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HANFORD TANK WASTE TREATMENT SYSTEM

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ABSTRACT

The US Department of Energy is constructing the Hanford Waste Treatment Plant which is the largest waste pretreatment and vitrification facility in the world. This massive facility will begin commissioning operations in 2009, with full scale production beginning in 2011. While this facility will provide a much needed waste treatment capability to meet the department accelerated cleanup goals for closure of the Hanford waste tank systems, it alone will not provide enough capacity to complete the waste treatment mission by the 2028 regulatory milestone.

The 53 million gallons of radioactive waste remaining in Hanford's 177 single and double shell tanks present a broad range of radiochemical and chemical contents. The US Department of Energy, Office of River Protection has established a strategy for waste retrieval and waste treatment that recognizes that all tank waste is not identical, and that other processes can be utilized to safely and economically treat tank waste for ultimate disposal.

Finalizing the overall waste treatment strategy is a complex balance between waste retrieval sequence, waste pretreatment, HLW glass formulation, LAW glass formulation, along with the projected production capacity of the retrieval and waste treatment systems. Optimization of this complex system requires use of sophisticated process and operational models.

The department is pursuing a 3-tiered strategy to define, develop, and deploy treatment capability that will meet the 2028 waste treatment milestone.

Ultimately, by tailoring the treatment process to the actual waste being processed, economies and efficiencies can be exploited to improve the overall treatment approach. The amount of sodium contained in the waste is an indicator of the overall processing demand of the various processing systems. In the end, DOE expects that each of the 3 elements will process approximately:

- The Waste Treatment Plant will process 100 per cent of the High Level Waste (HLW) and waste containing over one half of the LAW waste sodium.
- Transuranic (TRU) waste packaging and disposal will treat waste containing 2 per cent of the total waste sodium
- Supplemental treatment will treat waste containing a little less than one half of the Low Activity (LAW) waste sodium

Additional risk mitigation activities are underway to further enhance the evolution of the strategy for both the LAW and HLW treatment approaches and increase the confidence that the overall treatment mission can be completed by the 2028 deadline.

INTRODUCTION

The US Department of Energy is constructing the Hanford Waste Treatment Plant which is the largest waste pretreatment and vitrification facility in the world. This massive facility will begin commissioning operations in 2009, with full scale production beginning in 2011. While this facility will provide a much needed waste treatment capability to meet the department's accelerated cleanup goals for closure of the Hanford waste tank systems, it alone will not provide enough capacity to complete the waste treatment mission by the 2028 regulatory milestone.

The 53 million gallons of waste present in tanks today contains about 48,000 metric tonnes of waste sodium. At present, the quantity of sodium contained in the waste is the overall schedule limiting factor and is used as an indicator of progress to completion of the waste treatment mission. Sodium content, in general, flows to the low activity waste side and is the limiting chemical constituent in the Low Activity Waste (LAW) waste treatment system. One of the principal objectives of the overall strategy is to enhance the ability of the LAW system to treat wastes containing this sodium, which in turn accelerates the completion of the waste treatment end date.

The Waste

The 53 million gallons of radioactive waste remaining in Hanford's 177 single and double shell tanks present a broad range of radiochemical and chemical contents. This material came from a wide variety of nuclear fuel processing, uranium and radioisotope recovery, and plutonium purification and metal production activities. While much of the waste has been transferred repeatedly to support these various processing and recovery campaigns, along with tank waste concentration efforts, there are a number of tanks that have not been mixed with other processing wastes. DOE believes that certain Hanford tanks contain remote handled (RH-TRU) and contact handled (CH-TRU) TRU wastes; others contain wastes previously treated to remove cesium and are feed candidates for supplemental treatment; while still others contain wastes that should be processed by the WTP to be treated and immobilized as either immobilized low activity waste (ILAW) or high level wastes (HLW).

