); consolidating and mapping the location of debris objects containing Co-60; removing, treating, and disposing of the basin water; and filling the basins with grout/controlled low strength material (CLSM). The NTCRA is an interim action that reduces the risks to human health and the environment by minimizing the potential for release of hazardous substances. The interim action does not prejudice the final end-state alternative.

INTRODUCTION

The CPP-603A basin facility is located at INTEC at the INL (formerly the Idaho National Engineering and Environmental Laboratory [INEEL]) and is managed by CWI as part of the ICP. The INTEC began operations in 1952. Historically, spent nuclear fuel from defense and research projects was reprocessed to separate reusable uranium from spent nuclear fuel. In 1992, the U.S. Department of Energy Idaho Operations Office (DOE-ID) discontinued fuel reprocessing. The current mission for INTEC is to receive and temporarily store spent nuclear fuel and radioactive waste for future disposition, manage waste, and perform remedial actions.

Pending reprocessing, spent nuclear fuel was stored underwater in basins, including the CPP-603A Spent Fuel Storage Basins. By the year 2000, all inventoried spent nuclear fuel was removed from the CPP-603A underwater storage basins and placed in newer underwater or dry storage facilities at the INL. The storage basins are reinforced concrete structures with most of their volume below grade. Each of the three basins and the transfer canal were filled with water. The combined volume of water in the storage basins and transfer canal was approximately 4.5 million liters (1.2 million gallons).

After the spent nuclear fuel was removed from CPP-603A, the basins were no longer needed for fuel storage; however, they were still filled with water to provide shielding from the remaining radioactive materials. The DOE-

ID needed to eliminate the risk associated with maintaining this facility and its associated processes because the environmental risk would increase as the facility ages.

REGULATORY STRATEGY

The DOE-ID initiated a NTCRA to reduce or eliminate the risks associated with maintaining CPP-603A. The “Final Record of Decision Idaho Nuclear Technology and Engineering Center, Operable Unit 3-13” (DOE/ID-10660-R0) governs CERCLA sites within the INTEC facility designated as Waste Area Group (WAG) 3. [1] Therefore, the CERCLA removal action had to be consistent with the remedial action objectives established in the Final Record of Decision. An EE/CA conducted pursuant to CERCLA evaluated the risks associated with the sludge and the alternatives for addressing those risks.

The recommended action identified in the Action Memorandum (DOE/NE-ID-11194) was to perform interim stabilization of the basins. [2] The sludge in the basins would be removed and treated in accordance with the HWMA/RCRA (Idaho Code § 39-4401 et seq.; 42 USC § 6901 et seq.), rather than as part of the NTCRA under CERCLA. The scope of the NTCRA, as described in the Removal Action Work Plan (DOE/NE-ID 2006), included: removing a small high-activity debris object (SHADO 1) from the basins; consolidating and mapping the location of debris objects containing Co-60; removing, treating, and disposing of the basin water; and filling the basins with grout/controlled low strength material (CLSM) (referred to hereafter as grout). [3] The basin water would be removed while the basins were filled with grout to minimize exposure of the contaminated scum line. The grout would encapsulate remaining debris and provide shielding and containment of radioactive contamination, thereby minimizing possible migration and airborne contamination. The water would be pumped to the Idaho CERCLA Disposal Facility (ICDF) evaporation ponds and evaporated.

The final decontamination and disposition of the basin structure will be evaluated when the entire CPP-603 Complex is taken out of service. The NTCRA is an interim action that will reduce the risks to human health and the environment by minimizing the potential for release of hazardous substances. The interim action does not prejudice the final end-state alternative.

SLUDGE REMOVAL AND TREATMENT OVERVIEW

The CPP-603A basins contained an estimated 50,000 kg (110,200 pounds) of sludge. The sludge was composed of desert sand, dust, precipitated corrosion products, and metal particles from past cutting operations. The sediment was also known to contain radioactive contamination and hazardous constituents, including cadmium, lead, and U-235. The RCRA regulations allow a generator of hazardous or mixed waste to treat waste within 90 days without a permit as long as certain guidelines are followed. Sludge removal, treatment, and disposal were conducted under a subcontract to EnergySolutions Federal Services, Inc. (formerly Duratek Federal Services, Inc.). The sludge was removed from the CPP-603A basins prior to implementation of dewatering and grouting activities. Removal of the sludge occurred while the basins remained in service. The sludge was removed and treated to meet RCRA Land Disposal Restriction (LDR) standards and the Radioactive Waste Management Complex (RWMC) waste acceptance criteria (WAC). [4]

WASTE CHARACTERIZATION AND TREATABILITY STUDIES

The CPP-603A basin sludge had to be characterized in order to design a treatment method to stabilize the waste to meet LDR standards and the WAC for disposal. The basin sludge was sampled and analyzed according to a statistical sample and analysis design plan (DWO-603-PLN-001). [5] Thirty-six samples were obtained from 22 randomly selected locations throughout the basins. An additional eight samples were obtained from the south basin in areas expected to have the highest cadmium concentrations. The samples were analyzed for radioactive constituents and for the total metals Universal Treatment Standard (UTS) inorganic list.

The CPP-603A basin sludge characterization results showed that the material in the north and middle basins had to be treated differently than the material in the south basin (including the transfer canal). Treatability studies were performed for the two types of sludge. Initial studies were performed using surrogate materials to simulate the sludge. Once a recipe was identified, additional studies were conducted using actual CPP-603A basin sludge. The study results (DWO-RPT-003) showed that the north and middle basin materials could be treated using a recipe of hydrated Portland cement and a waste loading of up to 50% by volume of sludge. [6] The south basin sludge treatment required a mixture of hydrated Portland cement and Class F fly ash to achieve the necessary pH for effective treatment of the lead. A waste loading of up to 25% by volume of sludge was acceptable for the south basin.

SLUDGE REMOVAL

Extensive radiological surveying was conducted throughout the CPP-603A basin facility, prior to sludge removal operations. Basin floor surveys detected radiation levels ranging from 0.28 µGy/s (100 mR/hr) to 28 µGy/s (10.2 R/hr). Generally, the radiation levels in the basins were approximately 0.0139 µGy/s to 0.04 µGy/s (5 to 15 mR/hr) at the water surface and 0.28 µGy/s to 0.42 µGy/s (100 to 150 mR/hr) at the scum ring around the basin walls.

