1 of 1

*Technical Area Status
Report for Chemical/
Physical Treatment
Volume I*

*Prepared for:
U.S. Department of Energy
under contract
number DE-AC05-84OR21400*

May 1993

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**TECHNICAL AREA STATUS REPORT
FOR
CHEMICAL/PHYSICAL TREATMENT
VOLUME I**

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Prepared for the
U.S. DEPARTMENT OF ENERGY
OFFICE OF TECHNOLOGY DEVELOPMENT
Washington, D.C. 20585

August 1993

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for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC01-⁹²EW30030

MASTER

ACKNOWLEDGEMENTS

The authors would like to acknowledge the help and support of the entire Chemical/Physical Treatment Technical Support Group. This group identified potential technologies applicable to the Chemical/Physical Treatment System and provided technology descriptions and evaluations for the appendices. In addition to the authors, the members of this group are as follows: Charles Baldwin, EG&G Rocky Flats; David Chaiko, Argonne National Laboratory; Garry Bryan, Pacific Northwest Laboratory; Rick Moats, BDM Federal; Thurman Cooper, Westinghouse Hanford Corporation; Bob Gehrke, EG&G Idaho; Michael Baker, Martin Marietta Energy Systems Y-12 Plant; Bob Hickman, Lawrence Livermore National Laboratory; John Morrey, Pacific Northwest Laboratory; and Ellen Stallings, Los Alamos National Laboratory. In addition, the following individuals from the BDM Federal/Germantown staff helped in preparing this report: Paula Sydenstricker, Joe Lippold, Bill Dassing, Rod Debrew, Carroll Collier, and Geri Maher; Wayne Kot of the SAIC/Germantown staff also provided assistance. This support was provided under contract DE-AC01-93EW50512. We would also like to thank Stan Wolf, Division Director for Office of Research and Development, Waste Management Division (EM-542); Paul Lurk (EM-552); Paul Hart, the MWIP Program Manager; and Jan Berry, the MWIP Coordinator for supporting this effort.

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ACRONYMS

ASME	American Society of Mechanical Engineers
BRC	Below Regulatory Concern
BWR	Boiling Water Reactor
CPTS	Chemical/Physical Treatment System
DF	Decontamination Factor
DOE	Department of Energy
EM	Office of Environmental Restoration and Waste Management
EPA	Environmental Protection Agency
ES&H	Environmental Safety and Health
F&OR	Functional and Operational Requirements
FEH	Front-end Handling
FFCA	Federal Facility Compliance Agreement
FWF	Final Waste Forms
HEPA	High-Efficiency Particulate Air
IGR	Institute of Gas Research
LDR	Land Disposal Restrictions
LLMW	Low-level Mixed Wastes
LLW	Low-level Waste
MVR	Mechanical Vapor Recompression
MW	Mixed Waste
MWIP	Mixed Waste Integrated Program
MWTP	Mixed Waste Treatment Plant
MWTP	Mixed Waste Treatment Project
NPDES	National Pollution Discharge Elimination System
OGT	Offgas Treatment
OTD	Office of Technology Development
PCB	Polychlorinated biphenyl
PCE	Perchloroethylene
PWR	Pressurized Water Reactor
RCRA	Resource Conservation and Recovery Act
RDDT&E	Research, Development, Demonstration Test and Evaluation
RF	Radio Frequency
RO	Reverse Osmosis
SF	Separation factor
TASR	Technology Area Status Report
TCE	Trichloroethylene
TDS	Total Dissolved Solids
TSG	Technical Support Group
TTP	Technical Task Plan
UHPW	Ultra High Pressure Water
UV	Ultraviolet
VOC	Volatile Organic Compound
VR	Volume Reduction
WDS	Waste Destruction and Stabilization

EXECUTIVE SUMMARY

The Office of Environmental Restoration and Waste Management (EM) was established by the Department of Energy (DOE) to direct and coordinate waste management and site remediation programs and activities throughout the DOE Complex. The Mixed Waste Integrated Program (MWIP) was created by the DOE Office of Technology Development (OTD) to develop, deploy, and complete appropriate technologies for the treatment of all DOE low-level mixed waste (LLMW). The MWIP mission includes development of strategies related to enhanced waste form production, improvements to and testing of the EM-30 baseline flowsheet for mixed waste treatment, programmatic oversight for ongoing technical projects, and specific technical tasks related to the site specific Federal Facilities Compliance Agreement (FFCA).

The MWIP has established five Technical Support Groups (TSGs) based on primary functional areas of the Mixed Waste Treatment Plant (MWTP) identified by EM-30. These TSGs are: (1) Front-End Waste Handling, (2) Chemical/Physical Treatment, (3) Waste Destruction and Stabilization, (4) Second-stage Destruction and Offgas Treatment, and (5) Final Waste Forms. The focus of this document is the Chemical/Physical Treatment System (CPTS).

The CPTS performs the required pretreatment and/or separations on the waste streams passing through the system for discharge to the environment or efficient downstream processing. Downstream processing can include all system components except Front-End Waste Handling. The primary separations to be considered by the CPTS are: (1) removal of suspended and dissolved solids from aqueous and liquid organic streams, (2) separation of water from organic liquids, (3) treatment of wet and dry solids, including separation into constituents as required, for subsequent thermal treatment and final form processing, (4) mercury removal and control, and (5) decontamination of equipment and waste classified as debris. A primary deliverable from the CPTS TSG is a Technical Area Status Report (TASR). The TASR (this report) is designed to identify available technologies and commercial equipment, compare available and/or developing technologies to the baseline MWTP flowsheet, evaluate these technologies, and recommend modifications that will improve the baseline design concept. A natural product from the TASR exercise is the identification of knowledge/technology gaps which will lead to RDDT&E requirements for the CPTS.

APPROACH

Development of the CPTS is viewed as a three-step process. We are currently in the first step of the process. The process will identify needs and gaps in not only the CPTS but the entire MWTP system. The current draft of the TASR documents progress to date in setting up the structure for the evaluation process, information gathering to perform the analysis, and conclusions reached based on an informal analysis.

The first step involves setting system requirements and developing information related to process options. Since very little information relative to definitive requirements exists, judicious assumptions are made. Three sets of system requirements are put forth that encompass the estimated range of requirements. These consist of: (1) a simplified MWTP in which only minimal separations take place, (2) an augmented concept in which "problematic" constituents (chloride, sulfate, phosphate, heavy metals, and selected radionuclides) are removed, and (3) a second flowsheet augmentation in which the requirement to separate radionuclides from RCRA hazardous constituents is imposed. Given these three possibilities for system requirements, lists of potential technologies were developed. Detailed information on approximately 60 technologies was gathered for evaluation. This information is presented in the Appendices to the main report. The technologies fit into the broad categories of: solid (dissolved and suspended)/liquid, liquid/liquid, and solid/solid separations. Given the system requirements and potential technologies, a methodology must be followed to select the most appropriate technology(s) for a given application. The method proposed for this exercise is embodied in technology selection charts. One chart has been put forth in the report for each of the major waste feeds to the CPTS. The technology selection charts are proposed as a method to visualize the relationship between technologies and needs and to identify the ramifications of decisions. All decisions must be made in the system's context.

The second stage of the process will involve incorporation of ES&H requirements. The choice and sequence of technologies will be evaluated with regard to concerns such as contamination of downstream equipment and the specific requirements posed by unique processing constraints e.g., gloveboxes.

The third stage involves evaluation of the CPTS as a stand-alone system as well as a system integrated into the MWTP. This will be an iterative process utilized to optimize capabilities as well as cost.

STATUS

Most of the information required to conduct the somewhat rigorous three-stage analysis outlined above has been gathered and is summarized in this report. The framework for the analysis has been set, system requirements have been proposed, detailed information on technologies has been gathered, technology selection charts have been developed, and data requirements have been proposed. The analysis will proceed in the coming months to produce proposed, and technically defensible, alternatives to the MWTP baseline flowsheet. A non-rigorous assessment of technical needs has been performed and is summarized below.

RECOMMENDATIONS AND CONCLUSIONS

Based on analyses to date, and discussions with other TSGs, the following KDDT&E needs for the CPTS have been identified:

- * ***Mercury Processing.*** An understanding of the fundamentals associated with removal of mercury from the various host matrices must be developed as well as methods for removal from offgas and subsequent purification.
- * ***Aqueous Processing.*** Efforts needed in this area include how to process water most effectively to remove salts, evaluation of alternatives to the baseline treatment scheme, analysis and testing of the baseline approach, and evaluation of methods for recycling salts.
- * ***Decontamination.*** Decontamination for hazardous and radioactive species removal will be required for containers, heterogeneous waste, and potentially for waste classified as debris. New decontamination technologies, including industrial approaches, are required to minimize generation of secondary wastes.
- * ***Wet Solids Processing.*** Salts may cause significant processing problems in the Waste Destruction and Stabilization (WDS), Final Waste Forms (FWF), and Offgas Treatment (OGT) Systems. The two major waste streams containing salts are the aqueous and wet solids streams. Approaches to salt removal (such as leaching), segregation and final disposition are required.

CHEMICAL/PHYSICAL TREATMENT SYSTEM TECHNOLOGY AREA STATUS REPORT

SECTION 1 INTRODUCTION

1.1 BACKGROUND

The Office of Environmental Restoration and Waste Management (EM) was established by the Department of Energy (DOE) to direct and coordinate waste management and site remediation programs and activities throughout the DOE complex. To successfully achieve the goal of properly managing waste and cleanup of the DOE sites, EM was divided into five organizations: the Office of Planning and Resource Management (EM-10); the Office of Environmental Quality Assurance and Resource Management (EM-20); the Office of Waste Operations (EM-30); the Office of Environmental Restoration (EM-40); and the Office of Technology Development (EM-50).

The mission of the Office of Technology Development (OTD) is to develop treatment technologies for the operational and environmental restoration wastes where current treatment technologies are inadequate or not available. The Mixed Waste Integrated Program (MWIP) was created by OTD to assist in the development of treatment technologies for the DOE low-level mixed wastes (LLMW). Currently, much of the DOE's large inventory of LLMW is out of compliance with the Land Disposal Restrictions (LDRs) promulgated by the Environmental Protection Agency (EPA), making treatment of these wastes an important issue.

The MWIP is developing a unified approach for the treatment of all DOE LLMW presently in inventory and which is being generated. Although much of DOE's LLMW may be treated by available treatment facilities, the MWIP is developing more cost-effective, lower risk approaches. This is being done through coordination with the Mixed Waste Treatment Project (MWTP), under the auspices of the Office of Waste Management (OWM). The MWTP is developing a commercial baseline system, whereas the MWIP is developing system requirements for production of an acceptable final waste form, and improvements to the baseline system through testing and innovative technology. This treatment facility will include front-end handling capabilities and all processes through the generation of a stable waste form that is ready for final disposal.

Thus, the mission of the MWIP is to develop, for deployment, complete and appropriate technologies for the treatment of all DOE mixed low-level and transuranic wastes. Goals have

been established to achieve the stated mission through development of innovative technologies, and evaluation of existing technology for application to mixed waste treatment problems. These goals are as follows (Ref. 1):

- * Assess whether production of enhanced waste form(s) for low-level mixed waste makes sense.
- * Develop appropriate improvements to the baseline treatment scheme as identified by the MWTP.
- * Integrate mixed waste technical initiatives within OTD, and with OWM and the states.
- * Provide technical reviews and define key technical requirements, monitor progress, and incorporate data from mixed waste related technical initiatives within the OTD; and contribute to the evaluation of site-specific Federal Facility Compliance Agreement (FFCA) related work.

The DOE has established criteria that successful treatment technologies must achieve. The treatment technologies must be socially and politically acceptable; cost effective; and the final waste form must be able to meet or exceed all of the applicable regulatory requirements as mandated by the DOE, EPA, and state agencies. In addition, the treatment technologies that are developed must allow the DOE to meet the requirements in the FFCAs.

1.1.1 TSG Responsibilities

To achieve these goals, the MWIP has established five Technical Support Groups (TSGs), shown in Figure 1-1, based on the primary functional areas of the Mixed Waste Treatment Plant identified by EM-30. These TSGs are: (1) Front-End waste Handling (FEH), (2) Chemical/Physical Treatment (CPT), (3) Waste Destruction and Stabilization (WDS), (4) Offgas Treatment (OGT), and (5) Final Waste Forms production/assessment (FWF). Each TSG has assembled experts in areas pertinent to the particular TSG functional requirements.

The MWIP is responsible for issuing solicitations for Technical Task Plans (TTPs). The TTPs are the mechanisms that allow researchers to submit proposals and receive funding for the development and/or improvement of treatment technologies as determined to be needed by the TSGs or the Office of Waste Management (EM-30). The function of the TSGs is to identify

Figure 1-1. Mixed Waste Integrated Program Work Breakdown Structure

technology needs, review submitted TTPs, prioritize them, and make recommendations for use by DOE Headquarters in their funding decisions. The intent of this process is to identify the options available to address the treatment needs and to judge the relative ability of these options to meet the needs of DOE, including schedule constraints. In summary, the TSG responsibilities include:

- * Determine treatment technology needs.
- * Assess available treatment technologies against identified needs.
- * Identify potential new and evolving treatment technologies.
- * Maintain communication with other MWIP members, other TSGs including the systems analysis and waste characterization functions, and other ID's and IP's.
- * Develop a systematic approach that will provide a defensible rationale for the selection and funding of TTPs.
- * Assure that all developmental activities generate quality data.
- * Evaluate the progress of treatment technology development.

Once the TTPs are funded, the TSGs are responsible for ensuring that all developmental activities generate quality data, are on schedule, and within budget. With quality data, MWIP can then select the technologies with the greatest potential for successfully treating DOE LLMW. Pilot-scale demonstrations of these technologies will determine necessary design and operational parameters. Finally, MWIP will assist Waste Operations (EM-30) and Environmental Restoration (EM-40) in applying these technologies on a full-scale basis, providing technical support throughout the design, construction, startup, and operation of the treatment systems. The end result of this work will be to develop and demonstrate technologies that are safe, cost-effective, and can adequately treat the DOE LLMW to meet all appropriate requirements.

