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7. Abstract

A Retained Gas Sampler System (RGSS) is being developed to capture and analyze waste samples from Hanford Flammable Gas Watch List Tanks to determine both the quantity and composition of gases retained in the waste. The RGSS consists of three main components: the Sampler, Extractor, and Extruder. This report describes the functional criteria for the design of the RGSS components.

The RGSS Sampler is based on the WHC Universal Sampler design with modifications to eliminate gas leakage. The primary function of the Sampler is to capture a representative waste sample from a tank and transport the sample with minimal loss of gas content from the tank to the laboratory. The function of the Extruder is to transfer the waste sample from the Sampler to the Extractor. The function of the Extractor is to separate the gases from the liquids and solids, measure the relative volume of gas to determine the void fraction, and remove and analyze the gas constituents.

CONTENTS

LIST OF TERMS

atm	atmosphere
CM	Control Manual
DA/CU	Data Acquisition and Control Unit
DOE	Department of Energy
DST	Double-Shell Tank
EP	Engineering Practices
EPA	Environmental Protection Agency
FGWL	Flammable Gas Watch List
PSIG	Pounds per Square Inch Guage
Rev	Revision
RGSS	Retained Gas Sampler System
SD	Supporting Document
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
SA	Safety Assessment
SST	Single-Shell Tank
STP	Standard Temperature and Pressure
USQ	Unreviewed Safety Question
WHC	Westinghouse Hanford Company

FUNCTIONAL DESIGN CRITERIA FOR THE RETAINED GAS SAMPLER SYSTEM

1.0 INTRODUCTION

1.1 BACKGROUND

The Flammable Gas Watch List (FGWL) consists of six double-shell tanks (DST) and nineteen single-shell tanks (SST), which have the capability of generating, retaining, and suddenly releasing flammable gases, such as hydrogen and nitrous oxide. Sudden releases of flammable gas mixtures are a safety concern for normal waste storage operations and eventual waste retrieval. The Retained Gas Sampler System (RGSS) is being developed by Westinghouse Hanford Company (WHC) to extract a representative waste sample from a double-shell FGWL tank and measure both the amount and composition of "free" and "bound" gases (Wootan 1994b).

The radioactive liquid waste contained in Hanford storage tanks produces hydrogen through radiolysis of water and other hydrogenous compounds. Other gases, such as nitrous oxide and ammonia, are believed to form primarily from organic complexant chemical degradation reactions and to some extent from radiolysis mechanisms. Waste stored in Hanford FGWL tanks also has the ability to store these gases and suddenly release them in periodic "gas release events." Gases released periodically from tank 241-SY-101 were primarily hydrogen (H_2), nitrogen (N_2), and nitrous oxide (N_2O). Hydrogen in air is flammable over concentrations ranging from 4 to 75 volume percent. This has lead to numerous safety and operational concerns, including the potential for accidental release of the tank contents into the environment (Estey 1992).

Tank 241-SY-101 released thousands of cubic meters of gas to the dome space about once every one hundred days until the mixer pump was installed. Such gas release events were on occasion very violent and resulted in gas mixtures above the 4 volume percent lower flammability limit. Currently, the amount of gas released during a gas release event is calculated based on the tank volume change (i.e., variations in liquid level), while the gas composition is determined by analysis of gas in the dome space. The amount of gas remaining in the waste after a gas release event, however, is still unknown. During the April 1990 gas release event unusually large gas volumes were released. As a result, tank pressure rose above atmospheric conditions, while the waste surface elevation dropped 23.6 cm (9.3 in.). The behavior exhibited by tank 241-SY-101 suggests the presence of two distinct fluid layers. They are an upper convective layer where gas was formed and released on a continuous basis, and a lower non-convective layer where gas was retained in greater amounts and periodically released. Prior to pump operation the average non-convective layer void fraction was estimated to be 19%, with localized values as high as 35%.[1]

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[1] The hydrostatic pressure could produce a vertical void fraction gradient in the non-convective layer of 4 to 10%.

Current operation of the mixer pump in 241-SY-101 has altered the gas release/retention behavior of the waste. The waste level has remained fairly stable and gases are being released at approximately the same rate they are generated. Although the retained gas values are still unknown, the average void fraction is estimated at 3%, with variations depending on individual convective layer characteristics and the hydrostatic head.

Other FGWL tanks exhibit similar, but less extreme cyclic variations of surface levels. Tank 104-AN shows surface level variations of 7.6 to 20.3 cm (3 to 8 in.) within a period of about 1 year. Tanks 241-AN-105, 241-SY-103, and 241-AW-101 exhibit 2.5 to 5.0 cm (1 to 2 in.) surface level variations within periods ranging from 6 to 12 months. Tank 241-AN-103 shows little, if any, cyclic behavior and only a slight increase in surface elevation of 1.2 cm (0.5 in.) per year since 1990.

The amount and constituents of gas stored in Hanford waste tanks are needed to address the flammable gas safety issue.[2] Measurement of the stored gas in Hanford waste tanks will provide better hazards evaluations and may allow tanks to be removed from the FGWL. Current methods for determining the gas content of FGWL waste tanks rely on indirect measurements of the volume of stored gas. The RGSS will provide a direct measurement of the volume of the solid/liquid waste, the amount of trapped and dissolved gas released from this volume, and the gas constituents in a waste sample taken from a FGWL tank. This sample data will allow analysts with knowledge of actual tank conditions to determine the void gas content, total gas content including dissolved and adsorbed gases, and the gas constituents in the tank at the location the sample was taken.

