A NOVEL APPROACH TO DRUM VENTING AND DRUM MONITORING

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ABSTRACT

This paper describes the details and specifications associated with drum venting and drum monitoring technologies, and discusses the maturity of in-place systems and current applications. Each year, unventilated drums pressurize and develop bulges and/or breaches that can result in potentially hazardous explosions, posing undesirable hazards to workers and the environment. Drum venting is accomplished by the safe and simple installation of ventilated lids at the time of packaging, or by the inherently risky *in-situ* ventilation (depressurization) of "bulged" drums.

Drum monitoring employs either a Magnetically Coupled Pressure Gauge (MCPG) Patent Pending and/or a Magnetically Coupled Corrosion Gauge (MCCG) Patent Pending. Through patented magnetic sensor coupling, these devices enable the noninvasive and remote monitoring of the potentially hazardous materials and/or spent nuclear fuel that is contained in 55-gal drums and associated steel overpack containers.

INTRODUCTION

Drum Venting Background

The Hanford Site is one of the U.S. Department of Energy sites that generate and/or store the transuranic (TRU) wastes associated with national defense programs. In 1970, the U.S. Atomic Energy Commission defined TRU waste as a separate waste category and mandated storage in retrievable, contamination-free packages designed to last 20 years. Since 1970, approximately 37,400 suspect-TRU and TRU waste containers have been placed in retrievable storage in the Low Level Burial Ground (LLBG) at the Hanford Site [1]. TRU drums are visually checked for structural integrity, and placed in overpack containers, as needed, during the retrieval phase. Drums containing TRU material are vented, if necessary, and transported from the LLBG to a Treatment, Storage, or Disposal (TSD) facility, where they are stored for certification activities that support disposal at the Waste Isolation Pilot Plant (WIPP) in New Mexico.

In addition to checking structural integrity during the retrieval inspection, drums are checked specifically for venting devices. Drum venting is necessary because radiolysis of plastics and cellulosic materials in the waste matrix of TRU waste packages generate hydrogen gas, creating potential flammability hazards inside unvented drums. Over time, it is possible that the hydrogen-oxygen atmosphere can reach concentrations that pose fire or explosion hazards. Hydrogen levels as high as 27 percent (lower explosive limit is 4 percent) have been encountered in retrieved TRU drums at Los Alamos National Laboratory, LANL [2]. Venting over-pressurized TRU waste drums that contain elevated levels of hydrogen or other flammable gases could result in severe worker injury or death from the impact of a drum lid ejected as a result of internal deflagration inside the waste drum.

In 1978, the "Hanford Vent Clip" was installed on TRU waste drums originating from Hanford. This clip is an inch wide strip of stainless steel that was placed between the rim of the drum and the mating drum lid. Upon tightening of the lid hold-down ring, a complete seal was prevented, because the clip protruded approximately 1.5-inches below the ring. Nonetheless, not all TRU drums containing the Hanford Vent Clip have maintained adequate ventilation and/or the visible portion of the vent clip has been destroyed during storage.

Venting of retrieved TRU drums at the Idaho National Engineering and Environmental Laboratory (INEEL), LANL, and the Savannah River Site (SRS) has been successfully accomplished, by utilizing a Drum Venting System (DVS) that involves drilling a hole in the container lid with a spark resistant titanium nitride drill bit, followed by the installation of a Nucfil® filter or equivalent. To support the drilling of the lid, the DVS requires a complex system involving an ASME certified containment vessel, a glove box, the drilling mechanism, a HEPA filter system, and venting and sampling equipment. Though successful, this procedure is nevertheless quite cumbersome.

The "Hanford–Drum Venting System" (H-DVS) Patent Pending was conceptually developed for the *in-situ* venting or depressurization of TRU waste drums at the Hanford Site. The system involves the integrated use of a properly ventilated portable containment with expansion bellows, a simple mechanical advantage system, and a pneumatic ram. The system allows operators to safely install environmentally compliant drum ventilation in the field on existing or newly discovered drums. The system is easily deployable and adds incrementally small costs to the total cost of modest environmental remediation projects that involve repackaging of drums.