1.1.2 Chemical/Physical Treatment Technical Support Group

The purpose of the Chemical/Physical Treatment System (CPTS) is to perform the required pretreatment and/or separations on the waste streams passing through the CPTS for discharge or efficient downstream processing. Downstream processing includes waste

destruction and stabilization, offgas treatment, and final forms production; each of which constitute a system within the overall mixed waste treatment plant. Aqueous waste is processed for discharge through a National Pollution Discharge Elimination System (NPDES) discharge point or is recycled within the MWTP for process use. To achieve the goals of the MWTP, the tasks of the Chemical/Physical Treatment System (CPTS) TSG are as follows (Ref. 2):

- * Identify required CPTS capabilities and functions, existing technologies capable of meeting these functions, knowledge/technology gaps in these existing technologies, and technology deficiencies and associated RDDT&E requirements. These needs will be developed in coordination with EM-30, other TSG's, and specific sites.
- * Identify appropriate available pretreatment technologies that are required to prepare waste streams for primary treatment, such as destruction and stabilization technologies, or for final forms production. This includes development of chemical and physical treatment and separation technologies for:
 - Removal of suspended and dissolved solids from the aqueous stream and treatment of the aqueous stream to allow water discharge.
 - Separation of water and solids from organic liquids.
 - Treatment of wet and dry solids, including separation into constituents as required, for subsequent thermal treatment and final form processing.
 - Mercury removal and control.
 - Decontamination of equipment and waste classified as debris.
- * Develop a Technical Area Status Report (TASR) that identifies available technologies and commercial equipment applications, compares available and/or developing technologies to the baseline MWTP, evaluates these technologies, and recommends modifications to improve the baseline design concept. An outcome of this evaluation will be the development of an improved, lower cost mixed waste treatment system.
- * Review, evaluate, and prioritize proposals in the form of Technical Task Plans submitted to satisfy the identified needs.

- * Develop process specifications for pretreatment technologies for use in pilot plant facilities, and develop data requirements for pilot tests and review test plans.
- * Sponsor bench-scale studies as necessary to complete assessment of technologies that remove/separate species that are problematic to the WDS or OCT Systems, or to the production of enhanced waste forms.

The CPTS TSG was formed in FY 1993, and identification of technologies potentially applicable to the CPTS was begun in October of FY93. This technology list was expanded by the TSG in November at which time the research was begun for this TASR. Prior to this, the TSG identified specific needs for nitrate destruction and mercury removal from the various waste streams. Work has been completed to identify and evaluate nitrate destruction (Ref. 3) and mercury removal (Ref. 4) technologies.

1.2 OBJECTIVES

A long-term goal of the CPTS TSG is to develop a set of process specifications for non-baseline chemical/physical treatment technologies suitable for pilot system design and testing. The achievement of this goal will require significant coordination with the MWIP Systems analysis group and other TSGs to develop system specifications that define interfaces, input stream characteristics, and CPTS output stream characteristics required by downstream systems. Achievement of this goal will require meeting the following objectives:

- * Develop information regarding current and emerging technologies applicable to the CPTS.
- * Assess performance and identify deficiencies and the need for improvement of current technologies.
- * Evaluate current technologies against specified criteria, in a systems context.
- * Evaluate emerging technologies for performance compared to deficiencies in current technologies.
- * Identify which emerging technologies are worthy of continued development that will (1) make improvements to the baseline system to produce an enhanced final form; and (2) make improvements over the baseline in life-cycle cost, risk, and performance.

- * Perform technology/equipment trade-off studies with respect to established criteria.
- * Determine the development strategy for worthy emerging technologies that will address deficiencies and system needs.
- * Issue a report summarizing our conclusions and the basis of those conclusions.

This Technology Area Status Report provides several functions: it is the first step in defining requirements for the MWTP, and therefore, for the CPTS; it provides the initial investigation to identify, describe, and evaluate technologies applicable to the chemical and physical treatment portion of the mixed waste treatment plant, providing initial information required to achieve the goals of the CPTS; and allows identification of key issues required to process high priority waste streams. The current focus is on separation technologies applicable to liquid/liquid, and solid/liquid separations. However, this will be a living document that will change as additional information becomes available regarding the characteristics of the input waste streams, the requirements of the treatment and final form processes, and the characteristics of the various technologies. The ultimate goal is to improve upon the baseline treatment schemes, which consist of specific commercially available technologies, as currently identified by the Mixed Waste Treatment Project (Ref's. 5 and 6) and by site-specific treatment plans.

Proper selection of separation technologies is necessary to maximize performance, and to minimize capital and operating costs. In this preliminary report, information is developed that will lead to selection of appropriate technologies and the achievement of the CPTS goals. The focus of this initial effort is on commercial equipment or existing processes to determine where various technologies can or should be applied, the range of application, equipment performance bands, tests required to show applicability, and modifications and/or development efforts required to bring the equipment or process into compliance with the needs of the MWTP and site-specific treatment plans. As the system requirements are better defined, the technologies can be evaluated and selected based on specific system requirements. Knowledge of the capabilities of existing commercial equipment and processes, and knowledge of the waste treatment requirements, will allow determination of technology gaps and requirements for RDDT&E. Knowledge gaps will be identified that will serve as a basis for a coherent test approach and waste stream characterization to support technology and subsequent equipment selection.

1.3 CHEMICAL/PHYSICAL SYSTEM DESCRIPTION

The purpose of the CPTS is to process the incoming waste streams prior to destruction and stabilization and/or final forms processing. Input to the CPTS comes from the front-end handling system of the MWTP, and the output goes to the waste destruction, final forms or offgas systems. The incoming waste streams include aqueous, organic liquid, and wet solids. Homogeneous and heterogeneous dry solids enter the CPTS only if decontamination or leaching of selected species is required. In addition, the CPTS removes mercury from the waste streams, and performs decontamination on equipment, empty waste drums, and specified debris.

1.3.1 Interfaces

The CPTS receives waste from the Front-End Handling (FEH) System, performs the required separation and processing functions, and delivers the processed waste to the Waste Destruction and Stabilization (WDS) or Final Waste Forms (FWF) Systems. The Front-End Handling System has the responsibility for solid/solid separation of homogeneous and heterogeneous dry solids; however, the CPTS has as yet unspecified decontamination responsibilities for these solids. Offgas from the CPTS processes is treated in the Offgas Treatment (OGT) System.

The FEH System receives externally and internally generated waste streams, characterizes and segregates the waste, and transfers the waste to the appropriate processing line. Solid wastes are reduced in size and classified according to size, as required. Solid wastes are also separated into light and heavy combustibles, magnetic and non-magnetic metals, and inert solids. Waste streams sent to the CPTS include aqueous, liquid organics, wet solids, mercury contaminated wastes, and solids requiring decontamination. As discussed in Section 1.3.3, if there are specific separation requirements, dry solids may be sent through the CPTS to leach out problem species prior to sending the dry solids to the WDS or FWF Systems.

After processing in the CPTS, organic liquids and dry solids, which may have organic constituents, are sent to the WDS System for destruction of the organics. Dry inorganic solids are sent to the FWF System to be processed into a final waste form. The offgas from all systems is processed through the OGT System. Internal wastes, including scrubber solutions and other offgas system wastes, and decontamination wastes are processed through the CPTS.

1.3.2 Waste Stream Characteristics

The waste streams considered by MWIP are the DOE LLMWs as identified by the EM-30 Mixed Waste Treatment Project. The MWTP waste streams are divided into seven general categories listed below. Further descriptions of each waste category and subcategory are provided in References 5 through 7.

- * ***Aqueous Liquids.*** Aqueous liquids contain less than 1% organic content and are pumpable. This includes solutions and slurries containing less than approximately 40% suspended solids. This category includes corrosive acids, corrosive bases, reactive cyanides, and toxic metals. Contaminants include mercury, lead, and trace amounts of other toxic metals and hazardous organics. Internally generated streams include decontamination solutions, scrubber solutions containing metal chlorides, and condensate that does not meet disposal criteria.
- * ***Organic Liquids.*** Organic liquids include more than 1% organic content and most, but not all, streams are pumpable. This category includes non-halogenated organics, halogenated organics, and scintillation cocktails. Other contaminants include mercury and trace amounts of other toxic metals. Internally generated streams include solvents used in decontamination or to leach hazardous species from dry wastes. This waste stream represents a small fraction of the mixed low-level waste inventory.
- * ***Inorganic Solids.*** Inorganic solids contain wet and dry solids. The wet inorganic solids are not pumpable and include sludges, filter cakes, residues, absorbed liquid in vermiculite or clay, ion exchange resins, and salt cake. The wet solids waste stream represents the largest fraction of the mixed low-level waste inventory. Dry inorganic solids include processing salts, grouted or cemented sludges, ash, dust, soil, glass, ceramic crucibles, and brick. Unless specific species must be separated from the dry inorganic solid stream, or unless this stream requires decontamination, only the wet solids are processed in the CPTS.
- * ***Metal Wastes.*** Metal wastes include mixed ferrous and nonferrous metal pieces of various sizes and shapes. This category also includes liquid mercury, lead in the form of bricks, shipping casks, or shielding materials, and activated lead. Contaminants include trace amounts of other toxic metals. Mercury is the only metal

processed through the CPTS unless decontamination is required or specific species must be removed from the metal wastes.

- * **Organic Solids.** Organic solids include wet organics, paints and paint residues, resins, animal carcasses, wood, plastic, rubber, paper, cloth, rags, sludges, asphalt, graphite, and carbon. Unless specific species must be separated from these solids, they are sent directly to the WDS System and not processed through the CPTS.
- * **Heterogeneous Solids.** Heterogeneous wastes include mixtures of organic, inorganic, and metallic wastes. This category includes construction, cleanup and process debris, lab packs, gloveboxes, HEPA filters, reactor equipment, glovebox gloves, shielding aprons, lead acid batteries, and mercury-contaminated materials. Heterogeneous wastes also include trace amounts of other toxic metals. Mercury contaminated material is the only heterogeneous waste processed through the CPTS unless decontamination is required or specific species must be removed from the other heterogeneous wastes.
- * **Special Wastes.** Special wastes include waste streams that require extra care for treatment. This category includes tritium wastes, pyrophorics, nitrated rags and filters, compressed gases, beryllium wastes, and PCB solids and liquids. Several of these wastes will be processed through the CPTS; however, the detailed technology needs and capabilities have not been identified as of this writing.

1.3.3 CPTS Requirements and Configurations

The requirements of the CPTS, and the technologies needed to meet those requirements, are a function of the characteristics of the waste streams entering the CPTS and the requirements of the downstream processes or discharge limits (e.g., NPDES). That is, the requirements of the WDS, FWF and OGT Systems for the waste delivered to them for treatment by the CPTS. These requirements may take the form of physical characteristics (e.g., particulate size distribution) or chemical characteristics (e.g., salt content, pH, etc.). Requirements on the chemical characteristics may include maximum water content, or removal of species that may overload the offgas system or prevent the production of a final waste form that meets the land disposal restrictions.

Potential problem areas, as identified by the other TSGs, include difficulty in processing chlorides, nitrates, high sulfur, phosphorous, and chromium bearing salts in the WDS System.

The FWF System will have difficulty processing these materials, as well as carbon and metals, to produce an enhanced waste form (i.e., glass). Carbon from the CPTS will be sent to the WDS for incineration and metals will be removed from the solid waste streams and sent to the WDS metal melters. In general, the salts are constituents of the aqueous stream and will not be sent to the WDS; however, they will be sent to FWF as a homogeneous dry solid. These salts will require disposal whether selectively separated or separated from the aqueous stream as an aggregate. If they pose problems with glass production, then a different type of waste form (i.e., polymer cement, grout, ceramic, etc.) may be required.

Another problem area is micron size particulates that may clog burners in the WDS System, or blind filters on the OGT System. Volatile metals (Hg, Tc, Cs, Pu, Pb, or Be) or metal chlorides may be given off during WDS treatment or during vitrification and captured in the OGT System. This internally generated waste stream will be processed in the CPTS and the resulting dry solids, including chloride salts, sent to the FWF System for disposal.

Due to the lack of specific waste characterization and downstream process requirements, and the variations in character and composition among waste streams, trade-offs must be made regarding the application of the CPTS. Selective separation techniques to remove difficult to treat species, or to remove radioactive components, cannot be determined *a priori* since the characteristics and composition of the incoming waste is not known, and will not be known until the waste arrives at the MWTP. Since the treatment process will be a batch, rather than continuous process, any selective separation methodologies must be determined on a batch-by-batch basis, and each batch must be well characterized to determine the appropriate separation techniques. However, characterization of each batch of waste will be expensive, and the cost of providing a large number of technologies to handle every eventuality of waste composition will be prohibitive.

The CPTS can be configured in various ways depending on the process requirements. Candidate technologies for meeting these requirements are described in the appendices. Possible configurations are discussed in the following sections.

1.3.3.1 Configuration #1: Simplified Configuration

The simplified configuration is a conceptual foundation upon which additional requirements and alternative processes will be superimposed. This system includes separation

Figure 1-2. Simplified CPTS Configuration

of organic material from the aqueous stream, separation of water from the organic stream, and separation of particulates and dissolved solids in aggregate from the liquid waste streams. This is the least expensive and least complex level of separation for the expected wide variations in the waste streams entering the CPTS.

Organic liquids and aqueous waste will be separated in the CPTS. This is fairly easy to accomplish with existing, inexpensive technologies, although modifications and improvements to the technologies may be required. Particulates can be removed through various filtration and/or membrane processes, and dissolved solids and remaining suspended solids can be removed from the aqueous stream by evaporation and drying. The aggregate dry salts would then be sent to the FWF System for processing.

1.3.3.2 Configuration #2: Removal of Problem Species

This configuration, depicted in Figure 1-3, involves separation of compounds and/or species that may interfere with downstream processes including waste destruction, offgas processing, and FWF production or FWF disposal requirements. Technologies are being investigated for the separation of mercury from the various waste streams and the destruction of nitrates. However, selective separation of the many other species that could cause downstream difficulties may be difficult and expensive to achieve, in addition to generating an increase in waste volume to be processed due to the washing of wet and dry solids.

