THE TECHNICAL FLOWSHEET TO ACHIEVE THE MISSION OF THE ADVANCED MIXED WASTE TREATMENT PROJECT

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ABSTRACT

The Advanced Mixed Waste Treatment Project (AMWTP) was initiated in late 1996. The mission of the project is to safely treat 65,000 m^3 of predominantly mixed transuranic waste, located at the Idaho National Engineering and Environmental Laboratory site. Despite the expertise of the partners in this project and existing experience with similar treatment processes, the challenge facing the project is significant. It combines the need to process waste that is covered by the definition of debris and also treat non-debris and normal process wastes, whilst meeting the stringent Waste Acceptance Criteria and Permit Requirements. This paper outline the selection of technologies and the technical flowsheet to meet this challenge and indicates how the flowsheet was underwritten.

INTRODUCTION

In 1996, the DOE-ID awarded a team led by BNFL Inc, a contract to treat a volume of waste located at the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL) site. The task is known as the Advanced Mixed Waste Treatment Project (AMWTP) and its mission is to treat the waste safety and efficiently. This paper outlines the development of the technical flowsheet that supports the project and will achieve this mission.

BNFL Inc chose its team members for the particular expertise that they can bring to the project. The partners include:

- Morrison Knudsen who bring a long history of constructing major plant;
- GTS Duratek who bring their expertise in high temperature processes such as vitrification and their incinerator experience;
- BNFL Engineering Limited (BEL) who are based in the UK and are responsible for the design of the mechanical plant using their expertise gained at Sellafield, Springfields and other BNFL sites,
- Rocky Mountain Remediation Services (RMRS) who manage waste management at Rocky Flats and
- Science Applications International Corporation (SAIC) who has an extensive track record in permitting nuclear plants.

All of the team members have a role in defining the technology and flowsheet to satisfy the challenge set to AMWTP and their inputs are integrated by a Technical Manager with oversight of the entire project.

AMWTP is contracted to treat 65,000m^3 of waste located at the RWMC plus a further 20,000m^3 of yet, unidentified material. The waste to be treated was consigned to the RWMC from the early 1970's and originated from a variety of sites around the DOE complex. These include Battelle, Mound and Argonne although the majority came from the nuclear weapons facility at Rocky Flats in Colorado.

Originally, the waste was placed on a series of pads that were then covered by plywood, tarpaulin and a layer of earth as a freestanding berm on the site. In the early 1990s, a building was constructed over this earthen berm. In addition, there are containers in storage modules on the site [3].

Within the RWMC, the wastes are stored in drums, boxes, bins and cargo containers. There are about 125,000 drums in total, mostly 55-gallons (conventional oil drums) but some other sizes are also present (83, 30 gallon etc). There is also a range of types and sizes of boxes, the most prevalent being fiberglass-reinforced plywood (FRP) boxes, although there are simple plywood boxes and metal boxes of varying dimensions and designs. The approximate numbers of container types are described in Table 1[1]. Some of the boxes were or will be overpacked because of degradation or suspected degradation of the original package. The boxes tend to approximate to a size of 4 ft x 4 ft x 7 ft but there are oversized boxes and boxes used as a secondary container for drums. Most of the containers are capable of being contact handled

CONTAINER TYPE	NUMBER
Bin	550
Drum	127,690
Box (cardboard)	1
Box (wood)	8,800
Box (metal)	2,356
Other	27
TOTAL	**139,424**

Container Types
Table 1.

(radiation levels <200 mrem/hr) but some require remote handling due to the high radiation levels.

The bulk of the waste is transuranic or TRU waste (i.e. greater than 100 nCi/g) and about 95% is described as radioactive mixed waste, in that it contains or is suspected to also contain hazardous material as defined by the Resource Conservation and Recovery Act (RCRA). The distributions by container and waste type are shown in Figures 1 and 2.

Some of the waste may also contain Toxic Substances Control Act (TSCA) regulated material such as polychlorinated biphenyls (PCBs) and asbestos.

The waste falls into two categories based on the level of radioactivity:

1. Alpha low-level waste (ALLW) – contains alpha-emitting radionuclides with an atomic number greater than 92 and half-lives greater than 20 years and concentrations between 10 nCi/g and 100 nCi/g.
2. Transuranic waste (TRU) – identical to ALLW expect it has concentrations greater than 100 nCi/g.
3. Of the 65,000m^3 waste to be treated, approximately 40% is ALLW with the remaining 60% classified as TRU.

