Independent Oversight Review of the Hanford Site K-West Annex Facility Construction Quality

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Office of Safety and Emergency Management Evaluations
Office of Enforcement and Oversight
Office of Health, Safety and Security
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Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AMRL	AASHTO Material Reference Laboratory
ASTM	ASTM International
CHPRC	CH2M Hill Plateau Remediation Company
CRAD	Criteria, Review and Approach Document
cy	Cubic Yards
DOE	U.S. Department of Energy
DOE-ORP	DOE Office of River Protection
DOE-RL	DOE Richland Operations Office
FE&C	Federal Engineers and Constructors
HSS	Office of Health, Safety and Security
ITA	Independent Testing Agency
NCR	Nonconformance Report
psi	Pounds per Square Inch
QA	Quality Assurance
QC	Quality Control
QISI	Quality Inspection Services, Inc.
WTP	Waste Treatment and Immobilization Plant

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1.0 PURPOSE

The U.S. Department of Energy (DOE) Office of Enforcement and Oversight (Independent Oversight), within the Office of Health, Safety and Security (HSS), conducted an independent review of selected aspects of construction quality at the K-West Annex Facility. The onsite portion of the review was performed on September 9 and November 12, 2013, by Independent Oversight at the K-West Annex Facility construction site. After the onsite review, the project office provided additional data and records documenting concrete quality for review by Independent Oversight.

2.0 SCOPE

The scope of this assessment of construction quality included review of preparations for restart of construction on September 9, 2013, and observation of two concrete placement activities and visual inspection of completed concrete wall placements on November 12, 2013. Concrete quality records were also reviewed. Design and procurement programs were not included in the scope of this review.

Independent Oversight reviewed the specification and work instruction for concrete construction work, concrete quality records, and nonconformance reports (NCRs), and conducted a construction site walkthrough. During the walkthrough, Independent Oversight performed a visual inspection of the concrete in the truck bay walls that was placed on October 7 and 17, 2013. Independent Oversight also reviewed the records documenting the mixing of the concrete, delivery to the job site, and the results of quality control (QC) tests performed on samples of concrete.

3.0 BACKGROUND

The DOE Hanford Site is undergoing extensive cleanup to remove waste generated by nine former nuclear reactors and associated processing facilities dating from World War II that produced plutonium for atomic weapons for the United States defense program. The cleanup effort is managed by two DOE offices, the DOE Richland Operations Office (DOE-RL) and the DOE Office of River Protection (DOE-ORP). DOE-RL oversees the cleanup of the reactors, the processing facilities, the soil, and groundwater. DOE-RL also manages the demolition of the reactors and other facilities, and disposal of any plutonium and fuel rods remaining on the Hanford Site. CH2M Hill Plateau Remediation Company (CHPRC), under contract to DOE-RL, performs the design, onsite construction work, and monitoring activities necessary to complete the Hanford Site cleanup. DOE-ORP was established in 1998 to manage the 56 million gallons of liquid or semi-solid radioactive and chemical waste stored in 177 underground tanks at the Hanford Site. DOE-ORP serves as DOE line management for two functions: the Tank Farms, which maintain the 177 underground storage tanks; and design, construction, and operation of the Waste Treatment and Immobilization Plant (WTP), which will retrieve, treat, and dispose of the waste stored in the underground tanks. Design and construction of the WTP is managed by Bechtel National, Inc., under contract to DOE-ORP.

When the decision was made in the 1980s to end production of plutonium at the Hanford Site, the remaining fuels rods and rod fragments were temporarily stored in two water-filled underground tanks (basins) adjacent to the K- East and K-West Reactors. In the 1990s, it was discovered that the K-East

basin was leaking. The fuel rods were removed from both basins, dewatered/dried, stored in casks, and transported to the Hanford Container Storage Building, pending long-term storage in a national repository. However, the fuel rods had started to deteriorate while they were stored in the underground basins, producing a material called sludge (a radioactive mixture of fuel corrosion particles, small fuel rod fragments, metal fragments, and other materials). The sludge from the East Basin was transferred to the West Basin, and the East Basin was decontaminated and demolished.

