The following paper was presented by Louie Sferrazza at the Department of Defense Radioactive Waste Generators Conference in May, 2002 and also at the Solid Waste Association of North America's Special Waste Conference in April, 2001. Michael Williams, Ph.D. and Louie Sferrazza co-authored the paper.

PRESSURIZED DRUMS, WHAT EVERY HANDLER SHOULD KNOW

ABSTRACT

Reports of injuries from removal of lids from open-head drums that were internally pressurized are abundant. The United States Department of Energy alone has documented over 20 reports of injuries or near misses and almost 200 pressurized container incidents at its facilities from 1993 through 1999, and many more undocumented cases are likely. This paper examines underlying causes of injuries/near-misses associated with pressurized drums, quantifies the effects of drum lid reactions, and identifies risk-minimization procedures and practices. Internal drum pressure detection techniques that handlers can use on 55 gallon mild steel, open head type drums are discussed along with the limitations of these methods. These methods include pressure detection by visual inspection for bulging, drum lid flex testing, and listening for differences in tone produced by lid tapping. Contents and conditions that lead to internal pressure are described. Engineering controls to reduce the risk associated with opening drums that may be pressurized are presented. The diligent use of these pressure detection methods and engineering controls is especially critical for personnel dealing with drums containing unknown, radioactive and/or hazardous wastes. Excerpts from a newly developed safety training video will be shown to illustrate the extremely violent reaction potential of pressurized 55 gallon mild steel, open-head drums and to educate the drum handler, their supervisors, and other waste managers on safe handling methods.

Introduction

Government and commercial drum storage sites exist across the country, and these share many common tasks: storage, handling, sampling, shipment, and treatment of waste, to name only a few. Many of these tasks will require the container to be opened. Unfortunately, while opening a container can be a controlled, routine duty, it can also be a moment of violent pressure release that can lead to serious injury, even death. In addition, it can lead to spread of contamination to personnel and the environment. This takes place because, when released from a drum with internal pressure, the drum lid and retaining ring from an open-head type drum can become fast-moving projectiles. If the handlers removing the lid or bystanders are in the path of these projectiles, injuries occur. The rapid release of the lid under pressure may also likely cause the contents to be sprayed out of the drum. As a result, the handler and surrounding facilities may

become contaminated, exposing the handlers to harmful chemicals, requiring expensive environmental cleanups, and resulting in imposition of fines by regulating agencies.

Reports of injuries and near misses from removal of lids from open-head type drums that were internally pressurized are abundant. The Department of Energy (DOE) alone, through its Operating Experience Weekly [1], has documented over 20 reports of injuries or near-misses and almost 200 pressurized container incidents at its defense and research laboratory facilities from 1993 through 1999; most likely there were many more undocumented near misses.

Some Underlying Causes of Injuries and Near Misses

Some of the underlying causes of injuries, near misses, and other drum pressurization incidents on DOE sites have been reviewed by their engineers, and Table 1 and Figure 1 indicate the findings. Their analysis indicated that by far the largest contributor to these was lack of administrative controls and procedures and improper planning. That is, controls and procedures were not in place that adequately addressed the evaluation of whether a drum could be internally pressurized prior to its opening. In addition, improper planning for the possibility that a drum could be pressurized was another leading underlying cause. Interestingly, personnel error was indicated as one of the more minor issues contributing to these incidents.

Extremely Violent Drum Lid Reactions are Possible

Another likely contributor to injuries and near misses is the misunderstanding of the risk involved in opening drums with internal pressure and the extremely violent drum lid reactions that are possible. This violent response is due to the enormous upward forces that can be exerted on the drum lid: Figure 2 shows force exerted on the lid of a 55 gallon open-head drum as a function of internal pressure. Even at relatively low pressures, the upward force can be quite large. Table 2 lists the response of drum lids released from internally pressurized drums; the response represents the vertical height in which a drum lid was propelled when released from a 55 gallon mild steel, open-head drum. As would be expected, the response (height) increases with increasing internal pressure up the point where the drum self-vents at approximately 14 psi; however, the drum reseals at a lower pressure (approximately 4 psi). As a result, even a drum that appears to have self-vented may still contain dangerous levels of internal pressure.

Minimize the Risk

The forces involved and the associated drum lid responses make opening potentially pressurized drums an inherently hazardous activity. However, the risk of handling and opening drums can be minimized by:

- implementing a company health and safety program;
- recognizing the characteristics and evidence of potentially pressurized drums; and,
- employing prudent practices when opening drums.

Implement a Company Safety and Health Program Covering Drum Opening

As discussed above, the lack of administrative controls and procedures is one of the major contributors to drum pressurization incidents. A company safety and health program should be in place that ensures:

- containers are only opened after all appropriate safety & support precautions, controls, standard operating procedures, and permits are in place;
- safety & health professionals and others familiar with the contents, conditions, and background are consulted prior to opening drums;
- all appropriate P.P.E. is decided on and used during opening activities; and,
- engineering controls, such as restraints (e.g., EET's DRUM WEB [3] or other approved device), are employed as part of the company's overall drum opening safety program.

