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# Review of Recent Safety Programs at the Hanford Site for New In-tank Equipment

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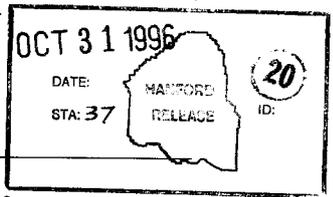
Abstract: The general safety criteria are reviewed; examples of several different safety programs are illustrated; cost and schedule information are presented; and outlines of general safety considerations and specific safety design requirements and solutions are listed. A suggested program approach is covered in some detail.

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**Revision 0**

**Review of Recent Safety Programs at  
the Hanford Site for New In-tank Equipment**

FOR TASK ORDER # 34 OF WHC CONTRACT MW6-SLB-370248

October 1996

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**Abbreviations and Acronyms**

DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
NEC	National Electrical Code
NFPA	National Fire Protection Association
SAR	Safety Assessment Report
TWRS	Tank Waste Remediation System

**Review of Recent Safety Programs at  
the Hanford Site for New In-tank Equipment**

**1.0 SCOPE**

This paper documents experience gained in the safety aspects of recent new equipment designs for the Hanford Site tank farms. The general safety criteria are reviewed; examples of several different safety programs are illustrated; cost and schedule information are presented; and outlines of general safety considerations and specific recent safety design solutions are listed. A suggested program approach is covered in some detail. The information in this document covers safety programs conducted from 1994 to 1996. Specific procedures are continually evolving and the latest safety procedures must be followed.

**2.0 INTRODUCTION**

Safety Assessments (SA) done for new equipment are performed to assure that tank operation will still be within acceptable safety limits. An assessment is only done after it is determined that the new equipment does not fall within the existing Safety Basis. The analysis can take many forms from a preliminary hazards analysis to a full Safety Assessment Report (SAR) involving detailed engineering and mathematical analysis of accident consequences, Figure 2-1. The SAR becomes part of the Authorization Basis for the equipment before it is approved for use in the field. Ultimately the safety assessment must have the concurrence of the U.S. Department of Energy (DOE).

The key to an effective safety effort is to have it done as a concurrent engineering effort, started early in the project, and have the personnel responsible for the safety work integrated, co-located members of the design team.

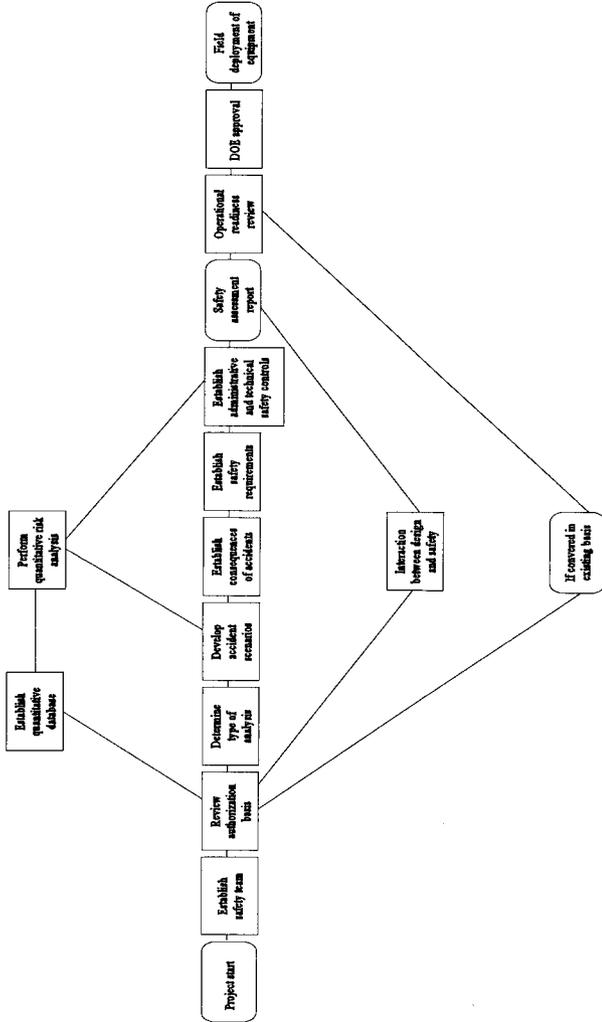
**2.1 SAFETY REQUIREMENTS**

The general requirements for safety are defined by:

- DOE Safety Criteria
- WHC General Safety Criteria
- Safety Criteria for Tanks on the Flammable Gas Watch List
- Safety Criteria for Tanks on the Organic Watch List.