One hundred and seventy six tanks remaining to be retrieved (tank C-106 has been retrieved) at the Hanford Site are currently categorized as:

- 11 contain contact handled TRU waste resulting from plutonium purification and recovery operations
- 9 contain remote handled TRU waste resulting from plutonium purification and recovery operations
- 27 contain soluble wastes with cesium levels low enough that further radionuclide removal by simple pretreatment systems to effect solid-liquid separation and perhaps, selective dissolution to further reduce the cesium concentration would be adequate. These wastes could then be immobilized as Low Activity Waste (LAW), and
- 129 single and double shell tanks contain wastes that will be principally treated by the WTP and supporting facilities, including the Supplemental Treatment Plant.

The US Department of Energy, Office of River Protection has established a strategy for waste retrieval and waste treatment that recognizes that all tank waste is not identical, and that other processes can be utilized to safely and economically treat tank waste for ultimate disposal.

The Treatment Strategy

Finalizing the overall waste treatment strategy is a complex balance between waste retrieval sequence, waste pretreatment, HLW glass formulation, LAW glass formulation, along with the projected production capacity of the retrieval and waste treatment systems. Some of the competing objectives that shape and drive the overall strategy include:

- Regulatory milestones (e.g. Tri-Party Agreement)
- Meeting the 1997 NRC incidental waste determination. This requires that the majority of the radionuclides be separated and incorporated into the HLW glass and ultimately be disposed of in the national repository. At the same time it drives the overall waste performance requirements of any ILAW planned for onsite disposal.
- Control of the HLW glass volume to reduce impacts to the national HLW repository and reduce overall lifecycle costs
  - Washing and leaching of the HLW sludge to remove non-radioactive elements that drive the overall volume of HLW glass ultimately produced. Currently ORP plans to remove much of the aluminum and chromium from the HLW sludges to substantially reduce the IHLW glass production to a target of around 10,000 HLW canisters.
  - Blending to control other elements that control glass volume after aluminum and chromium are removed. Currently, ORP uses the natural batch to batch blending that occurs by designing the retrieval sequence to maximize the interblending of troublesome constituents. This retrieval sequence blending is referred to as "incidental blending". Some specific tank materials have been identified for targeted pair-wise blending to deal with specific plant productivity or safety basis issues (e.g. sulfate levels, uranium criticality, etc.). ORP is evaluating additional targeted blending approaches that can further reduce the IHLW glass volume.
- Optimize the retrieval sequence to meet WTP feed objectives, while meeting single shell tank waste retrieval and closure milestones. Ultimately single-shell tanks will be closed as waste management units under RCRA, which typically includes the entire tank farm, along with buried pipelines and ancillary equipment. Retrieval of all the tanks in a single farm is often the most cost effective approach when compared to a "hop scotch" approach that pick a tank here, then jumps to another farm to get the "best" tank to blend with. Set up of retrieval in a farm requires development of the waste transfer and operations support infrastructure. In most cases, flushing and removing residual wastes from buried pipelines and ancillary equipment is best completed while the retrieval infrastructure is in place. In addition, the overall closure process must consider surrounding CERCLA remediation of surrounding or included sites, as well as impacts on the groundwater.

Optimization of this complex system requires use of sophisticated process and operational models that can link the initial tank inventory with HLW and LAW glass formulation models, account for the necessary construction of supporting infrastructure, the waste processing flowsheets, including any chemical additions that are required, and also consider the effective startup and operational schedules of the various processing facilities and supporting infrastructure. Currently, ORP uses the Hanford Tank Waste Operations Simulator (HTWOS) as its primary tool to develop and project tank waste retrieval sequence and schedules, project waste feed staging operations within the DST tank system, project waste feed batch composition along with waste processing operations to produce the final waste forms for LAW and HLW glass, and develop the schedule for supporting waste product intermediate storage and ultimate disposal. (CH2MHILL 2003)

The department is pursuing a 3-tiered strategy to develop and deploy treatment capability that will meet the 2028 waste treatment milestone. Currently underway are:

- Completion and startup of the Waste Treatment Plant, with subsequent enhancement of the Low Activity Waste melters during normal maintenance replacement of the melters (expected to occur by 2015), along with other productivity improvements in pretreatment and high level waste melter systems.
- Waste retrieval and packaging of TRU wastes contained in the tanks for geologic disposal in WIPP (RH-TRU will likely require washing in the DST system prior to drying and packaging)
- Supplemental treatment for previously separated wastes and waste pretreated in the Waste Treatment Plant pretreatment facility to immobilize Low Activity Waste in a borosilicate glass waste form, and in accordance with agreements previously reached with the Nuclear Regulatory Commission. (Paperiello, 1997)