Feedback from potential users of the data generated by the RGS system regarding data priorities and desired uncertainties have been included in the Appendix. Computer models and other analyses are used to predict the amount of trapped gas remaining in a tank after a gas release event. These computer models require numerous assumptions to be made about waste properties, such as the size and number of gas bubbles. Uncertainties are associated with the amount of gas which remains trapped in the waste after a gas release event. The analytic gas release models are refined based on measured tank data, such as the observed drop in the waste liquid level. To help calibrate the models further, data is needed on the amount of gas trapped in the waste. Calibration of these models with measured data will reduce conservatism in safety assessments and in work controls. Measurements of the stored gas in FGWL tanks will provide better hazards evaluations and may allow tanks to be removed from the FGWL.

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[2] Sampling waste in Hanford single and double shelled tanks is required to support waste characterization under the Resource Conservation and Recovery Act (RCRA). Resolution of tank safety issues, and development of tank waste retrieval techniques are also requirements of the Hanford Federal Facility and Consent Order, an agreement between Washington State, the U.S. Department of Energy (DOE), and the U.S. Environmental Protection Agency (EPA).

1.2 SCOPE

The RGSS consists of three main components: the Retained Gas Sampler, the Retained Gas Extruder, and the Retained Gas Extractor.

The Retained Gas Sampler (Sampler) is based on the WHC Universal Sampler design (H-2-85097, Rev. 2). The major components include the sampler housing, the piston, the rotary valve, the quadra latch, and the triggering mechanism. Modifications to reduce gas leakage include incorporating an additional o-ring seal on the sampler piston, using a double o-ring cable piston seal, and welding the valve housing to the sample housing.

The Retained Gas Extruder (Extruder) is a new device specially designed for the RGSS for extruding the waste material from the Sampler into the Retained Gas Extractor. The Extruder consists of a clamp assembly or cradle to constrain the Sampler, a push rod, hydraulic ram, leveling device, and instrumentation.

The Retained Gas Extractor (Extractor) is being developed to extract the gas (both free and bound) from the waste sample. The Extractor consists of a waste sample processing vessel, a second volume used for determining void fraction, a mechanical stirrer, sample heating and cooling system, a gas transport system for transferring the extracted gas from the processing vessel to the sample collection vessel and/or gas analysis instrumentation, sample ports for gas and liquid collection, insertion ports for introduction of waste diluent, a Sampler adaptor coupling, and control and monitoring instrumentation. Gas will be removed from the waste sample in the Extractor by the following methods: (1) mechanical stirring, (2) thermal treatment, and (3) dilution. The Extractor will be instrumented and the gas will be removed in stages to aid in characterizing the gas retention properties of the sample.

Functional design requirements for the RGSS components, the Sampler, Extruder, and Extractor, were developed as the function and design of the system matured. The early requirements were used to evaluate alternatives and develop a conceptual design. These were further defined by Bridges (1993) as the conceptual design developed into a prototype design (Wootan 1994a).

The Sampler has the following three primary functions:

- Capture a representative waste sample from a FGWL tank;
- Transport the captured waste sample with minimal loss of gas content from the tank to the laboratory; and
- Interface with other components to transfer the waste sample to the Extractor for processing.

The Extruder has one primary function:

- Interface with other components to transfer the waste sample from the Sampler to the Extractor for processing.

The Extractor has three primary functions:

- Remove and quantify the total amount of gas released from a waste sample;
- Provide a gas sample for analysis to identify and quantify the constituents of the released gas; and
- Identify released gas as free gas or trapped gas.

To accomplish these primary functions, the Extractor must perform the following five basic functions:

- Capture sample of released gas for analysis;
- Measure temperature and pressure;
- Heat and cool waste sample;
- Mix waste sample; and
- Dilute waste sample.

The RGSS will provide information on the gas content of a tank waste sample by processing the sample in a laboratory. In order to extract the gas, the laboratory conditions will, by necessity, not be the same as the tank conditions. The total quantity of gas, except for soluble gases such as ammonia and any gas leakage, will be the same for the waste sample for both laboratory conditions and tank conditions. The void fraction of the sample when it was in the tank depends on the tank temperatures and pressures. Knowledge of the laboratory sample gas quantities, composition, temperature, and pressure can be coupled with knowledge of the expected tank temperature and pressures at the location where the sample was taken to predict the gas void fraction in the tank. Extrapolation of the laboratory results to general tank conditions is beyond the scope of the RGSS.

1.3 SITE LOCATION

The application of the RGSS will be limited to hydrogen producing double shell tanks currently on the Hanford Flammable Gas Watchlist. Samples will be taken using push-mode sampling procedures. Access to the tanks will be through any 4-in. riser or any riser adapted to accomodate the core sampling equipment. Factors influencing the placement of sampling equipment at the tank are the same as those associated with the Universal Sampler. Specific site factors to be evaluated include:

- Minimal interference with existing facilities,
- Static and dynamic loading imposed on the tank and riser,
- Minimal disruption of contaminated soil,
- Utilities/site services,

- Environmental and safety considerations, and
- Minimal operator exposure to radioactive and chemical hazards.

The Extruder and Extractor will be located in the 1E2 hot cell of the 222-S Laboratory. The gas collection, analysis, and control/monitoring instrumentation will be located immediately outside the 1E2 hot cell. Factors influencing the placement of the Extruder and Extractor equipment in and around the hot cell include:

- Minimal interference with existing facilites,
- Utilities/site services,
- Environmental and safety considerations,
- Minimal operator exposure to radioactive and chemical hazards, and
- Minimal potential for spread of contamination during normal and off-normal operations.

