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DESIGN REQUIREMENTS DOCUMENT FOR SURFACE MOISTURE MEASUREMENT SYSTEM

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7. Abstract

This document contains the design requirements for the surface moisture measurement system currently under development in the 306E facility.

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DESIGN REQUIREMENTS DOCUMENT [DRD]
FOR
SURFACE MOISTURE MEASUREMENT SYSTEM [SMMS]

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DESIGN REQUIREMENTS DOCUMENT [DRD] FOR SURFACE MOISTURE MEASUREMENT SYSTEM [SMMS]

1.0 SUMMARY

An engineering work plan has been prepared which outlined the Surface Moisture Measurement System (SMMS) project. (See WHC-SD-WM-WP-300). The engineering work plan discussed the project history, goals, and the intended project work structure. Also included in this document are several basic design criteria for the SMMS project. The criteria in the engineering work plan will be removed via an ECN after this Design Requirements Document (DRD) is released.

The SMMS definitive design criteria, as they are currently understood, are contained within.

2.0 INTRODUCTION

Westinghouse Hanford Company (WHC) intends to measure the surface moisture in several different waste tanks. This document provides the design criteria for a SMMS.

To shorten the body of this document, only the criteria are presented. The Appendix A material is intended to assist the user of this DRD in understanding how these criteria were developed.

3.0 SYSTEM CRITERIA

As this project is a developmental effort, the criteria may not be fully attainable. Also, as the safety program is still refining which data they need to assure safeness, the criteria presented may change during the course of the project.

The SMMS system is conceptually comprised of:

1. Sensor (neutron probe)
2. Deployment Device
3. Data Acquisition Van
4. Decontamination System and Storage Hardware
5. In tank Vision System (camera)

3.1 SENSOR

The neutron moderation moisture probe has been selected as the first sensor technology to be deployed for surface waste moisture measurements.

The surface neutron moisture sensor should be optimally designed, based on experiments and modeling, to obtain sensitivity to waste moisture and to understand the depth of interrogation in the waste. Information from the top 5-15 cm of waste is desirable. Preference will be given to designs which may provide information about the moisture profile within that 5-15 cm depth.

The sensor package must fit through an available tank riser to sit on the waste surface. A deployment device can be used to control in tank placement.

The sensor package can use only one cable, to serve as a strength member as well as the instrumentation cable.

The neutron probe should be designed to obtain penetrating moisture data, up to a depth of 15 cm in very dry waste. Also, stratification information is desirable. Therefore, the probe should nominally provide at least three moisture indications, one of near surface only (4 cm), one of middle penetration (7 cm), and one of deepest penetration (12 cm). If the waste is wet, shallower average penetration depths will be acceptable.

The neutron sensing technique is sensitive to organic materials. Design of the probe should minimize potential organic effects whenever possible. It will be acceptable to estimate the amount of organic present, and use this information to adjust the sensor data during moisture data analysis.

The device should measure moisture in the range of 0 to 40% water based on the waste volume. Density estimates can be used to convert to weight percent estimates.

The final accuracy of the above sensor's measurement(s) should be +/-3 wt.%. [neglecting organic and unknown waste density effects]

High voltage to the detectors can be supplied by a power supply located within the probe head. The event signals from each detector can pass into a preamplifier for amplification and some shaping. Power to the probe head can be supplied by a 24 VDC cable. The signal pulses from the preamps can be transmitted to the acquisition system outside of the tank with two RG-174 cables contained in a custom built downhole cable. Alternately, time domain multiplexing may be employed using a single conductor cable.

The probe containment should adhere to Class 1, Division 2, Group B (NEC) hazardous location requirements. These requirements are defined in UL-1203. The enclosure will conform to the explosion proof structural requirements, but will not be proof tested. Upgrade of the equipment to comply with Class 1, Division 1, Group B requirements may not be possible later, and may require special certifications from nationally recognized testing laboratories.

The deployment cable should comply with the same Division 2 code.

Static electricity discharge prevention practices (applicable NFPA standards and guidelines) will be employed in the design of this system . Cables, which have plastic jackets, that roll over pulleys or other static charge inducing configurations shall have a semi-conductive jacket to drain or dissipate the static charge. The maximum surface and volumetric resistivity to ground for semi-conductive plastic will be less than 1 megohm, as tested per ASTM D257 or equivalent. [The resistance value of 1 megohm will dissipate static charge to prevent a static discharge. The plastic batch must be tested prior to extrusion. Therefore, testing of 1 mega-ohm on the finished cable can not be performed, but will be assured by pre-extrusion vendor documentation from the plastic's manufacturer.] Equipment presenting a static hazard will typically be bonded to a riser for field service, or use an acceptable alternate static control method.

The probe package will be designed so that the Cf-252 neutron source (approximately 16.0 μgram) can be removed easily and quickly and transferred to a radiological safe container, DOT 7A Type A, for source transportation. The source will be handled by standoff tools to provide ALARA conditions.

The probe package will be designed to withstand internal pressures of up to 500 psi. (This is the peak explosion pressure for hydrogen gas in the anticipated probe geometry).

The probe shall not break off the deployment arm at a load less than 2000 pounds. After a 400 pound load or greater, the conductors need not function anymore.

The maximum the neutron probe will weigh is 25 pounds, not including the deployment cable.

The neutron probe instrumentation package (in the tank) will include the following components: (1) one to four B^{10} lined neutron detectors; (2) a Cf^{252} source (~16 micrograms or equivalent) attached to a placement rod; (3) an adjustable high voltage supply (300 to 1600 VDC) sufficient to supply a maximum of four neutron detectors; (4) preamplifiers for the neutron detectors; (5) a temperature sensor; (6) equipment to transmit/receive signals/power via the probe cable; and (7) electrical safety barriers as necessary to comply with applicable NFPA code(s).

If more than one B^{10} lined neutron detectors are used, then a multiplexer or other switching system to allow the probe to transmit the amplified analog neutron event pulses to the up-hole instrumentation. One or more coaxial cables will be available in the neutron probe cable. The amplified and shaped neutron event pulses have a pulse height spectrum signature that must be observed to determine that the system is operating properly.

The signal cables will be attached to the data acquisition system located outside of the tank. These power/signal cable(s) will be supplied to the sensor package through a connector.

The neutron probe package (including the electronics and the neutron detectors) shall operate without loss in performance in gamma-ray fields up to 200 R/hr and at temperatures up to 190 degrees F (on contact with probe bottom touching the waste) for up to a 3 week continuous period. If some performance loss occurs at the extreme gamma-ray fields or temperatures, the system will account for this using a calibration correction to the moisture data.

The probe may be taken from freezing temperatures and placed into warmer temperatures, thus must be able to withstand condensation problems and still function.

The probe shall be constructed of material compatible with the waste surfaces it will encounter.

The package shall be able to perform approximately 30 inspections (per riser), 52 risers per year for 4 years with only minor repairs required. The cable and connector shall be able to withstand 300 inspections with minimal, if any maintenance.

The CF-252 neutron source has a half-life of 2.7 years and will need to be replaced periodically. The useful lifetime of the neutron source will be 3 to 5 years, (1 to 2 half-lives). This will be determined more precisely during the lab tests and calibration measurements.

The contact force generated between the crust and probe will be generated only by the probe's weight.

The probe surface that will contact the waste should be protected from contamination by use of some thin and chemically resistant barrier. This is primarily to ease decontamination of the probe during withdrawal.

3.2 DEPLOYMENT DEVICE

Manual operation of the deployment device is acceptable. The deployment may be somewhat restricted (from the optimal described below) if the riser is located near the tank wall or an adjacent riser contains equipment that interfere with the deployment envelope or if tank head space is limited.

The deployment system will interface with a portable field data acquisition system that controls sensor operation and records data.

The deployment system must interface with the sensor package, and fit through an available tank riser.

The deployment device may consist of a jointed arm that can be lowered through the riser into the tank airspace.

The deployment device should be able to rotate about the azimuth, 360 degree rotational freedom is optimal.

The deployment device should be able to place the sensor at a radius between 0 and up to 6 feet from the riser centerline. In certain cases, as determined by management, the reach may be limited to 3 feet maximum.

The deployment is to be monitored by an in-tank camera to determine the physical conditions and configuration of the sensor deployment. Incorporating an integral camera into the deployment arm or use of an existing in tank camera will be acceptable.

A decontamination system should be provided to allow remote cleaning of the sensor or deployment apparatus for ALARA considerations.

The deployment system will interface with a portable field data acquisition system that controls sensor operation and records data.

The deployment device must be able to place the sensor probe at least in sixty unique locations per tank (30 samples under one riser). Use of two different risers is anticipated.

The deployment device must be able to place the probe back to a previous test location, to allow moisture trending over time. The system should allow the user to repeat any measurements and at a higher spatial resolution to fill in missing gaps which were deemed necessary for further inspection.

The deployment device may rely on the use of field scaffolding in certain instances.

The deployment device will not be operated in a tank with less than 12.5 feet head space (distance between the riser stub inside the tank, and waste surface).

To help guide general design decisions, moisture measurement of one tank on a bi-yearly basis (once every other year) is considered adequate.

The deployment device does not need to be able to interrogate any large depressed surfaces, such as the craters caused by LOW installation, or salt well pumping.

The deployment device can be installed and removed with a crane.

The device must perform at least 28 complete test cycles with no failure. [A test cycle is considered placing the probe at 30 different locations under a riser].

If an integral camera system is selected, it should be designed so that it does not create a jamming potential under normal operation. In the event the camera does not retract correctly into the deployment device, and if the deployment arm will not settle back into position, the camera can be considered sacrificial. The camera, under these conditions, can be pushed down out of the deployment device, lowered to the waste surface, cut loose, and left inside the tank.

It is desirable, though not required, that the device should provide elevation data of the waste surface to +/- 1".

Electrical connections between the probe and data acquisition vehicle can be made after the probe is firmly sitting on the crust. [After the probe is positioned, the data acquisition system would be attached to a connector on the payout winch (drum) axle centerline, which is attached to the in tank probe via the downhole cable.]

Maximum outside diameter of the device shall be no greater than 3.60 inches to clear the minimum anticipated clear diameters of the 4" or larger risers. Concentricity of diameters is also to be maintained so that the device may fit down the riser.

Following deployment arm installation, the system should be designed to be operated with a minimal crew (nominally 2 persons). The winch systems at the riser top will be operable by one person and all above grade equipment in a surface contamination area (SCA) will be designed for use by personnel wearing personal protective equipment.

Probe position will be measured by visual gages or electronic encoders (as appropriate).