This treatment capability will be integrated into the overall River Protection Project system depicted in Figure 1. Wastes are retrieved from single shell tanks either for transfer to the double shell tank system, or treatment by either the TRU waste system or the Supplemental treatment plant (STP) (some wastes retrieved in DST’s will be treated via STP as well). Wastes contained in the DST’s are staged to the WTP for pretreatment and immobilization of the HLW and ILAW fractions. About half of the pretreated ILAW feed is immobilized by the WTP ILAW immobilization system, while the remainder is immobilized by the Supplemental Treatment Plant, once pretreatment removed radionuclides to meet levels that conform to the agreement previously reached with the NRC.

The Waste Treatment Plant

The Waste Treatment Plant is under construction and on schedule for a December, 2009 hot startup. DOE has continued to conduct research and technical work that shows promise of additional improvements in low activity waste glass formulations and LAW melter throughputs. DOE is planning to enhance the capability of the LAW facility in a series of natural evolutions, as plant equipment is replaced over the life of the facility. In similar fashion, enhancements to the pretreatment and HLW facilities are expected.

The expected WTP capacity enhancements include:

- Pretreatment facility enhancements to ion-exchange systems, evaporation systems and solid liquid separations systems that provide for additional pretreatment capacity. This pretreatment capacity is used to generate feed for the WTP ILAW immobilization system and the STP.

