STATUS OF DOE PROJECT: SAVANNAH RIVER SITE SALT WASTE PROCESSING FACILITY (SWPF)

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ABSTRACT

This paper describes the processing technologies and the facility design for the Salt Waste Processing Facility (SWPF) at the Savannah River Site (SRS). The SWPF will separate the high activity constituents (principally cesium, strontium, and plutonium) from the salt solutions in the High Level Waste (HLW) tanks at SRS. The concentrated high activity waste streams from SWPF will be sent to the Defense Waste Processing Facility (DWPF) for vitrification and the bulk decontaminated salt solution produced by SWPF will be sent to the Saltstone Production Facility (SPF) to be disposed of in grout vaults. The SWPF uses monosodium titanate (MST) to adsorb the strontium and plutonium present in the HLW. A Caustic-Side Solvent Extraction (CSSX) process with centrifugal contactors is used to remove cesium from the HLW. The SWPF design is based on "inherently safe" design principles and stringent as low as reasonably achievable (ALARA) requirements for radiation exposure. The SWPF Preliminary Design is nearing completion (baseline target completion date is May 31, 2005) and radioactive operations are scheduled to begin in July 2009.

INTRODUCTION

Thirty-six (36) million gallons (Mgal) of HLW with 426 million curies of activity are currently stored in 49 tanks in the F- and H-Area Tank Farms at SRS. The "Federal Facility Agreement for the Savannah River Site" [1] requires that tanks without full secondary containment be emptied and closed by 2022. The "Site Treatment Plan" [2] further requires that all HLW be processed by 2028. The Department of Energy (DOE) has established a more aggressive goal to complete HLW processing by 2019 ("Savannah River Site Environmental Management Program Performance Management Plan" [3]).

Previous material production operations at SRS have generated liquid HLW which is now being stored in the Tank Farms. The waste in the HLW tanks is comprised of three forms:

Precipitated sludge – 3 Mgal of settled solids with high concentrations of Sr-90 and actinides;

Saltcake – 16 Mgal of moist salt with moderate concentrations of Cs-137, Sr-90, and actinides; and

Supernate and interstitial liquid – 17 Mgal of salt solution with high concentrations of Cs-137 and low to high concentrations of Sr-90 and actinides.

The sludge is currently being removed and sent to the DWPF for vitrification. The bulk of the dissolved saltcake, supernate, and interstitial liquids will be processed by the SWPF. Prior to SWPF startup, some small quantities of low-curie salt waste will be processed by an Actinide Removal Process (ARP) and Modular CSSX Unit (MCU) or will be sent directly to the Saltstone Disposal Facility. The SWPF and ARP/MCU processes will remove and concentrate the Sr-90, actinides, and Cs-137 from the salt waste feed and send the high-activity concentrates to DWPF and the bulk decontaminated salt solution (DSS) to the SPF. The overall waste stream flow path for HLW disposition at the SRS is shown in Figure 1.

