Design, Fabrication and Start-up of Test Facilities for the LAWPS Full-Scale IX Column Test and Engineering Scale Test – 17418

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ABSTRACT

The U.S. Department of Energy (DOE), Office of River Protection's (ORP) primary mission is to retrieve and treat Hanford's tank waste and close the Tank Farms to protect the Columbia River. Mixed radioactive waste is stored in 177 underground tanks at the Hanford Site as reported in DOE/ORP 2003-02, Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of the Single Shell Tanks at the Hanford Site, Richland WA, Inventory and Source Term Data Package. The 177 underground tanks are estimated to contain about 56 million gallons of waste.

The Low Activity Waste Pretreatment System (LAWPS) Project provides for the early production of immobilized low activity waste (ILAW) by feeding LAW directly from Tank Farms to the Hanford Waste Treatment Plant's (WTP's) LAW Facility, bypassing the Pretreatment Facility. Prior to the transfer of feed to the WTP LAW Vitrification Facility, tank supernatant waste will be pretreated in the LAWPS to meet the WTP LAW waste acceptance criteria. The LAWPS will also facilitate the return of secondary liquid wastes from the WTP LAW Vitrification Facility to the Tank Farms.

In November of 2015 DOE's Tank Operations Contractor, Washington River Protection Solutions (WRPS), awarded a contract to the AECOM Team to design, fabricate and operate two test platforms to generate performance data at two different scales and demonstrate technology maturation. The first platform models the ion exchange (IX) columns at full scale, and the second platform models the integrated flowsheet (cross flow filter (CFF) and IX) at $1/9^{th}$ scale.

Both test platforms underwent shakedown and start-up testing in August 2016 and moved into actual testing and NQA-1 data generation shortly thereafter. This paper covers the engineering design, procurement, construction, installation, and acceptance testing of the test platforms (which are now operational) under an aggressive fast track schedule, and initial test data as available.

INTRODUCTION

Background

The U.S. Department of Energy (DOE), Office of River Protection's (ORP) primary mission is to retrieve and treat Hanford's tank waste and close the Tank Farms to protect the Columbia River. Mixed radioactive waste is stored in 177 underground tanks at the Hanford Site as reported in DOE/ORP 2003-02, *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of the Single Shell Tanks at the Hanford Site, Richland WA*, Inventory and Source Term Data Package. The 177 underground tanks are estimated to contain about 56 million gallons of waste.

The DOE ORP is responsible for the management and completion of the River Protection Project (RPP) mission, which comprises both the Hanford Site Tank Farms and the Waste Treatment and Immobilization Project (WTP). A key aspect of the RPP mission is to construct and operate the WTP (ORP-11242, *River Protection Project System Plan*). The WTP is a multi-facility plant that will separate and immobilize the tank high-level waste (HLW) and Low Activity Waste (LAW) fractions for final disposition.

The LAWPS Project provides for the early production of immobilized low activity waste (ILAW) by feeding LAW directly from Tank Farms to WTP's LAW Facility, bypassing the WTP Pretreatment Facility. Prior to the transfer of feed to the WTP LAW Vitrification Facility, tank supernatant waste will be pretreated in the LAWPS to meet the WTP LAW waste acceptance criteria. The LAWPS will also facilitate the return of secondary liquid wastes from the WTP LAW Vitrification Facility to the Tank Farms (see Figure 1 for process flowsheet schematic).

The overarching technical objective of performing the full-scale ion exchange test and the engineering-scale integrated test is to meet the technology maturation requirement for first of a kind DOE facilities. This is achieved via the following underlying objectives:

1. Test interactions between unit process operations;
2. Test removal of non-radioactive cesium from process stream;
3. Test removal of undissolved solids from process stream;
4. Confirm operational flow rate range and stability;
5. Confirm volumetric throughput of waste stream over flow operating range;
6. Confirm range of process temperatures over planned operating range;
7. Establish system hydraulics and process criteria;
8. Coordinate key control and monitoring components;
9. Establish treated product chemistry meets requirements (cesium, solids, and pH); and
10. Test the hazard control strategy for a no flow condition through the IX column.