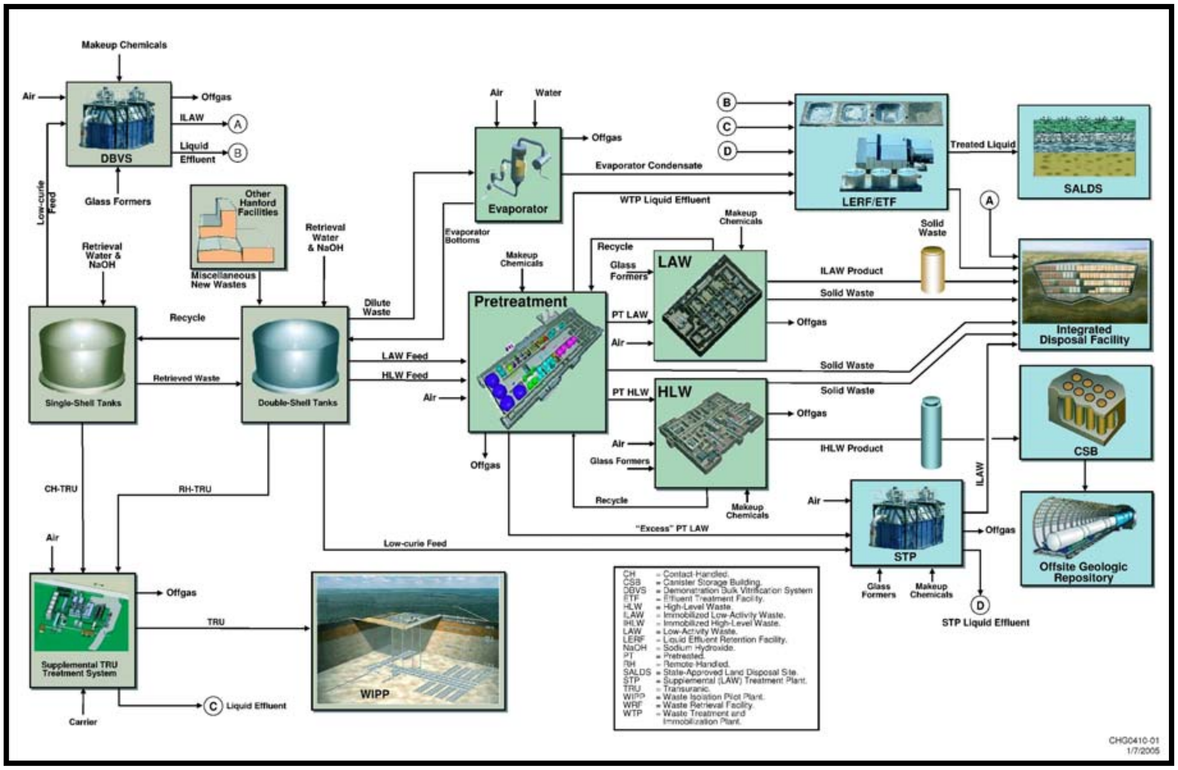

Fig. 1. River Protection project system

- LAW facility enhancements incorporating second generation melter technology that allows higher glass production rate and higher waste loading in the glass, along with expected improvements in glass formulations to improve waste loading
- HLW facility enhancements incorporating second generation melter technology that allows higher glass production rate and higher waste loading in the glass

It is expected that these enhancements should be in place to support higher WTP productivity by 2015.

TRU Waste Treatment System

The contact-handled TRU Waste Packaging System is currently in fabrication. The Department of Energy has projects underway to design, permit, and install TRU waste packaging systems at Hanford, and is working with the State and Federal regulators to determine the conditions under which this option can be successfully implemented.

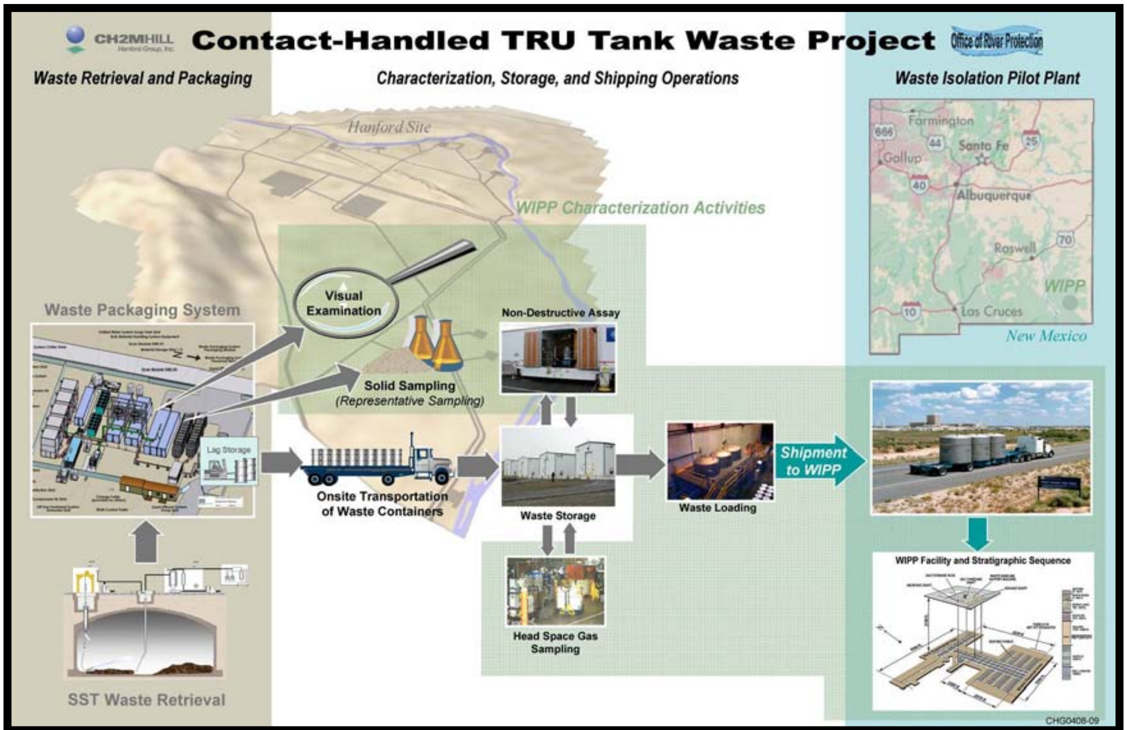

Fig. 2. TRU tank waste project

An overall schematic of the initial contact handled TRU (CH-TRU) system is illustrated in Figure 2. Suitable TRU waste is retrieved from SST storage and transferred for packaging. The resulting packages are inspected and certified, and interim stored at the Hanford TRU storage facilities.

