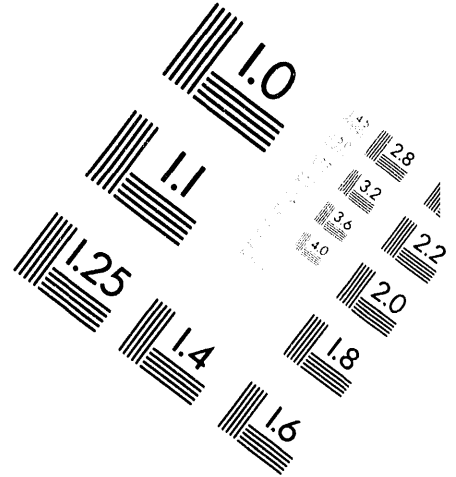
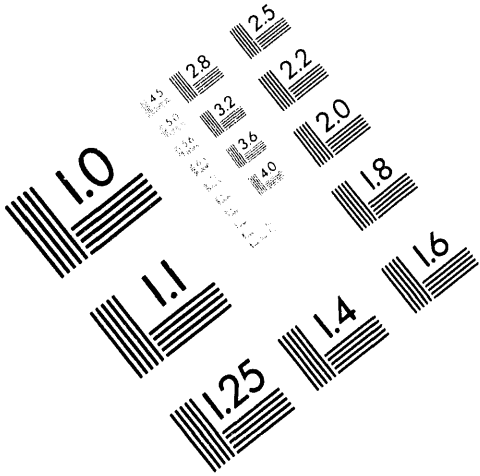




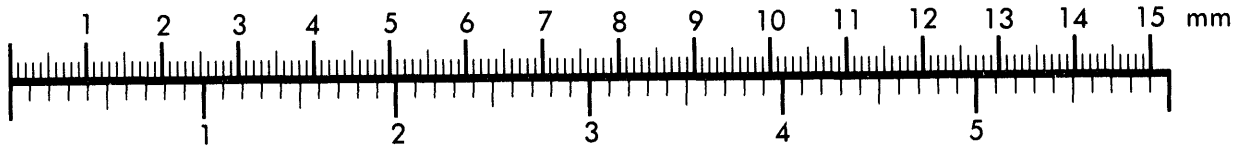
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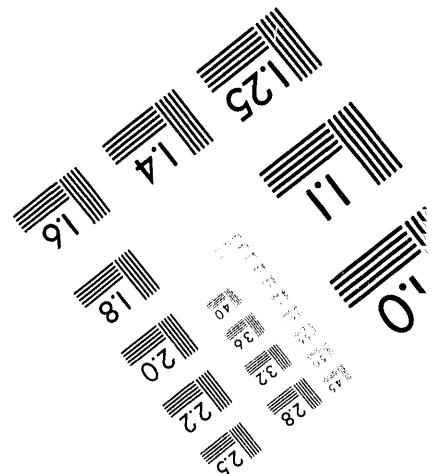
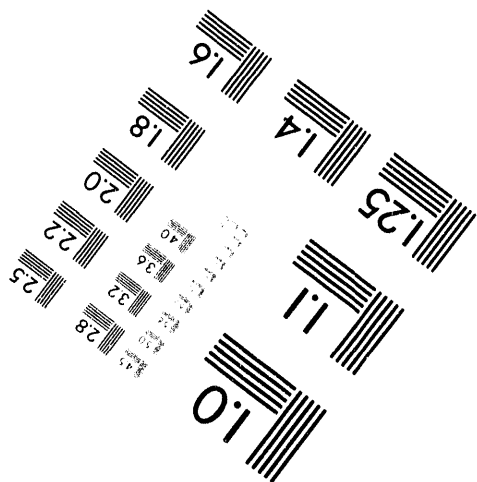
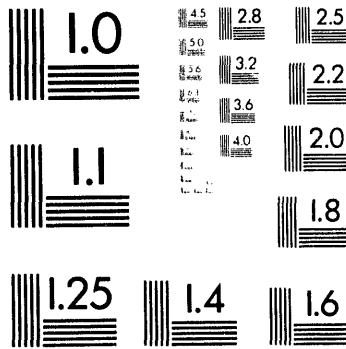
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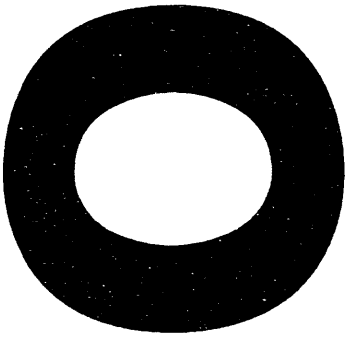
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Action Plan for Response to Abnormal Conditions in Hanford High-Level Radioactive Liquid Waste Storage Tanks Containing Flammable Gases

Prepared for the U.S. Department of Energy
Office of Environmental Restoration
and Waste Management



Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC05-87RL10930

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DISCLM-1, CHP (1-81)

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D. J. Sherwood

Date Published
March 1994

Prepared for the U.S. Department of Energy
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Hanford Operations and Engineering Contractor for the
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Title <i>Action Plan for Response to Abnormal Conditions in Hanford High Level Radioactive Waste Storage Tanks Containing Flammable Gases</i>				Unclassified Category	Impact Level
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New or novel (patentable) subject matter? <input checked="" type="checkbox"/> No <input type="checkbox"/> Yes			Information received from others in confidence, such as proprietary data, trade secrets, and/or inventions?		
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Title of Journal					
CHECKLIST FOR SIGNATORIES					
Review Required per WHC-CM-3-4		Yes	No	Reviewer - Signature Indicates Approval	
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Classification/Uncontrolled Nuclear Information		<input type="checkbox"/>	<input checked="" type="checkbox"/>		
Patent - General Counsel		<input checked="" type="checkbox"/>	<input type="checkbox"/>	S.W. Berglin <i>[Signature]</i> 3/1/94	
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**ACTION PLAN FOR RESPONSE TO ABNORMAL CONDITIONS
IN HANFORD HIGH LEVEL RADIOACTIVE LIQUID WASTE STORAGE TANKS
CONTAINING FLAMMABLE GASES**

D. J. Sherwood

ABSTRACT

Radioactive liquid waste tends to produce hydrogen as a result of the interaction of γ (gamma) radiation and water. In tanks containing organic chelating agents, additional hydrogen gas as well as nitrous oxide and ammonia can be produced by thermal and radiolytic decomposition of these organics. Several high-level radioactive liquid waste storage tanks, located underground at the Hanford Site, contain waste that retains the gases produced in them until large quantities are released rapidly to the tank vapor space. Tanks filled to near capacity have relatively little vapor space; therefore, if the waste suddenly releases a large amount of hydrogen and nitrous oxide, a flammable gas mixture may result. The most notable waste tank with a flammable gas problem is tank 241-SY-101. Waste in this tank has occasionally released enough flammable gas to burn if an ignition source had been present inside of the tank. Several other waste tanks exhibit similar behavior to a lesser magnitude. Administrative controls have been developed to assure that these Flammable Gas Watch List tanks are safely maintained. Responses have also been developed for off-normal conditions which might develop in these tanks. In addition, scientific and engineering studies are underway to further understand and mitigate the behavior of the Flammable Gas Watch List tanks.