The SMMS deployment arm is to be decontaminated to acceptable levels prior to moving it from riser to riser or for storage. Decontamination with water during withdrawal from the tank should only be done if absolutely necessary to prevent interference with subsequent moisture measurements. Use of a riser liner will be evaluated, and if an acceptable liner is located, it will be used to limit the contamination spread to the SMMS deployment arm from the riser's past use.

Use of stainless steel for metal components is preferred. All materials must be compatible with the tank environment and provide surfaces easy to decontaminate.

Radiation dose to workers is to be minimized and in compliance with the Hanford Site Radiological Control Manual.

After the unreviewed safety questionnaire (USQ) is completed, the system shall be evaluated to assure compliance with all USQ required controls.

Worker exposure to non-radiological toxic and physical hazards are to be controlled in accordance with the WHC Tank Farm Health and Safety Plan (HASP) WHC-SD-WM-HSP-002.

During withdrawal of the deployment arm from the tank, it is desirable to maintain 100% contamination control, using glove bags, plastic sleeving, greenhouse(s), and other standard tank farm practices.

The deployment device must be designed with an acceptable safety factor for the normal operational loads expected. A stress analysis report will be prepared to document loads, and as-built safety factors.

The system shall not compromise the integrity of the tank. Seismic and impact loads must be considered in the design structural analyses. If an impact limiting system is required, it shall also be analyzed in the stress analysis report.

The deployment system must be designed in a way to prevent permanent jamming when removing the arm from the tank riser. Credit may be taken for operators to assist rotating the deployment mast and crane moving up and down slightly to facilitate re-entrance to risers.

The motion control of the deployment device (envisioned as winches) must be self locking, to prevent unintentional unspooling. A friction brake or worm geared system is acceptable.

The winch drums for the various cables (camera, probe, arm actuation) will have a minimum diameter of ten times the deployed cable diameter. The instrumentation cable(s) routing through the hub of the drum is acceptable. Slip rings or a suitable alternative will be used where monitoring is required while motion is occurring.

The support mast will be constructed of a stainless steel (SST) tube and will have an adjustable collar at the riser to adapt to different riser elevations. The top of the mast will sit on a bearing resting on the riser which will allow the SMMS to be rotated 360° about vertical axis.

An impact limiting system may be necessary, and would be placed somewhere between the riser and the deployment arm during installation.

An integral camera can be deployed into the tank from within the mast. Readings at the zero foot radial position may be taken with limited to no visual support, due to arm interference with the integral camera.

The deployment system has a mechanical interface to the instrumentation package, the riser, and the lifting crane.

The deployment system has an electrical interface to the instrumentation cable, the downhole instrumentation package, and the computer system.

Device to be weatherproof to allow operation in any expected climate for several days duration.

The contaminated systems may be stored outside in a suitable package.

The hardware installed into the tank(s) are to be decontaminable and shall be contoured to allow "snag free" removal from riser.

The deployment system will be designed to operate in a temperature range of 0 to 100°F and in tank temperatures of 70 to 200°F. The in tank radiation environment is expected to be less than 200 R/hr.

The cables can be evaluated on a periodic basis to assure premature failure does not occur.

3.2.1 Prioritized Tank List

1) BY-110
2) BY-108
3) BY-104
4) BY-105
5) BY-103
6) BY-106

7) B-103

8) TX-118
9) TX-105

(List may change as requested by Project Management. If the list does change, this document need not be revised, unless significantly different interface equipment is required.)

3.2.2 Risers

The deployment device must use only one riser to place the probe in position. It is desired that the device fit through standard 4 inch or larger risers on the tanks.

3.3. **DATA ACQUISITION VAN**

The data acquisition system (DAS) must allow real time data analysis capability in the field.

The DAS must record all raw data for post processing at the end of a work day. Data download must be possible in under 10 minutes.

The DAS will be stored inside a van.

The SMMS will be a stand-alone system with no connections to existing tank farm control systems. Power for systems operation will be supplied as part of an equipment van. A computer system will interpret probe data in a real time mode to allow field placement and testing modifications. The field system must provide feed back to the operator concerning moisture readings.

The SMMS data acquisition is to be designed as an industrial hardened computer system, with a multichannel analyzer and support electronics (generator, wiring, etc.) mounted inside a van. The instrumentation should be located outside Surface Contaminated Areas, to the extent practical.

The data (at minimum) will consist of electronic compass data (azimuthal), arm angle of inclination, pulse quantity and height information from the neutron probe, and allow the operator to enter tank/riser location to tie this information to the data files.

All instrumentation, materials and software should be industry standard and be capable of modification or replacement with minor maintenance protocol. Documentation shall be available for all components and where pertinent shall include the part number, design drawings, software design descriptions, service and/or operations manuals.

SMMS instrumentation shall be capable of nuclear pulse counting with discrimination and the monitoring of radiological spectral data. The data acquisition system including the cable and signal conditioning electronics shall be capable of processing pulse rates (pulse height analysis and count data) up to 20,000 counts per second (cps). Data will be archived on a hard drive, and transferred to floppy disks for possible later analysis in the laboratory.

The system will provide power isolation for the downhole system utilizing 24 volt power for the downhole power supply and pre-amp.

All electrical wiring must comply with applicable NEC requirements.

The instrumentation van will be constructed to operate in most tank farm areas. The vehicle must have factory air conditioning. The vehicle should be able to idle in the field for several hours duration, with the A/C on, and not experience engine overheating. The van motor shall be protected against overheating, by an interlock system that will shut the van off if an overheat condition is occurring.

Operator interface will consist of a computer display and integral keyboard and camera controls. The console will be located to maximize access for the operator and service personnel.

The computer shall provide 8 MB of RAM and a 500 MB hard disk drive. It shall also have a minimum of three available ISA slots and a serial port. The computer system should be of an industrial strength that can better withstand the heat, vibration, and dust associated with transportation in a vehicle.

A graphical operator interface is planned for to simplify operation of the software. The interface should minimize operator use of the keyboard by providing easily understandable icons and automatic file naming conventions.

The computer system will interface with a multichannel analyzer and spec. amps [in a NIM BIN] via a GPIB bus. The computer also interfaces the electronic compass via a serial communication interface.

The software will acquire position information from an electronic compass and neutron count data from the MCA mounted in a NIM bin. This information will be combined with manual input position data (the radial distance from the riser) to provide a graphical representation of sampling results as they occur. This representation will be provided to the operator on the computer screen. In addition, the software will log the data to a file.

This vehicle will be self-contained, not requiring an external source of power.

Climate control will be accomplished with the vehicle's built-in heating and air conditioning systems.

The vehicle will have a 110 VAC power generation system with a battery-backed uninterruptable power supply (UPS) to stabilize power and provide uninterrupted power should the main system power stop operating. The system should be capable of operating at a minimum of six hours on battery power.

Provisions shall be made to allow a generator or site power to recharge the UPS batteries.

The Van will have sufficient lighting for instrument operation.

The Van will provide environmental protection for the console. Any hardware mounted outside the van will be able to withstand the typical Hanford environment.

Storage of the Data Acquisition and Control System when not in use will be in-doors.

The Data Acquisition and Control System is estimated to have a 10 year lifetime with normal preventative maintenance including replacement of short life components, such as cables and connectors.

3.4. DECONTAMINATION AND STORAGE

Primary decontamination of all in tank hardware shall be performed manually using existing decontamination techniques.

A water based decontamination system will be developed that can reduce the radiation level of the probe and deployment system to allowable levels when the system is withdrawn from the tank. Use of water will only be authorized if radiation dose rates exceed those established in the work package during equipment removal.

The water based decontamination system should be configured to provide cleaning to the flat bottom face of the neutron probe during withdrawal, while minimizing the potential of water splashing up and out of the riser during use. Use of the water based system is strongly discouraged, to prevent further water addition to the area immediately below the riser.

Above grade, post withdrawal decontamination is required if contamination levels are too high to allow transport in a DOT 7A container.

A weather tight storage container that can also be used as a transport container is required for the deployment arm. The sources must have a DOT 7A cask to allow their transport. The other miscellaneous equipment, such as decontamination sprayers, impact limiting frame, etc will be decontaminated sufficiently to allow transport to the next test location. No disposal containers are required, as the equipment will be portable plant equipment for many years. If any component becomes damaged beyond repair, it will be cut into sections and loaded into standard 55 gallon drums for ultimate disposal.

The system will reduce the radiation levels of the system to less than 100 mR/hr contact maximum. The dose (from contamination) is expected to be much lower than 100 mrem/hour as only the probe touches the waste, and it will be protected in a disposable membrane.

The system will be designed to handle the pressures and temperatures of the decontamination material.

The system is conceived to be a conventional wash ring design as recently used in the viscometer and void fraction projects, discussed in WHC-SD-WM-SDD-043 & -046.

The wash ring assemblies have a mechanical interface to the riser and the deployment system. The pumps will be gasoline driven, and will have no electrical demand.

Any hardware mounted outside will be able to withstand the typical Hanford environment. Water systems are to be rust free and self draining. If they can not be made self draining, drain plugs shall be provided to facilitate winterization.

Storage of the spray ring, when not in use, will be in an approved storage/transport container or other operations approved area.

3.5. IN TANK VISION SYSTEM (CAMERA)

The vision system is a variation of an existing custom 2.8" diameter TV camera. It will be mounted inside the mast and lowered down below the mast after the arm is raised. The system will provide visual feedback for all in tank operations including instrument deployment and placement.

The system will have a viewing range of 10', black and white only, and a 4:1 zoom. The system will have a 350° pan and 150° tilt capability, for 360° viewing. The system light sources must operate at under 80% of the auto-ignition temperature for gasses expected to be encountered in the hydrogen tanks. (Auto-ignition temperature definition per the applicable NFPA code)

Maximum OD is 2.8". At least one flat side must be present to route a 3/16" OD cable by the camera.

Maximum camera length is 42" long, including the gas sensor interlock systems.

Camera must provide viewing for a 3 week duration in a 300 R/hour radiation field.

Camera must be supported by one cable, which provides the lifting strength member as well as all signal interface for the camera system.

Camera instrumentation cable can not exceed 0.75" OD.

It is currently understood that a non-classified system may be operated in a non-classified hydrogen watchlist tank, as long as the activity being monitored is non waste intrusive, and the camera system becomes de-energized if a gas release is detected. The de-energization must be completed before an LFL condition is attained near the camera system. Thus, the general criteria is as follows: The camera system must be able to safely operate in a non-classified hydrogen watchlist tank. It is recognized that this camera system will not be suitable for operation in any NFPA hazardous classified tank. The acceptability of this design approach must be discussed and approved in the USQ documentation.