Container Distribution

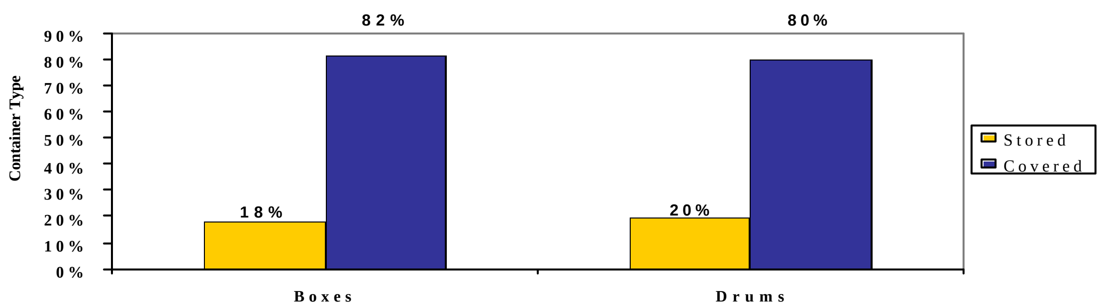


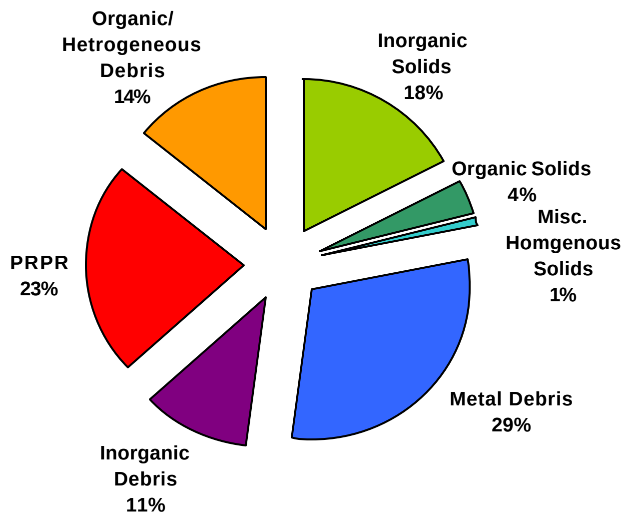
Figure 1.

In addition to the categorization based on radioactive concentration, the wastes fall into a number of groups shown in Figure 2. Within these waste groups, there are a number of items that require special handling or treatment. A good example of this is elemental mercury, which is part of the waste manifest and must be immobilized using a suitable technique, such as amalgamation. These wastes are defined within the project as Special Case Wastes (SCW).

The waste, when it was originally consigned to the RWMC was assayed using the best available techniques of the time and was shipped against the requirements for identifying and categorizing the waste. Individual drums and boxes carry with them an identification label but some were not given unique identifiers (the identifiers were given to batches of containers). Experience with trial retrievals and retrievals at other sites suggest that many drums can still be identified by the original labels. Nonetheless, it is anticipated that a number of containers, ca. 30% of the total (made up of unlabelled containers and those with no visible or readable labels) will have no useful label. There is therefore some uncertainty about the exact contents of several of the containers at retrieval, over and above the underlying variability of the waste.

TIMESCALES

The contract requires treatment of the waste to commence in 2003 and to be complete by 2015 (with a possible extension to 2018), in order to meet an agreement between the Governor of Idaho and the DOE [2]. This sets a demanding throughput for the facility, of about 7,000 m^3 per year.



AMWTP Waste Categories
Figure 2.

FATE OF THE TREATED WASTE

The 65,000 m^3 of waste must be prepared for disposal either as TRU waste (>100 nCi/g) or LLW (<10 nCi/g). The existing characterization data suggests the majority of the wastes are currently classified as TRU and will remain so during treatment. All TRU waste will be consigned to the Waste Isolation Pilot Plant (WIPP) in accordance with the WIPP Waste Acceptance Criteria (WAC). This implies that the waste must be acceptable to the shipping containers, known as TRUPACT II, and the constraints that apply to shipments to WIPP. These include:

- weight limits on individual waste packages;
- bulk weight limit of the TRUPACT II;
- treatment to prevent the accumulation of hydrogen or volatile organics in the head space of the transport containers,
- a wattage limit on the fissile content (80g equivalents of Pu-238);
- removal of PCBs, if present at greater than 50 ppm etc.

The low-level waste generated either by direct treatment of the waste or as secondary waste must be packaged to meet transport and disposal criteria.