Data collected during testing will be used by WRPS to validate the preliminary design, inform the final design of the permanent plant equipment, and demonstrate that the critical technology elements have advanced to a technology readiness level of 6 (prototypical system validation in a relevant environment).

The resin management and dewatering equipment functions for resin disposal will also be tested as part of this testing. Functions associated with fresh resin addition will be tested to verify the ability of the column to accept and properly deposit fresh resin within the IX column. The fresh resin addition system has not been identified as a critical technology element, therefore; prototypic representation of the resin addition equipment is not included in the testing scope.

LAWPS System Definition

The primary mission of the LAWPS is to provide treated tank farm supernatant LAW feed directly to the WTP LAW Facility in a safe, economic, and environmentally protective manner. The LAWPS will receive tank supernatant waste from the Double Shell Tank (DST) System. The LAWPS will treat the tank supernatant waste by separating entrained solids through a filtration system, and by removing radioactive cesium using an ion exchange system. The solids and cesium removed will be returned to the DST System. Treated waste will be stored in lag waste storage tanks and sampled to confirm the treatment process efficiency. Treated waste compliant with WTP waste acceptance criteria will be transferred to the WTP LAW Facility. A line diagram of the LAWPS, consistent with the functional components is provided in Figure 1, Low Activity Waste Pretreatment System Diagram. Components in yellow are those covered by the two test platforms.

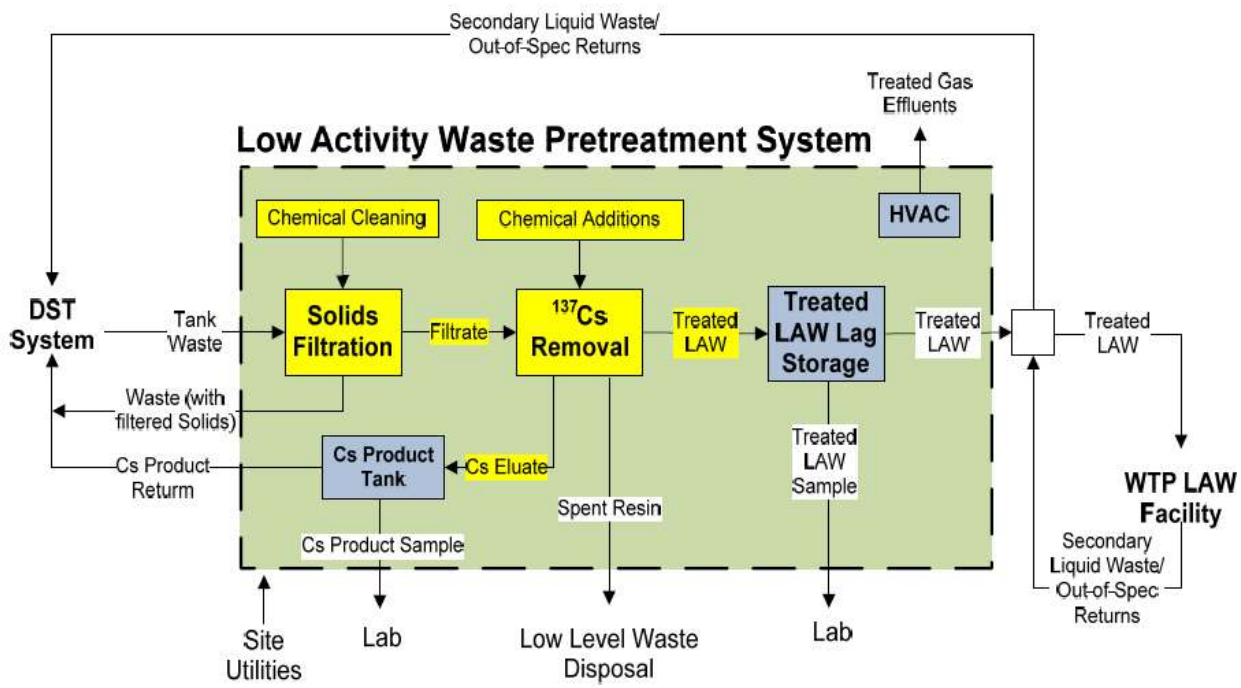

Fig. 1. Low Activity Waste Pretreatment System Diagram.

