Headspace Gas Analysis and Venting for TRU Waste Drums*

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INTRODUCTION

Transuranic (TRU) wastes generated in U.S. Department of Energy (DOE) operations have, since the early 1970's, been packaged to a large extent in unvented 55-gallon steel drums and have been stored with the intention of future retrieval. These wastes are intended to be disposed of permanently in the DOE Waste Isolation Pilot Plant (WIPP) facility. Today, there are safety concerns regarding these stored drums because of the potential presence of combustible headspace gases. Such gases can include hydrogen and methane resulting from the radiolytic decomposition of hydrogenous waste materials (e.g., paper, plastics, moisture) and/or from the presence of generally small amounts of combustible Volatile Organic Compounds (VOCs) that are cocontaminants of the TRU wastes. Any future handling and transportation of these waste packages must address this concern. Additionally, the WIPP Waste Acceptance Criteria require all packages to be vented, and all such packages to be shipped in the DOE TRUPACT-II Type B container must be both vented and shown to meet combustible gas concentration limitations. To provide a safe method for penetrating the drum lid and, if present, inner plastic liner lid, sampling and analyzing the headspace gases, and installing an approved filter vent, NFT Incorporated (NFT), working with the Westinghouse Savannah River Company (WSRC), has developed a Drum Venting System (DVS) for the remote performance of these venting and analysis functions. This paper discusses the design features and planned operations of the DVS.

DESIGN CRITERIA

The overall objectives of the project included the design, fabrication, assembly, and verification testing of a DVS capable of collecting and analyzing a headspace gas sample to WSRC specifications, purging the headspace gases if a flammable mixture is found present, and properly installing an approved filter vent in a previously filled TRU waste drum. Per the WSRC criteria, all waste drums to be processed will be

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contained inside 83-gallon overpack drums without lids, and a 90 mil high density polyethylene (HDPE) liner is assumed to be present inside each 55-gallon waste drum. The HDPE liner lid must be punctured by the filter device prior to the headspace gas sampling, analysis, and purge operations.

Real-time headspace gas analysis must include the following measurements and sensitivities:

Hydrogen - 1% to 100% concentration
Methane - 200 to 2000 ppm
Combustible VOCs - 200 to 2000 ppm

To meet the WSRC operational requirements, the system must be sufficiently portable to be readily relocatable to different drum storage locations. At the same time, because of the need to operate in "field" locations, the system was required to be fully self-contained, needing only adequate electrical power.

Contamination control during all phases of both normal operations and postulated abnormal events were to be incorporated in the system design. The worst case abnormal event is an ignition of combustible headspace gases resulting in a drum pressurization to a maximum of 136 psig.

Other DVS performance requirements/objectives included the following:

- Safe and efficient filter installation in a manner to ensure leak tightness of the filter seal to the drum lid;
- Reproducible and representative sampling of the headspace gases within the sealed drum;
- Effective purging of unsafe levels of headspace gases when necessary to ensure the continued safe handling of each drum;
- Capability to recover from interference with an impenetrable waste object;
- All normal operations designed to be accomplished with the drum kept in a sealed/filtered status at all times; and
- Remote operation, to the extent possible.

SYSTEM DESIGN

The NFT DVS, as depicted in Figures 1 and 2, is a stand-alone, skid-mounted system, only requiring external electrical power. The DVS is comprised of several components and subassemblies, including the powerhead subassembly, glovebox, drum cabinet, gas analysis system, air filtration system, and remote controller assembly. Each of these is described below.

