SEP 10 1996 Sta. 37 (26)

ENGINEERING DATA TRANSMITTAL

1. EDT 618449

2. To: (Receiving Organization) Retrieval Processes Development and Enhancements	3. From: (Originating Organization) Remote System and Sensor Applications	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: OM580	6. Design Authority/ Design Agent/Cog. Engr.: O. D. Mullen	7. Purchase Order No.: N/A
8. Originator Remarks: Transmittal of INEL HLLWT Waste Dislodging and Conveyance System F&R		9. Equip./Component No.: N/A 10. System/Bldg./Facility: N/A
11. Receiver Remarks: 11A. Design Baseline Document? [] Yes [X] No		12. Major Assm. Dwg. No.: N/A 13. Permit/Permit Application No.: N/A 14. Required Response Date:

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	WHC-SD-WM-FRD-029		0	Functions and Requirements for a Waste Dislodging and Conveyance System for the Idaho National Engineering Laboratory High Level Liquid Waste Tanks	N/A	1		

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
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18.	19.	20.	21. DOE APPROVAL (if required)
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Functions and Requirements for a Waste Dislodging and Conveyance System for the Idaho National Engineering Laboratory High Level Liquid Waste Tanks

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U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 618449 UC: 2060
Org Code: 8A800 Charge Code: BE0423
B&R Code: EW4010000 Total Pages: 63

Key Words: Functions and Requirements (F&R), Waste Dislodging, Conveyance System, Idaho National Engineering Laboratory (INEL), High Level Liquid Waste Tanks

Abstract: In 1990 the U.S. Department of Energy (DOE) Office of Technology Development initiated the Light Duty Utility Arm (LDUA) program to support the Consent Order between the State of Idaho, U.S. Department of Energy, and the Environmental Protection Agency that requires ceasing use of the 11 high level liquid waste (HLLW) storage tanks at the Idaho Chemical Processing Plant (ICPP).

Approved for Public Release

FUNCTIONS AND REQUIREMENTS

for a

WASTE DISLODGING AND CONVEYANCE SYSTEM

for the

IDAHO NATIONAL ENGINEERING LABORATORY HIGH LEVEL LIQUID WASTE TANKS

August 15, 1995

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1.0 INTRODUCTION

1.1. BACKGROUND:

In 1990 the U.S. Department of Energy (DOE) Office of Technology Development Initiated the Light Duty Utility Arm (LDUA) program to support the Consent Order between the State of Idaho, U.S. Department of Energy, and the Environmental Protection Agency that requires ceasing use of the 11 high-level liquid waste (HLLW) storage tanks at the Idaho Chemical Processing Plant (ICPP). The cessation of use is required to comply with the Resource Conservation and Recovery Act (RCRA). RCRA requires the HLLW underground storage tanks to have a double containment. All of the tanks at the ICPP tank farm are of single-shell stainless steel construction, and vaults for five of the tanks cannot meet current Idaho National Engineering Laboratory (INEL) seismic criteria. The Consent Order requires ceasing use of five tanks by the year 2009 (tanks VES-WM-182-186) and ceasing use of the remaining six tanks by the year 2015 (tanks VES-WM-180, 181, and VES-WM-187-190).

A major portion of the TFA program addresses the inspection, sampling and characterization of the tanks and the radioactive chemical wastes that were accumulated in the tanks and removal of the waste by the Confined Sluicing End Effector. Work is currently being conducted at Westinghouse Hanford Company, Pacific Northwest National Laboratory, Waterjet Technology Incorporated, Oak Ridge National Laboratory and the University of Missouri-Rolla to evaluate and develop some technologies having high probability of being practical and effective for the dislodging and conveying of waste from underground storage tanks. The findings of these efforts indicate that a system comprised of an end effector employing high pressure fluid jets to dislodge the waste, and a jet-pump conveyance system to evacuate the waste to the processing system, all maneuvered over the waste by one or more manipulator(s) or other mechanism(s), is a viable tank waste retrieval technology. The technological approach to waste retrieval from the INEL HLLW Tanks is based upon this research and development, and forms the basis for the design criteria set forth by this document. (Reference 1)

1.2. SCOPE:

The system used to dislodge the waste and convey it to an above ground location, from which it may be transferred to either the New Waste Calcining Facility or another tank, is collectively identified as the INEL Waste Dislodging and Conveyance (WD&C) system. The purpose of this document is to establish the functions and requirements for the design of the INEL Waste Dislodging and Conveyance (WD&C) system.

The general arrangement of the waste tanks and a general concept for the deployment of the retrieval system is presented as Figure 1. This figure is not to be interpreted as design guidance.

All waste treatment facilities or other tanks, and systems for transport of waste to these facilities after it has been retrieved by the WD&C system, are part of the balance of plant (BOP). All systems beyond the interface at the conveyance line outlet are considered part of the balance of plant. The manipulator system and latching mechanism to support WD&C operations are also considered separate systems from and not part of the WD&C system and are beyond the scope of this document for other than reference purposes. The requirements defined in this document are based on maneuvering the waste dislodging end effector within the tank using the Light Duty Utility arm (LDUA, Reference 2). Should an alternative method of maneuvering the WDEE be used, portions of this document may no longer be valid. Any alternative manipulator shall have dexterity and payload capacity at least equal to that of the LDUA. The latching mechanism or gripper required to link the WDEE to the manipulator in the tank is considered part of the manipulator for the purposes of this document.

Unless otherwise specified, the scope of this document is limited to only that equipment in the five basic WD&C sub-systems listed below, including the internal utilities required to support their operation. BOP elements are defined by this document only to the extent of their direct physical interfaces with and their performance requirements related to the WD&C System.

<u>The Sub-Systems Comprising the WD&C System are:</u>

1) Waste Dislodging End Effector (WDEE)
   - ☐ Dislodging end effector
   - ☐ End effector utilities & supply conduits

2) Waste Conveyance System (WCS)
   - ☐ Waste conveyance pump
   - ☐ Waste conveyance conduits
   - ☐ Supporting utilities

3) WD&C Deployment System (DS)
   - ☐ Deployment Boom
   - ☐ Hose and Cable Management

4) Confinement and Contamination Control (CCC)
- ☐ Containment housing
- ☐ Decontamination system

5) Instrumentation and Controls (I&C)
- ☐ I&C controls and monitors
- ☐ Actuators & sensors
- ☐ Data storage

1.3. ASSUMPTIONS AND UNKNOWNS:

Some requirements and parameters specified in this document are not fully defined at this time, but remain to be determined (TBD) before the WD&C design can be finalized. Such incompletely defined terms are identified in the text of this document by the symbol (TBDX), where the X represents a number for that particular unknown or family of unknowns. A complete listing of all TBD's are found in section 8 of this document and identify the organization responsible for their respective resolutions.

1.4. ACRONYMS AND ABBREVIATIONS:

The acronyms and abbreviations used in this document are defined as follows:

ALARA	As Low As Reasonably Achievable - DOE policy for worker exposure to ionizing radiation and hazardous materials
BOP	Balance of Plant (BOP). The BOP is a term used to refer inclusively to all other portions of the waste retrieval process not included in the WD&C system defined in this document.
CCC	Confinement and Contamination Control (CCC). That part of the WD&C system which acts as a barrier to protect personnel and the environment from contamination.
CMS	Cable Management System (CMS). That portion of the WD&C deployment system (DS) which handles and manipulates the conduit, hoses, cables, etc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).
DOD	Department of Defense (DOD).
DOE	Department of Energy (DOE).
DS	Deployment System (DS). Referring to the WD&C deployment system.
EE	End Effector (EE). A general term used to identify those special tools and instruments attached to the end of the LDUA arm by means of the TIP. Not part of the WD&C.
E-Stop	Emergency Stop button, or condition in control logic providing immediate, overriding shutdown of designated functions.
HLCS	High Level Control System (HLCS).
HLLW	High Level Liquid Waste tanks. Refers to the underground waste storage tanks located at the Idaho Chemical Processing Plant Tank Farm at the INEL

ICPP Idaho Chemical Processing Plant

ICS Instrumentation and Control System (ICS).

INEL Idaho National Engineering Laboratory (INEL). The Federal Government facility located near Idaho Falls at which the WD&C system will be employed.

ITH In-Tank Hardware (ITH). The tank being processed may contain various items such as cooling coils, RF (Radio Frequency) Level probes, corrosion coupons or other articles. All such structures are considered to be ITH.

LATA Los Alamos Technical Associates, Inc.

LDUA Light Duty Utility Arm (LDUA). A manipulator arm having reach, dexterity, control and payload capabilities for surveillance, characterization and retrieval operations in underground waste tanks. (See Reference 2)

OCC Operator Control Console (OCC).

OU Operating Unit

RCRA Resource Conservation and Recovery Act. The INEL HLLW tanks are presently out of compliance with the RCRA.

TBD To Be Determined (TBD). Requirements and parameters specified in this document which are not fully defined at this time, but remain to be determined before the WD&C design can be finalized. See section 8

TIP Tool Interface Plate (TIP). The TIP is a two part component of the LDUA used to allow end effectors to be manually attached to the end of the LDUA arm in a standardized manner. The arm TIP half remains attached to the LDUA arm. The end effector TIP half remains attached to the end effector. The TIP is not part of the WD&C.

UST Underground Storage Tank

Waste In this document the term "waste" refers only to those chemical compounds stored in the tank, which were the result of past processing of various chemical and nuclear materials, and does not include various ITH found within the tank.

WCS — Waste Conveyance System (WCS). That portion of the WD&C system that receives waste from the WDEE and transfers it above ground to the BOP.

WD&C — Waste Dislodging and Conveyance (WD&C). The overall system of equipment (excluding the LDUA or crawler and the GEE) directly used to dislodge and convey waste from inside the underground storage tanks to the interface with the BOP

WDEE — Waste Dislodging End Effector. That portion of the WD&C system used to dislodge waste from the tank and transfer it to the Waste Conveyance System.

World Model — A computer-based mathematical model of the tank and the retrieval systems. The world model is to be presented as a graphical display for operator reference.

2.0 FUNCTIONAL CHARACTERISTICS

The overall function of the WD&C system is to dislodge the waste inside a tank, clean the tank interior and convey the waste (including the solids, supernate, and a possible suspended layer of material that may be floating on top of the waste) and process fluids to a BOP interface point at the end of the WD&C conveyance system. This function must be accomplished in a manner protective of personnel and the environment.