1.4 PROJECT INTERFACES

The Sampler shall be deployed through existing risers using the Rotary Mode or Push-Mode Sample Truck, limited to push-mode sampling. The Sampler shall be mechanically equivalent to the Universal Sampler in interfacing with the Sample Truck equipment, including the drill string, shielded receiver, and transfer cask. Any change in hydrostatic head medium for obtaining retained gas samples shall be compatible with the Sample Truck equipment. The capability shall be provided to use alternate "drill bits" for the end of the drill string to minimize the disturbance of the waste during sample collection.

Transfer of the filled Sampler to the 222-S Laboratory hot cell shall be compatible with existing systems and shipping containers used to transfer core samples taken with the Universal Sampler.

The Extruder and Extractor will be designed for the 1E2 hot cell in the 222-S Laboratory in the 200W area. The supporting subsystems for the Extruder and Extractor will interface with existing hot cell systems, as necessary:

- Electrical supply,
- Water supply for sample processing and cleanup,
- Waste disposal systems for processing and cleanup,
- Heating, ventilation, and air conditioning systems,
- Compressed air systems,
- Heater/chiller solution for sample conditioning, and
- Inert gas systems.

2.0 PROJECT CRITERIA

2.1 FUNCTIONAL REQUIREMENTS

2.1.1 Sampler

The Sampler shall meet the following functional requirements:

- Be capable of capturing and retrieving a sample of waste from the top of the convective layer to the bottom of a FGWL double shell tank, within the limitations of push-mode sampling.
- Contain the sample in a safe, stable manner until the sample is removed for analysis.
- Be mechanically equivalent to a Universal Sampler except that the Sampler will not be operated in rotary mode.
- Provide a gas tight connection with the Extractor device.
- Permit mechanical extraction of the sample when connected to the Extruder and Extractor components.

2.1.2 Extruder

The Extruder shall meet the following functional requirements:

- Interface with the Sampler and Extractor and provide the means to transfer the collected sample, including solids, liquids, and gases, from the Sampler to the Extractor.
- Connect with the Sampler and Extractor so that the liquid, solids, and gases collected by the sampler can be transferred from the sampler to the extractor without exposure to the atmosphere, contamination of the sample, or loss of sample.

2.1.3 Extractor

The Extractor shall meet the following functional requirements:

- Separate the gas from the liquids and solids in a waste sample and transfer those gases to a collection vessel or analysis instruments for quantitative determination of the amount and constituents of the collected gas.
- Connect with the Sampler and Extruder so that the liquid, solids, and gases collected by the sampler can be transferred from the sampler to the extractor without exposure to the atmosphere, contamination of the sample, or significant loss of sample.
- Minimize loss of gas from the sample during its transfer from the Sampler.

- Be capable of heating the sample up to a temperature of 60 °C during extraction operations.
- Be capable of stirring a sample of tank waste to release trapped gas.
- Be capable of diluting the sample by a factor of 2:1 to release trapped gas.

2.2 PERFORMANCE REQUIREMENTS

2.2.1 Sampler

The Sampler shall meet the following performance requirements:

- Minimize "disturbance" of the tank waste in order to obtain as representative a sample as possible. This does not mean that the sample will be representative of the entire tank contents or of any entire layer contained in a tank, but it should be representative of the waste where the sample was taken.
- Be capable of capturing a sample volume of 250 cc to 350 cc.
- Fit within the Universal Sampler envelope (H-2-85097, Rev. 2) and be functionally equivalent to the Universal Sampler. The Sampler shall have the same capability for attachment to the drill string, and use the same shielded receiver and transfer cask as the Universal Sampler.
- The medium used to maintain the hydrostatic head in the drill string while sampling shall not interfere with the Sampler and Extractor operation and analysis.
- Use existing Universal Sampler casks and containers to ship the Sampler to the laboratory.
- Not react chemically or physically with nitrite, nitrate, caustic, or organic compounds.
- Fit in the physical space envelope of the 222-S Laboratory 1E2 hot cell and must interface with the Extruder and Extractor equipment.
- Be designed to operate in radiation fields of 1000 rads/hour. The expected dose to the Sampler for each use is less than 10,000 rads.
- Not exceed temperatures of 82 °C (180 °F) at any point in the Sampler operation or shipping.
- Retain helium gas with a leak rate of less than 10^{-6} atm-cc/sec at room temperature with an absolute pressure of 3 atm.[3]

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[3] The normal operating pressure for the Sampler is less than 3 atm (absolute).

- Be designed to contain radioactive material with a concentration of 2 curie (with 0.7 MeV gamma ray energy) per liter.

- Be operable in a FGWL tank environment potentially containing flammable vapors or liquids.

- Be designed as a single use device.

2.2.2 Extruder

The Extruder shall meet the following performance requirements:

- Be designed to fit inside the 1E2 hot cell in the 222-S Laboratory: the Extruder shall be capable of being installed in the hot cell through existing access ports; the Extruder shall fit through a rectangular opening of 76 cm by 122 cm (30 in. by 48 in.); the length of the Extruder shall not exceed 200 cm (6 ft 7 in.).

- The maximum envelope size of the Extruder inside the hot cell shall be 61 cm (2 ft) wide by 61 cm (2 ft) high and 200 cm (6 ft and 7 in.) long.

- Be capable of being cleaned for reuse within the hot cell.

