LAWPS Technology Maturation Program and Scaled Testing – 16589

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ABSTRACT

The Technology Maturation Program for the Low-Activity Waste Pre-Treatment System (LAWPS) had been developed utilizing the guidance of DOE-Order 413.3B for Technology Readiness and Technology Maturation. The technology maturation plan (TMP) for LAWPS established principal technology elements (TEs) for the proposed process, designated critical technology elements (CTEs), and identified the necessary activities to mature the technologies for successful deployment of the LAWPS System. The TMP is being utilized to guide the CTEs advancement to Technical Readiness Level (TRL) 6 for the combined Critical Decision 2 and 3 Milestones (CD-2/3) in the 413.3B process. The development of the TMP, the multi-scale testing program, culminating in the integrated scale testing as a predecessor to achieve TRL 6 are presented.

INTRODUCTION

Radioactive and chemical wastes from nuclear weapon production are stored in underground tanks at the Hanford Site, located in the state of Washington. The waste tanks contain a complex and diverse mix of radioactive and chemical waste in the form of sludge, salts, and liquids, necessitating a variety of unique waste retrieval, treatment, and disposition methods. Generically, the tank waste can be characterized as the following:

1. Sludge – Insoluble materials largely consisting of metal hydroxides and oxides that precipitated when acidic wastes from spent nuclear fuel processing and other activities were neutralized and converted to high pH for storage in carbon steel tanks. The sludge waste makes up the largest component that will be processed via high-level waste (HLW) vitrification into a stable glass form.

2. Supernatant – Liquid waste with high sodium content and high pH.

3. Saltcake – a mixture of salts that precipitated from supernatant as the specific gravity was increased by evaporation to reduce tank storage space requirements. Saltcake must be re-dissolved and processed as supernatant waste. The supernatant and saltcake contain the majority of highly radioactive Cs which must be separated and processed with the sludge stream into HLW glass. The decontaminated supernatant will be processed via low-activity waste (LAW) vitrification into a stable glass form.

4. Potential contact-handled transuranic waste (CH-TRU) – a mixture of sludge and saltcake consisting of some 1.4 million gallons in 11 specific single-shell

tanks (SSTs). The material in these tanks is being reviewed to determine the potential for transfer to the Waste Isolation Pilot Plant (WIPP) versus processed on-site into HLW and LAW glass fractions.

In order to begin immobilization of tank waste as soon as practicable, a Direct Feed LAW (DFLAW) flowsheet has been initiated. In the DFLAW configuration, LAW feed will be provided to the LAW Pretreatment System (LAWPS). The LAWPS will separate the HLW and LAW fractions and provide qualified LAW feed to the Waste Treatment and Immobilization Plant (WTP) LAW Vitrification Facility. Successful startup and operation of DFLAW requires the completion of engineering, design and construction of facilities, flowsheet stewardship, programs integration across facilities, generation of a series of permits, and development of the regulatory framework to dispose of the waste forms generated. This paper discusses the Technology Maturation Program for LAWPS.

The LAWPS Project provides for the early production of Immobilized Low Activity Waste (ILAW) by feeding decontaminated supernatant directly to the WTP's LAW Facility, bypassing the WTP Pretreatment Facility. Tank waste from Hanford double-shell tanks (DST) is treated for removal of solids and separation of Cesium-137 (^{137}Cs) isotope from the filtered waste stream to levels that are compliant with WTP LAW Vitrification Facility Waste Acceptance Criteria (WAC). LAWPS stores the treated LAW product before transferring to the WTP. The LAWPS system will be located near the waste tank farm and WTP facilities. A facility concept is shown in Figure 1. A cut away view of the LAWPS process vault is shown in Figure 2.

Figure 1. LAWPS Facility Concept.