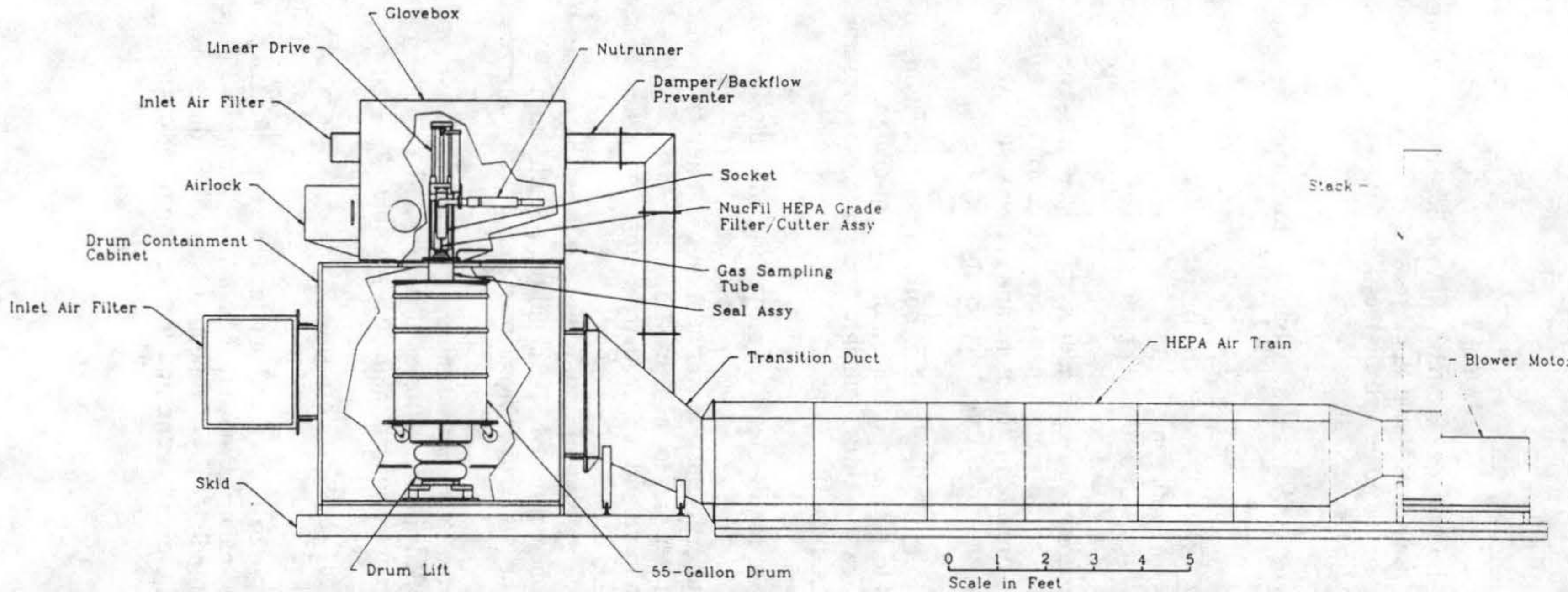

Figure 1. TRU DVS component schematic diagram.