The sludge was removed from the north, middle, and south basins; north and south transfer stations; and the transfer canal by vacuuming the material from the floors and horizontal surfaces (Fig. 1). Sludge removal was accomplished by commercial nuclear divers from Underwater Construction Corporation, under subcontract to EnergySolutions Federal Services, Inc. In some cases, diving efforts were assisted from the surface of the basins using long-handled reach tools to break up hardened sludge and to move debris from the area being cleaned.

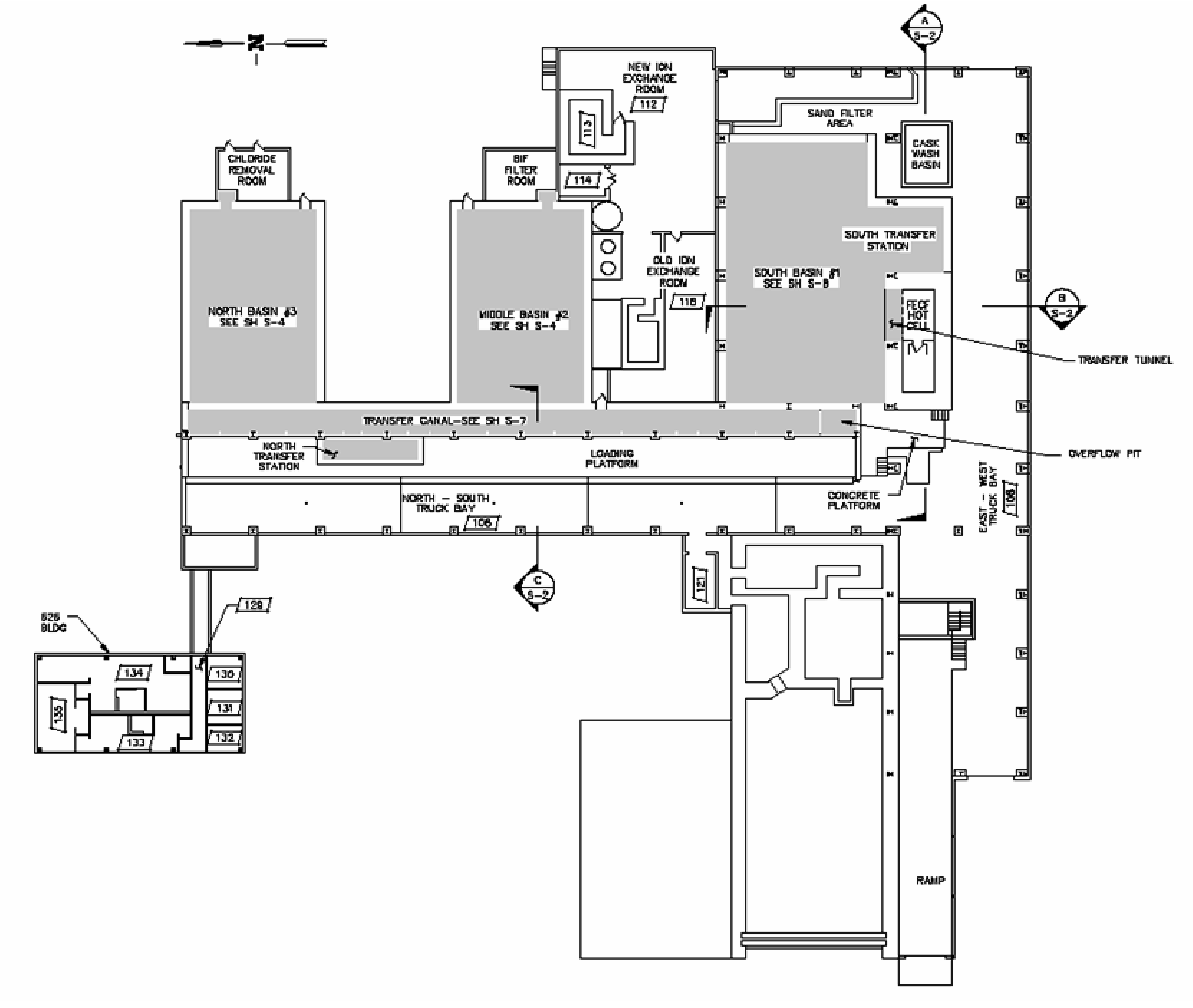

Fig.1 CPP-603A basin facility layout

The basin cleaning system consisted of a series of pumps, manifolds, interconnecting hoses, a high radiation diversion system, and waste receiving containers. [7] The waste transfer pump was located in the basin area and operated locally. The vacuum head and hoses were operated by the dive team. The vacuum head was covered with a 12.7 millimeter (0.5 inch) mesh screen to prevent large objects from getting plugged in the system. An air operated diaphragm pump was used to transfer the sludge/water mixture from the basin floor into 4,500 liter (1,200 gallon) high integrity containers (HICs) through each HIC’s fill-head. Excess water was removed by filtration and returned to the basins through a separate line connected to each fill-head. A waste inlet valve interlocked to a high level switch inside the HIC prevented overfilling of the HIC. The level in the HIC was also remotely monitored by a video camera integral to each fill-head. The HIC fill level was also limited by radiation dose rate. A radiation detector was located in the hole of a concrete "donut" upon which each HIC sat during sludge collection and treatment. Radiation readings and correlations were used to ensure grouted HICs would not exceed the contact handled limit of 1.4 µGy/s (500 mR/hr) at one meter.

An on-line radiation detector was positioned on the waste transfer pump suction line to detect any “hot” particles that may be drawn into the vacuum hose. The detector was interlocked with a 3-way valve, located about 15 meters (50 feet) downstream of the detector. When a hot particle was detected, the 3-way valve actuated to divert the slurry (and thus, the hot particle) back into a catch basket in the basin. At an operating flow rate of 190 l/m (50 gpm) and a distance of 15 meters (50 feet) between the detector and 3-way valve, the detector response time had to be less than 10 seconds. The detector response time was about 1-2 seconds, so there was adequate margin for the system to react. When in a bypass condition, the system continued operating until the alarm condition was reset by the operator. (Fig. 2)