Drum Monitoring Background

U.S. Department of Energy (DOE) guidelines DOE G 435.1-1, Section L. specifies:

> *"Vents or other mechanisms to prevent pressurization of containers or generation of flammable or explosive concentrations of gases shall be installed on containers of newly-generated waste at the time the waste is packaged. Containers of currently stored waste shall meet this requirement as soon as practical unless analyses demonstrate that the waste can otherwise be managed safely."*

The Environmental Protection Agency (EPA) assurance requirements regarding the disposal of spent nuclear fuel and TRU (40 CFR 191.14) specify:

> *"Disposal systems ... monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring."*

The above regulations address two concerns - container integrity and noninvasive monitoring. In 1998, Vista Engineering Technologies (Vista Engineering) personnel conceived of a novel means to measure pressure in a totally sealed steel container. The concept initially exploited the fact that stainless steel containers are virtually transparent to magnetic fields, which allows the rotation angle of a "magnet needle" to be measured *outside the container and with no penetrations of the container,* with an accuracy approximating 2 to 3 percent of full-scale.

Subsequent development has found that, although attenuation drops off dramatically, a magnetic signal can readily be detected through carbon steel barriers (e.g., 55-gallon drum lids) as well. This device, the Magnetically Coupled Pressure Gauge (MCPG) Patent Pending, requires no internal or external power supply, is resistant to radiation effects, and has an expected lifetime of more than 50 years. Vista Engineering has fabricated and delivered over 500 of these gauges to the U.S. Department of Energy for use by Hanford's Spent Nuclear Fuel (SNF) Program and Plutonium Finishing Plant (PFP) for monitoring containers storing nuclear materials. Magnetically coupled gauges can also "see" through carbon steel, provided that the magnetic permeability is uniform throughout.

The MCPG solved the pressure-measurement problem. By a simple extension of the well-proven MCPG technology, Vista Engineering has prepared a conceptual design for a Magnetically Coupled Corrosion Gauge (MCCG) Patent Pending. The MCCG is simple to fabricate, robust to withstand the shipping environment, made entirely of 316/304 stainless steel, and like the MCPG, is easily installed in the 3013 Bagless Transfer Convenience Can (BTCC). The current design provides for six (6) independent coupons.

DRUM VENTING DISCUSSION

Preliminary Design Requirements of the CVS

Based upon the TRU retrieval safety analysis, any Container Venting System (CVS) used at the Hanford Site has been identified as significant to worker safety [2]. As previously stated, venting TRU waste drums that are over-pressurized, or contain elevated levels of hydrogen or other flammable gases, can result in severe worker injury or death from an impact by an ejected drum lid caused by an internal deflagration inside the waste drum. The safety function of the CVS is to shield workers from missiles ejected from the waste drum during venting and filter installation activities.

Therefore, the functional requirement related to the CVS role in the hazards analysis is to mitigate the worker consequences of potential hazards associated with venting TRU waste drums that are over-pressurized or contain elevated levels of hydrogen gas. The CVS meets its functional and safety requirements, when it provides a contained and automated environment for the drilling and venting operations, thereby eliminating the manual performance of such activities by workers. Preliminary design requirements and goals are outlined in Tables I and II below.

Table I. Preliminary Design Requirements

No.	Preliminary Design Requirement
1	Ventilate drums having >50 psi internal pressure
2	Eliminate spark sources during ventilation
3	Install passive filtration for long term ventilation
4	Engineered barrier to missiles

Table II. Preliminary Design Goals

No.	Preliminary Design Goal
1	Maximum time allowed for filtration is 15 minutes
2	System is operated by two nuclear process officers (i.e. no specialized technicians)
3	Simple, robust, system
4	Operated at retrieval site
5	Return on Investment > 200% over 5 years

Proposed CVS Solution: The Hanford–Drum Venting System (H-DVS)

An engineered solution, called the "Hanford–Drum Venting System" (H-DVS) Patent Pending, has been developed for in-field venting of retrieved drums from long term storage in burial trenches. Vista Engineering has developed a pre-conceptual design that utilizes pneumatic rams to install air filters in a manner not harmful to the health and safety of site workers. The drum and contents are not expected to present a possible on or off-site dose above limits that would require Safety Class or Safety Significant features. However, possible reactions with flammable drum gases could yield sufficient explosive energy to launch drum heads that could seriously injure facility workers. The principle mechanism for housing required filter installation equipment is revealed in Figure 1 below.