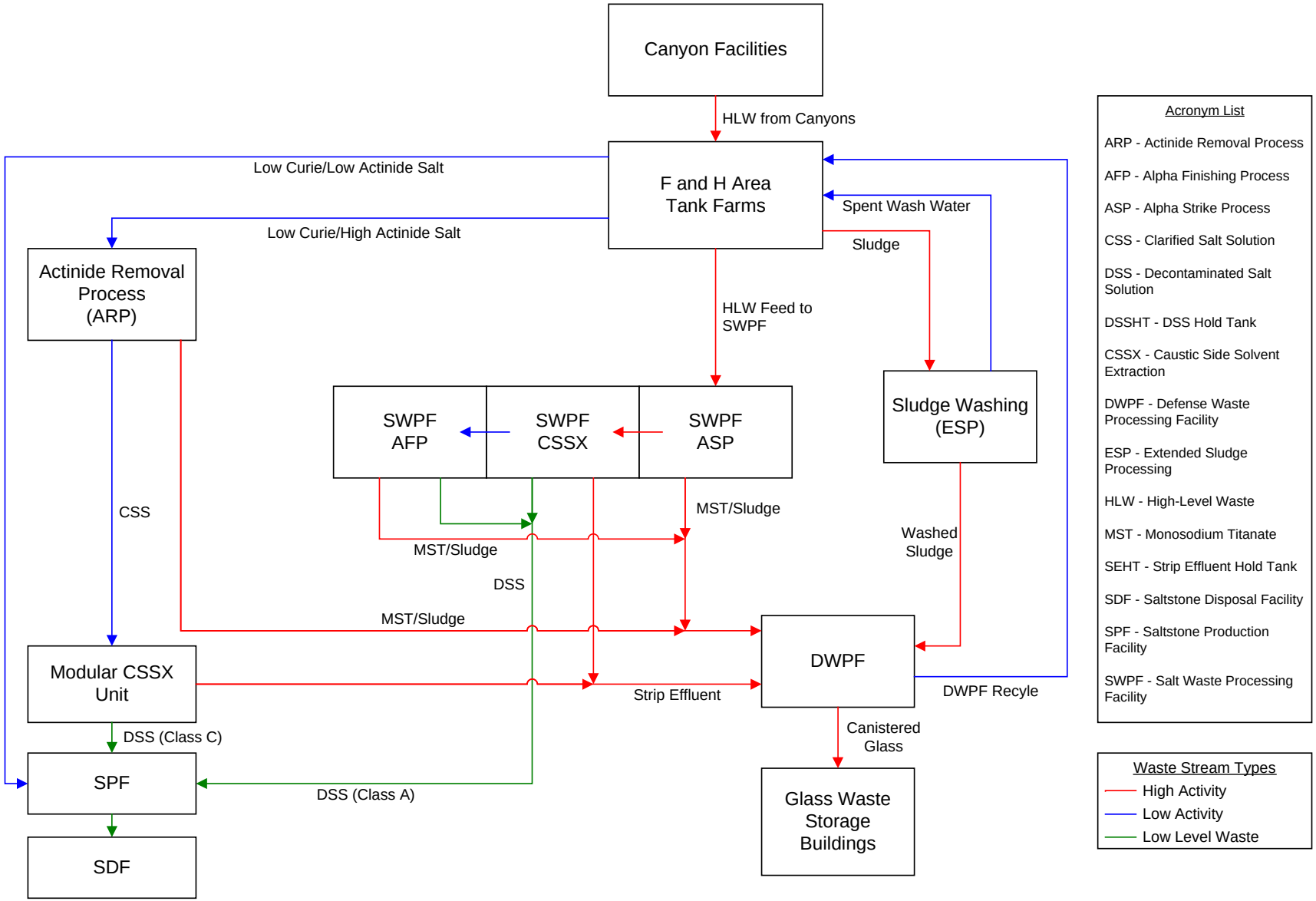

Fig. 1. SRS HLW Disposition Waste Stream Flowpath.

SWPF CONTRACTING STRATEGY

Parsons was one of two Engineering, Procurement, and Construction (EPC) contractors selected in September 2002 to prepare a Conceptual Design for the SWPF. The Conceptual Design Packages were submitted to DOE by both EPC contractors in November 2003. In January 2004, DOE down-selected Parsons to complete the SWPF project. Parsons' scope of work includes Preliminary and Final Design, Construction, Commissioning, and one year of Radioactive Operations. The Parsons' contract is based on a Cost Plus Incentive Fee model with specific safety, management, and technical performance objectives. The "Baseline Range" for the project will be submitted for Critical Decision-2 (CD-2) in early 2005.

PROCESS DESCRIPTION

The SWPF and ARP utilize a similar process for Sr-90 and actinide removal. This process uses MST to adsorb the Sr/actinides, and a 0.1 micron cross-flow filter to concentrate the MST and suspended solids in the waste. The filtrate (i.e., clarified salt solution), depleted in Sr/actinides, is then sent to a CSSX process which uses an engineered solvent to extract the Cs from the bulk waste and a low flow dilute nitrate acid stream to strip the cesium from the solvent. The bulk DSS is then sent to the Saltstone Disposal Facility to be disposed of as cementitious grout. The concentrated MST/sludge and strip effluent are sent to the DWPF for vitrification.

