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Functions and Requirements for Automated Liquid Level Gauge Instruments in Single-Shell and Double-Shell Tank Farms

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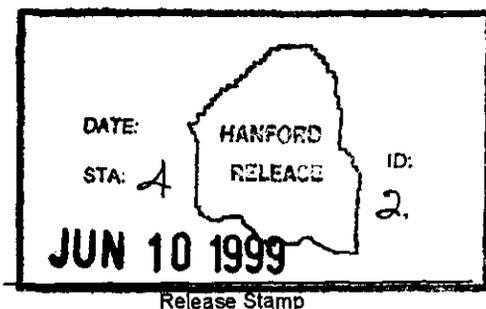
Abstract: This functions and requirements document defines the baseline requirements and criteria for the design, purchase, fabrication, construction, installation, and operation of automated liquid level gauge instruments in the Tank Farms. This document is intended to become the technical baseline for current and future installation, operation and maintenance of automated liquid level gauges in single-shell and double-shell tank farms.

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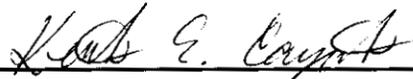

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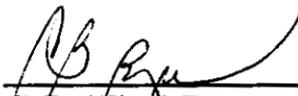
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NUMATEC HANFORD CORPORATION
FUNCTIONS AND REQUIREMENTS FOR
AUTOMATED LIQUID LEVEL GAUGE INSTRUMENTS
IN
SINGLE-SHELL AND DOUBLE-SHELL TANK FARMS



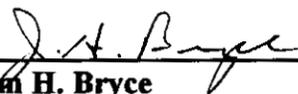
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1.0 SCOPE

1.1 OVERVIEW

This functions and requirements (F&R) document defines the baseline requirements and criteria for the design, purchase, fabrication, construction, installation, and operation of automated liquid level gauge instruments (ALGI) in the Tank Farms.

This functions and requirements document is intended to become the technical baseline for current and future installation, operation, and maintenance of ALGIs in single-shell tank (SST) and double-shell tank (DST) farms planned to replace existing conductivity gauges manufactured by Food Industries Corporation (FIC®).

Tank waste automated level monitoring systems are functionally composed of:

- A level gauge (displacer with transducer or conductivity probe).
- A data acquisition system.
- A data transmission system.
- Display, monitoring, recording, and alarm systems located in a control room, e.g. the Tank Monitor and Control System (TMACS).

This document does not provide the governing requirements or response criteria for operation and surveillance of the waste storage tanks. The individual operating specifications documents (OSDs), Technical Safety Requirements (TSRs), and operating procedures listed in section 3.5, are the sole documented authorities for these items.

Technology and methodology used for tank waste level monitoring may vary depending on the tank type and contents (e. g., surface conditions). This document does not cover the specifications for Liquid Observation Wells (LOWs) used for measuring the interstitial liquid level for tanks presenting a solid surface.

This document was developed according to the Tank Waste Remediation System (TWRS) Administration Manual, HNF-IP-0842, Volume IV, Section 3.4, Rev.1, *Functional Requirements and Technical Criteria*. It uses the outline in Appendix B of IP-0842, IV, Section 3.4, tailored to the specifics of automated liquid level gauges and to the specific activities related to their design, installation, operation, and maintenance.

This document complies with system engineering requirements for the development of Functions and Requirements and Systems Specifications documents (WHC-SD-WM-SEMP-0002, Rev.1, *Tank Waste Remediation Systems Engineering Management Plan*).

Section 7.0, *Appendix*, provides general information pertaining to the existing ENRAF® level gauge currently being used in Tank Farms.

1.2 BASIS AND OBJECTIVES

The existing automated level detection instruments, the Food Industries Corporation (FIC®) conductivity gauges, have had, and continue to have, operation and maintenance problems. The list of lessons learned provided below is also used to establish the F&R for new ALGI:

- The FIC® requires the tank content to conduct electrical current to the tank wall. Several tanks have a fairly dry or poorly conductive surface inhibiting the FIC's® ability to accurately measure the surface.
- The FIC® gauge requires instrument air to reduce condensation in the level gauge riser to the point that the moisture will not short out the current, thereby causing a failure of the level gauge.
- The FIC® gauge requires a special interface into the data recording system. It does not come with an interface that can be connected to a standard data logging system.
- Significant crystal growth on the FIC® gauge plummet affects the ability of the gauge to properly read the tank surface.
- The FIC® gauge is no longer manufactured making the replacement parts hard to obtain.
- Some tanks require level gauges that are qualified for hydrogen gas environments (National Fire Protection Association [NFPA], National Electrical Code Class I, Division 1, Group B). The FICs® do not meet that criterion.

Current level detection conductivity gauge (FIC®) is known to have maintenance problems. Given that it is no longer manufactured, replacement parts are difficult to obtain. Reliability, accuracy, and operation (need for compressed air) are other issues related to FIC®.

1.3 ENVIRONMENTAL, SAFETY FUNCTIONS AND SAFETY CLASSIFICATIONS

1.3.1 AUTHORIZATION BASES

The Authorization Basis documents for DSTs and SSTs are currently the TWRS Basis for Interim Operation (BIO) and associated Technical Safety Requirements (TSRs), and other technical basis supporting documents.

For Tank 241-SY-101 only, tank level monitoring systems are used for flammable gas controls and are classified as Safety Class Systems, Structures, and Components (SSCs) (BIO Sec. 5.3.2.14). The results of the analysis for 241-SY-101 level monitoring are:

- **BIO Section 2.1.1, “Safety Class Structures, Systems, and Components”**

Sec. 2.1.1.9, Level Monitors on Tank 241-SY-101, “The safety function ... is to indicate the tank waste level, which directs the operation of the mixer pump” [to prevent a sudden flammable gas release and deflagration].

With the exception of Tank 241-SY-101, tank level monitoring systems are classified as Safety Significant SSCs. Four additional accident scenarios are analyzed in the BIO and result in Safety Significant nuclear safety requirements for tank level monitoring:

- Tank bump (BIO Sec. 5.3.2.22)
- Subsurface leak resulting in pool (BIO Sec. 5.3.2.19)
- Surface leak resulting in pool (BIO Sec. 5.3.2.18)
- Subsurface leak remaining subsurface (BIO Sec. 5.3.2.7)

The results are:

- **BIO Section 2.1.2, “Safety Significant Structures, Systems, and Components”**

Sec. 2.1.2.6, Tank Level Monitors, “The safety function of level monitors, credited in subsurface leak resulting in pool, surface leak resulting in pool, and subsurface leak remaining subsurface accident analyses, is to indicate the waste level in the tank to support mass balance calculations during waste transfers”.