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Figure 2-1. Typical Safety Task in Support of a New Equipment Development Project.



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The principle concerns of the safety program are:

- Flammable or toxic gases evolving from the wastes that either explode, burn or escape from the tanks creating the possibility of personnel injury and the release of toxic or radioactive materials to the atmosphere.
- Radiation exposures including criticality accidents or direct exposure of personnel to high levels of waste radiation.

**Note:** Flammable gas problems are handled in accordance with established National Fire Protection Association (NFPA) and National Electrical Code (NEC) requirements.

See Appendix A for details of safety requirements.

## **2.2 SAFETY ASSESSMENT REQUIREMENTS**

Any safety analysis must be conducted in compliance with the procedures found in WHC (1996). Specifically, procedure SMS-10, Rev 0, entitled "*Authorization Basis Amendments and Annual Updates*", found in Engineering, Volume IV, provides an excellent roadmap into fulfilling the safety related requirements that will be required to conduct the activities described in this document.

Safety Assessments should be prepared using the "Interim Guidance for Preparing Safety Assessments" (DOE 1994). The contents of this document address the elements required in "Guidance for Preparation and Submittal of Basis for Interim Operation for DOE Nonreactor Nuclear Facilities" (WHC 1995).

Hazards analysis should use the guidance in Chapter 2 of "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports" (WHC 1992).

## **2.3 REGULATORY ISSUES**

Overall Hanford Site hazardous wastes are regulated by the following:

- The Atomic Energy Act of 1954 and DOE orders and regulations that describe how the radioactive materials are controlled.
- The Resources Conservation and Recovery Act of 1976; the regulations of the U.S. Environmental Protection Agency (EPA) and the State of Washington that describe how the hazardous waste components are controlled.

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Unfortunately the Hanford Site waste problem is complex and presents a definitive conflict of regulatory regimes. From a safety prospective, if the environment is adequately protected from radioactive wastes, this should also protect it from the chemical wastes. From a probabilistic risk standpoint, the mixed wastes should be judged from a worse case regulatory standpoint, i.e. the most stringent requirement, radioactive or chemical, should be used to make quantifiable judgments.

### 3.0 BACKGROUND

#### 3.1 RECENT PROGRAM HISTORY

Recent programs surveyed have used a variety of approaches to the safety process. The approach has depended on the type and complexity of the equipment involved, the tank environment expected, and the perceived risk of the operation.

The initial step in a safety program is to determine if the new equipment fits into the operational safety basis envelope of the facility or operation for which the equipment is being designed. If the equipment does fit in the safety basis previously established, there will not be a requirement for a new safety assessment.

Many of the analyses have used major parts of previous SA's. The assessments vary from preliminary hazards analysis coupled with hazardous operations analysis, to full SARs, with complex probabilistic risk analysis.

The work has been done by in-house groups including both the design engineering groups and safety groups, as well as outside agencies and subcontractors.

The time required for the analyses has varied from five months to 12 months, with an additional two to three months generally required for DOE sign-off.

The costs of the assessments vary widely and are difficult to sort out from other costs. The range of the costs would seem to be from \$100,000 to \$2M, varying primarily on the complexity of the equipment (how many components) being analyzed, whether the equipment comes into direct contact with the waste, and whether it is being used in a flammable gas tank. The cost of assessment for a facility or very large system can be higher.

The most effective projects have had the safety people on board the project team early on and have had them involved as part of the decision making process during design. The least effective projects have not involved safety until the systems were being built or where the equipment was pre-existing. The second situation has led to the use of operational controls to preclude major hardware design changes and has tended to create a negative relationship between the safety and hardware personnel. Concurrent engineering is the key to good safety related design and operational implementation.