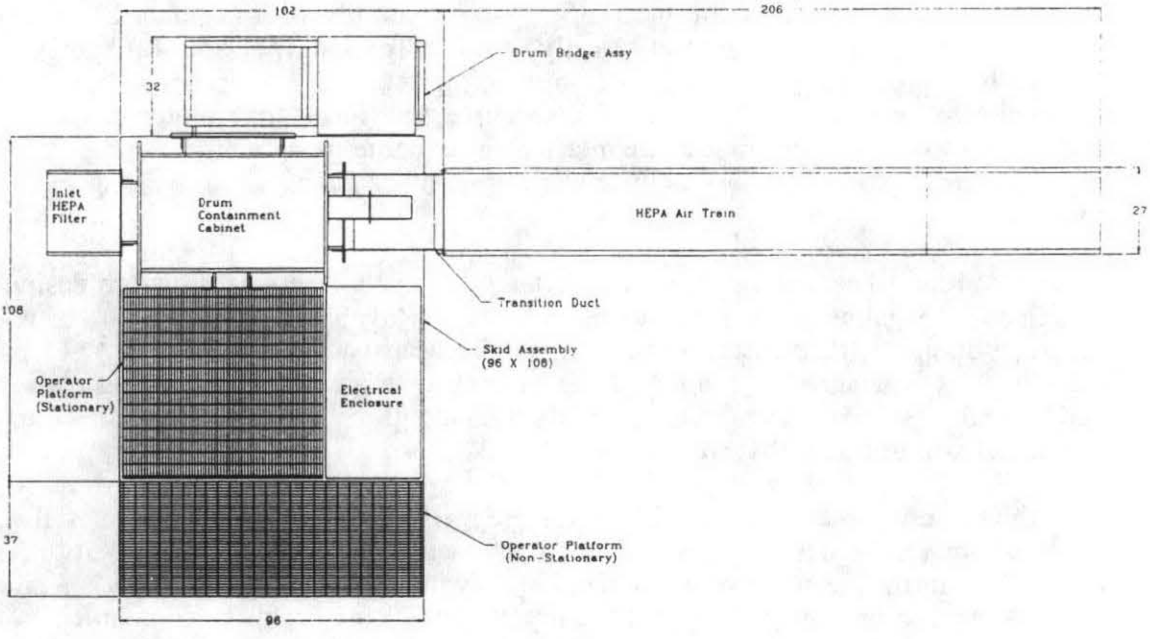

Figure 2. TRU DVS layout diagram (dimensions in inches).

Powerhead Subassembly. The electrically powered powerhead subassembly is the key mechanical subassembly within the DVS. It contains a structural frame that supports and stabilizes a linear drive and a nutrunner.

> Linear Drive. A stepper motor-driven, screw type linear drive controls the vertical movements of the powerhead assembly. The DVS employs a linear drive controller which precisely controls the movements of the powerhead assembly. The controller can store up to 100 unique and predetermined linear motion sequences or programs.
>
> Nutrunner. The DC-motor driven nutrunner is mounted to the powerhead frame and provides the rotary motion to a socket attachment that holds the head of the filter assembly during the piercing and insertion operations. This nutrunner is a variable-speed unit capable of operating at higher speeds when piercing the lid and slower speeds when installing the filter. The nutrunner functions as the torque source which enables the filter threads to cut into the drum lid such that the filter seats securely in the drum lid. The nutrunner controller is a microprocessor-based, programmable, rotary motion controller. The controller can store up to 64 unique and predetermined rotary motion sequences or programs.

Glovebox. The glovebox that contains the Powerhead Assembly was designed and fabricated in accordance with the American Glovebox Society's "Guidelines for Gloveboxes", AGS-G001-1994. An inlet filter housing contains one 8x8 in. gasket seal High Efficiency Particulate Air (HEPA) filter element. A small airlock (approximately 10x10x10 in) is provided to permit entry of drum filters and other small components, as needed.

All electrical components within the DVS glovebox comply with National Electrical Code standards in that they are intrinsically safe (nonsparking), or are of a "purge" design which prevents ignitable gases from entering their interior spaces where electrical discharges may be present. For example, the linear drive motor has a constant flow of air to prohibit any contact with ignitable gases which could possibly be present in the glovebox. The nutrunner, on the other hand, is nonsparking in design.

Drum Cabinet. The drum cabinet is a rectangular heavy steel box structure designed to enclose a 55-gallon waste drum within a 83-gallon overpack drum, and of sufficient size as to dissipate the pressure from a worst case headspace gas ignition to < 15 psig. The glovebox is attached to the top of the cabinet, with a common mounting plate used to seal the top of the cabinet and bottom of the glovebox. Following fabrication, the cabinet was successfully pressure tested to 22.5 psig.

The cabinet design includes a 24x24 in fluid seal HEPA filter housing for inlet air. A backflow prevention device is present in the cabinet to minimize the probability of filter failure in the case of overpressurization. Two doors are present. One is a small access door used primarily to inspect the top surface of the drum for contaminants prior to opening the large, drum access door. Both doors are gasketed to provide a tight seal during both normal operating conditions and abnormal events. Both doors have sensors to tell the operator of their open or closed status.

The drum lift and weighing subassembly is contained within the cabinet. The major components include a pneumatically - operated air-lift, and force transducers. Two force transducers (weight load cells) are used with the lifting mechanism to provide downward force information. Following placement of the drum in the cabinet, the lifting device is raised slightly to permit weighing of the total mass lifted, from which drum weight is determined. The drum then is lifted to seal against the drum lid seal, thus isolating the cabinet from the above glovebox. By adding a predetermined sealing force to the total weight, the total upward lift force required for this operation is determined.