The MST adsorption/filtration process for Sr/actinide removal operates in a batch-wise sequence. In the first step, the waste feed is added to an Alpha Sorption Tank (AST). Caustic and wash water (from the MST/sludge washing step) are then added to adjust the [sodium] from 6.4M to 5.6M. Multiple strikes of MST is also added at the same time. In the second step, the MST is added and mixed with the waste in the AST during which time the Sr/actinides are adsorbed onto the MST particles. In the third step, the MST and suspended solids present in the waste feed are concentrated into a 5 weight percent sludge by circulating the waste and MST through a 0.1 micron cross-flow filter which dewaters the waste and returns the slurry to the Filter Feed Tank (FFT).

The filtrate (clarified salt solution) from the sludge concentration step is staged in the Salt Solution Feed Tank (SSFT) for future processing in the CSSX system (step 4). The concentrated sludge in the FFT is transferred to the Sludge Solids Receipt Tank (SSRT) where it is washed (step 5) to reduce the $[Na^+]$ for vitrification. The washed MST/sludge is then transferred to the DWPF (step 6). The process flow for the Sr/actinide removal process is shown in Figure 2.

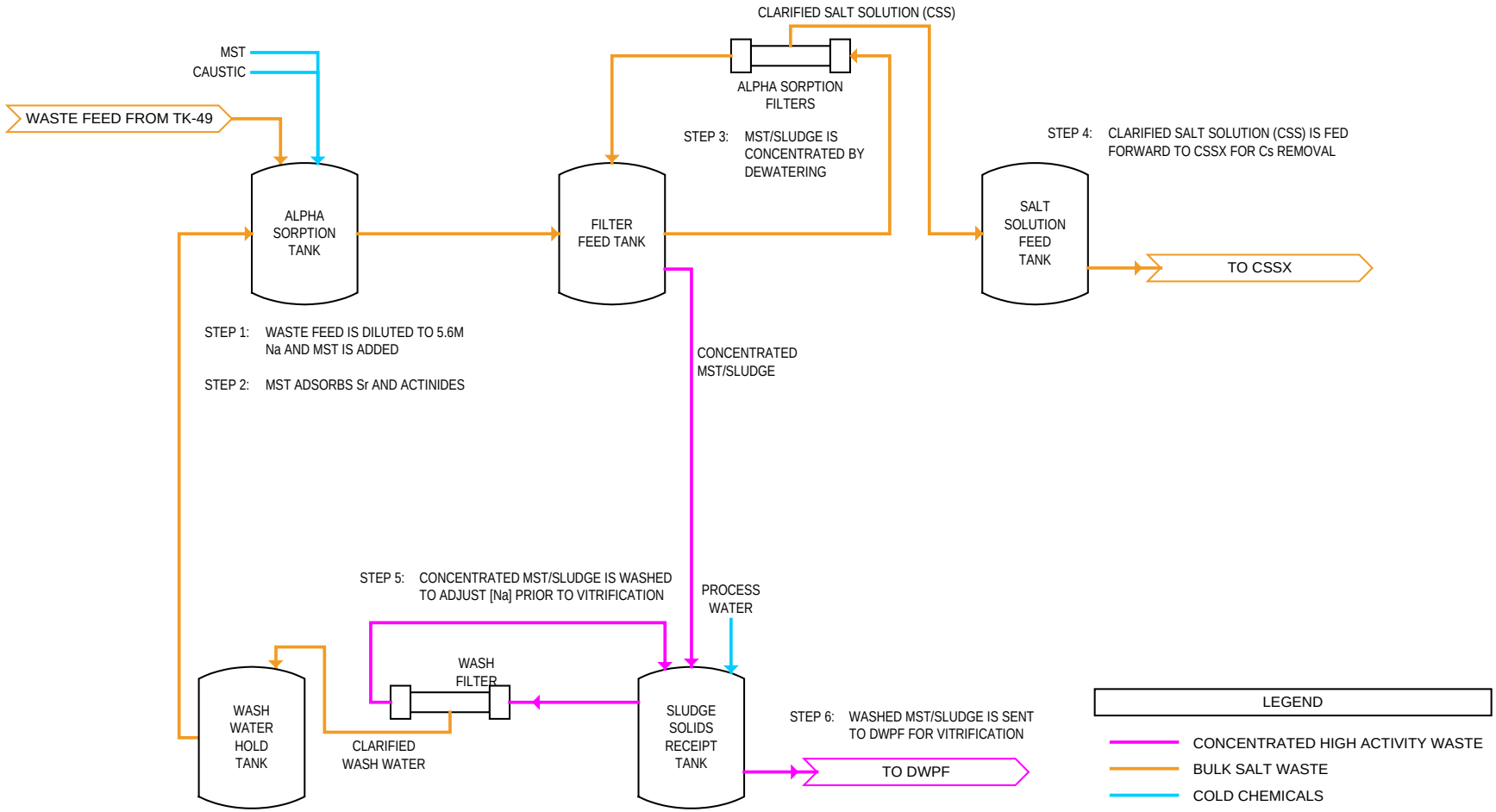

Fig. 2. Alpha Strike Process Flow.