Trade-offs need to be made regarding the most effective and least expensive manner of processing these species. For example, instead of trying to separate these species from “dirty” waste streams in the CPTS, it may be more cost effective to process the waste downstream, collect the species (i.e., metal chlorides, volatile metals, sulfates, etc.) in the OGT, and process the resulting OGT “clean” waste (e.g., scrubber blowdown) through the CPTS. The resulting dry inorganic salts would then be processed into a final form in the FWF System.

Even if the species that cause problems with glass formation are removed from the waste stream, they must eventually be dealt with in the FWF System as a concentrated salt and subsequently disposed. Waste forms other than glass may be required to immobilize certain species. If no waste form is available that will meet leachability criteria for specific species, then these species will require selective removal from the waste matrix in the CPTS; however, these requirements have not been identified at this time.

Figure 1-3. CPTS Configuration #2: Removal of Problem Constituents

1.3.3.3 Configuration #3: Separation of Radioisotopes from RCRA Hazardous Materials

This configuration, shown in Figure 1-4, involves separation of radioisotopes from hazardous (RCRA) materials and has the same problems associated with separation of selected problem species. Separation of radioisotopes from RCRA hazardous materials may have an advantage in that the two resulting streams may now be disposed of separately as low-level waste and hazardous waste. However, from a regulatory standpoint, separate disposal may be difficult to achieve. This level of separation may involve complex processes and may be expensive to achieve. For example, several different chemicals for precipitation may be required along with several pH changes and precipitation tanks, or several different sequestering or chelating agents may be required. If sequestering agents are used, various solvents may be required to remove the sequestered species in order to recycle the sequestering agent. Heavy metals may be removed or co-precipitated with the species of interest requiring additional downstream processing. Significant preprocessing may also be required to remove species that would interfere with the separation process. Finally, if it is necessary to separate radioisotopes from heavy metals, then all the wet and dry solids will require washing, leaching and/or decontamination which would greatly increase the volume of waste requiring processing.

If the non-radioactive portion of the waste must be further separated to remove species that may cause downstream processing problems, then a combination of configurations 2 and 3 will be required. This will significantly increase the complexity and cost of the CPTS, and increase the waste stream characterization requirements. These issues will be resolved over time through coordination with EM-30, specific sites, and the WDS and FWF TSGs.

1.4 SCOPE OF TECHNOLOGY AREA STATUS REPORT (TASR)

A variety of separation technologies will be described in this report, and subsequently evaluated not only for their versatility for processing variable waste streams, but also for their ability to selectively remove specific species if required. However, alternate CPTSs will be recommended that are less expensive than the baseline, require less equipment and are less complicated, are sufficiently versatile to accommodate wide variations in the input stream character and composition, and produce an aggregated dry solid to be sent to the FWF System. If it is eventually determined that specific constituents must be selectively separated from the waste stream, then specific technologies will be evaluated for this selective separation and alternate CPTSs recommended to achieve these goals.

Figure 1-4. CPTS Configuration #3: Separation of Radionuclides and RCRA Hazardous Materials

Initially, the CPTS was to include solid/solid separation on the homogeneous and heterogeneous dry solid waste streams. However, subsequent discussions have led to the transfer of these solid/solid separation processes (i.e., electrostatic separation, gravity separators, Trommel screens, etc.) to the Front-End Handling System TSG. These technologies will be included in the FEH TASR. Thus, the focus for CPTS technology evaluation is on those technologies that perform solid/liquid and liquid/liquid separation, species separation and mercury separation technologies, and decontamination technologies.

In general, destruction technologies, including non-thermal destruction, are part of the WDS System. However, certain destruction technologies for specific species, such as nitrate destruction, are included. In addition, commercial systems that include catalytic oxidation of organics in an offgas stream produced from an upstream separation process is included. However, in most cases, the offgas from a separation process will be sent to the offgas system for processing.

The CPTS has the broadest range of contaminants and potential technologies to be evaluated. The technologies that are described in the Appendices are listed in Table 1-1.

There is obviously some overlap between technologies: evaporation will concentrate solids in the bottom stream, as well as drive off low-boiling-point volatile organics; membrane technologies can be used to separate dissolved solids as well as large molecule liquid organics from water; and freeze crystallization can separate solids, organics and water. Steam reforming will destroy organics as well as nitrates and may be considered as part of the WDS System or the CPTS.

These technologies are described in detail in the Appendices. The objective is to provide sufficient information to evaluate the technologies in terms of applicability, effectiveness, and cost. Because details of the input waste streams, and requirements for the output streams from the CPTS, are not known, ranges of applicability and general effectiveness are provided. Advantages and disadvantages of each technology are described, and demonstrated performance of vendor equipment, or equipment at DOE field sites, is described. Demonstrations and tests required to validate the technology or equipment for the MWTP are also identified.

Section 2 of this report summarizes the approach for evaluating technologies, identifying RDDT&E requirements, and developing alternate systems. In Section 3, the CPTS is described with respect to the baseline Functional and Operational Requirements (F&ORs) (Ref's. 5 and 6), and alternate process concepts are discussed. Data and test requirements for evaluating

TABLE 1-1. CHEMICAL/PHYSICAL SEPARATION TECHNOLOGIES

Solid/Liquid Separation Technologies		
<ul style="list-style-type: none"> • Chemical Techniques <ul style="list-style-type: none"> - Neutralization - Coagulation/Flocculation • Biological Processing • Media Beds <ul style="list-style-type: none"> - Activated Carbon Adsorption - Non-Carbon Adsorption • Membranes <ul style="list-style-type: none"> - Reverse Osmosis - Ultrafiltration • Electrolysis • Electrokinetic Techniques • Thermal <ul style="list-style-type: none"> - Conventional Evaporation • Solvent Extraction • Nitrate Destruction <ul style="list-style-type: none"> - NAC Conversion - Electrochemical Ion Exchange - Chemical Reduction • Mechanical Separation <ul style="list-style-type: none"> - Sedimentation - Centrifugation • Electromagnetic Techniques <ul style="list-style-type: none"> - High Field Gradient Magnetic 	<ul style="list-style-type: none"> - Surfactants - Oxidation/Reduction - Chromatography - Ion Exchange Beds - Electrodialysis - Supported Liquid Membranes - Drying - Hydrothermal Processes - Calcination - Salt Splitting - Hydrocyclones - Flotation - Conventional Magnetic 	<ul style="list-style-type: none"> - Pyrochemical Processing - Precipitation - Affinity Chromatography - Biosorption - Microfiltration - Thin-Film Evaporation - Bionitrification - High Temperature Processes - Filtration
Liquid/Liquid Separation Technologies		
<ul style="list-style-type: none"> • Media Beds <ul style="list-style-type: none"> - Granular Activated Carbon • Distillation • Steam Stripping • Air Stripping • Mechanical Techniques <ul style="list-style-type: none"> - Centrifugation - Plate Settlers • Membranes <ul style="list-style-type: none"> - Pervaporation - Ultrafiltration 	<ul style="list-style-type: none"> - Biosorption - Flotation - Gravity Settlers - Microfiltration - Supported Liquid Membranes 	<ul style="list-style-type: none"> - Powdered Activated Carbon - Coalescers
Mercury Removal Technologies		
<ul style="list-style-type: none"> • Combustible Solids <ul style="list-style-type: none"> - Incineration • Noncombustible Solids <ul style="list-style-type: none"> - Acid Leach • Aqueous Liquids <ul style="list-style-type: none"> - Sulfide Precipitation - Cation Resins • Gases <ul style="list-style-type: none"> - Mersorb Pellets 	<ul style="list-style-type: none"> - Halide Complex Formation - Anion Exchange - Chelating Resins - Boliden/Norzinc Process 	<ul style="list-style-type: none"> - Mercury Polysulfide - 3M/BC Membrane
Decontamination Technologies		
<ul style="list-style-type: none"> • Mechanical Surface Removal Methods • Thermal Surface Removal Methods • Surface Cleaning Methods • Metal Refining Methods • Chemical Surface Cleaning Methods • Bulk Decontamination Methods 		

processes and equipment are discussed in Section 4, and recommendations based on the technology evaluation are provided in Section 5.

1.5 FUTURE EFFORTS

For the remainder of FY93, the CPTS TSG will perform the following tasks:

- * Continue to fill in the technology knowledge gaps for subsequent versions of the TASR.
- * Begin contacts with industry, DOE facilities, and academia to identify technology development efforts needed to meet the MWTP requirements, document experience with existing technologies, and identify and initiate collaborative efforts for CPTS work.
- * Initiate an alternatives analysis via the systems analysis task to evaluate technologies and process paths, determine additional information required, and evaluate assumptions.
- * Continue interaction with other TSGs and the MWIP program staff, and strengthen interactions with the EM-30 MWTP staff.
- * Develop process system specifications.
- * Begin interactions with the state of Colorado regarding the FFCA.
- * Review and recommend TTPs for funding.
- * Continue project management and oversight for funded TTPs.

Many of these tasks will continue into FY94. In addition, a more detailed analysis of process requirements and selection will be performed, and a more formal evaluation of the CPTS technologies will be started. The TASR will be updated based on these and FY93 efforts.

The FY94 call for TTPs included requests for technology development to meet the needs expressed by the other TSGs. These included the following:

- * Development of an understanding of the effect of mercury on the treatment processes for the various waste streams, and technologies to remove and control mercury in these waste streams.
- * Technologies to remove salts that would cause problems with downstream processes from the aqueous waste stream, and a plan to simplify the baseline approach to aqueous processing.
- * New decontamination technologies that would minimize secondary wastes.
- * Approaches to removing problem constituents, including salts, from wet solids.

SECTION 2 PROGRAM PLANNING APPROACH

Development of a CPTS involves identifying system requirements, identifying and evaluating technologies capable of meeting those requirements, evaluating the technologies and sequence of operations in a systems context, and identifying RDDT&E needs. This approach is divided into three stages as depicted in Figure 2-1.

- * **Stage 1.** We are currently in the first stage in which CPTS System requirements have begun to be developed, and CPTS technology and process options are being identified. In lieu of definitive requirements, potential system requirements will be assumed based on input from the other TSGs and other groups involved with the mixed waste program. Several of these requirements were identified in the previous section. The major tool used to identify the application of the various technology and/or process options is the Technology Selection Charts discussed below in Section 2.1.
- * **Stage 2.** In Stage 2 the Environmental Safety and Health (ES&H) requirements of the system are evaluated, and the CPTS technologies and processes are evaluated using criteria discussed in Section 4. The technologies and sequence of unit operations are evaluated and a risk analysis performed to minimize ES&H considerations. For example, contamination of downstream equipment requiring manual cleaning or changeout, process and technology specific issues, such as high temperature and pressure, or the use of toxic materials, and the requirement for gloveboxes.
- * **Stage 3.** During this stage, the CPTS is evaluated as a stand-alone system, and as a system integrated with the other MWTP Systems. This will allow resolution of individual system requirements and needs based on the MWTP process, ES&H, and site specific requirements, as well as total system costs. This is an iterative process in which the individual systems are modified to optimize the MWTP in terms of capabilities and cost.

Application of this approach will identify needs and gaps in not only the CPTS technologies, but also identify issues in the overall MWTP that require resolution.

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Figure 2-1. CPTS Program Approach

2.1 TECHNOLOGY SELECTION CHARTS

The first step in evaluating technologies for the CPTS is to identify potential requirements and technologies that may satisfy those requirements. The next step is to develop technology selection charts to match technologies to specific system requirements stated in the form of decisions. Because of the broad range of separations that may be required of the CPTS, and the wide variety of potentially applicable technologies, a method is needed to categorize the technologies with respect to their application within a systems context. The technology selection charts are proposed as a method of visualizing the relationship between technologies and needs, and to identify the ramifications of decisions.

Preliminary technology selection charts are shown in Figures 2-2 through 2-4 for the aqueous, organic liquids, and wet solids waste streams, respectively. Selection charts are used to identify those technologies that may be appropriate for a specific separation requirement. Technologies are selected based on input waste stream characteristics and output waste stream requirements. Once the selection charts have been developed, and technologies categorized as applicable based on the system requirements and waste stream characteristics, then a multi-attribute methodology may be applied to evaluate and prioritize the technologies for each application, for total plant performance, and downselect to a specific technology.

Another application of the selection charts is to determine the effect of decisions on the downstream processes and ultimately on the plant output, and to begin to determine equipment specifications. As an example, consider Decision #5 in the aqueous waste stream (Figure 2-2). If certain species are not removed from the waste stream, this decision can be propagated through the system using a systems analysis tool to determine its effect on the WDS, FWF and Offgas Systems. If a viable final waste form can be produced, and volatile materials collected in the offgas system (and subsequently removed from the scrubber solution in the CPTS), then the decision to not remove the subject species may be correct. If a viable final waste form cannot be produced, or if the cost of an offgas system becomes excessive, then the subject species may require removal prior to transfer to the downstream systems. However, other factors must also be taken into account before making the final decision including the cost of separation and removal of the species, pretreatment requirements, and waste stream characterization needs and costs.

1. Can or should gross suspended solids be removed?
2. Can or should suspended submicron fines be removed?
3. Is the waste primarily organic (<10% water) or heavy organic sludge or slurry?
4. Is the waste primarily water (<10% organics)?
5. Must heavy metals and/or radionuclides be removed?

Figure 2-3. Liquid Organic Waste Stream Technology Selection Chart

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1. Are the wet solids primarily organic?
2. Must organic material be removed from the wet solids?
3. Are there species that must be removed from the wet solids?
4. Is the aqueous wet solid stream pumpable?
5. Are there heat reactive components in the wet solids?

Figure 2-4. Wet Solids Waste Stream Technology Selection Chart

If the decision is to remove an offending species, then an assumed degree of separation can be used in the systems analysis. This decision can then be propagated through the MWTP to determine its effect and whether the assumed separation is adequate. This will allow us to begin determining required equipment or technology capabilities.