(A camera that can meet Class I, Division 2, Group B is being developed, but will not be ready for a December deployment. This camera may be installed in the SMMS deployment arm so that the SMMS system can someday be operated in a hazardous (Class I, Division 2, Group B) location.))

Operation of camera pan, tilt, zoom must be completely remote controlled, and able to be computer driven through the computer control system.

Position of pan/tilt to be encoded.

The vision system must be able to confirm the neutron probe is in contact with the waste surface. The system must be able to detect if the probe tips as a result of uneven waste surfaces.

Video signal may be real time, and capable of being recorded in the American format (NTSC). Delay due to integration of signal is acceptable.

Camera must be splash proof, to survive decontamination.

Camera must interface with the deployment arm dedicated winch, and any local connections for signal/power input/output.

Camera deployment cable shall be designed for a 100 lb. working load (4 times weight of camera system), and 300 lb breaking load. Conductors need only survive the 100 lb load.

Absolutely no exposed aluminum, anodized or not, is allowed to enter the tank space unless it is contained in a fashion which prevents any waste contact under accident conditions evaluated in the safety bases.

The deployment cable must have a conductive plastic jacket.

The camera must shut off all spark sources (lights, motors, etc) prior to igniting a gas release. The shut off system, currently envisioned as a pair of gas sensors, must meet safety class 1 requirements for the function of shutting of all camera spark sources after a release is detected. [This system is only qualified for use in non-classified, Hydrogen watchlist tanks.]

Camera must operate in temperature ranges from 0°F to 122°F maximum. Condensation must be considered when placing a cold camera into a warm tank.

A video signal must be made locally available to the deployment arm operator. The video signal must be capable of being recorded.

Control and TV monitor display will be mounted in the Instrumentation Van. Two 19" racks x 3.5" high, plus monitor. Estimated power requirement is less than 300 Watts.

The camera will remain an integral part of the deployment arm. It can be removed as required to perform general maintenance or repair when the deployment arm has been removed from the tank.

Use of the integral camera system in any hydrogen watchlist tank will require the safety class one (1) gas interlock system currently in development, described above.

4.0 SYSTEM OPERATIONAL SCENARIO

4.1 DEPLOYMENT

- Assemble downhole TV system into mast, if not already completed.
- Verify arm & mast lengths are adjusted for the tank to be tested.
- Hook-up instrumentation cables to the Van
- Install the greenhouse, decon sprayer, impact limiter to riser.
- Start-up van computer system and check the probe calibration.
- Rig and lift deployment arm and install in riser.
- Re-connect the camera and neutron probe cables to the monitoring system
- Raise arm.
- Lower TV System in tank
- Guide and lower probe onto waste surface

4.2 MOISTURE MEASUREMENT

- Take 6 readings in circular pattern.
- Raise probe, lower arm slightly, take 6 additional circular readings. Continue this routine until sufficient data is taken.
- Plot and analyze moisture data.
- Archive data.

4.3 RETRIEVAL

- Raise arm, retract camera, lower arm
- Raise probe to firm contact with lower arm.
- Secure electronics.
- Activate decon system only if absolutely necessary.
- Lift from tank with crane. Monitor radiation on SMMS.
- Put systems in transportation/storage containers.

5.0 CONCLUSION

Several comments have been incorporated into this design criteria over the last 2 months. It has been changed from an "FDC", to an "FDR", and finally to a "DRD". Regardless, it conveys the design criteria as they are currently understood.

A few comments from key people indicated that only criteria should be contained within this document, not the bases of the criteria. As the key design criteria bases were mostly developed prior to these types of comments, they were placed in the following appendix, with no further technical editing.

Thus, the following appendix is provided for information only. The only definitive criteria are those described in the main body of this document.

APPENDIX A

1.0 BACKGROUND

Radioactive wastes from defense operations have been accumulated in underground waste tanks at the Hanford site since the 1940s. Organic solvents were used in the defense production processing and were part of some of the waste streams. In the presence of oxidizing materials, such as sodium nitrate which is readily available in most tanks, ferrocyanide and many organics may undergo exothermic reactions. Such reactions require sufficient fuel, oxidizer, and temperature in order to occur. Given that there is sufficient oxidizer present in tanks and that the fuel content is unknown, but potentially sufficient to allow a reaction, all that may be required to initiate a reaction is a large rise in waste temperature. Certain initiators that could provide the energy for this rise in temperature may be considered credible. Therefore, the possibilities of reactions exist, and if started, could conceivably propagate undesirable consequences.

The reaction initiation and/or propagation may be precluded by the presence of sufficient moisture in the waste. If sufficient moisture is present in a fuel-containing waste boundary between an initiated reaction and a dry stoichiometric mixture of fuel and oxidizer, then modeling predicts that the water will absorb the energy released from the reaction so that it will not propagate through the waste boundary (Meacham et al 1995). Because the credible reaction initiators would occur at waste surfaces, sufficient moisture in the top layers of waste would provide evidence that the tank waste is in a stable and safe form for continued storage.

In general, measurement of the average moisture concentration of the top 5-15 cm of waste may allow WHC to classify tanks as conditionally safe if the moisture content were greater than 20 weight percent (wt.%). If surface moisture is less than 20 wt%, the waste can be sampled and analyzed for fuel concentration in order to determine if the waste is safely stored. Note that the 20 weight percent number is subject to change as the potential in tank reactions become better understood.

WHC has been developing instruments for measuring waste moisture profiles for tanks that contain liquid observation wells (LOWs). LOWs are pipes, sealed on the bottom end, that have been installed in about 60 Hanford site tanks from the above ground risers to near the tank bottom. Neutron probes and electromagnetic induction (EMI) moisture probes are the preferred technologies at this time. The neutron probe infers the moisture content of surrounding wastes by measuring their neutron moderating properties. These properties are a strong function of the hydrogen concentration of the waste which is primarily related to the water content. The EMI probe infers the moisture or hydraulic content of the waste. This is accomplished by inducing an electrical current in the waste and measuring the waste conductivity, which is primarily a function of the moisture content. The data available from LOWs can be used to augment surface measurements.

Computer models have been constructed to aid in both the design of these probes and in the interpretation of data obtained with these probes. The responses of the prototype neutron probes have also been calibrated in waste moisture simulants. While both the neutron moderation technique and the EMI technique have been used in the well logging industry for many years, the neutron technique is currently at a more advanced stage of development for in-tank application. Other techniques for moisture measurement include optical reflection techniques, such as near infrared scattering. These optical techniques are even less developed for in-tank application and only obtain moisture information from a depth of less than about 1 mm into the waste.

2.2 PLANNED SURFACE MEASUREMENT APPROACH

Surface moisture measurements from within LOWs have limitations, caused primarily by the way individual LOWs were installed. Various air gaps and other irregularities exist near the waste surface, that lead to very complex data reduction problems when using a neutron probe. Also, use of LOWs is limited if much of a tank's surface must be mapped for moisture. Therefore, the direct surface moisture measurement will be accomplished with an in situ sensor, deployed on a custom arm, through an available riser tank riser.

2.2.1 Sensor Selection

The neutron moderation moisture probe has been selected as the first sensor technology to be deployed for surface waste moisture measurements because of both its advanced state of development and its expected capability to rapidly meet the data needs. Other sensors may be deployed later, as needed, if the results of their development demonstrates their capability to obtain needed data. Because of the likely presence of organics in the tank wastes of interest, it is expected that the neutron probe data may benefit from additional supporting data, most likely from available samples, data obtained from the LOW with neutron and EMI probes, and possibly an EMI surface probe.

Determination of an optimal design for the surface neutron moisture sensor, given mechanical constraints, is desirable. Both computer modeling of detector responses and experimental tests will be performed in order to select the best configuration of the sensor package. These tests and computer predictions will be used to determine the expected sensor sensitivities to waste moisture and to anticipate the sensor depth of interrogation in the waste. Optimization of sensor design, to best obtain information from the top 5-15 cm of waste will be attempted. Preference will be given to designs which may provide information about the moisture profile within that 5-15 cm depth. The tests and modeling will also provide a better indication of the expected moisture measurement accuracy that will be attained with the designed sensor.

2.2.2 Deployment

The approach for deployment of the sensor instrumentation package will be to lower a deployment system and sensor package through an available tank riser to the waste surface. The deployment device is expected to consist of a jointed arm that will be lowered through the riser into the tank airspace. The arm will then be rotated through a controlled angle, positioning the probe (suspended from the end of the arm) at a radius between 0 and about 2 meters from the riser centerline. The arm will guide the probe deployment cable. The deployment cable will both mechanically lower the probe to the waste surface and will allow transmission of necessary power and sensor signals.

The arm will be operated from the surface and will allow for probe deployment anywhere within about a 2 meter radius circle under a typical riser. Manual operation of the probe deployment is acceptable. The deployment may be somewhat less if the riser is located near the tank wall or an adjacent riser contains equipment that interfere with the deployment envelope or if tank head space is limited.

The deployment is to be monitored by an in-tank camera to determine the physical conditions and configuration of the sensor deployment. Incorporating an integral camera into the deployment arm or use of an existing in tank camera will be acceptable.

A decontamination system should be provided to allow remote cleaning of the sensor or deployment apparatus for ALARA considerations.

The deployment system will interface with a portable field data acquisition system that controls sensor operation and records data.

3.0 UNDERSTANDING OF THE PROBLEM

3.1 OVERVIEW

Chemical safety vulnerability of the Hanford waste includes concerns related to potential uncontrolled condensed phase chemical reactions involving ferrocyanide and various organic substances. The waste forms are sludges and salt cakes which contain oxidizer and various quantities of water and/or fuel. Ample amounts of fuel and oxidizer materials may exist in some of the tanks to create unsafe chemical conditions that, given an ignition source, could lead to homogenous runaway and propagating chemical reactions. The presence of a minimum amount of water in the waste will stop the reaction (Ref.1).

The forces holding moisture in saltcake are far weaker than those exhibited in sludges. Less is known about the moisture content and profiles in saltcake than for sludge, in large part because of limited sample data (Ref.2). The moisture content of sludges generally varies between 18 to 65 wt%. (Ref. 2) which is uniformly distributed. Sludge drying studies now underway will determine the amount of surface drying that can be expected in exposed sludge, but the TOC values for sludge are generally extremely low. Potential problems in sludge seem less probable than in saltcake. Saltcake does not intrinsically retain sufficient moisture (i.e., greater than 20 wt%) to completely rule out propagating chemical reaction.