- Have a leveling device with a minimum of one inch adjustment in order to level the extruder. For the floor taper in the 222-S hot cell see drawing H-2-46760, sheets 1 through 3.

- Be compatible with all safety, shielding, and environmental requirements for hot cell operation in 222-S Laboratory.

- Have a design life of 3000 extrusion cycles or ten years.

- Function in a hot cell environment. Internal dose rates from the waste sample will be about 5 rads/hr.

- Be designed for a lifetime radiation exposure of 60,000 rads (5 rads/hour x 3,000 cycles x 4 hours/cycle).

- Provide a maximum extrusion force of 10,000 pounds-force.

- Limit the potential for inadvertant loss of sample materials or surface contamination.

- Generate a minimum of secondary wastes.

- Minimize the distance between the Sampler and the Extractor.

- Use the piston in the Sampler to extrude the sample.

- Maintain the Sampler piston within the Sampler with the piston seal intact. At the end of the extrusion cycle, the Sampler piston o-ring shall remain in the Sampler barrel, maintaining the seal during the gas extraction process.

- Placement and removal of the Sampler in the Extruder and operation of the Extruder in the hot cell shall be performed with remote manipulators.

- Extruder materials must be compatible with tank waste materials. The sample material is strongly alkaline with a pH of approximately 12.

- The minimum extrusion speed will be 2.5 cm (1 in.) per minute and the maximum extrusion speed will be 13 cm (5 in.) per minute.

- Be compatible with existing universal sampler valve opener and tool for removal of the quadralatch from the Sampler.

- Include a readout for hydraulic pressure in pounds per square inch with an accuracy of ± 0.18%.

- Include an extrusion force readout in pounds with an accuracy of ± 10 pounds at the low range up to 5,000 pounds force and an accuracy of ± 20 pounds from 5,000 to 10,000 pounds force.

- Include a piston displacement read-out in inches with an accuracy of ± 0.030 in.

2.2.3 Extractor

The Extractor shall meet the following performance requirements:

- Function in a hot cell environment. Internal dose rates from the waste sample will be about 5 rads/hr.

- Be compatible with tank waste materials and any diluent used in the gas extraction process.

- Be designed to fit inside the 1E2 hot cell in the 222-S Laboratory: the Extractor shall be capable of being installed in the hot cell through existing access ports; the Extractor shall fit through a rectangular opening of 76 cm by 122 cm (30 in. by 48 in.).

- Be compatible with all safety, shielding, and environmental requirements for hot cell operation in 222-S Laboratory.

- Limit the potential for inadvertant loss of sample materials or surface contamination.

- Generate a minimum of secondary wastes.

- Have a design life of 30 gas extraction cycles or one year.

- The primary Extractor vessel shall have a useable volume of greater than three times the volume of the Sampler to allow for a 2:1 dilution of the sample. A second vessel connected with the primary Extractor vessel shall provide a volume of approximately 300 cc for use in determining gas quantity, bulk liquid/solid waste volume, and ammonia concentration.

- Be capable of measuring the sample temperature and vapor space temperature over the range of 0 - 60 °C with an accuracy of 2.2 °C or better.

- Be capable of measuring the vapor space pressure over the range of 0 - 1.33×10^5 Pascal (0 - 1000 Torr) with an accuracy of 0.25% of reading or better.

- The volume of the Extractor and the second vessel shall be measured using evacuation and gas fill techniques based on the perfect gas law. Pressure measurements during these volume determination tests shall be made using transducers of accuracy 0.25% or better. At least 10 such operations shall be used to determine the gas volume based on an average of the results. The standard deviation of these results shall be 0.3% or better.

- The Extractor and associated analysis instrumentation shall measure the waste solid/liquid volume and the released waste gas volume (at STP) with sufficient accuracy so that the ratio of the gas volume to bulk waste volume has an absolute accuracy of no greater than 2% (e.g., if the actual ratio is 20%, the measured ratio would have to be between 18% and 22%). The 2% accuracy is an upper limit, and efforts should be made to make these measurememts as accurate as practical.

- The Extractor and associated analysis instrumentation shall measure the hydrogen concentration in the collected gas with an absolute accuracy of 2%.

- The Extractor and associated analysis instrumentation shall measure the concentration of nitrogen, nitrous oxide, and ammonia with a relative accuracy of 20% or an absolute accuracy of 2%, whichever specification is the least stringent for a given case.

- A connecting line will be provided to transfer extracted gases between the Extractor vessel and the gas sample collection and gas analysis instrumentation. This transfer line shall facilitate the gas transfer while allowing adequate flow and evacuation capabilities.

- The Extractor vessel and associated lines shall have helium leak rates of less than 10^{-6} atm-cc/sec.

- The Extractor system shall be capable of providing a vacuum of 1.333 Pascal (10^{-2} Torr) or better.

- The Extractor shall contain valved ports for the transfer of gases and addition of liquid diluent.
- The Extractor vessel and second volume shall be capable of being evacuated independently.
- The pressure in the Extractor vessel and the second volume shall be measured independently.
- Control of the Extractor components in the hot cell, such as opening and closing valves and operating the mixer, shall be with remote manipulators.
- The Extractor shall be capable of being cleaned for reuse within the hot cell.
- The Extractor vessel shall be capable of being opened in the hot cell with remote manipulators for cleaning.