Sec. 2.1.2.9, Waste Tank Level Monitors, “The safety function credited in the tank bump accident analysis is to indicate the waste level in the tank in support of implementing the tank temperature control ... applies to all DSTs and aging waste facility (AWF) tanks.”

Several Technical Safety Requirements and Administrative Controls rely on tank level monitoring as Safety Significant SSCs. These are:

- LCO 3.3.2, *DST and AWF Tank Waste Temperature Controls*
- Administrative Control/*Transfer Controls*, Section 5.12-2.b
“Monitor for increasing level in all tanks ...during waste transfer”.
- Administrative Control/*Service Water Intrusion Monitoring*, Section 5.21
- Administrative Control/*Tank C-106 Waste Temperature Controls*, Section 5.26; Tank heat load and temperature controls rely on the amount of waste transferred to tank 241-AY-102 (1 ft increments).

It should be noted that tank level monitoring systems are not required to perform any safety function to prevent or mitigate the consequences of a natural phenomena hazard (NPH) such as high wind, earthquake, ash fall, etc. (BIO, Sec. 5.3.2.23); nor are they required to function during or following an earthquake.

1.3.2 ENVIRONMENTAL

Federal regulation 40 CFR 265 applies to tank systems for the storage of hazardous waste. Article 193 states that secondary containment must be provided with a leak detection system, and Article 195 requires daily inspections, data gathering, and monitoring.

State regulation WAC 173-303, Section 400 includes the requirements established by 40 CFR 265 Subpart F to R.

WAC 173-303-640 further states:

“(4) Containment and detection of releases

(c) To meet the requirements of (b) of this sub-section, secondary containment systems must be at a minimum: ...

(iii) Provided with leak-detection system that is designed and operated so that it will detect the failure of either the primary or secondary containment structure or the presence of any release of dangerous or accumulated liquid in the secondary containment system within twenty-four hours, or at the earliest practicable time if the owner or operator can demonstrate to the department that existing detection technologies or site conditions will not allow detection of a release within twenty-four hours... ”

(7) Response to leak or spills and disposition of leaking or unfit-for-use tank systems.

(d) Notifications, reports.

(i) Any release to the environment, except as provided in (d) (ii) of this sub-section, must be reported to the department within twenty-four hours of its detection. Any release above the “reportable quantity” must also be reported to the National Response Center pursuant to 40 CFR Part 302.

(ii) A leak or spill of dangerous waste is exempted from the requirements of (d) of this sub-section if it is:

(A) Less than or equal to the quantity of one pound, or the “reportable quantity (RQ) established in 40 CFR Part 302, whichever is less; and

(B) Immediately contained and cleaned-up.”

DOE Order 5820.2A, *Radioactive Waste Management* contains generic requirements for level monitoring and leak detection for DSTs (Chapter I, Item 3).

2.0 TERMS, DEFINITIONS, AND SYMBOLS

2.1 LIST OF ACRONYMS

ALGI:	Automated Liquid level Gauge Instrument. Includes any level gauges technology based on measuring liquid levels, i.e., does not include liquid-solid interface measuring devices.
BIO:	Basis for Interim Operations
CAM:	Continuous Air Monitor
cm:	Centimeter
DCRT:	Double Containment Receiver Tank
DST:	Double-Shell Tank
F&R:	Functions and Requirements
FSAR:	Final Safety Analysis Report
l:	Liter
LOW:	Liquid Observation Well
m :	Meter
NPH:	Natural Phenomena Hazards
OSD:	Operating Specifications Document
SC:	Safety Class
SEL:	Safety Equipment List
SEMP:	System Engineering Management Plan
SS:	Safety Significant
SSC:	Systems, Structures, and Components
SST:	Single-Shell Tank
TMACS:	Tank Monitor and Control System

TSR: Technical Safety Requirement
TWRS: Tank Waste Remediation System
WAC: Washington State Administrative Code

2.2 LIST OF TERMS

ENRAF: Registered Trademark for Series 854 ATG, Automated Liquid Level Gauges, based on a displacer technology, manufactured by ENRAF-NONIUS.
FIC: Registered Trademark for liquid level gauges based on a conductivity probe technology, manufactured by Food Industries Corporation.

3.0 APPLICABLE DOCUMENTS

3.1 APPLICABLE HANFORD STANDARD DESIGN CRITERIA AND PRACTICES

HNF-PRO-097, *Engineering Design and Evaluation*, Fluor Daniel Hanford, Inc., Richland, Washington.

LMHC-9852008, *Subcontract Number 8023274-9-K001; DOE Order 6430.1A Design Criteria for Safety Class Structures, Systems and Components*, R. E. Raymond, TWRS Technical Operations and Engineering, Lockheed Martin Hanford Corporation, Richland, Washington, 18 March 1998.

WHC-SD-GN-DGS-30011, *Radiological Design Guide*, Westinghouse Hanford Company, Richland, Washington.

3.2 APPLICABLE CONSENSUS CODES AND STANDARDS

ANSI/ASME B16.5, *Pipe Flanges and Flanged Fittings NPS ½ Through NPS 24*, American Society of Mechanical Engineers, New York.

NFPA 70, *National Electrical Code (NEC)*, National Fire Protection Association.

NFPA 780, *Lightning Protection Systems*, National Fire Protection Association.

UBC Zone 2B, *Uniform Building Code*.

3.3 APPLICABLE DOE ORDERS

DOE Order 6430.1A, *General Design Criteria*, U.S. Department of Energy, Washington, D.C.

DOE Order 5820.2A, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

URCL 15673, *Human Factors Design Guidelines for Maintainability of DOE Nuclear Facilities*, Biotechnology, Inc., Falls Church, VA, (funded by DOE, 1985).

3.4 APPLICABLE GOVERNMENT REGULATIONS

40 CFR Part 265, *Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*, Code of Federal Regulations, U.S. Department of Energy, Washington, D.C.

WAC 173-303, 1998, *Washington Dangerous Waste Regulations*, Washington Administrative Code.

3.5 OTHER DOCUMENTS AND INFORMATION

HNF-SD-W211-FDC-001, Rev. 3, *Functional Design Criteria, Project W-211, Initial Tank Retrieval Systems*, Numatec Hanford Corporation, Richland, Washington.

HNF-SD-WM-BIO-001, Rev. 1, *Tank Waste Remediation System Basis for Interim Operation*, Fluor Daniel Hanford, Inc., Richland, Washington.