An adequate safety and health program is key to minimization of injuries associated with pressurized drums.

Recognize the Characteristics of Potentially Pressurized Drums

It is possible to recognize distinct characteristics of containers that are internally pressurized. For the 55 gallon mild steel, open-head drum, which is the industry workhorse when it comes to storing product materials and waste, these characteristics include:

- bulging at the top or bottom;
- difficult depressing the lid with the flex test;
- having higher tone when tapped compared to a drum not under pressure; and,
- having contents subject to degradation, reaction, or changes in temperature/conditions.

Bulging

Mild steel, open-head drums will usually deform or bulge at the top and/or bottom if under sufficient internal pressure. In general, 55 gallon mild steel, open-head drums in good condition begin to exhibit slight signs of bulging around 6 psi of internal pressure. Drums with significant bulging (e.g., can be "rocked" because of bulging bottoms) should be treated as extremely dangerous since these will likely contain relatively high internal pressures (>8 psi).

Flex Test

The flex test should be performed by applying downward force to the drum lid using the palm heel. For a 55 gallon mild steel, open-head drum below 4 to 6 psi internal pressure, flex of the drum lid 1/2 inch or more is possible. At 6 psi and above, it is difficult to depress the lid using ordinary palm heel force. Many times the flex test represents the only method used by handlers to determine if a drum may be pressurized. However, as indicated above, drums with internal pressures less than 6 psi, which can be partially flexed using the flex test, can produce violent drum lid responses that can cause severe injury or death. As a result, the other techniques described here should be utilized in conjunction with the flex tests to aid in evaluation of whether a container might be pressurized.

Differences in Tone

The tone produced by tapping the lid of a mild steel, open-head drum is higher than that for the same drum without internal pressure. The tone increases noticeably with increasing internal pressure. This increase in tone can be utilized in the evaluation of whether the container may be pressurized. However, keep in mind some people are less sensitive to changes in pitch or tone compared to others.

Contents/Conditions that can Lead to Internal Pressure

Internal pressure can result from a variety of mechanisms, including:

- Biological degradation produces gases that can cause buildup of internal pressure. Contents that can be subject to biological degradation or decomposition for which precautions should be employed include:
  - Wood (particularly if wet)
  - Paper and Cloth
  - Certain Inorganic Sludges (e.g., CaCO3, which can decompose to CaO and CO_2)
  - Wet Soil
  - Vermiculite
  - Animal Remains and Waste
  - Vegetation
  - Organic Sludge
  - Some Types of PPE.

- Chemical reactions of contents can produce gases and heat that can cause buildup of internal pressure. Some examples include corrosion of steel drums by acids, leading to buildup of hydrogen gas, and polymerization reactions leading to heat generation.

- Radiological degradation of contents that results in internal pressure can occur from radiolysis (breakdown by radiation) of organics. This degradation can produce hydrogen and other gases and produce heat.

- Some materials (e.g., chloroform and trichloroethylene) have relatively high vapor pressures such that only slight increases in temperature can result in significant volatilization and cause buildup of internal pressure.

- Both empty containers and those with contents can develop internal pressure through changes in storage conditions. For example, a change in storage temperature from 30 °F to 90 °F could result in an internal drum pressure of almost 2 psi. As another example, a 55 gallon open-head drum undergoing a change in elevation from sea level to Denver, CO could develop internal drum pressures over 2 psi.

Safety Notice Issue No. 93-01 [4] from the DOE Lessons Learned website is an excellent guide discussing potential reactions and other conditions that can lead to drum pressurization.

Chemical information websites such as Chemfinder [5] can also be used to aid in evaluation of the chemical properties that might contribute to drum pressurization.

Limitations in Judging Drum Pressure Characteristics

The above techniques represent methods that can be used to recognize characteristics of the standard 55 gallon mild steel, open-head type drum which is internally pressurized. However, there are limitations involving the use of these methods. Drums constructed from different materials can behave far differently under the same internal pressure. As an example, stainless steel drums may not exhibit bulging to the same extent as a mild steel drum. In addition, different sizes of drums behave differently. For example, 30 gallon mild steel, open-head drums can contain far greater pressures compared to 55 gallon mild steel drums without exhibiting signs of bulging on the top.

In addition, drums that do not appear to be bulging may still contain dangerous levels of internal pressure. For example, drums at 4 psi will likely not exhibit signs of bulging, yet are extremely dangerous to open.

Finally, drums lids that can be depressed with the flex test may still contain sufficient internal pressure (up to 6 psi) to also be extremely dangerous.

Engineering Controls

Due to the limitations that can exist in determining with certainty whether or not a drum is pressurized, engineering controls should be used as part of a company's overall safety and health program to reduce the risk associated with opening drums. Currently, both webbing-based and rigid-type devices are available as engineering controls to aid in drum opening activities. These fit over the drum, preventing the drum lid/retaining ring from becoming projectiles (see Figure 3). These devices are <u>not</u> for use on obviously pressurized drums, which must be remotely vented.

