PROHIBITED ITEMS IN RADIOACTIVE WASTE CONTAINERS: AN ANALYSIS OF THE HEALTH AND SAFETY BENEFITS VERSUS RISKS – 10144

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ABSTRACT

The development of waste transportation and disposal regulations in the USA has resulted in a substantial list of prohibited items or materials that are allowed in waste containers including free liquids, liquids in internal containers, pressurized containers, and the like. The reasons for these prohibitions were primarily to reduce the chance of an accidental release of waste during treatment, such as compaction, or during transport as a result of leaking or exploding waste containers and to prevent air, surface water, or groundwater pollution at disposal sites. Concurrently, the government regulation of the management of radioactive waste resulted in the development of much more stringent requirements for the transport and disposal of many of the radioactive waste forms than the comparable requirements for the transport of hazardous waste. These added requirements raise the question of whether the initial restrictions to protect health, safety, and the environment are still beneficial or have resulted in a greater worker health and safety risk than public health and safety and environment benefit.

Using the Waste Isolation Pilot Project as an example, this paper examines the evolution of the regulations for the transport and disposal of both hazardous and radioactive waste with respect to one type of prohibited item – pressurized containers. It presents the scientific or technical basis for those regulations with an emphasis on the associated health and safety risk and benefit for the public and the workers at the points of generation, the workers at interim management steps such as packaging, treatment, and transportation, and the workers at the disposal sites.

INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) is authorized to dispose of all defense-related transuranic (TRU) wastes generated by or for the Department of Energy (DOE) and its predecessors, the Atomic Energy Commission. TRU waste, which is to be disposed of in approved waste containers, must meet certain requirements and must be devoid of prohibited items. One prohibited item is pressurized containers, in the form of either aerosol cans or compressed gas cylinders, within the TRU waste container.

BACKGROUND

The Land Withdrawal Act (LWA) granted the U.S. Environmental Protection Agency (EPA) regulatory authority to conduct waste characterization activities for TRU waste destined for the WIPP. As directed by the Resource Conservation and Recovery Act (RCRA), the EPA requires all hazardous waste to undergo analysis to verify its composition and to ensure proper treatment/handling methods are employed. The EPA assigned oversight of nonradioactive TRU waste characterization at the WIPP to the New Mexico Environment Department (NMED), which in turn issued a Hazardous Waste Facility Permit (HWFP) that prohibits disposing TRU waste with certain physical and chemical characteristics at the WIPP, including explosives and compressed gases. According to Attachment B of the HWFP this is to prevent storage or disposal of ignitable, corrosive, or reactive wastes. The WIPP Waste Acceptance Criteria (WAC), developed by the DOE, reiterates EPA and NMED restrictions, including the compressed gas prohibition. The DOE explains in both The Contact-Handled (CH) and Remote-Handled (RH) Technical Safety Requirements (TSRs), prohibiting compressed gases is intended to eliminate ignition sources in TRU waste containers and prevent possible fires and explosions.

The EPA defines a compressed gas in 40 CFR 261.21 as “any material or mixture having in the container an absolute pressure exceeding 40 pounds per square inch (psi) at 70°F or, regardless of the pressure at 70°F, having an absolute pressure exceeding 104 psi at 130°F; or any flammable material having a vapor pressure exceeding 40 psi absolute at 100°F.” Compressed gases present two potential hazards: ignitability and reactivity. The Department of Transportation (DOT) divides Class 2 compressed gases into three divisions: Class 2.1 flammable gases, Class 2.2 non-flammable gases, and Class 2.3 poisonous gases. The internal pressure of a compressed gas container can become explosive or detonate if exposed to a strong ignition source or if heated under confinement. The potential presence of DOT Class 2.1 flammable gases in a cylinder presents an ignitability hazard. In addition to their principal contents, such as paint, the flammable propellants in aerosol cans that aspirate their contents introduce an additional hazard. Aerosol spray paint cans use hydrocarbons such as butane and propane as propellants, which can ignite when exposed to heat. Aerosol spray paint cans also contain a variety of volatile organic compounds (VOCs), which are carefully monitored and regulated at the WIPP because of their flammable and inhalant-associated risks.