The K-West Annex Facility is being constructed to serve as a load-out facility for the sludge stored in the K-West Basin. The sludge will be pumped into tanks enclosed in casks in a special trailer, which will then transport the sludge to the T-Plant for lag storage. The sludge will subsequently undergo treatment, processing, and preparation for long-term storage at an offsite national repository. The K-West Annex is classified as a hazard category 2 facility and is a seismically designed, safety significant reinforced concrete and structural steel building. The portion of the building where the trailer will be loaded is enclosed by reinforced concrete walls 20 feet high. A structural steel enclosure, 20 feet in height, will be constructed on top of the reinforced concrete structure to house operators, controls, and mechanical and electrical equipment. The design of the K-West Annex Facility concrete structure was completed by AREVA Federal Services under contract to CHPRC. Federal Engineers and Constructors (FE&C) is the general construction contractor for the project.

4.0 METHODOLOGY

This independent review of the K-West Annex construction project was conducted in accordance with applicable sections of HSS nuclear facility construction criteria, review and approach document (CRAD) HSS-CRAD-64-15, *Construction - Structural Concrete*.

5.0 RESULTS

Activities examined by Independent Oversight during the review are discussed below. Each activity is briefly described, followed by a discussion of the review performed by Independent Oversight. Conclusions are summarized in Section 6, and items for follow-up are discussed in Section 7.

Concrete Mix Design

The critical characteristic for the concrete in the K-West Annex facility is the concrete compressive strength, which the design of the K-West Annex Facility set at 4000 pounds per square inch (psi). Before concrete is placed in a permanent structure, the proportions of the ingredients (aggregate, cement, water, and admixtures) are selected based on trial mixes to demonstrate that the concrete has the design strength required for the project. The principal factor affecting concrete strength is the water-cement ratio (the ratio of the weight of water to the weight of cement in the mix, expressed as a decimal). Workability (the property of freshly mixed concrete to be mixed, transported, placed, and consolidated) is also an important characteristic of the concrete mix. Therefore, in addition to meeting the design strength requirements, the selected proportions need to result in a concrete mix with adequate workability to permit placement in the structure. The workability of concrete is measured by its slump, which is an empirical test that measures the consistency of the freshly mixed concrete. Slump is affected by the water-cement ratio and the entrained air content.

The concrete strength is determined by casting samples of concrete in cylindrical molds 6 inches in diameter and 12 inches high that are moist cured in a laboratory for a specified period and then subjected to an unconfined compression test. The methods for sampling the concrete and casting and curing the

cylinders are specified in various ASTM International (ASTM) standards. ASTM C 39, *Compressive Strength of Cylindrical Concrete Specimens*, is the method for measuring compressive strength. During concrete placements, the freshly mixed concrete is sampled and typically tested to determine the slump and entrained air content. Cylinders are also cast from concrete samples, cured, and subjected to unconfined compression tests to determine the concrete strength.

Chapter 5 of American Concrete Institute (ACI) Standard 318, *Building Code Requirements for Structural Concrete*, specifies the requirements for selections of proportions of material to conform to the required concrete design strength. ACI 318 requires that a concrete mix be designed to have a unconfined compression strength higher than the project design strength to account for standard deviation among concrete batches. This is typically referred to as a required overdesign value, which is based on field experience or trial batches.

Independent Oversight reviewed a Concrete Engineering Consultants, Inc., report titled "Concrete Mixture Evaluation for 100 STP KW Annex Modification Project," dated September 27, 2013. This report was prepared for Baker Concrete Construction to evaluate the mix design for the 4000 psi structural concrete used at the K-West Annex Facility. The report concluded that the mix design submitted by American Rock Products, Inc., of Richland, Washington, the supplier of ready mix concrete for the K-West Annex Facility project, met the requirement of ACI Standard 318, *Building Code Requirements for Structural Concrete*. The evaluation of the mix design was based on historical data from 24 consecutive tests from the concrete production facility to establish a standard deviation, as established by ACI 5.3.1.1 and 5.3.1.2. The evaluation showed that to allow for the standard deviation, the average strength of the concrete for the project was required to be 4630 psi. The mix design data submitted by American Rock Products showed that a maximum water-cement ratio of 0.46 would result in the 4630 psi average design strength.