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**ACTION PLAN FOR RESPONSE TO ABNORMAL CONDITIONS
IN HANFORD SITE RADIOACTIVE WASTE TANKS
CONTAINING FLAMMABLE GASES**

1.0 INTRODUCTION

1.1 BACKGROUND

Public Law 101-510, Section 3137, Safety Measures for Waste Tanks at Hanford Nuclear Reservation, requires that the Westinghouse Hanford Company (WHC) develop action plans that respond to temperature and pressure excursions or the release of waste material from any single- or double-shell tank at the Hanford Site. These high-level radioactive liquid waste storage tanks¹ have been identified and characterized by their contents which include the following:

- Ferrocyanide compounds
- Flammable gas mixtures at concentrations high enough to support combustion
- Waste with high levels of organic compounds
- High heat loads

These tanks are operated in accordance with Westinghouse Hanford Company specifications. Only Hanford high-level radioactive liquid waste storage tanks with the potential to contain flammable gas mixtures are addressed by this action plan.

There is a tendency for radioactive liquid waste to generate hydrogen through radiolysis of water and other compounds in the waste containing hydrogen. At concentrations greater than four-volume percent in air, hydrogen is flammable. However, the steady state production of flammable gases in stored waste is not necessarily a problem. The presence of flammable gases in a storage facility's vapor space is not a concern as long as the storage facility is adequately ventilated, and the waste releases gases as they are produced. On the other hand, if a waste storage facility does not have a ventilation system, the system fails, or the waste retains gas so that large amounts are released suddenly thereby

¹The tanks, large capped concrete cylinders lined with one or two carbon steel cylinders, are buried more than six feet underground. The largest tanks are 75 feet in diameter and 48 feet high and hold over one million gallons of waste. The cap, or dome of each tank, is penetrated in several locations so that risers can connect the dome space of the tank interior with surface structures.

swamping the ventilation system, then the concentration of flammable gases might be high enough to combust.

Some high-level radioactive liquid waste stored at the Hanford tank farms in single- or double-shell tanks retains the gas that it generates;² therefore, some of these tanks have been put on a Flammable Gas Watch List.

Gas mixtures with concentrations of flammable gases in excess of the lower flammability limit (e.g., four volume percent hydrogen in air) can burn if ignited. Such an event could lead to a release of radionuclides to the atmosphere through risers that provide a path from the tank dome to the ground level.³ If the concentration of flammable gases is high enough, ignition could detonate the mixture. An explosion might damage the tank and cause the release of radioactive effluents; a severe explosion could preclude further containment of the waste.

The primary safety measure in effect at the Hanford Tank Farms to prevent high-level radioactive waste from burning is to operate with restrictions that eliminate potential ignition sources.

Although the tendency of Hanford high-level radioactive liquid waste to generate and retain flammable gas was recognized as a serious problem by 1979, the problem not adequately addressed. Combustion of flammable gas mixtures in tanks was not adequately considered in the Safety Analysis Report WHC-SD-WM-SAR-016 (WHC 1989) of worst-case accidents; therefore an Unreviewed Safety Question was declared (DOE 1990). An investigation of this phenomena has resulted in a Flammable Gas Watch List for 25 waste tanks (Wilson and Reep 1991).⁴

Table 1-1 lists the Hanford Site high-level radioactive waste storage tanks on the Flammable Gas Watch List. Each tank has the capacity to store one million gallons of liquid waste. The newer double-shell tanks are generally filled to capacity while the single-shell

²During the period of time that waste is storing the gas being generated in it, the waste surface level increases because the retained gas takes up space. When the waste releases retained gas, the waste surface level decreases, and the pressure in the tank vapor space increases.

³Risers enable instruments to be inserted into the tank.

⁴Initially, a review of corporate reports and letters found that some tanks exhibited slurry growth, a possible manifestation of gas retention in high-level radioactive liquid waste. This resulted in 5 double-shell tanks and 15 single-shell tanks being placed on the Flammable Gas Watch List. Subsequent criteria resulted in addition of 2 more single-shell tanks. A unique ventilation system design exists at the 241 SX tank farm: the vapor spaces of 5 Flammable Gas Watch List tanks are vented through that for tank 241-SX-109. Therefore, tank 241-SX-109 was added to the Watch List. The waste surface level in tank 241-AW-101 was observed to increase, and then decrease, with pressure spikes accompanying both changes, so it was added to the Watch List. Organic Watch List Tank 241-U-107 was the last tank added to the Flammable Gas Watch List; it also exhibited slurry growth.

tanks often are not. Many single-shell tanks have been pumped dry in order to prevent leaks of radioactive material to the ground; all single-shell tanks have been removed from active service since the double-shell tanks were brought on line. More information about waste storage tanks on the Hanford Site is given in Appendix A.

Table 1-1. Flammable Gas Watch List Tanks.

Single-shell Tanks
241-A-101
241-AX-101
241-AX-103
241-S-102
241-S-111
241-S-112
241-SX-101
241-SX-102
241-SX-103
241-SX-104
241-SX-105
241-SX-106
241-SX-109
241-T-110
241-U-103
241-U-105
241-U-107
241-U-108
241-U-109
Double-shell Tanks
241-AN-103
241-AN-104
241-AN-105
241-AW-101
241-SY-101
241-SY-103
25 Tanks Total

Waste temperatures and surface levels and the vapor space pressure in tanks with the potential for accumulating flammable gases are monitored as frequently as practicable to expand understanding of the gas retention/release behavior. Tank 241-SY-101, which

exhibits the most extreme form of this behavior, is monitored continuously as follows: temperatures are taken inside the waste at 22 depths from two radial locations; temperature and pressure of the tank vapor space are also taken; hydrogen levels in the vapor space are monitored with a gas chromatograph; and nitrous oxide and ammonia levels are monitored with a Fourier transform infrared spectrometer.

Waste in tank 241-SY-101 retains so much of the gas generated in it that when the gas is released, violent waves are produced, and flammable gas mixtures have been measured twice. Tanks 241-SY-103, 241-AN-103, 241-AN-104 and 241-AN-105 exhibit similar behavior, but to a lesser degree. Single-shell tanks do not appear to store waste with this tendency. They were added to the Flammable Gas Watch List because at some time in the past waste stored in them exhibited slurry growth. Slurry growth is a gradual increase in waste volume associated with the retention of gas generated in the waste and/or generation of a low density condensed phase (e.g. foam). Waste surface levels in some single shell tanks have been found to vary with the barometric pressure, which suggest that they do contain waste with a gaseous phase.

1.2 PURPOSE

This action plan provides an overview of Westinghouse Hanford Company procedures for managing the behavior of high-level radioactive liquid waste storage tanks that have the potential for flammable gas mixtures in their vapor spaces. This plan is not a procedure or a manual; it is intended for information only. It will therefore not be updated automatically when the referenced procedures and manuals are revised.

2.0 MONITORING AND RESPONSE

2.1 INTRODUCTION

The federal government provides funding and programmatic guidance for operation of the Hanford Site; Washington state and federal laws supplement this guidance. The Department of Energy provides guidance to the Westinghouse Hanford Company through Orders, which are interpreted by Management Requirements and Procedures WHC-CM-1-3 (WHC 1993a). Guidance is reflected in Safety Analysis Reports which are written for specific facilities, for example, WHC-SD-WM-SAR-006 (Bergman 1986) and WHC-SD-WM-SAR-034 (Boyles 1989) for Hanford single-shell tanks, and WHC-SD-WM-SAR-016 (WHC 1989) for the double-shell tanks. These are similar to the Safety Analysis Reports written for commercial nuclear power plants. The Safety Analysis Report for Hanford double-shell tanks has been replaced by: (1) Interim Safety Basis WHC-SD-WM-ISB-001 (WHC 1993b) and (2) Interim Operational Safety Requirements WHC-SD-WM-OSR-016 (WHC 1993c). Safety requirements are used to develop operating specification documents for the single-shell tanks, double-shell tanks, and Watch List tanks. Safety and other requirements given in operating specifications are implemented through management manuals, supporting documents, and other documents as necessary. Field work is performed according to field procedures extracted from management manuals and supporting documents. Such procedures are implemented at the tank farms to ensure that temperatures, pressures and waste volumes in the tanks are maintained within acceptable limits.