The WD&C system shall be designed to clean the walls, floor and cooling coils in each tank as shown in Figures 2, 3.

The BOP for the INEL process effects transfer of waste to another tank or to a waste treatment facility. The interface between the WD&C and BOP will be at the end of the WD&C conveyance system for either case.

In-tank operations will be performed remotely, using robotic or teleoperated equipment, with operator vision provided by TV cameras and lights within the tank. These vision and lighting systems are not included in the WD&C equipment.

The following paragraphs provide a general description of the functions to be accomplished by each of the five basic subsystems of the WD&C system.

2.1. OPERATING STRATEGY

The WDEE and WCS are deployed into the tank by the WD&C DS through a tank riser. The manipulator, with the latching mechanism affixed, enters the tank through a different riser than the WD&C system, engages with the WDEE, and maneuvers it over the waste for dislodging and retrieval operations.

During retrieval operation, the WDEE remains attached to the inlet of the waste conveyance system conduit. Movement of the WDEE during the dislodging process may be either non-automated (full operator control) tele-operation or semi-automated (operator real-time control with some automated sub-routines), as selected by the operator(s) at their discretion. Full automation may be implemented to the extent supported by the LDUA controls and practical for the operators.

The manipulator cannot be deployed through the same riser as the WDEE. The WDEE will be deployed and maneuvered into position for engagement by means of the WDEE Deployment System (see Section 2.4 & Figure 4) The engagement function shall be provided by means of a latching mechanism supplied with and attached to the manipulator. After entering the tank, the manipulator will position the latching mechanism adjacent to the WDEE to enable it to grip the WDEE. The manipulator and latching mechanism function as the sole support and means of mobility for the WDEE during dislodging and retrieval operations and will move the WDEE relative to the tank waste in a manner determined by the operator. (Figures 5, 6)

The withdrawal of the WD&C from the tank is similar in principle to insertion. The system is placed in the same configuration as for the mating of the latching mechanism to the WDEE, the latching mechanism releases the WDEE, and the WD&C system is retracted through its riser. The WDEE need not be rigidly attached to the WCS or DS for insertion/retraction; it may be tethered by the utility and conveyance hoses and/or an independent tether . The tethered WDEE must hang in an orientation which allows retraction and does not stress the utility and conveyance hoses excessively.

2.2. WASTE DISLODGING END EFFECTOR:

The functions of the Waste Dislodging End Effector (WDEE) system are to dislodge waste and debris from the tank bottom and walls and from on and around the cooling coils and mobilize it for removal by the waste conveyance system. The WDEE System includes:

- the end effector (the WDEE) which acts directly upon the waste.
- the energy source(s) for the WDEE which provide power in the appropriate form(s), including prime movers (such as pumps and their associated fueling, cooling and exhausting equipment) and/or utility connections to site systems.
- the cables and hoses which transmit energy and/or working fluids to/from the WDEE from the energy source(s).

2.3. WASTE CONVEYANCE SYSTEM:

The primary function of the Waste Conveyance System (WCS) is to receive waste from the WDEE, convey it above ground, and deliver it to the BOP interface. The WCS includes:

- waste conveyance conduit which is attached to, and receives waste from, the WDEE.

- the energy source(s) for the WCS which provide power in the form(s) appropriate for the WCS, including prime mover and/or utility connections, fueling, cooling and exhausting equipment.

- the cables and hoses which transmit energy and/or working fluids to/from the WCS from the energy source(s).

2.4. WD&C DEPLOYMENT SYSTEM:

The primary function of the WD&C Deployment System (DS) is to provide means of deploying and retracting the WDEE, WCS conduit, and their utility hoses and cables into and out of a tank, providing limited manipulation of the WCS conduit, utility hoses and cables with respect to the WDEE, and handling them in a controlled manner during the dislodging and retrieval process. The WD&C DS includes:

- a deployment mechanism for deploying and retracting the WDEE (attached to the WCS conduit) into and out of the tank through a riser, presenting the WDEE to the latching mechanism, and positioning conduit, hoses and cables inside the tank for optimum waste dislodging and retrieval.

- a cable management system outside the tank to handle any lengths of conduit, hose and cable required outside the tank (above the riser) to accommodate the WDEE range of travel

The WCS conduit, and hoses and cables supplying utilities to the WDEE are supported by the WD&C deployment mechanism during insertion, waste retrieval and equipment retraction. As the manipulator moves the WDEE about the waste, the Deployment System will support and position the conduit, hoses and cables to the WDEE in such manner as to avoid exceeding the load capacity of the manipulator, and to avoid entanglement with the manipulator or obstacles. The degree of active control of the DS is to be the minimum necessary to perform the above functions.

2.5. CONFINEMENT AND CONTAMINATION CONTROL:

The primary function of the Confinement and Contamination Control (CCC) system is to shield and protect personnel and the environment from the in-tank atmosphere and the radioactive and toxic hazards associated with working at the tank risers, with the handling of contaminated WD&C equipment (i.e. the WDEE and portions of the WCS) and to provide means for storage, transportation, servicing and decontamination of the WD&C equipment. The CCC must enable personnel to safely perform maintenance on all WD&C equipment contained or confined therein.

The CCC shall incorporate a system to perform gross decontamination of the in-tank portions of the WD&C remotely as they are removed from the riser, and detail decontamination preparatory to servicing , transport or storage, and for decontamination of work enclosures, tools and equipment used. Provision is to be made for gross decontamination of other contaminated WD&C components prior to or during dismantling from the riser. Unacceptable contamination levels shall be detected and alarmed by radiation monitors provided by site Health Physics technicians.

The CCC shall include a functional means to prevent overspray from the decontamination system from spreading contamination to other zones within confinement.

The CCC will include (a) storage and transportation container(s) for the WD&C equipment. The CCC shall provide means, using remote handling techniques, for separating WD&C components subject to severe contamination and placing them in storage or transport containers. The CCC must be capable of complying with on-site transportation requirements applicable to WD&C equipment . It must be designed to properly support the contents and protect them from vibration and shock during road transport.

2.6. INSTRUMENTATION AND CONTROLS:

The WD&C Instrumentation and Control System (ICS) shall control and monitor the operation of the WD&C system and provide an operator interface. The WD&C ICS will not require direct control interface with either the manipulator or the latching mechanism except for common E-stops. The WD&C ICS shall not be slave to, or master over, the manipulator or the latching mechanism. The WD&C ICS shall provide joint position information defining the configuration of the DS to the World Model for position analysis and display, supporting motion planning and collision avoidance during position change modeling and physical position changes of the manipulator. Coordination between the manipulator and any active joints on the DS shall be required when the two systems are connected. This coordination may be accomplished manually by the operators of the two systems (the manipulator including the latching mechanism and the WD&C system).The WD&C ICS must provide for an interface to a future High Level Control System (HLCS) that would provide one operator with control of the manipulator, the latching mechanism, and the WD&C system.

The WD&C ICS shall provide the following:

a) Operator interface for the WD&C system.

b) A graphical real-time display of process variable information including control settings and system behavior.

c) A permanent record of selected system information sufficient to reconstruct and analyze events, system dynamics and waste properties.

d) Automatic, event triggered response to deviations from the normal operating envelope, designed to mitigate consequences of unsafe conditions and restore safe conditions. If such response requires stopping motion, the response shall include E-stop of the manipulator motion. The ICS shall require operator action to return the system to a normal operating status after any such automatic intervention. This function shall be coordinated with manipulator controls. E-stop of the manipulator shall initiate E-stop of the WD&C system.

e) Monitoring and alarming of WD&C conditions which may be hazardous to personnel and facilities.

f) A position information model to the manipulator World Model .

g) May provide a High Level Control System interface in the event that a HLCS is adopted.

h) Closed-loop control of WD&C subsystems subject to external perturbation

3.0 DESIGN REQUIREMENTS

This section of the document defines the requirements applicable to the design of the WD&C system:

3.1. GENERAL DESIGN REQUIREMENTS:

3.1.1. Environment Internal to the Waste Tank:

Those portions of the WD&C equipment which are exposed to the interior of the waste tank must be designed to remain fully operational and achieve full design life when subjected to the following normal in-tank environment:

3.1.1.1. Tank Contents

Tank wast consists of an aqueous supernate with a heel of apparently readily suspended particulate, with a vapor space above the supernate. There is solid waste deposited on and adhering to the internal tank structures

3.1.1.2. Tank Waste Properties

Tank waste sampling and characterization data is very limited. Sampling data has been taken from the process lines. The information following is a "best estimate" of tank waste properties and should be used conservatively. (see Ref. 3)

- Chemical - Non-heat generating, not sensitive to impact, rubbing or abrasion. The chemical environment is acidic with high levels of sodium. The maximum acid concentration is 6 molar nitric acid with a pH level of less than 1. High levels of chloride are also present up to 0.031 molar.

- Physical - Seventy five percent of the weight of the particles is estimated to be larger than 45□ with a density of 3.0 g/mL and account for 25% of the total weight. Most of the solids are expected to be in a granular form with combined specific gravity ranging from 1.25 to 1.12. Some of the solids have similar specific gravity near that of the supernate and will exhibit flocculent behavior.

- Quantity - 10 to 30 cm (3 - 12 in) of liquid supernate with a 2.5 to 7.5 cm (1 - 3 in) heel in the bottom of the tank. The maximum total amount of solids expected in the heel for each tank is estimated at 9000 kg for a 3 in-heel.

- Thermal - Temperature may range from 7 to 38 □C (45 □F to 100 □F). Thermal conductivity and specific heats are unknown.

- Radiological - The expected maximum radiation field at the solid waste surface is 500 R/h

- Topography. Each of the tanks with exception of tanks WM-181 and 184 contain cooling coils constructed from 1-1/2" SCH 80 SST that cover the interior tank surface. The cooling coils are aligned in pairs with each pair spaced 65 cm (18 in) apart with a stand off distance of approximately 15cm (6 in) from the tank wall and floor (see Figure 3). Sedimentary waste coats or covers the tank floor and cooling coils.