Observation of Concrete Placements

Independent Oversight observed two concrete placements at the K-West Annex Facility on November 12, 2013. These placements were for a slab covering the sand filter in the truck bay and a grade beam to resist wind loads adjacent to the south wall of the truck bay. The placements totaled approximately 20 cubic yards (cy). Section 033000, *Cast-In-Place Concrete*, of the AREVA *Construction Specification for Modified KW Annex* specifies the requirements for manufacture and placement of the concrete and QC and quality assurance (QA) inspection activities. The specified concrete design strength was 4000 psi.

Baker Concrete Construction, a subcontractor to FE&C, supervised the installation of formwork and the placement of reinforcing steel and embedded items in the placements, and performed overall supervision of concrete placement activities. Baker Concrete Instruction OWI 10235-05.01-10, *Concrete Placement*, prescribes the method to be used to place concrete.

Two inspectors from an independent testing agency (ITA), Quality Inspection Services, Inc. (QISI), a subcontractor to FE&C, reviewed the concrete delivery tickets listing the ingredients in the concrete (weight of coarse aggregate, sand, and cement, and volume of water and admixtures in the concrete); performed testing to determine the slump, entrained air content, temperature, and unit weight of the concrete delivered to the jobsite; and molded 6 inch diameter by 12 inch high cylinders to be used for unconfined compression testing. FE&C QC inspectors performed the inspections of the concrete placement activities, and personnel from CHPRC conducted QA surveillance of the various activities necessary to complete the concrete placements.

Independent Oversight examined the condition of the concrete placed in the walls of the truck loading bays on October 7 and 17, 2013. After the concrete forms were removed, Baker Concrete Construction

personnel conducted a condition survey of the concrete surfaces to identify any surface defects, which were then evaluated using the classifications listed in Table 1 of Baker Concrete Instruction OWI 10235-05.01-10. The areas and classification of the concrete surface defects were documented on drawings showing the inside and outside surfaces of the truck bay walls. Comparing the information on the drawings with the as-constructed walls, Independent Oversight concluded that the drawings accurately showed the type and extent of the concrete defects. None of the defects extended below the concrete reinforcing steel. The defects are considered minor and will be repaired using cosmetic repair methods specified in the Baker Concrete Instruction, which are in accordance with those recommended by the ACI. The defects do not affect the structural integrity of the truck bay walls and will not impact the expected service of the structure.

NCRs Initiated for Concrete Placement Discrepancies

Independent Oversight reviewed corrective actions for the following nonconforming conditions associated with concrete operations at the K-West Annex Facility: (1) exceeding the 90 minute time limit specified in ASTM C 94 between batching the concrete and completely discharging the concrete from the concrete delivery truck for three trucks on November 14 and 30, 2012; (2) failing to meet the requirements of ASTM C 31 for temporary storage of concrete test cylinders at the job site on November 14, 2012; and (3) loss of accreditation of the ITA between May 9 and October 30, 2013. Resolution of the NCRs is discussed under Section Effect of NCRs on Concrete Quality. Corrective actions to resolve the NCRs were adequate and the discrepancies did not affect concrete quality.

ASTM C 94, *Specification for Ready Mixed Concrete*, specifies that discharge of the concrete from the concrete truck shall be completed within 90 minutes after the mix water is added to the cement and aggregates (that is, when the concrete is batched in either the truck or the central concrete plant) or before the drum on the concrete truck has revolved 300 times, whichever comes first. The 90 minute time limit can be extended if the concrete is workable enough to permit placement without further addition of water.

On November 30, 2012, when concrete was placed for the fire protection thrust block, the 90 minute time limit was exceeded by 29 minutes. When the concrete in the truck had not been completely discharged within 90 minutes, the concrete supplier requested an extension from the CHPRC QC oversight engineer via telephone (the CHPRC QC engineer was not onsite). The CHPRC QC engineer denied the request to exceed the 90 minute time limit. However, by that time, the concrete had been placed. Subsequent to completion of the November 30, 2012, concrete placement, the CHPRC QC engineer received the data sheets from the November 14, 2012, concrete placement for the footings for the K-West Annex Facility structure and found that the 90 minute limit imposed by ASTM C 94 had also been exceeded for two of the six concrete trucks, one by 2 minutes and the other by 15 minutes.