Since ferrocyanide is not believed to be present in saltcakes (Ref.2), only organic fuel oxidizers reactions in saltcake will be discussed further. Note that the information in section 3.0 is subject to change, but is briefly presented here to help the design staff appreciate the complex nature of the safety concern.

3.2 ORGANIC - NITRITE/NITRATE REACTIONS

Organic bearing sludge and salt cake waste resulted from the need of removing Cs-137 and other fission products from the various waste streams. Organics added to the high level wastes including non-salt volatile organic substances like tributyl phosphate [TBP], normal paraffin hydrocarbon [NPH] and the non-volatile salt complexesants such as tetra-sodium ethylenediamine tetra acetate [EDTA], trisodium hydroxyethylenedimine triacetate [HEDTA], sodium citrate and sodium hydroxyacetate. Degradation of some of these compounds has occurred over time to produce substances like dibutyl phosphate [DBP] and sodium oxalate. These organic bearing wastes contain large amounts of oxidizer material [$NaNO_3$/$NaNO_2$] and various quantities of water.

The list of expected organic fuel is shown in Table 3-1. The first four organics in the table are not found to exhibit propagating reactions (Ref.1). The most susceptible organic fuel in Table 1 to be concerned about is sodium acetate (Ref. 1). For this fuel, the Total Organic Carbon (TOC) should satisfy the following inequality to prevent any propagation reaction (Ref. 1).

$$TOC\ (\%) < 4.5 + 17\ x_w\ , \qquad x_w < 0.2 \quad (3\text{-}1)$$

where x_w is moisture by Wt. %

For zero moisture, the inequality (3-1) predicts a value around 4.5% TOC for sustained propagation. This compares well to the lowest measured value of about 6% TOC for sustained propagation, a margin of safety of about 33%.

TABLE 3-1

Fuel	Formula
Dibutyl Phosphate	$(C_4H_9)_2\ HPO_4$
Tributyl Phosphate	$(C_4H_9)_3PO_4$
Al Dibutyl Phosphate	$Al[C_4H_9)_2PO_4]_3$
Na Dibutyl Phosphate	$Na(C_4H_9)_2PO_4$
Na Acetate	$NaC_2H_3O_2$
Na Oxalate	$Na_2C_2O_4$
Na Citrate	$Na_3C_6H_5O_7$
Na Sterate	$NaC_{18}H_{35}O$
Na_3 HEDTA	$Na_3C_{10}H_{15}O_7N_2$

Again, it has been shown that free moisture content greater than 20 wt% will prevent combustion for all anticipated fuel-oxidizer concentrations. It has also been shown that a bound moisture in the fuel greater than 20 wt% will prevent combustion for a stoichiometric mixture (Ref.3).

Although moisture levels well below 20 wt% may be possible with salt cakes, it is important to note that the non-volatile sodium salt organic appear to be highly soluble (Ref. 3) implying that the salt cakes are lacking such fuels, except the possibility of sodium oxalate. Further studies are on-going to quantify the precipitation of fuel in the saltcake.

In the case of sodium oxalate, it is largely insoluble in the supernatant solution and it could be present in the salt cake in the form of solids. The worst case scenario would be a stoichiometric condition. However, Fauske (Ref. 1) has shown experimentally that such a condition would not sustain a propagation even in the complete absence of water, because of low energy content.

Studies are underway to relate the lower bound of free moisture content in saltcakes to the relative humidity in the tank head space. For relative humidity values below 75%, Fauske (Ref. 1) has shown that the moisture level can be related to the amount of NaOH present. For relative humidity above 75%, the equilibrium moisture can be related to $NaNO_3/NaNO_2$. At 55% relative humidity, the experiment has shown that 5 wt% NaOH would result in a equilibrium moisture value of about 15 wt%. At relative humidity of 75% or higher, the moisture level is at least equal to ($NaNO_3/NaNO_2$) wt% present in the waste. These relations could help estimate the moisture levels, knowing the head space relative humidity and oxidizers concentrations.

3.4 DEPTH RANGE OF SURFACE MOISTURE PROBE

The surface probe requires two key design criteria: "How much surface area to scan, and how deep should a scan look". The surface area can be addressed by using longer arms, or more risers. Depth of measurement is a more complicated issue. The below discussion discusses technical work that may change with time, but provides insight to where moisture data should be obtained.

[LOW scans run from the tank waste surface to the tank floor. However, accurate moisture measurement using an LOW is not possible near the waste surface because of the large and irregular air gaps around the LOWs near the waste surface.]

Fauske briefly analyzed a transient heat transfer problem with a 1500 degree C source temperature on the waste surface. Assuming a totally dry material, of no fuel value, 200 degree C was reached in 1 hour at a waste depth of 14 cm. This calculation is useful to validate how deep an auger sample should be to confirm the lack of fuel. However, for moisture measurement criteria, this calculation provides little insight.

Fauske has continued his work on initiators. He is developing a relation between energies of initiators vs. reaction propagation of stoichiometric waste mixtures. In simple terms, a small initiator may not light the waste, where a larger initiator may. The maximum energy of organic tank waste has been conservatively determined as 1200 J/gram.

In discretized terms (looking at a 1 mm waste layers), the heat energy from an "ignited" layer is driven down to the next layer. In this approach, the initiator is assumed to have ignited the top layer, then the initiator ceased providing energy input. Sustained reaction occurs as the energy released from each layer is assumed to propagate downward, and initiate a reaction in the next lower layer. In all cases, per Fauske's work, a waste layer containing 20% by weight moisture will cause the waste reaction to terminate.

Assuming stoichiometric mixtures are present, and an initiator of sufficient energy ignites the first waste layer, there is some amount of waste burn that can be tolerated before unacceptable consequences happen. There has been no published work done to date concerning "how much waste can burn?". For instance, if only 2 cm can burn before the tank dome ruptures, obviously the moisture probe must confirm that by 1.9 cm deep, a layer of 20% moisture exists. Likewise, if 30 cm could acceptably burn, moisture data to a depth of 30 cm would be desirable.

The above focuses on an initiator purely from the waste surface. A second possibility is that an initiator penetrates to some distance under the surface due to kinetic energy. Thus, the potential initiators and energy magnitudes clearly dictate how deep to acquire moisture data.

There have been studies to examine accident scenarios to determine the size and weight of potential initiators and the likely distance an initiator would penetrate (Ref. 4). The potential initiators that have been postulated, such as hot slag from welding, sparks from grinding, or burning gasoline, do not have a large mass and would probably not penetrate very far, especially for the case of salt cake waste which is hard. The objects could penetrate deeper in the sludge waste, but sludges generally retain considerable water and therefore do not pose a propagation hazard unless the surface is dried. Note that it is possible for an object to fall along the gaps in the saltcake around LOWs and saltwell pumps.

Since much of the above analysis is being performed, or will be performed at a later time, the neutron probe should be designed to obtain penetrating moisture data, up to a depth of 14 cm in very dry waste. Also, stratification information is important. [ie: if analyses indicate that only the top 2 cm can burn before tank failure]. Therefore, the probe should provide at least three moisture indications, one of near surface only (2 cm), one of middle penetration (6 cm), and one of maximum penetration (14 cm). If the top waste is wet, the deeper penetration is less important, and the 14 cm criteria is less critical to measurement success.

3.5 SURFACE AREA REQUIRED

The SMMS system is intended to inspect approximately 2% of the tank area per riser entry. The SMMS system does not truly satisfy a random sampling criteria. However, it is stated [ref. 6] that the tanks are probably uniformly mixed, i.e. one sample would probably be representative, so that a sampling of two risers with 30 data point each would seem to be a conservative approach. If the spread in data being taken indicates a non-uniform condition, then more data samples may be required. The statistics of sampling in a tank will be dynamic, that is the on-going statistics will determine the requirements for the total data to be taken.

Until better statistical work is performed, or more in situ data become available, sixty samples per tank (30 samples under one riser) under two different risers will be sufficient.

3.6 DATA USE

Data analysis will be done by a computing system and engineering personnel in the field. More highly refined analyses may be performed later by using data transferred by disk. The analyzed data will be used by TWRS safety programs personnel to determine the state of the waste. If the waste is dry, safety programs will determine whether to take actual samples and send them to the laboratory, or to add water to the waste to assure interim waste stability, or propose another suitable alternative. As the program grows, a comprehensive data management plan may have to be formulated.

Moisture measurements away from riser centerline will allow WHC to address the representativeness of a typical auger sample. Concerns have been voiced that condensation and past riser use may have left a local wet spot under a riser, which may invalidate sample usefulness for moisture measurement.

3.7 TARGET TANKS

The primary tanks of interest are 20 tanks on the organics watch list [Ref. 9]. These are tanks judged to have the fuel potential to burn given an ignition source.

An additional 8 organic tanks have been judged as conditionally safe, see (Ref. 6). These tanks have not been sampled, but from a statistical study it has been determined that they may have the fuel potential to burn given an ignition source.

Tanks with saltcake waste are expected to be the driest. The sludge phase generally retains more moisture than saltcake, and typically has little organic waste. Saltcake doesn't intrinsically retain sufficient moisture (i,e., greater than 20 wt%) to completely rule out propagating chemical reactions. Specific conditions of fuel, moisture and temperature are required to support a condensed-phase propagating chemical reaction. Previous investigations indicate that all of the following conditions should be met simultaneously to sustain a chemical reaction.

TOC more than 4.5 wt%

Moisture less than 20 wt%

Temperature more than 200°C

The SMMS field schedule requires a prioritized list of tanks. The priority was established considering tank TOC estimates and tank physical locations. Also, supernate tanks will not be tested until they are stabilized. Saltcake tanks have priority over sludge tanks. The prioritized list of tanks to test is below. BY-104 (not an organic tank) was chosen as the debut tank, as it has an LOW and two recent auger samples and gas sampling data, giving good sources of comparative data.

Prioritized Tank List

East Area

1) BY-104
2) BY-103
3) BY-105
4) BY-106
5) BY-108

6) B-103
7) C-102
8) A-101

West Area

9) S-102
10) T-111
11) TX-105
12) TX-118

The remaining 14 tanks are not to be surface moisture tested, as they have a supernate layer on top of them at this time.

AX-102
C-103
S-111
SX-103, 106
TY-104
U-103, 105, 106, 107, 203, 204
A-102
BX-110

3.7.1 Risers

It is intended to integrate a camera into the SMMS design. Thus, only one riser would be required to perform a surface moisture scan. However, statistically, testing may be required from more than just one riser per tank.