3.1.1.3. Supernate Properties

- Chemical: The chemical environment is acidic with high levels of sodium. The maximum acid concentration is 6 molar nitric acid with a pH level of less than 1. High levels of chloride are also present up to 0.031 molar. (References 3, 3, 5)

- Physical: Poorly characterized. Properties of 6M nitric acid are the best estimate at this time.
  Viscosity - 6M nitric acid has absolute viscosity ~1.3 x that of water.
  SG - 6M nitric acid has specific gravity ~1.2 x that of water.
  A thin layer of organic compounds may be floating on the surface of the supernate.

- Quantities: Supernate volume remaining after jetting will range from 20,000-60,000 L (5000 -15000 gal), a depth of 8 - 30 cm (3 to 12 inches).

- Thermal: In tank temperatures range from 7 to 38 □C (45 □F to 100 □F). Thermal conductivity and specific heats are unknown..

- Radiological: The expected maximum radiation field at the waste surface is 500 R/h.

3.1.1.4. Vapor Space

- Chemical - Air, containing vapors emitted from the supernate. Some tanks may contain organics that could produce flammable gasses.

- □ Physical - The INEL HLLW tanks are activily ventilated and are kept at a pressure of -500Pa (gage) (-2 inches of water) Relative humidity ranges up to 100%.

- □ Thermal - Temperature may range from 7 to 38 □C (45 □F to 100 □F). .

3.1.1.5. Tank Structure

Tanks are 15.85m (50 ft) in diameter with a 3.35m (11 ft) dome and a 1.14 x10^6 L (300,000 gallon) capicity. Distance to the bottom of the tank ranges from 12.5 - 13.1m (41-43 feet) from grade for tanks WM182- 190, and 14.9 - 15.5m (49 -51 feet) for tanks WM-180 and 181. Each tank is constructed of a single shell stainless steel with a wall thickness of 8mm (5/16") at the bottom to the mid point of the tank, 6mm (1/4") wall thickness at the midpoint to the top of the tank, and 4mm (3/16") dome thickness. Each of the tanks contain cooling coils (with the exception of tanks WM-181 and 184). See figures 2, 3, 7.

3.1.2. Environment External to the Waste Tank:

Those portions of the WD&C equipment which are located external to the waste tank must be designed to remain fully operational and achieve full design life when operating in the following normal geophysical environment:

3.1.2.1. Ambient Temperature

System components shall be designed and constructed to function in external temperatures from -35□C to 49□C (-30□F to 120 □F) and shall be designed to tolerate additional heat loads resulting from operation in direct sunlight.

3.1.2.2. Storage Temperature

System components shall be designed to be stored in outdoor containers with an internal temperature range of -35□C to 49□C (-30□F to 120 □F). Note: Components are not required to operate at these temperatures, but all WD&C components (whether for use in-tank or out-tank) must be capable of operating after long term storage at these temperatures.

3.1.2.3. Relative Humidity

System components shall be designed and constructed to function in humidity ranging from 4% to 100%.

3.1.2.4. Wind Speed
System components shall be designed and constructed to operate in external wind up to 64 km/h (40 mph) and be able to withstand winds up to 129 km/h (80 mph).

3.1.2.5. Moisture
System components shall be designed and constructed to function in rainfall up to 50mm/h (2 in./h).

3.1.2.6. Snow Load
System must be able to function under snowfall accumulations of 60cm (2 feet).

3.1.2.7. Obstacles
Maneuverability is required to bring WD&C equipment within the tank farm area; the design must consider access through gates, above-ground ducts, and other above-ground equipment. Equipment shall be positioned using flat-bed trucks, forklifts or cranes, observing tank farm load restrictions. (Reference 4) Transportation equipment required to deploy the WD&C equipment shall be capable of traversing moderately rough terrain and negotiating obstacles up to 10 inches in height. System components shall be capable of withstanding repetitive dynamic forces induced during transportation.

3.1.2.8. Dust
System components shall be designed and constructed to function in an environment which has severe dust storms.

3.1.2.9. Exposure. System components shall be designed and constructed to function in direct central Idaho sunlight. Components shall not overheat or degrade due to direct exposure to sunlight.

3.1.3. Codes and Standards:

3.1.3.1. Temporary Equipment Installation
The WD&C system is an assemblage of temporary outdoor equipment and shall not be classified as, nor have to meet the requirements of, a

permanent facility. The following codes and standards shall apply to the design, fabrication and deployment of the WD&C equipment:

3.1.3.2. Electrical
Electrical wiring and components shall be in accordance with the National Fire Protection Association codes and National Electrical Manufacturers Association standards, as applicable.

National Electrical Manufacturers Association (NEMA) codes:

ICS 1	Industrial Controls and Systems
ICS 6	Enclosures for Industrial Controls and Systems

National Fire Protection Association (NFPA) 70-1993 National Electric Code

3.1.3.3. Piping
Piping shall be in accordance with ANSI-B31.3.

3.1.3.4. Structural
Structural elements shall be designed in accordance with the AISC ASD Steel Construction Manual (current edition)

Structural Materials Properties- All material properties used in structural and corrosion resistance calculations shall be in accordance with base / minimum properties listed in the following American Society for Testing and Materials (ASTM) codes or the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Codes* Section II, "Materials Specification." The material standard applicable shall be listed on fabrication / assembly drawings for each part.

American Society for Testing and Materials (ASTM) codes:

ASTM A 36	Structural Carbon Steel
ASTM A240	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate.

ASTM A 276	Stainless and Heat-Resisting Steel Bars and Shapes
ASTM A 193/194	Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service

The ASTM specification shall be documented for the 300 Series Stainless Steels that are selected for the fabrication of any component or structure in the system.

3.1.3.5. Welding

American Welding Society (AWS) codes:

D1.1 Structural Welding Code for Carbon Steel

D1.2 Structural Welding Code for Aluminum

D1.3 Structural Welding Code for Stainless Steel

3.1.3.6. Electronics and Communications

Electronic Industrial Association protocols:

RS-232	Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange
RS-281	Electrical and Construction Standards for Numerical Machine Control
RS-449	General Purpose 37 Position and 9 Position Interface for Data Terminal Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Interchange
RS-422-A	Electrical Characteristics of Balanced Voltage Digital Interface Circuits
RS-423-A	Electrical Characteristics of Unbalanced Voltage Digital Interface Circuits

3.1.3.7. Safety

Occupational Safety and Health Administration codes:

29 CFR 1910	Occupational Safety and Health Standards

3.1.3.8. Software

Institute of Electrical and Electronics Engineers (IEEE) codes andl American Nuclear Society (ANS) codes:

829 IEEE	Standard for Software Test Documentation
830 IEEE	Guide to Software Requirements Specifications
1063 IEEE	User Documentation
983 IEEE	Guide for Software Quality Assurance Plans
ANSI/ANS 10.4	Verification and Validation of Scientific and Engineering Computer Programs

3.1.3.9. Design

ANSI Y14.5M	Dimensioning and Tolerancing
AWS A2.4	Weld Symbols

3.1.3.10. Machining

ANSI B46.1	Surface Finishes
ASA B1.1	Screw Threads

3.1.4. Design/Analysis:

3.1.4.1. Safety Factors

All load bearing components whose failure would result in uncontrolled contact with the tank, damage to the tank, or loss of the arm or mast tubes into the tank shall meet a 5 to 1 safety factor on ultimate or a 3 to 1 on yield, whichever is more conservative. All other components. shall meet a 1.5 to 1 safety factor on yield with appropriate dynamic factors included.

3.1.4.2. Explosion

Although explosive concentrations of gases have never been detected in the HLLW tanks, equipment exposed to the in-tank atmosphere, directly or indirectly, shall be designed as a Class 1, Division 1, Group B as defined in the National Fire Protection Association (NFPA) 70-93 (NFPA 1993 Code 500/501).

3.1.4.3. Decontamination

All portions of the WD&C equipment subject to decontamination operations shall be designed to withstand water spray at 7 MPa (1000 psig) delivered through 15□ fan jet nozzles at a rate of 8 l/m/nozzle (2 gpm/nozzle) from a distance not greater than 100mm (4 inches). The decontamination medium could be demineralized water or cleaning fluid consisting primarily of 6 molar nitric acid.

All exposed surfaces must withstand repeated decontamination by one or more of the following solutions for follow-on cleaning (e.g., Washall and water with temperatures up to 200□F, Butchers Speedball compound, Raliac Wash compound, 3-to-6 molar nitric acid, 3-to-6 molar oxalic acid, and Turco cleaning compound 4502 at temperatures to 250□F.

The design shall minimize any collection points where waste could become trapped (i.e. rivets protrusions and crevices.)

3.1.4.4. Retrievability

The in-tank equipment shall be designed to ensure retrievability (i.e. in-tank equipment cannot hang up or become trapped in tank) during both normal and post-failure retrieval. The transition from the WDEE to the latching mechanism must be smooth to eliminate retrieval entrapment problems.

3.1.4.5. Geometry

The WDEE shall be able to reach between the cooling coils to the maximum expected 3 in. solid waste heel located on the tank floor. See Figure 3 for cooling coil configuration.

3.1.4.6. High Pressure Waterjetting Systems

A) Definitions:

1) Burst Pressure:- The internal pressure within a component of a high-pressure water jet system at which it will fail.

2) Manufacturer's Designated Burst Pressure:- that pressure at which either physical testing has shown that a component will fail, or at which the manufacturer has carried out physical testing of the component to validate that it will survive at that pressure.

3) Proof Testing:- a series of tests carried out to validate that a piece of equipment or component will withstand the operational conditions under which it will be used. This shall include operation for at least one hour at a pressure 1.5 times that of the working pressure.

4) Static Testing:- a test carried out in which the piece of equipment or component is subjected to an internal pressure, without fluid flow through the unit. For equipment subject to time varying loads such as pump pulsation, the static test shall be conducted using similar time varying loads.

5) Dynamic Testing:- a test carried out under pressure, during which the unit is subjected to the internal pressure designated for the test, with the test to include both the time variant loads to which the unit will be subject during operation (such as pump piston oscillation and the on-and off triggering of other system units) and on and off cycling of the pressure supply.

