PROCESS CONTROL PLAN FOR THE 241-C-200 SERIES WASTE RETRIEVAL SYSTEM

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Abstract: The C-200 Series tanks will be retrieved using a vacuum retrieval method. An articulating mast system in the tank will use vacuum to recover the waste and deposit the waste in the slurry tank on a skid. The process will transfer waste from the skid to 241-AN-106. This is the process control plan for this process.

Barbara Wolski 7/17/06

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Office of River Protection

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AC	Administrative Control
AMS	Articulating Mast System
CCTV	closed-circuit television
DST	double-shell tank
EPDM (rubber)	ethylene propylene diene monomer
ft	feet
ft/sec	feet per second
g/mL	grams per milliliter
gal	gallons
gpm	gallons per minute
HIHTL	hose-in-hose transfer line
HLAN	Hanford Local Area Network
HMI	Human-Machine Interface
HPT	Health Physics Technician
HVAC	heating, ventilation, and air conditioning
in.	inch
JCO	Justification for Continued Operation
lbs	pounds
lbs/gal	pounds per gallon
LCO	Limiting Conditions for Operation
MCS	Monitor and Control System
MRS	Mobile Retrieval System
NESL	Non-Entry Systems Limited
NOC	Notice of Construction
NPH	normal paraffin hydrocarbons
OGT	over ground transfer
ORP	U.S. Department of Energy, Office of River Protection
PLC	programmable logic controller
psi	pounds per square inch
psig	pounds per square inch (gauge)
scfm	standard cubic feet per minute
SST	single-shell tank
TBP	tri-butyl phosphate
TSR	Technical Safety Requirement
V	volt
w.g.	water gauge
WRS	waste retrieval system
%	percent
°F	degrees Fahrenheit
μm	micron

1.0 INTRODUCTION

This document describes the process controls for the 241-C-200 (C-200) series waste retrieval system operations. The C-200 retrieval/closure project is a subset of the overall River Protection Project. The C-200 project will perform single-shell tank (SST) C-200 series tank waste retrieval and transfer the waste to the double-shell tank (DST) system using vacuum retrieval technology (RPP-14983, *Project Execution Plan for 241-C-200 Series Waste Retrieval/Closure Project*). The systems provided by the C-200 project will support the transition of the C-200 series tanks to interim closure status.

1.1 OBJECTIVES

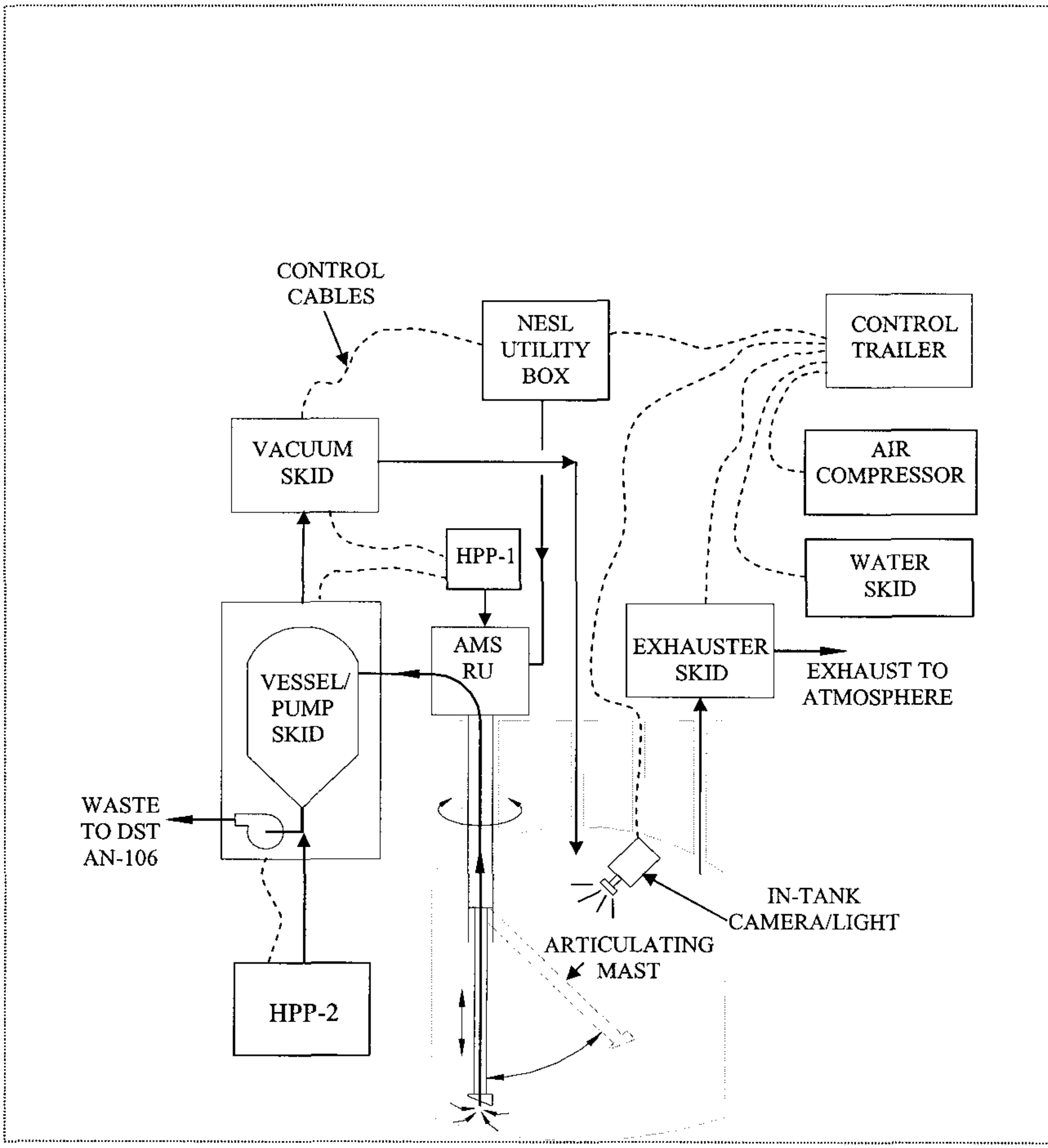
The C-200 series tanks are estimated to contain approximately 6200 gallons of residual waste sludge distributed among four tanks. The primary objective of the waste retrieval system operation is to retrieve the wastes in four tanks in the C-200 series to the practical limit of the technology used. This technology utilizes a retrieval system that employs a vacuum system for removing the waste from the tanks. This system introduces minimal amounts of liquids into the tank when compared to the previously employed sluicing technology. Compared to the past practice sluicing technology, the vacuum retrieval system is expected to minimize the consequence, and perhaps the probability, of inducing a leak within the SST.

The C-200 series retrieval system will retrieve and transfer waste from SST C-200 series tanks to tank 241-AN-106 (AN-106). The systems provided by the C-200 Retrieval Closure Project will support the transition of the C-200 series tanks to interim closure status. The C-200 Retrieval Closure Project will design, procure, construct, install, test, and turnover to Operations a fully functional waste retrieval system (WRS); conduct retrieval operations; and prepare C-200 tanks for interim closure. The retrieval of the four C-200 series tanks will be treated as a single project, and this process control plan will be used for all four tanks.

Figure 1-1 is a simplified arrangement of the waste retrieval system to be used. An Articulating Mast System (AMS) will be located in one of the tank risers on each tank and is extended and retracted as necessary to reach the bottom of the tank. The four AMSs (one per each of the four C-200 Series tanks) are connected topside to a vessel/pump skid and a vacuum pump skid that are centrally located to be shared among the four C-200 series tanks. The vacuum pumps pull the waste up through the AMS and deposit the wastes into a slurry tank. The retrieved waste is diluted in the slurry tank with raw water, and is then pumped from the slurry tank to tank AN-106 through a hose-in-hose transfer line (HIHTL). In-tank cameras are used to monitor the amount of solids being mobilized and to determine the locations of remaining wastes.

A control trailer houses the staff and systems used to monitor and control the waste retrieval activities. Operation of the AMS and topside skids is performed remotely from the control trailer. Active ventilation is connected to the tanks using a portable exhauster.

Figure 1-1. C-200 Series Waste Retrieval System.



2.0 PROCESS DESCRIPTION

This section includes a summary of the overall waste retrieval operations concept and the waste retrieval process. The waste chemistry is described in section 2.1; the waste retrieval operations concept is described in Section 2.2; and waste retrieval is briefly summarized in Section 2.3. Section 2.4 describes the tank and riser allocation, instrumentation, water distribution hardware, and waste retrieval system.

2.1 WASTE CHEMISTRY

The sludge in the C-200 series tanks consists primarily of oxides and hydroxides of metal salts. An extensive summary of the waste is provided in RPP-14627, *Characteristics of Waste in the C-200 Series of Hanford Underground Waste Tanks*. This work was revised to take the oxides into consideration in RPP-17045, *Calculation of Mass Balance for the 241-C-200 Series Tanks*. Table 2-1 summarizes the waste chemistry and properties.

Table 2-1. Major Chemical Constituents in Tanks C-201, C-202, C-203, and C-204

Constituent	C-201	C-202	C-203	C-204
Iron	25.2%	9.9%	3.2%	3.2%
Sodium	11.2%	16.1%	14.3%	14.3%
Nitrate	3.8%	9.9%	15.5%	15.5%
Oxalate	5.8%	5.5%	3.1%	3.1%
Carbonate	9.3%	14.6%	9.0%	9.0%
Uranium	14.1%	13.8%	16.1%	16.1%
Oxides	13.5%	6.4%	4.7%	4.7%
Water	8.7%	4.7%	41.7%	41.7%
Total of above	92%	81%	108%	108%
Sludge volume, gallons	581	1329	1600	1691

The sludge volumes are as given in the Best Basis Inventory on May 5, 2005 after converting from kiloliter to gallons. The row marked "Total of above" generally shows values close to 100%. This row is an indication that no major constituent was left out. The values are not precisely 100% due to analytical error, sample variations, and not all possible chemical species were analyzed. Greater than 100% is an indication that all important species were identified but there was some measurement error.

The radioactive constituents are given in Table 2-2 (RPP-14627, *Characteristics of Waste in the C-200 Series of Hanford Underground Waste Tanks*).

Table 2-2. Major Radiochemical Constituents in Tanks C-201, C-202, C-203, and C-204

Constituent	C-201	C-202	C-203	C-204
^{63}Ni	0.134	0.032	0.003	0.0892
^{90}Sr	87.1	165	19.9	10.9
^{90}Y	87.1	165	19.9	10.9
^{99}Tc	9.8E-03	9.1E-03	1.4E-03	4.3E-03
^{137}Cs	10.2	8.8	1.45	4.7
^{137m}Ba	9.6	8.3	1.4	4.5
^{151}Sm	36.3	35.2	34.8	27.8
^{155}Eu	0.08	0.05	0.01	0.0.2
^{234}U	0.04	0.04	0.05	0.01
^{238}U	0.05	0.04	0.05	0.02
^{239}Pu	7.2	6.4	1.11	0.006
^{240}Pu	1.56	1.38	0.24	0.001
^{241}Am	1.14	0.54	0.056	0.001
^{241}Pu	8.25	7.31	1.27	0.006
Total above	248.7	398.0	80.1	54.8
Units in μCi/g Data from: BBI May 5, 2005 Query				

Tank 241-C-204 (C-204) has appreciable amounts of organics present (PNNL-11309). The major organic present is tri-butyl phosphate (TBP). Very small amounts of normal paraffin hydrocarbons (NPH) were found with the tri-butyl phosphate. Vapor samples taken in the headspace of tank C-204 in 1996 also showed quantities of tri-butyl phosphate (PNNL-11698). Headspace vapor samples taken in 2004 also had very low concentrations of NPH; these samples were not analyzed for TBP (TWINS 2006). The total quantities of organic are not expected to cause problems in the AN-106. Estimates of the organic vapors expected to be seen under retrieval conditions are given in RPP-14841, *Organic Vapor Source Term for Tanks 241-C-201, 241-C-202, 241-C-203, and 241-C-204 During Waste Retrieval Operations.*

The waste has very little total heat generating capability. The temperatures have ranged from 55 to 70 °F. The temperatures follow an annual cycle with the ground temperature. No additional heat will be added to these tanks from process fluids or chemical reactions. No temperature monitoring is required for these tanks (RPP-17507, *Wavier of Temperature Requirements During Retrieval of 241-C-200 Series Tanks,*) and the thermocouples have been removed. The only heated liquid that will be put into the tanks will come from the water separator from the vacuum skid. This liquid is heated by work from the vacuum pumps and the water separator will be dumped at least every third batch back to the tank being retrieved. Volumes estimated are about 25 gallons per dump. The temperature may be up to 140 °F but the small volume will not heat the tank at a rapid rate.

The retrieval project prior to the C-200 retrieval project was the acid dissolution of sludge in tank 241-C-106 (C-106). The spent acid from tank C-106 was sent to tank AN-106. Caustic was added to tank AN-106 prior to receiving the spent acid. Enough caustic was added to tank AN-106 to more than neutralize the acid to be used without depending on expending some or all of the acid during the dissolution process. Some additional caustic was added as well. This excess caustic will still be there when waste from the C-200 tanks are sent to tank AN-106. The waste from C-200 is sludge that should have little impact on the caustic concentration in tank AN-106. The biggest effect on the caustic concentration is the dilution from the water used for retrieval and transport. The waste in tank AN-106 will be sampled after the retrieval so that the final status of waste in tank AN-106 will be known (Section 3.2.12).