Gas Analysis System. The headspace gas analysis system utilizes a Varian Model 3400 CX gas chromatograph (GC) tuned and calibrated to quantify hydrogen, methane, and a selection of VOCs. The dual column system uses an FID to detect the VOCs, and a TCD to detect hydrogen and methane. The system collects a real-time sample of drum headspace gas, and within approximately 5 minutes, prints out the gas concentration results. A personal computer (PC) software package fully automates the analysis and quantitation of the headspace gas results. The system alarms if any gas concentration exceeds the preset levels.

Air Filtration System. The air filtration system is responsible for ensuring that any radioactive contaminants released from a waste drum by any mechanism within the DVS are fully contained within the system. During operation, constant negative differential pressure is maintained within the drum containment cabinet and glovebox. The exhaust fan is an induced draft type, which is rated at 1,000 CFM maximum. The fan is equipped with a variable speed controller to permit the adjustment air velocity, and hence the pressure differential within the cabinet and glovebox. Parallel ductwork connects the outlets of the glovebox and cabinet to the common filter train. In the outlet from the glovebox, a adjustable damper is present to allow adjustment of the airflow and adjacent to the damper is a backflow device that prevents overpressure within the cabinet from backing up into the glovebox. The filter train consists of one roughing filter and two HEPA grade filters, all in series.

Remote Controller Assembly. An Industrial Process Controller (IPC) is the key interface between the machine and the operating personnel. The interface is a special touch-screen that allows the operator to control the course of action of the drum-venting process. For example, the linear drive controller and the nutrunner controller are electronically connected to the IPC, which issues discrete logic signals that cause the execution of predetermined motion sequences or programs. The IPC software prompts the operator for input via the touch-screen user interface. The resident software provides a flowchart-oriented operational basis for operation of the system (an operation is completed before the next operation in the sequence is begun). The entire control and data station is enclosed in an electrical cabinet enabling both personnel and equipment protection during the operation.

DRUM FILTER ASSEMBLY

The filter used normally in the drum-venting operation is pictured in Figure 3. A short-stem version used, in the event an impenetrable object is encountered, is also shown in Figure 3. The normal operations filter has a self-boring, self-tapping stem. The drill-type tip of this filter is made of hardened tool steel (high-speed steel). The housings of both units, which are otherwise identical, are fabricated of 316 stainless steel. The filter media is a carbon-bonded-carbon material and is performance tested to verify >99.97% removal of 0.3μ to 0.7μ particles. The air delivery capacity of the filter is 200 ml/minute at 1 in water column.

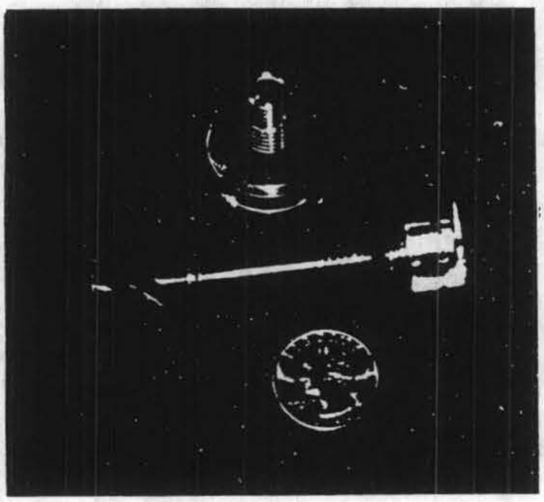

Figure 3. Standard and short filter assemblies.

OPERATIONAL SEQUENCE

The following is a description of the operational sequence upon which the DVS design and programming of IPC software is based.

Power Up. All DVS subsystems operate on 125 VAC power, except the air handling train which is 240 VAC, three phase. System power is initiated manually.

Change Operating Parameters. After powering up, the IPC displays currently set system process parameters which a qualified operator, by means of a password, can adjust if needed based upon prior knowledge of the drums to be processed.

Insert Filter In Socket. In preparation for DVS operation, the operator manually, through the glovebox gloves, places a filter into the specially designed, close-tolerance fitting, slotted round-head recess in the socket.

Drum Load. The operator opens the drum cabinet door and places the bridge platform in the recess to secure the door in the fully opened position. This allows the drum and dolly to be loaded into the cabinet and prevents the door from closing prematurely. The operator then removes the bridge platform and secures the door.

System Initialization. The IPC directs the HEPA blower to start up and reach its setpoint speed.

