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SAFETY EQUIPMENT LIST FOR THE LIGHT DUTY UTILITY ARM SYSTEM

G.A. Barnes

SGN Eurisys Services Corporation (SESC), Richland, WA 99352
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Abstract: This document identifies all safety equipment to be used for the Light Duty Utility Arm system.

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SAFETY EQUIPMENT LIST
FOR THE
LIGHT DUTY UTILITY ARM SYSTEM

HNF-2147

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February 1998

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FORWARD

The initial issue (Revision 0) of this Safety Equipment List (SEL) for the Light Duty Utility Arm (LDUA) requires an explanation for both its existence and its being what it is. All LDUA documentation leading up to creation of this SEL, and the SEL itself, is predicated on the LDUA only being approved for use in waste tanks designated as Facility Group 3, i.e., it is not approved for use in Facility Group 1 or 2 waste tanks. Facility Group 3 tanks are those in which a spontaneous or induced hydrogen gas release would be small, localized, and would not exceed 25% of the LFL when mixed with the remaining air volume in the dome space - exceeding these parameters is considered, "unlikely". Thus, from a NFPA flammable gas environment perspective the waste tank interior is not classified as a hazardous location. Furthermore, a hazards identification and evaluation (HNF-SD-WM-HIE-010, REV 0) performed for the LDUA system concluded that the consequences of actual LDUA system postulated accidents in Flammable Gas Facility Group 3 waste tanks would have either NO IMPACT or LOW IMPACT on the offsite public and onsite worker. Therefore, from a flammable gas perspective, there is not a rationale for classifying any of SSCs associated with the LDUA as either Safety Class (SC) or Safety Significant (SS) SSCs, which, by default, categorizes them as General Service (GS) SSCs. It follows then, based on current PHMC procedures (HNF-PRO-704 and HNF-IP-0842, Vol IV, Section 5.2) for SEL creation and content, and from a flammable gas perspective, that an SEL is NOT REQUIRED,-----HOWEVER!!! There is both a precedent and a prudence to capture all SSCs, which although GS, contribute to a Defense-In-Depth (DID) approach to the design and use of equipment in potentially flammable gas environments. This Revision 0 of the LDUA SEL has been created to capture these SSCs and they are designated as GS-DID in this document. The specific reasons for doing this include the following:

- o The recently issued Tank Farm SEL (SEL-040) established this precedent for a GS-DID category (as well as another) for its SEL. It was established by definition, even though this category is not yet populated within SEL-040, although intended to be. [Note: There is no other mechanism (procedural) for incorporating non-SC/SS SSCs in an SEL]
- o The SEL-040 definition of GS-DID included all SSCs which are not directly analyzed within the BIO, but which are credited by the FGEAB (part of an Administrative Control "safety program" established to fulfill a TSR resulting from the BIO) for satisfying an "ignition control set" for SSC operation in certain flammable gas environments, i.e., the ex-tank, dome space, and waste intrusive regions of Facility Group 1, 2, and 3 waste tanks. [There is currently ongoing discussion on whether or not to keep this as part of the GS-DID category definition.]
- o The design of the LDUA anticipated that it might be used in ALL Facility Group waste tanks and, therefore, design features were incorporated in the LDUA to enable this possibility. [It is these features (SSCs) that have been categorized GS-DID and used to populate this SEL.]
- o The current LDUA design, and its intended mode of operation in waste tanks, was evaluated by the FGEAB and resulted in its being approved for use in ALL Facility Group waste tanks.

[Note: This SEL only addresses LDUA usage in Facility Group 3 waste tanks.]

- o There exists a general TWRS consensus (a proceduralized requirement does not yet exist) that anticipates all separate (with perhaps disparate rationale and formats) SELs will be combined with the Tank Farms SEL (SEL-040) into a singular TWRS SEL (or a singular Tank Farm SEL, as a minimum). [The format and rationale of this SEL is modeled on SEL-040 and attempts to accommodate this eventuality.]
- o The Hazards Identification and Evaluation (HIE) document prepared for the LDUA concluded that the LDUA and its operation in Facility Group 3 waste tanks was bounded by the accidents analyzed in the BIO.
- o An additional intended purpose of including these GS-DID SSCs in this SEL is that their described safety function (w/ credited design features) is made visible and substantially improves capability for maintaining configuration control for same, e.g., through use of the Commercial Grade Item (CGI) dedication procedure.

As noted above, this SEL only addresses LDUA usage in Facility Group 3 waste tanks. LDUA usage in Facility Group 1 and/or 2 tanks will require revision of this SEL, and, most probably, other supporting documentation as well.-----G. P. Janicek, Characterization Project Design Authority, February 1998.

SAFETY EQUIPMENT LIST FOR THE LIGHT DUTY UTILITY ARM SYSTEM

1.0 PURPOSE

This document identifies the safety equipment for the Light Duty Utility Arm (LDUA) System. This document is intended to be updated as end effectors, that have a major impact on the LDUA system and its potential safety envelope, are added to the LDUA System.

2.0 SCOPE

This document describes safety equipment and provides safety classifications for the LDUA System and the current associated equipment, including the current end effector tools. It does not address routinely used tank farm equipment that is regulated by existing control manuals and procedures, such as ladders, fire extinguishers, electrical cords, gas bottles, and etc., which are part of the industrial safety program.

The safety equipment and associated equipment in this document are identified by reference to an evaluation of the LDUA for compliance to the Authorization Basis flammable gas ignition controls completed by the Flammable Gas Equipment Advisory Board (FGEAB-97-019, Rev 2, September 9, 1997). This SEL is based, primarily, on the FGEAB evaluation because an accident analysis for the design/operation specific to the LDUA system was not performed. A USQ Screening/Determination (TF-97-0523) determined that operation of the LDUA in facility group 3 tanks is bounded by the accidents analyzed in the current TWRS Authorization Basis (AB), (HNF-SD-WM-BIO-001). The basis for the USQ Screening/Determination was the Hazards Identification and Evaluation, HNF-SD-WM-HIE-010 (HIE) that was performed for the LDUA, which addressed the AB (HNF-SD-WM-BIO-001) analyzed accidents of concern to the LDUA operation in facility group three tanks only. It was determined that the LDUA is bounded by the AB accidents.