DESCRIPTION

Integrated Engineering Scale Test Platform

The LAWPS process equipment provides two functions and the engineering-scale integrated test demonstrates these operations, 1) remove solids from the waste simulant stream and 2) remove cesium (Cs) from the waste simulant stream. The

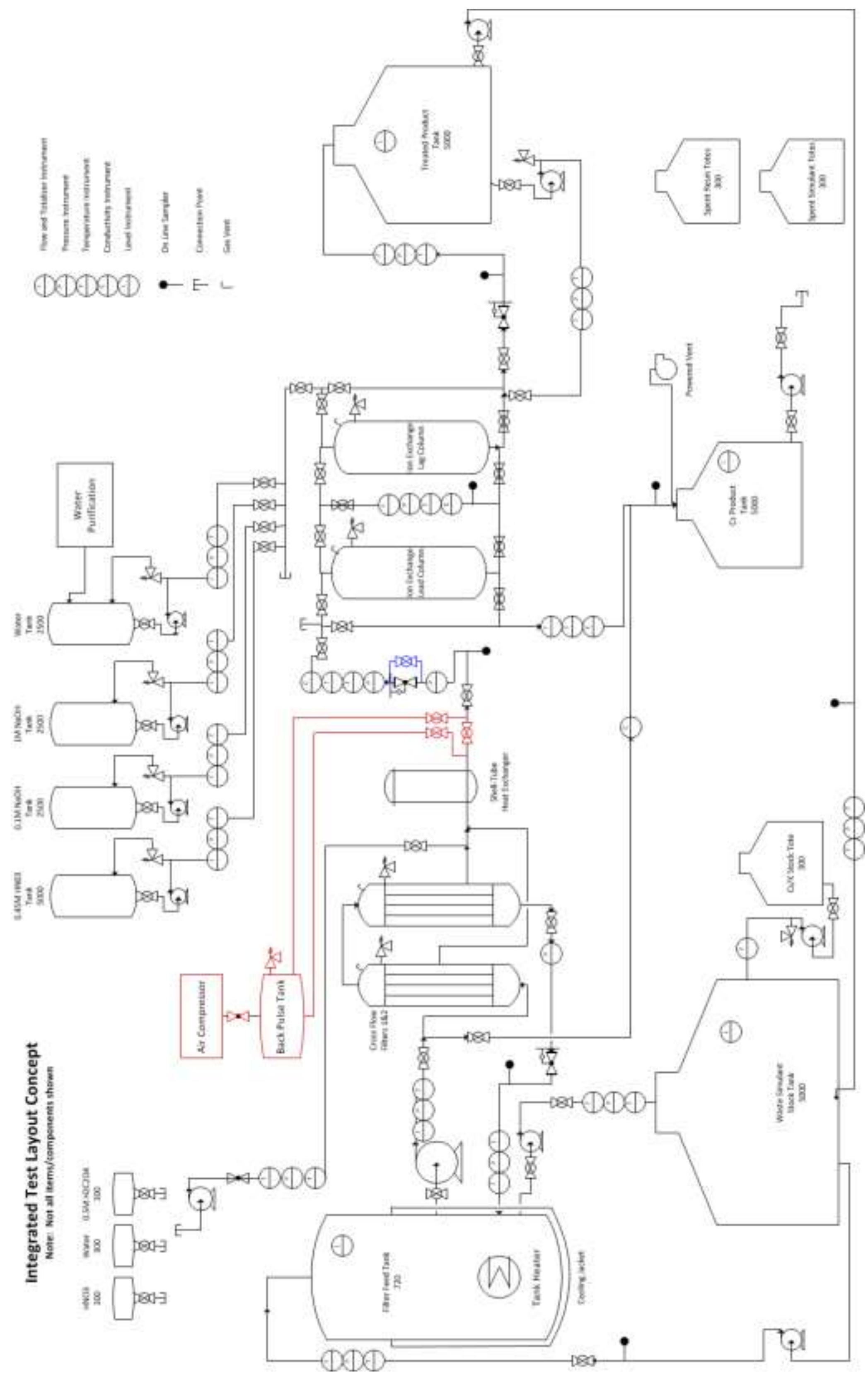

Fig. 2. Engineeering Scale Test Platform Schematic Process Flowsheet

first step is accomplished by passing waste through a Cross Flow Filter (CFF) to remove the solids. The second step in accomplished by passing the waste simulant through an Ion Exchange (IX) system.

The integrated test platform reflects the LAWPS planned design configuration at a $1/9^{th}$ process scale. A conceptual schematic of the test layout is shown in Figure 2. The key features of the test platform are described below.

The CFF System/Loop is configured to recirculate waste simulant from the filter feed tank (FFT) using a variable speed pump through a heat exchanger, CFFs, and return to the FFT at 22.7 m^3/hr (100 gpm). The loop includes temperature, pressure and flow instrumentation on the supply and return line, and has flow and pressure regulation to linear crossflow velocity at ~4.5 m/s (~15 ft/s) and tubeside pressure. The system is controlled via flow control valves on the two filtrate lines. Typical filtrate flow in this system is 0.76 – 3.8 l/min (0.2 – 1 gpm) per filter module. The CFF themselves are Mott 8-inch HyPulse™ LSX Dual-Pass filters with 12 filter tubes in each pass, which are 3.05 m (120 inch) long, 0.0127 m (½ inch) ID, a media grade of 0.1 µm, and a material type of 316L. There is also a back pulse system for filter cleaning activities. The CFF skid is shown in Figure 3.

The IX system contains two 0.36 m (14 inch) inner diameter full height IX columns each capable of containing approximately 34 gallons (129 liters) of spherical resorcinol-formaldehyde (sRF) resin in sodium form. The columns are fabricated from steel with multiple sight glasses for viewing the resin bed surface. The system includes conductivity, temperature, pressure, and flow instrumentation on the supply and exit of each column. There is valving that allows for multidirectional operation of the IX columns and isolation. Downstream of the columns is a pressure control valve which maintains a 207 kPa (30 psig) backpressure on the columns. The process flowsheet follows that of LAWPS in that the CFF recirculation pump provides all the pressure head to drive the filtrate through the IX columns and past the pressure control valve. The IX column skid is shown in Figure 4.


Fig. 3. CFF Skid


Fig.4. IX Column Skid

The engineering scale test platform is controlled via a FactoryTalk® programmable logic controller (PLC) and human machine interface (HMI) system from Rockwell Automation, which also provides a data logging function. This system is capable of operating the process system automatically, interfacing with all of the instrumentation to collect data and make adjustments to the operation based on the instrument inputs, and capable of controlling the pumps, valves (where automated), and heat exchanger system automatically. Figures 5 and 6 show typical HMI screens for the CFF and IX systems.