Once certification is complete, the waste containers are loaded into TRUPAC containers and transported to the Waste Isolation Pilot Plant (WIPP) for disposal. A similar approach would be established for the remote handled TRU waste once requirements become finalized. It is possible that water washing to remove soluble radionuclides might be required to meet Remote Handled-TRU (RH-TRU) transportation requirements. It is expected that the TRU system will be moved from tank area to tank area to efficiently utilize the overall packaging system, with additional shielding added to package the washed RH-TRU tank waste material.

Supplemental Treatment Plant

A full scale demonstration of the technology to be utilized in the STP is undergoing RDT& E testing. After completion of a technology review and contract negotiation process (Raymond, 2004), ORP is proceeding with demonstration of In-Container Vitrification technology. A Hanford full-scale bulk demonstration system (called the Demonstration Bulk Vitrification System or DBVS) is under construction, and is expected to produce a full scale waste package from waste retrieved from single shell tank S-109; ready for disposal by the end of calendar year 2005. Similar demonstration activities are underway for steam reforming operations on radioactive wastes at other Department of Energy Sites. It is expected that these demonstrations will be successful in showing that lower capital cost waste treatment options are feasible for certain Hanford tank wastes.

An overall flow diagram for this Supplemental Treatment demonstration is provided in Figure 3. First waste is retrieved directly from a S-109 and transferred to the Demonstration Bulk Vitrification System (DBVS). The ICV process converts LAW into a glass form by mixing the waste with soil and applying an electrical current.

The vitrification step occurs in a large, refractory-lined steel container which also serves as the disposal package. The process consists of feed preparation, container lining installation and electrode placement, container waste filling, in container vitrification, off-gas treatment, ventilation cooling, topping off the container, sealing the container, decontamination of the container, and passive cooling before transferring the entire container and its vitrified contents to the onsite Integrated Disposal Facility (IDF) for onsite disposal.

The future full scale Supplemental Treatment Plant (STP) will be scaled up by constructing parallel modules, based on the DBVS demonstration facility. The STP is expected to be conservatively sized with eight parallel ICV lines operating simultaneously as a repeating batch sequence and will treat an average (continuous) of 6 gal/min of Hanford LAW. The current concept is that the STP will receive wastes low enough in cesium staged in the tank system, along with pretreated wastes from the WTP pretreatment facility.

DOE is planning to make final decisions regarding the supplemental treatment technology and its deployment in 2006, in concert with the TPA milestone commitment. ORP expects that the full scope modular supplemental treatment system will begin operations in 2011.

The Overall Material Balance

The Office of River Protection periodically publishes a lifecycle technical description of the overall mission, which provides an overall material balance, processing schedule, facility need dates, waste form production, interim storage, and ultimate disposal requirements (ORP, 2003). This System Plan describes the implementation of the overall strategy at a point in time, and highlights where additional risk mitigation, overall system optimization and targeted development work can provide lifecycle benefits to the completion of the River Protection Project Mission. The current issue of the System Plan includes a Target Case which reflects the state of the overall mission completion strategy at the time of document issue, and a Stretch Case which illustrates what a set of given improvement might be able to achieve.

This ongoing planning process continues to identify improvements to the mission strategy over time. Work completed since the last system plan has identified upgrades to the overall strategy that begin to achieve some of the challenges identified in the System Plan Stretch case. This paper describes recent evolution of the overall system strategy. The following discussion provides a snapshot of how the overall strategy has continued to evolve since the last formal issue of the system plan. Given these identified capabilities and preplanned improvements deployed according to the overall schedule, ORP will complete the overall waste treatment mission by December, 2028 which is the current Tri-Party Agreement milestone for the completion of all Hanford tank waste treatment.