Application of the technology selection charts will allow a logical, step-by-step approach to determining system requirements, and to identify currently available technologies, developing technologies, and where they may fit within the CPTS. This will be based on chemical/environmental engineering principles, systems analysis, and the knowledge and experience of experts in the field including TSG members and equipment manufacturers. It is expected that technology gaps or RDDT&E needs will be identified for specific contaminant and species separation requirements for the various waste streams.

Initial development of these selection charts is based on the following assumptions:

- * Waste characterization data for DOE's mixed waste streams are probably not reliable enough to develop a CPTS flowsheet and system design based on average, unchanging waste stream composition. Final designs based on such an approach would prove to be unsatisfactory and ineffective.
- * If all waste streams were well characterized, the variations in composition within a given waste category would still seriously impact the appropriateness of a system design based solely on an average waste stream composition. Some degree of conservative design, or versatility, will be required in the CPTS design to deal with this waste stream variability.
- * Since cost is a major issue facing the MWTP, a CPTS that can perform more than one function or accept a wide variety of waste stream compositions through versatile design and technology selections would be a legitimate way to minimize cost.
- * There may be specific species or contaminants that must be removed from the waste stream prior to discharge to the environment, or prior to transfer to the WDS or FWF Systems. Environmental discharge criteria is embodied in EPA regulations and DOE orders. Requirements on the input to the WDS or FWF Systems have yet to be determined.

These charts can be expanded by assuming additional separation requirements based on the expressed needs of the downstream treatment systems. Note that this is one version of

these charts. Others may have different views and develop different versions of these charts including different decision points, or different sequences of decisions. One of the purposes of these charts is to begin to develop a dialog to determine the decisions that need to be made, the data required to make these decisions, and the effect of these decisions.

The selection of the path to take in the technology selection charts, and the application of technologies, depends on the waste stream characteristics, the requirements of the downstream processes, and the system requirements embodied in the EPA, DOE and site specific regulations for discharge and waste disposal. Technologies available to meet these requirements may be divided into four descriptive categories: transfer, concentration, transformation, and conditioning (Ref. 8).

Transfer technologies are employed to remove contaminants from a waste stream and transfer them to another medium. This transfer permits the original waste stream to be reused or discharged, or allows more cost-effective treatment technologies to be employed. Such technologies include decontamination of dry solids, chemical regeneration of media beds, filtration, ion exchange, and ultrafiltration.

Concentration technologies can be used to reduce waste volumes by concentrating the contaminants without removing them from the original waste form. When applied to liquids, these technologies usually permit reuse or discharge of the process effluent containing most of the volume and little contamination. For liquid concentration these technologies may include evaporation, distillation, crystallization, precipitation and flocculation. For wet solids, concentration technologies may include drying and dewatering.

Transformation involves destruction of the contaminants by changing the physical/chemical form of the waste or contaminants. For organic material, these technologies may include incineration and wet air oxidation. For inorganic material, these technologies may include processes such as nitrate destruction. The optimal use of incineration technologies usually requires pretreatment to remove excess water in liquids and wet solids.

Conditioning technologies include those operations that transform treated or untreated waste materials into forms that comply with the transportation or disposal requirements or both. These technologies include solidification, encapsulation and stabilization to prevent migration during disposal.

2.1.1 Aqueous Waste Stream

The decision chart for selecting aqueous waste treatment technologies from applicable technologies is shown in Figure 2-2. The liquid waste characteristics that can have an effect on technology selection are (Ref. 8):

- * Generation rate or feed stream flow rate.
- * Major contaminant identification and concentration.
- * Physical Characteristics – viscosity and density, number of liquid phases, boiling and freezing points, suspended solids content, size and density of suspended solids, and colloid content.
- * Chemical Characteristics -- Dissolved chemicals, dissolved chemical concentration, organic/inorganic species, ionic/nonionic elements, pH range, heat of vaporization, and heat of combustion.

In general, aqueous waste treatment processes concentrate the contaminants into much smaller wet- and dry-solid forms that usually require further treatment and/or conditioning to produce a final waste form. The treatment technologies also generate liquid wastes that can be reevaluated as a separate waste stream (Decision Point 1).

- * **Decision Point 1.** Can the waste be reused within the operating system or discharged to the environment without treatment?

To decide to reuse the waste, evaluate if the liquid waste is compatible with operating equipment or processes, and acceptable worker exposure to toxic or radioactive materials. To decide to discharge the waste, establish that discharge of the contained contaminants will not result in violation of public exposure limits.

- * **Decision Point 2.** Should or can suspended solids be removed by physical or mechanical processes?

Suspended solids, including colloids, may contain most of the contaminants in a liquid waste. In this case, removal of the particles may immediately result in a liquid suitable for reuse or discharge. The removal of suspended solids may also improve the performance of downstream technologies. The selection of specific separation technologies for removal of suspended solids depends primarily on the

concentration, size and density of the particles. After removal of the suspended solids, the chemical characteristics of the remaining liquid have significant influence on the selection of subsequent waste treatment procedures.

Sedimentation is considered to be the simplest and most cost-effective technique for removal of coarse particles, greater than 200 μm , and very fine high-density particles. For particle sizes from 5 to 200 μm , filtration and centrifugation methods would be more effective, with greater water separation from the solids achieved using centrifuges. Flocculation can be used to remove very small colloidal particles not amenable to filtration. The particulates removed from the liquid influent will probably be in the wet solids form with greater than 10% solids. Liquid wastes containing a wide range of particle sizes may require a combination of treatments to prepare the liquid for subsequent treatment processes - this is indicated by reevaluation through Decision Points 1 and 2.

- * **Decision Point 3.** Can or should suspended fines, colloids, or immiscible organics be removed?

This is similar to decision point 2 except more sophisticated technologies may be required to remove these materials. Membrane technologies such as ultrafiltration or microfiltration may be applicable for liquid-waste treatment when the solids cannot be recovered using more conventional methods. Membrane technologies can separate particles between about 0.001 and 10 μm , or high molecular weight (from 500 to 1500 gm/mole) organic molecules from aqueous solutions. If the contaminants cannot be removed with electrokinetic or membrane technologies, it may be possible to treat the liquid through concentration technologies, such as evaporation or distillation, or through organic separation or destruction technologies at Decision Point 4.

- * **Decision Point 4.** Are there organics in the aqueous stream?

Aqueous solutions may contain small amounts of organic contaminants, or chelating agents used in decontamination activities to remove metallic contaminants. Transformation techniques, particularly incineration, are the principal alternatives for eliminating concentrated organic fluids. Organic contaminants in aqueous streams may be destroyed by wet air oxidation or concentrated by adsorption beds or stream stripping with subsequent phase separation. Chelating agents in aqueous streams may be transformed chemically, or concentrated by membrane processes.

The resulting concentrates or wet solids still require treatment for subsequent disposal.

- * **Decision Point 5.** Must selective separation of specific dissolved species/solids be performed?

Transfer technologies such as ion exchange, reverse osmosis, and ultrafiltration are applicable for liquids with relatively low total dissolved solids (TDS) content. About 600 ppm is usually considered the nominal upper limit for use of these transfer technologies. However, this criterion and the effectiveness of transfer technologies for removal of dissolved contaminants also depend on waste and facility characteristics, such as the contaminants involved, the treatment method selected, and the type of equipment used. The waste volume may also influence the selection of the treatment method due to cost factors. For liquids with greater TDS content, some of the concentration technologies may be used to remove the dissolved solids from solution.

If the aqueous waste contains ionic species, ion-exchange technology may be used. The chemical characteristics have a principal role in determining the most effective ion-exchange procedure for a given waste. Both anionic and cationic ion-exchange resins are available to selectively remove most ionic contaminants, including radionuclides, from aqueous solutions. Electrodialysis, a technology that is not species-specific, might also be used for unique waste streams.

Selective precipitation, or sequestering agents, may also be used to remove specific species from solution. Whichever method is used to remove problem species, more detailed characterization of the waste stream will be required, and preprocessing may be required depending on the separation method.

- * **Decision Point 6.** Is additional treatment/solids removal required?

Further treatment may be necessary to remove difficult species prior to reuse or discharge of the "clean" aqueous stream. This may involve nitrate destruction techniques, or other methods to polish the waste stream to meet discharge criteria.

2.1.2 Organic Liquids Waste Stream

The decision chart for selecting liquid organic-waste treatment technologies from applicable technologies is shown in Figure 2-3. The liquid waste characteristics that can have an effect on technology selection are essentially the same as those for the aqueous waste stream (Ref. 8).

In general, liquid organic-waste treatment processes concentrate the contaminants into much smaller wet-solid, aqueous, and concentrate liquid organic forms which usually require further treatment and/or conditioning to produce a final waste form. The liquid organic waste stream may contain large quantities (up to 99%) of water.

As indicated previously, the sequence of decisions, or operations, may be modified. For example, the organics and water may be separated prior to removal of suspended fines. The appropriate sequence of operation needs to be determined through a more detailed systems analysis that determines the effect of decisions and operations on the system.

* **Decision Point 1.** Can or should gross suspended solids be removed?

Transformation techniques, particularly incineration, are the principal alternatives for eliminating organic fluids. Liquid wastes consisting primarily of waste oil, lubricant, scintillation fluids, and organic solvents can be ignited and burned in incinerators. Small quantities of water in this waste can be readily evaporated. Although removal of suspended solids from oil or other viscous organic liquids may not be the most cost-effective treatment procedure, it may be required to prevent particulate loadings that may cause downstream problems including plugging of burners in incinerators, blinding of filters in the offgas system, and accumulation of radionuclides in the incinerator ash and the offgas system.

* **Decision Point 2.** Can or should suspended submicron particulates be removed?

This is similar to Decision Point 1, except more sophisticated technologies may be required to remove these materials. At present, the technology for high efficiency removal of very fine particulates from organic liquids, which may have wide variations in viscosity, has not been identified. It should also be noted that the separated solids may be organic and inorganic. This mixture of solids may require special treatment in the wet solids line to separate the organic from the inorganic

material prior to drying, or separation in the dry solids line prior to sending the material to the WDS or FWF Systems.

- * **Decision Point 3.** Is the waste primarily organics (< 10% water) or heavy organic sludge or slurry?

If the waste is primarily organic material, waste destruction, usually by incineration, is the primary means of treatment. However, problem species may require removal prior to waste destruction. The presence of significant amount of water will decrease the efficiency of the incineration process and increase the energy requirement. If significant amounts of water are present, then the organic and aqueous liquids should be separated and treated by means appropriate for each stream.

Distillation procedures can often be used to separate organic compounds from aqueous solutions. The choice between distillation and other methods for organics/water separation will depend on waste quantity, organic concentration, and process cost.

- * **Decision Point 4.** Is the waste primarily water (<10% organics)?

If the waste stream is primarily water, then certain organic destruction technologies, such as wet air oxidation, can be used to destroy most of the organics in the waste stream. However, if the waste stream is intermediate in water and organics content (10%<organics <90%), then a phase separation technology may be appropriate. This would produce two streams: a concentrated organic stream suitable for incineration, and a dilute organic (or aqueous) stream suitable for an alternate organic destruction technology.

- * **Decision Point 5.** Must heavy metals or radionuclides be removed?

Heavy metals and radionuclides may be present as suspended solids in the organic or aqueous phases, or as dissolved solids in the aqueous phase. In general, the dissolved solids will end up in the aqueous phase when the two phases are separated. However, the organic phase may retain suspended solids or dissolved species in the form of organometallic compounds that require removal prior to transferral to the WDS System.

2.1.3 Wet Solid Waste Stream

Wet solids are considered to be moderately thick slurries containing at least 10% solids. Wet solids include evaporator bottoms, spent ion exchange media, spent media bed material, filter precoat material or filter cake, and expended (loaded) filter cartridges. Miscellaneous sludges with high solids content slurries are also considered wet solid waste. Wet solid waste also include biological waste from research programs consisting of animal carcasses, vegetation and biological cultures.

The decision chart for selecting wet solid waste treatment technologies from applicable technologies is shown in Figure 2-4. The waste characteristics that can have an effect on technology selection are (Ref. 8):

- * Generation rate or feed rate.
- * Contaminant concentration and radionuclide specific activity.
- * Physical Characteristics -- Free water content, solids content, viscosity, and boiling point.
- * Chemical Characteristics -- Chemical constituents, organic/inorganic species, heat of combustion, oxidizability, and pH.

Filtration and physical/mechanical concentration techniques are generally used to extract solids from high-water-content wet solids. The free-water component recovered during wet solids treatment is processed as an aqueous waste. Thermally induced drying and dehydration methods are applicable for low-water-content wet solids and result in dry solid waste to be sent to the FWF System.

- * **Decision Point 1.** Are the wet solids primarily organic?

Organic wastes can be effectively processed by combustion techniques. If the wet solids are primarily organic they may be transferred directly to the WDS System for destruction. If these organic wastes contain heat reactive components, methods other than incineration may be required for destruction.

- * **Decision Point 2.** Must organic material be removed from the wet solids?

In many cases organic liquids or organic solids may be mixed with aqueous inorganic wet solids and must be separated from the waste stream and sent to the WDS System. If organic material is left in the aqueous wet solids waste, it may interfere with filtering and dewatering processes, or cause extensive fouling in the dryers.

- * **Decision Point 3.** Are there species that must be removed from the wet solids stream?

There may be heavy metals or radioactive species that must be removed from the wet solids to decrease the loading on the dryer offgas system, or to allow formation of an adequate final waste form. If this is the case, a washing or leaching process may be used to remove the offending species. If water is used it will be processed through the aqueous treatment line, and if an organic solvent is required it will be processed through the organic liquid line. The "cleaned" wet solids will continue to be processed in the wet solids line.

- * **Decision Point 4.** Is the aqueous wet solid stream pumpable?

Wet solid wastes containing more than 80% water would have the consistency of a thin slurry and could probably be pumped to a drying system. Techniques for moisture removal from the wet solid waste depend on the solids content and particulate properties. These techniques include filtration, sedimentation, centrifugation, and pressure filtration. Filtration and sedimentation probably do not remove enough free water to permit efficient drying of the product; however, centrifugation or filter presses may provide sufficient dewatering for efficient drying.

Wet solids that are not pumpable will be transferred directly to a dryer to remove residual moisture. On the other hand, if the wet solids can be easily pumped, spray or flash dryers may be used without the dewatering step.

