Grout Isolation and Stabilization of Structures and Materials within Nuclear Facilities at the U.S. Department of Energy, Hanford Site, Summary - 12309

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ABSTRACT

Per regulatory agreement and facility closure design, U.S. Department of Energy Hanford Site nuclear fuel cycle structures and materials require in situ isolation in perpetuity and/or interim physicochemical stabilization as a part of final disposal or interim waste removal, respectively. To this end, grout materials are being used to encase facilities structures or are being incorporated within structures containing hazardous and radioactive contaminants.

Facilities where grout materials have been recently used for isolation and stabilization include: (1) spent fuel separations, (2) uranium trioxide calcining, (3) reactor fuel storage basin, (4) reactor fuel cooling basin transport rail tanker cars and casks, (5) cold vacuum drying and reactor fuel load-out, and (6) plutonium fuel metal finishing. Grout components primarily include: (1) portland cement, (2) fly ash, (3) aggregate, and (4) chemical admixtures. Mix designs for these typically include aggregate and non aggregate slurries and bulk powders. Placement equipment includes: (1) concrete piston line pump or boom pump truck for grout slurry, (2) progressive cavity and shearing vortex pump systems, and (3) extendable boom fork lift for bulk powder dry grout mix.

Grout slurries placed within the interior of facilities were typically conveyed utilizing large diameter slick line and the equivalent diameter flexible high pressure concrete conveyance hose. Other facilities requirements dictated use of much smaller diameter flexible grout conveyance hose. Placement required direct operator location within facilities structures in most cases, whereas due to radiological dose concerns, placement has also been completed remotely with significant standoff distances.

Grout performance during placement and subsequent to placement often required unique design. For example, grout placed in fuel basin structures to serve as interim stabilization materials required sufficient bearing i.e., unconfined compressive strength, to sustain heavy equipment yet, low breakout force to permit efficient removal by track hoe bucket or equivalent construction equipment. Further, flow of slurries through small orifice geometries of

moderate head pressures was another typical design requirement. Phase separation of less than 1 percent was a typical design requirement for slurries.

INTRODUCTION

The U.S. Department of Energy Hanford Site has, and is, currently conducting a wide spectrum of waste management and decontamination and decommissioning actions throughout the site. These range from radioactive and hazardous materials removal and disposal, to stabilization and isolation of materials in situ. A preferred (U.S. Department of Energy and its contractors, U.S. Environmental Protection Agency, Washington State Department of Ecology, stakeholders, and others) engineering alternative for management of a significant quantity of radioactive and hazardous materials is grout injection or direct placement. This is supported by federal regulation, i.e., Resource Conservation and Recovery Act of 1976 [1], the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 [2], the Superfund Amendments and Reauthorization Act of 1986 [3], the Hanford Federal Facility Agreement and Consent Order 1989 [4], and others. Records of decision relative to specific waste management and facilities management and decontamination and decommissioning actions also often mandate decisions and provide agreement for grout injection and placement projects where applicable.

To this end, facilities, methods, materials, and discussion of grout injection and placement are identified to provide a summary of several examples of past waste management and decontamination and decommissioning field actions at the Hanford Site. Due to unique design, physicochemical conditions, contamination materials and contamination levels, etc., each grout project has required unique treatment or remediation, equipment, materials, development, testing and deployment, technologies. These facilities, structures, and applications of grout technologies for the most part cover the back end of the nuclear fuel cycle, and provide a comprehensive technical and experience base for utilization of grout materials and equipment for future nuclear and other industrial decontamination and decommissioning projects.