Because the USQ Screening/Determination and the HIE only address the operation of the LDUA in Facility Group 3 tanks, the scope of this SEL is also limited to the identification of Safety Equipment pertaining to the operation of the LDUA in facility group 3 tanks. The use of the LDUA in facility group 1 or 2 tanks will require revision to the USQ screening/determination, the HIE and this SEL.

3.0 APPLICATION

The safety classification designation will be used as the basis for establishing the safety significance of various systems, components, and structures. It will also be used to confirm that the appropriate Quality, Safety, and Environmental Assurance is used during the completion of design and procurement activities and during field deployment, test, and operation of the LDUA systems. Section 6.1 contains the SEL for the LDUA system per the requirements of WHC-IP-0842. Each listing in Section 6.1 contains:

- system, structure or component
- function description
- safety function
- failure mechanisms
- design attributes
- failure effect on SSC safety function
- safety classification justification
- safety classification

4.0 SYSTEM DESCRIPTION AND OPERATION

4.1 LDUA SYSTEM

The LDUA System consists of a deployment vehicle, vertical positioning mast, a Light Duty Utility Arm (LDUA), a Tank Riser Interface and Containment (TRIC) module, an Operations Trailer, an At Tank Instrument Enclosure (ATIE) module, and end effectors (Hanford Drawing H-6-14055, *LDUA System Block Diagram*). These systems are described extensively in WHC-SD-TD-ER-005. The LDUA System will be used to perform inspection, light duty sampling, and characterization activities in support of the remediation of underground storage tanks containing hazardous, radioactive waste. It may also be used to perform light duty tasks required during actual remediation.

4.1.1 Mobile Deployment System

The Mobile Deployment System (MDS), which is a basic heavy duty truck with deployable outriggers, provides the supporting base for the LDUA and arm support components. The deployment vehicle is used for transporting and positioning of the LDUA which is contained within a mast housing that is mounted on the deployment vehicle. The deployment mast and LDUA is transported in a horizontal position on the deployment vehicle. The deployment vehicle also contains basic utilities that are needed for the hydraulic and electrical systems that power and control the actuators and transducers of the LDUA and deployment mast. These actuators and transducers are used to setup, align and take-down of the deployment mast over a tank riser. The deployment vehicle also contains a low level robotic arm controller with a control pendant that allows the deployment mast and LDUA to be operated in a "stand-alone,"

tele-operated mode without being connected to the control trailer

4.1.2 Vertical Positioning Mast

The vertical positioning mast (VPM) provides the mechanical means to safely and quickly deploy the LDUA in an underground storage tank. The VPM housing, which is mounted on the deployment vehicle, provides containment for the mast and LDUA arm during storage and during deployment and operation. During operation, the VPM housing is raised to a vertical position. The bottom of the mast housing contains a large diameter valve which is opened after the VPM is vertical and connected to the TRIC. This valve is part of the VPM containment which seals in any residual contamination that might be clinging to the mast or LDUA surfaces after withdrawal from a tank. The VPM also provides a confinement envelope function (see section 5.2.1) during LDUA in-tank operation.

4.1.3 Light Duty Utility Arm

The LDUA is a 5 member, 13.5 feet long, rigid manipulator arm with flexible joints that allow at least 6 degrees of freedom of motion for end effectors attached to the arm. The LDUA is attached to the deployment mast that is mounted on the deployment vehicle. The cabling, piping, etc. for electrical, water, hydraulic, and air utilities needed to manipulate and control the LDUA's flexible joints and attached end effectors, are contained within the LDUA's tubular structure. During deployment in a tank riser, the LDUA tubular structure is encased in a protective rubber boot that protects the LDUA from contamination and provides a confinement envelope to the LDUA purge gas system (see section 5.2.1). The end effectors are attached to the LDUA and connected to the utilities through the Tool Interface Plate (TIP) which is mounted on the wrist joint at the end of the LDUA arm. The LDUA and TIP interface enable the change out and safe manipulation of various inspection, light duty sampling, and characterization end effectors within the hazardous chemical and radioactive environment of an underground storage tank.

4.1.4 Tank Riser Interface And Confinement

The tank riser interface and containment (TRIC) provides sealed containment and mechanical interface between the VPM housing and a tank riser. The TRIC also provides access and containment space for the attachment and change-out of end effectors. The TRIC is mounted on top of a 14 inch ID riser isolation valve. The riser isolation valve is opened to allow the LDUA to be deployed into the tank riser. The lower section of the TRIC, which attaches to the riser isolation valve contains a decontamination spray system this is used to wash down the LDUA as it is withdrawn from the tank. The TRIC also provides the interface for bag-in and bag-out of end effector tools and sample containers which may become contaminated with radioactive, hazardous materials that are in the tank or tank riser. The TRIC also provides a confinement envelope function (see section 5.2.1) during LDUA in-tank operation.

4.1.5 Tank Instrumentation Enclosure

Instrumentation modules for control, actuators, and transducers controlled by the Control System Trailer are located in the At Tank Instrumentation Enclosure. This is an environmental hardened enclosure that is positioned inside the tank farm fence in close proximity to the LDUA deployment vehicle. Umbilicals connect the ATIE to the Operations trailer and to the LDUA on the Deployment Vehicle. There are no direct connecting paths between the ATIE and the tank interior where gases or air-borne materials may be exchanged.

4.1.6 Control System

The LDUA control system is implemented as a modular distributed control system. The control system allows for either local or remote operation of the LDUA. Only a limited subset of control capabilities are available at the local control pendant. The remote LDUA console (supervisory controller) provides access to more control functions and operational parameter than the local control pendant. The remote LDUA console is located outside the perimeter fence of the tank farm in the Operation control Trailer (OCT).

Setup of the LDUA over the riser is usually done using the local control pendant where the operations focus is on alignment of the VPM with the tank riser. Arm control (all travel outside of the VPM including end effector attachment/removal) is usually done from the remote LDUA console, where greater visibility of the system parameter is available.