6) Maximum Allowable Working Pressure (MAWP):- The maximum pressure, recommended by the manufacturer, at which a component is to be used. The MAWP shall not exceed forty percent (40%) of the burst pressure of the component for unmanned operation or twenty five percent (25%) of the burst pressure for manned operation. A system is not to be operated

above the lowest maximum allowable working pressure of any of its components. All pressure systems shall be equipped with a safety device to limit the system pressure to the maximum allowable working pressure of the weakest component, with a tolerance of ± 3% .

7) Maximum Operating Pressure (MOP):- The pressure at which the system is designed to normally operate, not greater than ninety percent (90%) of Maximum Allowable Working Pressure (80% for systems subject to frequent or large pressure cycles). System controls shall have the maximum operating pressure clearly posted and accurate direct pressure indication clearly visible to an operator using system pressure controls.

8) Manned Operation:- Equipment or components which may be pressurized while not isolated from all personnel by a physical barrier or adequate distance is considered to be under manned operation and shall be rated accordingly.

B) Requirements:

1) All high-pressure (>500psi) equipment for waterjetting and jet pump operation shall be operated at less than the "Maximum Allowable Working Pressure" (MAWP)

2) All high-pressure equipment for waterjetting and jet pump operation shall be rated with a MAWP which is to be established according to the above definitions, either:

a) by the manufacturer, for parts produced in volume, carrying a part number and a published pressure rating, and produced under an accepted quality assurance program.

b) by testing of like items, manufactured from certified like materials under an accepted quality assurance program, to "Burst Pressure" or "Manufacturers Designated Burst Pressure". Articles so tested are not to be used. The testing for the Manufacturer's Designated Burst Pressure shall be either a dynamic or static test, as appropriate to the duty cycle in the application.

c) for one-of-a-kind, specially-fabricated or experimental parts deemed too expensive for destructive testing, by detailed analysis (to include hand calculations or finite-element analysis) of all loads (including internal pressure, external forces, shock loading, and fatigue) conceivably imposed on the item. For articles intended for manned operation, design stresses at the MAWP are to be less than allowable design stresses at the working temperature as defined by ANSI B31.1 Code for Power Piping, 1989 Edition, Section 302.3 - Allowable Stresses and other Stress Limits and the referenced tables. For any materials not defined therein, the allowable design stress shall be not greater than 25% of the yield stress as published by the manufacturer of the material. For components intended for unmanned operation, the allowable design stress may be increased to 40% of the yield stress. All components rated under this definition shall be manufactured from certified materials and "Proof Tested ".

3) An operational model of specially designed or prototypic equipment, having a Manufacturer's Designated Burst Pressure established in accord with 3.1.4.6.B)2)(a) or (b) will be subjected to Proof Testing, and so certified by the manufacturer, before being used in a system. The proof testing shall be carried out using both Static and Dynamic testing of the component.

3.1.5. Operations:

3.1.5.1. Campaign Duration and Service Life Requirements

Equipment shall be designed to operate for a minimum 1 month campaign without scheduled or planned maintenance, based upon 160 hrs/month during campaign. Service life of major structural components shall be adequate to support a minimum of 8 campaigns (up to 12 months). Service life of moving mechanisms, parts subject to wear or degradation etc, shall be capable of supporting a minimum of 3 campaigns. Exceptions may be made, subject to prior engineering approval.

3.1.5.2. Access Riser

The entry riser(s) through which the WD&C (i.e. WDEE, DS, and WCS) shall enter into the tank, are 12 inch IPS schedule 10s stainless steel risers, 3 to 5m (10 to 15 feet) long. The risers were originally constructed in the 1950's with no requirements on straightness or circularity.

In this document, this access riser is also referred to as "the designated riser", or simply "the riser".

Effective riser internal geometric constraints are considered to be the same as those for the LDUA manipulator (Reference 2)

3.1.5.3. Mobility

The WD&C equipment shall be used over the riser until waste retrieval is complete, and then dismantled and moved to another riser at the same tank or at another tank. Such moves may occur several times over the life of the equipment. This will require that the WD&C be designed to facilitate such moves, with attention given to contamination control, dismantling and re-assembly, lifting via a crane or forklift and placement, and transportation by flatbed truck. All equipment intended for hoisting and/or rigging for hoisting shall conform to DOE/ID-10500, DOE Hoisting and Rigging Manual (Reference 6) Lift attachment points on the WD&C equipment shall be compatible with this hoisting equipment.

3.1.5.4. Ground Loading and Equipment Support

The WD&C ASSEMBLY, including all equipment will conform to the loading restrictions imposed upon the INEL HLLW tank farm. (Reference 4) The WD&C equipment will be supported over the riser independently, by means of a dedicated support structure.

3.1.5.5. Water, Addition to Tank

The addition of new water to a tank/tank waste by the WD&C system shall be minimized, and added water shall be retrieved to avoid any net addition to tank contents volume. To the extent possible, water/liquids shall be recirculated or reused.

3.1.5.6. Tank Pressure

The WD&C shall not create a positive pressure within the tank, nor within its own confinement system, as measured relative to ambient.

3.1.5.7. Remote Operation & Surveillance Required

The WD&C system shall be fully functional under the constraint of remote operation of its in-tank components and of those systems directly supporting dislodging and conveyance of waste. These remote operations shall be performed in fully automatic mode (an option for future campaigns), semi-automatic mode (automated subroutines invoked by an operator), or operator controlled mode, at the option of the operator. TV overview cameras, lights and monitors shall be provided by the manipulator. The video monitoring must provide sufficient resolution for the operator to evaluate tank surface conditions and control the dislodging process.

3.1.5.8. Recovery of all WD&C Components
The in-tank equipment shall not lose or leave any system components or materials in the tank or damage the tank.

3.1.6. Maintenance & Service:

3.1.6.1. Maintenance
The system shall be designed to minimize scheduled preventative maintenance. Components shall be selected and designed to reduce and facilitate maintenance and increase mean time between failure. All required service shall be indicated on the service chart in the operation and maintenance manual. Tags and/or notices shall be attached to warn against operation before necessary servicing after shipment.

3.1.6.2. Maintainability
Where possible and feasible all systems which contact the waste shall be designed for maintenance using remote handling techniques or, if remote handling is impractical and adequate decontamination is feasible, by a mechanic(s) wearing anti-contamination clothing, including three pairs of latex gloves and a respirator, working within an enclosure.

Maintenance shall be performed in the CCC at the riser to the extent possible and consistent with ALARA. Otherwise, equipment must be bagged out of the CCC and serviced in other appropriate facilities.

Human factors shall be taken into consideration and a modular design approach shall be implemented where appropriate to ensure ease of equipment setup, operation, maintenance, and removal.

3.1.6.3. Servicing.
The system shall be designed so the components that are most likely to fail are readily accessible and easily replaced as a unit or as a subassembly. The system shall be modular in design where appropriate to facilitate fast repair cycles.

3.1.6.4. WDEE Replacement
The WD&C equipment shall be designed for replacement of the WDEE while within the CCC system confinement, using remote handling techniques.

3.1.7. Materials and Processes:

Materials and processes used in fabrication of the WD&C components shall enable the equipment to comply with all design requirements specified in this document, including design life, operating and storage environments, and decontamination operations.

3.1.7.1. Standards
All structural materials and processes shall be in accordance with the standards specified in Section 3.1.3. In-tank components shall be constructed of materials resistant to the tank environment and qualified as spark resistant as much as practical to minimize the use of coatings. Suggested materials include, but are not restricted to, Austenitic stainless steel or titanium alloys that have been stress relieved.

3.1.7.2. Welding.
Structural welding and the qualification of welding personnel shall be in accordance with AWS standards referenced in Section 3.1.3.

3.1.7.3. Fluids
The WD&C equipment may use either electric, pneumatic, or hydraulic actuation. However, the tank environment severely restricts the discharge of organic compounds during operation and all possible failure modes. The maximum credible loss of hydraulic fluid or lubricant in an accident scenario shall be less than five (5) gallons.

The specific hydraulic fluids and lubricants to be used shall be tested, reviewed and approved prior to specification. Nonvolatile radiation resistant lubricants shall be used for in-tank components.

3.1.8. Site Utilities:

The utilities available on-site for support of the WD&C equipment are:

3.1.8.1. Electrical

Electrical power will be distributed at 480 V, three phase, 60 HZ, grounded or ungrounded; 120/208 V, three phase, 60 Hz, with grounded neutral; and/or 120/240 V, single phase, 60 Hz with grounded neutral.

3.1.8.2. Process water
Demineralized process water will be provided at the site via the plant process water system. The pressure and flow rate at the tap is at least 450 kPa (65 psi) and 40 L/min (10 gpm). Purity requirements must be addressed in the WD&C system specifications.

3.1.8.3. Compressed Air
Compressed air shall be available at the site from portable compressors. Purity, pressure and volume requirements must be addressed in the WD&C system specifications.

3.2. SPECIAL DESIGN REQUIREMENTS:

The following requirements are in addition to the general design requirements specified in section 3.1.

3.2.1. Waste Dislodging End Effector (WDEE):

3.2.1.1. Deployment and Operation
The WDEE, with WCS attached, will be inserted into and removed from a tank by passing through the riser (see section 3.1.5.2) by means of the WD&C deployment system. During operation the WDEE will dislodge waste and cause it to enter into the WCS. The WDEE and WCS will be moved about inside the tank by the manipulator and latching mechanism.

3.2.1.2. Attachment to Manipulator
The WDEE, working in conjunction with the WCS and DS, shall have provisions to allow it to be attached to and detached from the latching mechanism inside the tank. All such attachment/detachment operations shall be accomplished by the latching mechanism and the WD&C deployment boom, with the WDEE being passive. When the WDEE is released by the latching mechanism, the DS, WDEE and WCS must reliably assume a configuration that permits the WD&C system to be retracted from the tank.

Failure-free detachment of the latching mechanism from the WDEE must be given special consideration, since failure to separate may greatly impair the ability of both the manipulator and WD&C to retract from the tank.

3.2.1.3. Manipulator Capability
Because the WDEE is brought into operating position on the waste, and moved about the waste by the manipulator, it must achieve all its operating requirements within the performance capabilities of the manipulator. The applicable manipulator performance capabilities are as specified in Reference 2.

3.2.1.4. WDEE Function
The WDEE must dislodge any waste adhering to the tank floor, walls, cooling coils and other structures, mobilize the dislodged particulate waste materials into suspension in the supernate, and guide the waste suspension into the Waste Conveyance System (WCS).