FACILITIES DESCRIPTIONS

U-Canyon

The Hanford West Area U-Canyon Facility was originally designed as a plutonium recovery chemical (bismuth phosphate) separations plant, subsequently used for uranium recovery operations, and later used for materials and process equipment decontamination and storage. The structure is nominally 250 meters long, 20 meters wide and 23 meters high with approximately 40 percent of the structure below grade. The structure is primarily reinforced concrete with floors and walls ranging from approximately 1 to 3 meters thick. The primary structure contains 40 process cells oriented longitudinally within the structure with proximal pipe trench and ventilation tunnel also oriented longitudinally over the length of the structure process cells and proximal structures both above and below the canyon operating deck. An additional tunnel from the canyon structure ventilation tunnel to the sand filter stack structure was also part of the overall facility structure. The total volume to be grouted was estimated at 25,000 cubic meters. An overhead gantry crane serves to facilitate materials and equipment movement within and above cells and trench. A drain header connecting all cells also extends below the length of the structure connecting all process cells. Directly adjacent to the main structure and part of the overall structure are electrical, pipe, and operations galleries also extending over the length of the structure. Directly outside of the structure is a chemical process sewer that also extends the length of the structure and is connected to outside utility piping. Core holes were drilled through structure walls, cell cover blocks, deck floor, and sand filter plenum, for access of grout piping injection hardware.

Primary contaminants include, e.g., americium, cesium, plutonium, thorium, and uranium, in addition to lead, mercury, and organics. The canyon operating deck, from where most radiological materials were accessible was considered primarily an airborne radiation zone, with associated contamination, radiation, and high radiation area zones.

Railcars

Railcars (flat cars) with open top tanks carrying shielded casks used for transport of irradiated nuclear fuel and railcars (tank cars) used for transport of aqueous contaminated solutions, with capacities of approximately 16 and 88 cubic meters, respectively utilized the grout process to meet waste acceptance criteria for burial. These railcars were staged at the Hanford North Area rail spurs in preparation for grout stabilization and isolation as a precursor to transport for final disposition. Access to casks was through mechanical doors located on the top of each open top tank. Access to tank car internals was through piping in tank cupolas.

Primary contaminants were americium, cesium, cobalt, plutonium and strontium in addition to significant quantities lead used for cask shielding. Dose rates proximal to some casks were in high radiation, in addition to typical radiation zone areas. Radiological areas around the cars were categorized as high radiation.

Metal Finishing Plant

Located in the Hanford West Area, the Plutonium Finishing (234-5) Facility was used for preparation of plutonium metal for use in U.S. Department of Energy weapons programs. The main facility contains numerous pipe trenches directly below the main floor level. The under floor slab tunnel roof was on the order of 0.09 meters thick and was assessed as not capable of supporting equipment to be moved over the tunnel. Hence, tunnel grouting was required to provide loading capacity. Grout was injected through floor slabs via drilled core holes directly into the tunnels. Each tunnel to be grouted was isolated from other subgrade tunnels and passageways, etc., with lateral bulkheads.

Contaminants of primary concern within the trenches include americium and plutonium.

KE Fuel Storage Basin

The KE Fuel Storage Basin located directly adjacent to the Hanford KE weapons materials production reactor consisted of 3 main below grade reinforced concrete pools and ancillary fuels examination and fuel handling structures, i.e., elevator, view and weasel pits, and load-out pits. Filling these with grout provided a stable platform for demolition of the overhead fuel basin structure, containment of residual contamination within the subgrade basin structure, and significant reduction of dose rates. Prior to grouting, the fuel basin and ancillary structures, were dewatered. The volume of flowable fill grout placed was on the order of 6,300 cubic meters.

Radioactive constituents within the basin and ancillary structures included americium, cesium, plutonium, and strontium, for the most part. Airborne, contamination, high contamination, radiation, and high radiation zones were present in the work area on dewatering. Significant dose rates were found near the reactor discharge chute area within the fuel basin.

Uranium Trioxide Plant

The original design of the uranium trioxide plant was plutonium concentration and was later used for calcining of uranium nitrite hexahydrate for gaseous diffusion plant feed. The plant was physically connected to U-Plant via subgrade piping through a lateral tunnel. A portion of the tunnel and corresponding access pit was required to be backfilled with grout as a part of plant decommissioning. The tunnel and access structure was isolated from the adjoining U-Plant by a bulkhead. The tunnel structure volume was on the order of 87 cubic meters.

The tunnel and associated structure also contained significant free standing contaminated water. Dry bulk powder grout was placed first to absorb the contaminated water and cure into a structural monolith. Flowable grout was then placed into the access pit and tunnel to completely fill all accessible voids and again provide a structural monolith.