The CSSX process uses an engineered solvent (0.007M Calix[4]arene–bis (tert-octylbenzo-crown-60, 0.75M 1-(2,2,3,3-tetraflouropropoxy)-3 (4-sec-butylphenoxy)-2-propanol, 0.003M tri-n-octylamine, and Isopar®L) which extracts Cs from caustic waste solutions. The CSSX process is shown in Figure 3. The solvent is mixed with the waste feed in the bottom region of a centrifugal contactor and extracts the Cs from the waste (steps 7A and 7B). The organic and aqueous phases are then separated by the rotor action of the contactor (step 7C). Each extraction contactor (i.e., stage) provides a Decontamination Factor (DF) for Cs of approximately 2. The SWPF design employs 16 extraction stages to obtain a DF of > 64,000.

The DSS from the aqueous outlet of the extraction stages is depleted in Cs but still contains high concentrations of the Cs-137 daughter product, barium (Ba-137m). To reduce the Ba-137m activity, the DSS is sent to the Ba Decay Tank which allows time for decay (step 8). After Ba-137m decay, the DSS is stored in a DSS Hold Tank and then transferred to the Saltstone Disposal Facility for incorporation into grout and disposal (step 9). Alternatively, DSS with high residual levels of Sr and/or actinides, will be sent to an Alpha Finishing Process (AFP) for additional Sr/actinide removal. The AFP processing operations are identical to those described for the initial Sr/actinide removal process. The SWPF design baseline for Sr-90, actinide, and Cs-137 decontamination factors have been established high enough to allow the grout product to meet Nuclear Regulatory Commission concentration limits for Class A low-level waste.

After the Cs-laden solvent leaves the last extraction stage, it is "scrubbed" in 2 stages with dilute nitric acid to remove any potassium and sodium that were transferred to the solvent during extraction (step 10). The solvent is then stripped in 16 stages with a dilute low flow nitric acid stream (step 11). The Cs-depleted solvent leaving the strip stages is then washed with dilute caustic in 2 wash stages to remove organic impurities from the solvent (step 12). The solvent is then recycled back to the extraction stages. The aqueous outlet of the strip stages (i.e., strip effluent) which contains concentrated Cs is sent to the DWPF for vitrification (step 13).