3.2.1.5. Protect Tank Integrity
The operations plan and procedural controls shall ensure that the waste retrieval process shall not penetrate through the tank wall, floor or cooling coils, nor destroy the structural integrity of the tank wall, floor or cooling coils.

3.2.1.6. Dislodging and Cleaning Mechanism
The WDEE may use air, water (or other allowable fluids), mechanical means, or any combination of these methods, to dislodge waste and clean tank surfaces.

3.2.2. Waste Conveyance System (WCS):

3.2.2.1. Function
The WCS shall achieve transfer of the waste, supernate, or process media from the WDEE to the BOP interface. In general, the system shall be able to accommodate large variations in waste feed rate without plugging or stopping.

3.2.2.2. Conveyance Media
The media of conveyance shall be either air, water (or other allowable fluids), or mechanical, or any combination thereof.

3.2.2.3. Failure and Recovery
Should plugging of the WDEE inlet or the conveyance conduit occur, the system shall be designed to allow operators to clear the obstruction by back flushing or other means and restart the system without damage, with minimal addition of fluids and with minimal operator exposure.

3.2.2.4. Potential Obstructions
Pieces of waste, construction debris or ITH of sufficient size to lodge and create a flow blockage within the WCS are likely to be encountered by the WDEE. The WCS and WDEE shall include means of either processing such large material so that it may pass through the WCS, or be automatically rejected from entry into the WCS.

3.2.3. WD&C Deployment System (DS):

3.2.3.1. Function
The DS shall deploy the WDEE, with WCS conduit, utility hoses and electrical cables attached, into the tank through the designated tank riser (see section 3.1.5.2).

3.2.3.2. Manipulator Loading
The DS shall control deployment of the conveyance conduit, utility hoses, and cabling to the WDEE at all times, such that additional loads are not imposed on the WDEE during operation that will cause the total allowable loads on the manipulator to be exceeded. NOTE: total loads on the manipulator encompass loads from all sources, including static, dynamic, frictional or operating loads caused either directly by the WDEE, or imposed by any equipment attached to the WDEE.

3.2.3.3. Cable and Hose Management
The DS shall include a conduit, hose, and cable management mechanism to accommodate the large variation in distance between the WDEE and the above-ground equipment as the WDEE operates between the most proximate and distant areas of the tank. Manual means of paying out or retracting conduit, hoses and cables are acceptable, providing adequate safety precautions are taken.

The DS shall be designed to facilitate flow through the WCS by minimizing sharp bends and by strategic conduit, hose and cable positioning throughout waste retrieval operations.

3.2.3.4. Deployment, Engagement with Manipulator

The DS shall support and position the WDEE such that the manipulator with the latching mechanism can engage/disengage with it inside the tank. The DS must withstand loads generated by such operations and be able to extend to a zone within the reach envelope of the manipulator (see Reference 2) while providing sole support for the WDEE and attached utility lines.

The WD&C in-tank equipment must be deployable within the tank without requiring immersion of any part in the tank contents or contact with the waste surface by any component except the WDEE. The WD&C equipment must tolerate inadvertent immersion in supernate and suspensions of waste while deploying or operating and be readily decontaminated in the event of inadvertent immersion.

3.2.3.5. Support and Positioning of WDEE

The WDEE must be attached to the DS at all times. The mechanism for securing the WDEE to the DS shall permit the full range of motion of the WDEE relative to the DS required to present the WDEE normal to all targeted tank and waste surfaces, shall not interfere with the functionality of the WCS, and shall, when the WDEE is released by the latching mechanism, allow the WDEE and WCS to dangle from the DS in a position which will permit retraction of the WD&C equipment through the riser. Utility or conveyance conduits may perform this function if sufficiently strong and flexible.

3.2.4. Confinement and Contamination Control (CCC):

3.2.4.1. Function

The CCC shall provide containment and confinement, decontamination and service access with suitable operator protection for all potentially-contaminated WD&C equipment during transportation, deployment, operations, and some servicing or maintenance functions. The CCC shall provide means of cleaning the WDEE and contaminated portions of the WCS, DS and CCC as they are withdrawn from the riser and prior to or during dismantling of the WD&C from the riser.

3.2.4.2. Regulatory

The CCC shall provide means of assuring that applicable Federal, State, and site regulatory objectives are achieved (see Section 4).

3.2.4.3. Transportation & Storage

The WD&C equipment must be capable of complying with on-site transportation and storage requirements.

- For storage in a RMSA - Radioactive Material Storage Area the dose rate must be less than 500 mR/h at 1 foot

- For transport with appropriate safe guards 200 mR/h at 1 meter and for uncontroled transport 10 mR/h at 1 foot.

3.2.4.4. Atmospheric Confinement

The zone within this confinement barrier shall be maintained at a constant negative pressure relative to the ambient environment or any zone that has potential of being occupied by unprotected personnel. The interior of the confinement barrier will share atmosphere with the tank interior, with a pressure gradient established by tank ventilation such that make-up air will flow through the CCC into the tank, thereby preventing migration of contaminated or corrosive mist into the CCC.

3.2.5. Instrumentation and Control:

The WD&C ICS will include the necessary controls and sensors required for each of the WD&C subsystems:

3.2.5.1. Subdivision

Instrumentation and process control will potentially be divided into three physically separated areas. The first area will include the tank and immediately adjacent WD&C subsystems. The second area will be the WD&C Operator Control Console (OCC) and the operators environment. The third area will be the Balance of Plant Interface and will include the interfaces to utilities and the tanks, pipelines, etc. for disposal of the retrieved waste.

3.2.5.2. Define OCC

Process monitoring and control shall be primarily accomplished through the OCC which shall operate as the WD&C supervisory control and data acquisition system. Alarms reported by any subsystem shall be displayed at the OCC.

3.2.5.3. Physical Interfaces
The I&C system shall be designed to minimize physical interfaces between the OCC and the WD&C subsystem controller(s). Safety, ease of installation, reliability and ease of maintenance shall be functional requirements.

3.2.5.4. Levels of control Access
There shall be levels of control access which will allow access to all control parameters for engineering/supervisory personnel and an operational level which restricts parameters which could damage the tank or the WD&C system. Control access control shall be implemented by means of a password security system written into the control program to ensure that only qualified operators have access to the OCC operating system and WD&C process controls.

3.2.5.5. Standards

A) Software Design
All system software shall be completely commented and documented and the system source code shall be provided. All software shall be developed, tested, and documented according to IEEE standards in Section 3.1.3.8

All components required to modify, update, or change non-proprietary portions of the control software shall be provided as part of the system.

B) Code.
All code shall be written in C or C++. All coding shall follow software QA requirements listed in Section 3.1.3.8

C) Code Validation.
Software testing, and test documentation shall follow software QA requirements as described Section 3.1.3.8

3.2.5.6. Instrumentation Range
Instrumentation shall be designed to adequately detect and display 150% of anticipated abnormal range for all system parameters.

3.2.5.7. Failure Modes

Essential subsystems shall have enough local control and alarm monitoring capability to insure safe shutdown in the event of the loss of the OCC. Subsystem controller(s) will be designed to fail in a fail-safe condition in the event of the loss of power or loss of the OCC. All process and deployment system controls and critical instrumentation shall fail to a safe condition and shall be safely recoverable from power supply failures. Position and status encoders and indicators shall preserve absolute calibrations and not require re-indexing or adjustment of calibration after a power failure.

The system shall be designed such that a power surge, the loss of electrical power, or the return of lost power shall not result in hazardous motion of the system conditions. In the event of any manual, automatic, routine or emergency stop shutdown restart shall require a deliberate action by the operator.

3.2.5.8. Point of Control

Interlocks and control logic shall allow control of any system from only one point at any time and require that control be relinquished by one station before it can be taken at any other. Failure of the currently active point of control shall not prevent switching to alternate points of control.

3.2.5.9. Safety Class Items

Any Safety Class items will be identified and redundant systems will be incorporated where necessary.

3.2.5.10. Safety Class Alarms

Any Safety Class alarm functions shall be routed to a common, separate alarm panel with visual and audible indicators at the OCC.

3.2.5.11. Interlocks

Software and hardware interlocks will be incorporated on critical subsystems to insure that conflicting/undesirable events cannot occur.

3.2.5.12. Testing and Calibration

The system shall be designed for periodic in-place testing and calibration of instrument channels and interlocks. The design shall allow testing of protective functions such as "fault tolerant" systems.

3.2.5.13. Process Control Display

The process control system will be schematically displayed at the OCC. The OCC will display values of process variables (sensor readings, control signals and control settings) essential to safe and productive manual-control operation in real time.

3.2.5.14. Video Monitoring
Video cameras and associated video displays shall be incorporated into the OCC to provide the operator with a means of verifying system operation. Collision avoidance will be the responsibility of the WD&C operators. All video shall be recorded on tape medium with time coding synchronized with the OCC system clock.

3.2.5.15. Subsystem Communications
Communications between the OCC and the WD&C subsystem controller(s) shall be updated at a rate sufficient to meet control and monitoring requirements.

3.2.5.16. Computing & Data Storage
The OCC shall have sufficient computing power to simultaneously perform all control and monitoring functions, maintain and update a 3-D graphical display as the user interface with refresh rate sufficient to meet control and monitoring requirements, and perform data storage. On-line (immediately accessible) data storage capacity shall be sufficient to allow for logging and archiving of all process control settings, DS joint positions, significant sensor readings and resolved WDEE position along with time indexing linked to the manipulator control system clock for one 8-hour shift. Removable data storage media shall provide archiving capacity for the entire waste retrieval campaign. On-line data shall be archived in real time.

3.2.5.17. Sensors
Appropriate sensors (contact, flow, pressure, force/torque, distance measuring, etc.) shall be included in the WD&C as needed to assure proper performance, protection of personnel, environment and equipment, and accomplishment of WD&C functions.

3.3. INTERFACES:

The following requirements are in addition to the general requirements specified in section 3.1 and the special requirements specified in Section 3.2.

3.3.1. Waste Dislodging End Effector:

3.3.1.1. Interfaces Between the WDEE and the WCS:

A) The point of attachment/detachment between the WCS and the WDEE shall be close to the WDEE, to allow the WDEE to be replaced with minimum secondary waste generated.