- * **Decision Point 5.** Are there heat reactive components in the wet solids?

If heat reactive components are present, the wet solids may be safely dried in a low temperature vacuum dryer. Otherwise, a high temperature direct or indirect dryer may be used.

2.2 MULTI-ATTRIBUTE TECHNOLOGY EVALUATION

The MWIP Systems analysis group is developing evaluation criteria and a methodology that will be used to perform trade-off studies and evaluate proposed equipment and technologies, as well as evaluating the total mixed waste treatment system. This will be based on a methodology developed at Los Alamos National Laboratory specifically for the MWTP, and is described by R.B. Kidman in Reference 9. This methodology is a multi-attribute decision analysis where various technologies are scored based on specified criteria, weighted in accordance of importance, and the scores added up to allow prioritization and selection. Technology rankings will be developed, but may require caveats for special cases or special waste stream characteristics. For example, a particular type of filter may have a high score and be applicable for most waste streams, but a special filter may be required for a non-normal stream such as gelatinous material.

As indicated in Figures 2-2 through 2-4, several technologies may be appropriate for a given application to satisfy a specific system requirement. These technologies will be evaluated and prioritized with respect to criteria discussed in Section 4. In those instances in which only one technology can be identified for a specific application, the technology will be evaluated with respect to the identified evaluation criteria; a low score may imply that the technology is inadequate and RDDT&E efforts are required to satisfy the requirement.

This multi-attribute methodology will be used as additional information is gathered regarding technology characterization and capabilities, waste stream characterization, and system requirements. This methodology will continue to be applied in conjunction with a systems evaluation to evaluate and prioritize technologies in a systems context. In the meantime, preliminary evaluations will be performed using a less rigorous approach, but still applying appropriate criteria.

SECTION 3 SYSTEM DESCRIPTION

3.1 OVERVIEW

In this section the baseline CPTS, as defined for the MWTP, and alternative concepts are discussed. This baseline was developed under the direction of EM-30 and documented in References 10 and 11. The portions of the CPTS that are included in the baseline MWTP are shown within the dark lines in the Functional and Operational Requirements (F&OR) diagrams in Figures 3-1 through 3-4.

Note that these baseline F&OR diagrams for the MWTP are conceptual foundations to begin discussion of the system concept and requirements—there is flexibility to consider alternatives. These alternatives may be more than just modifications or upgrades of individual unit operations, but may consist of more revolutionary changes as considered appropriate for the particular waste stream.

As indicated previously, the CPTS consists of separate processing lines, shown in Figures 3-1 through 3-3, designed to pretreat the aqueous, liquid organic and wet solids waste streams. Mercury removal processes, with the baseline shown in Figure 3-4, have been evaluated as part of TTP OR 1320-10 and are described in Appendix N. Decontamination processes are summarized in Appendix O, although their location within the mixed waste treatment system are still to be determined.

The overall system requirements are to provide the FWF System with dry inorganic solids, the WDS System with liquid organics and organic sludges, and the Offgas System with the offgas from various processes; the gas stream may include particulates, aqueous, and organic vapors. The CPTS will pretreat the waste streams, at reasonable cost and complexity, to minimize problems associated with treating the waste in downstream systems.

Although the baseline MWTP indicates a significant number of processing steps, alternate processes may simplify the system by removing the organics for subsequent destruction, and removing the solids in aggregate for subsequent final forms production. On the other hand, if contaminants (inorganic salts or radioactive species) must be selectively separated from the aqueous wastes, then the system becomes more complicated.

93-0024-TR-03

Figure 3-1. Baseline Flowsheet for Aqueous Liquids Treatment Line

93-0024-TR-G-10

Figure 3-4. Baseline Flowsheet for Mercury Control Line

In addition, it would appear that these problem species must also be leached from the wet and dry solids waste, thereby significantly increasing the aqueous waste stream and further complicating the system. It should be noted that these salts and radionuclides must still be stabilized in a final waste form and disposed. The concept of removing the organic materials and the inorganics in aggregate are described in the alternate flow diagrams in the next section.

The liquid organic stream will be separated into a concentrated liquid organic stream and an aqueous stream containing less than 1% organic material in accordance with the specifications in Reference 10. The liquid organics are subsequently processed in the WDS System and the aqueous stream is processed through the aqueous waste treatment line. Wet aqueous solids are simply dried, the offgas sent to the Offgas System for treatment, and the dry solids sent to the WDS or the FWF System. Organic sludges will be sent directly to the WDS System for treatment.

3.2 AQUEOUS WASTE STREAM

The purpose of this subsystem is to separate organic contaminants, and suspended and dissolved solids from the aqueous matrix to produce "clean" water for recycle or discharge in accordance with applicable regulations. Any organics contained in the aqueous waste are either separated and sent to the Organic Liquids Treatment Line for further processing, or in the baseline system, oxidized in the wet air oxidation process (Unit 270 in Figure 3-1). Solids in the aqueous wastes are separated and processed in the Wet Solids Treatment Line along with any spent media (activated carbon, ion exchange resins, filter media, etc.).

The input to the aqueous waste stream consists of aqueous mixed waste from stored and newly generated sources, and internal transfers from within the MWTP. Stored and newly generated aqueous wastes, referred to as externally generated wastes, will be characterized in the FEH System. This waste stream is expected to contain suspended and dissolved solids, and up to one weight percent organic material. Liquids containing more than one weight percent organics will be first processed through the Organic Liquids Treatment Line. The implications of an aqueous stream containing more than one weight percent organics will be addressed in the evaluation and selection of treatment technologies.

Internal transfer streams include condensate from the wet solids line, the aqueous stream from sludge dewatering operations, scrubber solution from the Offgas Treatment System, aqueous waste separated from the Organic Liquids Treatment Line, and aqueous waste from decontamination operations. If problem species must be removed from the wet or dry solid

wastes, a washing/leaching operation will be required using water or other solvents. If water is used, the effluent will be processed in the Aqueous Waste Treatment Line; spent organic solvent will be processed in the organic liquid line. However, the baseline contains no provision for removing dissolved species from organic solvents.

The following sections describe the baseline process and alternative technologies applicable to the baseline, and alternate processes and associated technologies.

3.2.1 Baseline Process

3.2.1.1 Grit Filter

The grit filter (Unit 155.2) is the first processes in the aqueous treatment line that is part of the CPTS. The grit filter's function is to remove particulates greater than 3 mm using manually replaceable polypropylene filter elements. The assumption is that this unit has an 80% removal efficiency.

The TSG has expressed several reservations regarding the baseline filter. First, if replaceable filters are to be used, replacement should be automated to minimize exposure of personnel to hazardous and/or radioactive material. Another concern is that disposable filters increase the amount of wet solid waste produced. Finally, removal of only particles greater than 3 mm will allow smaller grit particles to pass through to settle in tanks and pipelines, clog valve mechanisms, and increase pump maintenance requirements.

Recommendations were to use a "permanent" filter that can be backflushed for cleaning, with a secondary and possibly a tertiary filter or electrokinetic method to remove fine particulates. Other mechanisms for removing grit include grit chambers (horizontal-flow, aerated, or vortex-type grit chambers) for initial grit removal from the aqueous waste. If the grit contains organic material it may be dewatered and sent to the WDS System. On the other hand, it may be washed to remove the organics with the clean grit sent to the FWF System and the organics sent to the Organic Liquid Treatment Line.

3.2.1.2 Special Treatment

A specialized batch treatment section of the process is provided (Units 140.1 and 150.1) for aqueous wastes that require some form of specialized treatment that the main process line

cannot supply. The stated purpose is to remove gross concentrations of solids (heavy metals, salts, radionuclides, etc.) by chemical precipitation and high efficiency dewatering (centrifugal or vacuum), and chemical destruction of cyanides and/or nitrates. The second stage of the special treatment unit is a sacrificial carbon adsorption unit designed so that the carbon beds can be changed out frequently, safely and easily. The media in this unit is intended to be used once and replaced without regeneration. Simple backflushing will be provided to remove gross fouling.

The issue regarding this special treatment process is for a potential wide variety of waste stream constituents and characteristics, and the fact that these will not be known until the batch of waste enters the "assign treatment" tank (Unit 130). Even then significant effort may be required to characterize the waste including laboratory analysis. Thus, requirements and technology needs for these processes cannot be determined until the waste stream is well characterized. Special treatment processes may require a variety of chemical additives for pH adjustment (precipitation, oxidation, etc.); additives and mixing tanks for coagulation, flocculation and settling of colloids; removal of organics or other species to prevent unwanted reactions due to chemical additions; and other processes to effectively and efficiently remove the desired species from the aqueous stream. Of course, once these species are removed they must still be dealt with by the WDS and/or FWF Systems.

Another issue is the use of replaceable carbon beds to remove organics from this waste stream. The purpose of these beds is not clear since carbon beds are used in the main treatment line, and use of additional beds will increase the secondary waste output to the wet solids stream.

3.2.1.3 Organics Feed Tank

The organics feed tank is a flotation cell used to separate the aqueous phase and immiscible organics. The organic fraction is skimmed off the top and sent to the Organic Liquids Treatment Line, and the remaining aqueous stream, containing small amounts of organics, is sent to the wet air oxidation process (Unit 270) which is part of the WDS System. The tank is equipped for air injection for flotation, injection of chemicals for neutralization or emulsion breaking, and external heat exchange.

Other separation methods may be required depending on the nature of the dispersed (organic) phase, the density relation between the aqueous and organic phases, the quality required of the aqueous effluent, and whether the organic phase is dispersed or an emulsion.

These methods may include coalescers and/or gravity separators for the dispersed phase. If the organic phase is in the form of an emulsion, membrane systems or coalescers may be required with chemical or heat treatment prior to separation.

3.2.1.4 Primary Treatment

The baseline primary treatment (Unit 150.2) consists of a first stage centrifugal filter and second stage carbon adsorption beds. The purpose of this unit is to separate the dissolved organics and remaining suspended solids, including specific ions such as Cs and Sr, from the aqueous stream. The centrifuge minimizes the solids sent to the carbon beds to prevent plugging and excessive backwashing. The filter medium from the centrifuge and used carbon will be sent to the wet solids line for treatment. The assumptions that went into selecting these primary treatment technologies for the baseline include 90% removal efficiency for suspended solids, 95% adsorption efficiency for organics, and a 10% adsorption efficiency for dissolved ionic species.

Again, the generation of secondary waste by using carbon beds as the primary treatment becomes an issue. Also, the purpose of these beds is not clear. Activated carbon is usually used to remove organic material; however, organic material has already been removed in the organic feed tank and wet air oxidation units. The efficacy of carbon beds in removing the wide variety of inorganics that may be in the aqueous waste stream is not clear. Other technologies appear to have higher removal efficiencies for dissolved species; these could eliminate the need for special treatment and decrease the burden on the secondary and tertiary treatment units.

Other technologies that may be applicable for primary treatment include sedimentation (with precipitation, coagulation and flocculation as preprocesses), filtration, evaporation, stripping, and freeze crystallization.

3.2.1.5 Secondary Treatment

The baseline secondary treatment (Unit 190) consists of evaporation by hot air sparging with high efficiency entrainment (mist) eliminators and subsequent condensation. This process is intended to remove all remaining inorganic ions from the aqueous stream to produce clean water effluent. If the condensate does not meet discharge specifications it may be recycled through the evaporator or sent to the tertiary treatment unit. The bottoms containing

concentrated solids may be sent to the solids concentration/dewatering unit for further concentration or sent directly to the wet solids line.

Other potentially applicable technologies that may be used to remove specific ionic species include ion exchange, electrolysis, and electrodialysis. Reverse osmosis may also be used to remove dissolved solids.

3.2.1.6 Tertiary Treatment

This treatment step (Unit 195) is designed for any additional treatment of the condensate required before discharge. Originally, the main contaminant was expected to be nitrates. Technologies suggested in the original baseline (Ref. 10) were reverse osmosis to remove nitrates, or electrolysis. A new design study (Ref. 11) has eliminated this tertiary process.

If nitrate is a problem with downstream processes, various nitrate destruction technologies are available including those listed in Table 1-1. Other processes that may be used to destroy nitrates in conjunction with organic destruction include steam reforming. However, it is not clear where in the process these technologies should be applied; prior to primary treatment or as a tertiary treatment process. Nitrate destruction technologies were evaluated as part of TTP OR 1320-04 and the results are summarized in Appendix I.

3.2.1.7 Solids Concentration/Dewatering

The purpose of this unit (Unit 180) is to concentrate the backwash and blowdown streams from the special treatment, primary treatment, and secondary treatment units. The solids removed from the water processed through the Aqueous Treatment Line are further concentrated and the wet sludge is sent to the Wet Solids Treatment Line. The baseline technology is wiped-film evaporation (Ref. 10) with the condensate recycled to the main feed tank (Unit 140.3).

Alternate and/or additional technologies that may be used for dewatering and concentration of solids include electrokinetic techniques, reverse osmosis, and mechanical dewatering and filtering. Technology selection will depend on the solids concentration, whether the solids are dissolved or suspended, and the particle size distribution.

3.2.2 Alternate Process Flows

The alternate processes are robust processes in that they do not depend on the composition and characteristics of the aqueous waste stream. Suspended solids and organic material are removed from the waste, and dissolved solids are concentrated in aggregate and sent on to the Wet Solids Treatment Line. Thus, no selective separation of specific species is performed. If, in the future, selective separation of specific species is required, then a specific process for this species may be installed upstream of the evaporator. However, it should be kept in mind that if selective separation is required in the aqueous line, then significant washing and leaching of the wet and dry solid wastes may be required to remove these problem species from those waste streams.

3.2.2.1 Steam Stripping and Evaporation

This alternate process, shown in Figure 3-5, replaces all the components past the grit filter in the baseline system with five major components: a filter system to remove suspended fines, a steam stripper to remove dispersed and dissolved organics, a liquid/liquid phase separator to separate the organics fraction from the condensate, an evaporator to concentrate the solids, and a guard bed to remove any remaining contaminants prior to clean water discharge.