Compressed gases and aerosols are not permitted in WIPP shipments. TRU Waste Authorized Methods for Payload Control (TRAMPAC) prohibits pressurized containers in TRUPACT and HalfPACT payloads. Empty aerosol cans are allowed as long as they do not contain more than one inch of residual liquids and do not impact the internal pressure or flammability potential of a package. On the other hand, spray paint suppliers are allowed to ship aerosol spray paint cans pressurized to 30-50 psi packed inside cardboard boxes, because the DOT considers spray paint a consumer commodity and regulates its transport under the classification of “other regulated material” (ORM). As a category with fewer stringent regulations than those of other classes of hazardous materials, ORM shipments do not require shipping papers, emergency response information, placarding, or formal training for workers. Shipments of spray paint do have quantity limitations with a maximum amount of 200kg per vehicle, and those who ship spray paint must possess a general knowledge of DOT regulations, complying with packing, marking, and labeling requirements.

Typical compressed gas cylinders, such as lecture bottles found at various DOE sites, can be pressurized up to 1800 psi and are permitted to contain DOT Class 2.1, 2.2, or 2.3 substances. Volumes associated with small laboratory compressed gas cylinders and aerosol cans range from 0.4 liters to one liter. Most aerosol cans are pressurized between 30-50 psi, and DOT specification 2P and 2Q aerosol containers must be tested to withstand burst pressures of 240 psig and 270 psig, respectively. Aerosol cans that have obviously been punctured are allowed to remain in the TRU waste containers. In contrast, compressed gas cylinders, even if empty, may not be left in TRU waste containers per NMED disposal restrictions contained in the WIPP HWFP. (The EPA considers a compressed gas container empty when the pressure in the container approaches “atmospheric.”) Apparently, the reasoning for this prohibition relates to the fact that there is no acceptable way to prove a compressed gas cylinder in a TRU waste drum is empty. Though, if it can be verified that the valve stem has been removed, then the cylinder is open to the atmosphere, which should be sufficient proof.

If compressed gas cylinders are found in a TRU waste container the prohibited item is removed and the drum is repackaged. This process involves opening the TRU waste container and removing the prohibited items—usually in a glove box – and puncturing the aerosol cans with the specialized equipment to protect workers from injury. The repackaging costs an average of $22,500 per container. TRU waste drum repackaging also places workers at increased risk for radiological exposure and injury. TRU radionuclides are primarily alpha emitters, so their internal dose conversion factors are expected to be significantly higher compared to other radionuclides found in the waste. As a result, inadvertent exposure to airborne TRU radionuclides can yield a significantly higher internal dose to a worker. In addition, external exposure to workers can occur from handling RH TRU drums multiple times. Reducing the number of times a TRU container is handled can reduce the potential for internal and external exposure, and the chance for an accident or injury to occur from repackaging TRU drums.

Another issue associated with the removal of compressed gas cylinders or aerosol cans from the TRU waste drum is the fact that these removed objects still require disposal, which may result in additional treatment. Such treatment of a contaminated cylinder generates additional hazardous and/or radioactive waste that must be stored or further neutralized—options that create more waste that must be stored indefinitely at generator sites. Treating, storing, and disposing of wastes associated with compressed gas cylinders or aerosol cans removed from TRU waste drums increase worker handling and further increase radiological exposure potential and the cost of waste disposal.

Steel drums used in TRU waste disposal must meet strict DOT standards and pass the DOT required drop, stack, vibration and leakproof tests. Various WIPP generator sites have conducted experiments to determine the maximum pressure the steel drums used for TRU waste disposal can withstand without failing. Drum failure is defined differently among the various sites performing these experiments. Lid loss or loss of contents constitute complete drum failure in the Savannah River Site (SRS) experiment, for instance; while Los Alamos National Labs (LANL) and Idaho National Laboratories (INL) use self-venting to define drum failure, due to the potential release of toxins, radionuclides, and flammable gases.

The SRS performed hydrogen deflagration experiments, during which it determined the concentration of hydrogen required to cause an empty waste drum to breach (defining breach as lid loss) when ignited. The SRS plugged the drums’ filter vents in order to prevent gases from escaping prior to ignition. The internal pressures of the drums were measured during the experiment, and it was determined that a minimum pressure of 105 psig was necessary for drum lid loss to occur. However, hydrogen concentration provides a better indicator of potential for drum failure because the maximum pressures fluctuate. Although the lower flammability limit for hydrogen is four percent by volume, greater than 14 percent hydrogen by volume was necessary to incur lid loss.

Table I. Results of SRS hydrogen deflagration experiments.