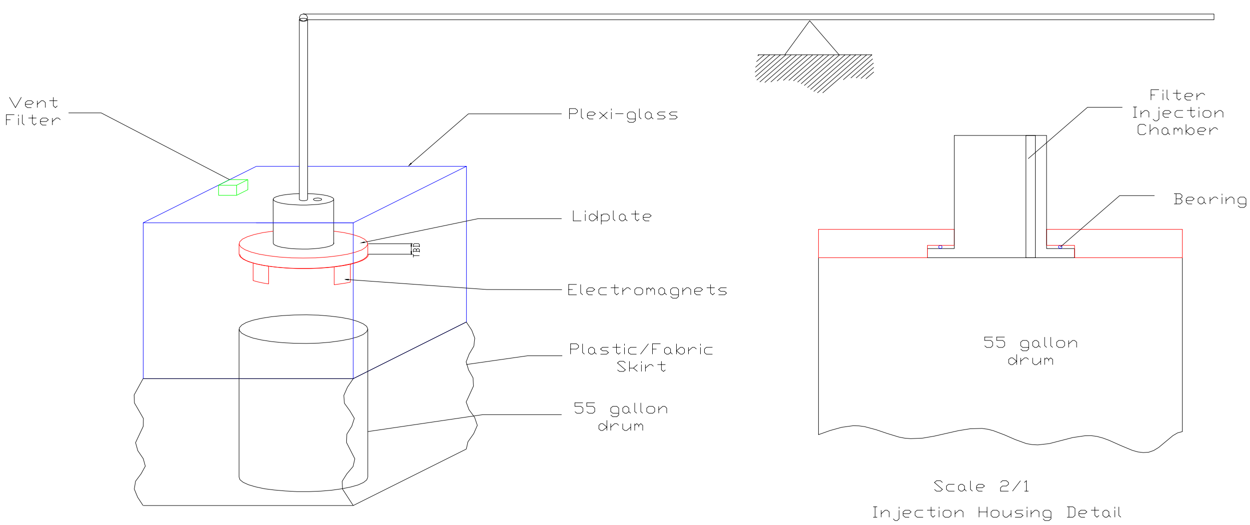

Figure 1. Preliminary design concept of H-DVS

The drum head restraint will likely be Safety Significant due to the possibility of serious injury to the worker. The proposed shroud and passive filter will provide a partial mitigation of any released alpha contamination during the venting and any upset sequences that occur during the venting.

The concept entails a drum head shroud made of a combination of stainless steel, electromagnets and Plexiglas®. The Plexiglas® enables visibility of the work surface for alignment of the filter gun. The magnets are proposed to be a three piece set that will engage the steel body of the drum below the top lip. The drum will then be connected to the steel portions of the drum head shroud with sufficient material and strength, to restrain the drum head, in the event that flammable gases are ignited during the venting process. A small 6" diameter sintered metal HEPA filter is proposed to be integrally mounted on the drum head shroud for filtered pressure relief of potential fugitive gases. The head shroud, weighing less than 200 pounds, will be moved into place by a counter-balanced lifting device that can be easily manipulated by a single field worker. This will eliminate a great deal of complexity associated with field hydraulics and/or motor driven devices. The entire system can be skid or cart mounted, to accommodate site specific field conditions.