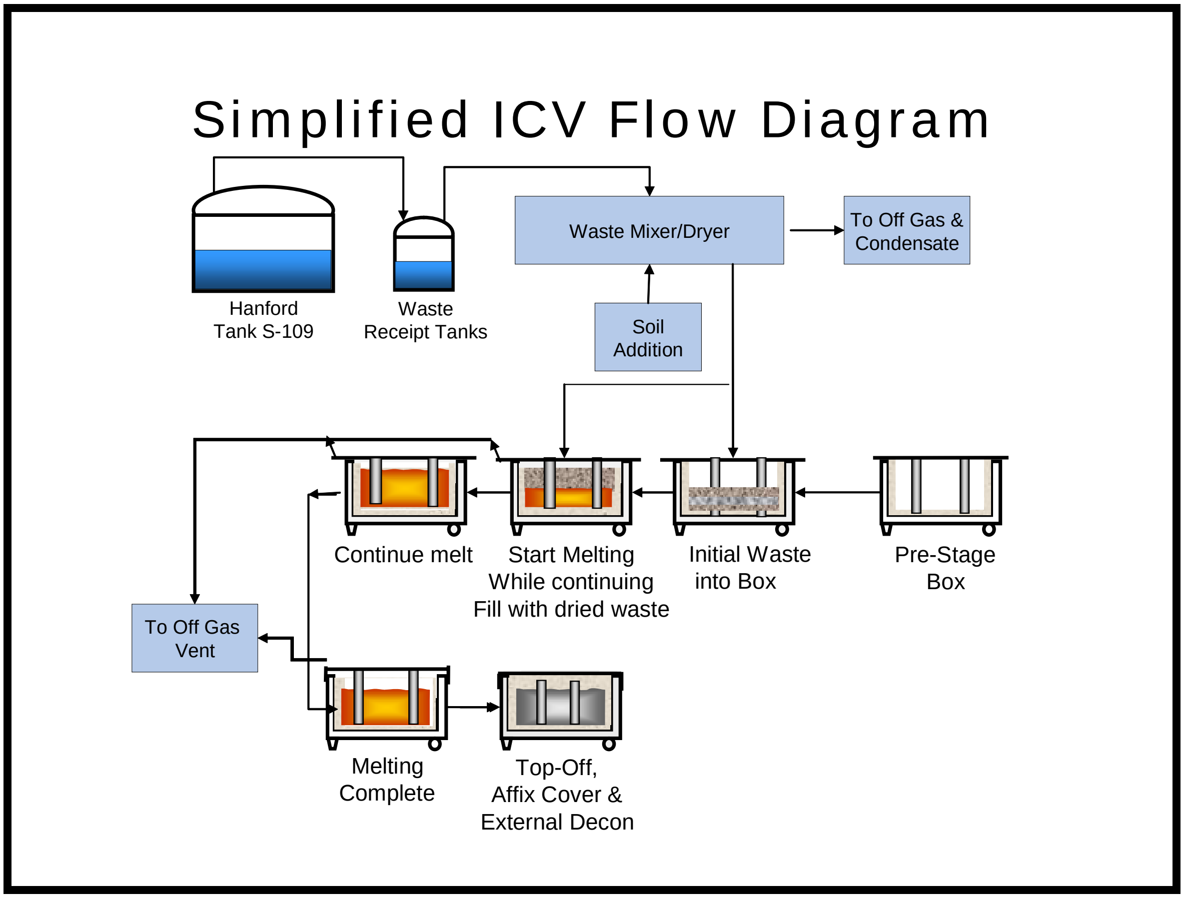

Fig. 3. In-Container Vitrification Flow Diagram

The needed production capacities and facility production schedules are provided in Table I.

An example of an overall lifecycle material balance for this overall strategy is depicted in Figure 4. As discussed earlier, the 53 million gallons of waste present today contains about 48,000 metric tonnes of sodium, with the overall treatment of the waste sodium pacing the completion of the overall mission. Caustic leaching of the waste sludges, and other process chemical additions account for an additional 11,400 metric tonnes of sodium to the overall waste treatment mission. Increasing the LAW treatment capability to enable acceleration of the waste treatment mission, provides one key element of the overall acceleration strategy. The specific quantities and percentages are examples of one of the current planning cases ORP is continuing to evaluate and refine as additional information and performance data becomes available.