2.2 PROCESS OVERVIEW

The waste retrieval system is designed to retrieve the remaining radioactive sludge and heel waste from the four C-200 series tanks 241-C-201 (C-201), 241-C-202 (C-202), 241-C-203 (C-203), and C-204, and transport this waste to the receiving tank AN-106. The initial volume of waste in the C-200 series tanks is estimated at approximately 6200 gallons. The C-200 series are 20-ft diameter tanks, and the AMS can reach all areas of the tank bottom. The AMS is used with the vacuum skid and vessel/pump skid to retrieve and transfer the waste to AN-106 with the minimum amount of water being used. The waste is vacuumed through the AMS and deposited in the slurry vessel. The gases are routed through the vacuum skid and returned to the tank being retrieved. The deposited waste is handled as a batch. Each batch is diluted with water as needed and pumped through an HIHTL to tank AN-106.

The following components are part of the process system and will be discussed further.

- Articulating Mast System (AMS),
- Vessel/ Pump Skid,
- Vacuum Skid,
- Hydraulic Power Packs,
- Compressed Air Skid,
- Water Skid,
- Hose-in-hose transfer lines (HIHTL),
- Pit jumpers,
- Electrical Supply System,
- Control Trailer, and
- Ventilation System.

2.3 NORMAL OPERATING MODE

The waste retrieval system will retrieve the waste from tanks C-201 through C-204 and then pump the retrieved waste to tank AN-106 through an over-ground HIHTL. The following discussion of retrieval operations provides an overview of how waste will be removed.

2.3.1 Retrieval of the Waste

The AMS is installed in riser 7 and is positioned such that the bottom of the support mast is above the bottom of the tank (this allows the mast to locate the suction intake on the tank bottom.) Each tank has an AMS system installed. The AMS is connected to a hose-in-hose transfer system, a hydraulic power pack, and a utility manifold that supplies water Only one of the four masts is connected and utilized at a time.

The vacuum is energized, initiating the pneumatic-assisted vacuum conveyance system to begin removing the tank waste. All operations in the tank are closely monitored by a camera system suspended in the tank dome space. Control of the system is performed using the computerized WRS. The AMS is capable of breaking up certain hard material. There is a high-pressure water spray (~300 to 1200 psi) manifold, mounted to the vacuum head, that performs as a scarifier for high shear strength wastes. The waste will be conveyed to a ~290 gal, vacuum and pressure rated, slurry tank located within the Vessel/Pump Skid. Each batch of waste is estimated to be ~250 gal. The amount of waste in the slurry tank is monitored by slurry tank load cells. When the slurry tank is full, as indicated by a high-level switch or high slurry tank weight, the system control initiates a vacuum break to establish atmospheric pressure within the slurry tank. This step allows the WRS to switch from a waste retrieval mode to a waste transfer mode.

2.3.2 Transport of the Waste

For the waste transfer mode, raw water can be supplied to the Hydrotrans® unit inside the bottom of the slurry tank. The transfer pump is energized and the waste is pumped from the slurry tank to tank AN-106. During transfer, water can also be added to the waste using the dilution control valve. The set point can be adjusted by the operator based on observations of the relative density readout, obtained from the Coriolis meter, on the operator control interface. The primary objective is to retrieve and transfer waste efficiently and without plugging. A second objective is to retrieve and transfer waste with a minimal addition of water.

When the slurry tank is empty, as indicated by a low-level switch or low tank weight, the control system can send a flush of raw water equal to one and half times the volume of the transfer line through the transfer line and closes the output valves to prevent drain-back of the residual slurry remaining in the transfer line. Provisions for flushing the transfer line at any time are incorporated into the design. All of the waste-processing subsystems, such as the Vacuum Skid and Vessel/Pump Skid, contain redundant back flushing capabilities.

2.4 EQUIPMENT DESCRIPTION

The various components and skids are discussed in the sections below. The descriptions are an overview with further details found in the references. Figure 2-1 shows an overview of the equipment layout for the C-200 retrieval.

2.4.1 Tank 241-C-200 Series Description

The construction and operating history of the 200-series tanks can be found in Appendix C of RPP-10435, *Single-Shell Tank System Integrity Assessment Report*. The C-200 series are 20-ft diameter tanks with a working volume of 55,000 gal. The wastes in the C-200 series of tanks originated during the pilot process studies of the Hot Semiworks. All of the supernatant liquids have been removed, leaving only a sludge layer in each tank.

2.4.1.1 Riser Allocation and Location

The riser locations in tank C-200 series are shown in the tank plan view in Figure 2-3. Figure 2-4 shows the tank profile view. Riser sizes and allocations are listed in Table 2-3. The C-200 series tanks have a ventilation duct that is rectangular and has a dogleg in the duct so that there is not a vertical access to the tank through the ventilation. The ventilation system will be attached to a plate on this duct. The AMS will occupy riser R7 in all tanks. Other risers will be used for the closed-circuit television (CCTV) camera, breather filters, vacuum-break lines, drain lines, etc.

Figure 2-1. C-200 Retrieval Equipment Layout

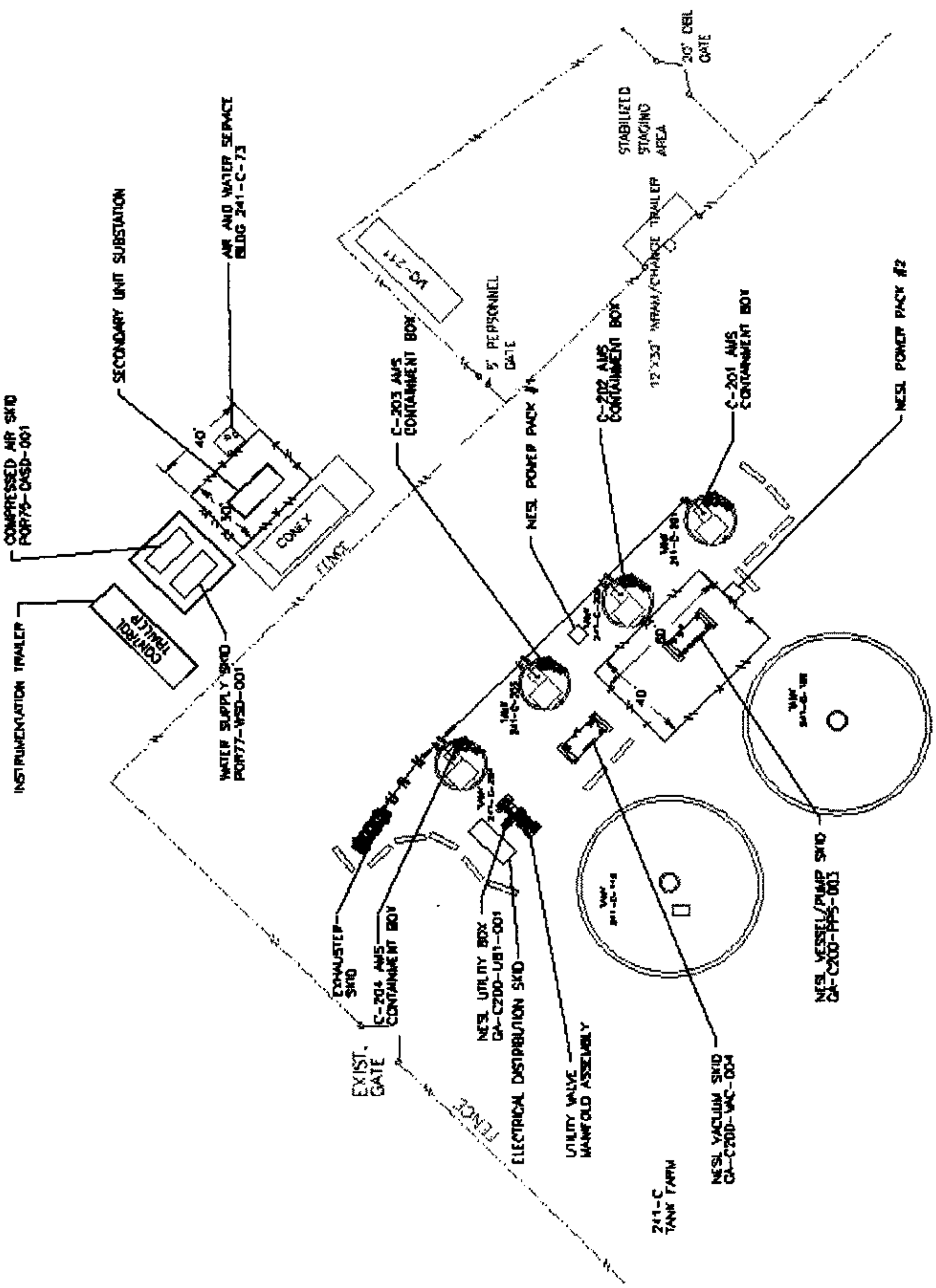


Figure 2-3. Typical 241-C-200 Plan View.

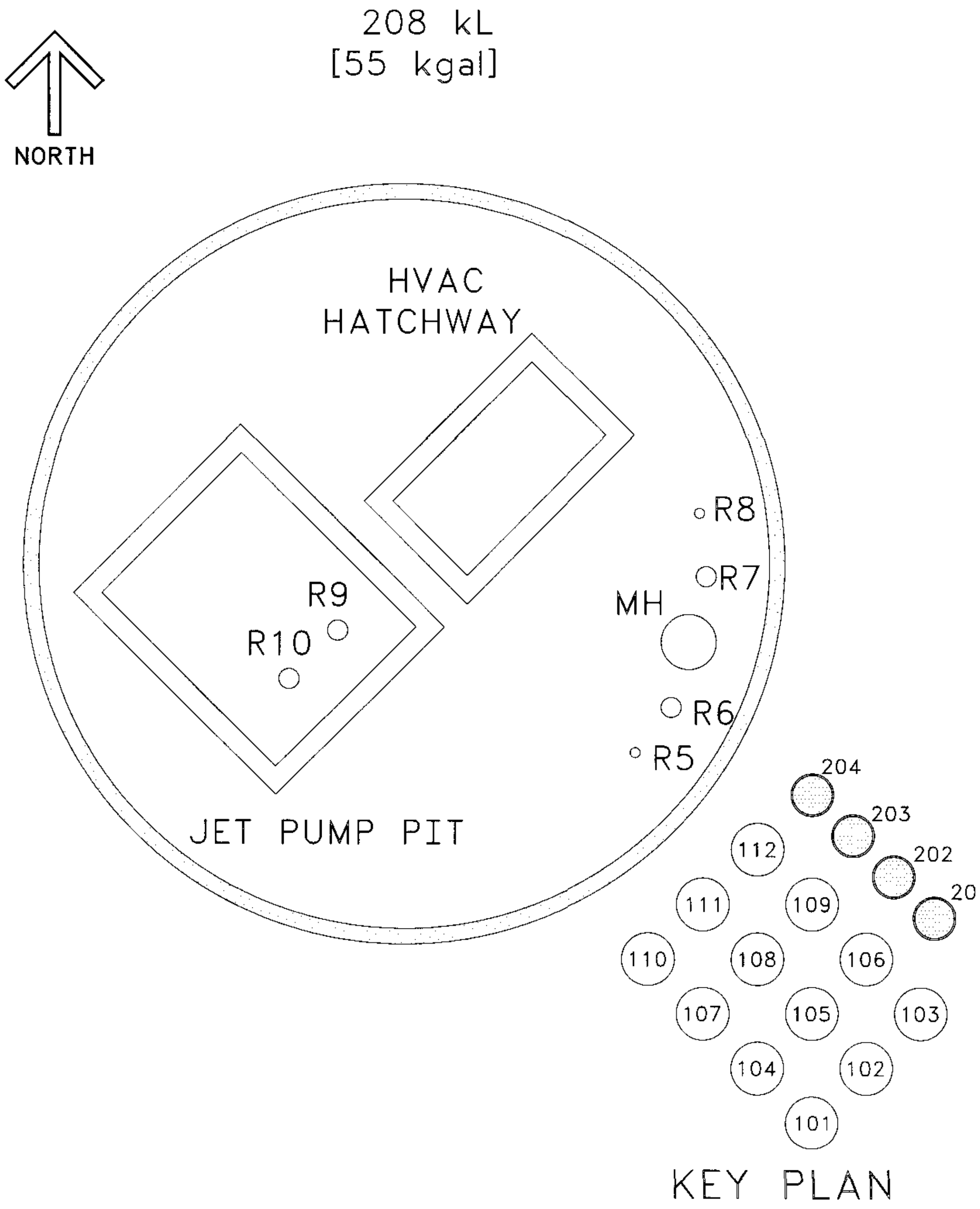
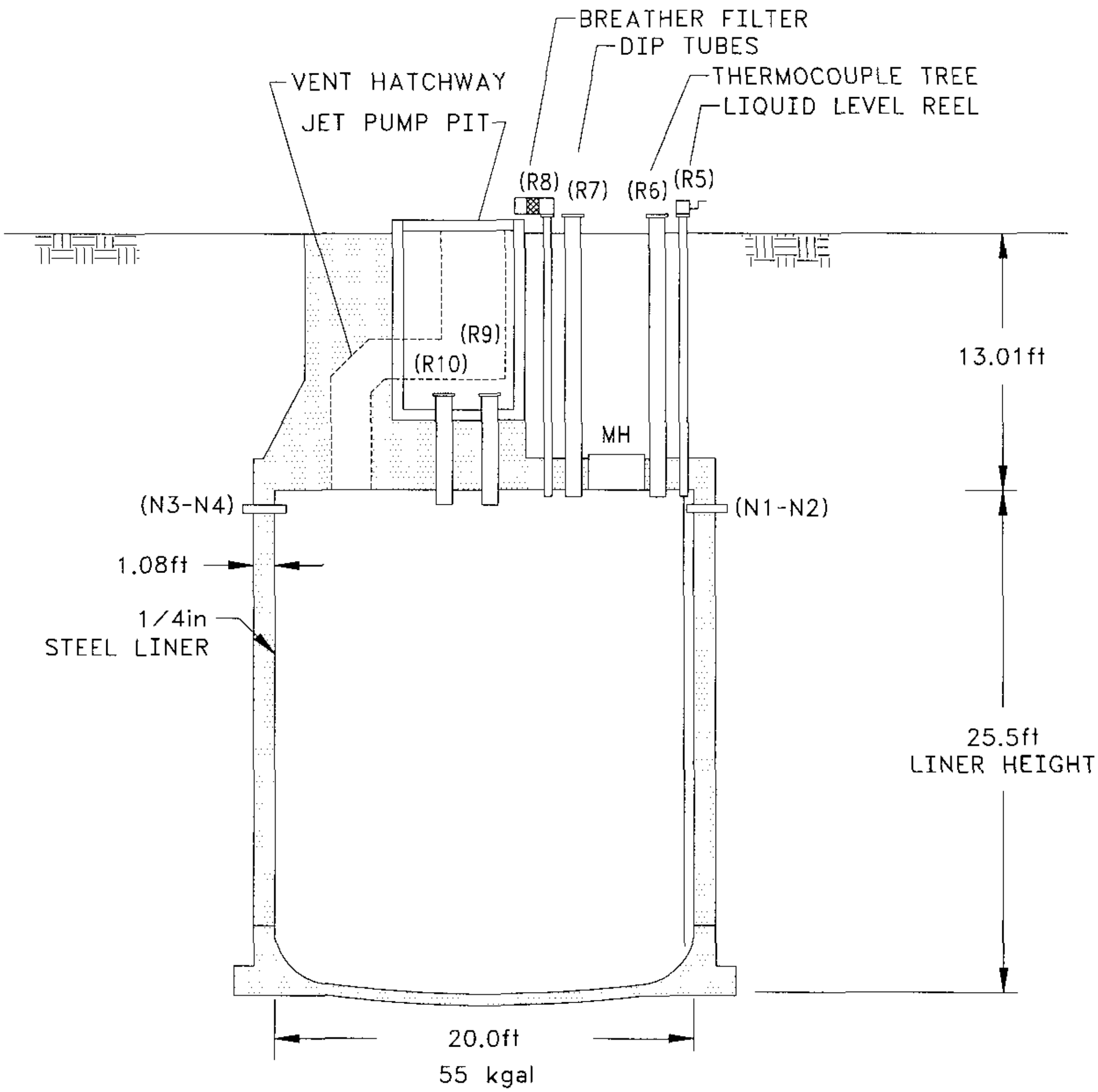