WHC-SD-WM-TI-634, Rev. 1, *Integrated Beta & Gamma Dose Calculations for Ferrocyanide Waste Tanks*, Westinghouse Hanford Company, Richland, Washington.

HNF-SD-WM-TSR-006, Rev.0, *Tank Waste Remediation System Technical Safety Requirements*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-SD-WM-SEL-040, Rev. 1, *Tank Waste Remediation System Safety Equipment List*, Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-IP-0842, TWRS Administrative Manual, Lockheed Martin Hanford Corporation, Richland, Washington.

Volume II, Section 5.2, Rev.2, *Waste Tank Surveillance Review*.

Volume IV, Section 3.4, Rev.1, *Functional Requirements and Technical Criteria*.

Volume IV, Section 3.12, Rev.1b, *Acceptance of Structures, Systems, and Components For Beneficial Use*.

HNF-2004, Rev.0, *Estimated Dose to In-Tank Equipment Phase 1 Waste Feed Delivery*, Numatec Hanford Corporation, Richland, Washington.

Instruction Manual, ENRAF ATG 854, Version 2.1, December 1992, Part No 4416.220

OSD-T-151-00007, Rev.H-21, 9/29/98, *Operating Specifications for the 241-AN, AP, AW, AY, AZ, and SY Tank Farms*, TWRS Operating Specification Document, Lockheed Martin Hanford Corporation, Richland, Washington.

OSD-T-151-00013, Rev.D-16, 9/16/98, *Operating Specifications for Single-Shell Waste Storage Tanks*, TWRS Operating Specification Document, Lockheed Martin Hanford Corporation, Richland, Washington.

OSD-T-151-00031, Rev.C-0-1, 1/13/99, *Operating Specifications for Tank Farm Leak Detection and Single-Shell Tank Intrusion*, TWRS Operating Specification Document, Lockheed Martin Hanford Corporation, Richland, Washington.

PNNL-11107, *Hanford Site Climatological Data Summary*, Pacific Northwest National Laboratory, Richland, Washington (1995).

SY Tank Farm Compliance Inspection Agreement, 1999.

TO-320-003, Rev. A-4, 8/21/98, *Waste Retrieval Sluicing System Material Balance*, TWRS Operating Specification Document, Lockheed Martin Hanford Corporation, Richland, Washington.

TO-040-180, Rev. D-1, 3/2/99, *Operate Tank Surface Level Monitoring Devices*, TWRS Operating Specification Document, Lockheed Martin Hanford Corporation, Richland, Washington.

WHC-SD-TWR-RPT-002, *Structural Integrity and Potential Failure Modes of the Hanford High-Level Waste Tanks*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-RPT-105, *Selection of ENRAF Gauge Wire Material Compatible with Hanford Waste Tank Environment*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-SEMP-0002, Rev. 1, *Tank Waste Remediation Systems Engineering Management Plan*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-TI-357, Rev. 1k, *Waste Storage Tank & Leak Detection Criteria*, Westinghouse Hanford Company, Richland, Washington.

(Note: This document is provided for historical information only.)

WHC-SD-WM-TI-573, Rev. 1, *Technical Bases for Leak Detection Surveillance of Waste Storage Tanks*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-TI-636, *Waste Storage Tank Level Detection Replacement Final Report*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-TP-267, *Test Plan for ENRAF Series 854 Level Gauge Wire Testing*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-WP-132, Rev. 2, *Tank Farm Instrumentation and Data Acquisition/Management Upgrade Plan*, Westinghouse Hanford Company, Richland, Washington.

4.0 FUNCTIONS AND REQUIREMENTS

4.1 SYSTEM DEFINITION

The system shall be capable of detecting changes, either increases or decreases, of tank waste level, while operating in a hostile environment (i.e., radioactive dose rates, heat, moisture, corrosive environment).

The waste tanks at Hanford require liquid-level monitoring for waste inventory, and to assist in detection of leaks. Globally, a 75-ft (23 m) tank holds approximately 2750 gal (10.4 cubic meters) per inch (2.54 cm) of waste level. The 1.16 million-gallon (4.39 thousand cubic meters) measuring range is about 420 inches (10.7 m)

The level reading is transmitted to the TMACS (HNF-4211, *Functions and Requirements for Tank Monitor and Control System*), located in the control room in building 2750-E, or it is recorded on data sheets for local readings.

4.2 CHARACTERISTICS

4.2.1. PERFORMANCE REQUIREMENTS

4.2.1.1 FUNCTIONS

The basic functions of tank level monitoring are to:

- Detect potential leaks from primary tank confinements in SSTs, and DSTs (DSTs have additional leak detectors and CAM installed in the annulus between the two shells).
- Detect tank overfill, water intrusion, and support mass balance calculations during transfers for all SSTs and DSTs.
- Activate alarms when operating limits are reached or passed.

Accurate and timely liquid level measurements are necessary to meet BIO safety requirements defined in HNF-SD-WM-BIO-001, *Tank Waste Remediation System Basis for Interim Operation* and administrative controls in HNF-SD-WM-TSR-006, Rev.0, *Tank Waste Remediation System Technical Safety Requirement*. Accurate and timely liquid level measurement and reporting are also requirements from the Washington State Administrative Code (WAC) 173-303.

Through remote connection to TMACS, continuous level monitoring can be performed. In addition, correlation of tank surface level with barometric pressures, and temperatures can be performed. Tank level monitoring ensures that all Authorization Basis, environmental, and other applicable regulatory requirements are met.

Structural limitations and tank vapor space pressure (OSD-T-151-00007 and OSD-T-00013) also require waste level to be monitored so that it does not exceed the maximum tank design specifications.

4.2.1.2 PERFORMANCE

The ALGI shall be capable of measuring tank waste level changes with a minimum accuracy (i. e., linearity) of +/- 0.25 inch (0.64 cm), over a full range of waste levels for any installation. The range of the instrument shall include the distance down to the waste level, from the top of the tank riser where the instrument is installed, in addition to a nominal maximum waste level (for a DST) of 420 inches (10.7 m). An accuracy of +/- 0.25 inch (0.64 cm) represents 687.5 gallons (2602.5 l) for a 75-ft (23 m) diameter tank. Table 4.1 shows the different values for accuracy of the level measurements depending on the functions and technical bases.