The Interim Safety Basis WHC-SD-WM-ISB-001 reviews safety documentation applicable to the tank farms in light of recent Unreviewed Safety Questions (such as the flammable gas issue). All known hazards important to safe operations of the tank farms have been identified in this document. The Interim Safety Basis will be replaced with a new Tank Farms Safety Analysis Report in the future.

If man-made or natural occurrences compromise tank integrity, Westinghouse Hanford Company will utilize Emergency Management Procedures WHC-CM-4-43 (WHC 1992) and Emergency Plan WHC-CM-4-1 (WHC 1993d). Responses to potential emergency conditions which might arise at the tank farms have also been suggested (Marsh 1991).

2.2 MONITORING

Surveillance requirements for both single- and double-shell tanks are in the Waste Storage Tank Status and Leak Detection Criteria (Welty and Vermeulen 1991). Vapor space pressures in double-shell tanks are monitored continuously on strip charts or at two-hour intervals. Pressures for the tanks are measured at the top of risers connecting the tank vapor space to the surface level. Double-shell tanks are actively ventilated, and tank pressures are

maintained at less than atmospheric to filter tank vapors from the atmosphere. These tanks, however, are allowed to exceed atmospheric pressure for 40 hours a year to accommodate maintenance work.

The majority of single-shell tanks do not have active filtration systems; therefore, they are at, or very near atmospheric pressure. Pressure readings are not taken from actively ventilated single-shell tanks.

Temperatures in Flammable Gas Watch List tanks are measured weekly, except for tank 241-SY-101 which is measured continuously. Temperatures in other double-shell tanks may or may not be measured weekly. Temperatures in many single-shell tanks are also measured on a weekly basis, but some are measured either semi-annually or, if their thermocouple trees are out of service, not at all.

Waste surface levels in single- and double-shell tanks are measured daily, because the tanks were designed to accommodate certain waste volumes and heat loads. Also, if the waste in a tank is topped with liquid, the waste surface level provides a means for leak detection. Surface level measurements are made manually or automatically using conductivity probes that contact the waste surface. Waste surface levels in single-shell tanks are measured as often as practicable, depending on the condition of the tank and stored waste.

The annular (tank within a tank) design of double-shell tanks allows for the following real time leak detection capability:⁵ continuous air monitors can detect radionuclides in the annulus air space, and conductivity probes will short if contacted by liquid. Single-shell tanks on the other hand, offer no such capability. Consequently a relatively convoluted approach must be taken to determine if these tanks are leaking. Daily surface-level readings can indicate whether a tank is leaking, but only if the waste is topped with liquid and evaporative loss is accounted for. Liquid observation wells can be used to determine the liquid surface level in tanks where the waste is topped with solid materials. Finally, dry wells located underneath or alongside a tank are able to detect leaks, since radionuclides present in the soil can be measured in these wells.

Portable gas monitors are used to sample the tank air space for flammable gas mixtures before work is performed on any Flammable Gas Watch List tank.

Permanent flammable gas monitors have been installed on Flammable Gas Watch List tanks 241-SY-101 and 241-SY-103. Six monitors were purchased in fiscal year 1993; one of

⁵Here a leak is defined as a tank opening that allows waste to be released to the surrounding soil. If the waste in a tank were to become chemically active, it could be released to the atmosphere through cracks or crevices in components located in the tank dome. Such releases would be detected because airborne radiation levels are monitored continuously at the Hanford tank farms.

these will be installed on each of tanks 241-AW-101, 241-AN-103, 241-AN-104 and 241-AN-105 in fiscal year 1994. Eighteen additional gas monitors will be procured in fiscal year 1994; they are scheduled to be installed on the remaining Flammable Gas Watch List tanks by April 1995. The flammable gas monitors provide on-line measurements for hydrogen; concentrations of other gases (e.g. ammonia and nitrous oxide) can be determined by taking grab samples from a port built into these monitors.

Additional capability for ammonia monitoring is being pursued in fiscal year 1994. Plans are being prepared for installation of ammonia monitors on the stacks of the AN, AW and SY tank farms. In addition, studies to determine the potential for ammonia release from high-level radioactive liquid waste tanks will be underway in fiscal year 1994.

2.3 EMERGENCIES

Three levels of emergency are defined for the Hanford tank farms. From lowest to the most extreme, they are as follows: (1) alert level, (2) site area, and (3) general. An alert level emergency would be declared if the waste stored in a tank exploded and produced only debris or an airborne cloud. A site area emergency would be declared if the waste stored in the tank was not uncovered. A general emergency would be declared if the dome collapsed, and waste could not be contained.

Managerial actions associated with these emergencies are described in Emergency Management Procedures (WHC 1992). Potential remedial actions from Marsh (1991) are described in the next section.

2.4 RESPONSES

This section describes Westinghouse Hanford Company responses to off-normal and emergency conditions in high-level radioactive liquid waste storage tanks. It also describes plans for dealing proactively with the presence of flammable gas mixtures in the tanks. The flammable gas retention/release phenomena is being studied so that it can be prevented from occurring, or can otherwise be mitigated.

The potential for liquid leaking from high-level radioactive waste storage tanks exists primarily in older, single-shell tanks. Unexplained decreases in tank liquid levels that exceed surveillance criteria are reported and analyzed, and corrective actions are determined.

For temperature increases in a Flammable Gas Watch List tank, corrective actions could include adjustments or modifications to tank ventilation systems, and/or dilution of tank waste with water.

Marsh (1991) postulates conditions for a storage tank explosion and suggests steps to remediate the situation. The conditions are as follows:

- (1) Condition 1. A small, rapid explosion that breaches the High Efficiency Particulate Air (HEPA) filters, or damages whatever (passive) ventilation system is on the tank⁶ but does not result in a sustained release of tank waste.
- (2) Condition 2. Same as Condition 1, but a sustained release of tank waste occurs.
- (3) Condition 3. A large explosion of tank waste breaches the ventilation system and ruptures the tank liner, but the tank dome remains intact; potential for waste leaking to the tank annulus⁷ and/or soil exists.
- (4) Condition 4. Same as Condition 3, but the tank dome collapses so that there is a loss of waste containment.

The responses to the four emergency conditions are as follows:

- (1) Condition 1. Restore remaining filtration of the tank to operational status; add water to extinguish the fire, if possible;⁸ and fix contaminants to the ground with water and/or soil surfactants.
- (2) Condition 2. Same as for Condition 1 with the additional action of limiting effluent discharge.
- (3) Condition 3. Same as for Condition 2 with the additional action of mobilizing equipment for cleanup of surface contamination.
- (4) Condition 4. Same as for Condition 3 with the additional action to restore containment or provide as much containment as possible.

In addition to having developed plans for dealing with off-normal circumstances and emergencies in the tank farms, the Westinghouse Hanford Company has a Waste Tank Safety Program to develop methods to mitigate flammable gas accumulations in high-level

⁶All double-shell tanks are actively ventilated with a HEPA filtration system. The majority of the single-shell tanks are not actively ventilated; instead they have passive breathing filters which allow the space in the tank dome to mix with the atmosphere.

⁷Single-shell tank liners contact a concrete shell while double-shell tanks have an additional inner steel liner so that an annular region is formed to detect and control leaks.