Figure 2-4. Tanks C-200 Profile View.



Note: Figure 2-4 is a historical profile view to give an understanding of the tanks. The various riser uses do not correspond to what the retrieval project will use. See Table 2-3 for the riser uses for the retrieval project.

Table 2-3. Tanks 241-C-200 Riser Descriptions

Riser ID	Minimum Diameter (inches)	Description	Access	Retrieval Use and Comments
R5	4	Breather filter	Above grade	Ventilation Inlet filter and CCTV camera in tanks C-201, C-202, C-203, and C-204.
R6	12	Vacuum Exhaust	Above grade	All tanks (C-201, C-202, C-203, and C-204) use R6 for Vacuum exhaust return. For tank C-203, this riser also receives the drain lines from all of the skids and the vacuum break line from the vessel/pump skid.
R7	12	Observation port	Above grade	AMS within its containment box.
R8	4	Liquid level reel	Above grade	An ENRAF[1] is installed on tanks C-201, C-202, and C-203 during retrieval. A camera and supplemental light will be installed on tank C-204 for use during retrieval.
R9	12	Sludge jet access, weather-covered	Inside pit	Not used as part of C-200 retrieval processing.
R10	12	Sluicing access, weather-covered	Inside pit	Spare riser except for tank C-204, which has a pump installed.
Hatchway	24 inch	Condenser pit, weather-covered	Via HVAC hatchway	Exhauster suction for tank ventilation connected to pit cover. For tanks C-201, C-202, and C-204, the skid and exhauster condensate drains are routed through the pit wall penetration.

Note: Primary reference source for above data are H-14-106126, Sheets 3-6.
CCTV =closed-circuit television
HVAC = Heating, ventilation, and air conditioning

2.4.2 C-200 Series Tank Ventilation System

A portable exhauster connected to C-200 series tanks is continuously operated when the AMS is operating in the tanks. The tank being retrieved is actively ventilated at 300 standard cubic feet per minute (scfm). The other tanks rely on passive ventilation. Waste retrieval activities shall cease if the exhauster is not operating. The exhauster provides an air sweep through the tank dome space to aid in the removal of generated aerosols and/or suspended particulates. This enhances visibility in the tank (visibility is needed for operator control of positioning of the AMS suction point). The exhauster also maintains the tank headspace at a negative pressure relative to the atmosphere to ensure aerosols and/or suspended particulates remain contained in the tank/ventilation system.

[1] ENRAF-Nonius Series 854 is a trademark of Enraf-Nonius, N. V. Verenigde Instrumentenfabrieken ENRAF-NONIUS CORPORATION NETHERLANDS, Rontegenweg 1, Delft, Netherlands.

2.4.3 Vessel/Pump Skid (H-14-106126-7)

The purpose of this skid is to receive waste from the C-200 series tank being retrieved, collect the waste in a slurry tank, and exhaust the air to the vacuum skid. The waste is retrieved out of the slurry tank using a Hydrotrans® with dilution water, and transferred to tank AN-106.

The waste comes into the skid and is directed to the slurry tank. The slurry tank is a 290-gal tank that has a working volume of 250 gal. The slurry tank is an ASME Section VIII pressure vessel, which is a credited design feature to mitigate release of contamination under accident conditions. The slurry tank is on load cells that are used to weigh the amount of waste received. The waste is separated from the entrained gases, which continue to the vacuum pumps. When the slurry tank reaches the full level as indicated by the load cells or the high-level switch, the waste retrieval activities are stopped by the WRS.

The vacuum system is turned off when the slurry tank is full and a vacuum break valve opens to the slurry tank to prepare for slurry transfer to tank AN-106. The air to break the vacuum comes from the tank being retrieved. A Hydrotrans® unit, in conjunction with the slurry pump, can be used to mobilize the tank contents with water and empty the slurry tank. As the waste leaves the slurry vessel, additional dilution water may be added prior to going into the slurry pump depending upon the measured specific gravity and the target waste density.

There are two slurry pumps, which are hydraulically driven progressive cavity helical pumps. Only one pump is operated at a time. The pumps have pressure relief valves that relieve overpressure back to the pump suction. The waste is then sent to tank AN-106 through the HIHTL.

The waste in the slurry tank, the valve positions, the pump operations, and other activities are all controlled remotely from the control trailer. The valves are air actuated and redundancy is provided. Operating configuration is switched between the two pumps approximately every fifth batch to ensure that the lines don't build up with waste and the valves remain operational.

This skid drains to the tank being retrieved. There are drains in the floor, the HVAC and the slurry tank drain. The drains from the HVAC and the slurry tank do not go through the leak detection station. These are anticipated drains and, by design, will not activate emergency shutdown of the system.

2.4.4 Vacuum Skid (H-14-106126-8)

There are two liquid-ring vacuum pumps in this skid. The pumps are interlocked so that only one can be started at a time, but both pumps may be operated at the same time, if necessary. (The pumps must be started sequentially.)

The air flow to the vacuum pump comes from the slurry vessel through a 4x8 in. HIHTL vacuum line. The discharge from the vacuum pump flows tangentially into a water separator, effectively separating the water from the gases in a cyclonic action. The gases are then discharged through a 4x8 HIHTL vacuum return line to the tank that is being retrieved. The water in the separator is used to supply the liquid-ring vacuum pump(s). Water flows to the pump by gravity and by the vacuum that the vacuum pump creates. The water also flows through a heat exchanger that removes the heat generated by the vacuum pump and keeps the water cool. High level and low level switches in the tank maintain water level in the water separator. The low-level switch opens a 2-in. water valve from the raw water utility skid. A high-level switch opens a 2-in. drain valve and water flows by gravity back to the tank. The drain valve is at the bottom of the tank so that any accumulated solids can be periodically drained from the system to reduce aerosol carry over into the exhaust line.

The 4x8 in. HIHTL vacuum return line is classified as safety significant due to the potential consequences of failure. The method of penetration of the water supply into the water separator is a design feature important to prevent the introduction of waste into the raw water system.

This skid drains to tank being retrieved. There are drains in the floor, the HVAC and from the cooler in addition to the water separator tank drain. The drains from the HVAC, the water separator tank, and cooler do not go through the leak detection station. These are anticipated drains and, by design, will not activate emergency shutdown of the system.

2.4.5 Control Trailer (H-14-106128-1)

Operations of the retrieval and transfer to tank AN-106 are controlled and monitored remotely from a trailer located approx. 100 ft. north of tank C-201. The control trailer contains work areas for the WRS control of the vacuum skid; vessel/ pump skid; AMS control systems; video displays monitoring in-tank, the pump, and vessel skids; and an Operations Engineer work area. The WRS Programmable Logic Controllers (PLC) are housed in the control consoles in this trailer.

Two doors located diagonally near the ends of the control trailer provide egress into and out of the trailer.

2.4.6 Hose-in-hose Transfer Line (H-14-105966, H-14-105967)

The waste will be transferred to the receipt tank in a 2x4 in. HIHTL. The transfer system consists of three sections of hose-in-hose pipes. The HIHTLs are ethylene propylene diene monomer (EPDM) rubber lined hoses. The primary hose is a nominal 2-in. diameter hose that is encased in a nominal 4-in. hose. The EPDM rubber will function well for the expected service life because the hose will be exposed to low organic concentrations for the entire mission. The HIHTL is insulated and has freeze protection.

Operational limits are as follows:

Temperature -	<180 °F temperature rating
Pressure -	<375 psig pressure rating.

The first section of HIHTL is the discharge from the slurry transfer pump on the vessel/pump skid to a connection point near the 241-C-03B pit, where it joins a pre-existing two-section HIHTL that runs to the central pump pit, 241-AN-06A, on tank AN-106. This two-section HIHTL was initially installed for saltwell pumping of tank 241-C-103 (C-103) and re-deployed for use in retrieval of tank C-106.

After routine batch transfers (~250 gal plus dilution water), flow through the HIHTL will be shut off. After the batch vessel has been emptied, the line will be flushed on a schedule that is within the controls given in section 3.2.8.

The transfer system will want to drain back to C-Farm but will be prevented by the valving and pumps in the pump skid. The HIHTL encasement will drain to leak detection modules installed to shut down the transfer if a leak should occur.

The hose-in-hose transfer system is used also for the vacuum and pneumatic transfer systems. These transfer systems will move primarily air and are either 3-inch or 4-inch hose inside an 8-inch hose.

Table 2-4 shows the various hose configurations that will be used for this activity.

Table 2-4. Hose-in-hose Configuration Summary

2" X 4" HIHTLs, Slurry lines		
Hose Origination	Hose Destination	Estimated length, feet
Slurry vessel transfer pump	Tank AN-106	985
Slurry vessel drain	Tank being retrieved	74.5 + 50 (jointed line)
3" X 8" HIHTLs, pneumatic lines		
Slurry vessel	Tank being retrieved	74.5
Tank being retrieved	Slurry vessel vacuum break	65 + 59 (jointed line)
4" X 8" HIHTLs, vacuum lines		
Slurry vessel	Vacuum skid	60.4
Vacuum Skid	Tank being retrieved	90
H-14-105966 OGT Line 2x4 HIHTL Assembly H-14-105967 OGT Line 3x8 HIHTL Assembly H-14-105976 OGT Line 4x8 HIHTL Assembly		

An analysis of the hose-in-hose system was performed. Issues such as heat trace, secondary containment pressure and air blow from the C-200 tanks to tank AN-106 were examined. Details on these calculations can be found in RPP-16664, *Calculations for C-200 Series Tanks Retrieval HIHTL*.

2.4.7 Utilities

The supply and distribution of electricity, water, and hydraulic fluid are described in the following sections.

2.4.7.1 **Electrical Skid and Inter-ties** (H-14-106132)

The electrical system is divided into two smaller subsystems. The secondary unit substation skid (POR84) is located outside the C Farm fence. This is where 13.8 kV power is transformed down to 480 volts (V). The electrical distribution skid (POR80) is located inside the C Farm fence next to the C-200 equipment. The skid has two transformers to reduce the power from 480 V to 120 V. This skid has 120 V and 480 V breakers.

POR84 supplies power to various pieces of equipment. The pieces of equipment are the compressed air skid (POR75), water skids (POR77), control trailer (POR85), and equipment located in C Farm. The breaker that supplies power to the C Farm equipment is a special breaker. It has a shut trip circuit that goes to a remote "Emergency Off" pushbutton located on the distribution skid. This allows personnel in C Farm to shut off all tank farm power by pressing this emergency stop button.