4.1.7 End Effectors

There are currently four end effectors that have been evaluated against the AB for use in Facility group 3 tanks. These end effectors are:

- **High Resolution Stereo Video System end effector (HRSVS)** - This end effector is capable of providing full high resolution color stereo video using two cameras and eight lights mounted in a ring arrangement. This type of end effector is used to accomplish visual surveillance of the tank interior. The cameras utilizes a multi-lens turret to provide optimum view and clarity of objects at various distances from the end-effector. The end effector size is approximately 30 inches long, 10.5 inches in diameter, and weighs approximately 58 pounds.
- **Gripper end effector** - This end effector has the capability to grasp and move objects of various sizes within the tank. The gripper end effector incorporate cameras and lights to enable stereo viewing of objects, enhancing the ability of operators to locate and manipulate objects. The gripper jaws are actuated pneumatically (with a 500 lb. closing force capability) and can open up to six inches. This end effector is approximately 24 inches in length, 10.5 inches in diameter and weighs approximately 55 pounds.
- **Waste probe** - The waste probes are used to measure physical properties of waste and/or in-tank equipment. Qualitative properties such as waste thickness, consistency and depth can be measured with the waste probes. The waste probes consists of 17-4 stainless steel

rods that have been mounted to a spring base. The spring base replaces the gripper jaws on the current gripper end effector. By driving the rods into the waste and actuating the gripper mechanism, an operator can get a sense of the thickness, depth and consistency of the waste. Deflection of the rods is measured against a calibrated pointer that indicates pressure applied and distance deflected. This probe is approximately 18 inches in length and weighs approximately 5 pounds.

- **Extended Reach End Effector (EREE)** - The EREE will be used to retrieve samples of waste from the tank bottom, walls, dome, and in-tank equipment. The EREE provides the capability to extend the reach of the LDUA system by up to 81 inches. The EREE is manufactured from 17-4 stainless steel and uses a two-piece telescoping mast that can be manually extended and retracted. Located at the end of the extending tube is a set of waste sampling scoops capable of acquiring an approximately 50ml waste surface sample. The end effector is also equipped with a color and black and white camera, along with two variable intensity lights. Maximum diameter of the end effector is 10.5 inches, the length fully extended is 81 inches, and the unit weighs approximately 38 pounds.

4.2 OPERATING SCENARIO

The LDUA will be used to deploy the above mentioned end effectors into underground storage tanks containing hazardous (caustic), radioactive wastes.

A crane is used to set several of the LDUA subsystem components into place on or near the tank (riser isolation valve, TRIC, PDS, and ATIE). LDUA system deployment starts with lowering the riser plug gauges down into the proposed access riser to insure that an unobstructed access into the tank is available. The next step is to attach the riser isolation valve to the riser. This valve when in-place and closed allows the remainder of the deployment setup work to be considered "not tank intrusive". Once the TRIC is attached to the top of the riser isolation valve, the remainder of the LDUA system can be deployed in the area near the riser. The deployment vehicle will be driven into a tank farm and positioned near the selected tank riser. The other on tank support equipment is positioned within 50 foot of the LDUA (ATIE, PDS, and Decon Trailer) and interconnected.

The operations trailer will be transported and setup at a convenient position outside of the tank farm fence where it is connected to AC power and the fiber optic control and data cables are then routed to the LDUA. Using the LDUA's low level, pendant controller, the deployment vehicle (truck) is stabilized by lowering and locking the deployment vehicle outriggers. Riser alignment is completed by raising the VPM, connecting it to the TRIC, then using variable travel in X, Y, Roll, and Pitch to position the arm in the center of the riser.

Riser alignment, deployment into the tank, in-tank operations, and retrieval are all completed without breaching the containment of the VPM and the TRIC. The TRIC valve and the VPM valve provide an air-tight containment seal between the TRIC and mast housing and between the TRIC and the tank riser. Both of these valves are open when the LDUA is deployed

in the tank.

The installation of an end effector on the LDUA is accomplished within the TRIC. With the riser isolation valve closed, the gate valve will be opened and the LDUA lowered into the TRIC. After an end effector is attached, the valve on the bottom of the TRIC is opened and the end effector lowered past the TRICs decontamination spray system into the tank riser. The in-tank, remote operation of the LDUA and end effector is monitored with video cameras attached to the LDUA and with auxiliary cameras deployed in other tank risers.

The operation of the LDUA and end effectors inside the tank is performed using the supervisory controller located in the control trailer. However, the LDUA System is also capable of performing all mast and LDUA (arm) operations in a tele-operated mode using local controls at the deployment vehicle. In this tele-operated mode, visual feedback of the LDUA in the tank would use the auxiliary cameras deployed in other tank risers. In normal operation, after the LDUA is aligned with the riser, the supervisory controller (in the control trailer) will be used to deploy the end effector to complete/perform characterization, sample retrieval or inspection functions.

The duration of operation of the LDUA System in a waste tank will range from 1 to 2 weeks, depending on the work scope for the specific tank. During this period, a number of end effectors will be used with change outs being performed without detaching the deployment mast from the TRIC. The end effectors will be detached and deposited in a suitable container. When the in-tank operations are completed, the LDUA and end effector will be decontaminated as the LDUA is withdrawn from the riser using the TRICs decontamination spray system.

After end effector withdrawal from the tank, the valve between the TRIC and the riser will be closed. After the end effector is removed from the LDUA, the LDUA will be fully withdrawn into the VPM housing. The VPM gate valve will be closed and the VPM housing will be detached from the TRIC. The deployment vehicle is then used to lower the VPM to the horizontal position. The outriggers will be withdrawn and the deployment vehicle driven off the tank. The TRIC will then be removed and the riser re-sealed with a blank flange.

5.0 SAFETY CLASSIFICATION

5.1 SAFETY CLASSIFICATION DEFINITIONS

The Project Hanford Management Contractor's (PHMC) safety classification system includes the following categories for structures, systems, and components (SSCs) as defined in HNF-SD-WM-SEL-040. This SEL is consistent with the approach taken in HNF-SD-WM-SEL-040.

- Safety Class structures, systems and components (safety-class SSCs). Systems, structures, and components (SSCs) including primary environmental monitors and portions of

process systems, whose failure could adversely affect (exceed the Evaluation Guidelines) the environment, or safety and health of the public as identified by safety analysis.

These are SSCs whose preventive or mitigative function is necessary to keep hazardous material exposure to the public below the offsite Evaluation Guidelines.

- Safety Significant structures, systems, and components (safety-significant SSCs). Structures, systems, and components not designated as safety-class SSCs but whose preventive or mitigative function is a major contributor to defense-in-depth (ie. prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis.