3.0 FACILITY INTERFACE CRITERIA

3.1 ARCHITECTURAL, CIVIL/STRUCTURAL

The installation and operation of the Extractor and Extruder shall utilize existing capabilities in the 222-S 1E2 hot cell: in the 222-S 1E2 hot cell the manipulator can lift a maximum of 50 pounds; the maximum lifting capacity in the hot cell is 300 pounds over the center of the cell using the chain hoist or the overhead crane.

Gas transfer lines and control/instrumentation leads shall be provided from the Extractor inside the hot cell to the gas collection, gas analysis, and monitoring/control instrumentation located outside the hot cell. Access penetrations shall be compatible with a new shield plug (H-2-85444) in the wall of the 1E2 hot cell.

Adequate space shall be provided adjacent to the 1E2 hot cell for the gas collection, gas analysis, and monitoring/control instrumentation to minimize the distance the gas must be transported.

3.2 HEATING, VENTILATION, AND AIR CONDITIONING

The Sampler, Extruder, and Extractor shall operate at the ambient 1E2 hot cell temperature of 30 to 40 °C. During the gas extraction process, variations in the ambient hot cell temperature shall be minimized.

3.3 UTILITIES

The operation of the Extractor and Extruder shall utilize existing capabilities in the 222-S 1E2 hot cell. Utility requirements will be defined during the detailed design stage.

In the 222-S hot cell the available facility support includes:

- Shop air supply at 90 PSIG. pressure,
- Water at 80 PSIG. pressure,
- Electricity 110 V, 60 cycles.

Any radioactive or hazardous wastes generated in the gas extraction and processing of the sample must be compatible with 222-S waste handling facilities.

3.4 AUTOMATIC DATA PROCESSING

An IBM-compatible Data Acquisition and Control Unit (DA/CU) shall be used to display, monitor, and record critical test parameters such as temperature and pressure. The DA/CU shall convert analog input data to engineering units, log data to disk, and alarm for out-of-limits operating conditions.

3.5 MAINTENANCE

The Extruder and Extractor systems shall be designed to permit routine maintenance activities with minimum operator exposure to hazardous or radioactive environments. As Low As Reasonably Achievable (ALARA) practices shall be used in all maintenance activities. The Extruder and Extractor designs shall permit access to all components requiring maintenance.

The Extruder and Extractor designs shall provide for removal and replacement of components as a non-routine operation.

The Extruder and Extractor designs shall be compatible with removal from the hot cell as a non-routine operation.

The Sampler design shall be compatible with removal from a tank from any position as a non-routine operation.

The Sampler design shall provide for removal and replacement of components as a non-routine operation.

4.0 GENERAL REQUIREMENTS

4.1 SAFETY

4.1.1 Safety Analysis Requirements

The Sampler will be used to collect samples only during periods when a hydrogen burn hazard does not exist. Under these conditions, there are no Safety Class 1 functions associated with the operation of the Sampler.

Operation of the Sampler, Extruder, and Extractor is Safety Class 3 in accordance with the requirements of WHC-CM-4-46, *Nonreactor Facility Safety Analysis Manual*, and WHC-CM-1-3, *Management Requirements and Procedures*, MRP-5.46, "Safety Classification of Systems, Components, and Structures."

The process of collecting samples with the Sampler must not cause damage to the primary tank or to any peripheral Safety Class 1 or 2 component. Damage to the primary tank or the riser in use must be prevented by design or precluded by administrative procedures.

Safety assessments for operation of the WHC Universal Sampler shall apply to the RGSS Sampler except for sampling in tank 241-SY-101. A specific safety assessment shall be completed for sampling in 241-SY-101 with the RGSS.

4.1.2 Contamination Control

The components of the RGSS that may be exposed to liquid waste shall be constructed of materials which minimize the potential for contamination.

The Extractor system includes gas lines and instrumentation and control leads connecting equipment outside the hot cell with equipment inside the hot cell. The design of these components shall assure that liquid waste cannot be moved from the Extractor vessel to outside the hot cell by any expected and undetected failure modes.

4.1.3 Shielding

The RGSS design and operation shall incorporate shielding as needed to meet ALARA principles.

4.1.4 Industrial Safety

Safety shall conform to WHC-CM-4-3, *Industrial Safety Manual*, and common industrial safety practices. Procedures developed for the installation, operation, and removal of RGSS components shall meet all applicable industrial safety standards and shall be detailed and approved prior to installation. Critical lifts shall be per DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual*.

4.1.5 Fire Protection

The design and operating procedures of the Sampler, Extruder, and Extractor shall be reviewed and approved by Fire Protection personnel to ensure meeting all applicable fire protection standards prior to installation.

4.1.6 Traffic Safety

While transporting the Sampler, all applicable traffic safety standards shall be met.

4.2 ENVIRONMENTAL PROTECTION AND COMPLIANCE

The applicable environmental requirements for new and modified facilities, as defined in Section 9 of WHC-CM-7-5, *Environmental Compliance Manual*, shall be identified and followed.

4.3 SAFEGUARDS AND SECURITY

No special safeguard and security requirements are needed beyond those currently in force.

4.4 NATURAL FORCES

The RGSS components are contained in existing systems, such as the Sample Truck equipment and the 222-S Laboratory. Therefore, no special analysis for natural forces is required.

4.5 DESIGN FORMAT

The drawings and design documents shall be generated in accordance with:

- WHC-CM-6-3, *Drafting Standards Manual*,
- WHC-CM-6-1, *Standard Engineering Practices*,
- WHC-IP-1026, *Engineering Practice Guidelines*,

4.6 QUALITY ASSURANCE

Design verification shall be accomplished through independent reviews between the cognizant engineer and Quality Assurance in accordance with the Acceptance Test Procedure; the As-Built Data Package; and WHC-CM-6-1, EP-4.1.

