National Aeronautics and Space Administration

Laboratory Pressure Vessel Explosion

Let Your Pressure Systems Manager Help You Be Successful

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Steve Lilley
Senior Safety Engineer
NASA Safety Center

This and previous presentations are archived at
https://sma.nasa.gov/news/safety-messages.

Summary

- **Date:** March 2016
- **Company:** University of Hawaii (UH)
- **Details:** A highly reactive mix of pressurized gases contained in a high-pressure tank ignited, resulting in a rapid rise in pressure.
- **Results:** The tank was blown to pieces, severely injuring the postdoc researcher who was operating the experiment. The laboratory and equipment sustained significant damage.

Key Conclusions

- Consult experts in lab safety practices and pressure systems design/fabrication early in the design process.
- Developing an effective and compliant design from the beginning helps you avoid system redesign and avoid rework, replacement, or failure of components.
- Supervisory, active reinforcement of lab safety practices beyond required formal training can trigger recognition and mitigation of serious hazards.

Background

- **Pressure systems:**
  - A pressure system is a structural system with an internal pressure that is different from the surrounding environment.
  - NASA, universities, and research institutes encourage innovative thinking as well as the development and testing of theories and ideas. This results in the purchase or construction of a wide variety of pressure systems products, sometimes with very unique designs.
- **NASA pressure systems:**
  - <u>Examples:</u>
    - Large, heavy-walled, high-pressure storage vessels with extensive piping and control valves
    - Systems that are designed and constructed to separate and chill liquid nitrogen (for controlling the temperature in an icing wind tunnel)
    - Systems that deliver high-temperature operation
  - The NASA pressure systems organizations typically include both NASA and contractor staff with years of experience in designing, reviewing, and inspecting this type of equipment.
- **Pressure systems for research/academia:**
  - Universities and research institutes often have pressure systems similar to many of the smaller NASA research systems. Some are comparable to NASA's larger research systems.
  - Many are akin to the lab systems constructed by NASA researchers in their labs, shops and offices with the goal of researching a particular reaction or operation.
  - Some are carefully conceived and highly engineered, while others have been assembled with good intent but without conducting or using hazard assessments.

Background

Common Problems With Pressure Systems

- The most hazardous system is often the one that has been assembled from readily available parts by a well-intentioned researcher who has not had a design review or a risk assessment performed. This can happen because of **avoidance** or a **simple lack of awareness** about how to obtain an assessment or the need to do so.
- System-level problems that may occur:
  - Use of brittle materials (e.g., PVC and cast iron) in pressurized gas systems
  - Use of components not rated for the operating pressures or temperatures
  - Failure to consider low or high operating temperatures
  - Inadequately secured components
  - Misunderstanding of pressure relief requirements
  - Inadequate relief system
  - Inadequate weld and other quality control
  - Failure to consider that low pressures against large areas can result in large forces
  - Inadequate procedures to protect personnel and assets

Background

UH Pressure System

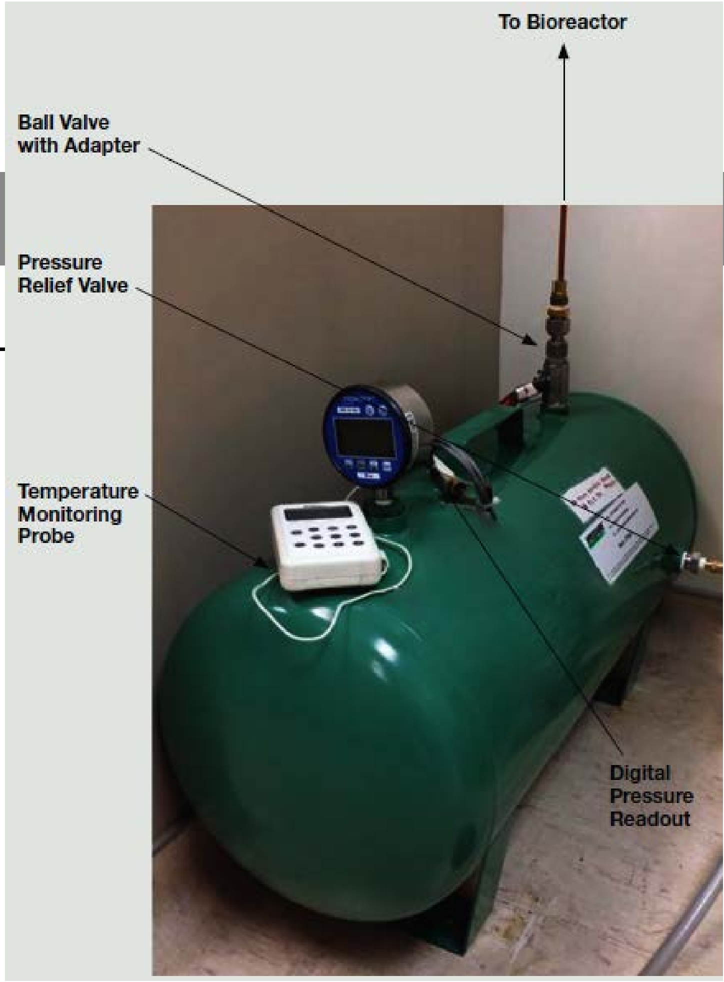
- Goal of experiment: To develop a local biofuels and bioplastics industry with reduced environmental impact versus current technology.
- Sought to optimize growth of the *Cupriavidus necator* bacteria, which results in PHA, a polyester that can serve either as an energy store or a plastic.
- Pressure system was needed to supply an optimal mix of gases at a particular pressure for consumption by the bacteria → pressure vessel (tank) and its associated components were used to provide a source for these gases.