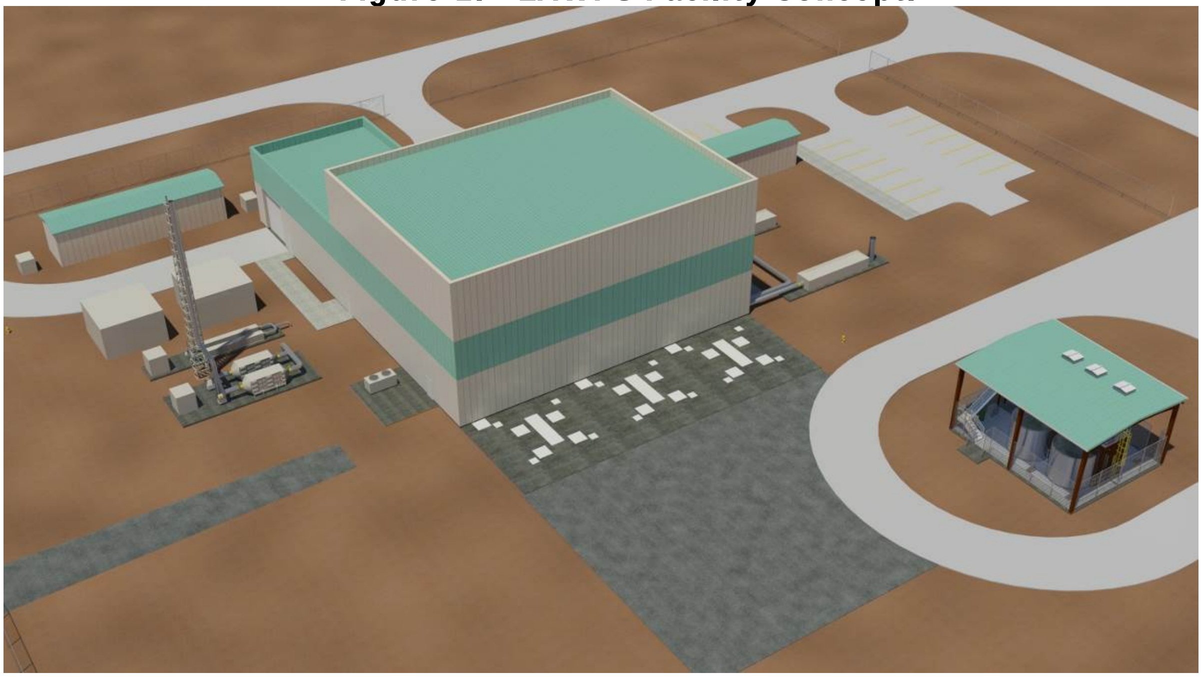
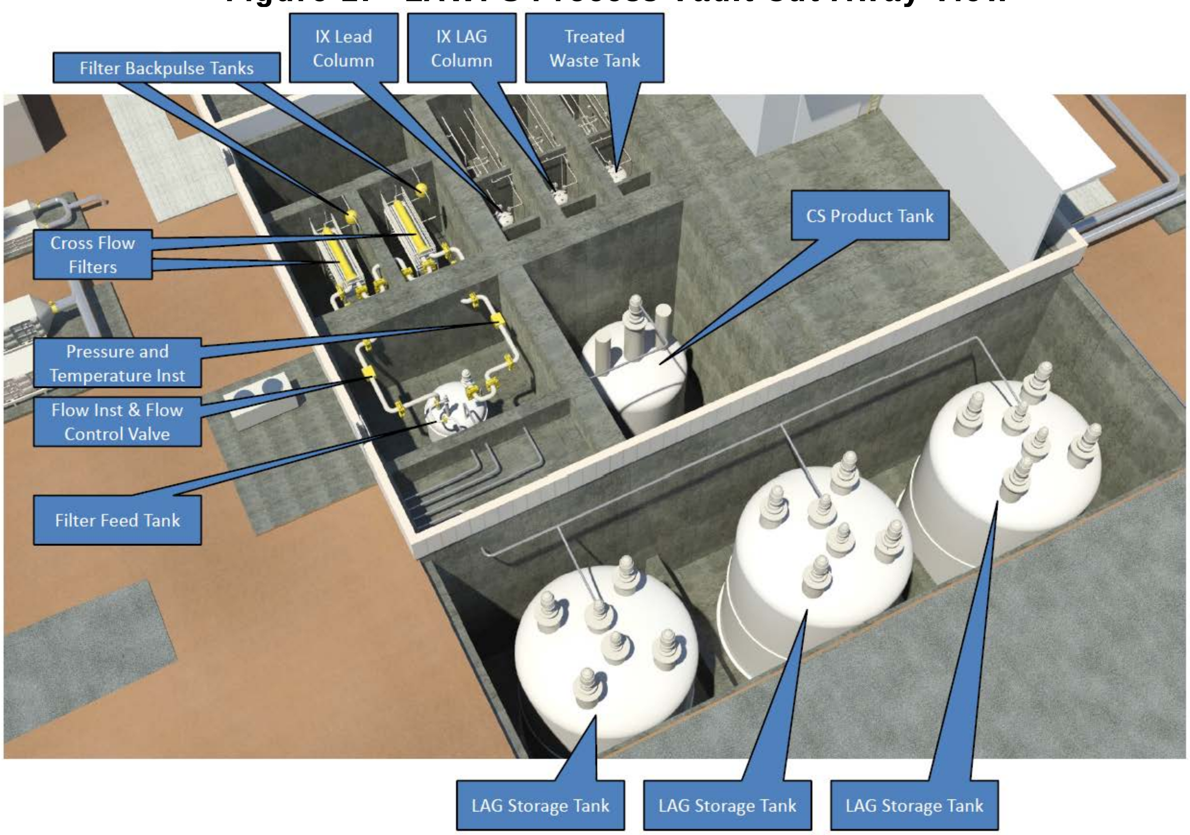