These are SSCs whose preventive or mitigative function is necessary to keep releases of radiological materials to onsite workers and toxic chemicals to the offsite public and onsite workers within the risk guidelines; or are otherwise considered significant to maintain defense-in-depth and worker safety. Both of these categories are credited or identified in the Authorization Basis accident analysis.

The following are two SSC subcategories that contain safety features, though not credited or identified in the Authorization Basis accident analysis, that provide defense-in-depth risk reduction to analyzed accidents, result from the implementation of Technical Safety Requirements (TSR) safety programs, or protect the facility worker.

- Defense-in-Depth structures, systems, and components (defense in depth SSCs). Defense-in-depth SSCs are SSCs which contain safety features, though not credited or identified in the Authorization Basis accident analysis, that provide defense-in-depth risk reduction to analyzed accidents, result from the implementation of Technical Safety Requirement (TSR) safety programs, or protect the facility worker.
- Facility Worker structure, system and component (facility worker SSC). These are SSCs which are not identified in the above categories, but which have specific design criteria related to protecting the facility worker from radiological or toxicological hazards. Examples include portal monitors, change trailers, or chemical monitoring systems.

5.2 LDUA SAFETY CLASSIFICATION

Based on the Safety Classification definitions above, and because this SEL only applies to LDUA activities in Facility Group 3 tanks (see section 2.0), the LDUA System safety equipment identified in this document are classified as General Services-Defense-In-Depth (GS-DID).

For facility group 3 tanks, only small localized Gas Release Events (GRE) are

anticipated. These GREs will not cause the tank head space to reach flammable gas concentration to exceed 25% of the LFL (HNF-SD-WM-BIO-001) and therefore any ignition of flammable gases during these small GREs will be localized. This localized ignition of flammable gases will not cause a waste tank fire, explosion or dome collapse. Because of this, the LDUA SSCs that prevent ignition of flammable gases do not need to be safety class or safety significant.

The selection of the GS-DID safety equipment is based on the definitions in HNF-SD-WM-SEL-040, the equipment identified in the FGEAB evaluation (FGEAB-97-019, Rev 2, September 9, 1997) and the accidents identified in the HIE. The FGEAB is tasked with implementation of the TSR flammable gas safety program controls identified in the AB and therefore, the FGEAB evaluation identifies which SSCs are required to meet the flammable gas controls in the BIO. The HIE identifies which SSCs are required to prevent other AB accidents (Release of contamination due to TRIC and tank riser damage during a wind storm). The Safety Equipment list for the LDUA system is shown in section 6.1 below.

5.2.1 LDUA Purge Gas System

During an in-tank operation, the LDUA system is purged by a constant flow of clean, low moisture (instrument grade) air. This purge gas flow allows the LDUA System to meet National Electrical Code requirements for operation in a Class 1, Division 1, Group B flammable atmospheres by maintaining the VPM, LDUA, and end effector internal air pressures above the pressure of the tank atmosphere. This pressure differential also keeps the interior surfaces of these components clean and uncontaminated by preventing the ingress of the tank atmosphere. Appendix A contains a detailed description of this purge system and a discussion of the LDUA System features which support the operation of this purge gas system.

A sniffer port is located on top of the VPM to insure that if the LDUA ever needs to be restarted while the arm is extended into a flammable zone, the area at the top of the VPM housing is clear of Hydrogen gas. A low pressure relief brass check valve is also included to allow purge gas to vent at the top of the VPM housing, thereby washing out that potentially static volume if all other flow paths are closed.

Based on the technical issues and conditions described in Appendix A, the LDUA System was found by the Site Flammable Gas Equipment Advisory Board (FGEAB) to be in compliance within the ignition control sets contained within the Authorization Basis (Standing order 97-01) or demonstrated equivalence to those ignition control sets (FGEAB-97-019, Rev.). The FGEAB determined that the LDUA System was qualified for use in all Facility Group Tanks, and all flammable gas controlled locations within those Facility Groups under the specified conditions.

5.2.2. Purge Gas Interlock System

The LDUA safety equipment and controls establish the baseline safety controls required for safe operation of the LDUA in a classified zone with a Type Z or X purged gas system. The

integrity of the pressure barrier that separates LDUA non-classified equipment from the classified zone is monitored and interlocked. This monitoring and interlock equipment provides a fail safe diverse and redundant detection of the loss of purge gas and pressure. Figure 1 in Appendix A shows a high-level block diagram of the interlock pressure sensors.

The circuit components of the primary and backup circuits are:

Primary Circuit Components:

- Purge #1: A2A5 (A2W16), Primary Purge Sensor
- Purge #2: A2A5 (A2W32), Redundant Primary Purge Sensor

These components are shown in essential drawing H-6-14055. The details of these components can be found in Vendor Information file 22803, Drawing 200205, sheet 15.

Backup Circuit Components:

- Purge #3: A2A6 (A2W17), Backup Purge Sensor
- Purge #4: A2A6 (A2W33), Redundant Backup Purge Sensor
- A7K1, Secondary Threshold Relay
- A7K12, Redundant Secondary Threshold Relay
- A7K16, Backup Delay On Timer

These components are shown in essential drawing H-6-14055. The details of these components can be found in Vendor Information file 22803, drawing 200207, sheet 7.

5.2.3. Static-electricity Dispersion

Grounding wire connectors are installed on all LDUA subsystems and components. The LDUA System installation includes procedures for assuring that grounding and bonding wires are connected, before any LDUA tank operation is initiated.

There are a number of polymer covered surfaces on tank intrusive hardware that might be subjected to static inducing processes. These are the LDUA, wrist covering, and Gripper End Effector (GEE) boot. However, under normal LDUA operating procedures, these surfaces will not collect static electricity. Decontamination could provide a discharge path for static electricity. To assure proper dissipation of any charge build up, the LDUA operating procedures require that these surfaces be cleaned by wiping with damp cloths and/or static-dissipative cleaning solutions.

The arm of the LDUA is encased in tight fitting, disposable polymer boot that protects the surfaces of the arm and the arm joints from contamination. The LDUA boot is made up of a resilient silicone rubber material that is covered by a conductive outer boot. If decontamination is not successful and radiation levels are high, the boot can be stripped from the arm and disposed of as waste. The wrist joint cover is made of a composite material and will also be, when

required for decontamination, wiped down with damp cloths and/or static-dissipative cleaning solutions.