⁸High-level waste storage tanks are located underground; waste is accessible through risers that connect the tank dome opening to the atmosphere. It may therefore be possible to locate burning waste and add water through the appropriate riser to extinguish fire.

radioactive liquid waste storage tanks. Two examples of the work being conducted by this program follow:

- (1) A large mixing pump has been installed into tank 241-SY-101 to determine if pumping the waste around inside of the tank will prevent it from accumulating gas, thereby preventing sudden releases of large amounts of gas. Results of this experiment indicate that this is in fact the case.
- (2) Gas monitors, which automatically detect hydrogen and allow grab samples to be taken from the vapor space, will be added to all high-level radioactive liquid waste tanks that might accumulate flammable gases. These monitors are similar to those which have been installed on tank 241-SY-101 and have operated successfully for over a year.

The Waste Tank Safety Program has also funded a variety of technology development activities which are directed at characterizing the unique physio-chemical processes that lead to gas retention in the waste, and its subsequent periodic release in large quantities. Such studies should provide sufficient insight into the behavior of the waste in this and other Flammable Gas Watch List tanks to enable the selection of the most appropriate mitigation strategy. For example, instead of mixing the waste in tank 241-SY-101, it may be possible to pump part of the waste into another tank in such a way that it does not cause a gas retention problem in the receiving tank either and dilute the remaining waste in such a way that it no longer retains gas.

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3.0 SUMMARY

High-level radioactive liquid waste tends to generate hydrogen gas, which will burn if ignited in air at concentrations higher than four-volume percent. Waste stored in some Hanford storage tanks may also retain such generated gas until (when the waste cannot accommodate any more) it is periodically released into the tank vapor space. If a tank is filled to near capacity there is little vapor space, and if the waste also tends to retain and release gas from time-to-time, then there could be a large amount of flammable gas released into a restricted space, resulting in a gas mixture that supports combustion. Since this behavior was not fully considered in the Hanford Tank Farms Safety Analysis Report, an Unreviewed Safety Question exists with respect to the presence of flammable gas mixtures in high-level radioactive liquid waste storage tanks. Twenty-five Hanford tanks are on a Flammable Gas Watch List because they potentially exhibit this behavior; tank 241-SY-101 is the most notable. This action plan provides a brief overview of WHC's management plans associated with these tanks. More detailed information is contained in the Hanford Site Tank Farm Facilities Interim Safety Basis WHC-SD-WM-ISB-001 (WHC 1993b). A new Tank Farms Safety Analysis Report will be prepared in the future to address Unreviewed Safety Questions such as the flammable gas issue.

Engineering and scientific studies are underway at Westinghouse Hanford Company to expand the understanding and mitigate the behavior of Flammable Gas Watch List Tanks. Automatic gas monitors are being procured in fiscal year 1994, and these will be installed by April 1995 so that tank vapors can be characterized. Samples of waste from these tanks will also be taken in fiscal year 1994 for laboratory analysis. These and other studies will be used in the new Safety Analysis Report.

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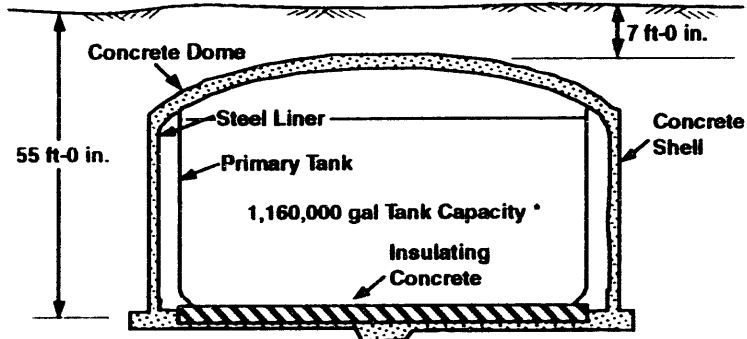
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APPENDIX A
HANFORD TANK FARMS

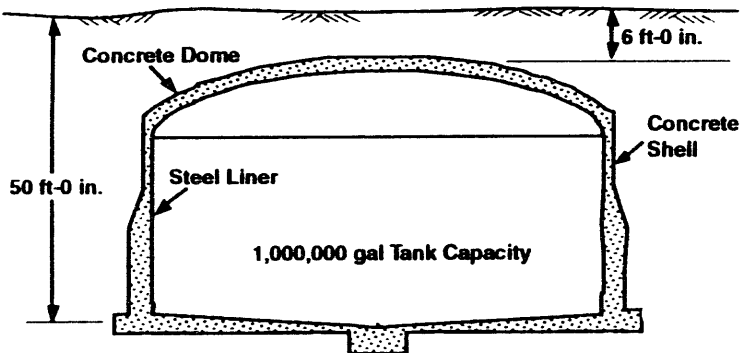
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A-3



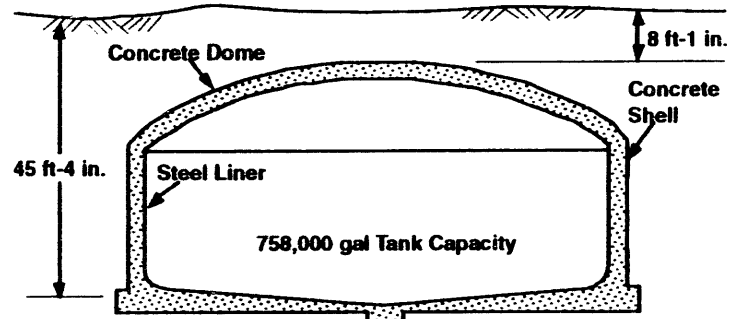
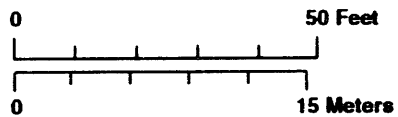
75-ft-Diameter Double-Shell Tank
Tank Farms: AN, AP, AW, AY, AZ, SY

* AY and AZ Have a Tank Capacity of 1,000,000 gal

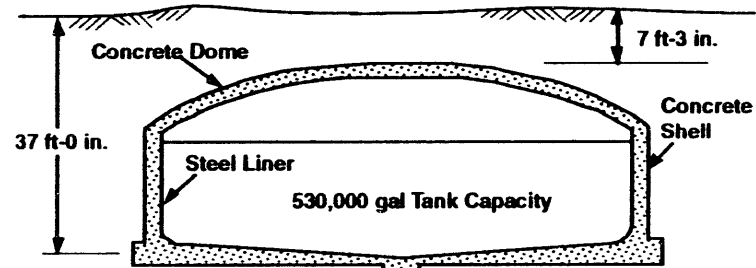


75-ft-Diameter Single-Shell Tank
Tank Farms: A*, AX*, SX

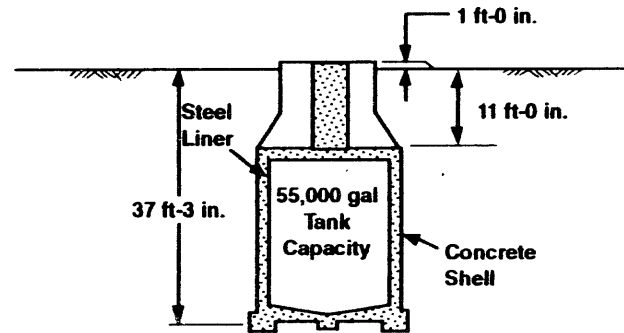
* A and AX have flat bottoms



75-ft-Diameter Single-Shell Tank
Tank Farms: BY, S, TX, TY



75-ft-Diameter Single-Shell Tank
Tank Farms: B, BX, C, T, U



20-ft-Diameter Single-Shell Tank
Tank Farms: B, C, T, U

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Figure A-1. High-Level Waste Tank Configuration.