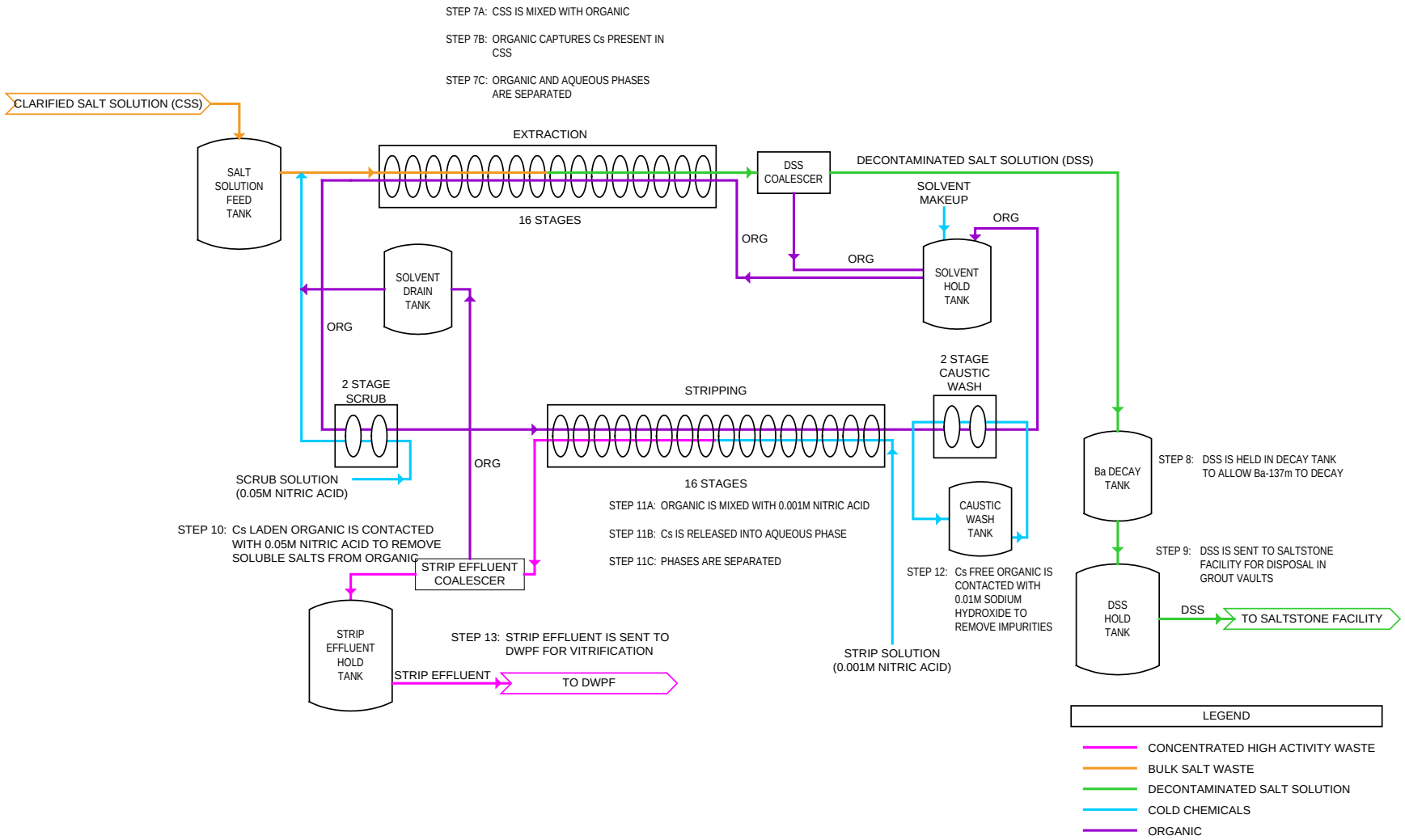

Fig. 3. CSSX Process Flow.

TECHNOLOGY DEVELOPMENT

The MST adsorption and filtration process has been extensively tested by the Savannah River National Laboratory (SRNL) and the University of South Carolina (USC) [4, 5, 6, 7]. The MST adsorption/filtration technologies are fully mature and ready for in-field deployment. The only additional design data needs relate to in-tank MST mixing system performance, filter cleaning operations, and operational control of the filtration circuit backpressure. Two additional tests are being conducted by Parsons to satisfy these design data needs. These tests include an Air Pulse Agitator (APA) test (~1/3 scale) to verify the effectiveness of the APA design in mixing and resuspending MST mixtures and a cross-flow filter circuit test (full-scale) to optimize the filtration monitoring and control scheme and the filter chemical cleaning process. Since the ARP will use the same MST adsorption/filtration process as the SWPF, additional operational data obtained after ARP startup may be available in time to support the SWPF final design.

The CSSX process has been extensively tested at SRNL, the Oak Ridge National Laboratory (ORNL), and the Argonne National Laboratory (ANL) [8, 9, 10, 11, 12, 13, 14]. This testing was performed using small scale (2–5 cm) contactors. Because of the sensitivity of contactors to variation in hydraulic flow parameters, Parsons decided to conduct two pilot tests of a CSSX system with commercial size contactors. The first of these pilot tests was completed in November 2003 and a follow-on test is planned for June 2005.