ASTM C 31, *Standard Practice for Making and Curing Concrete Test Specimens in the Field*, covers the procedures for making and curing concrete cylinders (specimens) at the jobsite. Cylinders molded at the jobsite are required to be stored in a vibration-free environment for a minimum of 24 hours under conditions that maintain the temperature of the cylinders in the range of 60 to 80 degrees Fahrenheit (to allow the concrete to harden sufficiently to prevent damage to the cylinders during transport). After 24 hours, the cylinders can be transported to the laboratory for curing at a temperature ranging from 70 to 77 degrees Fahrenheit. The ITA subcontractor failed to maintain the temperature of the concrete cylinders from the November 14, 2012, concrete placement between 60 and 80 degrees Fahrenheit when stored at the jobsite during the initial 24-hour cure period.

FE&C initiated a QA stand-down on December 5, 2012, to address both of these nonconforming conditions. The corrective action to ensure that discharge of concrete would be completed within the 90 minute time limit imposed by ASTM C 94 was to direct QISI to record on their field observation reports,

for each load of concrete delivered to the project, the concrete batch time, the batch time plus 90 minutes, the number of revolutions of the drum on the concrete truck, and the time when the discharge of the concrete from the truck was completed. Concrete remaining in the truck 90 minutes after batching was not to be used on the project and was to be discharged into a designated disposal area. The corrective action for failing to maintain the concrete cylinders between 60 and 80 degrees Fahrenheit during the initial 24-hour cure period was to provide jobsite curing boxes equipped with high and low automatic temperature controls capable of maintaining the required curing environment.

Section 1.3B of the *Construction Specification for Modified KW Annex* requires the ITA to be qualified to ASTM C 1077, *Standard Practice for Laboratory Testing of Concrete and Concrete Aggregate for Use in Construction and Criteria for Laboratory Evaluation*, and ASTM E 329, *Standard Specification for Agencies Engaged in Construction Inspection, Inspection, or Special Inspection*. The accreditation of the QISI laboratory was performed by AMRL, the American Association of State Highway and Transportation Officials (AASHTO) Material Reference Laboratory. AMRL is a voluntary program that commercial laboratory facilities participate in to demonstrate their qualifications to perform specified tests in accordance with established standards. AMRL was established at the National Institute of Standards and Technology (formerly the National Bureau of Standards) in 1988 to evaluate the qualifications of testing laboratories to perform construction materials testing.

On October 28, 2013, CHPRC performed a follow-up review of QISI's laboratory accreditation to verify that the laboratory had maintained accreditation to ASTM Specifications E 329 and C 1077 as required by the construction specification. The review disclosed that AMRL had suspended QISI's accreditation on May 9, 2013, for failure to provide a timely written response to AMRL regarding two minor deficiencies identified during AMRL's assessment of the QISI laboratory on November 20, 2012. The deficiencies were not serious enough to revoke QISI's accreditation, but one concerned maintaining the temperature of the concrete test cylinder curing tank in the QISI laboratory within the temperature range of 70 to 77 degrees Fahrenheit specified in ASTM C 31. This deficiency could have affected concrete cylinders from the K-West Annex project. An AMRL re-assessment of the QISI laboratory was performed on September 30, 2013, and accreditation was restored on October 30, 2013.

Independent Oversight determined that for the nonconforming conditions discussed above, CHPRC developed appropriate corrective actions. The NCR process and implementation appear adequate to address and resolve construction quality deficiencies.

Effect of NCRs on Concrete Quality

Independent Oversight concluded, after review of the concrete placement records, that the errors discussed above did not have a detrimental effect on the quality of the concrete. The 90 minute time limit imposed by ASTM C 94 can be waived by the purchaser if the concrete can be placed without further addition of water. The workability of the concrete can generally be maintained beyond 90 minutes in cooler temperatures. The ambient temperature during the concrete placements on November 14 and November 30, 2012, was approximately 45 degrees Fahrenheit. Since the concrete remaining in the ready mix trucks after 90 minutes was workable enough to be placed in the thrust block and footings without further addition of water, the quality of this concrete is acceptable. The significance of this NCR is that the inspection personnel at the job site failed to comply with the project specifications and permitted placement of concrete after the 90 minute time limit was exceeded without a waiver from CHPRC.