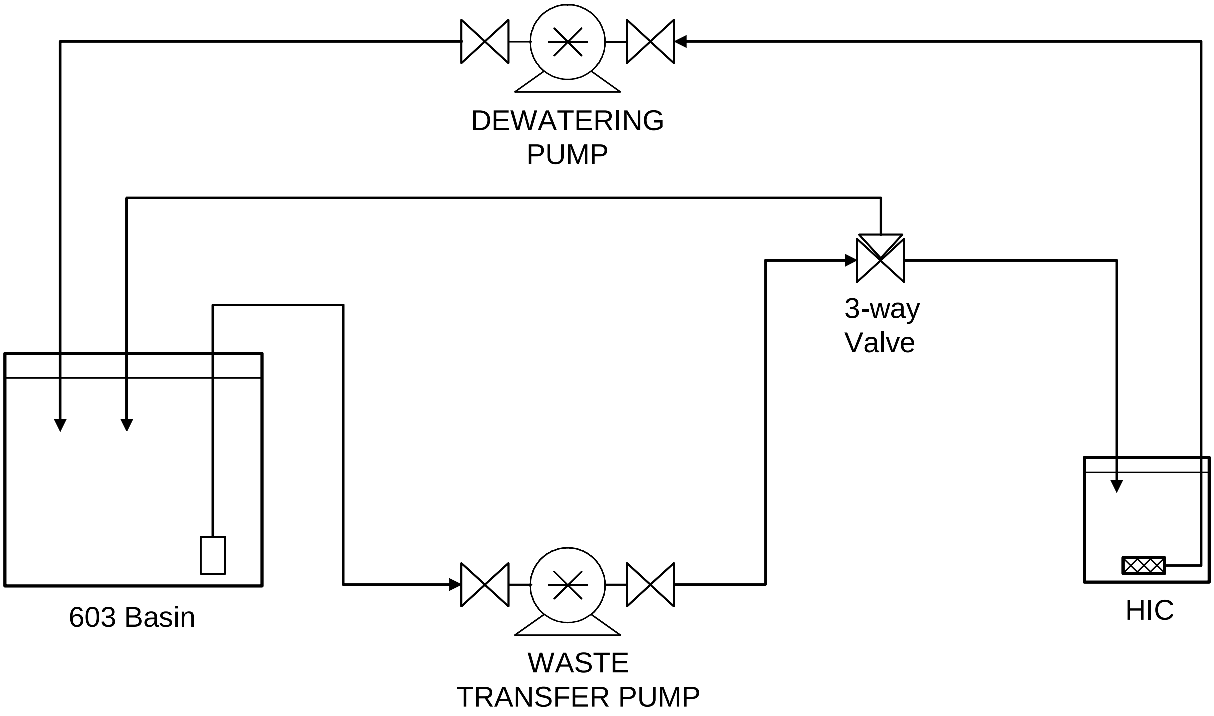

Fig. 2. Sludge removal process diagram

The sludge removal process began in the north basin, progressing to the middle basin and transfer canal, and concluded in the south basin. In order to maximize the efficiency of the dive team, the sludge transfer and solidification processes were separated into two distinct operations. This isolated the dive team from any delays that could result from solidification activities.

The north and middle basins and transfer canal are covered with fiberglass grating and radiation shielding deck plates. The horizontal concrete beams supporting the deck plates created an obstruction for diver access in the north and middle basins. Therefore, deck plates were removed from two areas of the north and middle basins and sections of concrete beams were cut to provide access. (Fig. 3) The configuration of the transfer canal prevented direct extraction of a diver in case of emergency. This constituted a “penetration” dive for which an in-water tender had to be present in direct line of access to the working diver.

Fig. 3. Diver entering basin through a diver access point

The dive team consisted of a dive supervisor, working diver, above-surface tender, in-water tender (in the case of penetration dives), and radiological control technicians. Generally, two dives were performed per day, supported by parallel waste receiving operations. Divers were rinsed with clean water while entering the basins to fill the pores of the dive suit and while exiting the basins to remove contamination. Divers had radiation survey instruments with them at all times for radiological control. Prior to each sludge removal evolution, divers performed a radiological survey of a working area of approximately nine square meters (100 square feet). This allowed the diver to identify and maintain adequate distance from radioactive hot spots. Discrete, high activity items were removed from the sludge using long-handled reach tools and placed in buckets away from the diver’s work area.

Divers worked from a submerged rolling platform that spanned the concrete beam spacers on the floor. This platform, which could traverse the length of the basins, kept divers at a distance of 60 cm (2 feet) above the floor at all times during the vacuuming process. Specialized extension grips were used to remotely pick-up and relocate various types of debris. Activities were monitored at the dive station by means of helmet-mounted cameras, with sound and video capabilities. The divers were also outfitted with electronic dosimetry on their torsos and each extremity, which was constantly monitored at the dive station by radiological control technicians.

Multiple sludge removal passes were made of each basin to ensure the basin surfaces were free of visible buildup and piles of sludge. The suspended material was allowed to settle for 48 hours prior to inspection. Visual inspection validated that the removal of sludge was successful. Visual inspection was accomplished with an underwater camera witnessed and verified by environmental support personnel. The underwater camera inspection consisted of the diver's helmet-mounted camera system and/or a hand-held remote operated underwater camera system.

DEBRIS HANDLING

A small high activity debris object (SHADO 1) identified in the south basin during basin scanning was removed from the basin prior to sludge removal operations, due to the possibility that it contained fissile material. While the object was still in the south basin, operations personnel used long-reach tools to manually transfer it to a basket suitable for dry storage in the Irradiated Fuel Storage Facility (IFSF) and removed it from the basin.

Two other objects potentially containing fissile material were found during sludge removal activities. The objects were relocated and isolated from diver sludge removal operations. Prior to placement of grout in the basins, the objects were removed and managed in the same manner as SHADO 1.

High activity debris objects containing Co-60 from nuclear reactor activation were found in the basins during basin scanning and sludge removal. Co-60 decays rapidly and has a half-life of 5.27 years. The total amount of Co-60 in debris objects is expected to decay to levels comparable to the basin environment by 2035, when dry fuel storage operations in the CPP-603 Complex are expected to end. Before water removal and grout placement in the basins, the discrete, high-activity Co-60 containing metal pieces were consolidated in the south basin to be grouted in place, and their location mapped for future reference. If the end state selected for the CPP-603 Complex includes removal of the basins and the debris objects, the mapping of these objects will allow workers to locate them.

A fuel piece end-box found during sludge removal and the contents of the "hot" particle catch basket were assayed using an underwater gamma detection system to quantify the amount of Cs-137 as a fission indicator. The results indicated that there was no uranium present. Therefore, the end-box and contents of the basket were left in the basins to be grouted in place.

SLUDGE TREATMENT AND DISPOSAL

The basin sludge was collected in HICs, as discussed above. Basin sludge treatment was accomplished by using commercially available materials in conjunction with proprietary process additives to blend the waste into an acceptable final waste form. All waste conditioning and solidification also occurred in the HICs. (Fig. 4) The HICs have dewatering filters oriented horizontally to maximize dewatering while minimizing plugging. The dewatering filters are located near the bottom of the HIC due to the low waste volumes. Preinstalled mixer blades allowed continuous agitation of the grout and sludge to ensure that it would cure to a hard, homogeneous, water-free waste form.