Tank waste level and head space below the risers are critical for design. The majority of the risers are outside pits, but many have instruments or equipment mounted in them. There are from four to ten 4" risers on each tank. There are also 6", 8" and 12" risers on the tanks that could be used with a deployment system adapter.

It is possible that some equipment will have to be removed from the risers to use the SMMS, but the retrieval of large equipment, the removal of weather coverings, and the use of fouled risers will be done only as a last resort. The use of open risers, observation port risers and breather filter risers is the baseline approach. Physical audits must be performed for the tanks of interest, photos taken and layouts made, to double check risers available and to determine the actual physical accessibility of the risers, equipment adjacent, etc. It should be noted that some risers are empty, but bent and un-useable.

Specific tanks, and their risers, will be investigated during the course of the design. Arm design modifications or field scaffolding may be required to assure one general design fits all the above tanks. A minimum of 12.5 feet head space, between the riser stub inside the tank, and waste surface, will be required to use the deployment arm.

[An alternate deployment design will be required for tanks with head space greater than 8 feet but less than 12.5 feet. This alternate design will most likely require the use of a 12" riser to attain the 2 meter nominal reach.]

3.8 FREQUENCY OF REQUIRED SAMPLING

The moisture content of waste is a figure of merit used to assess chemical safety of the tanks related to condensed-phase chemical reactions. It is important to determine the moisture loss over an operating period for the tanks to make sure it does not drop below the 20 wt% threshold. Fauske & Associate (Ref. 5) has evaluated the moisture evolution over a 50 year operating period and the general conclusions are:

- The only sludges which can potentially evolve long-term moisture contents below 20 wt% are those with initial moisture contents near about 26 wt%. But sludge typically has a high moisture content, 35% to 80% wt% (Ref. 5).

- Saltcake does not retain water as effectively as sludge for given humidity levels within saltcake tanks. The long-term moisture content of saltcake may only be assessed on an individual basis due to the time dependence of moisture level

Therefore, the initial determined moisture content and estimated moisture loss rates will drive the frequency that moisture monitoring must be performed to confirm continued safe storage. After the initial data are collected and analyzed, a monitoring system can be established as necessary. At this time, to help guide general design decisions, monitoring of one tank on a bi-yearly basis (once every other year) is considered adequate.

4.0 SUCCESS CRITERIA

Moisture knowledge near the waste surface is required. Although this knowledge may not by itself answer all of the safety questions of the tanks, it will provide important information which could drastically reduce the number of samples required. For instance, if the surface moisture levels in some of the tanks are 20 wt% or higher, there should not be a need for auger samples. If the surface moisture level is below 20 wt%, its value as well as its profile can be a guidance to the safety criteria. For example, if the surface moisture is above 15 wt%, it needs a large ignition energy source for a sustain chemical reaction. For lower moisture values, more sampling may be required, or one might add water to the waste to assure interim waste stability.

All safety concerns based on propagating waste reactions can be resolved if the moisture data shows that the waste is greater than 20% water by weight everywhere. Since it is unfeasible to test "everywhere", the waste should be tested from a surface contact sensor that can provide penetrating data from locations up to a depth of 14 cm under the waste surface. These results shall be combined with LOW moisture scans to allow conclusions concerning the surface and bulk moisture of a given tank's waste.

The surface monitoring will probably be unable to interrogate any large depression surfaces, such as the craters caused by LOW installation, or salt well pumping. The surface moisture data will have to be augmented with LOW scan data to address bulk tank moisture. Also, organic material can skew the neutron scan results. Therefore, an independent (and penetrating) moisture sensing technique, such as the EMI probe, may be required to independently confirm the neutron moisture probe data. Alternately, gas sampling data may provide insight into the amount and type of organic material near the waste surface.

The moisture monitoring efforts shall be considered successful if:

1) The weight percent water of the waste matrix can be determined from the surface to some depth, up to 14 cm under the free surface in selected areas.

2) The accuracy of the above measurement(s) is +/-3 wt.%. [neglecting hydrocarbon effects]

3) The placement and quantity of tests provide statistically useful information to the safety programs office to address their open safety issues.

The moisture monitoring efforts can also be considered successful if a wt.% water surface profile is developed that can address auger sample representativeness.

A tremendous cost savings can be realized if more than 3 auger samples can be eliminated.

As this project is a developmental effort, the above criteria may not be fully attainable. Also, as the safety program is still refining which data they need to assure safeness, the success criteria presented above may change during the course of the project.

5.0 NEUTRON SENSOR DESCRIPTION, FUNCTIONS AND DESIGN REQUIREMENTS

In this section, we discuss the moisture data requirements for determining the surface moisture content of the tanks, the neutron thermalization technique used to measure the moisture, the sensor design, and functional and design requirements for the sensor.

5.1 MOISTURE DATA REQUIREMENTS

As discussed in Section 3, the waste moisture content required to prevent a propagating reaction varies linearly from 0 to 20 wt.%. Above 20 wt.%, the fuel-moisture linear relationship no longer holds because the mixture becomes liquid continuous. A stoichiometric fuel-oxidizer mixture will not propagate when the moisture exceeds 20 wt.%. From the safety analysis, the minimum information required would be to know the moisture level of the exposed waste surface. If the moisture level of the exposed surface exceeds 20 wt.%, we are ensured that an initiator cannot start a fire. At this time, we understand that this data would provide sufficient information regarding the tank's safety.

However, it is also recognized the very top surface could be much dryer than a few centimeters down, from various chemical reactions and tank ventilation. Therefore, as the safety analysis evolves, we may find that it is desirable to know the moisture gradient over several centimeters within the waste. Exactly what moisture depth is required for the gradient has not been identified, however, we plan to determine as much of the gradient as possible with the moisture sensor we have chosen for these measurements.

The moisture data should be accurate enough to determine the moisture level to within 3 wt.% to a depth between 5 and 15 cm, in the complete absence of organic materials. Examination of the tank surface moisture should occur below one or more of the available 4" (or larger) risers found within the tank under inspection. A surface area below each riser with a diameter of approximately 12 feet (366 cm) will be scanned. About 15% of this area (as defined by the 6' radius) will be examined. Measurements should be made in a way to avoid large gaps in the data. The system should allow the user to repeat any measurements and at a higher spatial resolution to fill in missing gaps which were deemed necessary for further inspection. The scan can be conducted by fixing the radius and inspecting azimuthally around the center line defined by the riser.

The device should measure moisture in the range of 0 to 40% water based on the waste volume. Density estimates can be used to convert to weight percent estimates.

5.2 SENSOR SELECTION

To measure the surface moisture of the tank waste and meet the requirements discussed in Section 5.1, a probe based upon the thermalization of neutrons emitted by a radioisotope source presents the least development risk to WHC. In this section, we discuss the neutron thermalization technique, how it will be applied to these requirements, and discuss the open questions that must be answered to finalize the design.

5.2.1 Overview of the Neutron Thermalization Technique

To measure the amount of moisture in the surface waste, we will use a technique based upon neutron thermalization. This technique has been used for many years in other applications to measure moisture on the surface of soil and within oil-logging holes. In this method, neutrons are emitted by a source (usually from a radioisotopic source) out into the material under inspection (the waste, in this case). The source neutrons, which initially have an average energy of about 2 MeV, scatter from the nuclei of the waste and lose some energy each time they scatter. Because they have the same mass, the neutrons lose most of their energy, and most quickly, when they scatter from hydrogen nuclei (protons). The neutrons scatter several times and eventually slow down to thermal energies (0.025 eV). A thermal neutron sensitive detector located near the neutron source detects source neutrons which become thermalized by the hydrogen within the waste and scatter back to the detector. The more water present, the more hydrogen and the greater the count rate in the thermal neutron detector. So the detector count rate can be related to the hydrogen content (moisture and organics) of the waste material.

This technique has been applied to LOW measurements (Ref. 8) and to the cone penetrometer (Ref. 7). In each case, the neutron thermalization is used to measure the amount of bulk moisture (or water level) within the tank waste. In each of these applications, two detectors are used with the neutron source. The ratio of the two detector count rates (near field vs. far field) has been shown theoretically and experimentally to be very sensitive to the moisture content and very insensitive to the amount of neutron absorbers present within the waste. Furthermore, the use of a "near-far" configuration allows the examination of the waste over different volumes with different depth profiles. This type of arrangement could permit the identification of a moisture gradient to several centimeters within the waste.

The neutron detector baseline design is an ionization chamber lined with B-10. Thermal neutrons entering the chamber interact with the boron producing energetic charged particles which ionize the gas within the chamber. A central wire biased to about 500 to 700 Volts collects the charge produced by the recoil particles. The pulses generated are sent to a preamplifier and then to a spectroscopic analyzer for shaping and amplification. A scalar or multichannel analyzer (MCA) would be used to record the pulse(s) caused by each neutron event.

5.2.2 Application of the Neutron Sensor to the Present Task

We anticipate using two or three neutron detectors, one right next (near detector) to the neutron source (Californium, Cf-252) and the others several inches away (far detector). The detectors would be enclosed in a hermetically sealed package and set down on the surface so that each detector is separated from the waste surface by only the thin wall of the package. In this geometry, the near detector examines the waste a few inches directly below the detector and the far detector examines a larger and separate volume.

Other geometry's are also being considered. For example, a package with a near detector positioned horizontally and located next to the waste surface, and one or two additional detectors also positioned horizontally but directly above the near detector. The idea here is that the near detector would be sensitive to neutrons which penetrate deep into the waste, and the other detectors would be more sensitive to neutrons thermalized nearer to the waste surface. This will be studied with Monte Carlo-based modeling and lab tests as described in Section 5.2.3. To reduce affects caused by the presence of neutron absorbing materials (such as boron) within the waste, we will consider surrounding the detectors with a thin sheet of cadmium. The cadmium absorbs the thermal neutrons and permits only epithermal neutrons (energies above 0.3 eV) to pass into the probe for detection. Epithermal neutrons are much less affected by the neutron absorbers which react mainly with thermal neutrons. Furthermore, epithermal neutrons examine a smaller region of the waste since they have experienced fewer scatterings than completely thermalized neutrons.

High voltage to the detectors would be supplied by a power supply located within the probe head. The event signals from each detector would pass into a preamplifier for amplification and some shaping. Power to the probe head would be supplied by a 24 VDC cable. The signal pulses from the preamps will be transmitted to the acquisition system outside of the tank with two RG-174 cables contained in a custom built downhole cable. Alternately, time domain multiplexing may be employed using a single conductor cable.