Improper curing of concrete cylinders during the first 24 hours affects the results of the unconfined compression tests performed on the cylinders. The cylinders can be damaged if they are exposed to freezing temperatures, but the ambient temperature at the Hanford Site on November 14 and 15, 2012, was between 36 and 42 degrees Fahrenheit. However, the cylinders were most likely exposed to

temperatures lower than specified in ASTM C 31. Studies conducted by ACI, the Portland Cement Association, and various universities have shown that low temperatures during the initial curing period can result in concrete compressive strength test results approximately 500 psi lower at 28 days than those cured at between 60 and 80 degrees Fahrenheit as specified in ASTM C 31. Although the average of the compression tests performed on the concrete cylinders at the age of 28 days from the November 14, 2012, concrete placement was well above the design strength (results ranged from 5260 to 6020 psi), the ITA's failure to comply with the specification requirements for temperature control during the initial 24-hour curing period indicates that QC personnel may not pay sufficient attention to details.

The ITA laboratory's accreditation was suspended by AMRL for failure to respond to two minor findings, one of which concerned failure to maintain the specified temperature range in the concrete test cylinder curing tank. Failure to control the curing temperature could have resulted in low compression test results for the test cylinders from the November 14 and 30, 2012, and February 14, 2013, concrete placements. However, the 28 day compressive strength test results for the samples from these three concrete placements were well above the specified 4000 psi design strength, ranging from 5260 to 6065 psi. Thus, this deficiency at the ITA laboratory appears not to have affected the concrete on this project, and the deficiency has been corrected.

Review of Concrete Quality Records

Independent Oversight reviewed the results of QC tests performed on concrete samples from the eight quality-related (Q) concrete placements at the K-West Annex Facility completed between November 14, 2012, and November 12, 2013:

- Pour numbers FTG 01 and FTG 02, a concrete placement of approximately 55 cy for the footings for the K-West Annex facility on November 14, 2012.
- Concrete placement of approximately 5 cy for the fire supply line thrust block on November 30, 2012.
- Pour number 3216-03, a concrete placement of approximately 40 cy for the truck bay slab on February 14, 2013.
- Concrete placement of approximately 4 cy for a footing for the fire supply line on February 14, 2013.
- Pour number W-102, a concrete placement of approximately 85 cy for the south and east walls of the truck bay on October 7, 2013.
- Pour number W-103, a concrete placement of approximately 95 cy for the north and west walls of the truck bay on October 17, 2013.
- Pour number S103, a concrete placement of approximately 10 cy for the sand filter foundation on November 12, 2013.
- Pour number W-101, a concrete placement of approximately 10 cy for a grade beam on November 12, 2013.

Records examined included the concrete pour checklists, the concrete truck delivery tickets, the concrete field observation reports (which list the results of QC tests performed on the concrete delivered to the jobsite), and the concrete compressive strength test reports. An explanation of the data documented in each type of record and details of Independent Oversight's review are discussed below:

- The concrete pour checklists document completion and inspection of work required to prepare for the concrete placement, including formwork and installation of reinforcing steel, embed plates, and mechanical and electrical hardware. The required concrete mix and QC inspection requirements are also listed. Independent Oversight observed that the checklists for these placements were completed and properly signed.

- The concrete truck delivery ticket is a computer generated record that lists the truck number; the concrete mix number; the weight of coarse aggregate, sand, and cement, and volume of water and admixtures in the concrete batch; the water-cement ratio; the volume of the concrete (in cy) in the batch; and the time batched. Independent Oversight verified that the quantity (weight) of water in the mix indicated on the tickets for these placements did not exceed the maximum weight of water specified in the concrete mix, the water cement ratio was below 0.46, and the ingredients in the batch were properly proportioned in accordance with the concrete mix design. The QISI inspector signed each ticket, indicating that he had reviewed the data to verify the proper mix; recorded the time the truck arrived at the jobsite; and recorded the number of revolutions of the drum on the concrete truck when the truck arrived on site.