Other polymer surface items include the rubber boot covering the Gripper End Effector (GEE), the acrylic window in the LDUA shoulder camera, the Lexan windows in the TRIC and the plastic ring protecting the bottom lip of the HRSVS window is an acrylic material. The HRSVS protective lip is fabricated from conductive polymer materials. An anti-static fluid will be applied to the HRSVS seal prior to in-tank deployment. Under normal operation the camera and TRIC window surfaces and the GEE boot are not subject to static inducing processes during operation. The operating procedures require that surfaces be dampened by the decontamination spray and that decontamination or other cleaning operations, while the LDUA is engaged with a tank riser, will be with damp cloths and/or static-dissipative cleaning solutions.

The TRIC gloves may be subjected to rubbing contacts in normal operation. Part of the operating procedures includes a process to dampen the surfaces with the decontamination spray or apply an approved anti-static fluid. The TRIC rubber splash barrier is subject to rubbing against both the metal and the polymer surfaces of the VPM and the LDUA. The metal surfaces are electrically grounded so that contact with them won't induce a static charge. The splash barrier will be tilted out of contact with the LDUA unless water decontamination is being applied to the LDUA.

5.2.4. Riser Closure Valve Intrinsic Safety Barrier

The LDUA TRIC uses an intrinsic safety barrier module which is located between the ATIE and the limit switch on the riser isolation valve. The purpose is to provide an intrinsically safe electrical barrier for the limit switch which could potentially be exposed to a flammable hydrogen/air mixture. The riser isolation valve is located on the bottom of the TRIC where, when closed, it provides a gas sealed barrier between the tank riser and the TRIC. When open, it allows the LDUA to be lowered into the tank riser.

5.2.5. Mobile Deployment System Outriggers

The Mobile Deployment System (MDS), which is a basic heavy duty truck with deployable outriggers, provides the supporting base for the LDUA and arm support components. The deployment vehicle is used for transporting, and positioning of the LDUA which is contained within a mast housing that is mounted on the deployment vehicle. The MDS outriggers provide stability if high winds develop during operations.

6.0 SAFETY EQUIPMENT LIST

The following listing is a summary of the safety equipment associated with the LDUA system. For specific information about the individual components listed, refer to the specified section of this document:

Light Duty Utility Arm System	GS-DID/See section 6.1
LDUA	GS-DID/See section 6.1
Mobile Deployment System	GS-DID/See section 6.1
Tank Riser Interface Containment (TRIC)	GS-DID/See section 6.1
LDUA	GS-DID/See section 6.1.1
Primary Circuit Purge Sensor #1	GS-DID/See section 6.1.1
Primary Circuit Redundant Purge Sensor #2	GS-DID/See section 6.1.1
Backup Circuit Purge Sensor #3	GS-DID/See section 6.1.1
Backup Circuit Redundant Purge Sensor #4	GS-DID/See section 6.1.1
Secondary Threshold Relay	GS-DID/See section 6.1.1
Redundant Secondary Threshold Relay	GS-DID/See section 6.1.1
Backup Hardware Timer Delay	GS-DID/See section 6.1.1
Manual Electric Shutdown	GS-DID/See section 6.1.1
Static-Dissipative Outer Boot	GS-DID/See section 6.1.1
Mobile Deployment System	GS-DID/See section 6.1.2
Outriggers	GS-DID/See section 6.1.2
Tank Riser Interface Confinement (TRIC)	GS-DID/See section 6.1.3
Intrinsically Safe Riser Closure Sensor Barrier	GS-DID/See section 6.1.3

6.1 SAFETY EQUIPMENT LIST FOR THE LDUA SYSTEM

HOST ITEM IDENTIFICATION	SAFETY FUNCTION(S)	SAFETY CLASS JUSTIFICATION	SAFETY CLASS
Light Duty Utility Arm System	Monitor air purge pressure. Initiate system shutdown on loss of purge system differential pressure. Provide materials to dissipate static charge	Based on the Safety Classification definitions above, and because this SEL only applies to LDUA activities in Facility Group 3 tanks (see section 2.0), the LDUA System safety equipment identified in this document are classified as General Services-Defense-In-Depth (GS-DID). For facility group 3 tanks, only small localized Gas Release Events (GRE) are anticipated. These GREs will not cause the tank head space to reach flammable gas concentration to exceed 25% of the LFL (HNF-SD-WM-BIO-001) and therefore any ignition of flammable gases during these small GREs will be localized. This localized ignition of flammable gases will not cause a waste tank fire, explosion or dome collapse. Because of this, the LDUA SSCs that prevent ignition of flammable gases do not need to be safety class or safety significant. The selection of the GS-DID safety equipment is based the definitions in HNF-SD-WM-SEL-040, the equipment identified in the FGEAB evaluation (FGEAB-97-019, Rev 2, September 9, 1997) and the accidents identified in the HIE. The FGEAB is tasked with implementation of the TSR flammable gas safety program controls identified in the AB and therefore, the FGEAB evaluation identifies which SSCs are required to meet the Flammable gas controls in the BIO. The HIE identifies which SSCs are required to prevent other AB accidents (Release of contamination due to TRIC and tank riser damage during a wind storm). The Safety Equipment list for the LDUA system is shown in section 6.1 below.	GS-DID

The items listed below are the: Systems ☒ Structures Components for the above host item.

The safety classification of the items listed below is: Preliminary interim ☒ final

Item Identification	Item Functional Description	Item Safety Function	Item Failure Mechanisms	Item Design Attributes	Item's Failure Effect on SSC Safety Function	Item Safety Classification Justification	Item Safety Class
LDUA	The LDUA is a rigid manipulator arm with flexible joints that allow at least 6 degrees of freedom of motion for end effectors attached to the arm. The LDUA is attached to the deployment mast that is mounted on the deployment vehicle.	Provide electrical power interlock to ensure that if air purge is lost, the LDUA system shuts down. Provide materials that dissipate static electricity buildup.	Not Analyzed	Detection of purge pressure and interlocks are redundant. See section 6.1.1 for specific design attributes of individual components	Certain component failures affecting the proper management of ignition sources for this equipment cannot cause ignition of flammable gas in the dome space because only small GRE's are anticipated in facility group 3 tanks.	Accident analysis not required, equipment to meet TSR controls only.	GS-DID