### **3.2 COMPONENTS OF A SAFETY ASSESSMENT**

A safety assessment will aid in the following:

- Identify potential hazards in the tanks including installation, operation, and removal.
- Detail the equipment design.
- Define hazards, causes, and potential accident scenarios and their severity.
- Establish a quantitative database.
- Perform quantitative risk analysis to assess hazards.
- Establish consequence of accidents.
- Define design changes and establish administrative and technical safety controls to mitigate the consequences.

The tables of contents for three safety-related documents are found in Appendix B.

### **3.3 DESIGN FOR SAFETY**

The design of equipment to be used in the tanks needs to take into account:

- Operational interfaces with the tanks and the tank worker to meet all safety, shielding and environmental requirements.
- Explosion proofing against flammable gas hazards (Class I, Division 1).
- Materials selection to cope with caustic chemical and radiation degradation in the tanks.
- Safety/hazards analyses to meet DOE, EPA, Defense Nuclear Facilities Safety Board and State of WA requirements.
- Reliability and maintainability of the equipment to meet availability and decontamination requirements in a hostile environment (in and out of the tanks).

Specific equipment safety class designations and engineering notes for specific safety design features are covered in Appendix C.

#### 4.0 SUGGESTED APPROACH

A good rule of thumb to use on a relatively straightforward device going into a flammable gas tank is that the safety assessment should be achievable in the same time frame that it would take to design and build the equipment. This assumes that the safety assessment is done concurrently with the design process, starting no later than the inception of the preliminary design (layout) process, six to nine months.

The project safety costs should be a few hundred thousand dollars (\$200,000 to \$500,000) based on having a closely coordinated effort with at least one member of the safety assessment effort collocated with the design team. The cost of a safety assessment for a system for a non-flammable gas tank should be a fraction of this cost.

While the ideal situation would be to do the work entirely in-house, it may not always be practical to do so with the available resources. Several outside organizations have shown themselves very capable of doing the analysis work especially the calculation work and also presenting the work to the end point customer, DOE, or the Defense Nuclear Facility Safety Board. However, it is essential that the work be lead by the Hanford Site and that the project and technical direction come from the people on the project team responsible to assure that the final product meets the project requirements and is coordinated with the actual field operation.

The importance of the integrated team and a good flow of information in both directions can not be over emphasized. Where personnel have had close interactions with frequent face-to-face meetings, even when the personnel are not located on the same site, the results of the efforts have been much better with shorter schedules, less design and safety assessment changes, and lower costs. The concept of collocating the team so that communication can be more frequent and relationships can be better developed will optimize both cost and schedule.

There is also a need to establish an adjudicator within the project group to resolve differences between the design and safety people when they occur. Rapid solution of design issues is necessary to keep the project moving forward and to prevent changes at a later date. Unresolved Safety Questions dealing with the tanks in question must be addressed early in the process. Quantitative databases need to be established early.

The new TWRS "Basis for Interim Operations" Facility Safety Analysis Report currently being developed should provide additional guidance for the identification of hazards relevant to new equipment going into the tanks and will provide specific controls to be implemented to mitigate the above hazards. This information will be very useful to any group designing new in-tank equipment and will help in the identification of additional safety feature costs to be incurred in the development of new equipment. It can also be used by the Source Evaluation Board as an additional factor (the cost of hazards control and mitigation) in evaluating vendor bids with different in-tank equipment design features. This report needs to be supplied to all in-house design groups as well as to outside vendors bidding on new equipment.

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**5.0 REFERENCES**

- DOE, 1994, *Interim Guidance for DOE 5480.22 (TSR) and DOE 5480.23 (SAR) Implementation Plans*, DOE Standard 3011-94, U.S. Department of Energy, Washington, D.C.
- WHC, 1992, *Safety Analysis and Engineering Manual: Work Procedures*, "Interim Guidance for Preparing Safety Assessments," WHC-CM-6-32, Rev. 1, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1995, *Safety Analysis Manual*, WHC-CM-4-46, Rev. 4, (Defines safety analysis requirement for all of the Hanford Site), Westinghouse Hanford Company, Richland, Washington.
- WHC, 1996, *TWRS Administration Manual*, WHC-IP-0842, Rev. 0, (Further defines safety requirements specific to Hanford tank farms), Westinghouse Hanford Company, Richland, Washington.