**Table 4.1
ALGI Accuracy Requirements**

Functions	Required Accuracy	Basis/applicability
Support leak detection during waste transfers	+/- 0.5 in. (± 1.27 cm)	BIO ¹ /SEL, all tanks
Support mass balance calculations during transfers	+/- 0.25 in. (± 0.64 cm)	OSD/TSR, all tanks
Support temperature controls	+/- 2 in. (± 5.08 cm)	TSR/ DST, AWF waste levels > 15 ft (4.57m)/SEL
Primary leak/ intrusion detection	+/- 0.5 in. (± 1.27 cm)	TI-573 SSTs w/ liquid surface
	+/- 1.0 in. (± 2.54 cm)	TI-573 SSTs w/ liquid surface exhibiting seasonal level changes
	+/- 1.0 in. (± 2.54 cm)	TI-573 SSTs w/ floating solids
	+/- 3.0 in. (± 7.62 cm)	TI-573 SSTs w/ solid crust suspended on liquid layer.

¹: See Bases Section 4.2.1.3

The SST waste level monitoring system shall be capable of providing data to the TMACS for alarm capability at or below the specified Operation Limits. It shall be monitored to identify potential intrusion, tank overfilling, provide waste accountability during waste transfers, and detect primary tank leaks. For most SSTs (i.e., tanks with either a liquid or

semi-liquid surface, which varies with liquid level), the ALGI will be the primary tank level detection system.

The DST waste level monitoring system shall be capable of providing data to the TMACS for alarm capability at or below the specified Operation Limits. It shall be monitored to identify tank intrusion, tank overfilling, primary tank leak detection, and provide waste accountability during transfers. The DST leak detection system consists of three conductivity probes in each annulus, with the exception of SY-101 through SY-103, and a primary tank level instrument. The SY farm tanks are scheduled to have two additional conductivity probes installed in each annulus by December 31, 1999, in accordance with the SY Tank Farm Compliance Inspection Settlement Agreement.

In some cases, the system must also be able to measure waste levels accurately under conditions of waste agitation and foaming. This requirement may apply, for instance, where waste transfers occur into a tank at flow rates in excess of 200 gal/min, and where it is not an option to shut down the transfer pump intermittently to allow the waste to settle in order to obtain a level reading. Historically, inaccurate level readings have sometimes been observed in such cases. The requirement to monitor tank waste levels during waste transfers is based on TSR AC 5.12. Conceivably, the special conditions imposed by agitated waste may require a level instrument of a different design for certain tanks that are potentially involved in high-volume waste transfers.

Physical properties of the waste (see also Sec. 4.3.4) shall be considered in the design or selection of a level monitoring system. The system shall measure waste levels accurately over the anticipated range of conditions in the tank waste. Specifically, whatever physical parameters of the waste (e. g., conductivity, buoyancy) are actually sensed to derive a level indication, the system shall be capable of responding over the expected range of those parameters. The system should not provide anomalous readings in response to unusual conditions or local extremes in the waste properties.

In addition, the system shall be able to measure waste levels down to 6 inches or less in the bottom of 241-AN, 241-AP, 241-AW, and 241-SY tanks. A minimum liquid level is defined to provide extra protection against bottom uplifting of the tank's steel liner due to tank vacuum (OSD-T-151-00007, Section 7.2.2).

4.2.1.3 BASES

Bases for the ALGI accuracy values may have several origins:

- Authorization Basis; control of assumptions made in the accident analyses (e. g., maximum source term credited in leaks accident scenarios)
- Environmental regulations and codes
- Operating Specifications and requirements (e. g., tank level measurement accuracy needs to support mass balance calculations during transfers)

The current governing document for leak detection and tank level monitoring for all tanks (DSTs, SSTs, DCRTs, and catch tanks), is WHC-SD-WM-TI-573, *Technical Bases for Leak Detection Surveillance of Waste Storage Tanks*. This document relies on empirical approaches and data, engineering judgement, and best available technology to support the values shown in Table 4-1.

The TWRS Facility Safety Equipment List, HNF-SD-WM-SEL-040, Rev.1, requires tank level systems to measure waste levels with an accuracy of +/- 1.3 cm (+/- 0.5 in).

The WAC 173-303-640, (Ecology, 1990) (7)(d)(ii) states that “a leak or spill... is exempted from the requirements... if it is (A) less than or equal to one pound, or the Reportable Quantity (RQ) established in 40 CFR Part 302, whichever is less; and (B) Immediately contained and cleaned up”.

In terms of level change, the WAC one pound (approx. 1/8 gallon or 0.47 l) requirement results in approximately 0.000045 inches or 0.000011% of the maximum waste level in a DST (420 inches/1067 cm). This precision was shown to be well beyond the capabilities of modern field instrumentation, specifically for million gallon tanks (WHC-SD-WM-TI-636, *Waste Storage Tank Level Detection Replacement Final Report*).

Current operating specifications found in OSD-TI-51-00007, 00031, 00013, and TO-320-003, and TO-040-180 all rely on OSD-TI-573 technical bases and accuracy specifications.

The accuracy requirements that may be derived from the accident analyses in order to protect important assumptions are summarized in Table 4.2.

Table 4.2
ALGI Accuracy Requirements to Protect Accident Analysis Assumptions

Accident	Source Term/Volume of Waste Spilled	Equivalent Level Change for a 75-ft-diameter tank
Subsurface Leak remaining Subsurface (5.3.2.7)	7200 gal (27,255 l), unmitigated	- 2.6 in. (-6.60 cm)
Surface Leak Resulting in Pool (5.3.2.18)	1400 gal (5300 l), w/controls	- 0.5 in. (-1.27 cm)
Subsurface Leak Resulting in Pool (5.3.2.19)	3400 gal (12,870 l), w/controls	- 1.2 in. (-3.05 cm)

The accident scenarios listed above are all assumed to occur during waste transfer activities. The primary leak detection is assured by leak detectors installed either in the transfer pipe encasements, diversion pits, or jumpers pits, etc. The requirement to monitor tank waste levels to support mass balance calculations during waste transfers is based on TSR AC 5.12. In order to be able to measure a 1400-gallon (3,556 l)

discrepancy between the source tank and the receiving tank, ALGIs would need to have an accuracy better than +/- 0.5 inches (1.27 cm), preferably +/- 0.25 inches (0.64 cm).

In conclusion, a +/- 0.25-inch (0.64 cm) sensitivity requirement (to support mass balance calculations and leak detection during waste transfers) is the most stringent requirement among those driven by the Authorization Basis and Operations.

4.3 TECHNICAL DESIGN REQUIREMENTS, CONSTRAINTS, AND CRITERIA

4.3.1 DESIGN CRITERIA RELATED TO SAFETY

4.3.1.1 SAFETY CLASSIFICATION AND PERFORMANCE CATEGORY

Section 1.3 discusses the safety functions for tank level monitoring in SSTs and DSTs. Except for tank 241-SY-101, where tank level monitoring is a Safety Class function associated to flammable gas controls, SSTs and DSTs level monitoring are classified **Safety Significant (SS)**.