5.2.3 Modeling and Lab Tests to Address Open Questions

Several questions about the performance of the detector probe remain open and will be studied using both Monte Carlo based neutron transport modeling (MCNP) and laboratory simulated tests. These questions include: choosing the best overall geometry (e.g., the near-far geometry lying horizontally or vertically), optimizing the selected geometry, studying the affects of neutron absorbers on the detector response, studying the affects of uneven surfaces on the detector response, examining the penetration volume of the neutrons emitted into the waste and detected by the probe, and the ability of the probe to measure the moisture gradient within the waste.

Monte Carlo modeling will be used to examine these questions and to determine the amount of surface actually being examined by the source neutrons. Laboratory tests will be conducted at SAIC using available B-10 lined detectors and test beds to verify the results of the modeling results. The test beds will include layers of dry and wet sand (calibrated materials) to understand the response of the detectors in various geometries and to various moisture gradients.

5.2.4 Testing Plan

Earlier tests [Ref. 7] showed that the B-10 lined neutron detectors were capable of operating in an environment of 3,000 R/hr (gamma) and 250oF without any adverse performance effects. No additional radiation or thermal tests are required for the detectors.

The testing for the SMMS system will focus on measuring the response of B-10 detectors to stratified moisture layers of several depths to quantify and optimize the sensor response in the 2 to 14 cm region. The response of the detectors to two different levels of neutron absorber (boric acid) will validate methods for correcting the data for accurate measurements of moisture content in the presence of neutron poisons.

Previous testing at SAIC developed materials models for 14%, 19%, 25%, 31%, 47%, and 100% [wt. % water]. These tests used sand, gravel and volcanic rock mixtures fully saturated with water to simulate the waste with varying water contents. Small amounts of detergent and anti-rust were added to the water to prevent rusting of the mild steel barrels used for the tests. For the surface moisture tests 5 wt% and 10 wt% mixtures will be added to the available materials using polyethylene microbeads mixed with sand. These modeling techniques will be used for surface probe tests.

Stratification models will be assembled in shallow wash tubs using various moisture levels in layers from 2 to 14 cm thick. The layers will be separated by thin sheets of paper or plastic sheets. Measurements will be taken using B-10 probes in configurations determined from the calculational modeling program. Thin coverings of cadmium will be used on one detector to evaluate the value of measuring only epithermal neutrons.

The effects of neutron-absorbing materials on detector response will be studied using tubs contaminated with various amounts of boric acid. The amount of neutron absorbing material will be based upon the most conservative tank taken from the list of tanks above.

The barrels will be first filled with enough boric acid to achieve 50% the neutron absorption of the identified tank. Measurements will be made with and without a thin sheet of cadmium around each detector to absorb the thermal neutrons. After these measurements at the different moisture levels are complete, enough boric acid will be added to the barrels to achieve 100% the neutron absorption equivalent of the tank.

Also, calibration methods will be developed to verify sensitivity, accuracy, and required counting times. Tests will be performed as required to qualify the methods.

5.3 PERFORMANCE REQUIREMENTS

The accuracy of the measurements depends on statistical errors and on systematic affects. The statistical errors are related to the neutron count rates (which are affected by the size of the detectors, the neutron source, the source-to-detector distances, and the moisture level) and on the measurement time. Since there are many options for improving the statistical error (e.g., by increasing the measurement times or the source intensity), we anticipate that the statistical error will be insignificant, that is, much less than the required error of +-3 wt.% .

Systematic errors arising from, for example, the unevenness of the waste, the distance of the probes above the waste, and gain shifts in the electronics or detectors arising from changes in the temperature or high gamma-ray fluxes must also be quantified. These systematic errors will be studied with the modeling and in the lab experiments.

Unknown waste density, neutron poisons, and presence of hydrogen not in water form will also add to the overall system design uncertainty of +/- 3%. These effects shall be minimized, and must be quantified during the project to conclude the final overall error in the moisture probe reduced data.

5.4 SAFETY REQUIREMENTS

The probe containment should adhere to Class 1, Division 2, Group B (NEC) hazardous location requirements. These requirements are defined in UL-1203. The enclosure will conform to the explosion proof structural requirements, but will not be proof tested. Upgrade of the equipment to comply with Class 1, Division 1, Group B requirements may not be possible later, and may require special certifications from nationally recognized testing laboratories.

The deployment cable should comply with the same Division 2 code.

Static electricity discharge prevention practices (applicable NFPA standards and guideline) will be employed in the design of this system . All equipment will be electrically bonded. Cables, which have plastic jackets, that roll over pulleys or other static charge inducing configurations shall 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 1 megohm. [The resistance value of 1 megohm will dissipate static charge to prevent a static discharge. The plastic batch must be tested prior to extrusion. Therefore, testing of 1 megaohm on the finished cable can not be performed, but will be assured by pre-extrusion vendor documentation from the plastic's manufacturer.] All equipment will be bonded to a riser for field service.

The probe package will be designed so that the Cf-252 neutron source (approximately 16.0 μgram) can be removed easily and quickly and transferred to a radiological safe container, DOT 7A Type A, for source transportation. The source will be handled by standoff tools to provide ALARA conditions.

5.5 STRUCTURAL REQUIREMENTS

The probe package will be designed to withstand internal pressures of up to 500 psi. (This is the peak explosion pressure for hydrogen gas in the anticipated probe geometry).

The probe shall not break off the deployment arm at a load less than 2000 pounds. After a 400 pound load or greater, the conductors need not function anymore.

The maximum the neutron probe will weigh is 25 lbs, not including the deployment cable.

5.6 DESIGN DESCRIPTION

The neutron source and detector(s) shall be sized and geometrically arranged to aide in subsurface moisture data recovery. The ability to distinguish near moisture from far (deeper) moisture should be optimized (detect layering effects as best as possible).

The neutron probe instrumentation package (in the tank) will include the following components: (1) two to four B^{10} lined neutron detectors; (2) a Cf^{252} source (~16 micrograms or equivalent) attached to a placement rod; (3) an adjustable high voltage supply (300 to 1600 VDC) sufficient to supply a maximum of four neutron detectors; (4) preamplifiers for each of the neutron detectors; and (5) a temperature sensor.

If more than one B^{10} lined neutron detectors are used, then a multiplexer or other switching system to allow the probe to transmit the amplified analog neutron event pulses to the up-hole instrumentation. One or more RG-174 coaxial cables will be available in the neutron probe cable. The amplified and shaped neutron event pulses have a pulse height spectrum signature that must be observed to determine that the system is operating properly.

5.7 SUPPORT/INTERFACE REQUIREMENTS

For operation, the moisture sensor package will require 24 VDC supplied by an 18 AWG cable. The signal cables will be attached to the data acquisition system located outside of the tank. These power/signal cable(s) will be supplied to the sensor package through a connector.

The sensor package will be supported on an arm and lowered to the waste using the signal cable.

5.8 ENVIRONMENTAL DESIGN REQUIREMENTS

The neutron probe package (including the electronics and the neutron detectors) shall operate without loss in performance in gamma-ray fields up to 200 R/hr and at temperatures up to 150 degrees F for up to a 3 week continuous period. If some performance loss occurs at the extreme gamma- ray fields or temperatures, the system will account for this using a calibration correction to the moisture data.

The probe may be taken from freezing temperatures and placed into warmer temperatures, thus must be able to withstand condensation problems and still function.

The probe shall be constructed of material compatible with the waste surfaces it will encounter.

5.9 DESIGN LIFE REQUIREMENTS

The instrumentation package shall be designed to operate continuously for 3 continuous weeks. The package shall be able to perform approximately 50 inspections (per riser), 52 risers per year for 4 years with only minor repairs required. The cable and connector shall be able to withstand up to 10,000 total inspections under normal operating conditions.

The CF-252 neutron source has a half-life of 2.7 years and will need to be replaced periodically. The useful lifetime of the neutron source will be 3 to 5 years, (1 to 2 half-lives). This will be determined more precisely during the lab tests and calibration measurements.

6.0 DEPLOYMENT SYSTEM REQUIREMENTS

6.1 FUNCTIONAL REQUIREMENTS

The SMMS deployment arm can be installed and removed with a crane in a typical 4" (or larger) tank riser. It must perform at least 28 complete test cycles with no failure. [A test cycle is considered placing the probe at 30 different locations under a riser]. The minimum head height required for this will be 12.5'.

If an integral camera system is selected, it should be designed so that it does not create a jamming potential under normal operation. In the event of a failure, the camera can be considered sacrificial, be cut loose, and pushed into the tank from above.

Once installed, the SMMS deployment system can be manually controlled. The system should be able to place the sensing package (probe) on the waste surface up to 6 feet away from the vertical riser centerline, in various degrees of rotation about riser centerline. Winches can be used actuate arm rotation, camera deployment and sensing probe cables. Providing elevation data of the waste surface to +/- 1" would be an optimal feature.

Electrical connections between the probe and data acquisition vehicle can be made after the probe is firmly sitting on the crust. [After the probe is positioned, the data acquisition system would be attached to a connector on the payout winch (drum) axle centerline, which is attached to the in tank probe via the downhole cable.]

The contact force generated between the crust and probe will be generated only by the probe's weight.

The probe must be placed at various rotations about vertical centerline, at some radius (up to 6') away from riser centerline. [Rotational freedom can be restricted on a case by case basis if riser proximity to the tank wall or adjacent in-tank instruments is a factor. The radius may also be limited by the head space available in certain tanks.]

Maximum outside diameter of the device shall be no greater than 3.60 inches to clear the minimum anticipated clear diameters of the 4" or larger risers. Concentricity of diameters is also to be maintained so that the device may fit down the riser.

The neutron probe shall be able to be controllably deployed to assure crust irregularities do not affect data quality. A perpendicular orientation to the waste surface is acceptable, and may indeed be optimal.

Following deployment arm installation, the system should be designed to be operated with a minimal crew. The winch systems at the riser top will be operable by one person and all above grade equipment in an SCA will be designed for use by personnel wearing personal protective equipment.

Probe position will be measured by visual gages or electronic encoders (as appropriate).

For limited headspace tanks (between 8.5' and 12.5'), a 12" riser may be used, instead of a 4" riser. This application will require a different deployment mechanism, similar to the original design, but unique. This DRD mentions this application so the reviewers are aware of the first deployment mechanism's limitations. Funding is identified in 1996 fiscal year to build the limited headspace deployment system.