POR80 is the in-farm electrical distibution system for all C-200 farm equipment. This skid has two transformers, 120 V breakers, 480 V breakers, and the emergency shutdown panel. The pieces of equipment that it supplies power to are the pump skid, vacuum skid, utility skid, 10-horsepower hydraulic pump (HPP-1), 40-horsepower hydraulic pump (HPP-2), tank instrumentation, heat trace, and portable exhauster. This skid also has the emergency shutdown panel. This panel is safety significant. It houses leak detector relays that shutdown equipment if a leak is detected by the C-200 Series leak detectors. There are emergency shutdown buttons for the compressed air skid, water skid, pump skid, vacuum skid, and "Emergency Off" button for the POR84 breaker.

2.4.7.2 **Compressed Air Skid** (H-14-106126-18)

Compressed air is supplied to the air/water supply skid and to the raw water supply skid from the compressed air skid. The compressed air skid is self-contained including: a compressor, with a capacity of 150 scfm at 150 psig, receiver, filter, air dryer capable of drying the air to a dew point of –40 °F (at 120 psig), and a post drying filter. The air pressure is controlled to 150 psig with a pressure regulator. (Note: The system components use 100 psig air supplied from the utility skid, see Section 2.4.7.2). A pressure relief valve opens if the pressure exceeds 240 psig.

The status of the compressor system is monitored and displayed on a skid mounted control panel including: lube oil level, compressor temperature, receiver pressure, and system discharge (after pressure regulator) pressure. Alarm conditions on any of these conditions trigger a local alarm on the compressor skid. Alarm condition, compressor switch position, and the receiver and discharge pressures are also transmitted to the control trailer. The compressor may also be started and stopped and alarms acknowledged from the control trailer.

2.4.7.3 **Water Skid** (H-14-106126-16, H-14-106126-17)

Because raw water supply (flow and pressure) is limited at the C Tank Farm, a water supply skid will be utilized to boost flow and pressure as required for WRS operations. The water supply skid consists of a raw water system and a high-pressure water system mounted on a common skid.

The low-pressure water system consists of surge tank, pumps, and controls to supply up to 100 gpm to the utility manifold and the high-pressure water system. Raw water will be received into the surge tank from a connection downstream of the existing raw water backflow preventer inside the 241-C-73 Air/Water Service Building. Centrifugal pumps will boost water pressure and flow as required to maintain 220 psig operating pressure at maximum required flow. This tank is monitored for level and temperature, with tank level indication at the control trailer. The system generates alarms for tank low-low, low, and high-high conditions. Heat tracing and insulation on the water tank and all the piping and valves provides freeze protection. An air gap in the supply line feeding the surge tank provides the environmental isolation of the waste transfer system from the raw water system.

The low-pressure water pumps are constant-speed centrifugal pumps. Two pumps are provided but normally, one pump runs. Pumps are turned on and off from Hand-Off-Auto hand-switches on a local control panel on the water skid or by computer control from the control trailer. A current switch indicates pump run status, and a hand-switch indicator shows switch position. If the running pump fails, the other pump can be started manually or through an automatic process. A failed pump generates an alarm at the control trailer. Pumps shut down on surge tank low-low level alarm condition.

A control valve recirculates water to the supply tank to control low-pressure water supply pressure. The supply pressure and supply flow are monitored through signals sent to the WRS control trailer. Maximum low-pressure water supply pressure is limited by a pressure relief, spring-diaphragm style valve set to recirculate back to the surge tank at 250 psig.

Low-pressure water is distributed, as required, to the high-pressure water system and to the utility skid. From the utility skid, low-pressure water is distributed to the equipment skids and AMS (see Section 2.4.7.2). The high-pressure water system (H-14-106126-17) consists of pumps, filters, and controls to supply up to 15 gpm of high-pressure water to the AMS. Source water for the high-pressure water system is provided by the low-pressure water system. A positive-displacement plunger-type pump will boost pressure to ~300 to 1200 psig. Filters will remove particulate contamination for protection of AMS high-pressure water spray nozzles.

The high-pressure water pump only runs when required as selected by the operator. It is turned on and off from a Hand-Off-Auto hand-switch on a local control panel or from the WRS control panel. A current switch indicates pump run status, and a hand-switch indicator indicates switch position. If the pump fails, it is indicated in the control trailer.

The pressure of the high-pressure water supply is monitored by a pressure transmitter that sends a signal to the WRS control system. The pressure is controlled by a feedback control of the pump speed. The pressure target is controllable but is expected to be nominally 1500 psig.

A spring-diaphragm style pressure relief valve set to recirculate (back to the surge tank) at 1700 psig protects the system from overpressurization. High-pressure water flow supply is monitored by a flow-indicating transmitter, which sends a signal to the WRS control trailer.

Two parallel filters (<20 mesh, 0.02 in.) remove particulate from the water supply to the high-pressure pump. A differential pressure (dP) meter monitors the pressure drop. The dP is indicated locally on the water skid. If the dP exceeds 3 psi, a switch signal is sent to the WRS control system displaying a high dP alarm. Flow through the filters is selected through four manual valves isolating each filter. High dP conditions are corrected by replacing the filter cartridges.

2.4.7.4 **Hydraulic Supply** (H-14-106126-15)

The slurry transfer pumps on the vessel/pump skid and the AMS systems in each C-200 series tank are hydraulically powered. The hydraulic power is supplied by two power packs. A 10-horsepower hydraulic pump (HPP-1) supplies power to all the AMS functions. A single 40-horsepower hydraulic pump (HPP-2) supplies power to slurry pump functions.

Both hydraulic pumps have the following instrumentation or functions:

1. High temperature cutoff switch to prevent equipment damage
2. Cooling fan for cooling the hydraulic oil. The cooling fan starts and stops automatically based on fluid temperature.
3. Leak detector switch to shutdown if a leak is detected
4. Pressure transmitter that sends a pressure signal to the MRS computer
5. Low oil level shutdown switch

HPP-2 also has a key switch installed in the motor control circuitry. This is the location where the Administrative Control (AC) 5.12 Administrative Lock condition is applied.

2.4.7.5 **Utility Valve Manifold** (H-14-106126-11)

Compressed air from the compressed air skid and raw water from the raw water supply skid enter the distribution manifold. Both supply lines are monitored by flow transmitters, which send signals to C-200 farm flow totalizers for each stream. The quantities delivered are indicated on flow quantity indicators in the control trailer.

Air Supply: There are six delivery lines on the compressed air manifold and each is controlled with a hand valve (ref. H-14-106126-11). A pressure-regulating valve set for 100 pounds per square inch gauge (psig) and local pressure indicator are mounted on the utility skid between the delivery line to the skid and the header to the remaining delivery lines. Line pressure exceeding 125 psig will cause a pressure relief valve to open.

Water Supply: There are four delivery lines on the raw water manifold and each is controlled with a hand valve (ref. H-14-106126-11). Pressure-regulating valves and local pressure indicators are mounted on the utility skid between the delivery line to the skid and the header to the delivery lines.

Flow totalizers are located on the utility skid to identify the amount of water that goes to various locations. Totalizer FT-001 measures the water to the WRS system. Totalizer FQI-003 measures the amount of water that goes to the vacuum skid for make up water to the vacuum system. These totalizers should be recorded each day the retrieval system operates.

2.4.7.6 Leak Detection in Transfer Lines and Pits

Waste is transferred from the C-200 pump skid to tank AN-106 using an HIHTL. Leak detectors located at the pump skid, vacuum skid, and tank AN-106 pump pit are monitored and interlocked to HPP_2 and the two vacuum pumps.

The C-200 Series retrieval uses two different types of leak detectors. One is a conductivity probe, (H-14-105994-1, Item 1) and the other is a thermal probe (H-14-106091-5, item 5). When water comes into contact with the conductivity probe, it completes the circuit and the leak detector actuates. The thermal detector detects a temperature difference between two elements on the probes. Liquid flowing over the probe will cause a temperature difference. Other conditions, such as air flowing over the probe, may also cause a temperature difference.

2.4.8 Tank 241-AN-106

Tank AN-106 is the designated receipt tank. This tank will have approximately 290 in. of waste in it when retrieval of the C-200 series starts. Tank AN-106 is also designated to receive waste from tank C-103 waste retrieval activities. A detailed waste compatibility assessment was performed for the transfer of C-200 wastes to tank AN-106 that will establish requirements for making this transfer (RPP-RPT-29811, *Waste Compatibility Assessment of Tanks 241-C-103 and 241-C-204 Wastes with Tank 241-AN-106 Waste and Tank 241-AN-106 Waste with Tank 241-C-103 Waste*).

3.0 CONTROLS

The controls that apply to the waste retrieval activities are given in this section. This section only addresses the controls that are unique to the C-200 retrieval effort. Non-specific controls, such as lock and tag requirements, are not given in this document.

3.1 SAFETY BASIS CONTROLS

Changes of the technical safety requirements (HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements*) have been made to cover vacuum retrieval. Those requirements that need to be translated into controls are given below. The safety basis controls are requirements to satisfy those controls given in RPP-17190, *Safety Evaluation of the Waste Retrieval System Vacuum System for 241-C Tank Farms 200-Series Tanks*, that can be controlled by process controls. Those controls that are design features are not included below.

Since the start of vacuum retrieval activities in 2004, there have been three Justifications for Continued Operations (JCOs) submitted and approved by the U.S. Department of Energy Office of Rive Protection (ORP).

The first JCO was approved on January 19, 2005 (Letter 05-TED-007, *Approval of Justification for Continued Operation (JCO) of the C-200 Vacuum Retrieval Systems*) as requested in Letter CH2M-0500197, *Justification for Continued Operation of the C-200 Vacuum Retrieval Systems*. A potential inadequacy of the safety analysis (PISA) was declared because the ventilation system flow rate could be higher than what was previously analyzed and could increase the on-site toxicological consequence for filtration failure unfiltered release accidents. The higher flow rate could increase the risk bin for this accident from III to II. The review of potential consequences due to the high ventilation flow rate determined that identifying the portable exhauster stack as a compensatory measure reduces the onsite toxicological consequences to acceptable levels. A JCO was developed identifying the portable exhauster stack as a compensatory measure. HEPA filters and delta-pressure instrumentation were identified as defense-in-depth features.

The second JCO was approved on October 19, 2005 (Letter 05-TED-070, *Approval to Revise the Restriction on Single-Shell Tank 241-C-200 Series Vacuum Retrieval System Operation*) as requested in Letter CH2M-0503064, *Request for Approval to Revise the Restriction on Single-Shell Tank 241-C-200 Series Vacuum Retrieval System Operation*). The restriction on the vacuum retrieval operations was in response to a PISA declared following the contamination of personnel during removal of a compressed air supply line from the AMS. Vacuum retrieval operations were restricted pending results of the Unreviewed Safety Question determination. The hazard was eliminated by modifying the vacuum retrieval system. The AMS air line and lubricating water line at the AMS containment box bulkhead were disconnected and plugs were installed in the bulkhead penetrations. Safety basis documentation was revised to reflect the prohibition on connecting compressed air and lubricating water to the AMS.

The third JCO was approved on November 14, 2005 (Letter 05-TED-077, *Approval of Justification for Continued Operation (JCO) of the C-200 Vacuum Retrieval Systems, Revision 1*) as requested in Letter CH2M-0500197 R1, *Justification for Continued Operation of the C-200 Vacuum Retrieval Systems, Revision 1*. The vacuum retrieval operation, being conducted under an approved JCO, was suspended when it was discovered that there was an additional aerosol generation hazard unique to the 214-C-201 configuration. A PISA was declared because this additional hazard had the potential to toxicological consequences in excess of those approved by ORP via the existing JCO. The review of potential consequences from the additional aerosol generation hazard determined that the existing compensatory measure (i.e., the portable exhauster stack) continued to be adequate. The JCO was revised to include the additional aerosol generation hazard.

Table 3-1 is a summary of a number of Limiting Conditions for Operation (LCOs) and Administrative Controls (ACs) that were considered for controls. The bold numbers represent sections that have a control or significant information. The sections not in bold have less depth.

Table 3-1. DSA Controls Matrix

Control	Sections Discussed	Comments
LCO 3.1.1 Transfer Leak Detection Systems	2.4.3 2.4.4 2.4.6 **3.3.3** 4.8.1 4.11 4.11.1 4.11.2	Transfer leak detection will rely on leak detection systems. An automatic transfer shut down has been included in the control of the process. (4.8.1). Material balances will also be performed (3.3.3).
LCO 3.1.2 Backflow Prevention Systems		Design Feature. HNF-IP-1266 5.11 Transfer Controls
LCO 3.2.1 DST Primary Ventilation System	**3.2.12** **4.7**	Waste Compatibility requires tank AN-106 have ignition source controls for a Waste Group B tank.
LCO 3.2.2 SST Passive Ventilation Systems	**3.3.1** **3.3.2** 4.8.1	The Notice of Construction (NOC) requires active ventilation of the tank being retrieved (3.3.1).
AC 5.8 Emergency Preparedness		HNF-IP-1266 5.8 Emergency Preparedness
AC 5.9 Source Term Controls		HNF-IP-1266 5.9 Source Term Controls
AC 5.10 Flammable Gas Controls	**3.1.3** **4.7**	The vacuum retrieval keeps the headspace of the tank being retrieved well ventilated. The C-200 tanks are Waste Group C tanks and will remain so (RPP-18911, 2003). Two small tanks on the skids were analyzed for flammable gas and results presented in Section 4.7. Tank AN-106 will change from a Waste Group C to Waste Group B tank.