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Double-Shell Tank

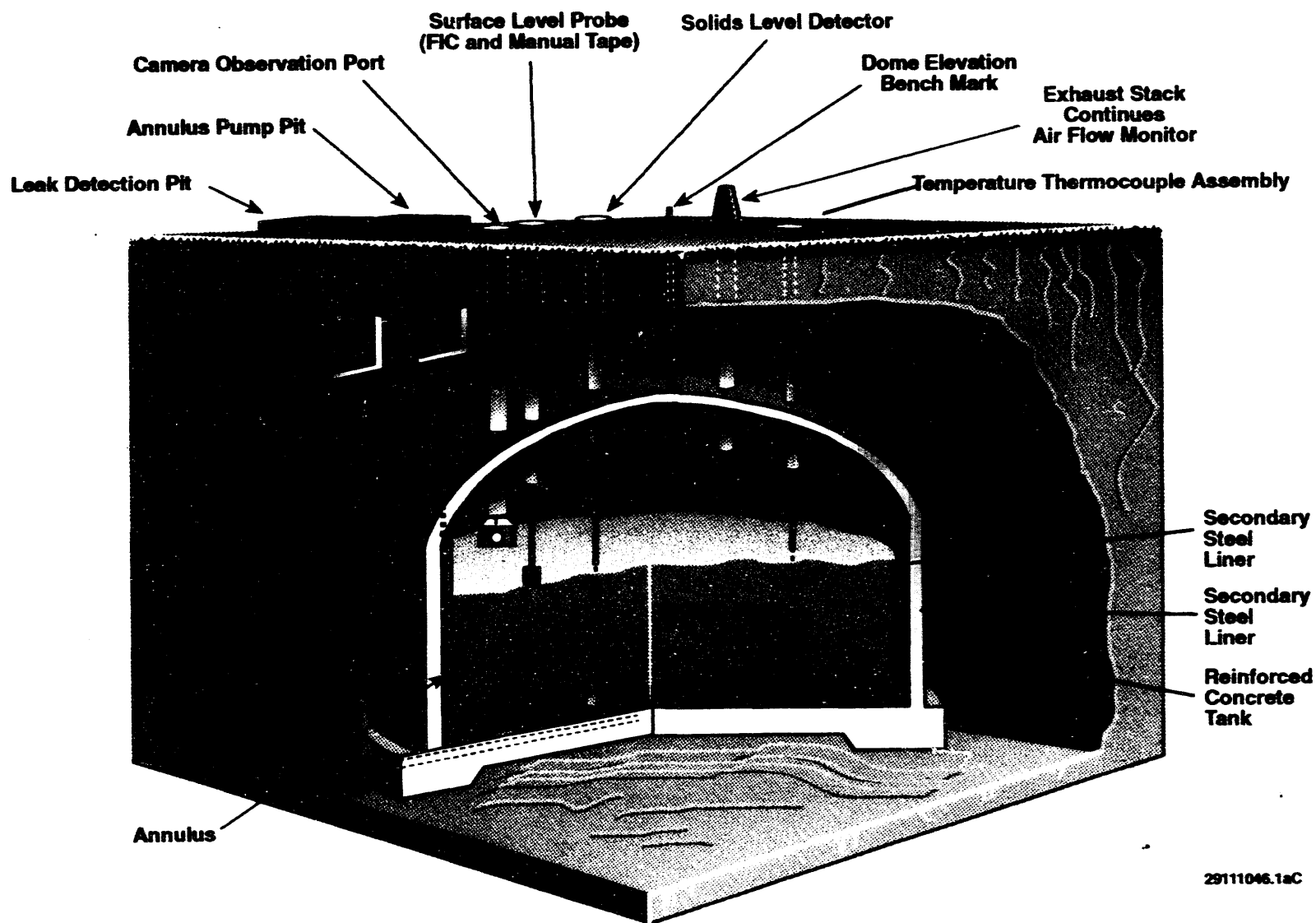


Figure A-2. Double-Shell Tank Instrumentation Configuration.

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Single-Shell Tank

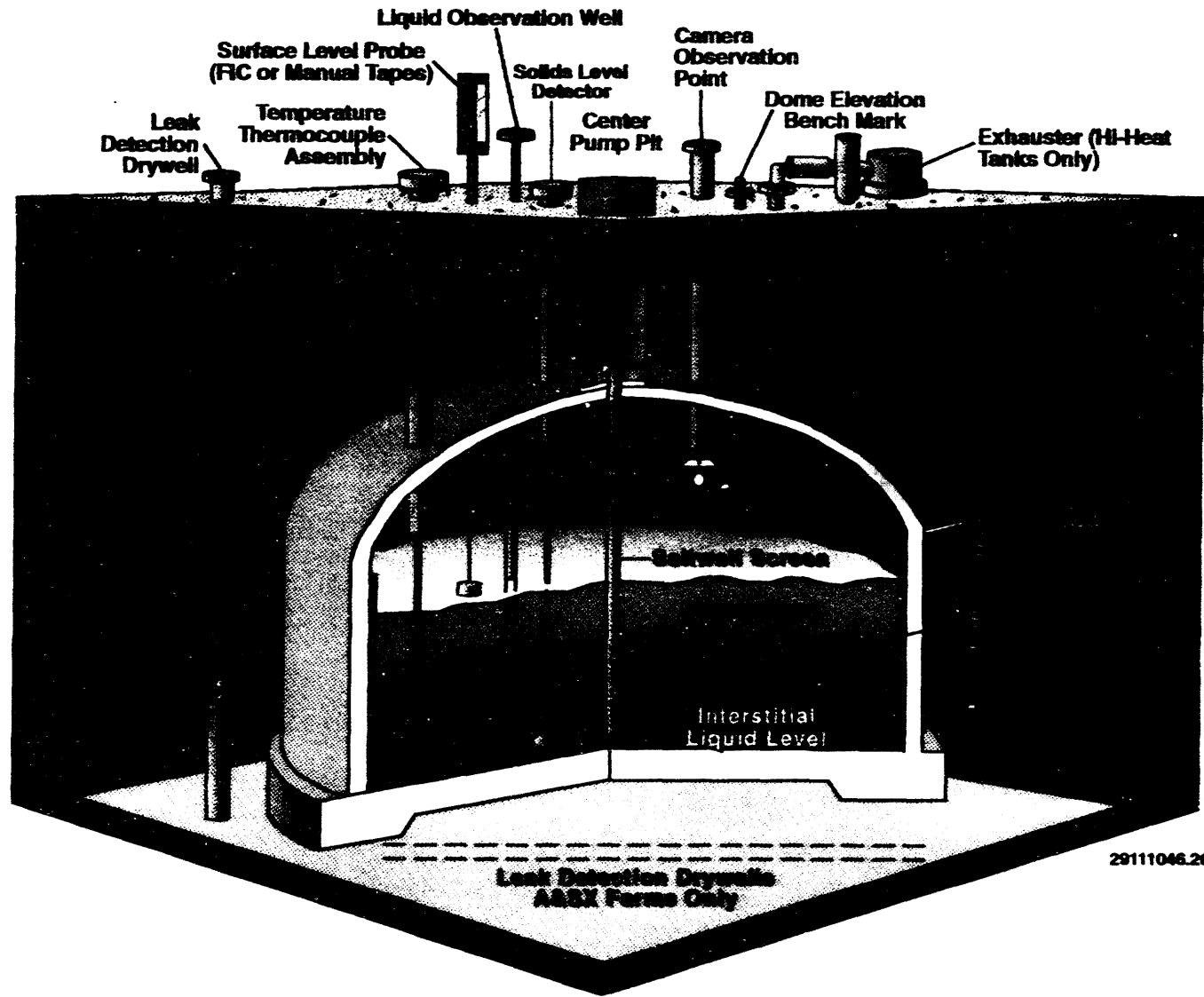


Figure A-3. Single-Shell Tank Instrumentation Configuration.