Hanging below the drum head shroud will be a chain mail and heavy plastic fabric bellows (skirt) that will settle to the ground and surround the drum during the attachment of the drum head. The skirt will be sufficiently strong to contain any side rupturing drum contents or gases, and will expand, as needed, to offset sudden pressurizations ranging from pre-set levels of approximately 50 psi to 5 psi within the bellows; thus preventing pressure related worker injuries. All gases will pass through the HEPA filter, before being vented to the atmosphere. The pointed tipped air filters are installed into the drum lid by a pneumatic ram (air gun).

The H-DVS is therefore conceptually developed for the *in-situ* venting of TRU waste drums, in a safe and environmentally compliant manner. The system is easily deployable and adds incrementally small costs to the total cost of modest environmental remediation projects that involve repackaging of drums.

DRUM MONITORING DISCUSSION

The Magnetically Coupled Pressure Gauge - MCPG

The Vista Engineering Technology — a magnetically coupled pressure gauge (MCPG) — was designed to provide an answer to the question, "how does one measure the pressure within a sealed stainless steel container, where no penetrations can be made for conventional measurement?" The answer — the MCPG — is derived from two observations: First, the magnetic permeability of the 300-series stainless steel, from which most DOE containers are made, is essentially transparent to magnetic flux. When a magnet is placed on the inside of the container, the force of that magnet is exerted upon (or detected by) another magnet or sensor situated on the outside of the container. Second, when an ordinary Bourdon tube type pressure gauge is placed within an aneroid reference chamber inside the container and when the gauge needle is replaced with a magnet, the Bourdon tube responds to pressure changes and rotates the "magnet needle" by an amount proportional to the applied pressure. By knowing the internal magnetic field orientation and the associated rotation angle and proportionality coefficient of an external readout unit, the pressure on the inside of the container can be easily measured from the *outside* of the container, *without* making any penetrations.

Figure 2 illustrates a MCPG and associated readout unit; both manufactured by Vista Engineering for Hanford's Spent Nuclear Fuel (SNF) Program. In SNF's containers, the magnetic flux easily traverses the eight (8) inch thickness to the readout unit, which comprises a compass calibrated in terms of pressure. Magnetically coupled gauges can also "see" through as much as ½-inch carbon steel, provided that the magnetic permeability is uniform throughout.

In early 2001, the MCPG was adapted to DOE's 3013 container system, to support the long-term PuO_2 storage requirements at Hanford's Plutonium Finishing Plant (PFP). In this adaptation, the pressure sender unit was built into the lid of the 3013's Bagless Transfer Convenience Canister (BTCC).

Photos of a partly assembled PFP MCPG and the MCPG integrated into the lid of a 3013 BTCC are shown in Figure 3. Vista Engineering has fabricated and delivered over 500 of these gauges

Figure 2. MCPG (left) and readout unit (right)

to the U.S. Department of Energy for monitoring containers that store nuclear materials. Similar units can be utilized in carbon steel 55-gallon drum lids.

Figure 3. Partly assembled MCPG (left) and MCPG built into lid of a 3013 BTCC (right)

The Magnetically Coupled Corrosion Gauge - MCCG

The conceptual design for the MCCG is an extension of the technology utilized for the MCPG. In the MCCG, a spring-loaded magnet is restrained from rotating by a stop attached to a corrosion coupon or corrosion test specimen. If and when corrosion occurs, the coupon "fails" which then allows the stop to move. This, in turn, allows the magnet to rotate. The rotation of the magnet is measured by an external sensor, which signals the failure of the coupon. Multiple coupons can be employed; each with different cross sections and adjustable stresses applied to the coupon. By observing the successive failure of two or more coupons, the corrosion rate of the process occurring in the container can be measured.

The conceptual design for the MCCG is illustrated in Figure 4. This perspective view of the MCCG shows the following components: A magnet installed on a pivot mechanism; a magnet support plate with a "finger" that extends from the central disk; and six (6) corrosion coupon mechanisms. In the design, a rotatable magnet is torsionally loaded by a hairspring situated beneath the magnet support plate.