AC 5.11 Transfer Controls	3.1.1	HNF-IP-1266 5.11 Transfer Controls
AC 5.12 Administrative Locks	4.7	HNF-IP-1266, 5.12 Administrative Locks
AC 5.13 Bulk Chemical Addition Controls		HNF-IP-1266, 5.13 Bulk Chemical Addition Controls. Only water will be added to the waste.
AC 5.14 Dome Loading Controls		Design feature. HNF-IP-1266, 5.14 Dome Loading Controls
AC 5.15 Tank Farm Instrumentation	4.8	HNF-IP-1266, 5.15 Tank Farms Installed Instrumentation
AC 5.16 Corrosion Mitigation Program	2.1 3.2.13 4.9	The water being used to retrieve and transfer the waste will dilute the caustic in tank AN-106. Tank AN-106 will contain excess caustic prior to the C-200 retrieval. After the retrieval has been completed, sampling in tank AN-106 is requested to verify the contents are within corrosion specification.
AC 5.17 Vacuum Retrieval Controls	**3.1.2**	This control prevents radioactive material building up in the water separator.

Section 4.7 is a section on flammable gas. That section explains additional analysis concerning flammable gas that did not lead to a control.

3.1.1 Doors Closed On Skids

Control: ***The doors on the vacuum skid and the vessel/pump skid will be closed when the administrative lock is removed.***

Basis: The doors to the skids form a barrier for mitigating any sprays or leaks from getting into the environment. The doors must be shut when the pumps are running and waste is flowing in the pipelines.

3.1.2 Drain Water Separator in Vacuum Pump Skid

Control: ***The water separator will be drained a minimum of every third batch of waste that is retrieved into the slurry tank.***

Basis: The slurry vessel in the vessel/pump skid removes approximately 98% of the waste. The other approximately 2% is captured in the water separator vessel. The waste will build up in concentration in this skid. The waste build up could increase the waste loading in the exhaust being returned to the tank. Dumping the water separator and refilling with clean water will keep the inventory from getting high. Every third batch of waste will not allow the build up to get excessive.

3.1.3 Ignition Source Control

Control: ***An applicable set of ignition source controls on tank AN-106 must be in place prior to retrieval of the C-200 series waste into tank AN-106. The 241-AN exhauster will be operational to meet this requirement. The verification will occur each day that the C-200 series retrieval is running.***

Basis: Tank AN-106 will be receiving solids from the retrieval of tank C-106 prior to the C-200 series recovery. The additional solids and volumes put into tank AN-106 during the C-200 series will change the Waste Group from C to B for tank AN-106 (RPP-18829, *Waste Group Assignment of Double-Shell Tank 241-AN-106 for Transfer from Tanks 241-C-106 and 241-C-203*). Therefore, the applicable set of ignition source controls will be implemented prior to the C-200 series retrieval. Current plans call for operating the C-200 series retrieval only on day shift. If the 241-AN exhauster is verified as operating prior to starting the C-200 series retrieval each day, then the periodicity requirement of daily verification is met. If the system is run 24 hours a day, then the exhauster will need to be verified as operating each day.

3.2 PROCESS CONTROLS

These controls assure that the process is under control.

3.2.1 Tank Pressure

Control: ***The vacuum in the tank that is being retrieved will be between 0 inch w. g. and the value listed in OSD-T-151-00013, Operating Specifications for Single-Shell Waste Storage Tanks.***

Basis: The value for the maximum vacuum is set by OSD-T-151-00013 to prevent the bottom of the tank from lifting up or the side walls from collapsing under vacuum. Because corrosion will reduce the tank wall thickness over time, the maximum allowable vacuum decreases over time. For the C-200 tanks, the maximum vacuum is 5.64 in. w.g. through calendar year 2006 and 5.4 in. w.g. through calendar year 2010. OSD-T-151-00013 provides allowable vacuum limits through calendar year 2028. The maximum pressure is to maintain a vacuum to contain particulate and aerosols from releasing to the environment.

3.2.2 Load Cell Totalizer

Control: ***The slurry tank will be considered full when the load cell totalizer (i.e. sum of all four load cell that the slurry tank rests on) reaches 2,500 pounds. This value may be changed by a process memo as experience is gained.***

Basis: This is the total of four load cells that the slurry tank is set on. This value is a starting value and can be adjusted during the campaign as experience is gained. The value is based on a maximum operating volume in the tank of 250 gallons and a estimated bulk waste density of 1.2 relative density (Section 5.1 has further details).

3.2.3 Slurry Flow Baseline

Control: ***Before any waste is retrieved, collect the discharge pressure, flow rate, and density of the system from the slurry/pump skid to tank AN-106 using water. This only needs to be performed on the first tank, tank C-203.***

Basis: This baseline information on the flow system using a known fluid (i. e. water) will be used to assist in predicting the maximum flowrates and minimum dilution requirements during the process. This will also serve as an integrated leak check of the system at operating pressure. The information will also be useful in future fluid flow analysis when a HIHTL system is used.

3.2.4 Slurry Density During Transfer to Tank AN-106

Control: ***The slurry density will start with a target density of 1.2 relative density (or equivalent in other units). This is a starting point to ramp up the slurry density. The density will be held for two batches. If the discharge pressure is below the limit given in Section 3.2.8, then the target density may be stepped up by 0.05 relative density. Dilution water will be used to control slurry density. A slurry density of 1.5 relative density is the maximum density to slurry. Water addition should be regulated to keep the density at the target density ± 0.1 relative density.***

Basis: Dilution water is controlled by the amount of water added to the Hydrotrans® unit. A target relative density of approximately 1.2 is less than 20% volume percent solids if the solids have a density of 2.3 g/mL. To minimize the amount of dilution water, the density may be increased by decreasing dilution water in small increments. The relative density increments will be 0.05. The pressure and flow rates will be watched for at least two batches after an increase.

3.2.5 Slurry Flowrate

Control: ***The flowrate of the slurry will be maintained between 60 and 80 gallons per minute.***

Basis: Flow rates between these values will keep the flow velocity between 6 and 8 feet per second which is well above the critical velocity to suspend solids.

3.2.6 Maximum Slurry Density

Control: ***Maximum slurry relative density will be 1.5.***

Basis: The maximum slurry relative density is limited to 1.5 until experience has been gained with pumping a slurry this dense long distances.

3.2.7 Slurry Discharge Pressure

Control: ***The maximum slurry discharge pressure will be 255 psig.***

Basis: The pressure relief valves on the HIHTLs will relieve pressure at 255 psig. This pressure is below the HIHTL pressure limit of 375 psig.

3.2.8 Slurry Flush Volume

Control: ***The slurry route from the slurry skid to tank AN-106 will be flushed with 1.5 times the line volume (~240 gallons). The slurry route must be flushed after a waste transfer under the following conditions:***

- ***The slurry transferred with a density of greater than 1.25 relative density.***
- ***The slurry transferred is greater than 1.1 for three batches, then flush after the third batch.***
- ***Whenever the lines will not be used for more than 8 hours, i. e. at the end of a day's retrieval.***

More frequent flushes may be performed based on the judgment of the Operating Engineer.

Basis: Solids may settle during the time period that the slurry vessel is filling from the tank being retrieved. The flush is to remove any solids from the line. A high velocity, > 60 gpm but less than 80 gpm desirable, should be used to re-suspend any solid material (Section 4.2). A density of 1.16 gram/mL has been successfully transferred. The starting line pressure was approximately 45 psi when flowing water at approximately 70 gpm. The line pressure after retrieval of tank C-203 was approximately 56 psi when flowing water at approximately 80 gpm. This is well within the operating parameters for pressure and does not show build up of solids in the line.

3.2.9 Flush at the End of Retrieval of Each Tank

Control: ***After each of the C-200 series tanks are retrieved, the system should be flushed with a minimum of 400 gallons.***

Basis: This flush will be performed from the AMS through the various skids and on to tank AN-106. The main purpose of this flush is for decontamination of the system so that dose rates will be low while setting up for the next tank to be retrieved (Section 5.3).

3.2.10 Radiation Controls

Control: ***During operation radiation control procedures assume the slurry tank is full and have designated a High Radiation area around the vacuum and vessel/pump skid. This area is fenced. Some planned entries will be made by Health Physics Technicians (HPTs), see Section 4.4 If operators need to access the vessel/pump skid, a "Decontaminating Flush" will be performed to transfer the waste out of the batch vessel and lines and then flush them with water to remove the radiation source (see Section 4.5, Decontaminating Flush) as needed.***

Basis: Shielding calculations and ALARA screening describe the assumed operating conditions and controls to conduct this project within ALARA guidelines (RPP-15199, *ALARA Review in Support of 241-C-200 Series Tank Retrieval*). Distance is the major mitigating factor used to minimize worker dose during the conduct of C-200 tanks retrieval and transfer. The waste retrieval system is designed to be automated and conducted mainly from the operations/control trailer. The trailer is located ~ 100 ft from the source radiation emitting from the retrieved waste. It is expected that HPT personnel will make regular rounds to physically observe and monitor equipment. Details of special monitoring activities are found in Section 4.4 of this report.

3.2.11 Sampling Requirements

Control: ***Tank AN-106 will be sampled for corrosion control after the C-200 Series Retrieval is completed. The mixer pump in tank AN-106 will be run for at least 15 hours between the end of retrieval and sampling to blend the tank contents.***

Basis: The purpose of this sampling event is to verify that tank AN-106 is still within the corrosion specification after the dilution caused by the water used to retrieve C-200 tanks (Section 4.9). Tank AN-106 is known to be stratified. Blending the tank prior to sampling will assure a better determination as to whether or not the tank contents are in corrosion specification.

3.2.12 Total Water Usage

Control: ***The total volume of water used for the retrieval of tanks C-204 and C-103 is limited to 200,000 gallons.*** *The waste level in tank AN-106 shall remain below 416 inches.*

Basis: The total volume of water used is limited to stay within the envelope that the waste compatibility assessment analyzed for tank AN-106 (RPP-RPT-29811). The volume of water is important for two reasons in the double-shell receiver tank. Additional water increases the waste volume in the receiver tank which, in turn, reduces the dome volume. A decreased dome volume increases flammable gas issues. Excess water also uses double-shell tank space that is valuable for furthering the retrieval mission. The waste level in tank AN-106 will remain below 416 inches. The level limit in tank AN-106 was the level used for the flammable gas evaluation during the waste compatibility assessment (RPP-18829, 2003, *Waste Group Assignment of Double-Shell Tank 241-AN-106 for Transfer from Tanks 241-C-106 and 241-C-200*).

3.2.13 Benchmarks for C-200 Series

Control: ***When the ENRAF is installed to tank C-202, the benchmark will be 18 inches (or the initial reading plus 6 inches which ever is greater) during the period of time that C-202 is being retrieved. The benchmark for tank C-201 is set at 14 inches and tank C-204 is set at 24 inches (or the initial reading plus six inches which ever is greater). Benchmarks shall not be exceeded.***

Basis: The water separator dumps are expected to be the major water source. Tank C-203 is to be retrieved first and then the drain lines transferred to the other tanks to prepare for catching the drain water. A benchmark for tank C-202 retrieval will be set at 18 inches or the initial ENRAF reading plus 6 inches which ever is greater.

The benchmarks for tank C-201 and tank C-204 will be verified during the retrieval of these tanks. If an ENRAF is not available, an alternative method of ensuring that the benchmark level is not exceeded is required. Alternative methods can include a visual comparison of the waste level to an in-tank feature of known elevation.

There is an additional requirement on level of 17,500 gallons for flammable gas control. The additional waste in a tank was of concern for the flammable gas issue (RPP-5926, *Steady-State Flammable Gas Release Rate Calculation and Lower Flammability Level Evaluation for Hanford Tank Waste*). The waste level of less than 99 inches will keep the contents of the tank to less than 17,500 gallons to prevent any flammable gas issue.

There is a requirement that no more than 6,800 gallons of solids be allowed to accumulate in a C-200 Series tank. This requirement can not be exceeded and no controls will be used. The BBI has 6200 gallons of waste spread out in the four C-200 series tanks at the start of retrieval. This requirement can not be jeopardized by the current volumes in C-200 tanks.

3.2.14 Simultaneous Retrievals into AN-106

Control: ***This process control plan does not prohibit simultaneous retrievals of multiple tanks into AN-106. Transfer procedures should be prepared to allow simultaneous retrievals.***

Basis: Tank C-103 is being retrieved into tank AN-106 at the same time as the C-200 series are being retrieved. Waste compatibility associated with simultaneous transfers has been evaluated (RPP-RPT-29811). Material balance for transfers and LDMM will have to accommodate simultaneous retrievals.

3.3 ENVIRONMENTAL CONTROLS

The environmental controls are imposed by the Notice of Construction, AIR 03-704 and the project Functions and Requirements document.

3.3.1 Exhauster Operation

Control: ***The new portable exhauster shall operate continuously when the AMS are operating in the tanks. Waste retrieval shall cease if the exhauster is not operating.***

Basis: The NOC requires this control (AIR 03-704, page 4 item 11). The continuous operation of the exhauster will control the radionuclides that may be suspended in the air during retrieval.

3.3.2 Vacuum Routing

Control: ***Vacuum exhaust drawn from the batch holding vessel shall be routed back to tanks. The tanks shall be maintained under a negative pressure during tank retrieval activities.***

Basis: The NOC requires this control (AIR 03-704, page 4 item 15). The vacuum exhaust will be routed from the vacuum skid to the tank being retrieved. Also see Section 3.2.1 for tank vacuum limits to prevent structural damage to the tank.