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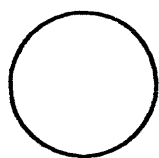
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Hanford Tank Farm Facilities

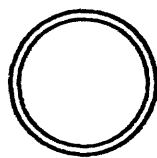
200 East

Note: All single-shell tanks were removed from service (not allowed to receive waste) on or before November 21, 1980

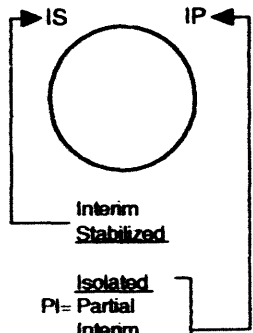
All Tanks 75 Foot Diameter
(Except 55,000 gal 20 foot dia.)



Single-Shell



Double-Shell



Interim Stabilized

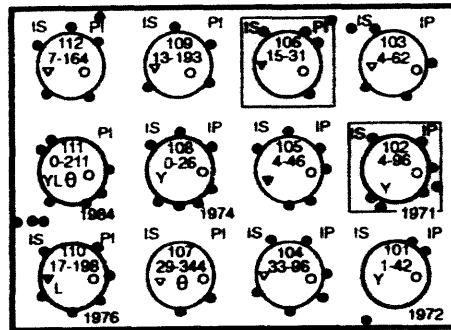
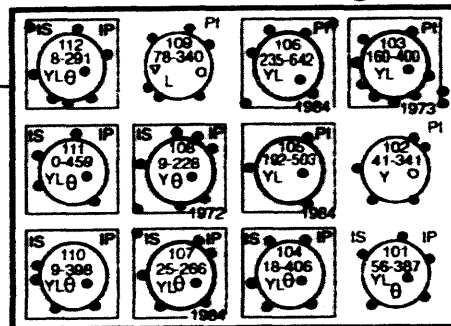
Sound
DCRT = Double Contained Receiver Tank
NHW = Neutralized High Level Waste
PAW = PUREX Acid Waste

Isolated
PI = Partial Interim
IP = Intrusion Prevention Completed

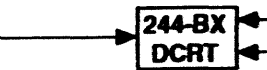
Tank Number

Radiation Monitoring Dry Well - Approx Location
(● = Active ○ = Inactive)

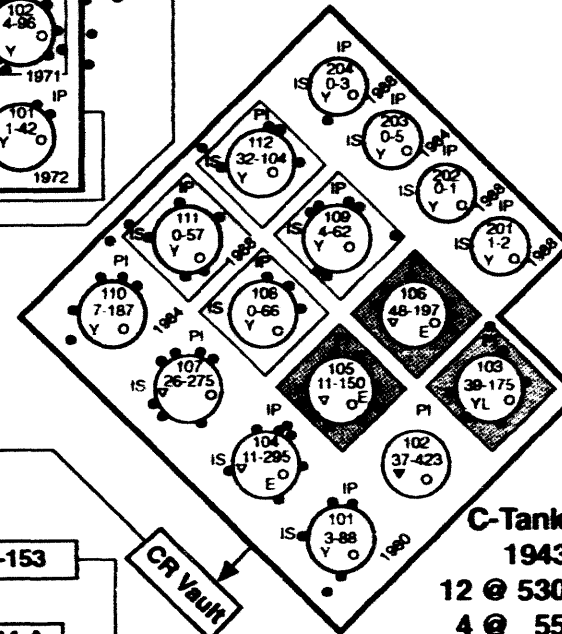
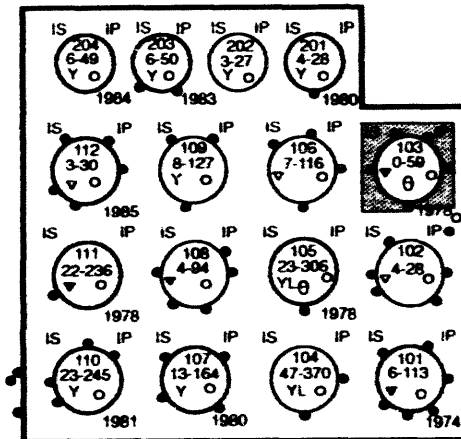
BY-Tank Farm
1948-49
12 @ 758,000 gal



BX-Tank Farm
1946-47
12 @ 530,000 gal

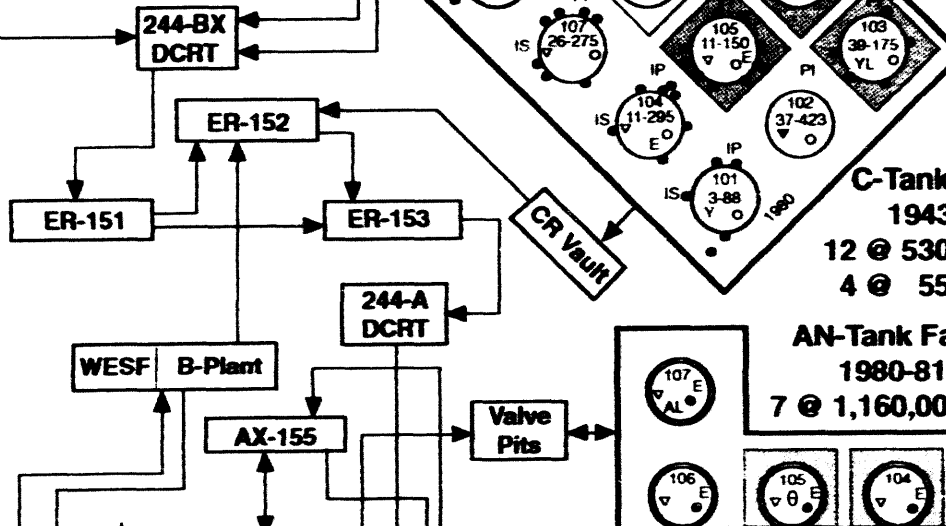
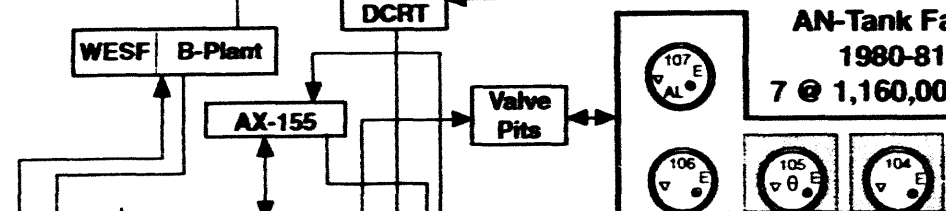


B-Tank Farm
1943-44
12 @ 530,000 gal
4 @ 55,000 gal



C-Tank Farm
1943-44
12 @ 530,000 gal
4 @ 55,000 gal

AN-Tank Farm
1980-81
7 @ 1,160,000 gal



Radiation Monitoring
Laterals Under Tank
(X = not used)

Drainable Liquid
Remaining (1000 gal)
(Inactive Tanks)

Total Solids
(1000 gal)
Salt Cake/
Sludge/DSS
(Inactive Tanks)

Operating
Exhauster

Watch List and
High Heat Load
Tanks

Liquid Level Gauges
▼ = FIC Read Manually
Y = Tape Read Manually
▽ = Auto FIC on CASS
▽ = Intrusion Mode FIC

Airlift Circulators
(107-AN and 102-AW
are inoperative)

Liquid Observation
Well (Low)