The fines removal may consist of secondary and tertiary filters with increasingly fine pore sizes, microfilters, or electrokinetic filters. The resulting solids will be sent to the Wet Solids Treatment Line along with spent filter media. The filter media should be able to be backflushed or automatically changed to minimize personnel exposure to hazardous and/or radioactive material.

A phase separator may be required before the steam stripper to remove dispersed phase liquid organics; the steam stripper will be used to remove dissolved organics. The condensate and organics may be sent to the Organic Liquids Treatment Line, or may go directly to a liquid/liquid phase separator of a type listed in Table 1-1. The separated organic fraction will be sent to the WDS System and the condensate recycled to the steam stripper.

The bottoms from the steam stripper is essentially free of organic material and contains dissolved solids. The bottoms are sent to an evaporator for solids concentration to approximately 50 weight percent solids, and to a wiped-film evaporator for further concentration. The bottoms will be sent to the Wet Solids Treatment Line, and the condensate through a guard bed, as necessary, for further processing.

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Figure 3-5. Aqueous Treatment by Steam Stripping and Evaporation

The guard bed treats the condensate from the evaporator in the event of liquid carryover into the vapor stream. The guard bed technology to be used is not defined at this time but may be adsorption, ion exchange, electrodialysis, nitrate destruction, or reverse osmosis.

3.2.2.2 Freeze Crystallization

The freeze crystallization alternative, shown in Figure 3-6, consists of removal of suspended solids, the freeze crystallization process, and phase separation of organics and water if required. The freeze crystallization process produces crystals of "extremely pure water" which float to the top of the solution highly concentrated in dissolved solids. This process may also have the ability to concentrate organics in a third stream; however, this has not yet been demonstrated. The washed ice may require additional treatment to remove any remaining contaminants before discharge, and the concentrated bottoms may require further concentration in an evaporator, or may be sent directly to the Wet Solids Treatment Line.

3.2.2.3 PO*WW*ERTM Process

This process, shown in Figure 3-7 (Ref. 12) and developed by Chemical Waste Management, Inc., uses two conventional treatment technologies in a new systems arrangement to treat complex mixtures of inorganic salts, metals and volatile and nonvolatile organics. The waste is concentrated in a forced circulation evaporator by boiling off most of the water and volatile compounds (both organic and inorganic). Air or oxygen is added to the vaporized fraction and then forced through a fluidized catalyst bed where the organics and inorganics are oxidized. Mist particles are removed from the vapor by the entrainment separator to keep the total dissolved solids concentration of the condensate in the range of <50 ppm.

Catalytic oxidation of the volatile contaminants produces CO₂ and water, and N₂ from ammonia. Acid gases, such as HCl, may also be produced and removed at the scrubber. The product vapor is condensed after the scrubber and the condensate and/or scrubber solution may require additional treatment. Pilot plant tests using this system have been performed by Chemical Waste Management, Inc. on hazardous waste streams; additional testing would be required for mixed waste streams.

Figure 3-6. Aqueous Treatment by Freeze Crystallization

Figure 3-7. Chemical Waste Management PO*WW*ER Treatment System

(Courtesy of Chemical Waste Management, Inc.)

3.3 ORGANIC LIQUIDS WASTE STREAM

The CPTS portion of the baseline Organic Liquids Treatment Line is shown in Figure 3-2. Input to the Organic Liquids Treatment Line consists of liquid containing more than one weight percent organic material. The input to the organic liquids waste stream consists of mixed waste from stored and newly generated sources, and internal transfers from within the MWTP. Stored and newly generated organic wastes, referred to as externally generated wastes, will be characterized and sorted in the FEH System.

This externally generated waste is expected to contain suspended and dissolved solids, and up to 99 weight percent water. The primary waste input includes organic liquids, spent solvents, scintillation vials, polychlorinated biphenyls (PCBs), and heavy oils, organic sludges and slurries. The waste form will be varied consisting of vials of liquid, lab packs containing liquid containers, and barrels of liquid, oils and sludges containing solids in the form of grit, rags, gloves, and small equipment items and tools.

Internally generated organic liquids will come from the phase separation processes in the Aqueous Waste Treatment Line. Organic solvents used in decontamination processes will also be sent to this treatment line. If problem species must be removed from the wet or dry solid wastes using an organic solvent extraction process, the used solvent will be processed through the Organic Liquids Treatment Line.

The purpose of the baseline Organic Liquids Treatment Line is to prepare the organic fluid wastes for further treatment in the WDS System. Water is separated from the organic material and transferred to the Aqueous Waste Treatment Line. Suspended solids are removed and sent to the Wet Solids Treatment Line. The organic liquid fraction, containing less than ten weight percent water and any dissolved solids, is sent to the WDS System for treatment. Thick oils, sludges and slurries are also sent directly from FEH to WDS for treatment.

The following sections describe the baseline process and alternative technologies applicable to the baseline, and alternate processes and associated technologies.

3.3.1 Baseline System

The assign treatment process (Unit 230) and the solids separation process (Unit 250.1) are part of the FEH System. In the assign treatment process, drums are opened and emptied, contents verified and characterized, then sent to appropriate downstream processes.

Concentrated organic sludges, slurries, thick oils, and concentrated organic liquid containing combustible solids such as rags, are sent directly to the WDS System for treatment. Drums containing a high fraction of solids, including lab packs and scintillation vials, are sent to solids separation. In the solids separation process, liquid containers are removed from lab packs and emptied for transfer to the concentrated organics tank (Unit 240). Vials and small containers are crushed: the filtered liquid is sent to Unit 240, and the solids (small glass and plastic particles, grit/dirt, scale, etc.) are sent to the Wet Solids Treatment Line.

Drums containing liquid organics and large noncombustible solid items, such as equipment items and tools, are also sent to the solids separation process. These solids are separated from the liquid matrix and sent to decontamination. The decontaminated items are then sent to one of the dry solids treatment lines or recycled, and the decontamination fluid sent to the liquid organic or aqueous line, whichever is appropriate.

The CPTS begins after sorting and assignment of treatment, and after crushing of vials and other liquid containers. Thus, the input is liquid organics containing over ten weight percent water and solids, and solids requiring decontamination. Heavy concentrated liquids are generally sent directly to the WDS System unless they contain mercury. If mercury is present, all wastes are sent to the CPTS for mercury removal before further treatment.

3.3.1.1 Filter

The purpose of filter Unit 250.2 is to filter the liquid from the vial crusher and from the tank into which lab pack containers are emptied. In the original baseline (Ref. 10) this is a small traveling belt filter. In the revised baseline (Ref. 11) this is a replaceable cartridge filter. The liquid is sent to WDS for treatment, and the filtered solids are sent to the Wet Solids Treatment Line. However, as indicated below, these solids may be sent directly to WDS for destruction of the organic material clinging to the solids, rather than to the wet solids line where they will simply be dried. An alternative would be to remove the organic material by a stripping process and process the resulting liquid through the aqueous or organic liquid line.

3.3.1.2 Liquid Separation

The input to liquid separation (Unit 240) is organic liquid containing varying amounts of water from external and internal sources (the aqueous line or decontamination). The baseline process for separating the organic and aqueous fractions is automated decantation. Other

phase separation operations which may be applicable are listed in Table 1-1 and described in the Appendices.

The aqueous fraction (or dilute organics) from the liquid separation process is filtered through filter unit 250.5, a cartridge filter, and sent to the wet air oxidation process (Unit 270). The concentrated organic fraction is filtered through filter unit 250.3, also a cartridge filter, and sent to the WDS for treatment. As indicated in Section 3.2.2, there are alternates to wet air oxidation and it may be more practical to send the aqueous fraction to the Aqueous Treatment Line to be treated by other means.

3.3.2 Alternate Process Flows

The wet solids line consists of drying operations, and drying liquid organics may present several problems including formation of agglomerates and solid organic coatings on the solids, fouling the dryer surfaces, and adding additional safety problems associated with generation of potentially explosive vapors. Such solids with concentrated organics should be sent directly to the WDS System for treatment, or the organics stripped from the solids prior to processing through the wet solids line. If the solids are too large, they should be first reduced in size in the FEH System. If a significant amount of water is present in this solid/liquid waste stream, then the water can be separated in the CPTS using phase separators, and the resulting organic liquid/solid waste stream processed as indicated above.

3.4 WET SOLIDS WASTE STREAM

The CPTS portion of the Wet Solids Treatment line is shown in Figure 3-3. Input to the Wet Solids Treatment Line consists of wet solids, or concentrated slurries, from the aqueous line, the liquid organics line, and wet solids from stored and newly generated external sources. This input is assumed to consist of aqueous sludges, absorbed liquids, resins, spent media, and cemented sludges. It is assumed that organic sludges will be sent directly from the Liquid Organics Treatment Line to the WDS System.

Input from the aqueous line will consist of liquid concentrated in dissolved or suspended solids; and spent media including filter media, filter cake, and media from carbon beds. Input from the organics line consists of spent cartridge filters containing fragments of glass and plastic coated with organic liquid such as scintillation liquid and liquid from lab packs. The organics line also processes drums containing solids in baths of organic liquids, such as oil. These solids

are crushed and filtered, and the wet filter media sent to the wet solids line. Externally generated wet solids may consist of drums of solidified aggregate that is crushed in the FEH System, drums of dumpable sludges, drums of sludges or aggregated solids that must be removed with a high pressure fluid, and equipment items and tools coated with organic liquids.

The purpose of the Wet Solids Treatment Line is to prepare the solids for subsequent treatment in the dry solids lines, the WDS System or the FWF System. The wet solids line consists of a grit screen and two dryers, one of which is a low temperature dryer for heat sensitive material. There are several issues regarding the baseline system. First, drying solids wetted with organics may leave an organic coating on the dryer walls and on the solids. An option is to send these organically wetted solids directly to the WDS System where the organics can be destroyed and the solids either processed in the dry solids line or the FWF System. Alternatively, the organics may be stripped from the solids prior to drying.

Another issue is that the baseline has no provisions for separating water from an organic liquid/aqueous/solid mix. If water is separated, then the organic liquid/solid aggregate can be sent to the WDS System. Also, there is no provision in the baseline to decontaminate equipment items or tools of organic liquids. Our assumption is that these items will be separated in the FEH System and sent to decontamination.

3.4.1 Baseline System

The feed preparation (Unit 310) and size reduction (Unit 320) are part of the FEH System. The feed preparation area receives wet solids from the organic liquid separation (Unit 250), sludge from the wiped film evaporator (Unit 180), wet solids from filters and centrifuges in the aqueous line, and drums containing wet solids from the receiving area. Dumpable sludge, and material which requires high pressure water jets for removal from the drums, are sent through a small roll crusher. Large solids and aggregates, and drums from which solids cannot be removed, are sent to size reduction (Unit 320) which consists of a large crusher/shredder operation. The output from the crushers goes to the grit filter (Unit 330).

The CPTS begins at the grit filter, after feed preparation and size reduction. Thus, the input includes aqueous sludges, solids containing absorbed or bound water, organic sludges, solids containing absorbed organic liquids, organic sludges containing water either inherently or from the drum rinsing operation, and solids with surface contamination of water or heavy or light organic liquids.

3.4.1.1 Grit Filter

The purpose of the grit filter Unit 330 is to remove oversize material from the waste stream. The oversize solids are sent to the size reduction units, and the small particle slurry is sent to feed tanks 340 and 345. In the baseline, the grit filter is a simple vibrating screen.

3.4.1.2 Primary Dryer

The purpose of the primary dryer (Unit 350) is to dry the feed and to pulverize the dried solids. A rotary dryer, using indirect contact steam heating, and adaptable to batch or continuous operation, has been selected in the baseline to minimize offgas and to provide the mixing and pulverizing action of the plows and mixing devices on the internal shaft. The unit is to operate at a solids outlet temperature of 200°C to remove adsorbed liquids and water of hydration of most salts. The dryer operates under negative pressure with an induced air sweep to remove offgas vapors which are processed through the condenser. The dried solids are further processed in the Homogeneous Dry Solids Treatment Line.

3.4.1.3 Low Temperature Dryer

The purpose of this dryer is to process special feed material in a lower temperature environment than the primary dryer. It is an indirectly heated rotary vacuum type dryer, using steam heat, and adaptable to continuous or batch drying. The special feeds are wet solids with unique properties that require special treatment. These may include nitrated wet solids, ion exchange resins, organics such as cellulosic adsorbents, spent activated carbon, mercury contaminated wet solids, chlorate salts, etc. Such materials may be thermally sensitive, have higher than normal radioactivity levels, or produce harmful vapors (HNO_3 , NH_3 , HCl , SO_2 , organic fumes, etc.) if subjected to the higher temperatures in the primary dryer. The offgas is processed through the condenser, and the dried solids are sent to the Homogeneous Dry Solids Treatment Line or directly to the FWF System.

3.4.1.4 Condenser

The dryer offgas condenser (Unit 360) in the original baseline (Ref. 10) services both dryers and is a conventional shell and tube design with the offgas on the tube side flowing in a downward direction. The new baseline (Ref. 11) has added a separate condenser (Unit 355.1) for the low temperature dryer. Other types of condensing equipment such as direct cooling,

mechanical refrigeration, etc. may be used. Non-condensables are processed in the Offgas Treatment System, and the condensate is sent to the Aqueous Treatment Line for processing. If the condensate is an organic liquid, it is sent to the Organic Liquid Treatment Line.

3.4.2 Alternate Process Flows

The wet solids line consists of drying operations, and drying liquid organics may present several problems previously discussed. Such solids with concentrated organics should be stripped of organics or sent directly to the WDS System for treatment.

3.5 MERCURY CONTROL

The CPTS portion of the baseline Mercury Control System is shown in Figure 3-4 which is based on the system described in Reference 11. Input to the Mercury Control System consists of all wastes containing mercury as determined by the manifest or by waste characterization in the FEH System. Externally generated sources may include mercury contaminated water, organic liquids or wet solids. Internally generated sources include mercury contaminated scrubber solution from the Offgas Treatment System, and mercury contaminated decontamination solution.