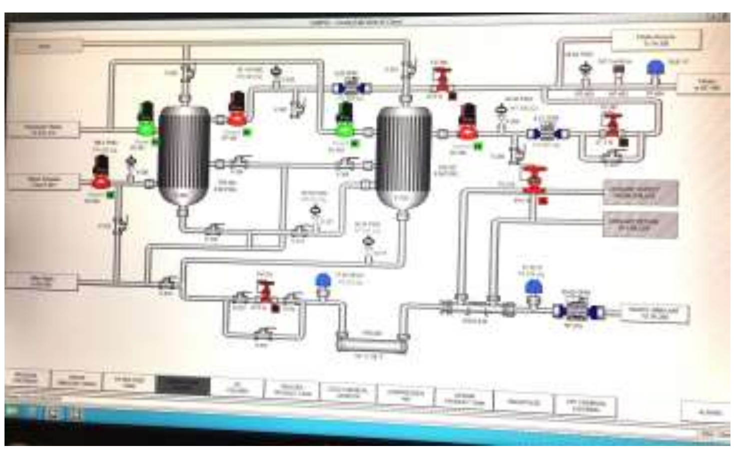
Fig.5. HMI screen for CFF System

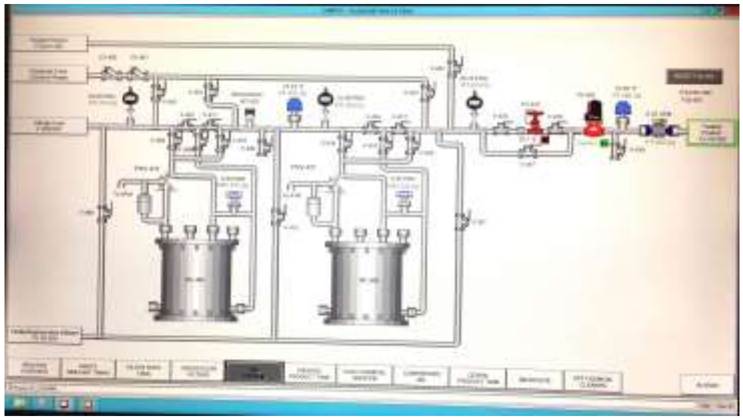

Fig.6. HMI Screen for IX System

The engineering scale integrated test facility was built over a period of four months and contains some 10,000 ft of wiring, 900 ft of stainless steel piping and 110 ft of stainless steel tubing. A panoramic shot of the facility is shown in Figure 7. The facility was commissioned against a very aggressive schedule, with no major issues identified, and moved into full NQA-1 testing in September 2016.

Fig.7. Engineering Scale Test Facility

Full Scale Ion Exchange Test Platform

The second LAWPS test platform, which was designed and constructed concurrently with the engineering scale platform, contains a full scale IX column. Test objectives include integration of an IX fluid recirculation and vent system as the planned hazards mitigation approach for a flammable gas deflagration or detonation, and over-temperature event as a result of a no flow condition in the IX column. Figure 8 provides a diagram showing the layout concept for the full-scale IX column test.

The test design incorporates a single full-scale column, which represents either a lead column or the identical sized lag column. The IX column is based off of the same design as that to be deployed in the Hanford Waste Treatment Plant, see Figure 9 for nominal features and dimensions. A translucent (acrylic) prototype column was constructed (Figure 10) to enable real-time observations of resin bed stability, internal flow characteristics, and mixing dynamics. The column heads are fabricated from fiberglass with stainless steel flanges and the column operates at an outlet pressure of 207 kPa (30 psig).

The IX column used in the LAWPS design has a sRF resin bed diameter of approximately 1.07 m (3.5 ft), a bed length of 1.28 m (4.2 ft), and a volume of approximately 1.16 m^3 (308 gals) in sodium form. The vessel has a straight side length of approximately 2.1 m (7 ft) and a vessel volume of approximately 2.24 m (593 gals). The total column height accounts for the resin expansion, the liquid distributor/collector, and allowance for head/tail space. The resin is contained within the column by a bottom Johnson screen (see Figure 11) and Johnson screen-wrapped distributor legs (see Figure 12). A support ring is provided along the top head to install an optional top Johnson screen if testing shows that to be necessary.