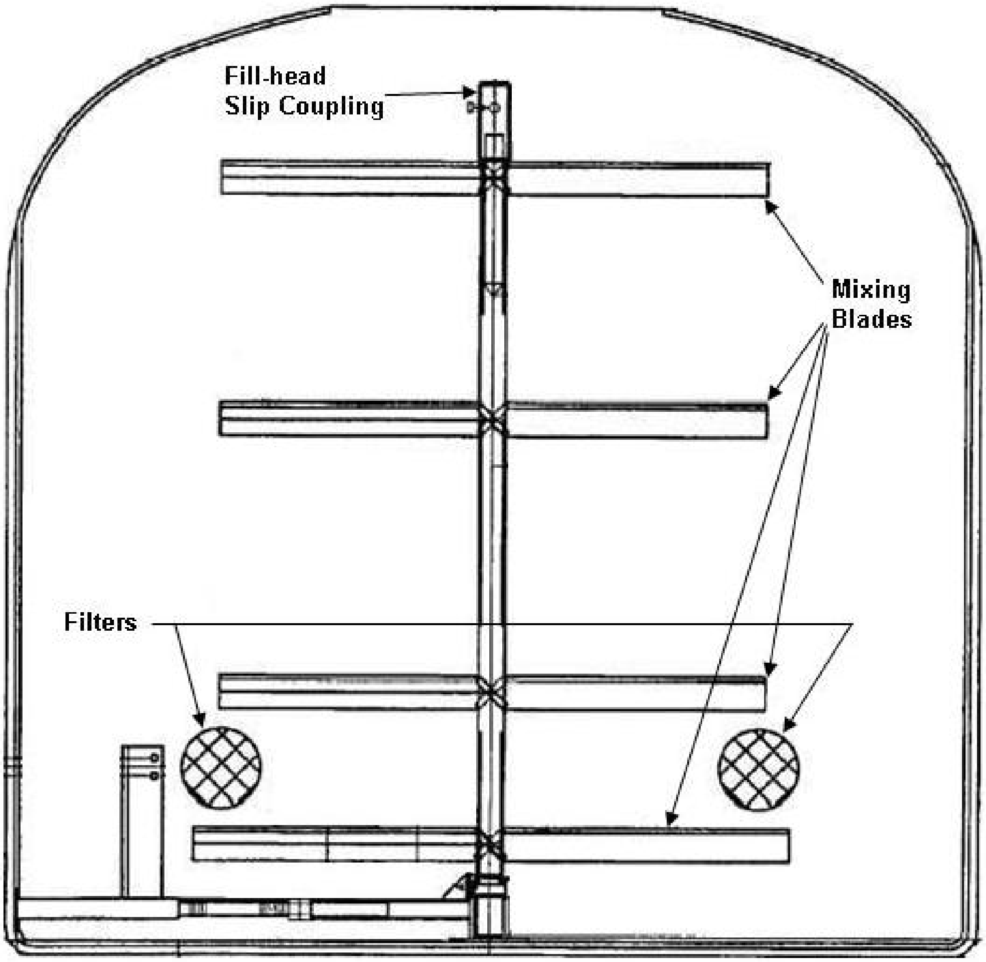

Fig. 4. Typical high integrity container used to capture and treat basin sludge

The sludge treatment system consisted of HICs, fill-heads, hydraulically-driven mixer blades, and grout delivery system. The waste treatment area held eight HICs at a time. It was a high radiation area, as defined by DOE's Radiological Controls Manual, and surrounded by shield walls. The system was operated and monitored remotely, utilizing fill-head controls, hydraulic control panel, and grout delivery system. The hydraulic power system was used to drive the mixing blades inside the HIC. The mixing blades were slip-coupled to the fill-head drive motor and remained within the HIC after treatment. The grout delivery system consisted of a grout pump and 5 centimeter (2 inch) diameter hoses that transferred grout from a grout pump, located outside of CPP-603A, to the HICs through a connection on each fill-head.

Basin sludge was transferred to the HICs and dewatered until one of the two limits was reached: waste loading volume or radiation dose rate. After four HICs were filled with basin sludge, premixed grout was delivered to the grout pump outside of CPP-603A. The grout was then gradually added to each HIC while the hydraulic unit powered the internal mixing blades. Once a HIC was filled with grout and the grout and sludge were well mixed, the grout transfer line was moved to another HIC. The basin sludge/grout mixture was then sampled through an access port in each fill-head. The samples were analyzed to verify effectiveness of the treatment method and to assign a fissile gram equivalent value to the treated waste container for Special Nuclear Material (SNM) accountability. This process continued until all four HICs were filled with grout and adequately mixed. The four HICs were then allowed to solidify for a minimum of 24 hours prior to being moved from the treatment area. During transfer operations, the grouted HICs were weighed and the net grouted sludge weights applied to fissile material sample results for SNM accountability purposes.

The solidified waste containers were then transferred to an interim storage area outside CPP-603A, referred to as the HIC farm. The HIC farm is a high radiation area surrounded by shield walls. The HIC farm is accessible by fork lift and has the capacity to store 56 containers. The solidified HICs remained in storage until sample analysis data was received, confirming that the containers met the disposal site WAC requirements and a fissile gram equivalent value could be assigned for SNM accountability purposes. The HICs were then transported to the Subsurface Disposal Area at the RWMC for final disposal.

SLUDGE REMOVAL AND TREATMENT RESULTS

Sludge removal and treatment operations began on August 2, 2005 and continued until April 28, 2006. The sludge was removed from the 900 square meters (9,700 square foot) basin area over the course of 304 dives. A minimum of two cleaning passes was necessary for each of the basin areas, with several passes required for the unloading stations and portions of the south basin. Sludge removal efforts met visual inspection criteria for basin surfaces to be free of visible buildup or piles of sludge, when viewed without magnification, after 48 hours settling time. The sludge was grouted in 54 HICs. Waste loadings of the HICs ranged from 20% to 40% by volume, depending on hazardous constituents and radiation levels of the sludge from various areas, as well as operating conditions at the time. Sampling and analysis of the grouted sludge verified successful treatment of the waste to meet the WAC for the disposal site. Radiation readings of the grouted high integrity containers ranged from 0.01 µGy/s to 1.2 µGy/s (4 mR/hr to 400 mR/hr) at 30-cm. Personnel exposure during the project totaled 0.14 Gy (14.3 person-rem), with the divers accounting for only 0.02 Gy (2 person-rem) of the total. The project demonstrated excellent safety performance. Although it entailed unique and high risk hazards there were no safety incidents associated with sludge removal and treatment operations.