The test equipment for the first pilot test was fabricated in Parsons' Fabrication Facility in Pasco, Washington. Testing operations were conducted in the Duratek Consolidated Facility in Barnwell, South Carolina by Parsons and General Atomics personnel. The testing was observed by DOE-SR, South Carolina Department of Health and Environmental Control (SCDHEC), and the South Carolina Governor's Nuclear Advisory Council. Based on the test results, Parsons and DOE have determined that the CSSX Pilot Test had adequately addressed all remaining technical issues for the baseline CSSX process. The remaining Engineering Development and Demonstration (ED&D) work to be performed by Parsons in 2004-2005 includes a larger scale (30 gpm) CSSX pilot test to optimize control system settings for the full-scale CSSX equipment to be used in the SWPF. Since the MCU utilizes the same CSSX process, some additional CSSX operational data may be available for use in optimizing the SWPF final design after MCU startup.

SAFETY STRATEGY

The SWPF has been designed to rely principally on passive controls to limit radioactive material releases due to postulated accidents. Safety shutdown is achieved by shutting down the process pumps and CSSX contactors. No further operator action is required to maintain safe shutdown. The process tanks are passively ventilated through HEPA filters into the process cells and the cell structures provide secondary confinement. During normal operations, the process tanks are maintained at a negative pressure with respect to the cells and the cells are maintained at a negative pressure with respect to the occupied areas of the plant by active cascaded ventilation exhaust systems. To provide additional defense-in-depth, each active ventilation system, and the plant and instrument air systems, have fully redundant trains which can be powered by a backup diesel generator.

FACILITY DESIGN

The process vessels used in the initial Sr/actinide removal process, and the CSSX contactor bowl assemblies and associated tanks, are located in "dark cells" which are inaccessible after plant startup. The equipment located in the dark cells have no moving parts. The camera units, valve internals, and cross-flow filter cartridges which are located in the process vessel cells are designed to be remotely replaceable through access plugs in the cell cover blocks. The contactor motors and the rotor internals are designed for "contact-handled" removal/replacement from the CSSX Operating Area located above the CSSX Contactor Cell. All process pumps and most of the valves and instrumentation are located in shielded labyrinth enclosures in the pump and valve galleries adjacent to the cells.

The process cells, the pump and valve galleries, the ventilation exhaust equipment rooms, and the control room are all located in the Core Process Area (CPA) of the plant. The CPA is a reinforced concrete structure designed to withstand Natural Phenomena Hazard (NPH) events, including tornados and earthquakes. The other areas of the plant include the Alpha Finishing Facility (AFF), the Cold Chemicals Area (CCA), the North Facility Support Area, and the East Facility Support Area. The process tanks, filters, and pumps for the second Sr/actinide removal process (if required) are located in the AFF. The chemical makeup and supply equipment for the Sr/actinide removal and the CSSX processes is located in the CCA. The mechanical and electrical support equipment is located in the North Facility Support Area, and the plant maintenance areas are located in the East Facility Support Area.

SWPF PROJECT STATUS

The SWPF project is currently in the Preliminary Design phase. The Process Flowsheets; Piping and Instrumentation Diagrams; General Arrangements; Piping, Electrical, Instrumentation and Controls, and Heating, Ventilation, and Air Conditioning drawings have been completed and the structural design and subsystem and component specifications are in process. Final Design is scheduled to be completed by March 2006 and the Radioactive Operations milestone is July 2009 (see Figure 4). The EPC contract includes fee incentives for cost and schedule performance. The total project cost is estimated at $440M.

