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Over-Pressurized Drums: Their Causes and Mitigation

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Introduction

Having to contend with bulging or over-pressurized drums is, unfortunately, a common event for people storing chemicals and chemical wastes. (Figure 1) The Department of Energy alone reported over 120 incidents of bulging drums between 1992 and 1999 (1). Bulging drums can be caused by many different mechanisms, represent a number of significant hazards and can be tricky to mitigate. In this article, we will discuss reasons or mechanisms by which drums can become over-pressurized, recognition of the hazards associated with and mitigation of over-pressurized drums, and methods that can be used to prevent drum over-pressurization from ever occurring.

Container Types

Chemicals may be stored and transported in a wide variety of containers with the drum being the most commonly used industrial container. While pressurization of smaller containers such as cans represents a safety hazard, hazards represented by their pressurization is typically not as significant and, therefore, will not be discussed here. Likewise, glass containers will also not be discussed. It should be noted that while tins and bottles are not formally addressed in this paper, many principles such as causes of drum pressurization may apply to these containers as well.

Drums are available in various sizes and types. The most common size drums are 30-gallon, 55-gallon, and 85-gallon and the most common types are closed-top and open-top drums. Closed-top drums have the top welded to the top of the drum body and usually have two bungs which can be used to either fill or empty the drum. Open top drums have lids that are unattached to the drum body, but are held in place with a metal ring called a chime. Closed-top drums are generally used for transporting or storing liquids and open-top drums are used for almost any purpose. A less common third type of drum having a large screw top is typically used as an over-pack container for 55-gallon drums that are damaged or leaking.

Drums may be constructed of many types of materials. Mild steel is the most common construction material, but other materials such as stainless steel, aluminum and nickel may also be used for more exotic applications. Plastics such as high density polyethylene

(HDPE) may be used for some drums, especially 85-gallon drums used for over-packing. Mild steel drums may have an inner plastic liner present as well.

Causes of Drum Pressurizations

Causes of drum pressurizations may be grouped into the following four distinct categories:

1. Chemical Reactions. Whenever chemicals or wastes are collected and/or combined inside a drum, the potential for chemical reactions that generate gases is present. Gas generation may lead to over-pressurization in sealed drums. Three common types of chemical reactions can result in gas generation. One is the oxidation of organic materials. In general, oxidizers will yield carbon dioxide; in the case of nitric acid, the oxidization reaction will yield nitrogen oxides as well as carbon dioxide. A second type of chemical reaction is hydrogen formation by acids reacting with metals including the drum (2). These reactions may occur from a drum constructed of an incompatible material being used to store or transport a chemical or from a leak in a drum liner that would allow the drum's contents to come into contact with the drum itself. A third type of reaction would be decomposition reactions such as the breakdown of hydrogen peroxide into water, releasing oxygen gas or of formic acid to yield carbon dioxide. In general, higher temperatures (such as when a drum is left exposed to direct sunlight) tend to accelerate the rates of chemical reactions resulting in higher gas generation rates and leading to more rapid buildup of drum pressure.
2. Biological Activity. Wastes, sludges and other materials may contain microorganisms that are metabolically active. When these microbes are present in a sealed drum, they can produce carbon dioxide, methane, or other gases, which can raise the pressure inside the drum. It should be noted that even material that appears dry such as leaves, dead branches, wood shavings, etc., still have enough residual water present to allow for microbial activity.
3. Radiolysis. Drums containing radioactive material along with organics or water (e.g., transuranic waste or mixed waste) can have radiolysis reactions occur inside them. In this situation, radioactive decay produces high energy radiation that can result in the formation of hydrogen and other gases from the breakdown of the water or organic material (3). The generation of these gases leads to the increased pressure inside the drum.
4. Temperature and Pressure Changes. Changing the physical environment can result in increased pressures. Moving a sealed drum from a cool environment into a much warmer one and/or placing a dark colored drum in direct sunlight can result in the pressure increasing from heated, expanding gases. The effect can be exaggerated if a relatively low boiling solvent is present inside the drum and the increased temperature, due to radiant heat absorption, results in an increased vapor pressure of the solvent (4). Likewise, moving a sealed drum from sea level to a higher altitude can result in a modest pressure increase.