SLUDGE REMOVAL AND TREATMENT CHALLENGES

An initial, major challenge of sludge removal and treatment was the discovery of lead in the south basin at concentrations above LDR limits. Previous basin sludge characterization efforts had not identified lead to be present in high enough concentrations that would require the sludge to be treated specifically for lead. The challenge came in finding a treatment recipe that stabilized both cadmium and lead. The addition of Class F fly ash was needed to control the pH within a range conducive to the treatment of both cadmium and lead.

Another major challenge was to obtain representative fissile material characterization for all of the various waste streams. Safeguards and Security requirements and procedures are written to control SNM and are not accommodating to waste disposal. Sampling and analysis methodologies had to be developed for characterizing grouted HICs, miscellaneous debris, contamination comprising the scum line, and the basin water being disposed of at the ICDF evaporation pond. The methodologies had to include laboratories, procedures, and equipment that were certified through Safeguards and Security.

To allow diver access in the north and middle basins, a section of a one foot wide concrete beam had to be removed. After analyzing the resulting forces, it was determined that a support would be required to prevent the resulting cantilevered beam from breaking. A support system resting on the two adjacent beams was fabricated and installed on either end of the cut location. A three foot long section of beam was then cut out and lowered into the basin. Four such access points were provided, enabling divers to descend via ladder to the basin floor.

Diver access into the transfer canal constituted a penetration dive. Penetration dives are high hazard dives where there is not a ready path to the surface. The surface of the canal was covered by deck plates and had no direct diver access points. Entry was underwater from the south basin. An additional diver is required to be in the water ready to assist the penetration diver. A dedicated tender is required for each diver in the water. With these precautions in place, the vacuuming of the sludge from the transfer canal proceeded smoothly.

The divers wore remote reading dosimeters on their torsos and each extremity. Failure of one dosimeter was acceptable, but more than that required the divers to exit the basin. A few problems were encountered with transmitter failure attributed to the humidity inside the diver suits and on a few occasions enough transmitters failed to require diver to exit the basin. The problem was solved by placing the dosimeter transmitters inside plastic bags taped to the diver.

Sludge removal was made more difficult and delays were encountered due to an unexpected hard layer of sludge. Sampling efforts and previous experience working in the basins had indicated the sludge was mostly light, flocculent material that could be easily vacuumed. However, the divers encountered hardpan material in several locations. This required the divers to use hand tools to break up the material. It also caused more frequent clogging of the vacuum head. The only solution was to continue mechanically breaking up hard pan. While not technically challenging, it was time consuming and physically hard work.

Visibility also caused some problems. The light sludge would easily go into suspension, reducing visibility to only a few feet. This was overcome by initially vacuuming a small area from the access ladder. The diver could then move forward from there, always clearing out a path in front of him.

A more difficult visibility problem arose when some of the grout equipment wash water was recycled back into the basins. The grout mixture included a plasticizer as an additive to prevent the initiation of curing while in transit from Idaho Falls to INTEC. When introduced to the basin water, its properties caused the particles to remain in suspension. This clouded up the entire south basin and suspended diver operations for several days until the particles finally settled. Recycling of grout washout water was prohibited thereafter.

While one HIC was filled with sludge/water from the basins, another HIC was dewatered. The dewatering filters in the HICs kept the sludge in the HICs, but tended to plug early. This problem was mitigated by dewatering the HIC while still pumping sludge into it. This kept the sludge from settling and caking on the filters, but still allowed the filters to function. Spinning the HIC mixing blades occasionally also helped agitate the contents and remove some of the sediment that caked the filters.

The HICs sat on a concrete "donut" with a radiation monitor in the hole of the donut to allow monitoring of the bottom of the HIC during sludge collection and grouting operations. After curing a minimum of 24 hours, the HIC was transferred to the HIC farm. Upon transfer of the first four grouted HICs, the bottoms of the containers were found to be bulged from the weight of the grout over the donut hole. Since the HICs could not stand upright on a flat surface, they were place on cribbing for transport and storage. Wooden stands were installed inside the holes to support the HIC bottoms during subsequent grouting operations.

After grouting, the HICs were moved to the HIC farm, where they remained until laboratory analyses confirmed they met the WAC for the disposal site. Of the 54 HICs generated from this project, eight were later found to have water inside the hollow lids. The water was sampled and found to be nonradioactive. The water was attributed to precipitation leaking in through the small vent holes along the sides of the lids. The fact that the other HICs had no water in the lids was attributed to slight differences in manufacturer tolerances. The issue was addressed by drilling a hole into the top of the eight lids and adding absorbent. The access holes were then sealed and the HICs were shipped to the disposal site without incident.

The structure housing the basins is poorly heated with no active ventilation. As the project progressed into winter months, freezing temperatures became a problem. The basin water got cold (as low as 9°C [48°F]), limiting the divers' stay times, in spite of dry suits and thermal clothing. On one occasion, the ambient air within the CPP-603A facility dropped to minus 8° C (17° F), freezing the divers' breathing air supply and obviously prohibiting operations. More frequently, the outside air temperature caused problems. Outside air was compressed to supply the air-driven pumps. As the compressed air expanded at the pump it froze; the heat of compression was not enough to overcome the ambient temperature. This was mitigated by heating the outside of the air lines, but did cause some delays.

Debris on the basin floor, larger than 12.7 millimeter (0.5 inch), was kept out of the HICs by a screen on the vacuum head. In some areas the amount of debris was so great that the screen had to be cleaned off every few minutes. This delay was eventually overcome by adding an in-line knockout basket that had 12.7 millimeter (0.5 inch) holes and required less frequent cleaning. Debris included nuts, bolts, pieces of aluminum screen, and rust particles.

HYDROGEN GENERATION

During grouting of the CPP-603A basin sludge, a report (EM-RL-PHMC-SNF-2005-002) was issued from the DOE Occurrence Reporting and Processing System discussing the generation of hydrogen during grouting of basin sludge at the Hanford, Washington, nuclear reservation. The sludge removal and solidification process at the CPP-603A basin facility was determined to involve similar chemistry, and therefore, similar issues with hydrogen generation. The primary source of hydrogen generation is a series of chemical reactions between the caustic grout and aluminum metal. Grouting was suspended pending further engineering evaluation.