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**APPENDIX A**  
**SAFETY REQUIREMENTS FOR**  
**IN-TANK EQUIPMENT**

(Requirements circa 1995/1996)

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**APPENDIX A**  
**SAFETY REQUIREMENTS FOR**  
**IN-TANK EQUIPMENT**  
(Requirements circa 1995/1996)

**A1.0 General Safety Requirements**

- Equipment used in-tank should be decontaminated to acceptable levels after use and stored for safe keeping. This decontamination is to occur prior to removal of the hardware from the tank, if possible.
- The in-tank equipment shall meet all safety, shielding and environmental requirements for attachment to tank risers.
- Radiation dose to workers should be minimized and in compliance with the WHC Radiological Control Manual.
- The all in-tank equipment should comply with all safety assessment requirements and shall incorporate Operations' comments unless agreement is reached to do otherwise.

For waste tank where the in-tank atmosphere contains flammable constituents, the environment inside the tank, above the convective layer constitutes, a Class 1, Division 1 Hazardous Location. Where the flammable gas is primarily hydrogen, it is designated as a Group B location. Consequently, electrical equipment and devices used in these areas which are directly exposed to the tank atmosphere during normal operation, as well as any other devices connected or coupled to the same wiring, must conform to the NFPA and NEC requirements for service in Class 1, Division 1, Group B hazardous locations.

**A2.0 Structural Compliance**

Equipment attached to the tanks needs to be analyzed for various design loadings, including seismic effects to the risers, and a design analysis report issued. Issues to be addressed include impact loading on the riser.

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**A3.0 NEC Requirements**

In-tank containment for hazardous tanks should adhere to NEC Class 1, Division 1, Group B, Hazardous Location Requirements. These requirements are defined in UL-1203. The in-tank protective package should conform to structural requirements but may not have to be proof tested, unless tanks with an actual Division 1 classification must be tested.

Static electricity discharge prevention practices (applicable NFPA standards and guideline) should be employed in the design of in-tank systems. All equipment needs to be electrically bonded. Cables, which have plastic jackets that roll over pulleys or other static charge inducing configurations, need to have a semi-conductive jacket to drain or dissipate the static charge. The maximum resistance to ground for semi-conductive plastic will be less than one mega-ohm. The resistance value of one mega-ohm will dissipate static charge to prevent a static discharge. All equipment must be bonded to a riser for field service.

**APPENDIX B**  
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**APPENDIX B**  
**TABLES OF CONTENTS FROM**  
**SAFETY-RELATED DOCUMENTS**

This appendix consists of the table of contents from the following documents:

- WHC-SD-WM-HIE-006, Rev. 0, B. D. Board, "Hazards and Operability Study for the Surface Moisture Monitoring System," April 1996.
- WHC-SD-WM-SAD-033, Rev. 2, J. W. Lentsch, "A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101," June 1996.

**Note:** This document also contains the Safety Assessment for the Void Fraction and Viscometer Instruments, Addendum 1 & 2.

- WHC-SD-WM-SAD-035, Rev. 0-A, J. W. Lentsch, "Safety Assessment for Rotary Core Mode Sampling Operations in Single-shell Tanks that are on the Flammable Gas Watch List," September 1996.

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**LIST OF TERMS**

EMI	electromagnetic inductance
HAZOP	Hazards and Operability
PCB	Polychlorinated biphenyl
smms	Surface Moisture Measurement System

**APPENDIX C**  
**SPECIFIC DESIGN FEATURES**

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**APPENDIX C**  
**SPECIFIC DESIGN FEATURES**

**C1.0 SAFETY CLASSIFICATION (circa 1996)**

The Hanford Site requirements for safety classification have recently evolved slightly from the previous criteria as follows:

Safety Class 1 Equipment, which is equipment in an area where problems could create a catastrophic event, such as radioactive material that could get off the site, is now being described as "Safety Class" equipment.

Safety Class 2 and 3 Equipment, equipment in an area where problems could create a containable release, are being described as "Safety Significant" equipment.