Figure 1. Mildly over-pressurized open top drums. Source: Los Alamos National Laboratory


Figure 2. Severely over-pressurized closed top drum. Note how both the drum top and bottom are bulging. Source: Sandia National Laboratory

Figure 3. Over-pressurized poly drum. Source: Idaho National Laboratory

Dangers of Drum Over-Pressurization

There are three potential safety issues associated with over-pressurized drums. The first is the amount of energy stored in a pressurized open top drum. Relatively small increases in internal pressures can represent a significant hazard. Open-top, 55-gallon drums provide a good example of why this is the case. The typical 55-gallon drum lid has a diameter of 23 inches which means the surface area of the lid is approximately 380 inches squared. Because there is such a large surface area, a relatively small pressure increase can result in a large outward force being exerted on the lid. This being the case, a 2 psi greater pressure on the inside of a 55-gallon drum as compared to the outside would result in approximately 760 pounds of upward force being exerted upon the lid (3). If this amount of pressure was present in an open top drum and the chime removed, then the lid, which weighs approximately 2 pounds, could be released with enough force to maim or kill the worker and send the lid approximately 4 feet into the air (Table 1).

Drum Internal Pressure (psig)	Approximate 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	

Table 1. Open-Head Mild Steel Drum Lid Response when Released from 55-Gallon Drum (3)

A second potential safety issue concerns drum failure. Greater pressures can cause drums to fail. Pressures required for the drum to fail and the mechanism of failure vary and are dependent upon the size and type of drum as well as the material of construction. Both open- and closed-top 30-gallon metal drums tend to fail catastrophically at internal pressures greater than 14 psig and 120 psig respectively. Open-top, 55-gallon metal drums tend to fail where the lid is connected to the drum body. Drum failure has been reported at as low a pressure as 14 psig, but some drums do not fail until pressures as high as 30 psig are attained. Sometimes this failure is characterized by a venting process on the chime and other times by releasing the lid with great force. This force can be large enough to throw the lid several hundred feet. Closed-top, 55-gallon metal drums all fail at either the top or the bottom with twice as many failing at the bottom. When a closed top drum fails at the bottom, it turns the drum into a projectile. Failure at the bottom of the drum becomes more violent as the volume of the liquid inside the drum increases. All closed-top 55-gallon metal drum failures occur below 48 psig (1), but HDPE drums can sometimes withstand greater internal pressures prior to failure. Unlike 55-gallon metal drums, it is common for the 55-gallon HDPE drums to fail though the side seam. 85-gallon overpack drums typically fail by venting through the screw top at pressures of 16 psig or less.

A third safety issue involves the drum's contents. While it is obvious that drum failure will lead to the violent release of the drum contents, it is less obvious that the ejection of an open top drum lid will likewise cause the drum's contents to be released. Releases may result in employee exposures, environmental contamination, and, in the case of flammable gases and liquids, a potential fire situation.

Symptoms and Measurements of Drum Pressurization

Bulging at the top or bottom of drums is typically the first indication that a drum is pressurized. (Figures 2 and 3) Using this method for determining pressurizations for less than 4 psig is difficult. Some drums may have an increased pressure of 2 psig and show no signs of over-pressurization yet this amount of pressure is enough to cause harm should the lid be released. Other drums may have a small bulge in the lid, but that bulge may be due to mechanical handling issue and represents no internal overpressurization. Because of this, making determinations as to whether a drum is over-pressurized or not based upon the distension of the lid becomes problematic. Significant bulging of the lid of a 55-gallon steel drum typically does not become apparent until the pressure inside the drum exceeds 4 psig. What is important about this is that a significant danger could be present at a few psig and the drum would show no overt physical signs of pressurization. As the pressure increases, the bottom bulging becomes more pronounced giving the drum a teetering appearance. At this point, both the top and bottom of the drum are distended causing the drum to become shaped like an egg standing on end. As the pressure increases even more, pinging will be heard. This pinging sound becomes more pronounced the closer the drum comes to failure. Any drum that is bulging on both the top and bottom and/or is making a pinging noise should be treated as an imminent hazard and appropriate emergency actions should be taken such as evacuation of personnel from the area.