6.1 SAFETY EQUIPMENT LIST FOR THE LDUA SYSTEM (cont.)							
Mobile Deployment System	The Mobile Deployment System (MDS), which is a basic heavy duty truck with deployable outriggers, provides the supporting base for the LDUA and arm support components. The deployment vehicle is used for transporting and positioning of the LDUA which is contained within a mast housing that is mounted on the deployment vehicle	Provides stability if high winds develop during operation	Not Analyzed	See section 6.1.2 for specific design attributes of individual components	Failure could result in MDS tipping over resulting in the release of radioactive contamination to the tank farm	Accident analysis not required, equipment to meet TSR controls only.	CS-DID
Tank Riser Interface and Confinement (TRIC)	The tank riser interface and containment (TRIC) provides sealed containment and mechanical interface between the VPM housing and a tank riser. The TRIC also provides access and containment space for the attachment and chime-out of end effectors	Provides intrinsic safety features to ensure waste tank gases are separated from equipment not approved for use in flammable atmospheres.	Not Analyzed	See section 6.1.3 for specific design attributes of individual components	Certain component failures affecting the proper management of ignition sources for this equipment cannot cause ignition of flammable gas in the dome space because only small GRE's are anticipated in facility group 3 tanks.	Accident analysis not required, equipment to meet TSR controls only.	CS-DID

Change-out of end effector

6.1.1 SAFETY EQUIPMENT LIST FOR THE LDUA SYSTEM (cont.)

HOST ITEM IDENTIFICATION	SAFETY FUNCTION(S)	SAFETY CLASS JUSTIFICATION	SAFETY CLASS
Light Duty Utility Arm	Provide air purge interlock system to ensure that if air purge is lost, the LDUA system shuts down. Provide materials that dissipate static electricity buildup.	Since an accident analysis was not required for the LDUA system (see section 2.0), the safety classification designation for the LDUA system is General Services (GS). Also, since the systems identified in the FGEAB evaluation (FGEAB-97-019, Rev 2, September 9, 1997) and the Hazards Evaluation (HNF-SD-WM-HIE-010) are required to meet the AB (HNF-SD-WM-BIO-001) controls (HNF-SD-WM-TSR-006), they are classified as Defense In Depth (DID).	GS-DID

The items listed below are the: Systems Structures Components ☒ for the above host item.

The safety classification of the items listed below is: Preliminary interim ☒ final

Item Identification	Item Functional Description	Item Safety Function	Item Failure Mechanisms	Item Design Attributes	Item's Failure Effect on SSC Safety Function	Item Safety Classification Justification	Item Safety Class
Primary Circuit Purge Sensor #1: A2A5 (A2W16), Vender Information file #22803, Drawing 200205, sheet 15.	Senses differential gas pressure between the purged enclosure and the tank pressure. Component is part of failsafe (1 of 4) shutdown circuit	Provides the "primary" loss of differential pressure signal for the purge gas system. Senses differential gas pressure between the purge gas input to the LDUA and the tank atmosphere pressure.	Not Analyzed	Sensor is calibrated to provide a linear output range of 1.0 to 6.0 volts dc for an input range from 0 to 3 inches of water pressure(VI #22803 SPAR 6.2.5.1).	Failure of sensor has no affect on the SSC safety function, since the system has four redundant sensors.	Accident analysis not required, equipment to meet TSR controls (HNF-SD-WM-TSR-006, para. 5.10.2.c.) only.	GS-DID
Primary Circuit Redundant Purge Sensor #2 A2A5 (A2W32), Vender Information file #22803, Drawing 200205, sheet 15.	Senses differential gas pressure between the purged enclosure and the tank pressure. Component is part of failsafe (1 of 4) shutdown circuit	Provides a "redundant", loss of differential pressure signal to the primary sensor.	Not Analyzed	Sensor is calibrated to provide a linear output range of 1.0 to 6.0 volts dc for an input range from 0 to 3 inches of water pressure(VI #22803 SPAR 6.2.5.1).	Failure of sensor has no affect on the SSC safety function, since the system has four redundant sensors.	Accident analysis not required, equipment to meet TSR controls (HNF-SD-WM-TSR-006, para. 5.10.2.c.) only.	GS-DID

6.1.1 SAFETY EQUIPMENT LIST FOR THE LDUA SYSTEM (cont.)

Backup Circuit Purge Sensor #3 A2A6 (A2W17), Vendor Information file #22803, Drawing 200207, sheet 7.	Senses differential gas pressure between the purged enclosure and the tank pressure. Component is part of failsafe (1 of 4) shutdown circuit	Provides a signal for the backup threshold sensor that outputs an alarm for a low differential pressure reading (below 0.3 in water differential pressure).	Not Analyzed	Sensor is calibrated to provide a linear output range of 1.0 to 6.0 volts dc for an input range from 0 to 3 inches of water pressure(VI #22803 SPAR 6.2.5.1).).	Failure of sensor has no affect on the SSC safety function, since the system has four redundant sensors.	Accident analysis not required, equipment to meet TSR controls (HNF-SD- WM-TSR-006, para. 5.10.2.c.) only.	GS-DID
Backup circuit Redundant Purge Sensor #4 A2A6 (A2W33), Vendor Information file #22803, Drawing 200207, sheet 7.	Senses differential gas pressure between the purged enclosure and the tank pressure. Component is part of failsafe (1 of 4) shutdown circuit	Provides a "redundant, backup", purge gas differential pressure signal.	Not Analyzed	Sensor is calibrated to provide a linear output range of 1.0 to 6.0 volts dc for an input range from 0 to 3 inches of water pressure(VI #22803 SPAR 6.2.5.1).).	Failure of sensor has no affect on the SSC safety function, since the system has four redundant sensors.	Accident analysis not required, equipment to meet TSR controls (HNF-SD- WM-TSR-006, para. 5.10.2.c.) only..	GS-DID
Secondary Threshold Relay A7K1, Vendor Information file #22803, Drawing 200207, sheet 7.	Relay connected to outputs of the purge sensors and provides alarm signal to control system	Fail Safe, isolates all power from purged enclosure (VPM, arm & end effector) when the backup Purge Sensor shows a low differential pressure	Not Analyzed	Must see a pressure greater than .3 inches of water pressure in purged enclosure to power up arm/VPM	Failure of relay has no affect on the SSC safety function, since the system has redundant devices.	Accident analysis not required, equipment to meet TSR controls (HNF-SD- WM-TSR-006, para. 5.10.2.c.) only.	GS-DID
Redundant Secondary Threshold Relay A7K12, Vendor Information file #22803, Drawing 200207, sheet 7	Relay connected to outputs of the purge sensors and provides alarm signal to control system	Fail Safe, redundant isolation of all power from purged enclosure (VPM, arm & end effector) when the redundant backup Purge Sensor shows a low differential pressure	Not Analyzed	Must see a pressure greater than .3 inches of water pressure in purged enclosure to power up arm/VPM	Failure of relay has no affect on the SSC safety function, since the system has redundant devices.	Accident analysis not required, equipment to meet TSR controls (HNF-SD- WM-TSR-006, para. 5.10.2.c.) only.	GS-DID