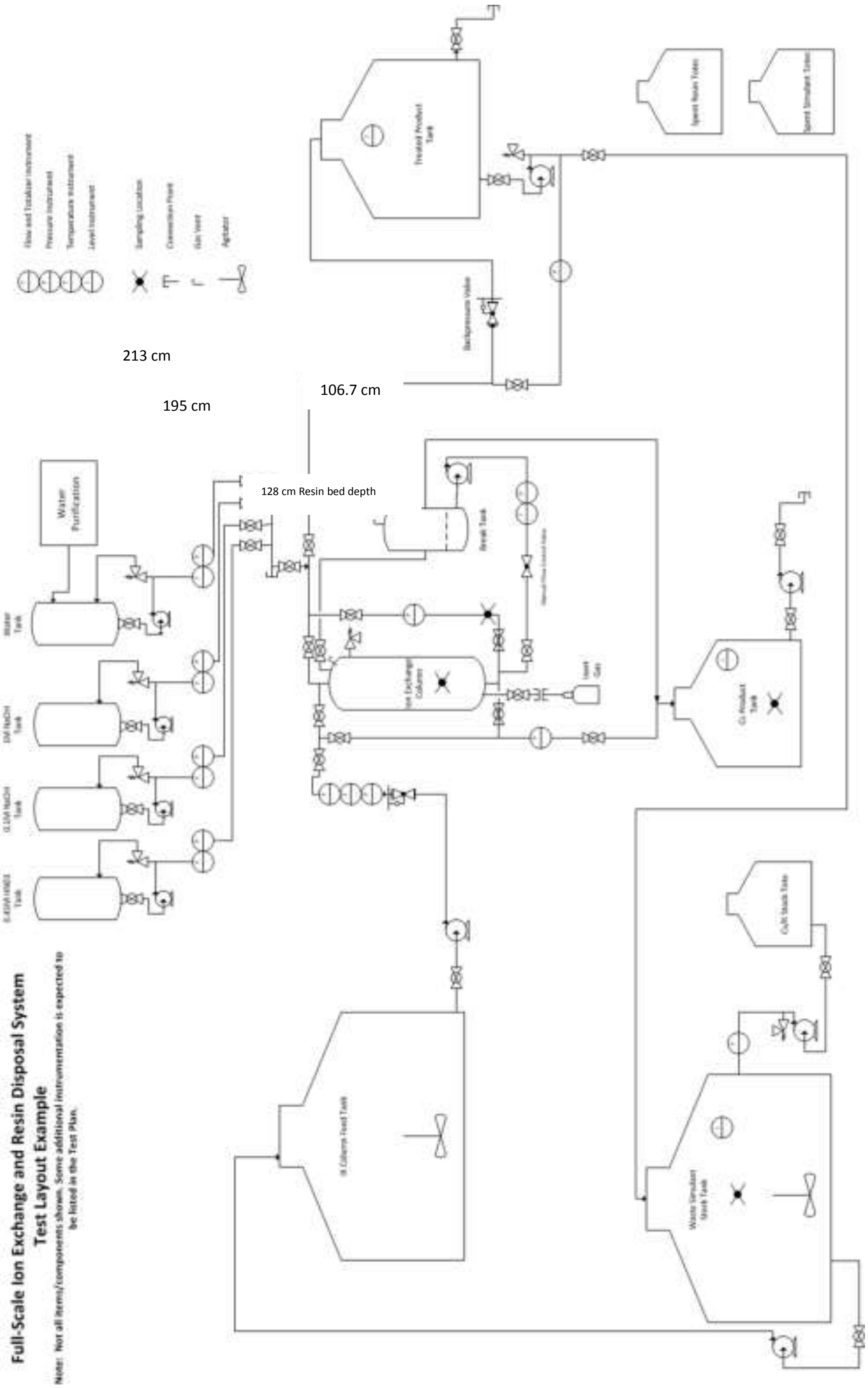

Fig.8. Full-Scale Ion Exchange Column Test Schematic Process Flowsheet

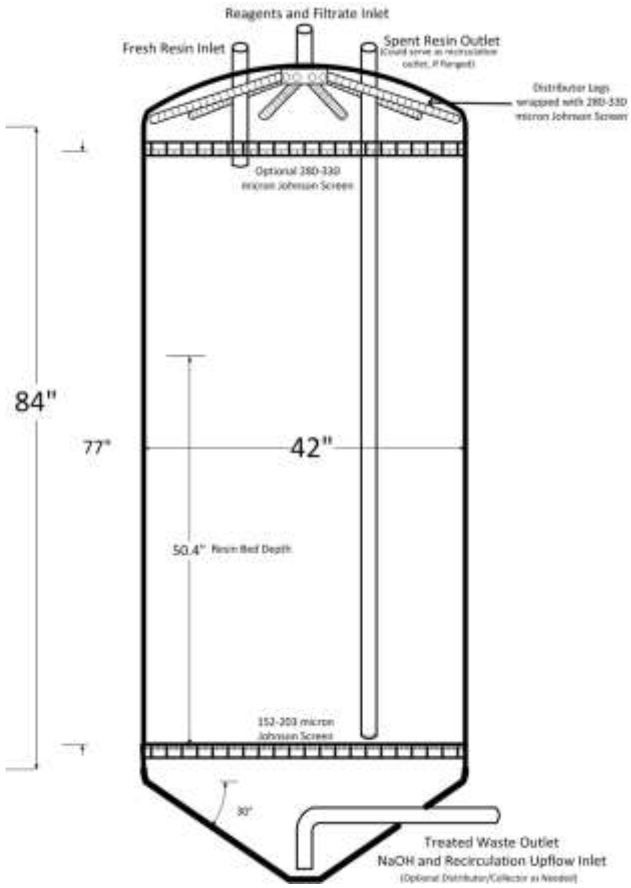

Fig.9. Full-Scale Ion Exchange Test Column

Fig.10. Acrylic IX Column

The column was constructed with the ability to accommodate an alternate bottom screen design should gas buildup beneath the screen cause a degradation in column performance. Figure 11 shows a view through one of the lower viewports of the gas diffuser system which generates this gas for testing purposes.

Fig.11. View Through Bottom Sight Glass Port Showing Diffuser Piping and Johnson Screen

As with the engineering scale test platform, the full scale IX test platform is controlled via a FactoryTalk® programmable logic controller (PLC) and human machine interface (HMI) system which also performs the data logging function.

Fig. 12. Top Head with Distributor

Figures 13 and 14 show the full scale IX column and the supporting tankage required to hold the large volumes of simulant (typically 151 m^3 (40 kgals) per test). The original column design incorporated a resin dump system into a dump pan beneath the column which drove the height of the column. This system was subsequently changed to a forced recirculation system which is now being designed and incorporated into the test platform.

Fig.13. Full Scale IX Test Column Containing Resin

Fig.14. Simulant and Product Storage Tanks

After overcoming some issues with the seals on the acrylic IX column, testing started in October 2016 collecting NQA-1 data. Figure 15 shows the IX resin approximately one hour into the elution process. The change in color as the resin changes from sodium to hydrogen form can be clearly seen in the acrylic column which, in this case, confirms even flow distribution across the resin bed.

Fig.15. sRF Resin Part Way Through Elution Process

CONCLUSIONS

This paper has very briefly presented an overview of the design and engineering detail of both the LAWPS Engineering Scale Test Platform and the Full Scale Test Platform. These were constructed concurrently over a period of approximately four months, with a total period of ten months from contract award to test startup and collection of NQA-1 test data. This required very close integration of several different teams from different companies, located in different geographic areas of the country.

ACKNOWLEDGEMENTS

The authors would like to thanks all those involved from AECOM, AEM Consulting, AVANTech, Mid-Columbia Engineering, and WRPS for enabling this project to achieve success in delivering operating test platforms to allow the necessary data to be generated to characterize and underpin the design of the crossflow filtration and ion exchange systems within the Hanford LAWPS.