There are not many tests that can be performed to determine the pressure inside a drum. One test that many perform is the "flex" test. ***This test should never be attempted.*** If one cannot depress the bulging lid with the palm of the hand, then the internal pressure is likely above 6 psig. Attempting this test can result in the lid being violently ejected from the drum resulting in injury or death to the worker. Recently, efforts have been made to use the "Kettledrum" effect (5). If one views the drum lid in the same manner as a kettledrum membrane, then one can understand how an increasing pressure inside the drum would place more strain on the drum lid which would in turn change its resonance frequency when "thumped". Using this concept, attempts have been made to correlate the resonating frequency of the drum lid with pressures inside the drum.

Mitigating Pressurized Drums

Many methods have been developed to mitigate over-pressurized drums. Methods used are:

1. Uncontrolled Penetration. Early on, the preferred method of mitigating over-pressurized drums was to kinetically puncture them using either a bow and arrow or a bullet. However, there are many reasons why this method is no longer favored. First, in many instances, the drum must be moved from its current location to a safe (remote) area and moving a potentially unstable drum is not an intrinsically safe activity. Second, using an uncontrolled method for breaching the drum can result in the drum failing explosively, with parts of the drum being thrown over large distances. Lastly, the uncontrolled breaching of the drum can result in the drum's contents spilling onto the ground requiring subsequent remedial clean-up activity. If the drum comes apart violently, then this clean-up activity becomes more complex and expensive.
2. Drum Web (6). A device called a drum web can be used during the breaching of open-top drums. A drum web is webbing that is affixed to the drum. It covers the top of the drum and is held in place by cinching the web to the side of the drum. Once in place, the bolt holding the chime in place can be loosened. Upon loosening the chime, pressure will either be released by slowly venting around the rim or the lid will be violently ejected. If the lid is violently ejected, then the drum web will catch the lid and prevent it from causing damage. One difficulty associated with using the drum web involves how the chime is to be loosened. If the chime is manually loosened, then the worker must be sure to stay away from the lid lest it be forcefully ejected off the top of the drum. This issue can be resolved by using a remote device to loosen the chime. Another issue would concern the potential ejection of the drum's contents should the lid be forcefully removed. Ejected contents would potentially result in contamination of the ground and nearby workers. A third issue is that the over-pressurized drum may be required to be moved from its original location in order to place the web on the drum. Lastly, if a drum web is used to control the violent release of a drum lid, then the violence of the lid releasing event may cause adjacent drums, which may also be in a state of overpressurization, to become destabilized.

3. Controlled Penetration. The preferred method for venting drums is to use a controlled penetration technique. (Figure 4) If the over-pressurized drum is closed top, then the bung can be slowly loosened. Once the bung is loosened, the drum will start to vent. This venting occurs long before the bung can be completely unscrewed. For open-top drums, the preferred method is to use a drum punch. In this process, a device is placed over the top of the drum that serves as the puncturing platform and also holds the drum in place. A hydraulic punching device with a non-sparking tip is then driven into the lid and the pressure released.