6.1.1 SAFETY EQUIPMENT LIST FOR THE LDUA SYSTEM (cont.)

Backup Hardware Timer Delay A7K16, Vender Information file #22803, Drawing 200207, sheet 7	Backup time delay provided by relay	Hardware timer to provide a 1 hour and 50 minute delay that is nominally 10 minutes shorter than the Primary Time Delay that is generated by a software algorithm. Unacceptable software errors are generated if the hardware delay does not time out first.	Not Analyzed	Timer is to provide fail safe startup delay of system of 1 hour, 50 minutes (+/- 5 minutes).	Failure of timer has no affect on the SSC safety function since the system will not operate if software does not receive signal from timer.	Accident analysis not required, equipment to meet TSR controls (HNF-SD-WM-TSR-006, para. 5.10.2.c.) only.	GS-DID
Manual Electric Shutdown	Hardware switch that is connected to purge gas system interlock	Hardware switch that "kills" all power to the LDUA when actuated	Not Analyzed	When actuated, all circuits within the LDUA shall be de-energized	Failure of manual electric shutdown has no affect on the SSC safety function since the system has redundant purge gas differential pressure sensors that will automatically shut down the system on loss of purge	Accident analysis not required, equipment to meet TSR controls (HNF-SD-WM-TSR-006, para. 5.10.2.c.) only.	GS-DID
Static Dissipative outer boot Vender Information file #22803, Drawing 200337, sheet1	Flexible boot made of partially conductive polymer	Provide a path for the dissipation of static-electricity accumulated in non-normal operations	Not Analyzed	The static-Dissipative covering on the flexible, polymer boot prevents the build up of static charge on the polymer boot surface	Failure (tearing or ripping) of the boot will not prevent it from performing it's safety function (dissipating static charge)	Accident analysis not required, equipment to meet TSR controls (HNF-SD-WM-TSR-006, para. 5.10.2.c.) only.	GS-DID

6.1.2 SAFETY EQUIPMENT LIST FOR THE LDUA SYSTEM (cont.)

HOST ITEM IDENTIFICATION	SAFETY FUNCTION(S)	SAFETY CLASS JUSTIFICATION	SAFETY CLASS
Mobile Deployment System	Provides stability if high winds develop during operation	Since an accident analysis was not required for the LDUA system (see section 2.0), the safety classification designation for the LDUA system is General Services (GS). Also, since the systems identified in the FGEAB evaluation (FGEAB-97-019, Rev 2, September 9, 1997) and the Hazards Evaluation (HNF-SD-WM-HIE-010) are required to meet the AB (HNF-SD-WM-BIO-001) controls (HNF-SD-WM-TSR-006), they are classified as Defense In Depth (DID).	GS-DID

The items listed below are the: Systems Structures Components ☒ for the above host item.

The safety classification of the items listed below is: Preliminary interim ☒ final

Item Identification	Item Functional Description	Item Safety Function	Item Failure Mechanisms	Item Design Attributes	Item's Failure Effect on SSC Safety Function	Item Safety Classification Justification	Item Safety Class
Outriggers	Load of the deployed LDUA system transferred to Four hydraulically actuated outriggers	Outriggers distribute the load of the LDUA system over a larger area for stability during high winds	Not Analyzed	Outriggers designed to support overall load of LDUA system when deployed during high winds up to 40-mph	Failure of components have no effect on SSC safety function because an administrative control imposed on all LDUA operations requires that the LDUA be retracted into the VPM housing, the VPM isolation valve closed and the VPM lowered when wind speeds reach 30-mph	Accident analysis not required, equipment to meet BIO controls (HNF-SD-WM-BIO-001, para. 5.10.2.c.) only..	GS-DID

6.1.3 SAFETY EQUIPMENT LIST FOR THE LDUA SYSTEM (cont.)

HOST ITEM IDENTIFICATION		SAFETY FUNCTION(S)		SAFETY CLASS JUSTIFICATION			SAFETY CLASS
Tank Riser Interface Confinement (TRIC)		Provides intrinsic safety features to ensure waste tank gases are separated from equipment not approved for use in flammable atmospheres.		Since an accident analysis was not required for the LDUA system (see section 2.0), the safety classification designation for the LDUA system is General Services (GS). Also, since the systems identified in the FGEAB evaluation (FGEAB-97-019, Rev 2, September 9, 1997) and the Hazards Evaluation (HNF-SD-WM-HIE-010) are required to meet the AB (HNF-SD-WM-BIO-001) controls (HNF-SD-WM-TSR-006), they are classified as Defense In Depth (DID).			GS-DID
The items listed below are the: Systems Structures Components X for the above host item.							
The safety classification of the items listed below is: Preliminary interim X final							
Item Identification	Item Functional Description	Item Safety Function	Item Failure Mechanisms	Item Design Attributes	Item's Failure Effect on SSC Safety Function	Item Safety Classification Justification	Item Safety Class
Intrinsically Safe Riser Closer Sensor Barrier, H-6-14129, H-6-14145, H-6-14340 and H-6-14134	Intrinsically Safe Barrier (ISB) module between the ATIE and the limit switch	The ISB limits the energy of potential sparks, due to accidental grounding or shorting, below that required to ignite a flammable hydrogen/air mixture.	Not analyzed	ISB is rated per NFPA 70 for providing intrinsically safe circuit in a NFPA Class I, Div. 1, Group B environment. The ISB is compatible with the valve limit switch.	Failure of ISB has no effect on SSC safety function because failure is fail safe by design and vendor test.	Accident analysis not required, equipment to meet TSR controls (HNF-SD-WM-TSR-006, para. 5.10.2.c.) only.	GS-DID