B) The method of attachment/detachment between the WCS and the WDEE shall be accomplished with minimal operator exposure, using remote handling techniques.

C) The WCS shall remain attached to the WDEE as the WDEE is moved about within the tank by the manipulator.

3.3.1.2. Interfaces Between the WDEE and the Tank:

The WDEE shall clean all interior tank surfaces and cooling coils below the dome/side joint.

3.3.1.3. Interfaces Between the WDEE and the manipulator:

The WDEE design shall include an appropriate attach point(s) with which the latching mechanism may engage (see Reference for latching mechanism TBD 1).

3.3.2. Waste Conveyance System:

3.3.2.1. Interface Between WCS and the Tank:

Gases or liquids exiting from the WCS in excess of what can be accommodated by the BOP, shall be returned to the tank through the designated riser.

3.3.2.2. Interface Between WCS and the Waste Transport System:

A) The WCS shall terminate in a 2 or 3 inch nominal diameter, raised-face, class 150#, pipe flange per ANSI B16.5-1968, as an interface to the BOP.

B) The parameters of the flow induced by the WCS must be compatible with the BOP inlet conditions existing at their interface during steady state flow. These BOP inlet conditions are defined in Reference 3

3.3.3. WD&C Deployment System:

3.3.3.1. Interface Between DS and the WDEE:

The DS shall include means of attaching to the WDEE and holding it in position(s) for engagement/disengagement with the latching mechanism. The DS shall control the motions of the WDEE, utility hoses and cables to facilitate:

- insertion/retraction into/from the tank
- mating the WDEE to the latching mechanism
- manipulation of the WDEE by the manipulator during waste retrieval.
- separation of a contaminated WDEE from the DS, conveyance and utility conduits by remote handling techniques

3.3.3.2. Interface Between WD&C Deployment System and the WCS:

A) The DS shall deploy and support the WCS in a manner that the total combined loads from all sources (WCS, WDEE, latching mechanism, etc) do not exceed the allowable loads for the manipulator (see Reference 2).

B) In-tank portions of the WCS are supported and positioned by the DS as the WDEE is moved about within the tank by the manipulator (see Figures 5, 6). The range of travel of the WCS and DS must be compatible with this WDEE operating envelope (see 3.3.1.2).

C) Above-ground portions of the WCS within the protective confines of the CCC, are supported, controlled and managed by the WD&C deployment system to minimize wear and pressure drop caused by bends, friction, etc.

3.3.3.3. Interface Between WD&C Deployment System and the manipulator:

Although the DS does not directly make contact with the manipulator, it shall be required to position the WDEE within the reach envelope of the manipulator and hold the WDEE such that the manipulator can engage/disengage with the WDEE using the latching mechanism (see Figure 4). DS position information is provided to the World Model to support prevention of "inadvertent interfacing" of the DS with the manipulator

3.3.4. Confinement and Contamination Control:

3.3.4.1. Interface Between CCC and the WCS:

Above-ground portions of the WCS which are directly subject to contamination shall be enclosed within the CCC for purposes of contamination control.

3.3.4.2. Interface Between CCC and the DS:

Above-ground portions of the DS which are directly subject to contamination will be enclosed within the CCC for purposes of contamination control.

3.3.4.3. Interface Between CCC and WD&C In-Tank Components:

All in-tank portions of the WCS, DS, and WDEE must be capable of passing through the decontamination zone of the CCC and being effectively decontaminated thereby. See section 3.1.4.3

3.3.5. Instrumentation and Control Interfaces:

3.3.5.1. Interface Between WD&C System Controller and WDEE:

A) The WDEE I&C shall safely monitor and control the operational parameters for dislodging the waste from the tank and mobilizing it into the waste conveyance system.

B) Fluid pressure sensor(s) shall be incorporated into the WDEE hydraulic supply to adequately assess the performance of the system. Sensor information shall be provided to the OCC through the WD&C controller responsible for controlling the output of the WDEE pump(s).

C) Fluid flow sensors (inlet and bypass) shall be incorporated in the WDEE pump units. The net flow in the high-pressure output shall be calculated by the OCC to allow the operator to assess the condition of the WDEE orifices.

D) WDEE pumping equipment shall be equipped with sensors to monitor power, temperature, and filter differential pressure. This information shall be supplied to the OCC through the WD&C controller. This information may be in the form of two-stage switch outputs providing for alarms/indicators of values greater than normal and secondary alarms or E-stops for values reaching critical levels.

E) All instrumentation hardware shall include the required signal conditioning electronics to complete the interface to the local control system. All instrumentation hardware, including sensors, signal conditioning units, wiring and cabling shall adhere to standards applicable to the environment.

F) Appropriate sensors (contact, standoff distance measuring etc.) to maintain an adequate level of control shall be included on the WDEE.

3.3.5.2. Interface Between WD&C System Controller and WCS:

A) The WCS I&C shall include sensors and instrumentation to safely monitor and control the operational parameters for waste conveyance to the BOP.

B) The WCS I&C shall provide sensors and instrumentation sufficient to detect blockage of the conveyance line at any point and allow the operator to infer the general location of the blockage (e.g.; in the inlet, the WDEE, the discharge line or the BOP interface...).

C) Working fluid flow rate (inlet and bypass) and pressure sensors (supply and output) shall be incorporated at the WCS pump. Fluid pressure/flow information will be provided to flow controllers and to the OCC. Net fluid flow to the pump shall be calculated and displayed at the OCC. "Loss of Fluid Flow" alarms shall be provided at the OCC.

D) WCS pumping equipment shall include power monitoring and temperature sensors for the motor(s).

E) Back flush operation shall be initiated by the operator at the OCC in the event of a system blockage. Back flush pressure shall be limited to prevent damage to system components.

F) All sensors and other instrumentation shall include the required signal conditioning electronics. WCS status will be displayed at the OCC. Wiring and cabling shall comply with applicable standards for the environment.

3.3.5.3. Interface Between WD&C Controller and WD&C DS:

A) The WD&C DS I&C shall safely monitor and control DS functions: inserting the DS, WDEE and CS equipment into the tank, positioning the WDEE for mating to the latching mechanism and providing in-tank management of CS hardware.

B) The WD&C DS will be remotely operated to configure it within the tank to present the WDEE in a position such that the manipulator can mate the WDEE to the latching mechanism inside the tank. The movement of the DS during deployment will be active, while movement of the DS during operation may be active, passive, or a combination thereof. During operations, the WD&C operator will position the DS to reduce the dynamic and static loads mechanically imposed on the manipulator. DS movement may be accomplished by the WD&C system controller, and may be coordinated with the motion of the manipulator and WDEE.

C) The DS will incorporate joint position sensors and linear displacement sensors to provide position feedback to the WD&C system controller and the World Model. The DS operator shall have a graphical user interface providing rendered viewing of the World Model from at least two simultaneous operator-controllable viewpoints.

D) The WD&C operator has the responsibility for coordinating and approving the movement of the DS. The WD&C operators primary concern is collision prevention between the WD&C, the manipulator and internal tank components.

E) Hardware interlocks shall be incorporated to prevent unanticipated/undesired movement during constrained phases of operation such as insertion through the riser.

F) Proximity sensors may be required at strategic positions to assist in mating with the latching mechanism and to preclude contacting the manipulator and tank support structures during operation.

G) The WD&C DS system controller shall have provisions for manual operation from local controls independent of the OCC. During manual operation, essential sensor information shall be displayed locally.

H) The WDEE shall be properly secured and oriented to the DS prior to entering or exiting the tank. This status shall be indicated at the OCC and verified by the operator. Hardware or software interlocks will be incorporated for transfer of the WDEE to the latching mechanism to require that the WDEE be attached to one or the other at all times during that transfer.

3.3.5.4. Interface Between WD&C System Controller and DS CMS:

A) The WCS I&C shall safely monitor the payout and retrieval of hoses, conduits and/or cables by the CMS subsystem in coordination with the motions of the DS.

B) The CMS may be a passive system requiring only limited sensor information. If the CMS requires more elaborate actuators (winches, motors, etc.) appropriate subsystem control shall be implemented.

C) Position encoders and load sensors shall be incorporated where appropriate and configuration/load information provided to the WD&C controller and displayed on the OCC. Alarms and interlocks shall assist the operator in preventing the tearing of cables or hoses during CMS operation.

D) Temperature and power sensors shall be incorporated to monitor the operating status of those CMS motors and winches subject to high loading or high duty cycles.

3.3.5.5. Interface Between WD&C System Controller and CCC Subsystem:

The CCC I&C shall safely monitor and control the operation of the CCC. Functions and conditions to be controlled and/or monitored include:

- Internal pressure, to be maintained at less than ambient.

- Radiation levels at service access points shall be checked by site operations personnel with portable equipment. Provisions must be made for insertion of the measuring equipment and for securing it in place inside the CCC at appropriate locations.

- Leak detection of WDEE utilities and conveyance line inside the CCC.

- Control of the gross decontamination operation during retraction of WD&C components from the tank is required. Decontamination spray at the riser is to be actuated automatically by retraction of any in-tank WD&C equipment. Limited control functions will be required during other cleaning operations and will be accomplished primarily by the CCC subsystem controller operating in stand-alone mode.

3.3.5.6. Interface Between WD&C System Controller and manipulator World Model:

A) The WD&C Controller shall provide WD&C position to the manipulator World Model. Motion of WD&C DS or CMS shall require update of the manipulator World Model

B) Similarly, the World Model may provide collision control information to the WD&C Controller for collision control during movement of the DS.

3.3.6. Interfaces With Tank:

3.3.6.1. Interfaces Between Tank and the CCC:

A) The CCC is the primary interface between the WD&C equipment and the tanks, tank vaults, risers and bunkers, or tank farm surface.

B) The CCC shall seal to the existing concrete bunkers surrounding the designated risers through a compliant connection. Typical riser bunkers are defined by Reference 7 Design shall be based on field-verified measurements.

C) The geometric sum of all axial and lateral loads imposed on the riser by the CCC shall be less than 50 lb. The geometric sum of all bending moments and axial torsion applied to the riser shall be less than 100 in-lb.

D) The CCC, including the housed or deployed WD&C equipment, shall not impose loads on the tanks, vaults or tank farm surface in excess of those allowed by Reference 4.