Reaction rates, and therefore the rate of hydrogen generation, depend on the amount of aluminum metal present in the sludge or basin, and on the surface area of the aluminum metal pieces. Experimental data indicate that within three hours of grout addition, hydrogen generation essentially stops, because the aluminum metal develops a protective oxide layer. A study of the CPP-603A basin sludge solidification process concluded that hydrogen could be generated during basin grouting and in the high integrity containers that were used to solidify sludge. (EDF-6677) [8] Under conservative assumptions for aluminum mass, configuration, and leak paths for dissipation of hydrogen from each fill-head, the rapid rate of hydrogen generation during mixing could lead to a hydrogen concentration of 4% (the lower flammability limit for hydrogen) within about 16 minutes.

Compensatory measures described in SER-JCO-1 were put in place for HIC grouting. [9] An active ventilation system was implemented to sweep any hydrogen generated out of each HIC’s air space. The system consisted of a chimney attached to the sample port opening on each fill-head and two air-movers. The air movers were connected in parallel and draw a minimum of 56 l/m (2 cf/m) of ambient air through each fill-head for a minimum of three hours after grout addition. HIC grouting operations were resumed and continued without incident.

Prior to movement of each HIC, its fill-head was removed and replaced with a vented lid. The grouted HICs sat for several hours while the grout hardened sufficiently to allow transport of the HIC. These factors provided assurance that a flammable atmosphere could not exist in any of the already grouted HICs.

A similar evaluation was conducted for basin grouting. Based on the inventories of aluminum remaining in the basins, dispersion mechanisms, and flow paths, it was determined that hydrogen concentrations would not reach 4% during basin grouting. Therefore, no mitigative actions were necessary. During basin grouting, bubbling was evident in a localized area of the south basin directly above a box of debris. Monitoring of the gas indicated it to be hydrogen, but at a concentration significantly less than the 4% lower flammability limit. It should be noted however, that the bubbling was observed over a period of several weeks, contrary to the three hours indicated by experimental data.

BASIN DEWATERING AND GROUTING OVERVIEW

Following sludge removal, basin water was removed while the basins were filled with grout. The water was pumped to the ICDF evaporation pond for disposal. The rate of water removal and grouting was controlled as to not expose the highly contaminated scum line along the basin walls. The grout encapsulated any residual sludge remaining from sludge removal operations and debris left in place in the basins. The grout provides shielding and containment of the radioactive contamination, thereby minimizing possible migration and airborne contamination.

BASIN WATER CHARACTERIZATION

Approximately 4.5 million liters (1.2 million gallons) of basin water were to be pumped via above-ground pipe to a nearby evaporation pond at the ICDF, a CERCLA permitted, double-lined pond. The ICDF WAC had two applicable criteria; a pH limit of 12.5 and radionuclide concentration limits. [10] After sludge removal, the remaining basin water was re-characterized and verified to be acceptable for disposal at the ICDF. However, conditions had to be monitored to ensure that did not change as basin dewatering and grouting operations progressed. Basin water samples were collected daily from an in-line sample port for pH, total suspended solids (TSS), and fissile material content. The pH and TSS were analyzed in the field, while samples for fissile material were analyzed by the INTEC analytical laboratory.

Rather than sample the water each day and wait for analytical results on a suite of radionuclides before pumping basin water, it was determined that the limiting isotope, Ba-137m, could be tracked by another indicator. Characterization of the basin water after the sludge had been removed showed that the dissolved radionuclides were well below WAC limits. A portion of the residual sludge, however, was assumed to go into suspension during grouting operations, manifesting as TSS. By limiting TSS, the Ba-137m would be limited, accordingly. A limit of 500 ppm TSS was determined as the amount that would keep all radionuclides below the WAC limits. Although it was known that the grout mix would raise TSS with non-radioactive solids, the conservative limit of 500 ppm was retained. If that limit were reached, additional analysis would be required to verify radionuclide concentrations.

In addition to characterizing basin water for radionuclide loading, the fissile material content was also determined for SNM accountability. Since the basins had been used for storing fuel, and fuel cutting activities had occurred, it was known that the water and residual sludge had some fissile material hold-up. This material had to be accounted for in the overall fissile material inventory and taken “off the books” when transferred to another facility. In addition to the initial basin characterization, daily grab samples of water being transferred were also taken for SNM accountability.

Another radiological concern was the basin scum line. Similar to a bathtub ring, the scum line was an area all along the walls and pillars of the basins that contained a high level of radiological contamination. It was the result of previous basin operations that had produced high contamination of the basin water. The basin walls are unsealed concrete and very porous. The water itself, although still highly contaminated, was much less contaminated than the scum line. The scum line had a band-width of about 15.2 to 45.7 centimeters (6 to 18 inches) and needed to remain covered during grouting. Had it dried, the resulting airborne contamination could have shut down operations in the entire CPP-603 facility due to the lack of ventilation controls.

BASIN WATER REMOVAL

As grout was pumped into the basins, water was displaced at the rate of 2.54 centimeters (1 inch) of water level per 23 cubic meters (30 cubic yards) of grout. The individual basins are hydraulically linked via a transfer canal, but it was desirable to keep the grout from freely flowing from one basin to the next, to better control grout levels within each basin. To that end, stop logs (metal plates the same width as the basin/canal interface) were inserted between each basin and the transfer canal. This provided an adequate barrier to grout flow, but still allowed water to freely flow from the basins to the transfer canal to the overflow pit.

The overflow pit is isolated from the transfer canal, except via a weir opening at the top. It served as a clear well, providing room for suspended grout particles to settle, while relatively clear water was removed. Water was removed from the overflow pit via a centrifugal pump, through a duplex filter, and pumped 430 meters (1,400 feet) to the ICDF evaporation pond. Filters with mesh sizes of 100 to 400 microns were installed to control TSS and were to be changed out based on pressure differential and radiation levels. Suspended solids remained extremely low until late in the project, and 200 micron filters were used during the majority of operations. Instruments were installed to monitor filter pressure drop, filter radiation levels, flow rate and total flow. An in-line sample port allowed collection of samples of the flowing water for pH, TSS, and radionuclides.

The transfer line was single-contained High Density Polyethylene (HDPE) and was inspected continuously for leaks during pumping operations. Inspections were performed via daily walk down and by remote operated cameras. Where the pipe passed under existing roads it was double-contained inside steel pipe and visually inspected at the open ends. There was no remote leak detection.