7.0 REFERENCES

1. Drawing, Hanford, H-6-14055, *LDUA System Block Diagram*.
2. Hazards Identification and Evaluation (HEI) for LDUA, HNF-SD-WM-HIE-010
3. HNF-PRO-704, 1997, *Safety Analysis Manual*, Fluor Daniel Hanford Inc., Richland, Washington, 1997.
4. Internal Publication, WHC-IP-0842.
5. Report, *Flammable Gas Equipment Advisory Board Interpretation/Recommendation*, FGEAB-97-019, Rev.2, September 19, 1997 (Attachment 1 of LMHC-9756007).
6. Safety Equipment List, Tank Farms, HNF-SD-WM-SEL-040.
7. TWRS Authorization Basis, HNF-SD-WM-BIO-001
8. USQ, "Screening/Determination," TF-07-0523.

DESCRIPTION OF THE LDUA SYSTEM PURGE GAS SYSTEM

1.0 LDUA PURGE SYSTEM

The Light Duty Utility Arm (LDUA) System is purged by a constant low flow of instrument grade (clean, low moisture) air. The internal pressure of the end effector, LDUA, and Vertical Positioning Mast (VPM) are maintained above the pressure of the tank atmosphere (see Figure 1). This meets National Electric Code requirements for operation in Class 1, Division 1, Group B flammable atmospheres. This pressure differential also keeps the interior surfaces of these components clean and uncontaminated by preventing in-leakage of tank atmosphere.

Purge air is supplied by the Purge Air Supply System (PASS) and carried by hose to a quick disconnect fitting on the deployment vehicle. At this point, the purge air pressure operates between 35 and 90 psi with a nominal 45 psi operational pressure. The purge air is carried by hose through the VPM, LDUA, and Tool Interface Plate (TIP) into the end effector. The purge air is released in the end effector and flows through it into the LDUA via vent openings provided in the TIP. The purge flow continues through the whole length of the LDUA and into the inner and then outer VPM tubes. From the outer VPM tube, it passes into the VPM housing from where it is exhausted into the TRIC. There is a wiper seal at the base of the VPM housing that restricts the flow of purge air exhaust from the VPM housing in order to maintain a positive pressure in the VPM housing. The purge system is designed to maintain a nominal pressure (with respect to the tank reference pressure) in the end effector and LDUA of 2.5 inches of water in the VPM outer tube and VPM housing. The purge system will operate with both passively and actively ventilated tanks.

As indicated in Figure 1, differential pressure sensors monitor the purge pressure at the top of the VPM inner mast tube (also provides coverage for the end effector and LDUA) and the VPM Housing (also provides coverage for the VPM outer mast tube). These sensors are referenced to the tank pressure by a pressure tap on the Riser Isolation Valve just above the tank riser flange. An alarm is activated on the LDUA Console if the differential purge pressure falls below the minimum set point (type Z purge). In addition, an automatic shutdown of electrical power to the end effector and LDUA (type X purge) can be selectively enabled. There are redundant differential pressure sensors at each location and the control circuitry is designed so that either sensor in the pair can independently initiate the automatic shutdown. The loss of purge air, warning threshold is set at 0.9 inch of water. The shutdown threshold for the first of the pair of sensors is set at 0.5 inches of water, and for the second of the pair at 0.3 inches of water. An adjustable time delay is provided that prevents the application of electrical power to the end effector and LDUA until the purge flow has been on for the required minimum time.

The PASS, which supplies instrument quality air for use by the LDUA purge system, also provides air for operating the VPM housing isolation valve and for light use by end effectors that

have pneumatic devices (via the At Tank Instrumentation Enclosure (ATIE)). To assure that there is a continuous, uninterrupted air supply, the PASS contains two identical compressor units that are designed for outdoor use. In operation, one compressor provides purge air while the other unit is in standby to automatically provide purge air should the first unit fail, or as a supplementary air source if additional air flow is needed due to short term flow demands from tooling and other pneumatic applications. Each compressor unit features a 20 gallon ASME coded receiver, and a continuous duty oil-less compressor that supplies at least 3.5 SCFM air at 75 psi to 80 psi. Short term flow demands up to 7.0 SCFM can be accommodated when the standby compressor unit provides supplementary air with the on-line unit. The LDUA purge system requires a nominal 2.5 SCFM. Filters remove particles of 0.5 micron or larger and an air drier reduces the dew point to -40 °F or lower. Pressure differentials across filters and driers can be locally monitored, and the air delivery pressure can be locally monitored and controlled. A 50 ft long power cord provides electrical power for the compressor motors. A 37 ft long air supply hose is used for attachment to the purge inlet of the LDUA using color coded, keyed, double end shut-off quick connects to assure proper connections. A check valve at the end of the air supply hose prevents any potentially contaminated air from flowing back from the LDUA when the system is depressurized.

2.0 PURGE FLOW PATH VERIFICATION

The purge gas flow path is important for the initial sweep of a volume. A step was inserted into the operating procedures to verify the purge gas flow rate at the "Tool Interface Plate". This measurement is made each time an end effector is changed. This control was added to verify that the purge gas flow path was sweeping up the arm from the end-effector up to the VPM. During a design "failure analysis" it had been determined that an operator would not have an independent indication that the purge flow was washing the arm from the end effector and not just flowing from a broken line in the VPM or Outer tube. (Once a purge pressure source has been applied to the volume, the inner-tube and VPM housing pressures assure the barrier integrity is intact, but do not indicate the flow path of the purge gas. NFPA codes do not require that the purge flow path be monitored. NFPA codes require a .1 inch pressure differential between a classified zone and unclassified equipment. The LDUA has several diverse and redundant interlocks that insure system power is shut off before the pressure drops below .3 inches).

3.0 VPM PURGE PATH AND SAMPLING PORT

A sniffer port on the top of the VPM has been added to insure that if the LDUA ever needs to be restarted while the arm is extended into a flammable zone, the area at the top of the VPM housing is clear of Hydrogen gas. A low pressure relief brass check valve has been added to this area to allow purge gas to vent at the top of the VPM housing, thereby washing out that potentially static volume.

Figure 1. LDUA Purge System Schematic.