Figure 2. LAWPS Process Vault Cut Away View



In accordance with DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, Technology Readiness Assessments (TRAs) and Technology Maturation Plans (TMPs) are required for 'Major Systems Projects' (i.e., those with total project cost greater than $750M) prior to Critical Decision 2. However, application of 413.3B requirements is also recommended for smaller projects, such as LAWPS, as well as Operational Activities, such as technology demonstrations, that involve the development and implementation of new technologies or technologies in new operational environments. The combination of the TRA and the TMP comprise the guidance documents for a comprehensive approach to maturing technology elements of a system. A key component of the technology readiness level (TRL)/TMP process is the integration of various technologies into a system. The DOE Office of Environmental Management (EM) has developed a Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Implementation Guide to assist in conducting TRAs and developing TMPs. Included in the guide are TRL calculator tables used to ascertain the maturation level, including integration, of CTEs. The systematic resolution of the maturation process up to the initiation of scaled testing of the LAWPS is described below.

LAWPS TECHNOLOGY MATURATION PLANNING

In support of technology maturation, the LAWPS project utilized the EM TRA/TMP Implementation Guide to provide a systematic approach to determine the technology readiness using the TRL calculators and to document the plans to mature the technologies in a TMP. The process includes the necessary activities to mature technology to TRL 9 (hot operations) with the initial planning base focused on activities to mature the technology to TRL 6 by the end of the CD-2 Preliminary Design Phase. The technology maturation process for the LAWPS was initiated by a multidisciplinary team utilizing the following rigorous approach.

1. Identify the Technology Elements.
2. Identify which Technology Elements are also Critical Technology Elements.
3. Perform a top-level TRL determination.
4. Complete the applicable TRL tables for each CTE utilizing relevant technology maturation activities including a deep-dive review of technical references to ensure applicability.
5. Identify the necessary activities to mature the CTEs to TRL 6.
6. Compare activities with current project baseline scope and schedule to identify any further necessary maturation activities.

During the development of the plan, the main consideration was to focus on a near tank option with filtration and ion exchange as the preferred technologies as determined in an earlier analysis of alternatives. The plan needed to reflect any new data/technology development work performed after the initial technology readiness assessment performed in 2011. With the publication of a revision of the DOE

Technology Readiness Assessment guide in 2013, all of the new recommendations and requirements needed to be addressed.