6.2 SAFETY REQUIREMENTS

The SMMS deployment arm is to be decontaminated to acceptable levels prior to moving it from riser to riser or for storage. Decontamination during withdrawal from the tank should only be done if absolutely necessary to prevent interference with subsequent moisture measurements. Use of a riser liner will be evaluated, and if an acceptable liner is located, it will be used to limit the contamination spread to the SMMS deployment arm from the riser's past use.

Use of stainless steel for metal components is preferred. All materials must be compatible with the tank environment and provide surfaces easy to decontaminate.

Materials should be non-sparking and be electrically grounded. Cable designs will utilize semi-conductive jackets.

Radiation dose to workers is to be minimized and in compliance with the Hanford Site Radiological Control Manual.

After the USQ is completed, the system shall be evaluated to assure compliance with all USQ required controls.

Worker exposure to non-radiological toxic and physical hazards are to be controlled in accordance with the WHC Tank Farm Health and Safety Plan (HASP)

WHC-SD-WM-HSP-002.

During withdrawal of the deployment arm from the tank, it is desirable to maintain 100% contamination control, using glove bags, plastic sleeving, greenhouse(s), and other standard tank farm practices.

6.3 STRUCTURAL REQUIREMENTS

- The arm and deployment mast are to be designed with an acceptable safety factor for the normal operational loads expected. A stress analysis report will be prepared to document loads, and as-built safety factors.

- The instrumentation probe cable connection will have a breaking strength of 2,000 pounds.

- The system shall not compromise the integrity of the tank. Seismic and impact loads must be considered in the design structural analyses. If an impact limiting system is required, it shall also be analyzed in the stress analysis report.

- The deployment system must be designed in a way to prevent permanent jamming when removing the arm from the tank riser. Credit may be taken for operators to assist rotating the deployment mast and crane moving up and down slightly to facilitate re-entrance to risers.

6.4 DESIGN DESCRIPTION

6.4.1 Winch systems

The deployment system will use several manual winches to lift the probe arm and lower the instrumentation package to the waste. There will also be a winch for the integral camera system. The winches must be self locking, to prevent unintentional unspooling. A friction brake or worm geared system is envisioned.

The winch drums for the various cables (camera, probe, arm actuation) will have a minimum diameter of ten times the deployed cable diameter. The instrumentation cable(s) routing through the hub of the drum is acceptable.

Slip rings or a suitable alternative will be used where monitoring is required while motion is occurring.

6.4.2 Support Mast (as applicable)

The support mast will be constructed of SST tube and will have an adjustable collar at the riser to adapt to different riser elevations. The top of the mast will sit on a bearing resting on the riser which will allow the SMMS to be rotated 360° about vertical axis. The camera will be deployed into the tank from within the mast.

6.4.3 Arm

The arm will be adjustable from vertical to 90° [horizontal]. The arm will allow the instrumentation package to be deployed at a varying radius of 0 feet up to 6 feet from the riser centerline. The arm will be raised by a cable. The instrumentation system will be deployed by a cable inside the mast and over the arm. The minimum cable bend radius is 5 times the cable diameters.

Readings at the zero foot radial position may be taken with limited to no visual support, due to arm interference with the integral camera.

6.4.4 Instrumentation Cable

The cable will have a 4000# breaking strength with a 2,000# breaking strength at the instrumentation package interface. The cable is (nominally) made up of 2 ea. RG-174 coaxial signal cables and 2ea. 18 Ga. shielded cables. The use of a Kevlar strength braid and a polypropylene semi-conductive jacket will be acceptable.

6.5 SUPPORT/INTERFACE REQUIREMENTS

The deployment system has a mechanical interface to the instrumentation package, the riser, and the lifting crane.

The deployment system has an electrical interface to the instrumentation cable, the downhole instrumentation package, and the computer system.

6.6 ENVIRONMENTAL DESIGN REQUIREMENTS

Device to be weatherproof to allow operation in any expected climate for several days duration. The data acquisition system will be stored indoors. The contaminated systems may be stored outside in a suitable package.

The SMMS is to be decontaminable and shall be contoured to allow "snag free" removal from riser.

The deployment system will be designed to operate in a temperature range of 0 to 100°F and in tank temperatures of 70 to 200°F. The in tank radiation environment is expected to be less than 200 R/hr.

6.7 DESIGN LIFE REQUIREMENTS

The cable specification shall require the cable to survive 10,000 cycles at working load (60 pounds). The deployment mechanical system should be designed for 10 years life with general preventive maintenance procedures. The cable should be evaluated on a periodic basis to assure premature failure does not occur once field operations begin.

7.0 DATA ACQUISITION AND CONTROL SYSTEM REQUIREMENTS

7.1 FUNCTIONAL REQUIREMENTS

The SMMS will be a stand-alone system with no connections to existing tank farm control systems. Power for systems operation will be supplied as part of an equipment van. A computer system will interpret probe data in a real time mode to allow field placement and testing modifications. The equipment will be easy to operate, for eventual turn over to tank farm operations.

The SMMS data acquisition is to be designed as a field hardened computer system, with a multichannel analyzer and support electronics (generator, wiring, etc.) mounted inside a van. The instrumentation will be located outside Surface Contaminated Areas, to the extent practical.

The data (at minimum) will consist of electronic compass data (azimuthal), arm angle of inclination, pulse quantity and height information from the neutron probe, and allow the operator to enter tank/riser location to tie this information to the data files.

All instrumentation, materials and software should be industry standard and be capable of modification or replacement with minor maintenance protocol. Documentation shall be available for all components and where pertinent shall include the part number, design drawings, software design descriptions, service and/or operations manuals.

SMMS instrumentation shall be capable of nuclear pulse counting with discrimination and the monitoring of radiological spectral data. The data acquisition system including the cable and signal conditioning electronics shall be capable of processing pulse rates (pulse height analysis and count data) up to 20,000 counts per second (cps). Data will be archived on a hard drive, and transferred to floppy disks for possible later analysis in the laboratory. A comprehensive data management plan may be warranted as the data library begins to grow.

7.2 SAFETY REQUIREMENTS

The system will provide power isolation for the downhole system utilizing 24 volt power for the downhole power supply and pre-amp. The in-tank electronics will comply with NEC intrinsic safety requirements for a Class 1

Division 2 Group B location. A detailed NEC compliance paper shall be prepared to address tanks, classifications, and compliance with those classifications.

All electrical wiring must comply with applicable NEC requirements.

7.3 STRUCTURAL REQUIREMENTS

The instrumentation van will be constructed with the capability for off-road use. The vehicle must have factory air conditioning. The vehicle must be able to idle in the field for several hours duration, with the A/C on, and not experience engine overheating. The van motor shall be protected against overheating, by an interlock system that will shut the van off if an overheat condition is occurring.

7.4 DESIGN DESCRIPTION

7.4.1 Control Console

It will consist of a computer display and integral keyboard and camera controls. The console will be located to maximize access for the operator and service personnel. It is intended to use a swivel based rack system that can be operated from the driver's seat or outside the passenger door.

7.4.2 Data Acquisition and Control

7.4.2.1 System Computer

The computer will be capable of running a windows style program and an accepted control type of software. At a minimum it shall provide 8 MB of RAM and a 500 MB hard disk drive. It shall also have a minimum of three available ISA slots and an RS-232 serial port. The computer system should be of an industrial strength that can better withstand the heat, vibration, and dust associated with transportation in a vehicle.

7.4.2.2 Operator Interface

A graphical operator interface is planned for to simplify operation of the software. The interface should minimize operator use of the keyboard by providing easily understandable icons and automatic file naming conventions.

7.4.2.3 Hardware Interfaces

The computer system will interface with a multichannel analyzer and spec. amps [in a NIM BIN] via a GPIB bus. The computer also interfaces the electronic compass via RS 232 interface. The multichannel analyzer will interface via 24v signals downhole to the 500v power supply and the two probe preamps. Downhole communication is through the custom cable detailed in 5.5.

7.4.2.4 Software Interfaces

The software will acquire position information from an electronic compass and neutron count data from the MCA mounted in a NIM bin. This information will be combined with manual input position data (the radial distance from the riser) to provide a graphical representation of sampling results as they occur. This representation will be provided to the operator on the computer screen. In addition, the software will log the data to a file.

7.4.3 Instrumentation Vehicle

7.4.3.1 Vehicle Structure

Above-tank instrumentation will be housed in a vehicle. The vehicle will provide ground clearance adequate to transverse typical terrain found in the tank farms. This vehicle will be self-contained, not requiring an external source of power.

Climate control will be accomplished with the vehicle's built-in heating and air conditioning systems. The vehicle will be no larger than a full size van to allow for maneuverability in the farms.

7.4.3.2 Power - UPS

The vehicle will have a 110 VAC power generation system with a battery-backed UPS to stabilized power and provide uninterrupted power should the main system power stop operating. The system shall be capable of operating at a minimum of six hours on battery power.

Provisions shall be made to allow a generator or site power to recharge the UPS batteries.

7.4.3.3 HVAC

The Van will have a HVAC system capable of handling the environmental and the instrumentation heat load. Preferably, this will be possible with only the stock HVAC systems supplied on the vehicle.

7.4.3.4 Lighting

The Van will have sufficient lighting for instrument operation.

7.5 ENVIRONMENTAL DESIGN REQUIREMENTS

The Van will provide environmental protection for the console. Any hardware mounted outside the van will be able to withstand the typical Hanford environment.

Storage of the Data Acquisition and Control System when not in use will be in-doors.

7.6 DESIGN LIFE REQUIREMENTS

The Data Acquisition and Control System is estimated to have a 10 year lifetime with normal preventative maintenance including replacement of short life components, such as cables and connectors.

8.0 DECONTAMINATION and STORAGE SYSTEM REQUIREMENTS

8.1 FUNCTIONAL REQUIREMENTS

Primary decontamination of all in tank hardware shall be performed manually using existing decontamination techniques.

A water based decontamination system will be developed that can reduce the radiation level of the probe and deployment system to allowable levels when the system is withdrawn from the tank. Use of water will only be authorized if radiation dose rates exceed those established in the work package during equipment removal.

The water based decontamination system should be configured to provide cleaning to the flat bottom face of the neutron probe during withdrawal, while minimizing the potential of water splashing up and out of the riser during use.

Above grade, post withdrawal decontamination is required if contamination levels are too high to allow transport in a DOT 7A container.

A weather tight storage container that can also be used as a transport container is required for the deployment arm. The sources must have a DOT 7A cask to allow their transport. The other miscellaneous equipment, such as decontamination sprayers, impact limiting frame, etc will be decontaminated sufficiently to allow transport to the next test location. No disposal containers are required, as the equipment will be portable plant equipment for many years. If any component becomes damaged beyond repair, it will be cut into sections and loaded into standard 55 gallon drums for ultimate disposal.