BASIN GROUTING

The basin grout was designed to be a controlled low strength material and self-leveling. The low strength requirement was to allow for future removal of the entire structure, pending identification of the final end state for the CPP-603 Complex. The placement method, grout pumps, and 10 centimeter (4 inch) diameter hoses pumping distances over 30 meters (100 feet), also dictated that the grout be quite flowable. It was also important that it capture any remaining residual sludge. The minimum strength requirement was 17,000 hPa (250 psi). No maximum strength was specified, but the grout had to be removable with conventional excavation equipment.

Laboratory tests were conducted in aquariums to develop acceptable mixes, and were evaluated for grout washout, effect on water pH and TSS, strength, and pumpability, as indicated by puddle diameter. A large scale mockup was then built to further evaluate recommended mixes. The mockup consisted of three plastic lined, wooden tanks, 8.5 meters (28-feet) long by 1.2 meters (4-feet) wide by 1.8 meters (6-feet) deep. Raceways were built into the bottoms to simulate the troughs along the bottoms of the north and middle basins. The tanks were filled with water and a surrogate sludge consisting primarily of bentonite, kaolinite, boehmite and ferric oxide, was placed on the bottom. The ferric oxide, besides being a constituent of the basin sludge, also acted as a color marker to help determine when all of the surrogate sludge had been captured by the grout.

Several different grout recipes were tested in the three mockup basins and two recipes were finally selected: one for bulk-fill of the basins and a second for pipe-fill and final capping of the basins. The bulk-fill recipe comprised 90% of the grout used and consisted of cement, fly ash, and sand. This recipe used ratios of 18.66 sand: 2.3 fly ash: 2.6 water: 1 cement, by weight. A plasticizer additive was also incorporated into the mix for flow control. The second mix consisted only of cement and fly ash with no aggregate and was used for filling in debris piles on the basin floor and final leveling. This recipe used ratios of 4.78 fly ash: 1.67 water: 1 cement, by weight. The same plasticizer additive was used along with an inhibitor to prevent early set. Adjustments were made to the recipe during the project to account for changing conditions as operations progressed.

Mockup tests showed that both recipes captured the sludge within the first few pours. Each basin was filled over the course of at least eight lifts or pours. The height of the lifts was dictated theoretically by heat generation and practically by the amount of grout that could be pumped in one day. Results of the actual grouting verified that the sludge was well captured. There was no increase of radioactivity in basin water during the grouting.

The grout was supplied from a batch plant erected on site, then trucked 0.80 kilometers (0.5 mile) to the delivery point. Delivery was via commercially available grout pumps positioned outside of the CPP-603A facility and 10 centimeter (4 inch) diameter hoses. To penetrate the asbestos impregnated building walls, carbon steel transition pieces were fabricated which contained a pressure gauge, rupture disc, and isolation valves. Three such transition pieces were built to access the north, middle and south basins, respectively.

To place the grout in the bottom of the basins a tremie pipe system was used. Ten centimeter (four inch) diameter carbon steel tremie pipe, in 60 centimeter (2 foot) sections, ran from the basin deck level to the bottom of the basin. As grout flowed through the grout delivery hoses and down through the tremie, the grout level began to cover the bottom of the tremie. This was desired to minimize the amount of water the grout flowed through, thus minimizing grout washout. At the end of the day's lift, the tremie was raised and the top 60 centimeter (2 foot) section was removed. The shortened tremie was then reinserted into the basin ready for the next lift. The 10 centimeter (4 inch) diameter hose leading to the tremie had a working pressure of 55,000 hPa (800 psi). It was made of heavy rubber, reinforced with steel wire, and thus difficult to bend. To make the transition from horizontal hose to vertical tremie, several large radius carbon steel elbows were fabricated. The elbows were portable and could be used at any grout insertion point.

The majority of the grout was inserted at the center of each basin and the grout flowed outwardly. However, there was some mounding at the insertion points. Therefore, at the end of the project, a few additional points were added to level out the grout profile.

In the north and middle basins and transfer canal, narrowly spaced horizontal beams provide support to the shielded deck plate and walking surface, but also form a gap that would be difficult to fill in with grout pumped from below via the tremie. To solve this problem, a 5 centimeter (2 inch) diameter hose assembly was fabricated and attached to the 10 centimeter (4 inch) diameter main hose. The 5 centimeter (2 inch) diameter hose was small enough to fit within the gap between the lead shielded deck plates, but also required a low flow rate to prevent exceeding the rupture disc burst pressure on the grout delivery system.

A grout placement plan was devised early in the project to control the type and amount of grout to be placed in each basin. Lifts were generally constrained to no more than 1.2 meters (4 feet) deep with a one day curing period allowed between lifts. In practice, the average lift was about 60 centimeter (2 feet). Two grout pumps were used so that two basins would receive pours one day, and another basin and the transfer canal would receive pours the following day. At peak efficiency, 10 trucks per hour delivered grout to the two pumps, resulting in up to 405 cubic meters (530 cubic yards) being poured in a day. The limiting factors were the delivery rate of the grout pumps and the removal rate of the water pump.

Additional caution was needed during water removal and grouting of the Fuel Element Cutting Facility (FECF) transfer tunnel. This appendage to the south basin is partly separated from the basin by a shield wall that penetrates the top 3 meters (10 feet) of the basin. As grout rose in the basin to the 3 meter (10-foot) level, it met the bottom of the shield wall. Continuing to pump grout would have raised the grout level in the transfer tunnel, potentially displacing water from the tunnel into the FECF cell. This was not acceptable because FECF cell floor drains do not drain to environmentally permitted tanks. Therefore, it was critical to prevent water from overtopping the FECF parapet. This was successfully accomplished by carefully filling the basin area along the shield wall until the grout level reached the bottom of the shield wall and letting it cure before adding more grout to the south basin. This action effectively sealed off the transfer tunnel. At the end of the project, the remaining water was pumped out of the FECF transfer tunnel into the basins and grout was pumped over the top of the FECF cell wall into the transfer tunnel.

Due to the physical configuration, it would have been very difficult and hazardous to manipulate the 10 centimeter (4 inch) diameter hose into the FECF transfer tunnel area. So, the 5 centimeter (2 inch) diameter hose assembly used in the gaps between deck plates in the north and middle basins was used as an extension to the 10 centimeter (4 inch) diameter hose. The grout had to be very runny to move through the 5 centimeter (2 inch) diameter hose without increasing the backpressure and bursting the rupture disc. A suitable recipe was devised and the grout successfully pumped into the FECF transfer tunnel in two lifts.