3.3.6.2. Interfaces Between Tank and the WD&C Deployment System:

The in-tank portions of the WCS, with the WDEE attached, must be capable of passing through the designated riser by means of the DS.

3.3.7. Interfaces With WD&C Internal System Utilities

Components of the WD&C may be pneumatically, hydraulically, or electrically actuated. The energy may be transmitted directly from site utilities or indirectly through a prime mover, such as a pump, generator or compressor. Any prime movers and all conduits (cables, hoses, etc) used to transmit energy to the WD&C equipment are defined as WD&C Utilities. These WD&C utilities shall interface with the WD&C equipment in accordance with the following paragraphs of this section.

3.3.7.1. Interface Between WD&C Utilities and WDEE:

A) The point of attachment/detachment between the WDEE and the utilities it requires for operation, should be close to the WDEE, to allow the WDEE to be replaced with minimum secondary waste generated.

B) The method of attachment/detachment of the WDEE to its utilities shall be accomplished with remote handling techniques.

C) The attachment and routing of utilities to the WDEE should impose minimal constraints on the maneuvering of the end effector and mating of the end effector to the DS or the latching mechanism.

3.3.7.2. Interface Between Utilities and the DS:

Utilities required by the WDEE, DS or in-tank portions of the WCS, should be routed along (and supported by) the DS.

3.3.7.3. Interface Between Utilities and the CCC System:

Utilities to WD&C components contained within the CCC system shall have the capability of being connected/disconnected from the CCC confinement housing at both sides of the confinement wall (to facilitate replacement of components within confinement and assure modularity of the WD&C hardware).

4.0 REGULATORY REQUIREMENTS:

The following State and National regulatory codes are applicable to the WD&C system:

A) 10CFR 1021 National Environmental Policy Act (NEPA)

B) 40CFR 61 Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPS).

C) DOE Order 5400.1, Preoperational Monitoring of Facilities, Sites, and Operations.

D) DOE Order 5400.5, Radiation Protection of the Public and the Environment

E) Resource Conservation and Recovery Act of 1976 (RCRA)

F) Atomic Energy Act of 1954

G) Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

H) National Electric Code

I) OTHERS as may apply

5.0 SAFETY AND QUALITY ASSURANCE

5.1. Safety Requirements

Safety requirements for the HLLW tank farm operations, including the retrieval work are defined in Reference 8

5.2. Quality Assurance Requirements

Quality assurance requirements for the HLLW Tanks WD&C equipment are defined in Reference 9

6.0 REFERENCES

1. D. A. Summers, R. D. Fossey, M. D. Mann, and J. G. Blaine. 1994. Hazardous Waste Dislodging and Conveyance: The Confined Sluicing Method. PNL-10074, Pacific Northwest Laboratory, Richland, Washington. See also Bibliography Items 1 - 7 for further information.

2. The following documents collectively define the LDUA. They are not to be used separately:
   a) Specification for the Light Duty Utility Arm System; WHC-S-124 Rev. 3
   b) Specification for the INEL Light Duty Utility Arm and Deployment System; WHC-S-385 rev 0; 13 April 1995.
   c) Light Duty Utility Arm System Acceptance Test Report System Serial No. 201.-SPAR-LDUA-R.068 (This is the SAPR test results on unit 1.)
   d) Light Duty Utility Arm System Verification Report SPAR-LDUA-R.069 (lists the dev. from spec.)
   e) Light Duty Utility Arm Detailed Design Report SPAR-LDUA-R.025, Spar Aerospace, 9/94
   f) Light Duty Utility Arm Detailed Design Review Package : T J Samuel, Westinghouse Hanford Co. 10/94

3. ICPP Heel Removal and Handling Study , ICF Kaiser Engineering ,May 20, 1994

4. Evaluation of Vaults for Vehicle Loads, Figure 15 "Limitations on Vehicle Loads in ICPP Tank Farm During HLWTFR Construction"; Advanced Engineering Consultants; 8/26/93

5. Barnes, G.E.; Waste Dislodging and Conveyance End Effector Development for the INEL HLLW Heel Removal; INEL, Lockheed Idaho Technologies Co. ; INEL-94/0122; 10/1994

6. DOE/ID-10500, DOE Hoisting and Rigging Manual

7. Drawings (INEL): "Tank Riser Covers" 1578-cpp-780/790-s-2 index code number 138099; "Tank Riser Covers Plot Plan and Schedule" 1578-cpp-780/790-s-1 index code number 138098.

8. "Hazard Prevention and Control Manual" ; INEL (Accessible via INEL site Web network)

9. "Quality Assurance Management Manual"; INEL (Accessible via INEL site Web network)

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8. Smalley, J., Evans, M., Lew, J., Stoughton, R. , Baker, C. 1994, Long Reach Manipulator End Effector Utility Lines and Conveyance System Routing, PNL (Draft)

9. Hatchell, B. K., M. W. Rinker, and O. D. Mullen, Hazardous Waste Retrieval Strategies Using a High Pressure Water Jet Scarifier,"Proceedings of the 8th American Water Jet Conference, Water Jet Technology Association, St. Louis, Missouri.

10. J. A. Bamberger, M. W. Rinker, D. G. Alberts, D. A. Summers, G. R. Golcar, O. D. Mullen, and B. K. Hatchell. 1995. Waste Dislodging and Conveyance, Remote Retrieval of Solid and Sludge Radioactive Wastes from Underground Storage Tanks with Limited Dilution, PNL-SA-26482. Proceedings of Environmental Restoration '95 - Committed to Results Conference, Denver, Colorado, August 13-18, 1995.

11. J. A. Bamberger, M. A. McKinnon, D. A. Alberts, D. E. Steele, and C. T. Crowe. 1994. FY93 Summary Report Development of a Multi-Functional Scarifier Dislodger with an Integral Pneumatic Conveyance Retrieval System for Single-Shell Tank Remediation, PNL-8901. Pacific Northwest Laboratory, Richland, Washington.

12. J. A. Bamberger and D. E. Steele. 1993. "Developing a Scarifier to Retrieve Radioactive Waste from Hanford Single-Shell Tanks," PNL-SA-22721. Proceedings of the 7th American Water Jet Conference, M. Hashish, ed., Water Jet Technology Association, St. Louis Missouri, pp. 737-745.

13. M. R. Powell. 1994. UST-ID Waste Dislodging and Conveyance FY 1993 Technology Development Summary Report. PNL-9787, Pacific Northwest Laboratory, Richland, Washington.

14. M. W. Rinker, O. D. Mullen, and B. K. Hatchell. Waste Dislodging and Conveyance Testing Summary and Conclusions to Date. PNL-10095, Pacific Northwest Laboratory, Richland, Washington.

15.E.G.G&G Idaho, Inc., Conceptual Design Criteria for the Tank Farm Heel Removal Project At the Idaho Chemical Processing Plant. Rev. 1, August 1994.

16. Westinghouse Idaho Nuclear Company, Scope of Work Statement for a Scale Model Mixing Pump Test/Study in Support of Conceptual Design of the Tank Farm Heel Removal Project, Rev. F, August 1994.

17. Westinghouse Idaho Nuclear Company, "General Practices/Limitations Liquid Waste System" Chemical Plant Operation Procedure, WINCO CPOP 4.3.5.1, Rev. 17.

18. E.G.&G Idaho, Inc., "CPP Primary Waste Collection and Storage Facilities," ICPP Tank Drawings, 057498-503.

19. Christensen, M.R., Letter, MRC-13-94, "Sample Analysis for In-Situ Development," June 8, 1994.

20. E.G.&G Idaho, Inc., "Quality Assurance Project Plan For Sampling Activities on the ICPP HLLW Tanks Using the RTI System," QAPjP E-039, Revision 1, August 1, 1994.

21. Idaho Chemical Processing Plant, Tank Drawings, 104725, 105161, 10563, 106200, 106204, 106208, 106211, 106227, 106236, 106237, 106241, 106248, 117917, 117919.

22. Swenson, M.C. Letter, MCS-12-94, "Time Required For Purging Vapor Space of Tank Farm Vessel," July 7, 1994.

23. Westinghouse Idaho Nuclear Company, "Tank Farm Transfer Procedures," WINCO CPOP 4.3.5.4., Chemical Plant Operation Procedure, Rev. 28.

24. Westinghouse Idaho Nuclear Company, "Tank Farm-Leaking Tank Transfer Procedure," WINCO CPOP 4.3.5.7., Chemical Plant Operation Procedure.

8.0 TBD's

1. Latching mechanism specification, design drawings. Assumed for the present to be similar in size and function to the ORNL Gripper End Effector furnished with the Modified Light Duty Utility Arm to grasp the Confined Sluicing End Effector.

FIGURES

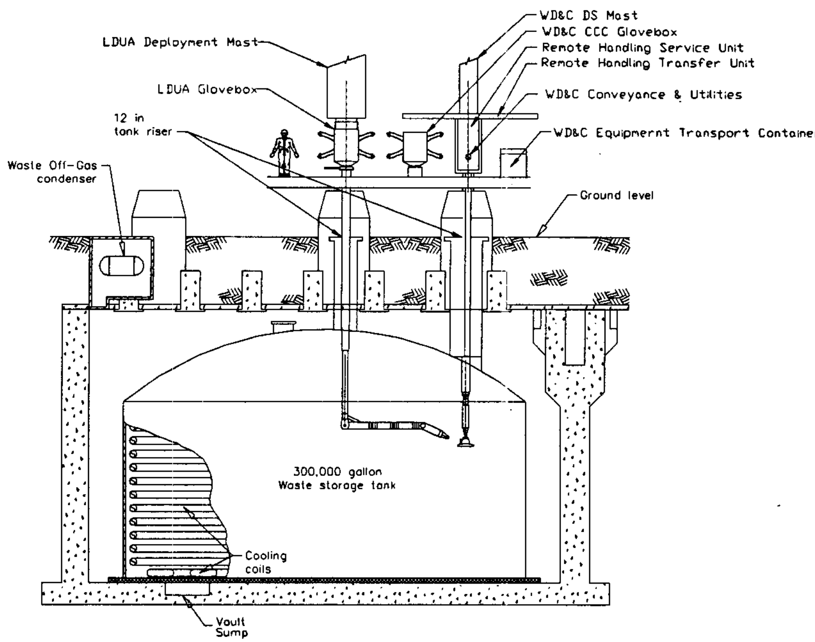


Figure 1: General Arrangement - Insertion of LDUA and WD&C into Tank (Conceptual Sketch - NOT TO BE TAKEN AS DESIGN GUIDANCE)