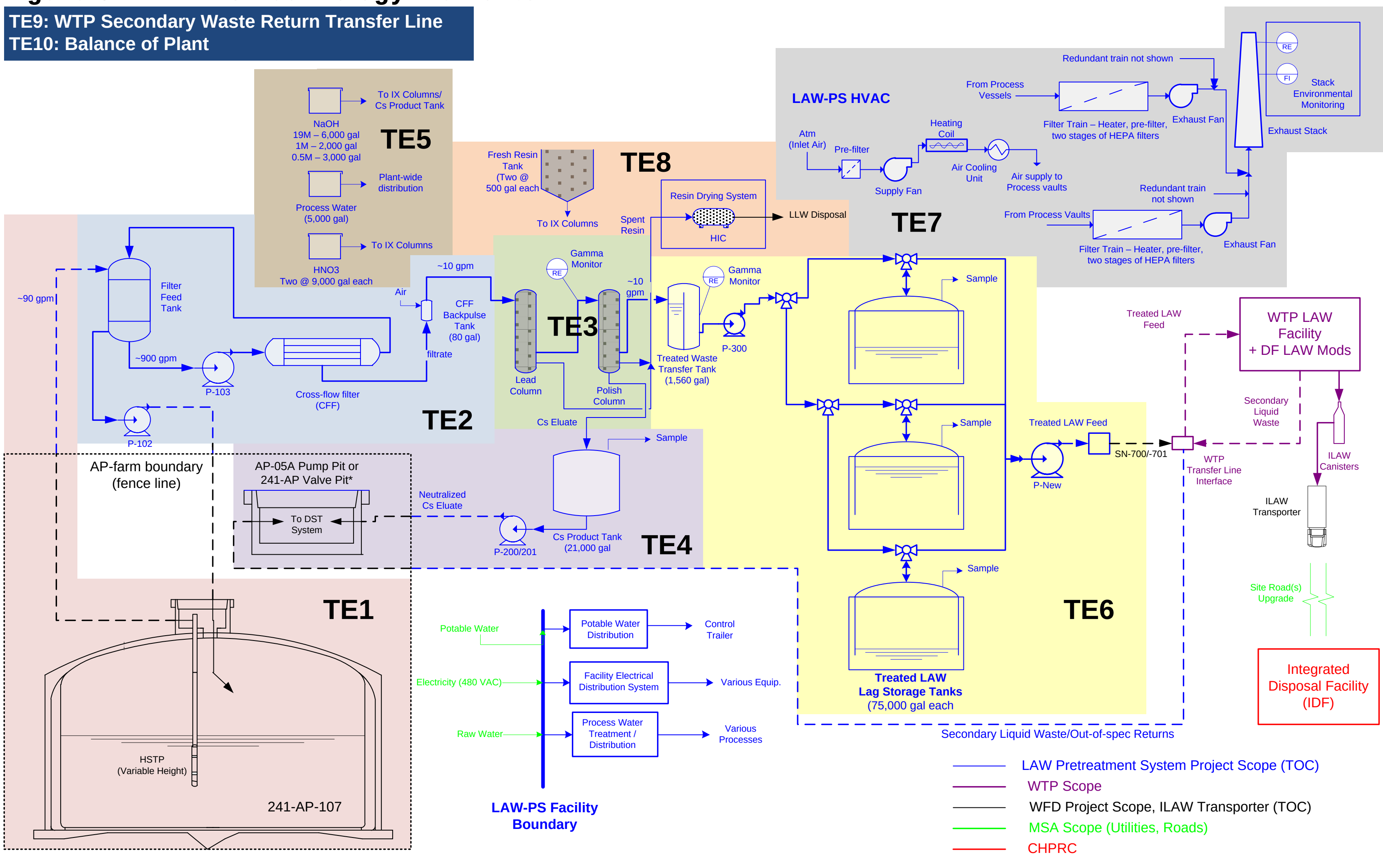
IDENTIFICATION OF CRITICAL TECHNOLOGY ELEMENTS

The technology elements of the LAWPS System were developed based upon the major subsystems. The technology elements were divided as follows:

- TE1: AP-107 feed and transfer system including slurry return from CFF
- TE2: Cross-flow Filtration including feed and back-pulse system
- TE3: Ion Exchange System utilizing spherical resorcinol formaldehyde (sRF) including resin regeneration system
- TE4: IX Eluate Neutralization and preparation for return to DSTs
- TE5: Aqueous Makeup (AMU) and Chemical Addition System
- TE6: Treated LAW Storage and Transfer System
- TE7: Heating, ventilation, and air conditioning systems (HVAC)
- TE8: Resin Replacement and Disposition including Self-engaging Dewatering System™
- TE9: Secondary liquid waste transfer return line
- TE10: Balance of Plant

A summary of the technology elements TE1 through TE8 is shown **Figure 3**. Each identified TE is highlighted as a shaded region on the figure. LAWPS completed an alternatives analysis of potential technologies as part of the conceptual design documented in RPP-RPT-58066, *Low-Activity Waste Pretreatment System Alternative Analyses Summary Report*. These technologies formed the basis for determining the Technology Elements.

Figure 3. LAWPS Technology Elements.



The next step was to determine which TEs are also critical technology elements (CTE). The EM TRA/TMP Implementation Guide provides a series of questions for determining whether a TE should be designated a CTE. The key focus of the questions center around identifying at-risk technologies essential to the successful operation of the facility, and if technologies are new or are being applied in new or novel ways and/or environments.

Utilizing the DOE Guide, the 10 TEs were assessed. The resulting four CTEs identified for the LAWPS in this project phase are:

- TE2 – Cross-flow filtration (CFF) including feed and back-pulse system
- TE3 – Ion exchange using spherical resorcinol-formaldehyde (sRF) resin
- TE4 – Ion exchange eluate neutralization and preparation for return to double-shell tanks (DSTs)
- TE8 – Resin replacement and disposal system

Upon identification of the CTEs the maturation level plus the required activities needed to elevate the TRL were then determined. Utilizing the TRL definitions and calculators from the DOE Guide, a self-assessment of the TRL for each CTE was performed. The results of the assessment determined that all four CTEs would be considered a TRL 4 for the application in the LAWPS project. This level was selected due to certain TRL questions that could not be answered in the affirmative. These questions were then used to help shape the necessary tasks to achieve the next Technology Readiness Level.

TESTING PROGRAM FOR LAWPS CRITICAL TECHNOLOGY ELEMENTS

In order to attain TRL 6 status for the CTEs within LAWPS using the DOE Guide, a testing program was developed for engineering scale integrated testing. The primary focus of the testing was to demonstrate integration of TE2 Filtration and TE3 Ion Exchange. The neutralization process (TE4) is performed using the resulting simulant waste products produced by the elution and regeneration process. The CTE portion of the Resin Replacement and Disposition System (TE8) is limited to resin handling from the columns. Therefore, specific portions of TE4 and TE8 are included in the integrated test as required and portions of these CTEs will be evaluated separately during follow on maturation activities.

INTEGRATED TEST PLANNING

Determining the scope and content of the integrated testing was performed utilizing the following approach.

1. Identify the overall processes for the LAWPS. Example: Process DST waste to treated LAW.
2. Identify the functions for each of the overall processes. Example: Remove Cs-137 and solids to the required limits.

3. Identify test objectives associated with each function. Example: Verify material balance for Cs and solids removal.

Test Objectives

Using the process described above, the following summary level test objectives were identified.

- Removal of undissolved solids from the process stream
- Removal of non-radioactive cesium from the process stream
- Testing a range of operational flow rates
- Determine the volumetric throughput of the waste stream over operational flow range
- Coordination of key control components
- Demonstrate ion exchange column resin loading, waste processing, regeneration and resin removal operations
- Demonstrate neutralization of the elution streams
- Demonstrate discharge of resin from the column
- Demonstrate CFF operation and cleaning
- Demonstrate undissolved solids management in filtration feed system
- Evaluate gas generation/retention/release

Testing Scope

The bulk of the test program is focused on filtration and ion exchange. The DOE Guide states that the engineering scale should typically be greater than $1/10^{th}$ scale to less than full scale with the use of simulants to match relevant physical and chemical properties.