The strategy depicted in Figure 4 represents the maximum acceleration that can be achieved by increases in the LAW treatment capacity alone. The entire system is close coupled, and delicately balanced. Further acceleration can only be achieved by further capacity enhancements of pretreatment, LAW treatment, and HLW treatment systems simultaneously.

Table I. RPP Waste Treatment Capacities and Production Schedule

Waste Treatment System	Production Capacity	Production Schedule
Waste Treatment Plant	34 MT ILAW glass/day 5 MT HLW glass/ day	**Waste Treatment Operations 2/2011 – 12/2028**
TRU Waste Treatment	900 MT of sodium (equivalent)	**1/2006 – 1/2011**
Supplemental Treatment Plant	**31 MT LAW glass/day with 8 process lines**	**1/2011 – 12/2028**

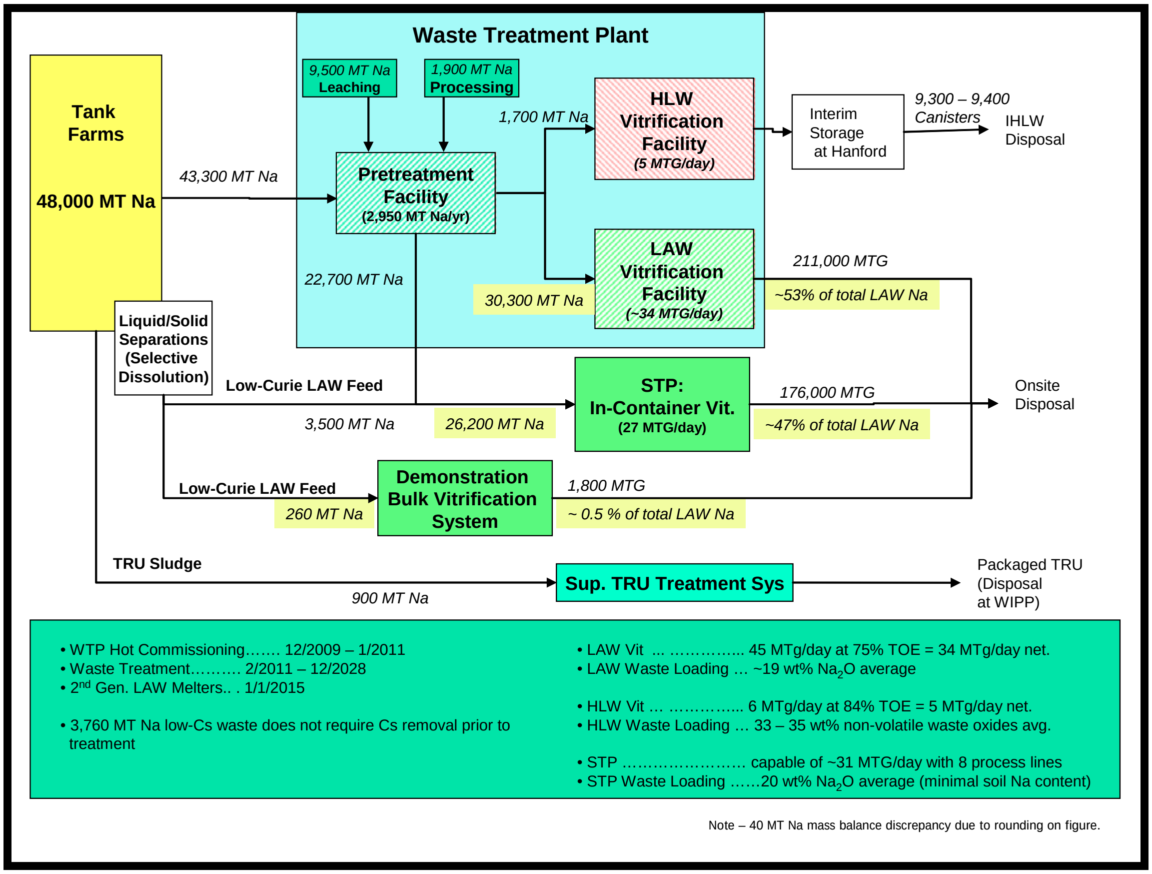

Fig. 4. Example of Lifecycle Material Balance for the RPP Waste Treatment System

The tank waste represented by the 48,000 MT of sodium is treated via one of the three primary pathways previously discussed:

- Tank wastes containing about 43,000 MT of waste sodium is routed to the Waste Treatment Plant for pretreatment, LAW vitrification, and HLW vitrification

  - Nearly half of the pretreated waste is routed to the Supplemental Treatment Plant (STP) for LAW immobilization, the remainder is immobilized by the WTP LAW capability
- Wastes containing about 3700 MT of waste sodium contained in wastes previously treated to remove radionuclides are assumed to require only simple solid liquid separation (and potentially selective dissolution to reduce radionuclide concentration for As Low as Reasonable Achievable (ALARA) considerations) and is treated by the Demonstration Bulk Vitrification System (DBVS) or the full scale STP.
- TRU wastes containing approximately 900 MT of waste sodium is treated, packaged and shipped to WIPP for disposal

These treatment pathways result in the entire inventory of the Hanford tanks to be disposed as:
- ~9300 – 9400 Immobilized HLW canisters that will ultimately be disposed at the National HLW repository
- ~211,000 metric tonnes of LAW glass will be produced by the WTP ILAW facility and disposed onsite
- ~176,000 metric tonnes of LAW glass will be produced by the STP facility and disposed on site
- Wastes containing approximately 900 metric tonnes of waste sodium is packaged as either CH-TRU or RH-TRU and is disposed in the Waste Isolation Pilot Plant (WIPP)

Further Risk Mitigation

The Office of River Protection is continuing to evaluate additional risk reduction measures that can further improve the overall strategy. Fractional crystallization is a well developed industrial technology used to purify and prepare clean salts of industrial and commercial uses (e.g. borax, table sugar, etc.). ORP, with the assistance of DOE-EM, has awarded a demonstration contract to evaluate, design, and demonstrate a system which could be deployed to remove decontaminated salts from single and double shell tank wastes, in effect providing additional cesium decontamination for those wastes prior to treatment in the STP. If successful, this technique could allow ORP to accelerate the treatment of LAW wastes, and make additional DST space available much earlier, thus facilitating the retrieval of wastes from single shell tanks, as well as helping to accelerate the completion of the mission.

High Level Waste (HLW) glass formulations have a number of solubility limits that drive the overall strategy, and ultimately the schedule. Tailoring the HLW sludges by water washing, caustic leaching (to remove aluminum), oxidative leaching (to remove chromium), and waste blending are effective strategies to reduce the total amount of HLW glass that must be made to complete the overall HLW immobilization mission. The ORP current planning baseline relies on incidental blending (blending that is inherent in the designed tank retrieval sequence) in the tank farms, along with water washing, caustic leaching, and oxidative leaching in the Waste Treatment Plant, to reduce the number of HLW canisters to a target level of about 10,000 canisters for completion of the mission.

ORP has chartered its contractors to conduct additional integration studies that will identify approaches to address some of the overall system bottlenecks inherent in the multi-step washing and leaching processes, along with enhanced sludge blending strategies. It is expected that these efforts will result in further optimization, and will continue to increase the confidence that the overall mission can be completed prior to 2028.

CONCLUSIONS

Taken together, this strategy will provide enough of the right capability, at the right time to complete the overall treatment mission in 2028. Ultimately, by tailoring the treatment process to the actual waste being processing, economies and efficiencies can result in improvements to the overall treatment approach. In the end, DOE expects that each of the 3 system elements will process approximately:

- TRU waste packaging and disposal will treat about 2 per cent of the total waste sodium
- Supplemental treatment will account for a little less than one half of the LAW waste sodium
- The Waste Treatment Plant will process over one half of the LAW waste sodium and 100 per cent of the HLW.

Additional risk mitigation activities are underway to further enhance the evolution of the strategy for both the LAW and HLW treatment approaches. This additional risk mitigation activities help increase the confidence that the overall treatment mission can be completed prior to the 2028 deadline.

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