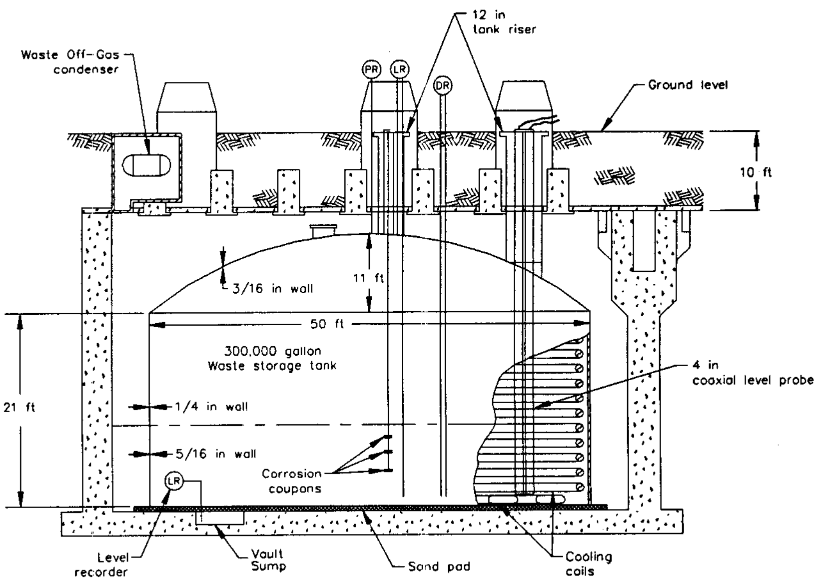
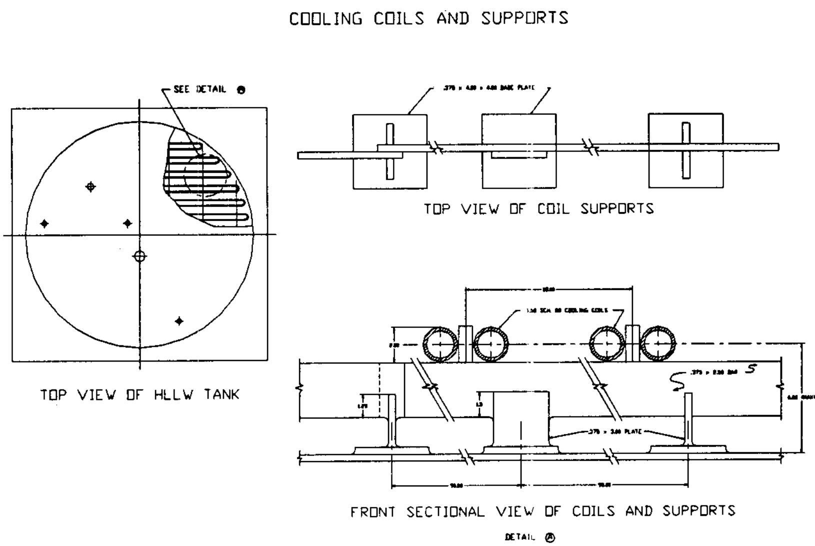


Figure 2: Typical Tank Section (Taken from Reference 3)



Note: All dimensions in inches.

Figure 3: Details - Typical Cooling Coils (from Reference 3)

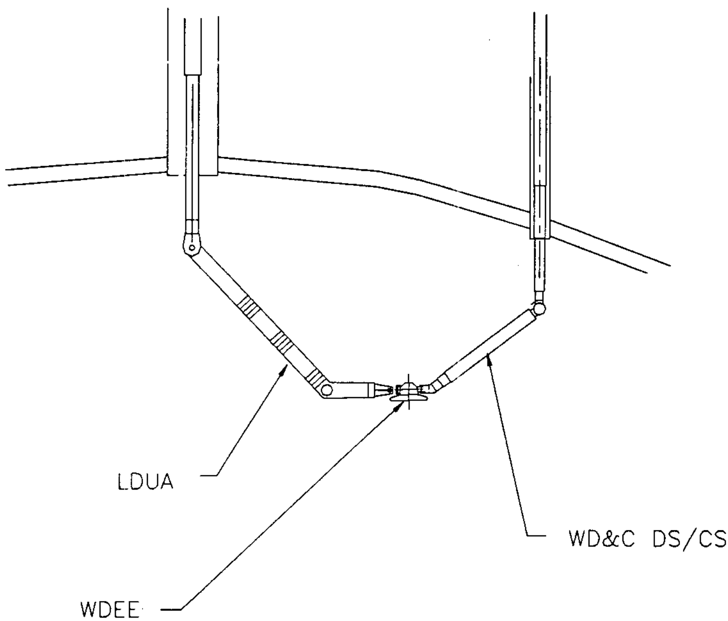


Figure 4: Engagement of Latching Mechanism on the LDUA with the WDEE

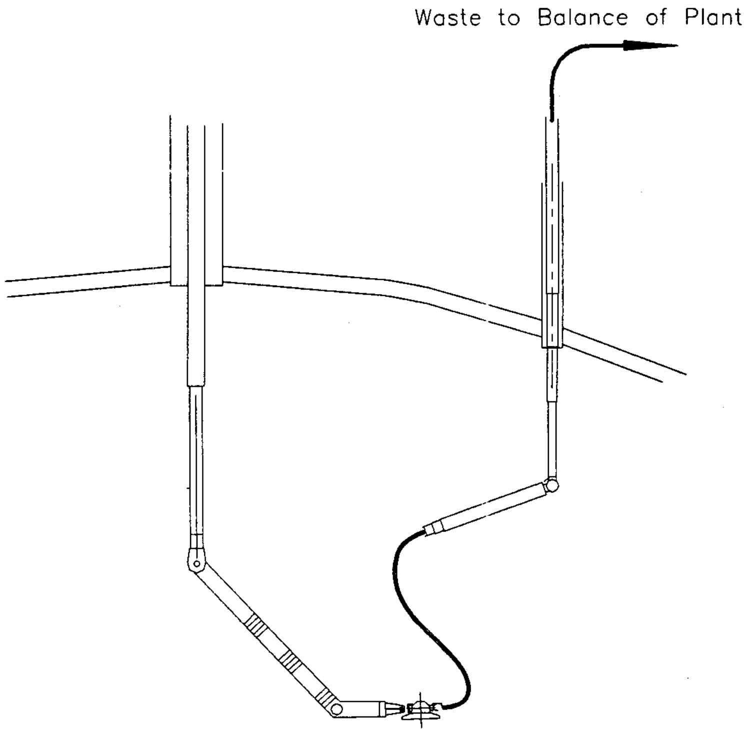


Figure 5: LDUA Manipulating the WDEE in the Tank

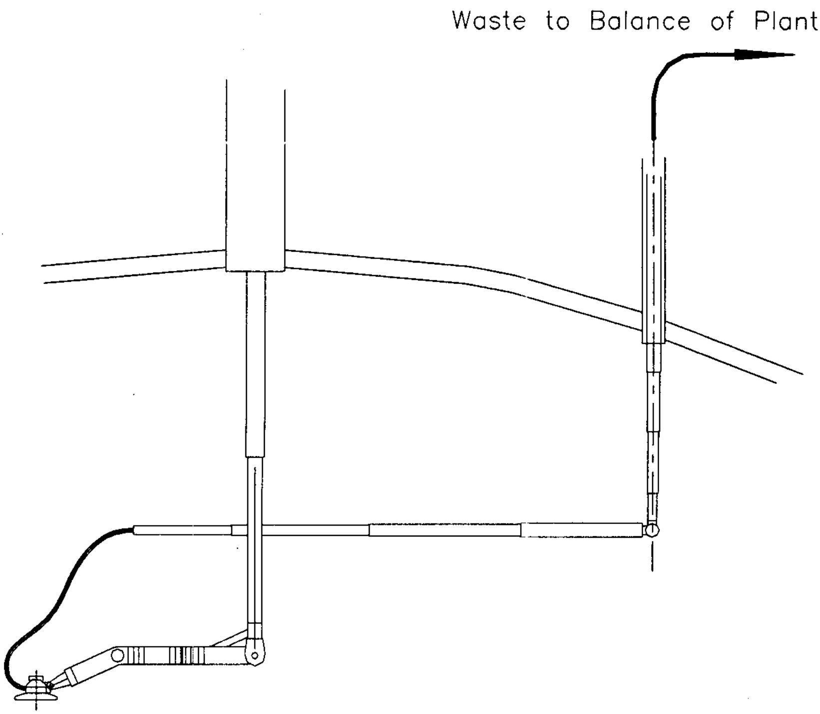


Figure 6: LDUA Maneuvering WDEE in the Tank

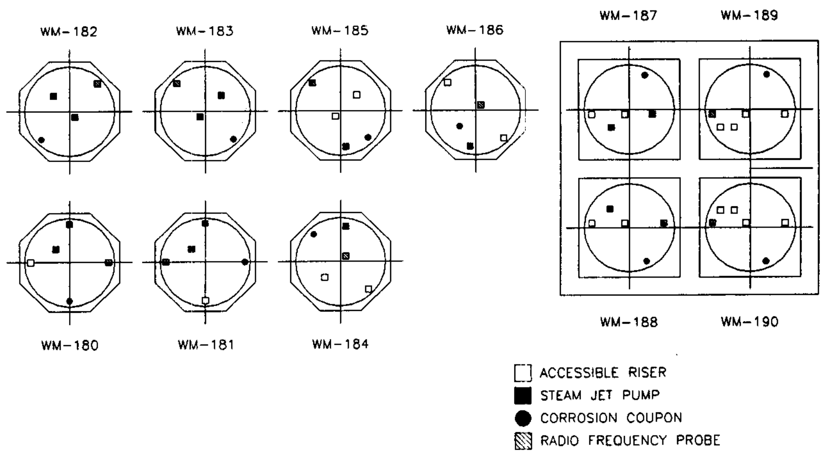


Figure 7: Risers Locations (Taken from Reference 3)