8.2 PERFORMANCE REQUIREMENTS

The system will reduce the radiation levels of the system to less than 100 mR/hr contact maximum. The dose (from contamination) is expected to be much lower than 100 mrem/hour as only the probe touches the waste, and it will be protected in a disposable membrane.

8.3 SAFETY REQUIREMENTS

System shall comply with all safety assessment (or USQ) requirements not currently listed in this document.

8.4 STRUCTURAL REQUIREMENTS

The system will be designed to handle the pressures and temperatures of the decontamination material.

8.5 DESIGN DESCRIPTION

The system is conceived to be a conventional wash ring design as recently used in the viscometer and void fraction projects, discussed in WHC-SD-WM-SDD-043 & -046.

A CO2 based system was briefly evaluated. A CO2 based system requires technical development before it can be reliably deployed in the field. Also, an exhauster will be required to prevent the tanks from becoming pressurized during use of a CO2 system. There was insufficient funding during fiscal year 1995 to develop the technology and supporting systems.

8.6 SUPPORT/INTERFACE REQUIREMENTS

The wash ring assemblies have a mechanical interface to the riser and the deployment system. The pumps will be gasoline driven, and will have no electrical demand.

8.7 ENVIRONMENTAL DESIGN REQUIREMENTS

Any hardware mounted outside will be able to withstand the standard Hanford environment specs.

Storage of the spray ring, when not in use, will be in an approved storage/transport container or other operations approved area.

8.8 DESIGN LIFE REQUIREMENTS

Design life goal is 10 years with normal preventative maintenance and replacement of high wear components.

9.0 VISION SYSTEM REQUIREMENTS

9.1 EXISTING SYSTEM CHARACTERISTICS

The vision system is a variation of an existing custom 2.8" diameter TV camera. It will be mounted inside the mast and lowered down below the mast after the arm is raised. The system will provide visual feedback for all in tank operations including instrument deployment and placement.

9.2 PERFORMANCE REQUIREMENTS

The system will have a viewing range of 10', black and white only, and a 4:1 zoom. The system will have a 350° pan and 150° tilt capability, for 360° viewing. The system light sources must operate at under 80% of the autoignition temperature for gasses expected to be encountered in the hydrogen tanks.

Maximum OD is 2.8". At least one flat side must be present to route a 3/16" OD cable by the camera.

Maximum camera length is 42" long, including the gas sensor interlock systems.

Camera must provide viewing for a 3 week duration in a 300 R/hour radiation field.

Camera must be supported by only one cable, which is also the instrumentation cable.

Camera instrumentation cable can not exceed 0.75" OD.

At this time, only 6 tanks (their dome spaces) on the Hanford site are an NFPA Class I, Division 2, Group B hazardous location. All other tanks are electrically non-classified. Project management had requested the entire SMMS system be qualified to operate in a Class I, Division 2, Group B hazardous location. However, other Hanford projects have funded a different design approach that has been accepted for the SMMS project.

This design approach allows a non-classified system to be operated in a non-classified hydrogen watchlist tank, as long as the activity being monitored is non waste intrusive, and the camera system becomes de-energized if a gas release is detected. The de-energization must be completed before an lower flammability limit (LFL) condition is attained near the camera system. Thus, the general criteria is as follows: The camera system must be able to safely operate in a non-classified hydrogen watchlist tank. It is recognized that this camera system will not be suitable for operation in any NFPA hazardous classified tank.

[A camera that can meet Class I, Division 2, Group B is being developed, but will not be ready for a December deployment. This camera may be installed in the SMMS deployment arm so that the SMMS system can someday be operated in a hazardous (Class I, Division 2, Group B) location.]

Operation of camera pan, tilt, zoom must be completely remote controlled, and able to be computer driven through the computer control system.

Position of pan/tilt to be encoded.

The vision system must be able to confirm the neutron probe is in contact with the waste surface. The system must be able to detect if the probe tips as a result of uneven waste surfaces.

Video signal must be real time, and capable of being recorded in the American format (NTSC).

Camera must be splash proof, to survive decontamination.

Camera must interface with deployment arm cable winch and slip rings.

Camera deployment cable shall be designed for a 100 lb. working load (4 times weight of camera system), and 300 lb breaking load. Conductors need only survive the 100 lb load.

Absolutely no exposed aluminum, anodized or not, is allowed to enter the tank space unless it is contained in a fashion which absolutely prevents any waste contact under any accident conditions evaluated in the safety bases.

The deployment cable must have a conductive plastic jacket.

The camera must shut off all spark sources (lights, motors, etc) prior to igniting a gas release. The shut off system, currently envisioned as a pair of gas sensors, must meet safety class 1 requirements for the function of shutting of all camera spark sources after a release is detected. [This system is only qualified for use in non-classified, Hydrogen watchlist tanks.]

Camera must operate in temperature ranges from 0°F to 122°F maximum. Condensation must be considered when placing a cold camera into a warm tank.

A video signal must be made locally available to the deployment arm operator. The video signal must be capable of being recorded.

Control and TV monitor display will be mounted in the Instrumentation Van. Two 19" racks x 3.5" high, plus monitor. Estimated power requirement at 110VAC is less than 1KW.

The camera will remain an integral part of the deployment arm. It can be removed as required to perform general maintenance or repair when the deployment arm has been removed from the tank.

9.3 SAFETY REQUIREMENTS

The SMMS integral camera system will not be electrically qualified to operate in any hazardous classified tank environment.

Use of the integral camera system in any hydrogen watchlist tank will require the safety class one (1) gas interlock system currently in development, described above.

10.0 SYSTEM OPERATIONAL SCENARIO

10.1 DEPLOYMENT

- Assemble downhole TV system into mast, if not already completed.
- Verify arm & mast lengths are adjusted for the tank to be tested.
- Hook-up instrumentation cables to the Van
- Install the greenhouse, decon sprayer, impact limiter to riser.
- Start-up van computer system and check the probe calibration.
- Rig and lift deployment arm and install in riser.
- Re-connect the camera and neutron probe cables to the monitoring system
- Raise arm.
- Lower TV System in tank
- Guide and lower probe onto waste surface

10.2 MOISTURE MEASUREMENT

- Take 6 readings in circular pattern.
- Raise probe, lower arm slightly, take 6 additional circular readings. Continue this routine until sufficient data is taken.
- Plot and analyze moisture data.
- Archive data.

10.3 RETRIEVAL

- Raise arm, retract camera, lower arm
- Raise probe to firm contact with lower arm.
- Secure electronics.
- Activate decon system only if absolutely necessary.
- Lift from tank with crane. Monitor radiation on SMMS.
- Put systems in transportation/storage containers.

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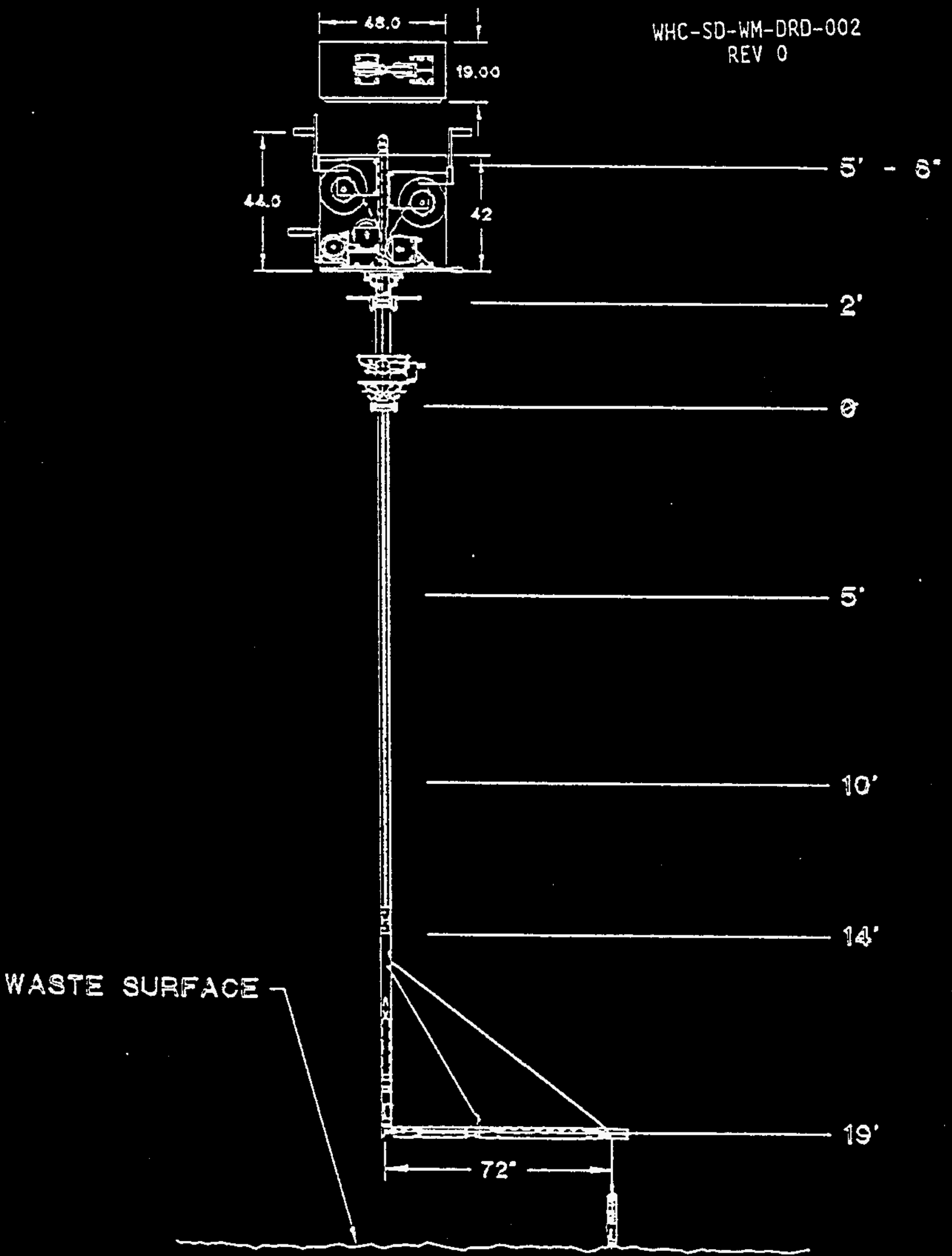

Moisture Probe in Measurement Position.
MOIST-1C