3.3.3 Material Balance

Control: ***Material balances will be performed during transfers from the vessel/pump skid to tank AN-106. Additional material balances will be performed during day shift by Engineering for tank leak detection and mitigation. Material balances will be used to estimate amount of waste removed and amount remaining.***

Basis: The purpose of performing material balances is to monitor retrieval and identify material balance discrepancies that may indicate a potential leak. This control is required to support leak detection and monitoring for vacuum retrieval operations and is required by RPP-16525, *C-200-Series Tanks Retrieval Functions and Requirements* (Section 4.5.1). Additionally, material balances during transfers are standard procedure and are required by TSR AC 5.11, Transfer Control, and *Temporary Waste Transfer Line Management Program Plan*, RPP-12711. Material balances for LDMM purposes are generally performed during day shift by Engineering (Section 4.11). This material balance will also be used to estimate the amount of waste removed from each tank and the amount remaining to be retrieved.

3.3.4 Limit hydraulic pressure to the AMS

Control: ***Limit the hydraulic pressure provided to the articulated mast system (AMS) to the minimum practical.***

Basis: The purpose is to minimize the potential for poking a hole in the bottom of the tank with the AMS. The control comes from RPP-16525, The hydraulic pressure has been limited by design and equipment changes on the AMSs installed in the tanks. No further process limits are needed.

3.3.5 Minimize presence of liquid pools

Control: ***Minimize the presence of liquid pools to the extent practical. This can be accomplished by retrieving waste as much as practical from the center of the tank out.***

Basis: The purpose is to minimize the amount of liquid that could leak and the hydraulic head to drive the leak. The control comes from RPP-16525. It is recommended that the last batch of the retrieval period attempt to vacuum up all remaining liquid before shutdown.

3.3.6 ENRAF Reading Frequency.

Control: ***The ENRAF on tanks C-203, C202, and C-201 is to be read at least quarterly.***

Basis: The purpose is to determine if there is a leak to the environment. The control comes from RPP-16525. The ENRAF will not sense waste level below about 1,100 gallons. Above that level, the ENRAF is the primary leak detection device for C-202.

During retrieval of a tank, the AMS does not leave a level surface. Therefore, the single point measurement of the ENRAF is not an accurate depiction of the waste volume in the tank. The ENRAF may be recorded but the visual observations will be as valuable. The main method to prevent leaks will be to remove any liquids to a minimum when not actively retrieving.

Tank C-203 (and other C-200 series tanks after they are retrieved) needs to be monitored for intrusion. Currently the ENRAF in tanks C-203, C-202, and C-201 hits the metal tank bottom and nearly 1,000 gallons of water would have to intrude before the ENRAF will register. When each C-200 tank is retrieved, the tank changes status and OSD-T-151-00031 which specifies quarterly reading once again applies.

3.3.7 Walkdown of aboveground portions of the tank system.

Control: ***The aboveground portions of the tank system need to have a walkdown for visual inspection each day.***

Basis: The requirement for the daily inspections for above ground portions of tank systems comes from WAC 173-303-400 and is being met through procedure TF-OR-ST1-DW Daily rounds for C-Farm. An additional check of the aboveground portion of the tank system integrity will be done before the start of each waste transfer period (waste transfer period is defined as removal of admin lock to reinstallation of admin lock).

4.0 OPERATING STRATEGY

The process flow diagram (H-14-106125) provides an overview of the flows and volumes expected in the operation of the retrieval system. This diagram does not show the batch characteristic of the process.

The process control of the retrieval can be broken down into two major areas: retrieval of waste or in-tank activities and transfer of waste or ex-tank activities. In addition, the cleanout of equipment and skids will also be addressed. Off-normal operations will be addressed in a different section.

The overall scheme for the retrieval is a batch process. The batch size is governed by the volume of the slurry tank in the pump/vessel skid. Each batch will be performed as many times as required until the current working tank is emptied. Then, the system will be reconfigured for the next tank, and the batch sequence will begin again.

The retrieval will start with tank C-203. When tank C-203 is finished, the drain hoses and exhauster ventilation will be reconfigured so that drainage will be to the tank being actively retrieved. The retrieval order is tank C-203, tank C-202, tank C-201, and tank C-204. A tank may be stopped early, the process switched to a different tank, and then the first tank may be finished later.

At the end of the initial retrieval of tank C-203, a comprehensive radiological survey will be performed of the tank C-200 retrieval system. The survey will include entry into all skids, if possible, with radiation and contamination surveys performed sufficient to identify potential leaks, points of buildup and to assist in planning for eventual end of mission clean out and preparation of skids for movement.

The following is a generalized list of the various steps needed for each batch.

1. Configure valves and hoses properly for the tank to be retrieved. This will require the following hoses or valves to be configured.

    - Exhauster set to selected tank;
    - Hydraulic hose, raw water and high pressure water hoses to selected mast;
    - Vacuum line connected to selected tank;
    - Vacuum exhaust/vacuum break to the selected tank; and
    - All drain lines connected to selected tank.

2. Start the various utilities such as exhauster, water skids, hydraulic pump, air compressor, etc.

3. Vacuum transfer waste from the tank to the slurry tank using the AMS to collect the waste. Continue until the slurry tank is full or the tank being retrieved is empty.

4. Idle or shut off the vacuum system and break the vacuum in the slurry tank.

5. Start the Hydrotrans®, as needed, and the slurry pump. Transfer the waste from the slurry tank to tank AN-106. The major amount of dilution water for slurry transport is added at the Hydrotrans®.

6. Flush the line with 1.5 line volumes (240 gallons) of water using the criteria found in Section 3.2.8. Using the slurry pump to provide motive power is the recommended method but other methods may be used. Secure the pump and align the valves properly to hold the flush water in the line.

7. Repeat steps 3 to 6 as needed.

The complete sequence is repeated as often as is needed to empty all the tanks. A cycle from start of loading the slurry tank to the next start of loading the slurry tank may take from less than one hour up to several hours, depending on the waste and the technique used to operate the AMS.

4.1 IN-TANK OPERATIONS

Waste retrieval operations will use the AMS. The AMS will be manipulated to remove the waste from the bottom of the tank. Water can be put into the tank through the AMS to soften the sludge and allow it to be retrieved. A high-pressure water jet (scarifier) is available to disrupt hard sludges. The water also serves to "lubricate" the waste as it moves to the slurry tank. A CCTV system (H-14-106025) is used to allow the AMS to be controlled and positioned.

At the start of retrieval of each tank, the camera will be used to examine the contents of the tank. The location of equipment and debris will be noted. The waste retrieval will start in the center of the tank. The waste will be removed from the center out as much as practical. This will allow any free liquids to drain into the center cavity of the tank where the liquid can be easily removed.

The AMS will be manipulated in a systematic method to vacuum the waste. The suggested method would be to clear a path across the center of the tank, removing waste down to the tank bottom. The AMS would then be used to widen this path, working on both sides of the path until retrieval has been performed over the entire tank bottom. During this process, the amount of water used should be minimized. Specifics on this approach will be documented in a process memo.

After retrieval has been performed over the entire tank bottom and a minimal amount of waste remains, the scarifier or water flushes may be used to wash down and move remaining solids so that the AMS can retrieve them.

The AMS may be used sparingly to push aside debris in order to get access to the waste behind the debris. The high-pressure water may be used to wash down, knock loose, and move the remaining waste so that the AMS can access it.

Photos of the tanks show a pump, loose pipes, steel tapes and at least one rag in tank C-204. Tanks C-201, C-202, and C-204 have rubber hoses attached to an eductor on the bottom of the tank. This debris in the tank will add to the difficulty in retrieving the waste. Come of the debris will be too heavy to be moved to get at the waste below or behind it and the waste will need to be moved away from the debris using high-pressure water or water flushes. The AMS suction intake is covered with a screen with 0.34 in. square openings. This screen should prevent any of the debris from entering the slurry vessel.

The retrieval system will deposit the waste retrieved along with any water needed into the slurry tank. The tank is on load cells and has a high level switch. Waste is accumulated until the load cells or the high-level switch indicate that a full tank has been retrieved. At that point, the retrieval system will automatically stop retrieval, idle the vacuum system, and vent the slurry tank. The system is capable of automatically starting the dilution and transfer system, however, the normal operation mode is for the system operator to start the transfer using the WRS.

The amount of weight that the load cells show for a full load will be adjusted with experience. It is suggested that the starting estimate for the waste bulk density be taken as 1.2 g/mL. For a 250-gal tank this means:

$$(250\ \text{gal})*(8.33\ \text{lbs/gal})*\ 1.2 = 2{,}500\ \text{lbs.}$$

This will be the starting point for the load cells. This set point will be adjusted during the campaign as experience is gained.

The last step in completing a tank is to flush the AMS and the line connecting the AMS to the vessel/pump skid with raw water. This decontamination step is most important for the slurry line between the tank and the vessel/pump skid and is of less importance to the AMS

The goal is retrieval of as much tank wastes as technically possible, with tank waste residues not to exceed 30 cubic feet (cu. ft.) in each of the 200 series tanks, or the limit of waste retrieval technology capability, whichever is less.

There are several problem areas that may limit the ability to retrieve the waste. These are discussed below.

1. The angled head of the AMS will not contact the waste flatly in all parts of the tank. The operation of the arm will allow the "toe" of the AMS to rise from the floor. When this happens, the ability to vacuum decreases.
2. Some waste may adhere to the floor and not be removable with the scarifier.
3. Loose, hard chunks of waste may not break down to smaller than 0.34 in. to go through the screen.
4. Tank internals may not allow full access to the waste with the AMS. While the AMS has the ability of pushing aside rather large items, some internals may be fastened or not easily moved. These internals will cast a "shadow" of waste that may not be attacked with the AMS.

The final volume determination will be made by a video scan of the tank. The following criteria for a successful video scan have been proposed.

- Clear, good quality video that shows what is on the bottom of the tank.
- Video images should be gathered in three different locations: one with the camera about 25 ft off the floor (top), the second at about 15 ft off the floor (middle), and the third about 5 ft or less off the floor (bottom).
- The top video should try to show the mapping layout of the entire floor below. Pan slowly around the outside edge of the dish so that welds on the knuckle plates and tank dish can be seen in relation to the waste. Slowly zoom in on objects. Try to show how far objects are buried into the waste.
- The middle video should try to complete the mapping of the waste footprint; it will also be the first attempt to show the waste depth and contours.
- The bottom video is to examine the contour of the waste in the tank and provide another perspective for determining the waste depth at different locations.
- As much lighting as possible is needed for the videos.
- Video should show close ups of items left in tank such as waste bergs, waste surface irregularities, liquid to liner/sludge interfaces, and the tank knuckle region.
- Video should include all surfaces (bottoms, dome, sides, etc)

The video will be performed systematically. The video will sweep slowly from center of tank to the tank wall. Then the camera will index the pan by 10 degrees and sweep from wall to center; then index again etc. This will continue until the entire tank has been surveyed. The AMS arm may be maneuvered into the picture occasionally to provide a known dimensioned object for scaling.

4.2 EX-TANK OPERATIONS

The system automatically switches to transfer mode when the slurry tank reaches the limit on the load cells or the high level switch is tripped. At that point, vacuum is idled and the vacuum to the slurry tank is broken. The water to the Hydrotrans® is used to mobilize and fluidize the waste in the slurry tank and dilute the waste to a consistency that can be pumped to tank AN-106. From the Hydrotrans®, the slurry enters the progressive cavity helical pump. After the pump, the slurry passes through an ultrasonic de-agglomerator, which will break down large particles and agglomerates to homogenize the slurry. A Coriolis flow meter is used to measure flow and density. A pressure meter is used to monitor the discharge pressure from the system. The slurry then flows through the hose-in-hose transfer system to tank AN-106. The flow rate is to be controlled between 60 and 80 gpm.

Dilution water is the key process control parameter during transfer. Large amounts of dilution water will lower the slurry density and lower the viscosity, which will lower the discharge pressure to transport the slurry to AN-Farm. Conversely, low dilution water will increase the slurry density, increase the viscosity and increase the discharge pressure. The amount of water used to transport the solids should be minimized to conserve space in the double-shell tanks. The process control strategy is to start the campaign with rather dilute slurry and then adjust to less dilution water as experience is gained. A target density of approximately 1.2 g/mL represents a slurry with less than 20% by volume of solids if the solids have a density of 2.3 g/mL. The recommended strategy is to use water to get the pressure and flow baseline. Then increase the density set point to 1.2 g/mL. The density set point can be increased up to 1.5 g/mL. Density set point changes should be made in small increments (e.g. ~.05 g/mL). The increments will be done on a batch basis. The pressure will be monitored while approaching the maximum density. The pressure should not exceed 255 psig. This value is chosen as being below the HIHTL limit and at a pressure allowing water flushing without being boosted with the slurry pumps to clear any plugs. The 1.5 g/mL limit represents a 40% by volume slurry if the particle density is 2.3 g/mL.

To keep the solids suspended during transport, the velocity through the HIHTL should be high. The desired velocity will be 6 to 8 ft/sec. The minimum velocity should be 5¼ ft/sec. This translates to a desired flow rate of 60 to 80 gpm in the 2-in. diameter HIHTL. A minimum flow rate is 50 gpm and flows higher than 80 gpm are allowed if the pressure does not exceed 255 psig..

The batch retrieval approach will produce intermittent flow during the transfer. The slurry flow to AN-farm may be as short as 3 minutes or up to 30 minutes depending on the amount of dilution necessary. The slurry flow to AN-farm will be stopped for about 30 to 60 minutes while the slurry tank is filled with waste from the tank being retrieved. The line to AN-farm should be flushed as specified in Section 3.2.8. More frequent flushes may be performed based on the judgment of the Operating Engineer. The progressive cavity pump can be used as motive force for the flush. A high velocity, > 60 gpm with 100 gpm desirable, should be used to resuspend any solid material. In addition, the transfer line should be flushed with at least 400 gal whenever any tank is completed.