The design documents generated for the tasks identified in this work plan shall be prepared and verified in accordance with WHC-IP-1026, EP-2.0, "Engineering System Design Control," and WHC-CM-3-5, *Document Control and Records Management Manual*. The tasks associated with this work plan shall meet the requirements of WHC-CM-4-2, *Quality Assurance Manual*.

All key components will be calibrated at the WHC Standards Laboratory and/or by a procedure developed during this project.

Computer software written for the operation of the Data Acquisition and Control Unit for the RGSS shall be prepared and controlled in accordance with WHC-CM-3-10, *Software Practices*, including SP-3.0, "Development," and SP-6.0, "Configuration Control."

4.7 DECONTAMINATION AND DECOMMISSIONING

The design of the Sampler, Extruder, and Extractor shall facilitate decontamination so that components can be decommissioned or disposed of at a future date.

The project design shall minimize hazardous and nonhazardous waste generation and use of hazardous materials during construction, operation, decontamination/decommissioning, and Resource Conservation and Recovery Act (RCRA) closure. Materials which are designated as hazardous or will be designated as hazardous waste at disposal shall be documented by the project on drawings or other design documentation as appropriate.

4.8 OPERATING PERSONNEL AND SERVICES

Tank Farm Operations must support the deployment (insertion, removal, handling) of the Sampler in FGWL tanks. Operation of the Sampler during sample collection will be performed by trained crews of the Core Sample Truck. Personnel involved in these operations shall be trained in all safety aspects of operating in the FGWL environment and the tank sampling equipment, including any special aspects related to the use of the Sampler. All required personnel protective gear shall be used at all times when samples are being collected.

The 222-S Laboratory must receive the Sampler and process the sample to extract the retained gas. Operation of the Extruder and Extractor in the 222-S Laboratory 1E2 hot cell will be performed by personnel trained in all safety aspects of operating in the hot cell environment and the Extruder and Extractor equipment.

The 222-S Laboratory must analyze the extracted gas and prepare any gas samples for analysis in other laboratories. Operation of the gas transfer, collection, and analysis equipment outside the 222-S 1E2 hot cell will be performed by personnel trained in the safety aspects of the gas collection and analysis equipment.

4.9 TESTING

Acceptance testing of the Sampler, Extruder, and Extractor shall be accomplished to ensure compliance with these functional and performance requirements. Testing will be in accordance with an approved acceptance test plan. Quality assurance will verify all acceptance testing.

The Sampler and Extractor will be leak tested using helium gas. Letter reports documenting the results shall be generated.

The Extractor will be tested to assure adequate gas extraction capabilities. A letter report documenting the results shall be generated.

Validation of the computer software used in the DA/CU shall be included in the acceptance testing.

The Sampler will be tested for sample collection efficiency and ability to transfer the sample to the Extractor. A letter report documenting the results shall be generated.

After the Extruder and Extractor are installed in the 222-S 1E2 hot cell, integrated testing shall be performed, using a non-radioactive waste simulant, to verify the performance of the RGSS. An acceptance test report documenting the results shall be generated.

5.0 CODES AND STANDARDS

SPECIFICATIONS	SPECIFICATION NUMBER
Dimensioning and Tolerancing for Engineering Drawings	ANSI Y 14.5
Sampling Procedure and Tables for Inspection by Attributes	MIL-STD 105E
Welding and Brazing Qualifications	HS-V-S-0013
Structural Welding Code - Steel	ANSI/AWS D.1.1

6.0 REFERENCES

Bridges, A. E., 1993, *Preliminary Design Requirements and Criteria for the Prototype Retained Gas Sampler and Extraction (RGS) System*, WHC-SD-WM-CR-054, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual*, U.S. Department of Energy Richland Operations Office, Richland, Washington.

Estey, S. D., 1992, *Tank 101-SY In-Situ Gas Measurement Feasibility Study*, WHC-SD-WM-RPT-057, Westinghouse Hanford Company, Richland, Washington.

Wootan, D. W., 1994a, *Design Recommendations for the Prototype Retained Gas Sampler and Extraction (RGS) System*, WHC-SD-WM-ES-285, Westinghouse Hanford Company, Richland, Washington.

Wootan, D. W., R. C. Bolden, A. E. Bridges, N. S. Cannon, S. A. Chastain, B. E. Hey, R. C. Knight, C. G. Linschooten, A. L. Pitner, B. J. Webb, 1994b, *Summary Report on the Design of the Retained Gas Sampler System (Retained Gas Sampler, Extruder and Extractor)*, WHC-SD-WM-ER-387, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-1-3, *Management Requirements and Procedures*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-3-5, *Document Control and Records Management Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-3-10, *Software Practices*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-2, *Quality Assurance Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-3, *Industrial Safety Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-46, *Nonreactor Facility Safety Analysis Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-6-1, *Standard Engineering Practices*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-6-3, *Drafting Standards Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-7-5, *Environmental Compliance Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-IP-1026, *Engineering Practice Guidelines*, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

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DON'T SAY IT --- *Write It!*

DATE: May 12, 1994

TO:		
	R. E. Bauer	L6-37
	A. E. Bridges	L5-01
	N. S. Cannon	L6-38
	S. A. Chastain	L5-01
	G. D. Forehand	R2-31
	M. W. Goheen	P7-22
	B. E. Hey	T6-09
	G. D. Johnson	R2-78
	R. C. Knight	L6-38
	R. B. Lucke	P8-08
	L. R. Pederson	K2-44
	A. L. Pitner	L5-01
	D. J. Sherwood	R2-78
	H. Toffer	H0-38
	B. J. Webb	S2-48
	D. W. Wootan	H0-40

FROM: D. W. Wootan H0-40

Telephone: 376-4635

SUBJECT: RGS DATA USER REQUIREMENTS

Introduction

Six double shell tanks (DST) and eighteen single shell tanks (SST) are on the Flammable Gas Watch List (FGWL) because they have a significant potential for generating, retaining, and suddenly releasing flammable gases. Sudden releases of gas mixtures above the lower flammability limit are a serious safety concern for normal operations and eventual retrieval.