Implicit in these waste definitions is the necessity to avoid any waste product in the range 10 nCi/g Pu equivalent to 100 nCi/g Pu equivalent. Such a waste form would be too high for disposal as LLW and falls short of the lower limit for TRU (i.e. an orphan waste).

The plan is to dispose of the TRU waste at WIPP. However, within the project provision is made to accommodate the situation where disposal WIPP is not available. In this instance, it is necessary for the TRU waste form to also meet the Land Disposal Restrictions (LDR).

ADDITIONAL CONSTRAINTS

In addition to meeting the WACs, the project must satisfy all of the safety and permitting requirements for such a plant. The project must also meet the standards set by the BNFL group as embodied in the Company Safety Health and Environment Manual (CSHEM). Furthermore, it is required that the project must demonstrate a 65 % volume reduction based on the TRU waste produced, i.e. WIPP bound waste.

The project is a privatization, which effectively means the project team is remunerated against treated product, the price of which is fixed before processing. Consequently, there is a financial target to meet as opposed to a traditional cost plus approach to waste treatment.

TECHNOLOGY SELECTION

The underlying philosophy for technology selection requires that in addition to meeting the constraints described above, the following approach be adopted. Firstly, technologies were selected with a significant track record that covers not only the functionality of the process but also its reliability, ease of maintenance, demonstrated throughput etc.

Secondly, a philosophy was developed to maximize the level of characterization of the waste at an early stage. The principle being to build upon the existing data and ensure that waste could be processed in the most effective manner. It was however recognized, that given the uncertainties and the fallibility of comprehensive characterization the process must be designed to be robust enough to cope with imperfect characterization.

It was recognized that the throughput must be sustained over a lengthy period and indeed represented a relatively high throughput for a TRU waste treatment facility when compared to worldwide survey of such facilities. Consequently, the plant design was underpinned with extensive Operations Research (OR) modeling to provide confidence in the design and to identify pinch points in the process.

The waste contains fissile material at levels that mean that a criticality cannot be precluded on the grounds of mass of fissile material alone. Thus, the flowsheet and process must be compatible with a viable criticality safety case that assures that a criticality cannot occur in the facility. This viable criticality safety case is achieved by consideration of concentration, control of feed, and instrumentation to detect the level of fissile material in the essential parts of the facility.

Since the project will consist of a number of stages, clear acceptance criteria, WACs, have been developed between the various components and processes embodied in the project. These represent the envelope of waste material around the flowsheeted values. For a particular process step, they represent both acceptance criteria and a product specification of the proceeding process(es).

THE AMWTP PROCESS

The project is effectively divided into three major phases:

- Retrieval of the waste;
- Characterization of the waste;
- Treatment of the waste.

Retrieval

Before the treatment of waste in the plant can commence, the waste must be removed from the Transuranic Storage Area, Retrieval Enclosure (TSA-RE). The TSA-RE is essentially an earthen berm covering the waste, over which a building has been constructed. The efficient retrieval of waste is crucial to the project as it allows an inventory of waste to be built up which will allow optimal processing within the plant. The types of wastes that can be retrieved are constrained by the sequence in which they were originally emplaced. Consequently, the project opted to begin retrieval early (2002) with the aim of building this inventory.

The waste will be exposed by removing the earth from the berm using techniques such as a vacuum cleaner type device; (the Guzzler) developed using DOE funding. The containers will be removed with conventional equipment such as forklift trucks. In the event of containers being breached or simply being in poor condition such that a breach cannot be precluded, the containers will be overpacked (83 gallon drums for drums or an overpack crate for boxes.) The overburden and interstitial soil will also be sampled and treated if necessary. For flowsheet purposes, conservative assumptions were made as to the level of overpacking and soil treatment required.

Characterization

The purpose of characterization is to confirm the identity of the waste where its label is still evident or assign a waste identification. The characterization should also confirm or define within the errors, known as the total measurement uncertainty (TMU), the level of fissile material in the containers. This must cope with the range of fissile materials in the waste and any possible inhomogeneities in the distribution of fissile material through the waste.