The need to remove mercury from the aqueous, organic liquid or wet solids streams prior to further treatment has not been determined. It would seem that removal of mercury from the organic streams (either organic liquids or solids wetted by organic liquids) would be necessary prior to thermal treatment to prevent or minimize mercury entering the general offgas treatment system. In addition, removal of mercury early in the aqueous treatment process appears sensible to minimize mercury contamination of downstream process equipment. However, the technologies and methods for mercury removal from these waste streams have not yet been defined.

3.5.1 Baseline System

The baseline Mercury Control System starts with roaster bakeout (Unit 560) of dry solids from the homogeneous and heterogeneous dry solids lines. The offgas is routed to the mercury condenser (Unit 565) and knockout pot (Unit 565.1) for partial mercury recovery. These units are part of the WDS System.

Mercury containing 10 to 100 nCi/gm of alpha emission will be sent directly to the decontamination area. Spent decon solution will be collected in drums and sent to the Aqueous Treatment Line. Decontaminated items are sent to the low level waste handling area.

3.5.1.1 Mercury Cleanup System

The CPTS begins downstream of the roaster with the mercury cleanup system. The offgas from the knockout pot is routed to the mercury cleanup unit (Unit 565.3 through 565.3E) which uses the Boliden/Norzink Process. This consists of a scrubber reactor (Unit 565.3) that eliminates mercury vapor completely from a gas stream. The offgas containing metallic mercury vapor is scrubbed in a counter-current flow with mercuric chloride solution and produces a mercurous chloride precipitate.

Offgas from the scrubber in the mercury cleanup unit is sent to the secondary combustion chamber (Unit 480 which is part of the WDS System), and the offgas from this unit is sent to the offgas treatment system (Unit 490 which is part of the Offgas Treatment System). The aqueous blowdown from the offgas quencher and venturi scrubber is passed through a mercury separation bed (Unit 562) which is part of the CPTS. This is a packed bed cartridge containing a specific mercury adsorbent. The aqueous effluent is piped to the Aqueous Treatment Line, and the spent mercury adsorbent cartridge is sent to the mercury bakeout roaster.

The precipitated mercurous chloride sludge from the mercury cleanup unit is transferred to the mercury stabilization unit (Unit 595). It is not clear what constitutes this unit. It may be part of the FWF System; however, there is an issue with producing an enhanced final form (i.e., glass) with chlorides as input. It may be more appropriate to convert the mercurous chloride to a mercury sulfide prior to incorporating it into a sulfur polymer for disposal. If this is the case, the conversion process should be part of the CPTS. This issue will be resolved in the future.

3.5.1.2 Mercury Recovery and Stabilization

Bottoms from the mercury knockout pot are sent to a mercury distillation unit (Unit 585), to produce purified mercury for reuse. The bottom residues from the distillation unit are periodically drained into the mercury/sulfur reaction tank where they react with molten sulfur to produce cinnabar. At this time it is unclear whether this will be the final form used for disposal, or if the mercury sulfide is further processed into a sulfur polymer final form in the FWF System. Offgas from the mercury collection tanks is routed to an activated carbon guard

bed before being sent to the Offgas Treatment System. It seems that this should be a mercury specific adsorbent similar to Unit 562 rather than a general carbon bed adsorber.

3.5.2 Alternate Process Flows

Alternate process flows have not been developed at the time this report was published. Additional work is being done to evaluate the baseline; define the need for removal of mercury early in the treatment process; and define and evaluate alternate technologies, and technologies available to perform mercury removal from organic and aqueous liquids.

SECTION 4 DATA REQUIREMENTS

4.1 INTRODUCTION

Specification and selection of separation processes and equipment depends on the characteristics of the mixture or solution entering the process, the required characteristics of the material leaving the process, and the characteristics of the separation method and equipment and their effect on upstream and downstream processes. In this section the data required to develop system performance specifications, and process and equipment requirements will be discussed. In addition, criteria for evaluating equipment and technologies will be presented.

4.2 SYSTEM PERFORMANCE SPECIFICATION DATA

The primary output from the CPTS aqueous stream is clean water for recycle, reuse, or emission to the environment. Organic liquids and vapors are supplied to the thermal treatment module, and dry solids are supplied to either thermal treatment or final form processing. The data required to develop a system design, and to specify equipment, primarily relates to the regulatory requirements of the aqueous effluent, the requirements on the composition of the organic liquid stream supplied to thermal treatment, and the required composition of the dry solids stream supplied to thermal treatment and final form processing. That is, the performance and output requirements of the CPTS must be defined.

In addition to the system output requirements, requirements on the individual pieces of equipment within the system must be identified. The required pretreatment of the waste stream must be defined for the equipment item in question to function properly with minimum maintenance and operating cost. Also, the output range of the equipment item in question must be determined over a wide range of potential input conditions to ensure that downstream equipment functions properly.

Before a final solution to the separation problems can be reached, reasonable, desirable, and attainable performance requirements must be developed. This is particularly true for the solid/liquid separation issues. The purpose of separation must be determined (i.e., clarification, particulate removal, dissolved solids removal, separation of specific ionic or dissolved species, etc.). Performance requirements may cover several items necessary for successful operation. A list of various items follows. These should be considered before eliminating potential separation methods.

*** Process requirements to be defined:**

- Minimum amount of suspended solids in the feed that must be recovered in the solids product.
- Maximum liquid content in the final solid product.
- Maximum amount of cleaning or “backwash” fluid used in the separation process. The amount of cleaning fluid should be minimized since it is a secondary waste stream and there is a cost factor associated with its eventual treatment.
- Maximum amount of suspended solids in the liquid product stream. In most water reclamation circuits, at least 90% of solids from each particle size must be removed per pass through the solids removal equipment; otherwise, a buildup of fine solids will occur adversely affecting processing.
- Maximum particle size in the liquid product stream. Most membrane or cartridge filter installations require suspended solids elimination down to some specified particle size depending on the processing steps that follows or product requirements.
- Maximum amount of dissolved solids in the liquid product stream.
- Species separation required in the liquid and solid product streams.
- Particular dissolved solids that must be removed and where this removal is required in the process.
- Particular radionuclides that must be removed and where this removal is required in the process.
- Maximum amount of water remaining in the liquid organic stream or the organic wet solid stream.
- Allowable particle size in the wet solid stream.
- Required system versatility to process wide variations in input stream composition.

- * **Minimize Energy Requirements.** Because of the higher costs for thermal drying, efficient mechanical dewatering may be desirable.
- * **Volume or weight of solids and liquids to be processed per unit time.** The amount of solids and liquids to be processed should be determined carefully. Availability of certain types of equipment, as well as overall plant availability should be considered, and there is typically an average and maximum process rate. These factors will also influence the number and type of equipment employed in cases where below average processing rates are anticipated.
 - Average.
 - Maximum.
- * **Special Situations.**
 - Scaling tendencies. Cases involving scaling will require special design to reduce scaling, permit easy descaling, and decrease downtime required for cleaning.
 - Corrosion tendencies. Cases involving corrosive chemicals may require special materials of construction.
 - Safety and hazard considerations.
 - Expected plant discharges (gas, solid, and liquid).
- * **Influence of upstream and downstream requirements (System Analysis).**
- * **Economics or cost factors (capital and operating) and associated constraints.**
- * **System Requirements.**
 - Flowrate required - average, peak or constant.
 - Pressure available, including inlet pressure, initial (clean) differential pressure and maximum (dirty) differential pressure.
 - Throughput change frequency, whether a function of batch size, operating life, or differential pressure increase.

- Precipitation, coagulation, flocculation requirements and methods, frequency and conditions.
- Pretreatment/pretreatment of the fluid for downstream requirements (i.e., deionization, reverse osmosis, or roughing filters).
- Equipment requirements, including provisions for peak versus average demand, future increases in batch size or flowrate, and spatial limitations.

4.3 SYSTEM INPUT DATA

Input waste stream characterization is required to develop functional system specifications and detailed equipment design specifications for optimum operation. However, if the system is to be a versatile system wherein solids (suspended or dissolved) are removed as an aggregate without species separation, and organic/aqueous phase separation is performed in bulk, then detailed characterization of the input to the CPTS may not be necessary. However, if polishing operations on the "decontaminated" streams are necessary, then characterization of the input stream to the polishing equipment may be required. In addition, it will be necessary to be aware of the presence of corrosive or heat sensitive materials, materials that may cause serious fouling of heat transfer surfaces, or specific species that must be removed from the effluent. Input stream characteristics would include particle size distribution; particle characterization; liquid characterization including pH, viscosity, rheology, and chemical composition including solute characterization; feed solids concentration; and specific gravity differences. These feed characterization requirements are discussed in the following sections. Although all of these feed properties may not be required for a specific application, they all should be considered when developing system and equipment specifications, and when evaluating equipment and potential limitations.

4.3.1 Particle Size Distribution

Particle size distribution is a major factor in the selection process of solid/liquid separation equipment; complete size distribution and ranges within that distribution should be established. Particle size analysis should indicate the maximum particle size (usually 90% is smaller than this size), the percent finer than 200 mesh and, if possible, the percent finer than 10 microns (the maximum size of colloidal particles). In addition, the size distribution should

be plotted to determine whether a typical Rossin-Rameller relation exists; if there is a serious deviation from this distribution, a significant change in equipment can result.

The maximum size is important for some equipment, and the minus 10 micron percentage determines whether a flocculant may be necessary. Practically all the specific surface area will be found in the -200 mesh solids when they are present at about eight weight percent or higher, and this is more important in the case of the -10 micron content.

Particle size range alone will not provide a single solution to the solid/liquid separation problem. More must be known before a separation method can be selected. Laboratory scale testing on representative samples will be required to ensure dependable application over a specified range of conditions, and in some cases pilot-scale testing will be required.

4.3.2 Particle Characterization

The nature of the solid, as to whether it is crystalline, amorphous, organic, or dissolved as an ionic species, can greatly influence the choice of separation equipment and techniques. The abrasive character of the solids will affect the materials of construction and equipment lifetime. Crystalline or granular solids will usually separate more easily in all equipment even if they are relatively fine.

Shape and surface factors can be important. Flat platelets or disc shapes will settle slower, and in filtration, may act as "check valves" to the flow of liquid through a filter or filter cake. Even crystalline shapes can reduce filtration rates through blinding. For example, gypsum can be grown so it is easily filtered; however, it can also form needle-shaped crystals that can plug pores of a filter media and rapidly cause blinding. This can be remedied by using a continuous belt drum or horizontal filter in which the filter medium is continuously removed from the filter, washed, and returned to the filter surface.

If the solids are porous this can result in higher moisture content of the dewatered solids. Porous solids also make it more difficult to remove dissolved salts by washing of filter cakes. When dissolved solids must be separated from porous solids, it may be better achieved by using a two-stage separation with intermediate repulping rather than a single stage with washing.

4.3.3 Liquid Characterization

The character of the liquid medium is important including pH, chemical composition, and viscosity. Several characteristics that should be determined are as follows:

- * Chemical composition, providing information on the properties of the fluid that may indicate a corrosion study is warranted, to determine any material compatibility issues, and to determine the quantity and character of the solutes.
- * Identification of the organic species present that may cause fouling of heat transfer surfaces and media beds, and that would allow determination of the physical characteristics for selection of liquid/liquid separation processes.
- * Fluid viscosity, which directly affects the flowrate, pumping power required, and structural requirements of filter media and media beds.
- * Surface tension, which can affect filter media integrity and performance.
- * Fluid temperature, affecting viscosity and applicable material properties.

The dissolved solids content and particularly any compound that must be recovered or removed to some minimum value, or any temperature sensitive compounds that may be a safety issue, should be known as these will influence equipment selection and performance. For example, the mandatory specification of 99% or greater recovery or removal of a dissolved compound may require several separation stages and will probably limit the type of equipment that can be considered.

Another factor to be considered is scaling (unwanted precipitation of salts). Supersaturation of some compounds such as silicates, gypsum, silica, carbonates, etc., at slightly elevated temperatures and high or low pH values will usually result in scaling, which may be compounded by the presence of suspended solids in the feed. If a few degrees of cooling occur, crystallization results in unwanted precipitation and significant deposition upstream and downstream of the equipment, as well as in the equipment itself. This may cause blinding of filter media or media beds, or surface scaling in heat transfer equipment. Thus, if scaling is not considered processing rates can significantly decrease, moisture content can increase, and downtime due to extensive maintenance and cleaning requirements can increase.

4.3.4 Feed Solids Concentration

In most cases, separation rates based on suspended solids in the feed, such as the generation and use of filter cake, are increased as the solids concentration is increased. Thus, the unnecessary dilution of the filter feed should be avoided. However, there are some situations and separation methods in which the feed must be diluted to increase the solids separation rate. The feed suspended solids concentration has a strong influence on performance and a dependable average value and concentration range must be obtained.

4.3.5 Specific Gravity Difference

Knowledge of the solid/liquid and liquid/liquid specific gravity difference is critical because it is part of the driving force for some separation methods (i.e., classification, centrifugation, sedimentation, phase separation, etc.).

4.4 CRITERIA FOR PROCESS SELECTION

In this section, criteria used to evaluate and select equipment are identified and described. Volume reduction and/or ability to separate specified components may be the ultimate selection criteria. However, this may be tempered by economic criteria and other constraints including applicability to needs, schedule requirements to have a system online, reliability, risks associated with innovation, technical maturity, operability and complexity. Other criteria include property differences of the material to be separated, scale of operation, testing requirements for final equipment design, operational costs, useful life, safety, radioactive contamination control, maintainability, and separation efficiency. Much of the material in this section is based on the discussion in References 9 and 13.

4.4.1 Initial Screening

The first step is to define the problem. Usually, this entails establishing input stream characteristics, and purity and recovery specifications. Final product purity is established by regulations, whereas intermediate requirements are established by economics or requirements of downstream equipment.

Once the system needs, as identified in Section 4.2, are defined, a technology selection chart can be developed for each of the waste streams. The application of selection charts is

discussed in Section 2 for the aqueous, organic liquids, and wet solids waste streams. Technologies can be selected by determining whether they can perform the desired separation function on the waste stream with the characteristics identified in Section 4.3, or if they can provide the waste stream characteristics required by a downstream process. Once it has been determined that a technology may be applicable based on the system requirements and waste stream characteristics, then other evaluation criteria may be applied to downselect to a specific technology.