The corrosion coupon mechanism incorporates a "finger stop" at the top of the mechanism. In the "armed" position (i.e., unbroken corrosion coupon), the finger stop lies in the same plane as the "finger" of the magnet support plate, and although under torsional stress, the support plate is kept from rotating by the finger stop (Figure 4, bottom left). In the "failed" position (i.e., when corroded coupon breaks), the finger stop raises to allow the finger to rotate clockwise 60 degrees to the next in-plane finger stop (Figure 4, bottom right). The notch near the bottom end of the machined section forms the actual corrosion coupon or specimen point, which is held under tension by Belleville Washers. Turning the nut compresses the Belleville Washers and places tension upon the corrosion coupon. Such stress accelerates the "stress corrosion cracking" process — the principal corrosion failure mechanism that occurs in welded assemblies such as cans, tanks, and pressure vessels. Table III below reveals results of coupon specimen stress tests.

Table III. Specimen diameter required for specified stress at 430 pounds force

Coupon Number*	1	2	3	4	5	6
Stress (psi)	30,000	25,000	20,000	15,000	10,000	10,000
Diameter (inches)	0.135	0.148	0.165	0.161	0.197	0.197

* Different sets of Belleville Washers were used in Specimens 1-3 and Specimens 4-6

As shown in Figure 4, six identical corrosion coupons arranged at 60-degrees intervals, are placed under decreasing levels of tensional stress.

Assuming a uniform environment, stress corrosion cracking will cause the first coupon to fail first, since the applied tensional stress is greater than for the other coupons. This allows the magnet to rotate by 60-degrees to the next highest-stressed coupon. After that coupon fails, further corrosion will cause the second coupon to fail, allowing the magnet to rotate another 60-degrees to the next coupon, and so on. By measuring each successive failure, and knowing the stress applied to each coupon, valuable corrosion rate information can be obtained.