**C2.0 ENGINEERING NOTES ON SAFETY DESIGN FEATURES  
TO BE USED IN THE TANKS**

These safety features were designed using safety requirements in force in 1994.

**C2.1 PRESSURE SWITCHES FOR ELECTRICAL ENCLOSURES**

Pressure switches can be used to de-energize non-qualified electrical components at the top of the riser when a tank has a positive pressurization. The area immediately adjacent to the primary enclosure (the top hole instrument enclosure) may become NFPA Class 1, Division 2, Group B during a tank pressurization. This area may have non-qualified equipment present. Thus, the non-qualified equipment presents a spark hazard and the control system can thus be classified as Safety Class 2.

One design of the void fraction instrument senses tank pressure using two pressure switches. The two switches send signals via two separate wires run to the control console. The control console has two separate relays that lock in when the correct pressure is sensed in the tank. If correct pressure is lost to either pressure switch, or a general power loss is experienced at the cabinet, the relays open and prevent power from reaching the non-qualified electrical components in the potentially hazardous zone. Redundancy and fail-safe are stressed here as this system is considered an "active" system per the WHC Management Requirements and Procedures, and requires redundancy of active components to meet Safety Class 2 criteria. The applicable electrical codes and the design concepts for compliance are discussed in detail by J. H. Russell et al. (1994).

An emergency stop button should be used to create the same shut-down conditions the pressure switches cause, using many of the same components. The "E-Stop" button itself, and associated active components, are Safety

**Class 3 items.**

- The pressure switches should be UL approved for Class 1, Division 1, Groups A, B, C, and D locations. They should be redundant as they are active. These switches are considered Safety Class 3 items.
- The wire runs between the pressure switches and control console are passive. They are considered Safety Class 4 items.

The relays in the control cabinet are redundant and are Safety Class 3 components.

Successful acceptance testing of this assembled system would qualify it for Safety Class 2 service. Following any maintenance to any of these Safety Class components, the ATP must be re-run sufficiently to assure the pressure switch system still functions per design.

**C2.2 PROXIMITY SWITCH SYSTEM FOR EQUIPMENT MOVING IN AND OUT OF THE TANKS**

A proximity switch can be used to assure that devices being lowered into the tank are in the home position before the equipment is removed from the riser. This switch is mounted below the top of the tank environmental interface plate, and is, therefore, exposed to a Division 1 environment and presents a spark hazard. This system would use an Intrinsic Safety (shunt zener diode) Barrier. This sensor/barrier combination should come from the factory UL-approved as a matched set.

Therefore, the proximity sensor and associated barrier is considered Safety Class 3 item. The UL approval (Class 1, Division 1, Group B), acceptance testing and visual inspection of fabrication by the Fire Protection Engineer assure these components are suitable to perform a Safety Class 2 function.

**C2.3 VENTILATION SYSTEMS INTERLOCKS FOR ELECTRICAL ENCLOSURES MOUNTED ON RISERS**

During initial start up, or immediately following a tank pressurization, dome gas may have been allowed into the primary top-hole enclosure and must be ventilated back into the tank dome space. Gas may also get trapped in the immediate area around the primary enclosure after such an event, so must also be ventilated away from potential spark sources.

The primary enclosure ventilation is motivated by the lower dome pressure than atmospheric pressure. At minus one inch of water gauge inside the tank, the flow rate through the primary enclosure must be at least 3.5 cfm. The flow control is accomplished by using an orifice plate between the primary enclosure and the riser.

Appropriate flow rate can be assured by use of a calibrated pitot tube and manual read out gauge. If the correct flow rate is occurring, the correct purge volume is assured automatically by the timers in the control console. When the pressure switches "see" the correct tank pressure (the switches sense below the orifice), they close, sending a signal to the cabinet relays discussed above. The relays cannot send power to non-qualified equipment until the timers have completed timing. The timers are redundant also.