These systems shall meet the minimum design criteria documented in DOE 6430.1A for non-safety class systems.

DOE Order 6430.1A, Section 1300-3.2, *Safety Class Items*, states that *“Safety Class and non-safety class items shall comply with Section 0140, Quality Assurance. The design of systems, components and structures that are not safety class items shall, as a minimum, be subject to conventional industrial design standards, codes, and quality standards. Failure of these items shall not adversely affect the environment or the safety and health of the public. In addition, their failure shall not prevent safety class items from performing their functions”*.

HNF-PRO-097, *Engineering Design and Evaluation*, provides the technical requirements for designing engineered safety systems according to their performance category. Tank farms, both SSTs and DSTs are Hazard Category 2 facilities. Tank level monitoring systems were shown to be Safety Significant SSCs in the TWRS BIO because they prevent onsite workers from receiving radiological and toxicological exposure above the evaluation guidelines. As a result, Table 1 of HNF-PRO-97 shows that tank level monitoring systems should be considered Performance Category 2 (PC-2) systems.

4.3.1.2 NATURAL PHENOMENA HAZARDS

Tank level monitoring systems are not required to perform any safety function during or after the occurrence of extreme natural phenomena events (e.g., earthquake, high wind, tornado, snow fall, ash fall, etc). Therefore, as a minimum the UBC Zone 2B natural loads are required to be accounted for the design and installation of tank level monitoring systems.

The above requirement is based on management directive LMHC-9852008, *DOE Order 6430.1A Design Criteria for Safety Class Structures, Systems and Components*, R. E. Raymond, 1998.

4.3.1.3 PROTECTION OF SURROUNDING OR INTERFACING SAFETY SSCs

The 3-over-1 rule should be applied in order to ensure that the failure of the level gauge supports and connections to the tanks do not jeopardize the confinement safety function (leak tightness), as well as the load applied to the tank structure during normal operation conditions. Equipment to be added to the tank shall be verified to not exceed tank dome loading requirements (Section 4.6).

No design or installation requirements are identified relative to earthquake accelerations. No safety related SSCs are identified in the TWRS BIO for the mitigation of the consequences of an earthquake. Mitigation is based on administrative and emergency procedures (i.e., stop waste transfer and tank intrusion activities and evacuate non-essential personnel).

Underground tank structures are classified PC-3 and were verified to resist 0.19g seismic accelerations. The addition of tank level monitoring equipment should be verified to not impair the assumptions made in WHC-SD-TWR-RPT-002, *Structural Integrity and Potential Failure Modes of the Hanford High-Level Waste Tanks*.

4.3.2 EXTERNAL ENVIRONMENTAL CONDITIONS

The following Hanford site conditions are documented in PNNL-11107, *Hanford Site Climatological Data Summary*, 1995.

- **Precipitation:** The system shall operate under the following precipitation conditions:

Annual precipitation range:	8 cm to 30 cm (3.1 in. to 11.8 in.)
24-hour precipitation:	4 cm (1.56 in.)
Annual snowfall:	0.8 cm to 110 cm (0.31 in. to 43.3 in.)
Depth of snow:	62 cm (24.4 in.)
Hail diameter:	10 mm (0.4 in.)

- **Relative humidity:** The system shall operate in humidity ranges between 0% and 100%:

Highest monthly mean relative humidity:	80 %
Lowest monthly mean relative humidity:	32 %
Daily change:	30 %

- **Temperature:** The system shall operate under the following temperatures conditions:

Temperature range: - 33°C to 46°C (-27°F to 115°F)

Rate of increase: 6°C (22°F) in 0.5 hours

- **Sand and Dust:** Design of systems shall consider potential sand/dust concentrations of 0.177-gm/cubic meter with a typical size of 350 micrometers.
- **Solar radiation:** TWRS systems shall be designed to operate at solar radiation levels up to 406 Watts/square meter.

4.3.3 SYSTEM QUALITY FACTORS

4.3.3.1 DESIGN LIFE

Based on the needs of the facility, and the expected length of the TWRS mission, an expected design life of 25 years can be reasonably assumed. This applies to the overall system, not to a limited set of components that may require replacement as part of normal routine maintenance. It is recommended that an alternative generation analysis be performed to document the operation and maintenance concept for the ALGI, which would include validating an acceptable design life.

4.3.3.2 RELIABILITY

- **Separation and Physical Protection:** Given the safety significant function of tank level monitoring, no specific separation or physical protection is required. The bases are that even in the event of failure of the ALGI, other systems could be implemented during the time needed for repair. In addition, a failure of ALGI will not result in any significant radiological or toxicological release that could affect the worker, or public health and safety, or the environment.
- **Single Failure Criteria and Redundancy:** This is not applicable to most level instruments as they are Safety Significant, not Safety Class, SSCs. Redundant ENRAF® gauges are installed in Tank 241-SY-101, the only location where waste level monitoring is credited with a Safety Class function (i. e., related to flammable gas), to satisfy the single failure criterion.

4.3.3.3 MAINTENANCE

Each design shall provide for routine maintenance, repair, or replacement of equipment subject to failure. Safety significant items shall be designed to allow inspection, maintenance, and testing to ensure their continued functioning, readiness for operation, and accuracy. Ancillary equipment shall be located in an area least likely to be contaminated. The capability shall be provided for the maintenance of contaminated

equipment that cannot be repaired in place. This capability shall include the necessary provisions for confinement, ventilation, and waste control.

ALGIs using displacer technologies should account for the potential of build-up of salts and crystals on the displacer contacting the waste. This accumulation of weight may impair the reading. Periodic weighing of the displacer and adjusting for an added weight will need to be made possible in order to return the reading to its proper value. Periodic clean up of the displacer and its wire shall also be incorporated in the design (WHC-SD-WM-WP-132, Rev.2, *Tank Farm Instrumentation and Data Acquisition/Management Upgrade Plan*).

Administrative Control AC 5.19, *Process Instrumentation and Measuring and Test Equipment*, requires a program to be maintained to identify and programmatically control process instrumentation and measuring and test equipment used to verify process parameters (e.g., level, temperature, flammable gas concentrations) to comply with the TSRs.

The TWRS Facility Safety Equipment List (SEL-040) further specifies that tank level detection systems shall be calibrated annually to ensure compliance with the functional requirements stated in section 6.6.1 of the SEL, *Tank Level Detection Systems*.