4.3 DRAINAGE CONSIDERATIONS

Tank C-203 will be the first tank to be retrieved. The configuration for tank C-203 retrieval has all drains going to tank C-203. Any water from drainage will be retrieved along with the other waste. After each retrieval, the system will be reconfigured and the drainage will go to the tank that is actively being retrieved.

Tank C-202 will be the second tank of the series to be retrieved. This will remove the solid waste from the tank. It should be pointed out that the ENRAF is located on riser 8 on the edge of the tank. The dish bottom will need to fill with 1100 gallons before the ENRAF will start to register the liquid. The ENRAF is not hooked to the TMACS surveillance system. Readings may be obtained at the ENRAF meter on the tank.

The largest volume to drain will be associated with the contaminated water from the water separator. The water separator is to be dumped every third batch and will put about 20 gallons into the tank each dump. In addition, if the water separator gets too high, a high level switch will automatically dump a portion of the water in the separator. A material balance will be performed by Engineering to determine how much liquid is added to the tank.

During or before retrieval, the ENRAF will be used when possible to measure the level in tanks C-203, C-202, and C-201 (Section 3.3.6). The calculated level below Riser 8 is 10.5 inches from the bottom of the center of the tank. This corresponds to a calculated volume of 1100 gallons. The volume of waste in tanks C-202 and C-201 is small enough that the ENRAF will probably be resting on the knuckle portion of the tank bottom rather than on the waste. The benchmark is set in Section 3.2.13. If the reading corresponds to the level of the tank bottom, then the ENRAF will only function as a high level alarm. The TV camera is the only method for estimating the level in the tank when the level is below what the ENRAF will read. This method of estimating depth is subjective to a certain extent. Current plans are to only operate the camera on the tank being retrieved.

4.4 RADIATION CONTROL

During operations involving retrieval, the slurry tank and retrieval lines will have the potential to cause a high radiation area in areas outside of the skid. The major radiation source during operation will be from the batch tank on the vessel/pump skid. This vessel routinely fills and empties as part of batch operations of retrieving from the C-200 tanks and transferring waste to AN-106. Radiation emissions are essentially proportional to the amount of waste in the receiving vessel. Therefore, dose rates are highest when the vessel is full.

While the internals of the skid will have high radiation area controls in place during operations, the area outside of the skid, including retrieval lines, will be under surveillance and the area will be placed under high radiation controls as necessary based on surveys. Areas placed under high radiation area controls will be either fenced or guarded based on the best judgment of the field work supervisor and the HPTs in the field (RPP-15199, *ALARA Review in Support of 241-C-200 Series Tank Retrieval*).

To verify the information that the radiation controls were set up with, the following activities are planned.

1. After the batch vessel is first filled and before the waste is emptied, an HPT will enter the high radiation area and do a survey.
2. After the batch vessel is emptied for the first time and before the flush so the line is still full of waste, an HPT will survey the line from the vessel/pump skid to tank AN-106.
3. After the batch vessel is filled the second time and before the waste is emptied, an HPT will enter the high radiation area and do a survey.
4. From then on, an HPT will do a survey of the transfer route and High Radiation Area perimeter shiftly during waste retrieval operations.

These surveys will form a baseline and allow verification of the dose rate calculations and verify radiation controls are adequate and to ensure that dose rated continue to stay at allowable levels.

4.5 DECONTAMINATION FLUSHING

After each tank is completed or anytime retrieval will switch to another tank, operations personnel must enter the exclusion zone to reset the valves and hoses. If the radiation from contaminated equipment, especially the slurry receiver vessel, is too high, then a decontamination flush must be done. This can be performed using the manual mode on the control system. The slurry vessel will be emptied by the Hydrotrans® and transfer pump to tank AN-106. Then, the slurry vessel flush system will be initiated and the accumulated water and sludge will be transferred to tank AN-106. The transfer line should be flushed with at least 400 gals of water to clear the vessels, pumps, and piping of residual contamination. The seal water separator in the vacuum skid will be dumped to the tank being retrieved and filled with clean water at least every third batch. The AMS can be flushed by flowing water through the AMS into the tank and by vacuuming water from the tank to the slurry vessel. Other piping can be flushed as required to maintain acceptable radiation levels.

4.6 END OF MISSION CLEAN OUT

When the four C-200 series tanks have been cleaned out, the equipment is to be prepared for lay-up and transport or for disposal. This equipment may be moved to other tanks in the tank farm for retrieving other waste or a decision may be made to dispose of the equipment. The equipment needs to be cleaned up enough to allow acceptable exposure during dismantling and moving. Decisions regarding the acceptable levels of remaining exposure will be made according to ALARA principles.

The water skid, the electrical distribution skid, the hydraulic power packs, compressed air skid, and the utility valve manifold are expected to not be contaminated and will be available for other use.

The pump skid and the vacuum skid must be decontaminated before tank C-204 is finally completed. When an agreement has been reached that the C-200 series waste retrieval has been completed, clean out of the vacuum retrieval system will be performed. As much as possible, the flush water used for the clean out should be pumped to tank AN-106; the volume of liquid draining back into tank C-204 and/or left in the vacuum retrieval system should be minimized.

The equipment needs to be decontaminated sufficient to allow transportation, dismantling, and reinstallation. Decisions regarding acceptable levels of radiation and contamination will be made as part of the planning process using ALARA principles.

The steps to be performed for the end of mission clean out will be developed and incorporated into a revision of this process control plan prior to the completion of tank C-204 retrieval.

4.7 FLAMMABLE GAS

The process using pneumatic transport is very well ventilated. There is no chance for flammable gas to accumulate in the headspace of the C-200 series tanks. The C-200 series tanks are governed by the DSA (RPP-13033, *Tank Farms Documented Safety Analysis Report*).

Initially the C-200 series tanks and tank AN-106 are classified as Waste Group C tanks. The C-200 series tanks will generate lower amounts of flammable gas as the waste is finally removed from them. The C-200 series tanks will remain Waste Group C tanks (RPP-18829, *Waste Group Assignment of Double-Shell Tank 241-AN-106 for Transfer from Tanks 241-C-106 and 241-C-203*). With the additional waste received in tank AN-106 from both the tank C-106 retrieval and the C-200 retrieval, tank AN-106 changes from a Waste Group C tank to Waste Group B tank. The requirement to implement appropriate flammable gas source term controls before the C-200 retrieval is in RPP-18702, *Waste Compatibility Assessment of 241-C-200 Series Tank Retrieval Waste (SST-R-05-04) with Tank 241-AN-106 Waste*. The appropriate flammable gas source term control is in LCO 3.2.1 which requires that tank AN-106 have active ventilation.

The current plans are to operate C-200 retrieval on day shift only. Verifying the exhauster in AN farm is operating will be part of the start up activities. Therefore, the exhauster will be verified each day that C-200 retrieval is running. This will satisfy the periodicity requirement in the LCO.

The slurry tank in the vessel/pump skid will accumulate radioactive waste that will generate hydrogen gas. The gas generation was assumed to be the same as the waste from C-200 series. The waste was assumed to fill 250 gallons in 290 gallon tank leaving 40 gallon headspace. An analysis (RPP-17512, *Flammable Gas Generation and Release Rate of the Pump Skid Slurry Tank for the Sludge Retrieval of the C-200 Tanks*) showed that, without ventilation, the time to 25% of the lower flammable limit can be reached in between 3 and 7 days. The time to reach 100 % of the lower flammable limit is between 11 and 29 days. This analysis was used to prepare the DSA for the C-200 series operation. Ignition source controls are applied to the slurry vessel to mitigate the hazard.

The analysis in RPP-17512, *Flammable Gas Generation and Release Rate of the Pump Skid Slurry Tank for the Sludge Retrieval of the C-200 Tank*, also bounds the water separator because the water separator will always have a diluted waste and the headspace-to-waste ratio is greater. This means that the flammable gas will be generated slower and has, proportionally, a greater volume of headspace to dilute the flammable gas. Therefore, a separate analysis for the water separator was not needed. Ignition source controls are applied to the water separator to mitigate the hazard.

The Flammable Gas Equipment Advisory Board assessed the ignition source control for the vacuum retrieval system. The findings are presented in RPP-17825, *Flammable Gas Equipment Advisory Board Report FGEAB-03-002*, and show that the C-200 retrieval has acceptable ignition source control.

4.8 INSTRUMENTATION

The various signals from the skids are transmitted to the control trailer where the signals are monitored. The control trailer contains two different operator stations: the Mobile Retrieval System (MRS) and the C-200 WRS that is being constructed for this project. The two stations will communicate together and pass information back and forth. Further details can be found in RPP-16476, *Software Implementation Plan for C-200 Waste Retrieval Systems (WRS)*, and RPP-16156, *C-200 Series WRS Operations and Maintenance Manual.* The system is summarized below.

Process Variables read directly from field instrumentation:

- C-200 series dome pressure at the four tanks,
- Waste retrieval and transfer line leakage (From C-200 WRS Pump Shutdown System),
- Emergency Shutdown Event (From C-200 WRS Pump Shutdown System),
- Radiation Monitoring at the Vessel/Pump Skid and the Vacuum Skid,
- Raw Water Flow, and
- Compressed Air Flow.

Process Variables communicated through the MRS/WRS Ethernet link:

- Waste transfer (slurry) flow rate,
- Waste transfer (slurry) pressure,
- Waste weight in the slurry tank, and
- Permissive-to-run from the WRS PLC to the MRS PLC.

Process Variables monitored at the Ventilation Controls Subsystem:

- C-200 series tank vacuum/pressure.

Manually Calculated Variables:

- Material Balance calculation based on volume of waste pumped by the slurry pumps minus the volume of waste calculated from the tank AN-106 level transmitter.

4.8.1 Equipment

The waste retrieval system Monitor and Control System (MCS) is a distributed PLC and Human-Machine Interface (HMI) based control system. The system includes six subsystems:

- Leak Detection System,
- MRS PLC,

- Ventilation PLC,
- WRS PLC,
- HLAN personal computer (PC), and
- Remote monitoring station.

The Leak Detection System is a dedicated set of safety instrumentation designed to detect leaks of radioactive waste. When a leak is detected, this system activates a hardwired C-200 WRS pump shutdown and reports to the WRS PLC.

The MRS PLC is the primary controller for the AMS and retrieval system by the waste retrieval system vendor. This PLC reports process values to the WRS PLC for trending. This PLC accepts the permissives from the WRS PLC to begin operation and terminate operation.

The Ventilation PLC is a standalone PLC that controls the exhauster skid. This PLC controls the ventilation skid to maintain a vacuum on the tanks. Pressure transmitters supplied by CH2M HILL report the pressures of the tanks to the WRS PLC for trending and alarming.

The WRS PLC controls the air compressor skid and the water skid. The WRS PLC coordinates operations of the MRS PLC and reports system status to a remote location via a wireless bridge.

The HLAN PC provides a display of the AN-106 tank levels and tank temperatures posted to the site TMACS system. Trending of these values is already provided in the G2 database system. These process values are not interfaced to the WRS PLC. The HLAN PC node is located at the break trailer adjacent to the control trailer.

4.8.2 Interfaces

The interface between the MRS PLC and the WRS PLC is a peer-to-peer Ethernet link between the two PLCs. The MRS PLC, HMI, and joystick controls station are utilized to monitor and control all of the mechanical equipment skids.

Less critical and non-interlocked signals such as tank AN-106 temperatures and tank AN-106 level of the receiver tank can be viewed at the HLAN node installed in the control trailer.

Leak detectors and associated leak detector panels are installed at the vessel/pump skid, vacuum skid, AN-106 pit, and other locations and are wired to the leak detection system. The leak detection system reports any detected leaks to the WRS MCS and the hard-wired pump shutdown circuit.

4.8.3 Monitoring Philosophy

Located in the Control Trailer will be the C-200 series WRS Monitor and Control Station. This station will perform the functions of logging the required data for the retrieval operation, monitoring for appropriate system alarms, and communicating alarm conditions between the different WRS support systems. That data relevant to the C-200 series WRS operation will be logged at the station.

A panel collects the output from new instrumentation installed in the tank for the C-200 series WRS project and signals from systems that support the equipment at the C-200 series tanks. New instrumentation includes pressure transmitters for the tank dome space. The C-Farm Electrical Distribution System does not have a link to the C-200 series tanks' PLC(s) because no power monitoring data is to be collected from this electrical system.

Data that is collected from the Water Skid includes the flow rate of raw water. The tracking of the raw water flow destined for the retrieved tank is used to complete a material balance for the system. Level at the receiver tank can be used to verify the volume transferred. From the Compressed Air Skid the flow of air is monitored and recorded. From the vacuum skid, the flow through the AMS is monitored and recorded.

Located at the receiver tank is the receiver tank's Ventilation Tank Primary System. The dome pressure signal is the only signal monitored at the WRS PLC from this system.

4.9 PROCESS SAMPLING

Current needs for tank measurement / sampling and analysis are:

- Determine the OH^- concentration in tank AN-106 at end of retrieval.
- Estimate the amount (volume) of waste remaining in the C-200 series of tanks.

The waste in tank AN-106 will have excess hydroxide that was added to tank AN-106 for the retrieval of tank C-106. The excess hydroxide is anticipated to be ample to prevent DST contents going out of corrosion specifications. On the other hand, there is no measured caustic demand for the C-200 sludge and the water used will dilute the tank AN-106 waste. Therefore, tank AN-106 should be sampled to verify that the waste is within specifications. The mixer pump in tank AN-106 should be operated for at least 15 hours between the time the retrieval is finished and the samples pulled. This will provide blending of the wastes and prevent stratification.