The level of grout in each basin was measured using a weighted sounding line. Limited visibility made underwater camera inspection ineffective and low overhead space made a long pole impractical. Readings were taken after each lift and mapped to track grout profiles and prepare for the following lift.

When the basins were about 85% full, grouting operations slowed down considerably. Less basin water meant that pH could change much more quickly and the pH limit was being approached. This complicated the logistics of the final lift. The stop logs between basins were covered with grout by this time, so grout from the basins could flow uncontrolled to the transfer canal. The very runny grout that was planned to top off the basins was intended to run from one basin to another to fill in depressions and create a level the surface. However, it also had high washout characteristics and could have caused the pH to increase above the ICDF WAC limit with the small amount of water remaining. The solution was to connect a submersible pump to the priming water connection on the water removal pump and remove all remaining basin water to ICDF. By this time, the basin scum line was adequately covered with grout therefore removal of the remaining water was not a radiological concern. Once the water was removed, the basins were topped with the self-leveling grout. Grout was raised to within 10 centimeter (4 inches) of the basin wall in the final lift.

Throughout most of the project the maximum TSS was 35 ppm, well below the 500 ppm used as control mechanism for Ba-137m. However, as with pH, the TSS increased significantly as the volume of water diminished towards the end of the project. When that occurred, the solids were sampled and analyzed for radionuclide content. The results showed that the composition of the solids was two orders of magnitude less than the ICDF WAC for Ba-137m. That, coupled with the fact that the sludge had been captured by the grout at that point, allowed the TSS limit to be eliminated for the remaining duration of dewatering and grouting.

BASIN DEWATERING AND GROUTING RESULTS

Basin dewatering and grouting began on August 22, 2006 and was completed on November 3, 2006. Following the final water removal and grout delivery an inspection was performed to verify project requirements were met. Grout levels were found to be within specification in all basins and minimal residual water was found. The volume of grout added to the basins was 4,990 cubic meters (6,530 cubic yards). The amount of basin water removed was 4.5 million liters (1.2 million gallons). An additional 200,000 liters (53,000 gallons) of clean water was transferred to the ICDF evaporation pond during very cold weather to prevent the transfer line from freezing solid overnight. Radiation exposure was about 0.02 Gy (2 Rem), which was 30% less than anticipated. Filter changes were required less often and the amount of radioactive solids collected was minimal. This portion of the project also demonstrated excellent safety performance. There were no skin contaminations or safety incidents during the dewatering and grouting operation.

BASIN DEWATERING AND GROUTING CHALLENGES

The biggest delays in the project were the result of changing the type of fly ash used in the grout. Fly ash comes in two major types, designated Class C and Class F. Mockup tests were performed using Class F fly ash, and the specification for the batch plant was for Class F fly ash. However, when the batch plant went into operation, the availability of Class F fly ash was severely limited, and Class C fly ash was substituted. The grout recipe was adjusted for Class C fly ash, but the new mix was not tested prior to pumping it into the basin. On the first day of grouting operations, the grout mix was too thick, and only a few truck loads were pumped. After some additional adjustments and testing with full truck loads the next day, a new recipe was identified which was much more workable. The new mix had satisfactory flow and strength characteristics, but expected pH levels were affected by the different fly ash material.

The mockup tests had indicated the highest pH to be expected with Class F fly ash was about 12.3. Calculations accounting for the different compositions of the two fly ashes showed that even the Class C fly ash would not reach a pH of 12.5. The grouting experience, however, proved that the Class C fly ash could produce a pH higher than 12.5. As a pH of 12.5 was approached, the project shut down for two weeks, pending development and implementation of corrective actions.

Several options were evaluated. The preferred approach was to add nitric acid directly into the basins to lower the pH. It was determined that 760-1500 liters (200-400 gallons) of 13 molar acid would be required. Safety considerations associated with manually handling that amount of acid impacted the use of this option. Since the water from the CPP-603 bas was addressed under a CERCLA removal action and INTEC is within the area of contamination, discussions were held with the DEQ and EPA to discuss potential options. The technical limit for the ICDF evaporation ponds is based on the design limitations of the liners, which can handle a pH of 13, so it was determined that it was permissible to increase the pH of the basin water to 12.85. However, the maximum pH observed was 12.77. Only about 151,000 liters (40,000 gallons) of water were transferred to the ICDF evaporation ponds at a pH of 12.5 or higher.

Some delays also occurred as a result of grout lines becoming plugged. This was not prevalent on days when high volumes of grout were pumped, but on days when low volumes were pumped, the grout had time to begin to set up in the lines. Twice during cleanout operations, which involved pushing a foam ball through the line with water pressure, the rupture disc burst. The line was cleaned out manually and the rupture disc was replaced. No rupture discs burst during grouting operations.

Because of a desire to keep the lines from plugging during the all-day grouting operations, the project pumped a couple hundred liters (a few dozen gallons) of water through the lines every 2 hours. This proved to be counter-productive with the back-fill grout mix that contained sand. The cementitious materials were carried away and the sand left behind. This caused high back pressure when grouting was resumed, and on some occasions the operation had to be stopped and the lines cleaned out manually.

Tremies became stuck several times, when the grout around the tremie was deeper than the overall grout level. In most cases the tremies were able to be freed later, but in two cases they were abandoned and remain grouted in the basin. Alternate grout placement locations were readily made. Additionally, the tremies were raised more frequently to minimize the amount of grout mounding around them.

CONCLUSION

Closure of legacy DOE facilities poses a series of interesting and unique challenges compared to those faced during operation. Though any single aspect of the design and decommissioning may well have been previously used, the combination is unique. Advance planning is clearly required for the success of a technically challenging project such as this, but unexpected problems still arise.

In the case of the CPP-603A basins, the sludge removal project used divers and water pumps to vacuum sludge into HICs where the sludge was grouted. This had all been done before, but the basin configuration and sludge consistency posed unique technical challenges. Through creative thinking and teamwork the challenges were met and the sludge was successfully removed, grouted, and transported off-site, completing the first phase of basin deactivation.

For the basin grouting portion the biggest difficulty arose from the change of fly ash, driven by an industrial shortfall of the desired raw material. Here again, some creative thinking provided a viable solution, at the cost of some delays, but no other major consequences.

The scope of the project, carried out over the course of two years, was to remove remaining fissile material, remove and treat 50,000 kg (110,200 pounds) of highly contaminated sludge, remove 4.5 million liters (1.2 million gallons) of contaminated water, and fill the basins with 4,970 cubic meters (6,500 cubic yards) of grout. This was all successfully accomplished with no injuries and no contamination events.

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