Operations feedback and experience call for functional tests and calibration to be performed at least every six months. The six month schedule is based on the fact that the level gauges operate in a hostile tank environment (Section 4.3.4). Frequency may differ on some tanks. More frequent maintenance intervals may be justified, for example, for instruments located in high-heat tanks. Current maintenance practices are discussed in Section 7.1. Below are listed potential issues related to tank level instrument that could be used to develop a maintenance strategy for these systems:

- Build up of waste on the displacer or wire, thereby increasing its weight and volume (for level gauges using a displacer).
- Portions of the gauge located inside the tank can corrode.
- Material can crack (especially true for displacers).
- The gauge (probe or displacer) can stick to the waste.
- Electronic compounds may have limited life duration when exposed to high level of radiation.

Testing: Designs shall include provisions for periodic testing monitoring, surveillance, and alarm systems.

Maintainability: The design of equipment shall incorporate the objective of efficient maintainability. The surveillance, testing, and maintenance of a system and its restoration to operational effectiveness, shall be achieved at a minimum life-cycle cost with a minimum level of support services. The UCRL 15673, *Human Factors Design Guidelines for Maintainability of DOE Nuclear Facilities*, shall be considered for system design.

Fault Detection/Fault Isolation: Designs shall provide for the detection and isolation of faults to systems, structures, and components as necessary in order to minimize the risks associated with faulty operation to plant, personnel, and environment. Protection systems and associated instrumentation controls shall be designed in accordance with DOE 6430.1A, *General Design Criteria*, Section 1660-99.0.2.

Calibration: Systems shall be designed to allow periodic calibration. Calibration cycles shall be in accordance with manufacturer's instruction, and maintenance strategy.

4.3.4 TANKS INTERNAL ENVIRONMENT

4.3.4.1 EXPLOSIVE GAS ENVIRONMENT

Detailed requirements can be found in *Flammable Gas-Administrative Control/Ignition Controls*, Section 5.10. See Table 5.10-1 of the TSRs for detailed requirements and applicability depending on Facility Group and nature of activity.

4.3.4.2 HIGH HEAT

Decay heat of the waste stored in SSTs and DSTs vary depending on each tank. Tank waste temperature is maintained below 195°F (90.6°C) in the top 15 ft (4.57 m) per LCO 3.2.2.

Waste temperature shall not exceed 250°F (121°C)-safety limit (SL 2.1.1, *Waste Temperature*).

Project W-211, Initial Tank Retrieval System (HNF-SD-W211-FDC-001) assumes a tank vapor space temperature range from 50°F to 200°F (10°C to 93.4°C).

4.3.4.3 PRESSURE

Waste tanks, specifically DSTs are maintained at negative pressure compared to the atmosphere for confinement reasons by the primary ventilation systems. Tank dome spaces are maintained between 0.06 to 1.49 kPa (0.25 to 6.0 inches of water gauge) of vacuum (SEL Section 6.1.3, DST/AWF Ventilation).

Single-shell tanks that are not actively ventilated are subject to atmospheric pressure changes. The greatest monthly range is 2.14 inches (5.41 cm) of Mercury (29 inches of Water/73.66 cm) (Section 4.3.2).

4.3.4.4 CHEMICAL AND CORROSIVE ENVIRONMENT

Waste solutions range from pH 7 to pH 13+.

4.3.4.5 ELECTROMAGNETIC RADIATION

The maximum radiation dose rate calculated for Ferrocyanide waste SSTs (WHC-SD-WM-TI-634, Rev. 1) was 3.79+/-0.19 Gy/h (379 Rad/h) at the bottom of tank 241-BY-106 and 2.10 +/-0.19 Gy/h (210 Rad/h) at the waste surface for tanks 241-U-103 and 241-A-101. The design criteria used for project W-211, Initial Tank Retrieval System (HNF-SD-W211-FDC-001), is 5 Gy/h (500 Rad/h).

HNF-2004, *Estimated Dose To In-Tank Equipment Phase 1 Waste Feed Delivery*, provides the estimated dose rate in DSTs. The results are summarized in Table 4.3, below.

Aging and potential failure of the electronic equipment as a result of radiation exposure should be analyzed.

Table 4.3
Radiation Dose Rates in DSTs

Tank	Peak Dose Rate rad/h (calculations)
241-AN-102	150
241-AN-103	260
241-AN-104	350
241-AN-105	200
241-AN-106	140
241-AN-107	170
241-AW-101	350
241-SY-101	130
241-SY-102	80
241-SY-103	130
241-AP-102	340
241-AP-104	340
241-AY-101	1100
241-AY-102	10
241-AZ-101	1000*
241-AZ-102	580

*10,000 rad/hr measured

4.3.4.6 VIBRATION

For ALGIs to be installed on tanks that bear rotating equipment (e.g., pumps, mixer pumps), impact of vibrations resulting from the operation of such equipment needs to be analyzed.

4.4 MATERIALS

The system, subsystems, and equipment shall comply with the corrosion prevention and control requirements of DOE Order 6430.1A, Section 0262, *Corrosion Control*.

4.5 MECHANICAL ENGINEERING

The level gauge shall mount on the tank riser by means of a standard 4 inch, Class 150, raised face pipe flange per ANSI/ASME B16.5. For larger tank risers, the facility has adapter spools available to provide a 4-inch flange interface for the level gauge.

Section 4.3.1.2 discusses the requirements for NPH loads to be credited to the design.

The following discusses the current approaches implemented for historical information. The level gauge installation and associated electrical cabinet stand are structurally bounded by the following analyses. Calculated safety margins are based on component stresses or overturning resulting from design basis natural phenomena hazard loads; please refer to Table 4.4.

The safety function of the primary waste tank structure is not defined in the current authorization basis (BIO, Sec. 2.1) and has been deferred until issuance of a TWRS Final Safety Analysis Report (FSAR). A reasonably conservative approach to installations of riser-mounted equipment is to regard the tank and risers as a Safety Class (SC) or Performance Category '3' (PC-3) structure, and to analyze stresses induced in tank riser based on SC loads acting on supported equipment in their zone of influence, regardless of the actual safety class of the equipment in question (i.e., by using the 3-over-1 approach).

This analysis must be based on the loading (e. g., seismic acceleration) values defined for the SC riser but may use the methodology appropriate to the lower safety class of the equipment (HNF-PRO-97). This implies that a simplified dynamic analysis, or even a static analysis based on peak acceleration values, may be used in such evaluations where appropriate to the structural complexity of the system.