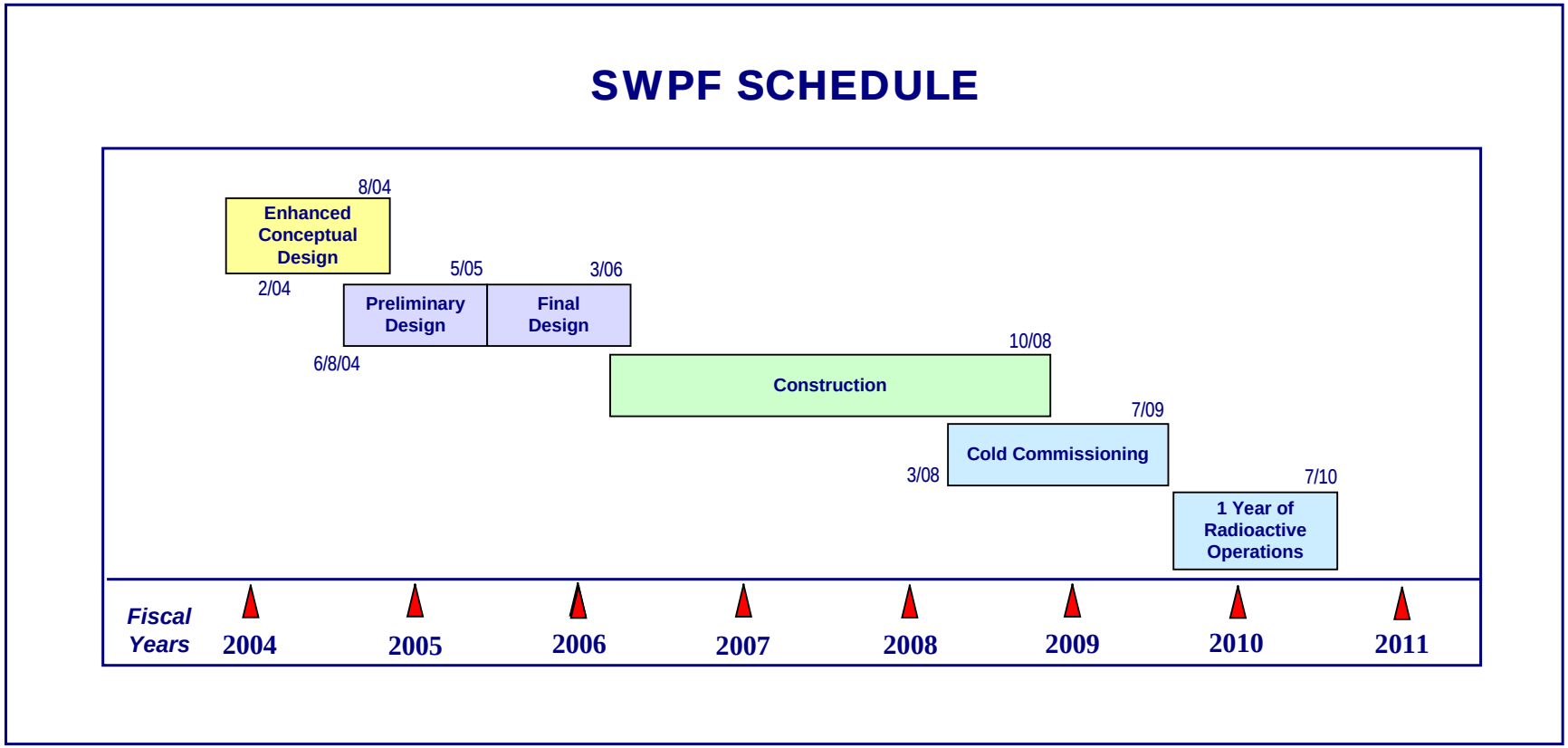

Fig. 4. SWPF Project Schedule.

CONCLUSIONS

The SWPF is the last remaining facility needed to complete treatment of the HLW at the SRS. The SWPF will process over 90% of the HLW currently in storage in underground tanks. The facility will include Sr/actinide and Cs removal and concentration processes which are needed to provide low volume high activity feed to the DWPF for vitrification and a high volume low-level waste feed to the SPF for disposal in grout.

The Sr/actinide removal process uses MST to adsorb soluble Sr/actinides present in the waste feed. Cs is removed from the waste by the CSSX process. The MST adsorption and the CSSX processes have been extensively tested by DOE and Parsons funded test programs. Final process optimization tests for MST mixing/resuspension and CSSX solvent recovery will be completed by Parsons in early 2005.

The SPWF was designed to meet specific safety, management, and technical objectives. These objectives included: (1) reliance principally on passive safety features; (2) robust defense-in-depth confinement controls; (3) maintain worker radiation doses ALARA; (4) simplify erection of structures and equipment installation; (5) modularize equipment to facilitate installation and testing; (6) maximize plant throughput and radionuclide separation; and (7) eliminate secondary liquid waste. The SWPF design baseline includes many innovative design features that meet these objectives.

The SWPF project is currently in the Preliminary Design phase. In order to complete HLW processing by 2019, the SWPF must begin "hot" radioactive waste processing by 2009. The project is nearing completion of Preliminary Design and is on track to begin Long-Lead Procurement and Site Development in late 2005. The long-term goal is to complete construction and commissioning and begin with processing operations in 2009. Both Parsons and DOE-SR intend to meet this aggressive schedule.

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