The scale chosen for the main integrated engineering-scale prototypic test of the CTEs was $1/9^{th}$ scale with the primary scaling factor being the volumetric process rates. The size of the scale allowed for selection of commercially available components, reducing the cost of the equipment, operation time and simulant while still preserving the technology integration functions using simulant with the relevant physical and chemical properties. The scaling factor was applied to the overall process and the individual components were then sized accordingly.

The key focus of the equipment sizing was to maintain process velocities, residence time and chemical performance at the scaled process rate. The variables selected were specifically chosen due to their influence on integration of the technologies. Table 4 shows some of the key components and the resulting scaling factors used.

Table 4 Scaling Factors

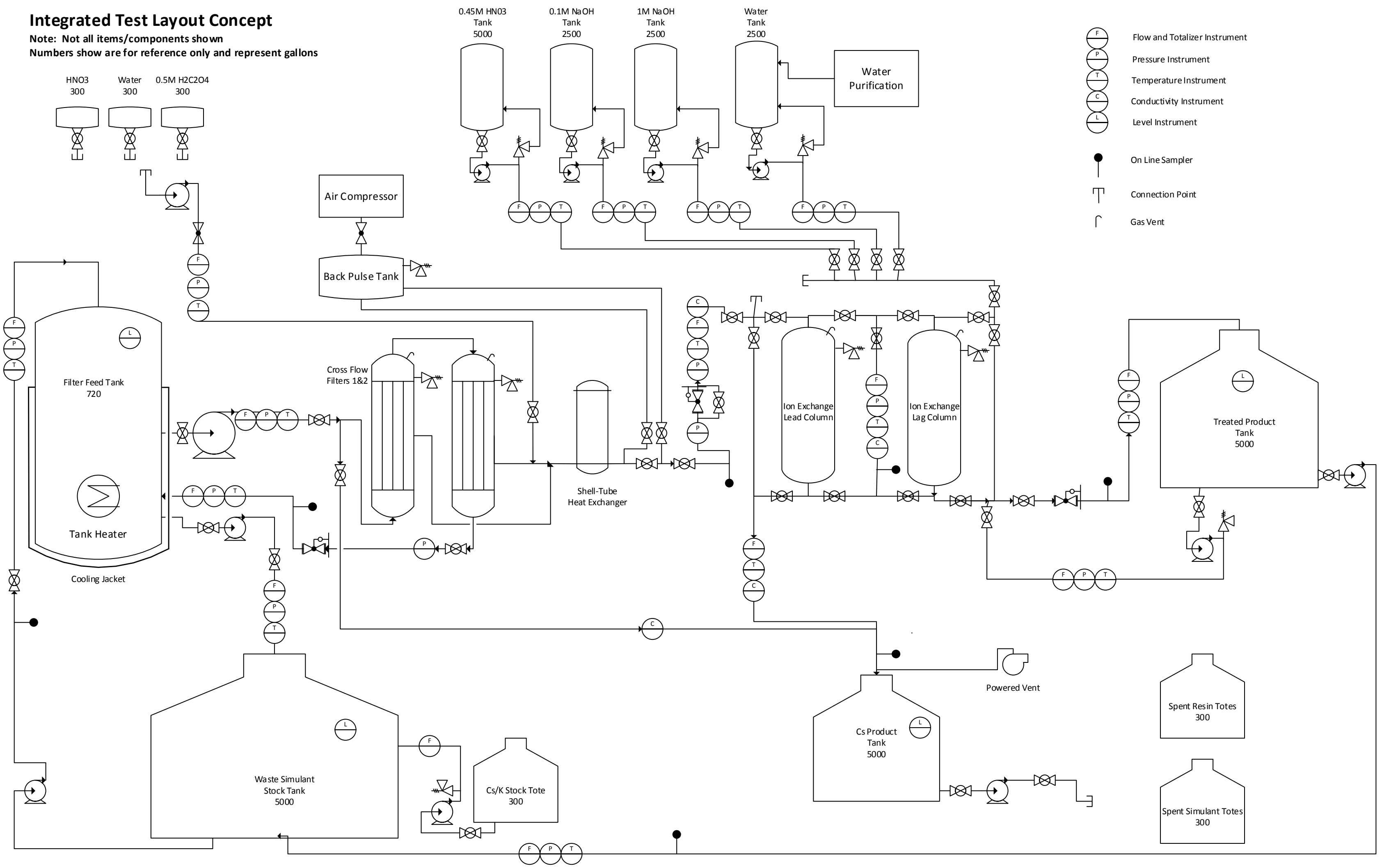
Scale	Filter Flow Rate	CFF Configuration	Filtrate Line Size	IX Column Configuration
Full Scale	12 gpm	2 filters 204 tubes ½-inch ID 532 sq. ft. total	1 inch	42 inch diameter Full Height
1/9th Scale	~1.3 gpm	2 filters 24 tubes ½-inch ID 62 sq. ft. total	⅜-inch	14 inch diameter Full height