In addition to the above, other engineering controls have been utilized, such as placing fork lift tines over the drum to be opened, using cargo netting placed over multiple containers, or using wiring to hold down the lid. However, these practices have not typically been tested and so are not recommended since failure could potentially lead to serious injury.

Conclusions

In summary, it is recommended that each container that is to be opened be treated as suspect for internal pressurization. As a result, the steps for opening the container should consist of:

- following all documented procedures and company controls (e.g., work permits);
- evaluating contents and history for potential problems;
- looking for signs of bulging;
- performing the flex test;
- listening for unusually high tones produced by tapping the lid; and,

- using engineering controls.

Field operating personnel routinely handling containers can, by recognizing the evidence and through the use of these prudent practices, techniques, and tools, reduce, if not altogether eliminate, injuries caused by pressurized drums.

References

1. Department of Energy Operating Experience Weekly, on the World Wide Web at http://tis.eh.doe.gov/oeaf.
2. Department of Energy Operating Experience Weekly, Summary 97-03, on the World Wide Web at http://tis.eh.doe.gov/oeaf.
3. For information on the Drum Web, see http://www.eetcorp.com.
4. Department of Energy Safety Notice Issue No. 93-01, on the World Wide Web at http://tis.eh.doe.gov/oeaf.
5. Chemfinder on the World Wide Web at http://www.chemfinder.com.

Table 1. Underlying Cause Analysis (Source: [2]).

Cause Code	Percent
Inadequate administrative control	44%
Work organization/planning deficiency	33%
Policy not adequately defined, disseminated, or enforced	23%

Table 2. Drum Lid Response when Released from 55 Gallon

Drum Internal Pressure (psi)	Drum Lid Response, Vertical Height (feet)	Initial Upward Force (lbf)
1	~2	380
2	~4	760
4	~8	1521
6	~10	2281
8	~12	3041
10	~15	3801
12	~20	4562
14	>20	5322
>14	typically self-venting	

Drum Under Internal Pressure.

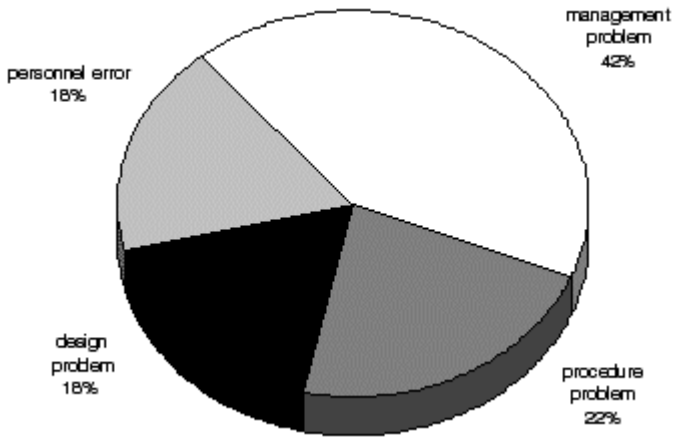

Figure 1. Underlying Causes (Source: [2]).

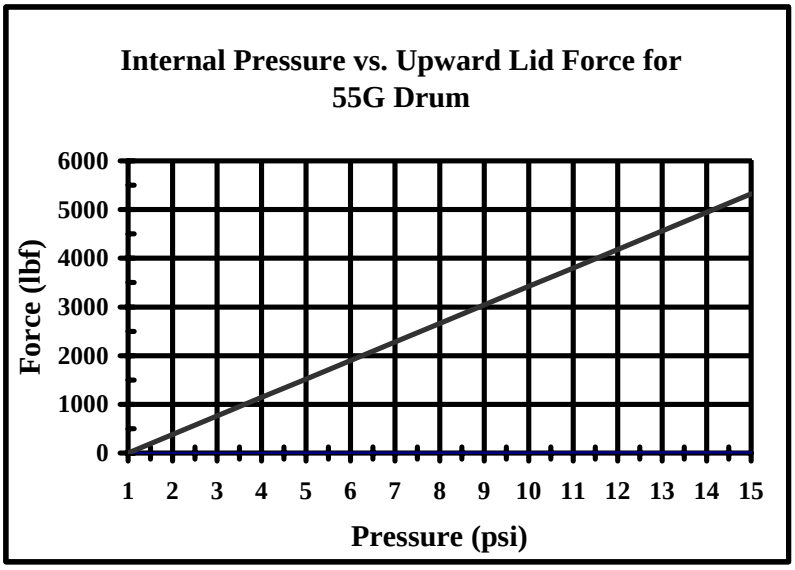

Figure 2.

Figure 3. Sample Engineering Controls for Opening Potentially Pressurized Drums (left, Drum Web 5585 from EET Corporation [3]; right, rigid-device from Machine Kinetics).