Test #	H2 Concentration, Vol %	Maximum Pressure, psig	Observations
14	13.3	70	Bulged
18	13.9	69	Bulged
12	14.1	138	Bulged
11	14.9	69	Bulged
13	16.5	121	Bulged
10	16.95	137	Lid Blown
17	18.0	211	Lid Blown
16	22.7	320	Lid Blown
9	35.3	105	Lid Blown

EG&G Idaho performed tests on DOT 17C 55-gallon unvented (empty) waste drums to examine the explosion potential of hydrogen mixtures in air. Before performing the explosion experiments, EG&G Idaho examined the hazards of over-pressurization using non-flammable gas. Compressed air was pumped into the waste drum until it reached an internal pressure of 22 psig. At that pressure, a leak developed around the gasket, but the drum lid did not blow off. EG&G Idaho therefore determined that a maximum pressure of 10 psig could consistently be contained inside a drum without leakage. This is also the working standard for DOT specification waste drums.

LANL studied various waste drums' response to internal pressurization using both open- and closed-head drums. Open-head drums have lids sealed with a ring that closes with a nut and bolt fastener, whereas closed-head drums' lids are welded to the drum's body. The pressure inside the empty drums was increased in five psig increments and allowed 30 seconds to stabilize. Open-head drums tended to fail by self-venting next to the nut and bolt fastener on the ring, whereas closed-head drums tended to fail explosively.

Table II. Results from Los Alamos drum pressurization experiments.

30 gal open-head	30 gal closed-head	55 gal open-head	55 gal closed-head	85 gal Overpack
-Fail below 50 psig -Bulge at top and bottom -self vent at nut and bolt closer on ring	-Able to hold and maintain pressures >120 psig -Fail explosively at top or bottom ends	-Vent at or below 32 psig -Vent adjacent to nut and bolt fastener on ring -Only bulge at top and bottom ends	-Fail at 48 psig and above -Fail explosively at top or bottom end -	-Self vent at 16 psig or less -Venting occurs at nut and bolt closure

The waste drums used in the experiments do not completely and accurately represent the waste drums sent to the WIPP; the drums used in the experiments were either not vented or the vents were plugged. All TRU waste containers sent to the WIPP are required by the HWFP to be vented. The minimum airflow required for a WIPP-approved vent is one liter/min at one psi. Had vents been used, they could have relieved some of the internal pressure in the drum and would have consequently altered the findings of the aforementioned experiments. Westinghouse Savannah River Company estimated that a puff of smoke observed around the closer ring of the drum during the SRS hydrogen deflagration experiments relieved approximately one percent of the waste drum's internal pressure. A compressed gas container could be ignitable, but it might not produce a flammable mixture in a waste drum were it to leak. In order for a compressed gas to present an ignitability risk inside the drum a few events must occur:

- A pressurized container must release enough flammable gas to reach the substances' lower flammability limit (LFL) (the majority ranging from a low of about 0.7 percent to three percent by volume, depending on the gas).
- Enough oxygen must be present in the waste container for the reaction to occur.
- There would have to be an ignition source inside the waste container to start the reaction. Experiments performed by EG&G Idaho determined that a flammable concentration of hydrogen could not be ignited by dropping or puncturing the waste container.
- The drum vent would have to be plugged or blocked in order for the flammable gas to maintain its concentration.

Propellants found in aerosols are liquid at room temperature and are further restricted due to residual liquid limitations of WIPP TRU waste. Aerosol containers found inside TRU waste containers with greater than one inch of liquid remaining must be removed. For a hypothetical example, a 0.5 liter (500 ml) aerosol container with all liquid remaining was left inside a 55-gallon TRU waste drum. If isobutane, one of the most common gases used as a propellant, was used at a 1:1 product-to propellant ratio, the aerosol would contain 250mL of isobutane. This amount translates to approximately 2.2 inches of liquid in a three-inch-diameter aerosol container, which is clearly more than the regulatory residual liquid limit of one inch. The liquid-to-gas dispersion ratio for isobutane at standard temperature and pressure (STP) is 1mL liquid to 229.3mL gas. An instantaneous release of an aerosol container with 250mL of isobutane would add 57.3 liters of isobutane gas to the TRU waste drum. This would increase the pressure inside the TRU waste drum by 6.3 psi, assuming 60 percent void space in the drum and ignoring the effects of the filter vent. Under these conditions, two or more full aerosol containers would have to rupture or leak within an unvented drum for the pressure to exceed 10 psig, considered the upper limit of competency of 55-gallon drums. The release of 57.3 liters of isobutane inside a 55-gallon TRU waste drum would surpass the chemical's upper flammability limit (UFL) of 8.4 percent.