Screen - Jet Pump

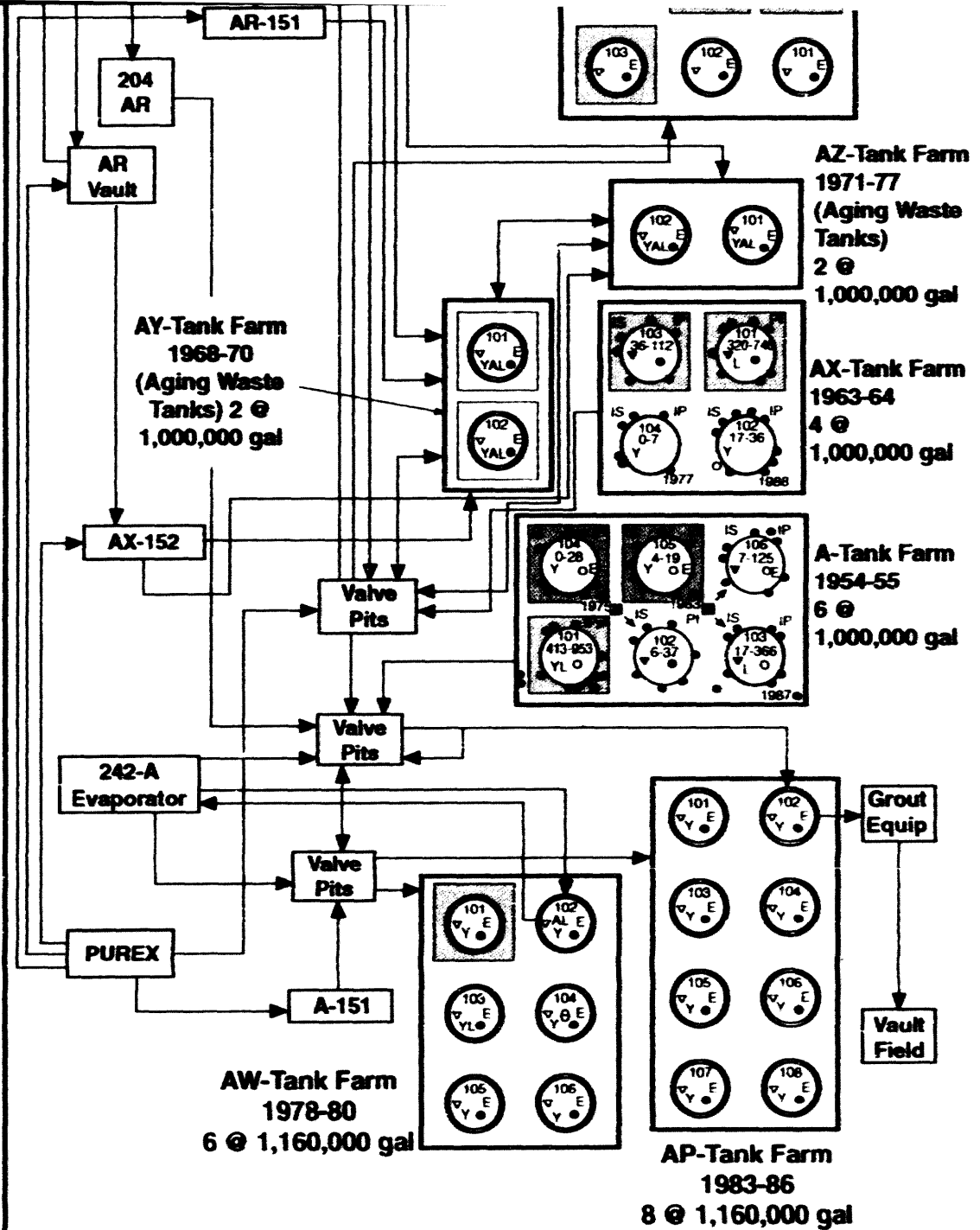
Assumed
Leaker

Temperature Reading
Automatic Readings:
● By CASS for DSTs
○ Manual Readings)

Assumed
Leaked
Date

Watch List Tanks

- Ferrocyanide
- H2/Flammable gases (109-SX has potential only-other tanks vent thru it)
- Organics
- High Heat - 106-C only on Watch List (cooling water added)



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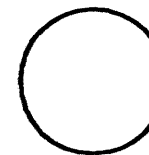
Hanford Tank Farm Facilities

200 West

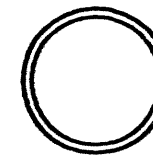
Note: All single-shell tanks were removed from service (not allowed to receive waste) on or before November 21, 1980

———— Double Walled Pipe
 ———— Single Walled Pipe Direct Buried

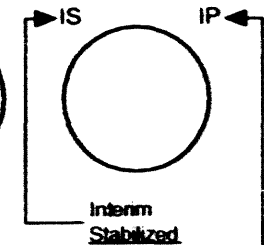
All Tanks 75 Foot Diameter
 (Except 55,000 gal 20 foot dia.)