The Retained Gas Sampler and Extraction (RGS) system is being developed to retrieve a sample of waste from a FGWL tank and measure both the amount and composition of the gas in the sample, including free gas in the form of bubbles and dissolved or adsorbed gases.

Problem Description

Tank 241-SY-101 is an example of a FGWL tank exhibiting the gas retention/release behavior. In the past it has typically released thousands of cubic feet of gas to the dome space about every one hundred days. Such gas release events have occasionally been very violent and resulted in mixtures of flammable gases that would have burned if ignited. During the April 1990 gas release event (GRE) in tank 241-SY-101, sufficient gas was liberated that the tank pressure increased enough to become positive relative to the surrounding atmosphere, concurrent with substantial drop in the surface elevation (9.3 inches). This behavior in SY-101 is believed to be due to the presence of a non-convective layer where gas is retained below a convective layer where gas is continually released. The amount of gas released during a GRE can be estimated based on the tank level change. Tank monitoring instruments and samples of the gas in the dome space provide some indication of the constituents of the released gases. However, the amount of gas remaining in the waste after a GRE is unknown.

The maximum average void fraction in the nonconvective layer based on buoyancy effects is 19%, but localized values could be as high as 35%. The hydrostatic pressure could result in an axial gradient in void fraction in the nonconvective layer of 4 to 10%.

The current operation of the mixer pump in SY-101 has altered the gas release/retention behavior. The waste level has remained fairly stable and it appears that gas is being released at approximately the same rate it is being generated. Instead of a non-convective layer below a convective layer, there likely exists two convective layers. There could be unmixed regions in the tank where local concentrations of retained gas may be higher than the average. Although the amount of retained gas is still unknown, the average void fraction with the pump operating has been estimated to be around 3%. There may be different void fractions in the different layers of the tank. There will still be an axial gradient in the void fraction due to the hydrostatic head.

Other FGWL tanks exhibit similar, but less extreme cyclic variations of surface elevation. Tank 104-AN shows surface variations of approximately three to eight inches with a period that approaches one year, but with no major change in the mean surface level. Tanks 105-AN, 103-SY, and 101-AW exhibit one to two inch surface variations with periods of about one-half to one year, and small but finite increases in mean surface elevation in recent years. Tank 103-AN shows minimal cyclic behavior and only a slight increase in surface elevation of about one-half inch per year since 1990.

In addition, some single shell tanks tanks may be storing gas without evidence of release, such as those exhibiting slurry growth or level changes that correlate with atmospheric pressure changes.

Data Needs

The measurement data required includes the void gas content, total gas content including dissolved gases, and the gas constituents. The data will be used by tank modelers and in the evaluation of safety assessments, mitigation activities, and eventual retrieval of the wastes. The amount of stored gas is the primary parameter for safety analyses.

The void gas measurement is needed to: calibrate models of tank behavior, reduce conservatism in safety analyses and work control limits, increase understanding of pump operation effects, and evaluate mitigation effectiveness and alternatives. This information may also support the evaluation of release mechanisms. Measurements of the void fraction in other tanks will allow a better hazards evaluation and may allow their removal from the flammable gas watch list.

Gas void measurements will be used to calibrate TEMPEST calculational models of tank behavior. These models are used by PNL and LANL analysts to predict tank behavior under normal, perturbed, and accident conditions. Currently, conservative assumptions are used in these models regarding gas content. Calibration of these models with measured data will allow a reduction in current conservatism in safety assessments and in work control operational limits.

Current estimates of the physical properties of the waste used in these models, such as viscosity, are based on assumptions regarding void fraction. Thus, accurate measurement of the void fraction may allow a reduction in the conservative assumptions for rheological properties in the safety analysis. However, accurate assessment of rheological properties based on the void fraction also requires knowledge about the size of the bubbles in the waste.

The RGS will not directly provide information concerning the size of the bubbles. Some information on the presence of large bubbles may be inferred if the sampler captures a very large gas fraction (>35%).

The mixer pump in SY-101 has altered the gas retention behavior in that tank. Instead of convective and nonconvective layers, there appear to be two convective layers. The periodic level fluctuations in SY-101 have been greatly reduced, but the amount of retained gas is still unknown. Knowledge of the amount of retained gas after pump operation will increase understanding of the effectiveness of the mixer pump as a mitigation technique.

Measurements of the amounts and distribution of gases in SY-101 and other FGWL tanks will allow a better understanding of the behavior of the waste. Other FGWL tanks exhibit behavior that is less extreme than SY-101. This could be due to the presence of waste layers that do not generate or retain gases. Void measurements might be able to detect such layers. Better predictions of waste behavior will allow a better evaluation of mitigation alternatives. Measurements of the amounts and distribution of gases remaining after mitigation may be required to quantify the effectiveness of any mitigation process.