If an aerosol container with one inch of liquid remaining in a standard three-inch-diameter by eight-inch tall container were breached inside a TRU waste container, it would increase the isobutane concentration to 10 percent. This release would exceed the UFL and thus, would not create a flammable mixture inside the TRU waste container. The resulting pressure increase would be minor, with an increase of 1.7 psi. An empty aerosol container with one percent liquid remaining would only increase the isobutene concentration to 0.3 percent inside the TRU waste drum (considerably lower than the LFL for isobutene of 1.8 percent). This release would increase the internal pressure of the TRU waste drum by 0.06 psi, and 167 such aerosols would have to release instantaneously for the pressure to reach 10 psi. There is only a small opportunity between one inch and one percent of remaining liquid where the release would be within the flammable range for isobutane in a container of this size.

National laboratory standards and safety manuals do not permit compressed gas cylinders to be emptied to a pressure lower than 25 psi, a measure that prevents internal contamination of cylinders and allows them to be recycled/refilled without purging. DOT 3E lecture bottles have an internal volume of 0.441 liters; the atmospheric volume of an ideal gas pressurized to 25 psi would be 0.75 liters. One mole of an ideal gas at standard temperature and pressure (STP) has a volume of 22.4 liters; therefore, this release would add 0.033 moles inside a 55-gallon TRU waste container. This addition would then increase the pressure by 0.08 psi, which is 125 times less the failure pressure of 10 psi determined by EG&G Idaho. The addition of 0.75 liters of a flammable gas would not produce an ignitable mixture because the peak concentration of the substance could only reach 0.36 percent by volume. If a full lecture bottle pressurized to 1800 psi were to release its contents in a 55-gallon TRU waste drum, it would increase the internal pressure of the drum to 5.81 psi, which would still not reach the TRU waste container working standard pressure of 10 psi. However, assuming a lower flammability limit of two percent, a lecture bottle pressurized to 70 psig or more could produce an ignitable mixture within a 55-gallon drum with a 60 percent void volume if it were to leak.

In addition to the low probability that a gas cylinder or aerosol can would cause a TRU waste drum to breach, health and safety risks to both workers and the public associated with that possibility are further mitigated by the fact that all TRU waste containers are transported in Type B shipping containers. These are specifically designed to safely contain radioactive materials even in the most damaging hypothetical conditions. The TRUPACT-II Type B shipping container has a design pressure of 50 psig; therefore, the aforementioned pressurized container/aerosol releases would be negligible. Furthermore, release of a full aerosol container (250mL of propellant) inside the TRUPACT-II Type B shipping container (60 percent void volume) would not reach a LFL of two percent.

CONCLUSIONS

Waste characterization activities for TRU waste bound for the WIPP would benefit from modifying current practices and altering restrictions with respect to the presence of pressurized containers in TRU waste containers. Specifically, this report concludes the following:

- The right combination of a flammable substance, oxygen, and an ignition source to create explosive or flammable conditions inside a TRU waste container could not be replicated under expected waste matrix conditions.
- The health and safety risks associated with increased internal and external radiological exposures associated with the removal of pressurized containers from TRU waste containers appear to be greater than the risks associated with leaving them in the TRU waste containers for transport and disposal at WIPP.
- There are significant expenses associated with the removal and subsequent treatment of pressurized containers.
- Filter vents required on WIPP TRU waste drums reduce the associated risks of pressurized buildup, and the probability of a blocked filter vent is highly unlikely based on previous container pressurization and venting tests.
- Various experiments have demonstrated the robustness of the TRU waste payload containers to withstand either explosive releases or fires should one or more compressed gas cylinders and aerosol cans in the payload containers fail and release their contents.

In addition, aerosol containers that meet the residual liquid restrictions do not need to be punctured, and empty compressed gas cylinders (<25 psi) do not need to be removed from the TRU waste containers. These changes would not alter the safety factors associated with handling TRU waste containers during transport or storage because:

- The release of a fully pressurized lecture bottle sized pressurized container would not reach the working standard pressure of 10 psi.
- An “empty” laboratory lecture bottle cylinder of 25 psi or less would not pose an ignitability or reactivity hazard.
- A full aerosol container, if breached, would not reach the working standard pressure of 10 psi.
- Empty aerosol containers (< one percent liquid) could remain inside a TRU waste container without impacting the internal pressure or flammability.

Finally, the implication of this study is that small quantities of otherwise hazardous gases or vapors do not pose a danger under many circumstances and that regulatory constraints may therefore be overstated. The packaging requirements could be revised regarding these prohibited articles since they pose a health and safety risk to workers during removal/repackaging but do not pose a health and safety risk to the public, and the environment if left in place.

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