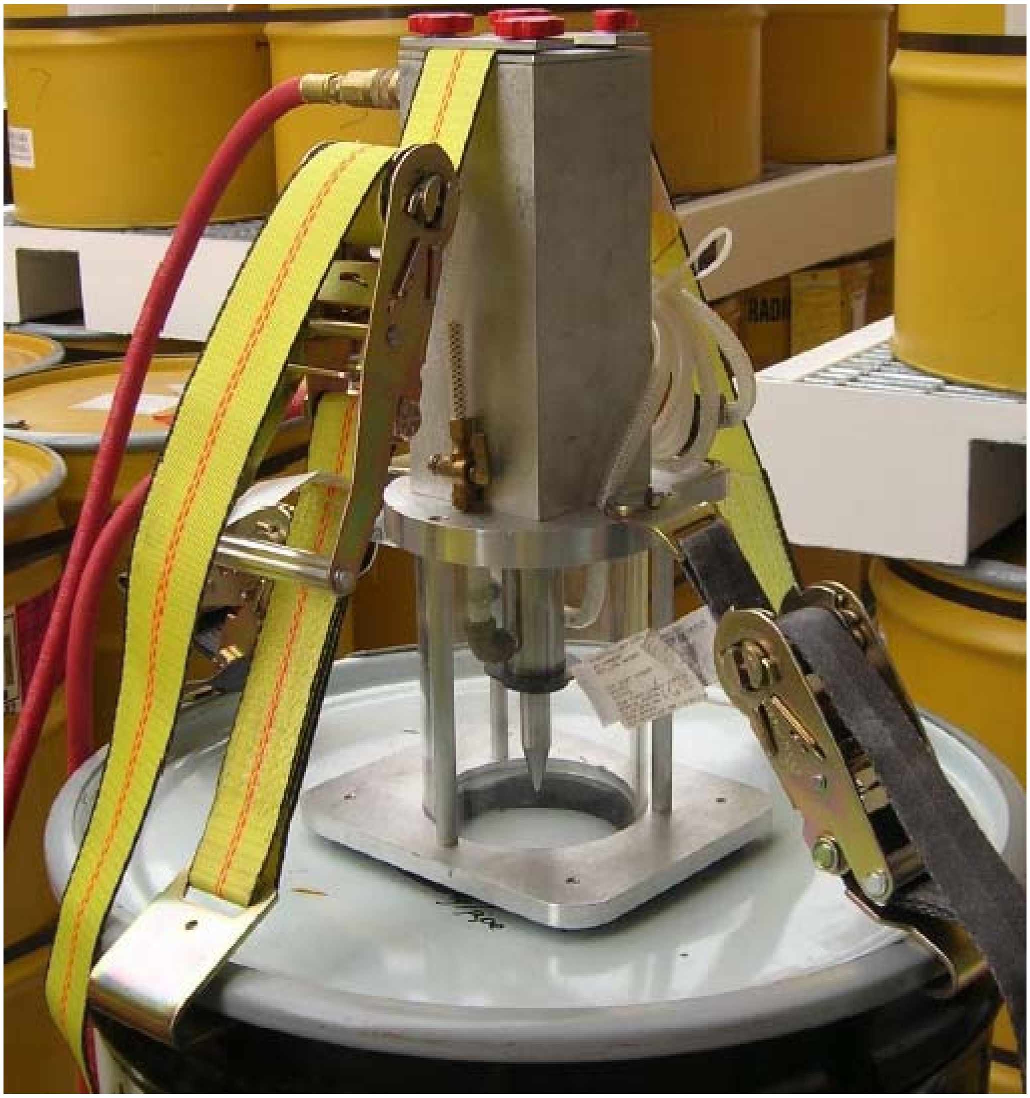

Figure 4. Controlled penetration device. Source: Loa Alamos National Laboratory

Preventing Drum Over-Pressurizations

There are several steps that can be taken to help insure against drum over-pressurizations. The first is to know what materials that are being placed into the drums and ensure that they will not undergo any type of gas or heat generating reaction. The second step is to store the drum in a controlled temperature environment and out of direct sunlight. This will prevent the expansion of gases from the drum due to radiant heating which can lead to pressurization. Lastly, if the potential for pressurization is known and if the drum lid is configured to accept one, then a pressure relief device should be used. These devices are available with pressure ratings as low as 1 or 2 psig. If these devices are used, then it is important to get the correct type of venting device. For example, if repeated venting may occur, then a rupture disc would not be appropriate.

Conclusions

Drum pressurization can represent a significant safety hazard. Unless recognized and properly mitigated, improperly manipulated pressurized drums can result in employee exposure, employee injury, and environmental contamination. Therefore, recognition of when a drum is pressurized and knowledge of pressurized drum mitigation techniques is essential.

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