Seismic loads were shown to govern design in the case of level gauge assemblies, due to their high ratio of weight to surface area. Stresses induced in the tank riser by NPH loads acting on this equipment were addressed. The analyses looked at typical liquid level installations, consisting of an assembly that includes a full-port ball valve and sight glass in addition to the level gauge itself. The referenced calculations were based on the SC-2 and SC-3 load criteria in use at the time for these systems, which are similar to the current Performance Category '2' (PC-2). The difference in peak seismic acceleration values between PC-3 and PC-2 is on the order of 2:1.

However, as Table 4.4 shows, relatively large safety margins were calculated for stresses induced in the 4-inch tank riser by NPH loads acting on this riser-mounted equipment.

The liquid level assembly can be characterized as a rigid, lumped mass, which is bolted to the riser to form a simple system with a cantilever beam response mode when seismically accelerated. A dynamic analysis is not necessary in such cases. Therefore, the existing calculations and resulting large safety margins may be regarded as bounding for the tank riser when used as physical support for the liquid level gauges assemblies.

Electrical cabinets associated with the liquid level gauge are supported on a bolted steel framework, mounted to a heavy concrete base which rests on grade or is partially buried. The connections between the liquid level gauge and the electrical cabinet are flexible. The cabinet stands were also analyzed to SC-2 load criteria in use at the time (Table 4.4). Both structural stresses in the support frame and overturning of the cabinet and support assembly was considered. In these cases, the equipment is relatively lightweight for its size and wind loads acting on its centroid area were shown to govern the design. As shown in Table 4.4, the safety margins are adequate for this equipment but are typically smaller than those calculated for the liquid level gauge riser mounting. However, in these cases the failure or overturning of a cabinet stand is unlikely to directly impact the tank riser and can be considered as outside its zone of influence.

Table 4.4

EQUIPMENT DESCRIPTION	REFERENCE DOCUMENT	EQUIPMENT WEIGHT, LB	RISER DIAM, IN.	RISER/CA HEIGHT, IN.	SAFETY MARGIN		NPH CRITERIA USED
					S*	OT*	
RISER-MOUNTED EQUIPMENT							
AN-107 ENRAF Densitometer Assembly (incl. flanges and ball valve)	WHC-SD-WM-DA-188	270	4	15 (riser flange)	11:1	N/A	SC-3 per SDC-4.1; Seismic
ENRAF Level Gauge Assembly (incl. flanges and ball valve)	WHC-SD-WM-ANAL-028	302	4	24 (riser flange)	36:1	N/A	SC-2 per SDC-4.1; Seismic
ELECTRICAL CABINET SUPPORTS							
Bracket Assembly for Level Gauge Elec. Cabinets, Project W-320 (not incl. concrete base)	HNF-1880	160	N/A	35 (CA)	4.0:1	N/A	SC-2 per GC-LOAD-1 Wind
Level Gauge Elec. Cabinet Supports (not incl. concrete base)	WHC-SD-WM-DA-188	101	N/A	30 (CA)	N/A	1.8:1	SC-3 per SDC-4.1; Wind
Level Gauge Elec. Cabinet Supports	WHC-SD-WM-DA-144	127	N/A	36 (CA)	6.5:1	1.0:1	SC-2 per SDC-4.1; Wind
TMACS and Elec. Box Support (not incl. concrete base)	WHC-SD-WM-DR-010	120	N/A	54 (CA)	1.5:1	1.4:1	SC-2 per SDC-4.1; Wind

CA = Centroid Area

S* = Stresses

OT* = Overturning

4.7 ELECTRICAL, INSTRUMENTATION, AND CONTROLS

The tank farms' electrical distribution systems shall provide power for the operation of the level gauges. No emergency or standby power is required. The electrical power supply systems are classified SS (see HNF-SD-WM-SEL-040).

In those cases where existing manual tapes are being replaced with automated level gauges, the potential need for a backup power source for the level gauge shall be addressed. The manual tape operates without requiring facility power, and in some cases is considered by Operations to be an alternative means of level monitoring that is necessary to meet the intent of WAC 173-303 and other regulations. These include requirements both for detecting leaks and reporting them within 24 hours. However, tank level measurements and waste transfers can be scheduled according to planned electrical outages. Site operating history indicates that unplanned outages are an infrequent occurrence, and there is little likelihood of an electrical outage approaching 24 hours duration.

In addition, as discussed in Sec. 4.2.1.3 above, the level of accuracy necessary to detect a reportable leak (i. e., in excess of one pound) is well beyond the capabilities of any modern field instrumentation for use in large tanks. This includes both manual tapes and more advanced automated level gauges; these technologies are only capable of detecting accidents or leaks on a much larger scale, as needed to defend safety analysis assumptions in the Authorization Basis.

Therefore, it is recommended that an engineering analysis be performed to determine what basis exists, if any, for requiring the system to provide level indication during electrical outages, and what design approach would be most effective for satisfying such a requirement. This analysis should be based on a review of regulatory drivers and other requirements applicable to tank leak detection and reporting, as well as the availability and sensitivity of alternative tank leak detection methods. Finally, it should present a comparison of options for providing level monitoring during unplanned electrical outages, including a "no-action" alternative, maintaining a manual tape backup instrument, providing means of operating individual ALGIs using portable power supplies, or providing uninterruptable power sources in each facility.

4.8 INDUSTRIAL AND OCCUPATIONAL SAFETY

This F&R document describes a system rather than an activity. Industrial and occupational safety provisions will be addressed in specific project's documentation or facility manuals and procedures.

4.9 RADIATION AND NUCLEAR CONTROL

This F&R document describes a system rather than an activity. Radiation and Nuclear Control provisions will be addressed in specific project's documentation or facility manuals and procedures.

The system shall comply with the radiological design criteria provided in WHC-SD-GN-DGS-30011, *Radiological Design Guide*.

4.10 HUMAN ENGINEERING

Design and installation of ALGIs will apply the provisions of DOE 6430.1A, Section 1200-12, *Human factors Engineering*, as applicable.

4.10.1 PERSONNEL AND TRAINING

System, subsystem, and equipment shall be designed for operation by personnel trained and qualified in the requirements of DOE Order 5480.20A, *Personnel Selection, Qualification and Training Requirements for DOE Nuclear Facilities*.

4.11 PROJECT RELATIONSHIPS-OPERATIONS

Operation requirements and practices (methods, location, action criteria, monitoring frequency, operational tank levels limits) are documented in WHC-SD-WM-TI-357, Rev.1k, *Waste Storage Tank and Leak Detection Criteria*.

HNF-IP-0842, Volume II, Section 5.2, *Waste Tank Surveillance and Review* (April 24, 1997), provides instructions for liquid level monitoring

Operating Specifications are OSD-T-151-00007 for DSTs and OSD-T-151-00013 and 00031 for SSTs.