Uranium was considered the primary contaminant of concern.

Cold Vacuum Drying / KW Reactor Fuel Load-Out

A general area was established for injection of grout into drums and waste disposal containers proximal to the Hanford Cold Vacuum Drying Facility and near the 100 KW Reactor Fuel Basin. Drums and containers were injected with slurry grout on an asphalt pad and within the fuel basin rail load-out area. Drums were fitted with high efficiency particulate air filtration located at an elevation of approximately 4.9 meters above the base of each drum, for displaced air. Disposal containers were fitted with high efficiency particulate filters affixed to the top of each container such that container tops could be removed after injection to inspect void fill completeness.

Radioactive contaminants of primary concern were considered equivalent to that of the fuel basin above.

PLACEMENT/PRODUCTION EQUIPMENT

Production Pumps and Piping

High capacity concrete trailer mounted line pumps (three different models) were used primarily for bulk grout placement on large basins, cells, tunnels, etc.. High capacity maximum 90 cubic meter per hour at 10,900 kilopascals, 41 cubic meter per hour at 7,900 kilopascals, or 26 cubic meter per hour at 7,580 kilopascals pumps, with 400 kilowatt, 73 kilowatt, or 51 kilowatt prime movers, respectively. Typical operational production rates for these pumps were 60, 51, and 37 cubic meters per hour, respectively.

A high capacity truck mounted concrete articulated boom pump (Figure 1 and 2) with a nominal reach capacity of 28 meters, a maximum throughput of 117 cubic meters per hour at 8,860 kilopascals, utilized a 276 kilowatt prime mover. Typical operational throughput for this pump was on the order of 49 cubic meters per hour.

Figure 1. Articulated boom grout placement truck and transit-mix truck, off loading into chemical separations plant cells through high pressure ridged and flexible piping.

Figure 2. Grout placement into contaminated rail car vessels using remote articulated boom truck directed by personnel in aerial lift.

Where highly controlled low placement grout volume was required, i.e., less than 19 cubic meters per hour, a twin hydraulic progressive cavity pump operated at less than 1,039 kilopascals powered by a 29 kilowatt prime mover, was used.

A dual static and variable elevation head tank system was used to inject waste disposal drums and closed disposal boxes. The primary tank consisted of a vortex mixer and shearing pump, whereas the secondary tank consisted of a vortex circulation tank connected to the high pressure side of the shearing pump tank and low pressure side connected back to the vortex mixer shearing pump tank. This system consisting of shearing the secondary vortex circulation tanks could be adjusted in elevation and flow and served to maintain pressure into drums and containers from 0 to approximately 219 kilopascals. This was required due to confinement concerns with potentially airborne materials contained in each and potential burst pressure of the tanks and boxes.

Both rigid steel pipe and braded steel flexible hose, adapters, fasteners, etc., were used to transfer wet grout materials from pumps to their point of discharge (Figure 3). These were engineered to operate at less than 8,610 kilopascals with a burst pressure of 13,790 kilopascals. Pipe and hose sizes used were either 0.05 or 0.13 meter internal diameter dependant on large or small volume placement application.

Hoses and associated hardware were cleaned out between injection intervals, primarily using compressed air and in-line cleanout device via a portable air compressor operating nominally at 830 kilopascals at 6 cubic meters per minute. Compressed air cleanout was required where contamination control was of significant concern, in addition to the concern of reducing or eliminating phase separation water. Other non critical grout placement applications used water cleanout at standard grout pump volume per unit time and pressures.

Figure 3. Remote grout placement in spent fuel storage basin through rigid piping. Personnel access was prohibited in basin throughout placement actions due to excessive dose.

Batch Plant

A portable batch plant (dry batch method) was used at the Hanford U-Plant Facility for production of aggregate and non aggregate slurry grout. This plant was capable of producing (maximum) on the order of 81 cubic meters of material per hour with integral silos of portland cement and fly ash and ancillary hopper for aggregate (sand). All other water mixed grout materials was batched offsite at a high production volume wet-batch plant.

Transportation

All water mixed grout was delivered in standard transit mix trucks with batch sizes nominally of from 7.2 to 9 cubic meters.