Single-Shell



Double-Shell



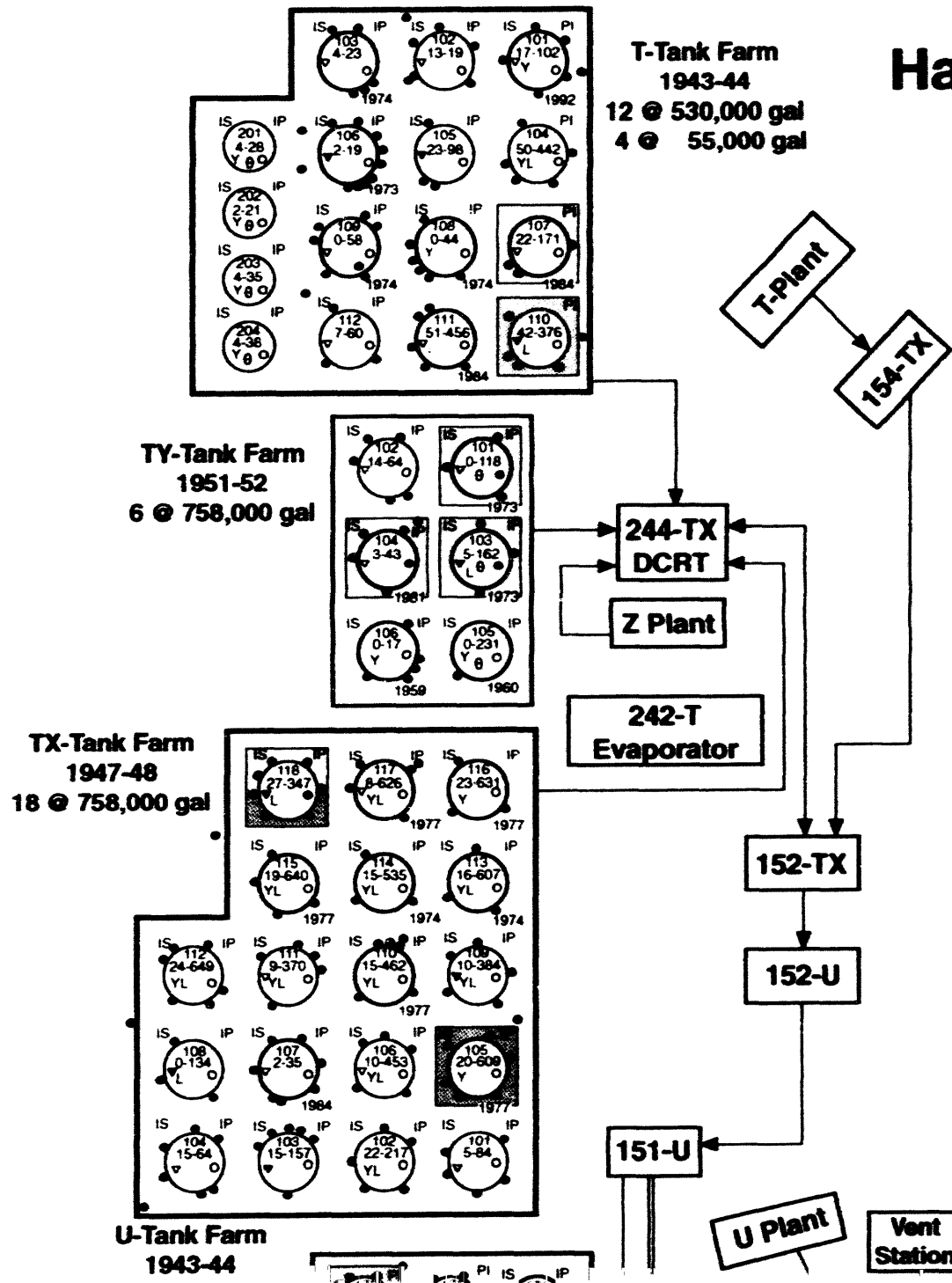
Interim Stabilized

Sound
 DCRT = Double Contained Receiver Tank
 NHW = Neutralized High Level Waste
 PAW = PUREX Acid Waste

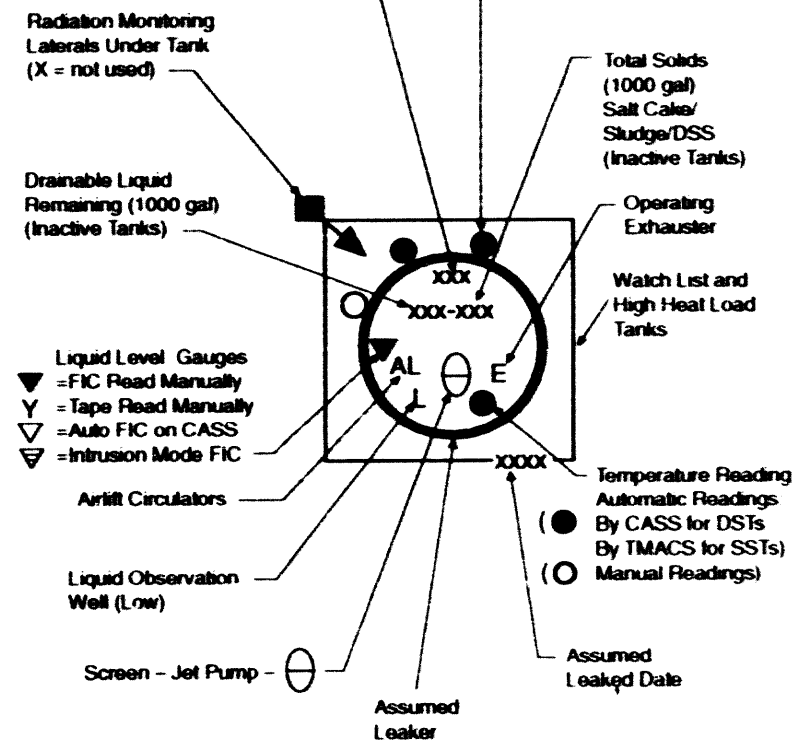
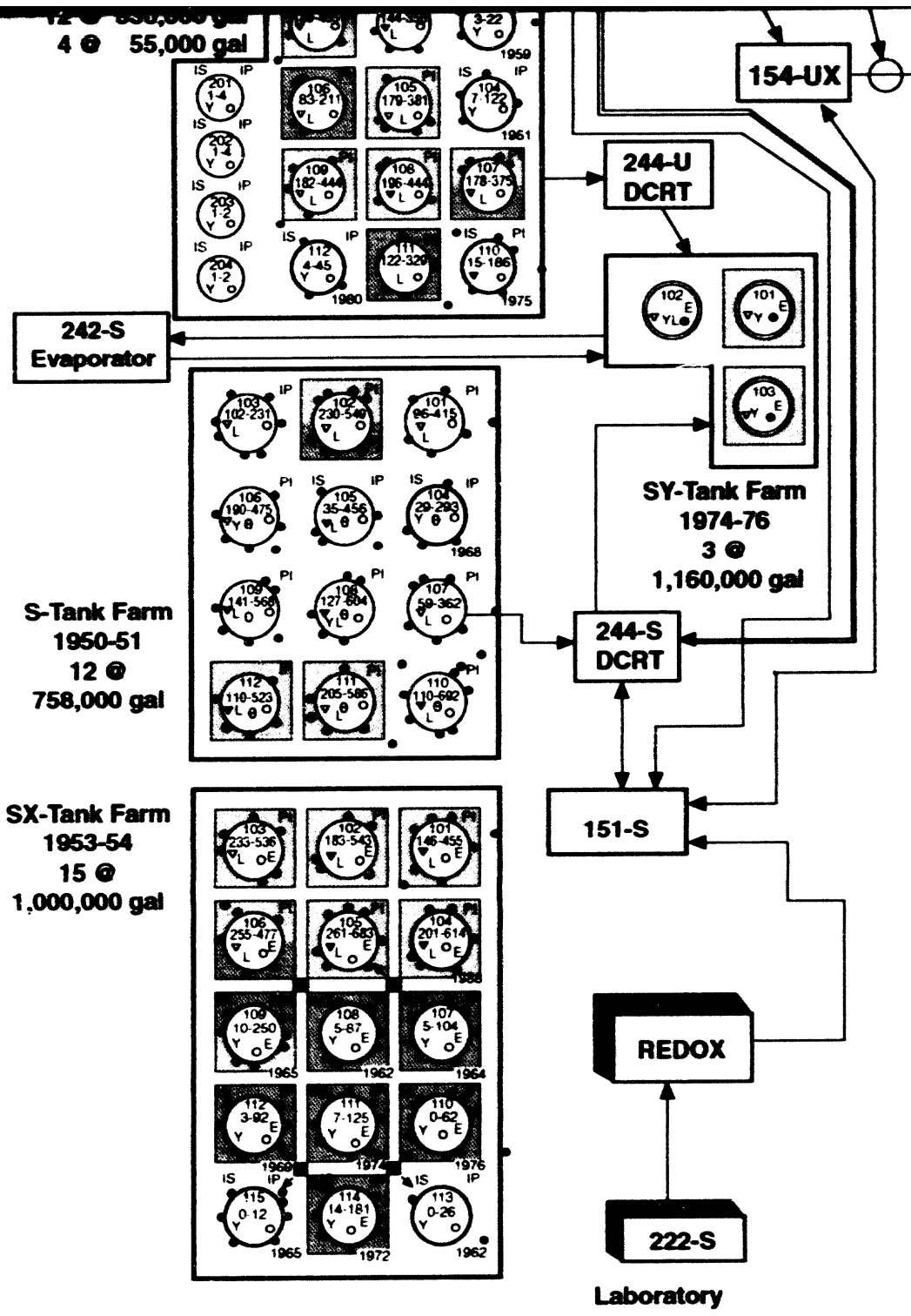
Isolated
 PI = Partial Interim
 IP = Intrusion Prevention Completed

Tank Number

Radiation Monitoring Dry Well - Approx Location
 (● = Active ○ = Inactive)



CF A-7/8



Watch List Tanks	
	Ferrocyanide
	H2/Flammable gases (109-SX has potential only-other tanks vent thru it)
	Organics
	High Heat - 106-C only on Watch List (cooling water added)

Status as of January 31, 1994 - Updated Monthly Issued by WHC/WTPE

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