This approach resulted in a reduction in size for most of the component parameters. However, some attributes were intentionally left at full-scale dimension. This was done to maintain a specific physical performance attribute important to the testing or due to the fact that scaling of the item was not practical or could negatively impact the applicability of the scaled results to the full scale design. Key examples of this included:

- Full height Ion Exchange (IX) Column – Maintained the pressure drop across the resin bed, flow velocities and chemical performance
- Full size sRF Resin Beads – Maintained the hydraulic and chemical performance characteristics of the resin
- Full size individual CFF tube length, diameter, and pore size – Maintained the cross sectional surface area and boundary layer filter cake effects at planned velocities

A schematic of the planned test configuration is show in Figure 4.

Figure 4. Planned Test Configuration.



Support Tests

In addition to the integrated scaled test some key information was needed to support ongoing design efforts and inform or simplify the integrated engineering scale test. Separate support tests were set up to address these needs and are described below.

CFF Support Tests

- Utilization of a small-scale (single filter tube) CFF to test a range of simulants (mainly particle size/type evaluations) and cleaning approaches - This test evaluates a number of potential fouling agents and cleaning methods without the time and expense of engineering scale operations.
- Evaluating the effect of chemical cleaning on CFF elements – uses sample “coupons” of the filter media to evaluate potential corrosion of the filter tubes that could result from routine cleaning of the filter with acids.

IX Support Tests

- Determine the gas generation rate and composition expected to be evolved from waste with sRF present – Gas generation in tank waste has been extensively studied. However, more information was needed for waste in the presence of sRF resin. Since the irradiation of the full height columns during integrated testing was impractical due to ALARA concerns a separate evaluation was established to answer this question. This test uses simulants and resin with a radiation source while monitoring for gas volume and type.
- Gas retention and release from resin – Gas release from tank waste has been extensively studied however, retention/release of gas from a sRF bed required further understanding. This test uses simulants and resin with a gas generation mechanism to produce bubbles in the resin bed. The volume of gas retained and the release mechanism are monitored to further understand the resin’s expected behavior.
- Full scale prototypic column and resin dump pan (RDP) evaluation – Due to the scaling effects and other considerations a full scale column test and a full scale evaluation of the resin dump concept was needed to support design efforts. This test effort focuses on the sensitivity of the mixing dynamics, wall effects of the column and resin removal effectiveness for the RDP.

SUMMARY

By using the USDOE’s TRA/TMP planning process, WRPS has developed a Technology Maturation Plan and testing program to mature the LAWPS to TRL 6 prior to support a CD-2 decision. This effort was performed by first identifying TEs, identifying the CTEs, evaluating the TRL of the CTEs, and identifying the activities necessary to support maturation of the CTEs. The second phase developed the test objectives by identification of the overall processes, functions of each process, and specific test objectives for each function to support integrated testing. The third phase involved selection of the testing scale and identifying support tests that were required to enhance or simplify the engineering scale integrated test.

Implementation of the maturation effort is currently under way as WRPS has selected a testing contractor to perform the engineering scale test and full scale column testing. Testing is scheduled to start early in 2016 with a planned completion by December 2016. Other support testing efforts are being performed by Savannah River National Laboratory and the Pacific Northwest National Laboratory with a planned completion of March 2017. The results from these efforts will be included in the final reporting of the Integrated Test.

REFERENCES

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