Dry grout was delivered by truck to placement sites (uranium trioxide plant tunnel) (railcars) in 1,815 kilogram bulk bags. Dry grout bulk bags were articulated using a long reach 4,535 kilogram fork truck where dry grout was directed into rail tank cars through a pneumatically vibrated funnel apparatus. Dry grout was added to the uranium trioxide plant surface access structure directly from bulk bags opened over the access pit.

PLACEMENT MATERIALS

All identified facilities, structures, vessels, etc., were grouted with portland cement and fly ash based cementitious materials. Where cost was of primary concern due primarily to the requirement for large volumes, mortar sand was incorporated into the grout mix design. Because nominally all injection, placement, etc., of grout was required to be pumped from large to small capacity placement pumps, either high concentrations of portland cement and/or fly ash or viscosity modifier materials were incorporated into the mix design to negate pump and placement line plugging. An air entraining agent was incorporated into some mix designs to reduce costs.

Grout strength requirements were varied dependant on application, i.e., chemical separations facilities strength was required to exceed 10,340 kilopascals as the facility is to be left in situ in perpetuity. The strength of grout within the fuel basin and metals finishing plant was mandated in contrast at approximately 344 kilopascals due to the requirement that the grout (and entrained contaminants) was required to be removed, i.e., low break-out strength after placement and cure by track-hoe excavation equipment, and later transport to a solid waste disposal site. Grout mix designs were specified to have predetermined unconfined compressive strength values from 28 (standard test) to in excess of 56 days.

Flow requirements for grout and grout slurry were also variable per application. For example, grout with mortar sand (aggregate) was used in chemical separations cells and tunnels with open accessible voids. Non aggregate grout was used where for example; small diameter piping, vessels, and voids required complete void fill. Flow was also of significant importance where slurry was required to penetrate small aperture openings in waste containers especially within disposal vessels or to flow long distances, i.e., tunnel filling. Where long injection times at low volume per unit times were required, significant quantities of set retarder admixture was used in grout slurry, i.e., up to 4 hours set retardation. Pumping enhancement was promoted with a viscosity modifier admixture, for example at fuel basin and railcar applications, which was included in mix designs.

Grout, aggregate and slurry mix designs, were formulated to produce less than 1 percent phase separation water, such that there was negligible quantity of free standing water on the grout surface on curing. This also provided additional assurance that void volume was minimal.

Bulk portland cement and fly ash (mixed in equal quantities per unit mass) was used for solidification of standing water containing contaminants, i.e., within subgrade tunnels (uranium calcining facility and within railcar tankers. The quantity of bulk dry cement and ash were calculated in each application to match the free standing water within the structure, such that there was no or little residual volume of bulk power on cessation of placement.

Materials quality testing and quality control of all mix designs were evaluated in the laboratory and field by standard American Society for Testing and Materials and American Concrete Institute tests and protocols. Atypical tests were also conducted, where required, for field testing of grout, i.e., static flow and flow cone analysis of materials at pump locations for approval of grout receipt and pumpablity.

CONCLUSIONS

On the order of 30,000 cubic meters of cementitious grout have recently been placed in the above noted U.S. Department of Energy Hanford Site facilities or structures. Each has presented a unique challenge in mix design, equipment, grout injection or placement, and ultimate facility or structure performance. Unconfined compressive and shear strength, flow, density, mass attenuation coefficient, phase separation, air content, wash-out, parameters and others, unique to each facility or structure, dictate the grout mix design for each. Each mix design was tested under laboratory and scaled field conditions as a precursor to field deployment. Further, after injection or placement of each grout formulation, the material was field inspected either by standard laboratory testing protocols, direct physical evaluation, or both.

REFERENCES

[1] Resource Conservation and Recovery Act of 1976, 42, USC 6901, et seq..

[2] Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq., Pub. L. 107-377, 2002.

[3] Superfund Amendments and Reauthorization Act of 1986, 42, USC 103, et seq..

[4] Hanford Federal Facility Agreement and Consent Order 1989, Washington State Department of Ecology, U. S. Environmental Protection Agency, and U. S. Department of Energy. Olympia, Washington.