- Concrete field observation reports show the weather and temperature; list the acceptance criteria and results of quality tests performed on concrete samples for entrained air content, slump, and concrete temperature on the freshly mixed concrete; record data from the concrete truck tickets; document the results of unit weight testing on the freshly mixed concrete; the number of cylinders molded for unconfined compression testing; and, for all concrete placements completed since November 30, 2012, record the concrete batch time, the batch time plus 90 minutes, the time when the discharge of the concrete from the truck was completed, the number of revolutions of the drum on the concrete truck when the truck arrived on the jobsite, and when the discharge of concrete was complete. The maximum number of revolutions recorded for any truck was 275, less than the 300 specified in ASTM C 94. Independent Oversight reviewed the results of the slump, entrained air, temperature, and unit weight tests performed on the freshly mixed concrete and found that all tests met the specification requirements, except for two trucks that had entrained air contents outside the specification limits of 4.5 to 7.5 percent. The first truck (for the November 14, 2012, placement) was rejected because the entrained air content was high, at 9.5 percent. When a composite sample from the truck for the 4 cy footing placement on February 14, 2013, was tested, the entrained air was found to be slightly low, at 4.2 percent, although an initial test had showed 5.1 percent. FE&C initiated NCR number FE&C-NCR-2013-002 to document and disposition the slightly low entrained content. The NCR was closed by concluding that the concrete was acceptable to use as is. Independent Oversight concurs with that conclusion.

- The concrete compressive strength test reports for laboratory cured samples from the eight placements documented unconfined compression test results at 28 days ranging from 5260 to 6020 psi for the two 2012 concrete placements and from 5395 to 6065 psi for the six concrete placements completed in 2013.

The unconfined compression strength of the concrete at 28 days has generally exceeded the specified design strength by more than 1000 psi. The records indicate that the quality of concrete placed at the K-West Annex Facility through November 12, 2013, generally complied with specification requirements. The exception was one truck that had low entrained air content but was ultimately judged acceptable, as discussed above.

6.0 CONCLUSIONS

Independent Oversight determined that the records for the concrete placed through November 12, 2013, show that concrete quality at the K-West Annex Facility meets the specification requirements and is adequate. FE&C and CHPRC developed appropriate corrective actions to disposition and correct the nonconforming conditions that occurred during the first two concrete placements. Sampling and testing of concrete met or exceeded specification requirements. The water-cement ratio for all concrete placed

was less than 0.46 and the minimum concrete compressive strength at 28 days was 5260 psi, exceeding the required 4000 psi design strength.

7.0 ITEMS FOR FOLLOW-UP

Independent Oversight will continue to follow up on construction work at the K-West Annex Facility by conducting additional reviews of concrete construction activities and structural steel erection, as well as corrective actions to address discrepancies identified during construction.

Appendix A
Supplemental Information

Review Dates

Onsite Review: September 9 and November 12, 2013
Offsite Review of Records: December 19-24, 2013

Office of Health, Safety and Security Management

Glenn S. Podonsky, Chief Health, Safety and Security Officer
William A. Eckroade, Principal Deputy Chief for Mission Support Operations
John S. Boulden III, Director, Office of Enforcement and Oversight
Thomas R. Staker, Deputy Director for Oversight
William E. Miller, Deputy Director, Office of Safety and Emergency Management Evaluations

Quality Review Board

William A. Eckroade
John S. Boulden III
Thomas R. Staker
William E. Miller
Michael A. Kilpatrick

Independent Oversight Site Lead for Hanford Site

Jacob Wechselberger

Independent Oversight Team Composition

Joseph Lenahan

Appendix B
Documents Reviewed

- CH2M Hill Construction Specification for Modified KW Annex, Document number 44577 CSI – SPEC-001-033000, Rev. 4, Cast –In-Place Concrete
- Baker Construction Instruction OWI-10235-05.01-10, Rev. 1, Concrete Placement
- Concrete Engineering Consultants, Inc. Report titled "Concrete Mixture Evaluation for 100 STP KW Annex Modification Project" dated September 27, 2013
- CHPRC Condition Report CR-2013-2651
- FE&C NCR-2013-002