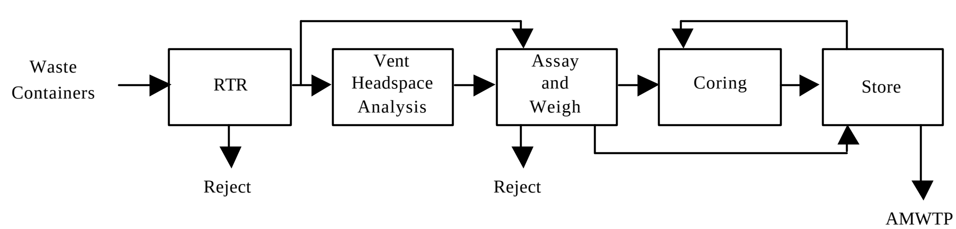
To assist in confirming the identity of waste the headspace will be sampled to detect radiolytic hydrogen or volatile organics. This process also allows the headspace to be aspirated such that any potential flammability hazard is minimized.

Finally, characterization will involve the sampling of waste to confirm and define its content. This is particularly targeted at wastes that will be consigned to the non-debris treatment route.

The characterization is carried out to build an inventory of waste for treatment. As such it will be carried out in a separate facility as opposed to within the main treatment facility and will run from the onset of retrieval and throughout the life of the treatment plant. It will therefore be necessary to move waste to and from storage to the characterization facility.

The first stage of the characterization will be achieved by Real Time Radiographic (RTR) interrogation. This equipment will identify debris and give a strong indication of the presence of sludges or process wastes, as evidenced by a homogeneous and relatively opaque RTR image. The RTR will also be used to identify such troublesome materials as massive items concealed in process waste or free liquids. It is accepted that RTR cannot infallibility identify these items and provision in made in the downstream processes to accommodate these materials.

Assay, the identification of fissile material, will be achieved by a mixture of passive and active neutron detection systems coupled with gamma detection systems. Both these assay systems and indeed RTR have been employed extensively worldwide and their use can be supported by abundant reliability and performance data. The headspace analysis will be achieved by piercing the lid of the incoming containers and fitting a filter in the resultant hole. After piercing the headspace can be sampled and analyzed using convention spectroscopic techniques e.g. infra red and mass spectroscopy. The insertion of the filter allows the containers to be handled and stored prior to introduction to the treatment facility. The equipment to meet this service is routinely used around the DOE complex. Coring waste in drums is also routinely carried out. However, the usual procedure is to take off the drum lids and replace them after coring. Since drums must be returned to storage after coring and to avoid excessive handling the project has elected to devise a system where the drum lid can be pierced, the corer inserted and the lid closed with a sealing device. This particular item is to be the subject of a development program and will avoid introducing drums to a contained and contaminated area to take the core samples. A schematic representation of the equipment in the characterization facility is shown in Figure 3.



Characterization Facility Schematic
Figure 3.

Treatment

As noted earlier the treatment of waste is driven by the different constraints on debris and non-debris waste. In the case of debris, the main drive is for volume reduction. Consequently, supercompaction of the waste was selected to achieve volume reduction and to produce a stable waste form with minimal voidage. The non-debris waste must be treated to destroy or remove the hazardous organic component and generate an acceptable waste form. In selecting the treatment route for the 22% of non-debris, careful analysis was carried out of the available options. Factors such as ability to treat the waste, demonstrated ability to meet a high throughput, maturity of the technology, avoidance of unacceptable secondary wastes, etc., were analyzed. There are a wide range of technologies identified in the literature that hold potential for performing to the required standard. Unfortunately, few have a significant track record and many are unproven and carry with them the risk associated with conceptual techniques or processes in the early stages of development. Simply recovering the hazardous materials was not desirable and aggressive or thermal destruction process recommended themselves to meet treatment and volume reduction constraints. Of the thermal processes, only incineration has been used extensively with success in treating TRU waste and hazardous materials. Having selected incineration to treat the smaller non-debris stream, a further assessment was carried out to select the detailed design concept for the incinerator. With the two core technologies in the flowsheet selected, namely supercompaction and incineration, consideration was then given to the processes to present the waste to these processes. Debris type waste is contained in both boxes and drums, whereas non-debris waste or process wastes are predominantly found in drums.

Items that fall outside of the debris/non-debris categorization must be removed from the process. A capability within the plant is required to achieve this.

The main treatment facility, Advanced Mixed Waste Treatment Facility, consists, therefore of process lines to process and open, if necessary, drums together with two lines to dismantle the boxes and repackage the contents, principally for supercompaction.

Drum Line

The drum line will only accept drums with a fissile content of ≤ 200g Pu equivalents. Drums exceeding this WAC will be rejected and stored. Entry to the drum line for drums and overpacked drums will be via an airlock system, to prevent transfer of contamination. The bulk of the drums (will proceed directly to the supercompactor without further treatment. Within the drum line, there is the capability to open drums, take samples and remove the inner liners or contents before incineration. In addition, material can be repackaged to go to the supercompactor, which is sized to accept standard 55-gallon drums.