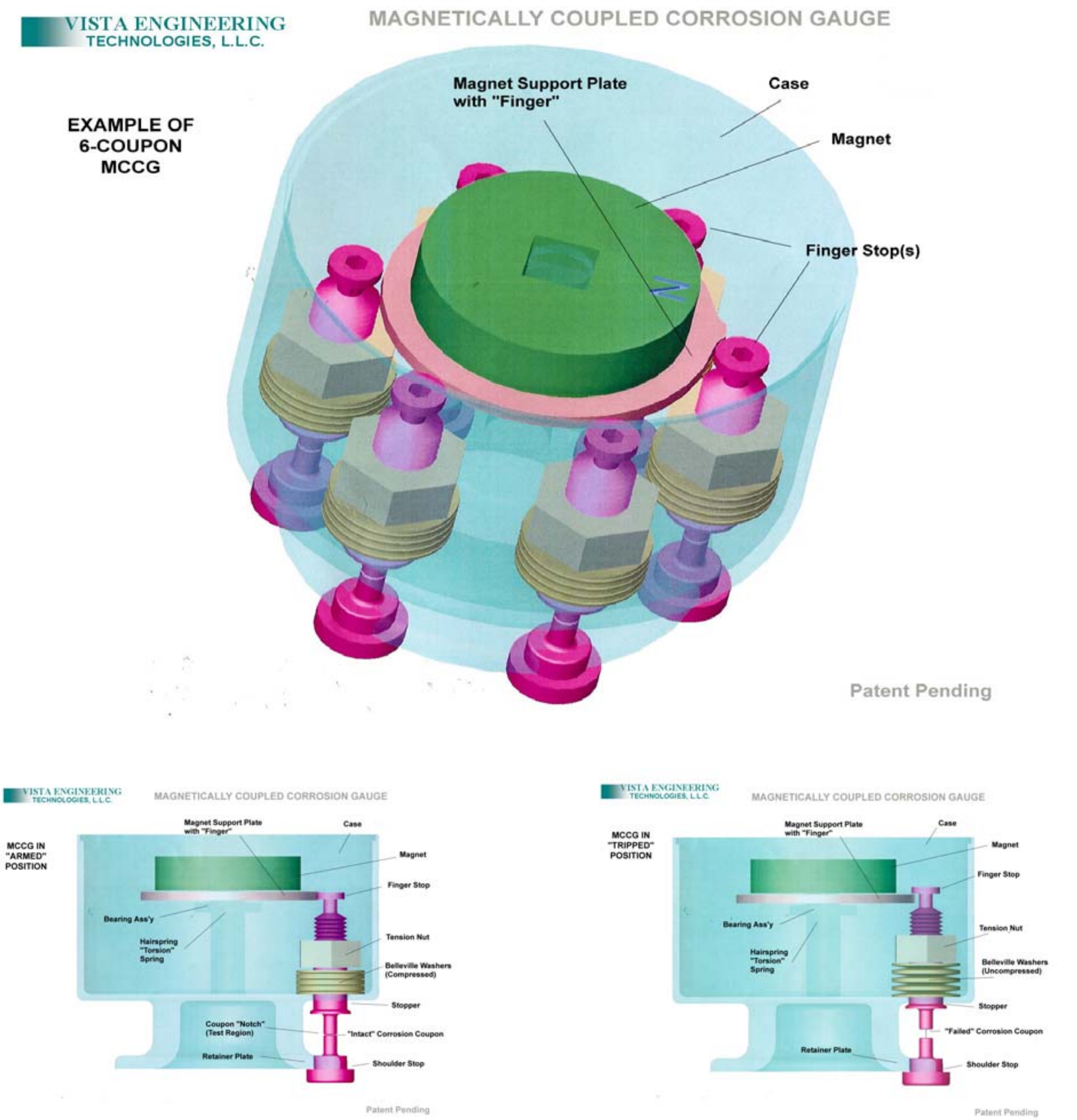

Figure 4. Top - A perspective view of the MCCG with six identical corrosion coupons
Bottom - Corrosion coupon in "armed" state (left) and in failed state (right)

The next-generation MCCG will have a non-uniform angular distribution of coupons, arranged in such a way to identify the failed coupon by the unique angular change observed between coupon failures. This tactic is a "defense-in-depth" and assures that the corrosion process can be monitored and quantified, even if the zero-coupon index position is lost.

With a minor seal adaptation to the current design, the MCCG can be used in myriad applications that require liquid immersion of the gauge. Utilizing the MCCG with multiple coupons during chemical decontamination, or during the cleaning of critical system components, would provide valuable corrosion rate information for multi-step applications, in addition to the corrosion rate for the entire process. Installing the MCCG in piping or holding tanks could provide valuable material compatibility data that can be used to evaluate system integrity and estimate end of life.

When placed in strategic locations, the MCCG can be used as a safety device that provides advance notice of unacceptably high corrosion conditions. For instance, use of a multi-coupon MCCG in a pipeline that transfers a substance to a critical location would enable an evaluation of a critical material under specific system conditions; thus providing estimates of previous corrosion and future corrosion. So, in addition to being able to detect corrosion, the multi-coupon MCCG enables the *measurement* of the corrosion process as well.

SUMMARY

This paper has described the conceptual design for the Hanford–Drum Venting System (H-DVS), and has also described the existing magnetically coupled pressure gauge (MCPG), as well as the prototype corrosion monitoring gauge (MCCG). The H-DVS allows site workers to safely install filtered vents into bulging drums, in a safe and easily deployable manner at a small incremental cost to the total project budget. Vista Engineering has fabricated and delivered over 500 MCPGs to the U.S. Department of Energy for use by Hanford's Spent Nuclear Fuel (SNF) Program and Plutonium Finishing Plant (PFP) for monitoring containers that store nuclear materials. The conceptual design for the MCCG is an extension of the technology utilized for the MCPG. In addition to detecting overall corrosion in storage systems such as drums, piping, and holding tanks, the multiple coupon configuration enables the *measurement* of corrosion rates as well.

For more information about the Vista Engineering Technologies MCCG, contact the authors at info@vistaengr.com, or call them at (509) 737-1377.

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