4.4.2 Property Differences

Having established the products to be separated in the waste stream and the purity and recovery desired for each, the next step is to determine which separation methods are capable of accomplishing the separation. In order for two components to be separable, there must be some difference in properties between them. Typical property differences used as bases for separation include:

- * **Equilibrium Properties.**
 - Vapor pressure.
 - Solubility.
 - Distribution between immiscible liquid phases.
 - Melting point.
 - Chemical reaction equilibrium.
 - Electric charge.
 - Surface sorption.
 - Specific gravity.
- * **Rate Properties.**
 - Diffusivity.
 - Ionic mobility.

- * Molecular Size.
- * Molecular Shape.

4.4.3 Scale of Operation

The scale of operation often is the determining factor in the selection between alternative separation processes. One method of separation may be economical for a large scale process, whereas another method may be more economical for a small scale process.

Many separation operations have an upper limit on the capacity that can be handled by a single unit. This upper limit may represent a true limitation imposed by the physics of the process, while in other cases the upper limit is imposed by the maximum scale on which commercial equipment is manufactured. If the capacity is limited, multiple units may be used in parallel.

4.4.4 Design Reliability

Design reliability is the most important factor in the choice of one process over another because, when constructed, the plant must work as expected. Design reliability cannot be defined *a priori* because it depends on the amount of testing and demonstration performed before a suitable commercial scale design is produced. In general, those systems that use high-speed equipment (i.e., more prone to breakdowns during operation), and require many components are less reliable.

4.4.5 Pilot Plant Operation

Pilot plant operation to test or scale-up separation process design is required for certain separation methods. In addition, it may be necessary to pilot plant a process to test the integrated operation of all the units. Small scale and pilot plant operation and testing implies added costs to the system design and development process.

4.4.6 Maintainability

Low maintenance technologies that are easier to maintain in a radioactive or toxic environment, require less total maintenance, less "hands on" maintenance, and less intricate or

complicated maintenance procedures should rate higher than those technologies that have higher maintenance needs or are difficult to maintain. High maintenance technologies generally have the following characteristics: above normal number of moving parts, poor component accessibility for maintenance, and questionable component reliability. The ability to automate the normal maintenance operations, such as cleaning or replacing spent media, would be a plus in rating a technology.

4.4.7 Capital Costs

Factors that affect capital costs include:

- * **Scale of Operation.** For very small-scale operations, the required capacity may be less than the available commercial equipment. Then, custom equipment will be required. On the other hand, if multiple parallel lines are required because the capacity of the plant is larger than the commercial equipment available for a single line, the capital cost may rise at a faster rate than the single-line scale-up factor.
- * **Design Reliability.** Larger safety factors are applied when design methods are less reliable causing larger capital costs. There is also a tendency to install more extensive control systems and more spare backup equipment when there is uncertainty in the design. This design uncertainty will result from immature technologies and from lack of detailed knowledge of feed characteristics.
- * **Necessity of a Pilot Plant.** Pilot plants are usually considered part of the research and development expense, but often they are maintained as part of the full-scale plant and used for troubleshooting, testing proposed plant modifications, or to handle plant overloads. This is particularly appropriate for the MWTP since so little is known about the feed characteristics. Therefore, the cost of R&D, a pilot plant, and required testing should be factored into the cost of a technology.
- * **Number of Steps Required.** Capital cost is usually directly related to the number of steps required in a process to achieve a specified level of separation.

4.4.8 Operational Costs

Factors that affect operational costs include:

- * *Maintenance Costs.* These costs include the costs of cleaning and replacing separation media, media cost, cost of chemicals used for regeneration and cleaning, disposal of contaminated separation media and cleaning chemicals, and general plant maintenance associated with separation equipment. These costs would be one of the selection criteria for separation equipment and/or methods. In addition, operating costs must include chemicals and reactants required for chemical treatment and separation.
- * *Energy Requirements.* Energy cost may be the dominant operational cost, and may influence capital costs in the form of heat exchangers, pumps, compressors, etc. Therefore, energy requirements are an important consideration in the selection of separation processes. Concern should be directed not only to the amount and cost of energy delivered directly to the process, and the amount of fuel required to deliver this energy, but also to the quality of energy that flows through the process as defined by the second law and the potential for energy recovery.

4.4.9 Separation Efficiency and Decontamination Factor

Separation efficiency is a function of the differences in equilibrium compositions and transport rates due to the fundamental physical phenomena underlying the separation. It also depends on the construction and flow configuration of the separation device. In some instances, the separation efficiency can be derived analytically for certain idealized processes. However, there are separation processes that are so complex or poorly understood that a factor cannot be readily defined. In these situations the separation efficiency must be obtained empirically from experimental data. Such is the case for separations by electrolysis, flotation, and evaporation, for example.

For the separation of particles from fluids, a total, or overall, separation efficiency can be defined as the ratio of the mass of all particles separated to the mass of all solids fed into the separator. Unfortunately, the performance of most suspended solids separation equipment is highly size dependent so that different size particles separate with different efficiencies. Thus, the total efficiency is very dependent on the size distribution of the feed solids, and therefore is unsuitable as a general criterion of efficiency. Values of total efficiency quoted in manufacturers literature may result in misleading conclusions about the separational capability of equipment unless they are accompanied by the particle size distribution of the feed solids, the density of the solids, and other operational data.

The decontamination factor is defined as the ratio of the feed concentration to the final product concentration for the contaminant being removed from the feed. This may be available from equipment vendors based on previous tests or operational experience, or additional testing may be required to develop this factor for specific equipment and technologies. Decontamination factors may be used to evaluate the ability of equipment to remove dissolved salts or organic material from a waste stream, and to determine the requirements for additional downstream processing.

4.4.10 Primary Pollutant Removal

This is a measure of the ability of the technology to remove the required species or component(s) with high efficiency and minimum number of steps, thus satisfying the requirements of downstream processes. This includes the ability of a technology, or series of technologies within the system, to meet the waste water discharge requirements, or to meet the requirements of the Final Forms process to comply with the Land Disposal Restrictions (LDR) requirements. The technology, or system, must meet all regulatory and effluent standards and requirements for permitting.

4.4.11 Secondary Waste Generation and Volume Reduction

Ability of the technology to minimize the volume of secondary waste produced, and to produce the secondary waste in a form easily processed downstream by the WDS and FWF Systems. This includes the ability to entrain the radioactive components into a waste residual that will go to final forms processing rather than to incineration and potentially end up in the offgas system. The amount of secondary waste generated refers to that collected in filter media, adsorber beds, etc., as well as the discarded material such as spent media and cleaning or backwash fluids. Certain spent media may require formulation of specialized final forms. This criteria also includes the ability of the technology or process to reduce the original waste volume.

4.4.12 Safety

A safety assessment is based on whether the technology can operate within the acceptable range of risk exposure to the operators and the public. Safety decisions are based on two separate criteria: contamination control and inherent hazards. Contamination control is the ability of the technology to entrain or control the spread of radioactive or hazardous

contaminants. Characteristics of a technology that affect contamination control include liquid effluents, dirty systems, and penetrations. Liquid effluents downrate a technology because of the issues related to contamination and dispersion resulting from spills. Dirty systems are those that, through normal operations, tend to build up residues (especially powders) that can easily become airborne or spread by some other method. These systems tend to pose a radiological and toxic control problem, particularly during maintenance. Penetration refers to the opening of a door, manhole, or some other portal into the system or equipment for servicing the internals or for injecting the waste to be processed. Penetration of the system can lead to problems such as spills and airborne contamination. These criteria involve the capability of a technology to control and minimize the spread of contamination (radioactive or toxic). Inherent hazards include working with toxic chemicals, high speed equipment, explosive or highly combustible reactants, high temperature, high pressure, and electrical energy hazards. Inherent hazards are considered to be the most significant problem and should be given twice as much weight as the other safety concerns. All of these safety concerns represent a hazard to public and worker safety and the environment.

4.4.13 Versatility

The technology should be assessed regarding its capability to respond to or conform to changing requirements, to be sensitive to wide changes in the instantaneous feed characteristics, and to accept a wide variety of waste components and configurations. A technology that is capable of accepting new or a wide variety of waste components to meet new requirements will rate higher than technologies that require major changes or perhaps cannot be modified to meet new requirements. In addition to the ability to accept waste streams with a wide range of characteristics or components, the technology should be able to remove multiple pollutants. To some degree this ability depends on the total system concept and design; however, some technologies have inherent capabilities that result in multiple pollutant removal and may meet most of the requirement for removal.

4.4.14 Experience/Maturity

This criterion measures the degree to which the technology can be developed, tested, and ready for operation within the required timeframe (an operating Mixed Waste Treatment Plant by FY-2005). Technologies that are fully developed, operational, time-proven, and commercially available would rate a higher score than emerging, unproven technologies. This

assumes that mature technologies present less risk of implementation than unproven technologies.

This is considered an important criterion because it eliminates some of the risk associated with the selection of a system that will require a large investment of both time and money. Mature systems will typically have had many of the technological problems worked out and will more likely have been tested under a variety of conditions. Mature systems are also time proven so that reliability factors are available and potential problems can be mitigated by proper design. Application of the technology at several operating facilities may also be used as an evaluation criterion because of the added experience that this would bring, regardless of whether the technology is new or old. Multiple vendors should be considered a value in that it demonstrates that the technology is well known.

4.4.15 Simplicity/Operability

Technologies with lower number of pretreatment steps, post treatment steps, or that minimize the secondary waste streams should be rated higher than ones with a larger number of steps in the operation, generate secondary waste streams that are difficult to handle, or are difficult to operate.

Simplicity is an indicator of the potential success of a system. This evaluation criterion is subjective and therefore requires engineering judgement. Both reliability and maintainability, discussed above, are related to simplicity through the application of heavy-duty, well-built equipment since certain technologies will have inherent weaknesses in terms of sturdiness. Ease of operation includes such issues as requiring frequent attention, requiring complicated operating procedures, and using several subcomponents that perform necessary functions but require monitoring or some interaction from the operations personnel. Difficult to operate equipment or systems may have the following characteristics: complex feed requirements, above normal support system requirements, frequent hands-on operational needs, and high manpower requirements.

A significant variable affecting the cost and complexity of separation processes is the number of steps required to effect the desired separation. However, the number of steps required is not an absolute determinant of the cost or complexity; in some instances it is easier and more economical to use a separation sequence consisting of several steps even though it is possible to accomplish the separation with only one step. Although, in the majority of cases, a

single-step process will be more economical than a multistep process, it may end up more complex and more difficult to maintain.

4.4.16 Throughput

Equipment or system throughput adequate to meet system requirements, without the additional cost of parallel modules, will be rated higher than a technology with lower throughput rates.

4.4.17 Acceptability

Acceptability of a technology refers to its ability to be in regulatory compliance; easily permitted; have community acceptance; display thorough monitoring, accounting and management of wastes, energy and materials; show the least safety risk and the most radiation control; and produce the most desirable waste form or the most usable "cleaned" product.

4.4.18 Systems Integration

As components and technologies are evaluated, one must bear in mind how the component will operate within the total system, what the pretreatment requirements are for the component to operate properly and reliably, and the effect of the output on downstream processes. Ancillary equipment, such as high pressure pumps or vacuum pumps, should be identified so that not only the specific component is costed and evaluated, but also the ancillary equipment required to make the component work is included in the cost and evaluation process.

SECTION 5 RECOMMENDATIONS AND CONCLUSIONS

5.1 EQUIPMENT/TECHNOLOGY RECOMMENDATIONS

The Appendices have been developed to provide information for a broad range of technologies applicable to the CPTS. Over the next several months technology selection charts will be expanded as system requirements are refined, and technologies categorized based on their applicability to a specific waste stream and separation requirement. The technologies will then be evaluated and gaps in capabilities, or improvement needs in existing technologies, identified. This process will lead to the identification of RDDT&E needs to accommodate specified requirements, or to decrease system cost. This section will summarize the results of this effort, recommend the technology (or technologies) to be used or that would warrant further testing and/or development, and identify RDDT&E needs for the CPTS.

5.2 CONCLUSIONS

Based on analyses to date, and discussions with other TSGs, the following RDDT&E needs for the CPTS have been identified:

- * ***Mercury Processing.*** Develop an understanding of the fundamentals associated with removal of mercury from the various host matrices (aqueous, organic, solid, and gaseous), capture from the offgas stream, and subsequent purification. Knowledge of the effect of various potential forms of mercury on the treatment process is required, as well as an understanding of the effect of other volatile species, such as water and organics, on the performance of the process.
- * ***Aqueous Processing.*** Efforts needed in this area include the following: how to process water most effectively to remove salts, evaluation of alternatives to the baseline treatment scheme, analysis and testing of the baseline approach, and evaluation of methods and requirements for recycling salts such as salt splitting.
 - ***Salts.*** The current approach with regard to salts is to evaporate the aqueous phase to a point where a concentrated salt solution is produced and subsequently processed through the wet solids treatment line. The salts (especially chloride, nitrate, and sulfate) contained in this concentrate are problematic to downstream processing steps in the WDS, FWF and OGT

Systems. Thus, alternative approaches, including industrial solutions, to address the salts are required.

- **Baseline Alternatives.** Alternatives to the baseline approach have been suggested by the CPTS TSG and described in Section 3. These include steam stripping to remove organics and freeze crystallization. Versatile alternatives to the baseline, such as these, are required to minimize system complexity, secondary waste streams, and cost.
- * **Decontamination.** Surface decontamination for hazardous and radioactive materials will be required for containers, heterogeneous waste, and potentially for waste classified as debris. The baseline approach includes simple washing, drying, and monitoring which generates large volumes of secondary waste in the form of spent solvents. New decontamination technologies, including industrial solutions, are required to minimize generation of secondary wastes.
- * **Wet Solids.** As indicated for treatment of aqueous waste streams, salts may cause significant processing problems in the WDS, FWF and OGT Systems. The two major waste streams containing salts are the aqueous and wet solids streams. Approaches to salt removal (such as leaching), segregation and final disposition are required.

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