What Happened

- During operation, the highly reactive mix of pressurized gases contained in the tank ignited. This resulted in an extremely rapid pressure rise, far beyond the capacity of the pressure relief valve.
- The tank was blown to pieces, severely injuring the postdoc researcher who was conducting the experiment.
- The explosion caused significant damage to the laboratory and equipment involved.

Proximate Cause

The digital pressure gauge probably acted as a path to ground for a static charge that ignited the hydrogen/oxygen gas mixture contained within a 13-gallon pressure tank.

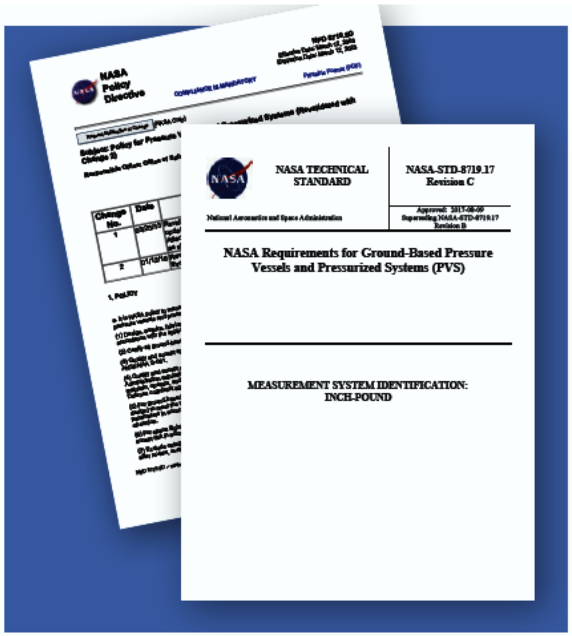


Underlying Issues

- Pressure systems design or design review — no formal hazard assessment
- Risky component selection
- Reactive media
- Hazardous contents
- No recognition of Hawaii state Occupational Safety and Health Administration (OSHA) regulations or safety risks; incomplete campus safety policy and oversight
- Lack of hazard communication between faculty and researchers

Applying Lessons Learned to Current and Future NASA Missions

- NASA has developed a Pressure Systems Safety program that has helped minimize the number of pressure systems mishaps over the years.
- NASA policies and standards:
  - **NPD 8710.5, Policy for Pressure Vessels and Pressurized Systems:** Provides top-level policy to ensure the safety of pressure systems both on the ground and in space
  - **NASA-STD 8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PVS):** Provides direction on achieving the safe operation of pressure systems on the ground (agency implementation document for compliance with the OSHA regulations in this area)
- Each NASA center has a Pressure Systems Manager (PSM) who is responsible for oversight, with responsibilities as specified in NPD 8710.5.
- Nearly all NASA centers have local documents tailored to their individual needs and that provide further detail on achieving the safe operation of pressure systems.



Applying Lessons Learned to Current and Future NASA Missions

Risk Assessment Tips

- Ignorance of the risks doesn’t make them go away.
- Performing a risk assessment specific to an experiment is the best way to formalize the actual likelihood and severity of potential undesired outcomes during the course of the activity (without this assessment, subjective judgment usually underestimates potential dangers that can lead to serious injury or illness).
- While there is a trade-off between efficiency and safety, **the laws of physics make no allowances for each individual’s personal risk perception.**

Applying Lessons Learned to Current and Future NASA Missions

Steps for Building a Safe Pressure System

1. **Consult the experts:** Seek input from knowledgeable associates and the PSM. Active reinforcement of lab safety practices beyond required formal training can improve recognition and mitigation of hazards, such as noncompliant pressure systems. Experienced engineers and scientists should seek to identify those hazards they've yet to imagine, rather than expect success.
2. **Start early:** Invite the PSM into the process early to gain the greatest benefit. It is faster and less expensive to design an experimental pressure system with compliance in mind up front than to stop an experiment, redesign, retrofit, or replace components, and then start over. Costs and delays are kept to a minimum.

→ **<u>Call to action</u>:** If you encounter a pressure system that isn't in the NASA Pressure Vessels and Systems program, consult your center's PSM. **It is much better to bring a system into the program a little late than to risk a serious accident.**

Questions for Discussion

- If your organization works with NASA-defined pressure systems, how does your PSM keep these systems safe and compliant with NASA policy?
- Does your organization have a process in place to ensure that your pressure systems are included in your center’s pressure systems program?
- When building a pressure system, how do you identify potential hazards during the design phase?
- If a potential safety issue is detected in an operational pressure system, what processes exist to make the system safe with respect to engineering and safety standards?