Drum Weigh. The IPC initiates a flow of pressurized air into the air stroke actuator. As the actuator slowly inflates, the drum is lifted until the beam of a photoelectric sensor is broken. This indicates the drum is sufficiently raised to be weighed by the force transducers.

Drum Lift. Upon receiving a signal from the operator, the IPC reinitiates the flow of air to the actuator which lifts the drum further to where the lid is pressed against the molded rubber seal of the seal assembly in the cabinet ceiling with the appropriate lift force, as measured by the force transducers.

Form Vacuum Chamber. Upon achieving the appropriate lift force, the operator initiates a signal causing the powerhead socket to descend into the seal assembly cavity. As this occurs, the vacuum pump begins to evacuate the now sealed cavity.

Seal Test. With the chamber formed and evacuated, the DVS tests the integrity of the chamber by monitoring any in-leakage of air. If the reduced pressure in the chamber is seen to increase by less than a predetermined amount over a short period of time, an adequate chamber seal has been achieved. If an adequate chamber seal is not achieved, the operator can either retry to form the chamber or proceed to the next step, noting that the headspace gas analysis results may be compromised by outside air.

Bore to Sample Depth. Upon receiving a signal to proceed, the nutrunner is caused to descend and rotate at "boring speed." In this operation the drum lid first is penetrated, and subsequently the liner lid is penetrated. However, the self-tapping threads of the filter assembly have not yet engaged with the drum lid. At this point, all downward and rotational motion of the filter ceases. As soon as the drum lid is penetrated, headspace gas fills the small evacuated chamber created above.

Sample Analysis. The hollow stem and access stem holes of the filter allow flow of headspace gases into the sealed chamber. The operator now initiates the gas sampling and analysis operation of the GC. Here, headspace gas is slowly pumped from the drum, through the small chamber, to the GC. Upon completion of the gas sampling and analysis, the PC displays the analytical results.

Headspace Gas Purge. When an undesirable concentration of combustible gas is measured, an evacuate/purge cycle is initiated. Here, the drum headspace gas is partially evacuated, followed by refilling with dry nitrogen. This cycle can be repeated as needed to reduce the combustible gas concentration. Subsequently, the headspace gas is resampled and analyzed for verification that the drum is safe to handle.

Install Filter. Following completion of an analysis showing acceptable headspace gas concentrations, the operator initiates the filter installation process. The IPC synchronizes the nutrunner controller and the linear drive controller to operate at the optimum thread speed and feed (descent) rate, based on the filter's thread characteristics. Using the nutrunner's torque transducer output, the IPC slowly lowers the powerhead socket until the torque transducer output indicates the threading operation is in progress. Rotary and downward motion continues until the torque transducer output achieves the predetermined setting, approximately 18 ft-lbs, thus indicating that the filter is properly installed.

Impenetrable Object. An impenetrable object is detected at any point in the boring or filter installation process. Such an indication will immediately stop all powerhead motion, with the IPC indicating the status to the operator. Should this occur during the boring operation, the subsequent gas sampling/analysis and evacuate/purge (if needed) cycles will be completed before any corrective action. Following the operational stoppage (and the continuation of operations, as appropriate), the operator can direct the powerhead assembly to retract the filter into the glovebox. At this point, the long-stem filter is replaced with a short-stem filter (see Figure 3), which then is installed in the normal manner.

Lower and Unload Drum. Following completion of the filter installation, the operator lowers the drum in the chamber. At this point, the operator opens the small access door and can check the drum lid near the filter for contamination. If any is found, the drum lid can be wiped clean to a level acceptable for removing the drum from the chamber. The drum then can be removed from the chamber through a reversal of the "drum load" step, and another drum subsequently can be loaded.

SUMMARY

Trial operations of the DVS to date have shown a normal cycle time of approximately 25 minutes/drum, with an increase of this time to approximately 45 minutes/drum if the evacuate/purge and resampling steps are mandated. Operational parameters have been established wherein the installed filter meets the leak tightness performance objective as determined by subsequent testing of the seal. All other operational objectives of the DVS also have been demonstrated. The NFT DVS has been shown to provide a safe and effective method for venting previously filled drums of TRU waste.