The area around the primary enclosure is clearly open to the atmosphere or force ventilated using fans. The fans run at all times the pressure switches "see" the correct tank pressure. They are qualified to operate in a Division 2 environment. Therefore, the orifice plate flow characteristics are Safety Class 3. The ID of this plate, combined with cable OD, is also considered in the SA to limit possible waste entrainment accidents. The thickness is considered in the SA as worker shielding. Therefore, the entire assembly is Safety Class 3.

The pitot tube and local read-out are Safety Class 3 items to assure correct indication of flow. The interconnecting tubing and fittings are Safety Class 4.

The redundant timers are both Safety Class 3 items.

The ventilation fans outside the primary enclosure are Safety Class 3 items, in that they must meet Division 2 requirements. The wiring to the fan motors is Safety Class 4.

Successful acceptance testing of the assembled ventilation system qualifies it for Safety Class 2 service. Following any maintenance to any of these Safety Class components, the ATP must be re-run sufficiently to assure the ventilation systems still function per design.

## **C2.4 MATERIALS COMPATIBILITY AND THE USE OF ALUMINUM IN THE TANKS**

Stainless steel is generally the material of choice in the tanks. Titanium can be used as well as other steel alloys.

Aluminum will react with tank waste. SA would consider that an exothermic reaction may ignite a Division 1 environment. While Al can be used in the tanks, it requires special protection. SA will require that Al materials be protected from waste contact. Direct contact with full strength waste can be inhibited by a water decontamination system, but would be assured by the plastic bag placed around the component. The plastic covering (bag or equivalent) must be resistant to the waste being sampled, and must not be damaged. Therefore,

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the plastic bag would be considered as safety Class 3. (A damaged bag must be replaced to assure no waste contact can occur.)

The combination of waste resistant plastic covering, intermittent inspection and the SA analysis would qualify a system for Safety Class 2 service.

### **C2.5 MOVING PARTS MOUNTED INSIDE THE TANKS**

The mechanical motion of components, such as cable drum, pulleys, bearings, etc., have the potential to become hot (if a failure occurred) and ignite the postulated Division 1 environment. Analysis should be done, as need, to assess the equipment as-built drawings, and to establish the credibility of this type of accident and establish failure rates.

All moving components can potentially be classified Safety Class 3 if correct materials and loadings are used.

### **C2.6 STATIC CHARGES PROTECTION FOR PLASTIC COATED PARTS IN THE TANKS**

The wire rope used to lower devices in the tanks is generally plastic coated to inhibit waste entrapment. The plastic coating may create static sparks. Therefore, a conductive plastic coating is suggested. The wire rope with correct plastic coating can be considered a Safety Class 3 item. Prior to initial installation, or possible replacement, the plastic coated cable must be tested to assure there is less than one mega-ohm resistance between the outside of the plastic coating and the wire rope core.

The combination of a Safety Class 3 plastic coated cable and further required testing assures that the cable meets the Safety Class 2 criteria for spark control.

### **C2.7 WATER ADDITION TO THE TANKS**

A tank truck shall be used to supply decontamination water. This is to prevent unlimited water supplies from flooding the tank. There is no Safety Class attached to the tank truck, except for the water inside.

The allowed decontamination GPM may not exceed 3.5 gpm. This is controlled through quantity and sizes of spray nozzles. The spray nozzle tips are Safety Class 3 items for these characteristics.

**C2.8 VALVES TO ISOLATED RISER MOUNTED EQUIPMENT FROM THE TANKS ATMOSPHERE**

Isolation valves can be used to close and seal in-tank equipment from the tank riser. The valve is Safety Class 3. A Safety Class 4 valve may be used if suitable acceptance testing is done to qualify it for Safety Class 3 service.

The pressure in the enclosure should be monitored along with the ventilation gauge to determine if the isolation valve is indeed fully closed or open. The gauge is Safety Class 3. Safety Class 4 gauge may be used if sufficient testing is completed to assure the gauge will work.

**C2.9 RADIATION DETECTORS TO MEASURE WASTE ENTRAINMENT ON EQUIPMENT DURING RETRIEVAL FROM THE TANKS**

A radiation detector operating continuously is generally specified by the SA. This detector, in its entirety, is generally Safety Class 3. It may be Safety Class 4 procured, but current calibration stickers and field HPT approval can justify it for Safety Class 3 service.

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