The RGS gas void measurements can be used to compare with the in situ void measurements by the void fraction meter, which will provide more spatial distribution data. The use of both the RGS and Voidmeter to measure void fraction provides independent and diverse capabilities that provide additional confidence in the measurements.

Measurement of the dissolved and tightly bound gas content is needed to determine the total potential release for safety analyses, mitigation activities, accident conditions, and eventual retrieval. This measurement will also detect very small bubbles that may not contribute to the void fraction measurement. Measurements of the free gas will identify the gases participating in normal gas releases. Measurements of gas in solution and tightly bound gas attached to particles will provide the total gas volume.

Measurement of the primary gas constituents will also reduce conservatism in the safety assessments. Hydrogen is the most important constituent and is the driver for the safety analyses and normal operations limits. Nitrous oxide is an oxidizer and is important for determining the flammability of the gas mixture. Ammonia is the major soluble gas and is present in both the gas and liquid phases of the waste. The measurement of total ammonia is important to determine the total release volume for accident analyses. Ammonia is flammable but the major concern is as a major toxic hazard. Nitrogen is a major constituent of the gas and provides a dilution factor for the safety assessment burn. Measurement of other minor constituents will increase understanding, but are not of critical importance. A possible exception is methane, which is a soluble gas and can be a noticeable contributor to the safety assessment burn even at small concentrations because of its high fuel value.

Uncertainty Needs

The data users have not provided hard uncertainty requirements for these parameters, but have indicated desired ranges. The highest priority parameters are the void fraction and the hydrogen content. For the general case of void fractions ranging from 0% to 35%, a 2% absolute uncertainty would be the minimum to calibrate models of tank behavior. This is the accuracy requirement being applied to the Voidmeter measurements. For the specific case of the present status of SY-101 with the pump operating, the expected void fraction is about 3% with around 100% relative uncertainty. Under these conditions, a target of 20% relative uncertainty is desired. A single point measurement would be the minimum needed to calibrate models.

Hydrogen constitutes about 30% of the gas, and the current estimated absolute uncertainty is about 5%. To provide a significant improvement, this would need to be reduced to 1% absolute uncertainty. Nitrous oxide and nitrogen are the other major gas components, and a target relative uncertainty of 20% is desired. Ammonia will be found in solution as well as in the gas, and is expected to be about 5% of the gas. A reasonable target for total ammonia is 20% relative uncertainty. A relative uncertainty of 100% was suggested as probably sufficient for the other gas constituents.

Sensitivities

Errors in the RGS measurements of gas content and composition will be contributed by the waste sampling process, the gas extraction process, and the gas analysis process.

The RGS system will attempt to obtain representative samples of waste from a FGWL tank, but this should not be interpreted to mean that a representative sample is representative of the entire tank contents or of any entire layer contained in a tank. Multiple samples would be required to achieve "representative sample" status for even one layer of waste in a tank. A single sample would be sufficient to provide a calibration point for models of tank behavior, but the more samples collected the more accurate the calibration.

The process of taking a sample will disturb the waste to some extent, and may result in the release of some of the retained gas. It is expected that argon gas will be used to maintain the hydrostatic head during sampler changeout. Some amount of argon gas or tank cover gas may be present in the sample. Partial filling of the sampler due to low recovery efficiency may result in reduced gas pressures or diluted gas contents. These effects will be minimized by the design of the drill bit and sampling procedure, and will be examined by testing.

The RGS sampler will minimize gas losses through leakage or permeation while the sample is transferred from the tank to the laboratory, thereby maintaining the in situ pressure of the waste sample. However, the sample temperature will be lower than the tank temperature, since no provisions for heating the sampler during transfer are planned. In the laboratory the sample will be extruded into an evacuated extractor box. The sudden expansion of the sample will cool the sample material. Once the sample is extruded, it will be heated to typical tank temperature before the gas extraction process is initiated. It is expected that the changes in temperature and pressure will alter the soluble gas concentration. Measured gas concentrations will need to be corrected to reflect the tank conditions. The effect of the temperature and pressure changes of the sample on the retained gas will be investigated by testing or analysis.

Accurate measurements of the temperatures and pressures in the extractor system, along with well characterized volumes, are required to determine gas fractions. The efficiency of the gas extraction process will also contribute to the gas measurement uncertainty. The final step in the extraction of total gases is anticipated to be dilution of the sample to reduce the viscosity of the waste and dissolve many of the solids. A fraction of the solids in the sample will remain after the dilution process, and any gases trapped by the remaining solids will contribute to the uncertainty in the total gas measurement. The efficiency of the gas extraction process for releasing all of the soluble gases such as ammonia must also be characterized.

Because the RGS system makes extensive use of existing tank sampling equipment, such as the sampling truck and drill string, it is limited to those locations that can be push-mode core sampled. This limits sampling to the available 4" risers. Sampling must be coordinated with the master sampling schedule, since the sampling trucks are in demand for other tank characterization sampling activities. Sampling can not be performed with the pump in operation.

The number of samples taken per tank will be determined by various factors. A minimum of one sample per tank would be adequate to calibrate tank behavior models if there was a high assurance of the integrity of the sample and the sample is taken from a layer of waste that is well characterized by the temperature profile. Multiple samples are desired to indicate potential variability in tank properties and sample integrity. Taking samples from more than one riser location will provide some additional variability information, but still will not characterize the range of properties expected in the tank.