Box Line

The box lines will accept containers through airlock doors and the containers will have lids removed to allow access to the waste, these drums are also limited by a fissile mass. After tipping the opened boxes, their contents will be size reduced and placed in 55-gallon drums prior to supercompaction. A robust manipulator with appropriate end effectors will be used to achieve size reduction and repackaging. The packaged waste from both the drum and boxlines will be moved by a central material transfer system to the supercompactor and the incinerator 'sludges' and non-debris waste can be introduced to the pretreatment for the incinerator.

Supercompaction

Supercompaction of drums of waste is a well-proven method of achieving volume reductions as high as 80%. It produces a compact that retains its shape both by plastic flow of the waste and by the restraint imposed by the distorted drum and metal or material in the drum. The diameter is restrained by a bolster device, giving the compacted waste the appearance of a large hockey puck. The larger proportion of the waste in the AMWTP (80%) will find its way to the supercompactor.

Incinerator System

The incinerator system will consist of a shredder to size reduce the incoming feed, i.e. process waste and package liners. This material will then be conveyed to the incinerator itself.

The volume of waste consigned to the incinerator is small (design treatment rate ca 650 lbs. per hour) and has a relatively low organic content compared to the feed to most incinerator systems. The results in the incoming waste having a low calorific (fuel) value and thus would not be expected to show a particularly high volume or mass reduction, perhaps ca 50%.

The incinerator is designed with a screw feed primary combustion chamber fuelled by propane. The ash falls from the auger to an ash handling system. The primary combustion chamber is insured by a secondary combustion chamber to burn the volatilized and partially burnt organics. It will be sized to accommodate organics destruction including and particularly polychlorinated biphenyls (PCBs).

A very important part of the incinerator system is the air pollution control system. This will consist of the following components with a variety of complimentary functions as defined below:

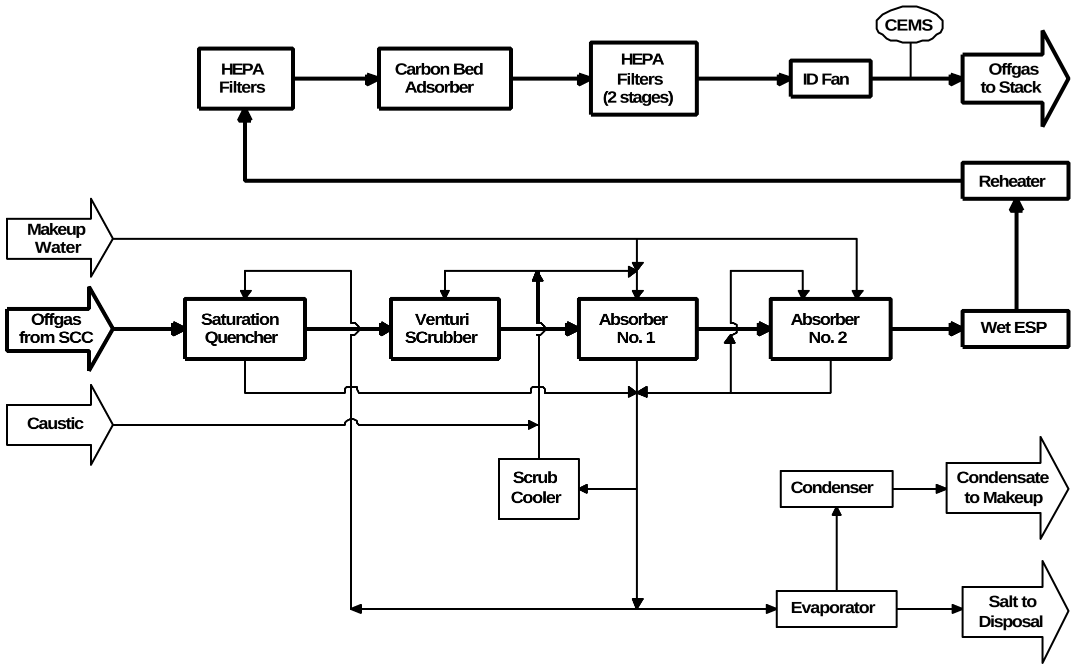
- Quench system (particulates, acidic gases and steam removal);
- Venturi scrubber (Acid gas and particulate removal);
- Two scrubber systems (acid gas removal, mercury trapping, particulate removal);
- HEPA filters (x 3) (particulate removal);
- Carbon Beds (x 2) (volatile organics and mercury vapor removal);
- Electrostatic precipitator (particulate and aerosol removal).