The final evaluation of the amount of waste left in the C-200 series will be done by analyzing the CCTV scans of the inside of the tanks. The various pieces of equipment in the tank will be used as a comparison of the size of the waste remaining.

4.10 C-200 MATERIAL BALANCE

The material balance will be done to gain knowledge on how the process works and to satisfy Environmental functions and requirements committed to Washington Department of Ecology. The C-200 WRS features a number of sensors that provide information useful for material balance considerations: water totalizers, load cells measuring the weight of the slurry tank, limit switches in the slurry tank, Coriolis flow meter on the outlet of the slurry tank measuring relative density and flowrate, transfer pressure indications, and tank AN-106 ENRAF. An overall material balance will be performed by Engineering on normal workdays. However, the material balance will be approximate since the volume of waste remaining in the C-200 series tank that is being retrieved is inaccurate. There is no method for a measurement other than visual estimate of the remaining volume.

The material balance will be discussed in two parts: the time that the slurry tank is being filled and the time period that the slurry tank is being emptied.

The slurry tank is on load cells that will weigh the contents. The contents will include the waste that is retrieved and the water that is used to retrieve the waste. The amount of waste that is being retrieved will be the difference between the measured water usage and the weight from the load cells.

The amount of water used is measured by a flowmeter at the utility skid. The utility skid measures all the water being used. There is a separate water meter for the high-pressure water. The water is split into four streams after the flow meter. One stream goes to the AMS system and all of that water will go the slurry tank. One stream will go to the vessel/pump skid. This water is metered in the vessel/pump skid and will not usually be part of the liquid in the slurry vessel. This water is typically used for dilution during pumping. A third stream goes to the vacuum skid. This stream is not measured in the skid. The water is used, on demand, to keep the water separator full of water. This water is used in the vacuum pumps. The vacuum water separator will typically be full at the start of a retrieval cycle. The fourth stream is a spare.

The vacuum pump will pull air through the system. The air leaves the vacuum pump saturated and carrying droplets. These droplets are removed in the water separator. The air then goes back to the tank that is being retrieved. In the process, some of the water in the saturated air condenses and enters the tank being retrieved. This is not an inconsequential amount of water. This water will be picked up with the waste and enter the slurry tank but will not be metered.

Another problem is the bypass stream coming from the slurry tank. Tests indicate that between 1 and 5% of the waste may not be removed in the cyclonic action in the slurry tank. This waste will continue on to the vacuum pump to be scrubbed out there. That means that 3 to 15 gallons per batch of waste could end up in the water separator. The water separator will be dumped after a few cycles back to the tank being retrieved.

A water totalizer has been installed to measure the water that is used in the vacuum skid. The water meters in the vessel/pump skid will provide the amount of water being added to dilute the waste during pumping the waste to tank AN-106. The total flow and density will be taken from the Coriolis meter down stream of the pump. The amount of fluid received in tank AN-106 will be measured by the ENRAF. It should be noted that there are indications of crust or foaming during pumping tank C-106 into tank AN-106. If this foaming persists during the pumping of C-200 series, the receiving tank level measurement will be compromised.

Retrieval of other tanks into tank AN-106 could happen at the same time that the C-200 series tanks are being retrieved. The material balance routines for both the transfer and the LDMM will have to be adjusted to accommodate both retrievals if they are simultaneous. Under that circumstance, the C-200 series retrieval can not rely on the ENRAF in tank AN-106 providing meaningful data. The flowmeter on the slurry line will be use instead for the volume of slurry being transferred.

When all of these considerations are taken into account, the material balance will provide valuable information. However, the material balance will probably not be accurate enough to tell if a tank has a leak. The only measurements in the tank being retrieved will be visual estimates of the waste remaining. These will not be accurate until the final analysis for closure.

4.11 LEAK DETECTION, MONITORING, AND MITIGATION (LDMM)

The primary goal of the C-200-Series Tanks Project LDMM strategy is leak mitigation (i.e., reduction of leak loss potential) and is presented in RPP-16525. The operational strategy takes actions to minimize liquid available for leakage from the onset of retrieval and to minimize the time at risk (RPP-15230, *C-200 Series Tanks Retrieval Leak Detection Monitoring and Mitigation Strategy White Paper*).

Leak minimization for a waste retrieval tank leak will be provided by actions taken during waste retrieval. These include the following:

- Addition of water to the retrieval tank is minimized and liquid pools that form are removed as practical.
- Waste will be retrieved to the extent practical by working from the center of the tank outwards.
- Retrieval activities are performed only while a video camera is in place to observe the AMS suction nozzle and waste surface.
- Equipment handling controls are used to minimize the potential for dropping equipment into the tank which could penetrate the tank bottom during installation.
- The hydraulic pressure to the AMS is reduced to the extent practical while still permitting acceptable AMS operation to minimize the potential for putting excessive pressure on the tank wall during retrieval operations.

All these actions minimize the potential leak volume prior to a leak occurring, not after a leak is discovered. The planned approach to leak detection monitoring during waste retrieval will be the same if the retrieval takes longer than anticipated. If there is a need to operate the system longer than the estimated time periods to demonstrate the limit of the technology to recover waste that is difficult to retrieve, the basic leak minimization step is still to limit the volume of any free liquid in the tank.

4.11.1 Leak Detection, Monitoring, and Mitigation (LDMM) Description

The planned LDM for each C-200 series tank undergoing waste retrieval is:

- Following retrieval of waste from a tank, a mass balance will be performed around the tank. A report shall be issued providing the results and supporting documentation for a waste unaccounted for (WUF) calculation using Equation 4-1 (or similar equation) for each C-200-series tank retrieved. Should the WUF be within the limit of error for the measurement process, there will be no further documentation required beyond the WUF report.

$$WUF = [(1 - \theta_s) \times (V_{C\text{-}200s}) - (1 - \theta_e) \times (V_{C\text{-}200e})] + \Delta V_{water} - \Delta V_{evap} - \Delta V_{AN\text{-}106} \pm \Delta V_{oth} - LE \qquad \text{Eq. 4-1}$$

Where:

θ_s = waste porosity at start of retrieval
θ_e = waste porosity at end of retrieval
$V_{C\text{-}200s}$ = best estimate of starting waste volume
$V_{C\text{-}200e}$ = best estimate of ending waste volume
ΔV_{water} = volume of water in C-200 retrieval equipment at start + volume of water added to C-200 water skid + estimate of volume of skid HVAC condensate and exhauster seal pot condensate added - volume of water in C-200 retrieval equipment at end
ΔV_{evap} = estimated volume of water vapor removed from the tanks due to evaporation
$\Delta V_{AN\text{-}106}$ = change in volume of tank AN-106 due to additions from C-200 transfer line
ΔV_{oth} = this covers all other volume changes such as additions to drains
LE = limit of error associated with porosity, C-200 volume measurements, water volume measurements and tank AN-106 volume measurements

- During waste retrieval operations, limited leak detection capability will be provided by the mass balances performed for process control purposes (Section 4.10). These will compare water volume added to the WRS with the volume of waste and water removed from the tank. No retrieval tank waste volume measurement will be available during retrieval except for the visual image provided by the TV camera employed during active operations. A waste surface reading could be taken for tanks C-203 and C-202 during extended down times, should waste retrieval be temporarily suspended. Without a waste surface measurement the usefulness of a mass balance for leak detection during retrieval is limited to spotting significant leaks only, and then only under limited conditions.

4.11.2 Leak Detection Techniques

Because of low volumes of waste in the C-200-series tanks, estimated retrieval duration, and operational approach to minimizing free liquids, a free liquid surface will not be present, and no in-tank static liquid level monitoring is planned in the SSTs.

A direct ENRAF level-sensing instrument will be used in tank AN-106, the receipt tank for waste retrieved from the C-200-series tanks. This instrumentation has a high degree of resolution and repeatability and is well suited for the volumetric method in tanks with a measurable air-liquid interface.

Liquid waste and slurries will be transferred from tank C-200-series tanks to tank AN-106 using temporary over ground HIHTLs and existing valve pits. Leak detectors will be monitored in the tank C-200 retrieval control trailer. The WRS will shut down if a leak is detected in the transfer system.

Leakage from the primary HIHTL (inner hose) will be contained by the secondary confinement system (outer hose) and may be detected by one of the pit leak detectors, material balance data, or radiological surveys. The secondary confinement system has been designed to drain any fluid released from the primary hose to a common point for collection, detection, and removal. The hydraulics of the C-200-series tanks to tank AN-106 HIHTL cause any leakage to the secondary containment to drain towards C-200. Leak detection elements installed in AN-106 pit and pump skid actuate an alarm and annunciator light in the control room if a leak is detected and shut down the retrieval pump

Tank AN-106 is selected as the receiver DST for waste from the C-200-series tanks. A leak from the primary vessel is detected by either a conductivity probe leak detection system installed in the annulus or a continuous air monitor that detects airborne radionuclides entrained in the annulus ventilation exhaust stream. Detection of a leak into the annulus of the tank by either system activates an audible alarm and an annunciator panel light.

The tank annulus is designed to collect and direct waste that leaks from the primary tank to the annulus for detection and transfer. Slots cut in the insulating concrete that supports the tank at the bottom are designed to drain any leakage to the annulus floor. Conductivity probe assemblies on the annulus floor and a radiation monitor leak detection system on the annulus ventilation system are installed to detect tank leaks.

Mass balance will be used for C-200-series tanks. The uncertainties associated with mass balance methods for leak detection are larger than the 250 to 900 gal (approximately half the waste volume in each tank) that could be added to each tank for waste retrieval. Because the volume of liquid added to any of the C-200 series tanks is relatively small, it is anticipated that leakage of these volumes will not be measurable.

As good engineering practice, process control data will be used to compare liquid added to liquid removed from the tank. A running total of volume of liquid added to the tank and dilution water added for transfer conditioning will be compared to the volume of liquid fraction of the waste pumped into the transfer line (per Coriolis slurry density and flow rate sensors) to reveal a gross deficit due to possible leakage.

Static level detection will be used for mass balance calculations in receipt tank AN-106.
Flow meters on the vacuum retrieval system transfer piping will provide mass balance input from the C-200-series tanks.

5.0 RESPONSE TO OFF-NORMAL CONDITIONS

In general, a graded response to off-normal conditions is preferred where circumstances permit. For operational efficiency, if more than one choice is presented by the condition, the choice that maintains system operability to the maximum extent will usually be preferred.

5.1 LEAK DETECTED IN-TANK

If a C-200 series tank is suspected of leaking at any time during waste retrieval system operations, the leak assessment process shall be immediately initiated per TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process*. This process can be triggered by anomalous data from any legitimate leak detection source, either in-tank or ex-tank. An initial evaluation is made within three days. If the initial evaluation shows a potential leak, then a formal leak evaluation is performed.

As soon as data is received that indicate a possible leak, a decision must be made on the best course of action. Generally, the choices will be:

- When data is received indicating a possible leak, waste retrieval will terminate in an orderly manner to remove as much free liquid from the waste as possible. Therefore, if waste retrieval is already underway, any water addition should be terminated and the AMS operated to remove as much free liquid as possible prior to retrieval shutdown.
- During the time data is received that indicate a possible leak, waste retrieval will continue, because that is the only available method to mitigate the severity of a potential leak. If a tank is determined to be leaking, standard practice is to initiate emergency waste retrieval as soon as possible. Therefore, if waste retrieval is already underway, it should continue during the leak evaluation.
- The waste retrieval system activities will be immediately suspended and the equipment placed in a safe condition.

If the tank is ultimately determined to be "sound," the retrieval process may be restarted. If it is determined to be an "assumed leaker," further analysis will be needed to determine the proper course of action.

5.2 LEAK IN TRANSFER PIPING OR PITS

Upon alarm actuation, the appropriate annunciator panel board is verified for the presence of the alarm, and the shift manager is notified. The alarm response procedure is followed and pump shutdown is assured. A Health Physics Technician dose rate survey is required at the specific location of the alarm. The alarm must be identified as an actual leak, instrument malfunction, or maintenance activity.

5.3 LINE PLUG

If a plug occurs in the transfer line, attempts will be made to clear the line via a water flush. Using the slurry pumps to apply pressure is the preferred approach. The pressure should be ramped up relatively slow so as not to suddenly pack the plug at higher pressures. If the line plug cannot be cleared, the plugged line can be replaced. The MRS design includes a backup pump outlet flange to which a new line can be installed.

5.4 ARTICULATING MAST SYSTEM FAILURE

The AMS is rated for the same pressure as the HIHTL (375 psig) and, therefore, can be backflushed with 175-psi water. This activity will be performed if the AMS is determined to have plugged.

If the AMS failure is related to the hydraulics or control system, other options are available. If the failure is in the hydraulic system resulting in a loss of hydraulic pressure, the AMS will return to the vertical position. If needed for repairs, the AMS could then be extracted through the riser.

5.5 RADIOLOGICAL RELEASE OR HIGH-RADIATION LEVELS DETECTED

Normally, upon indication of such an event, it is desirable to investigate the cause of the condition and, if necessary, respond with an orderly shutdown of the system. Only under obvious and serious circumstances would an immediate system shutdown be warranted to limit potential personnel exposures.

5.6 HIGH TANK HEADSPACE FLAMMABLE GAS CONCENTRATIONS

There are very small amounts of waste in any of the C-200 series tanks to generate or accumulate flammable gas. Flammable gas is not anticipated to be an issue during retrieval. No ignition source controls will be employed during retrieval other than tank ventilation.

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