4.12 QUALIFICATION

The system shall include provisions for periodic testing of monitoring, surveillance, and alarm systems.

5.0 QUALITY ASSURANCE

Quality assurance (QA) provisions (inspections, responsibilities, tests and examinations, etc.) are either specified in specific projects management plans or in facility-specific manuals or procedures.

The liquid level gauges must be provided as SS equipment with appropriate documentation. Gauges must be certified by the manufacturer and acceptance tested before installation in the field. Maintenance, part replacements, or modifications are also performed in accordance with appropriate QA requirements.

6.0 TURNOVER

Dispositions for turnover are addressed in specific project management plans. Turnover of ALGIs is accomplished in accordance with the requirements outlined in HNF-IP-0842, Volume IV, Section 3.12, *Acceptance of Structures, Systems, and Components For Beneficial Use*. The ALGIs to date have typically been accepted using the J-6 Modification Impact Review form (BD-6000-195) in the Work Control System work package.

7.0 APPENDIX - ENRAF CHARACTERISTICS

7.1 PERFORMANCE CHARACTERISTICS

Procedure WHC-SD-WM-TI-636, *Waste Storage Tank Level Detection Replacement Final Report*, concludes, after having tested several technology available on the market, that the ENRAF® Series 854 level gauge is a suitable replacement for the FIC® gauges.

According to the Instruction Manual, ENRAF® ATG 854 gauges have the following performance characteristics for local display:

- Accuracy (level): +/- 1 mm (0.04 in)
- Sensitivity: +/- 0.1 mm (0.004 in)
- Repeatability: 0.1 mm (0.004 in)

A remote capability is built into the gauge: digital or analog. The analog output (4-20mA) is easiest to implement since it is a standard signal, which will interface with any data acquisition system such as TMACS.

Testing results of the ENRAF® gauge are documented in WHC-SD-WM-TI-636, *Waste Tank Level Detection Replacement Final Report*. In the digital output mode the remote reading will always be identical to the local display and continue to be +/-0.04 inches specified by the manufacturer. However, additional software and hardware are required. In the analog output mode, the span of operation must be restricted if the remote display needs to read identical to the to the local display. This is caused when the ENRAF® converts the numeric value to digital, and when the TMACS converts the numeric value back to digital. These errors are due to such things as non-linearity and anticipated temperature drift of electronic signals.

The ENRAF® analog output has a specified maximum error over the full operating temperature range of +/- 0.15% of span, and the Acromag analog input has a specified maximum error over the full temperature range of +/- 0.06% of span. If the two errors are in the same direction, then the worse case combination is about +/- 0.2% of span. If the range 0-400 inches is chosen, the worse case error would be $0.002 \times 400 = 0.8$ inches. Thus the TMACS reading could disagree with the local display by as much as +/- 0.8 inches.

The analog output span should be limited to about 50 inches ($0.002 \times 50 = 0.1$ in) to obtain a high certainty that the TMACS reading will agree with the field reading to within +/- 0.1 in.

Active waste tanks may require being able to read the entire operating range on TMACS and have a high accuracy also. This can be done with the digital communications interface to TMACS (WHC-SD-WM-TI-636, page 22).

Accuracy tests between the gauge readings and the Acromag readings were performed using different ENRAF® span settings. The accuracy was show to be well within the 0.2% worse case.

Current functional testing and calibration of level gauges is performed in accordance with plant procedures, 6-TF-300, *ENRAF Series 854 Displacer Weight Check and Calibration Check*, and 6-TF-125, *ENRAF Series 854 Maintenance and Calibration*.

Regarding maintenance of the ENRAF gauges, feedback to date from Operations shows:

- 3-4 Infrared Connectors have been replaced.
- 2 displays have been replaced.
- 1 force transducer has been replaced.
- Entire gauge has been replaced: AZ-101 two times, T-107, once.

7.2 PRINCIPLE OF LEVEL MEASUREMENT

For the ENRAF® technology and method, the principle is based on the detection of variation in the buoyancy of a displacer. The displacer is suspended from a strong, flexible wire, which is stored on a precisely grooved measuring drum. The shaft of the drum is connected to the stepping motor via magnetic coupling.

The actual weight of the displacer in air is known by the system. The apparent weight of the displacer is measured by a force transducer. The displacer is lowered periodically. When it contacts the liquid for which the level is to be measured, the transducer detects the displacer's apparent weight change. The actual output value of the force transducer is compared with a desired value for the apparent weight of the displacer (e.g., apparent weight of the displacer when it rests at the surface of the liquid to be measured). If a discrepancy exists between measured and desired value, an advantage software control module adjusts the position of the stepper motor until the desired value is obtained.

7.3 COMPONENTS

See Instruction Manual ENRAF® 854 ATG, Version 2.1, December 1992, Part No. 4416.220 (See WHC-SD-WM-TI-636 for detailed features).

- **Displacer:** The displacer shape, weight, and construction material must be compatible with the waste for which the level is being measured. The basic requirements for displacer selection relate to:
 - The potential for crystal buildup on the displacer which would modify its apparent weight.
 - The potential for a large bottom surface area of the displacer to become stuck in sludge.
 - The need for the displacer material to be compatible with the corrosive, high heat, and dose rate environment in the tank.

- The need for the displacer to be lowered and lifted in the tank riser without any risk of locking inside the riser.
- **Wire:** 0.007-inch diameter strong flexible wire.
- **Stepping Motor:** Turns one revolution for every 10 mm of vertical movement of the displacer. One revolution is divided into 200 steps; therefore, one step is equivalent to 0.05 mm.
- **Measure Processing Unit (MPU):** Digital or 4-20 MA analog output
- **Grounding:** 4 mm stranded copper wire.
- **Power Supply:** 110, 130, 220, 240 VAC
Power rating: 65 VA at 50 Hz
- **Operating Temperature Range:** ENRAF[®] are designed to operate within – 40°C and 80°C (- 40°F and 176 °F).

7.4 LESSONS LEARNED

The measuring wire, initially made of stainless steel, experienced corrosion due to the presence of chloride ions resulting from the radiation breakdown of PVC coating in the riser. A pt-20%Ir alloy is now used for the wire in order to prevent such a risk. Basis for this choice is documented in WHC-SD-WM-TP-267, *Test Plan for ENRAF[®] Series 854 Level Gauge Wire Testing*, G. A. Barnes 9/14/94, and WHC-SD-WM-RPT-105, *Selection of ENRAF[®] Gauge Wire Material Compatible with Hanford Waste Tank Environment*.