The flow diagram for these units is shown in Figure 4.

Waste Packaging

The pucks from the supercompactor and such massive debris items that are not amenable to supercompaction will be placed in 100-gallon drums and the waste contained within a grout envelope. This process is known as macro-encapsulation.

The ash is also contained by grout but since it is intimately mixed with the grout, the process is known as micro-encapsulation.



Air Pollution Control System Flow Chart
Figure 4

Secondary Waste

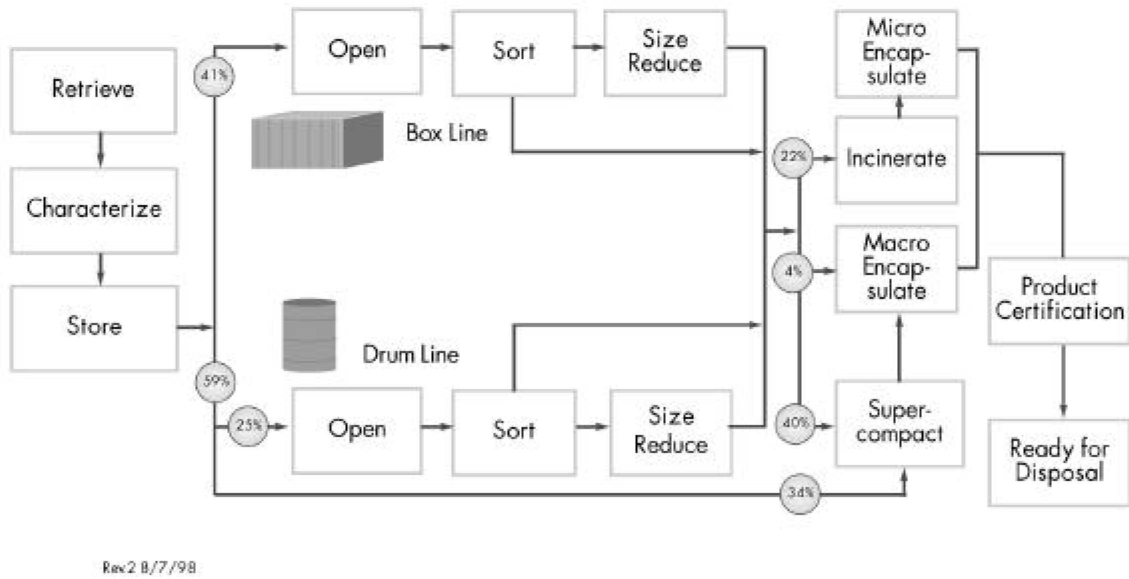
The main secondary waste, the aerial effluent from the incinerator system, is treated with the air pollution control (APC) system described previously. The aqueous residues from the APC will be evaporated and the resultant salt, principally sodium chloride, together with recovered mercury salts, will be microencapsulated. The remainder, HEPA filters and spent sorbent carbon will be returned to the process.

Secondary wastes such as liquids will also be returned to the incinerator, as sorbed material, from the SCW treatment facility where it will be analyzed and sorbed. These liquids may be contaminated liquid from SCW or decontamination activities as well as liquid inadvertently expressed from the waste during supercompaction.

A further source of significant volumes of secondary wastes include LLW derived from boxes, drums, overpacks etc. and personal protection equipment (PPE) together with maintenance waste. These wastes will be disposed of in appropriate containers to a suitable LLW site.

Integrated Flowsheet

The integrated flow diagram for the AMWTP, that is retrieval, characterization and storage, is shown in Figure 5. It is to this integrated system that the OR model is applied to test and assure the plant throughput. Whilst each component of the process can be tested in isolation the efficiency of the overall system will depend on the availability of feed, reliability, ease of maintenance, availability of staff, and impact on upstream/downstream and parallel processes. The integrated flowsheet has been extensively modeled in terms of volumetric throughput to confirm plant performance.



AMWTP Integrated Flowsheet
Figure 5.

SUMMARY

There is a frozen flowsheet for AMWTP that will meet the mission of the project both in terms of its ability to produce an acceptable waste form and to meet the required throughput. The flowsheet will also meet the primary requirement of achieving the treatment of the waste safely using proven or extensively tested equipment.

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