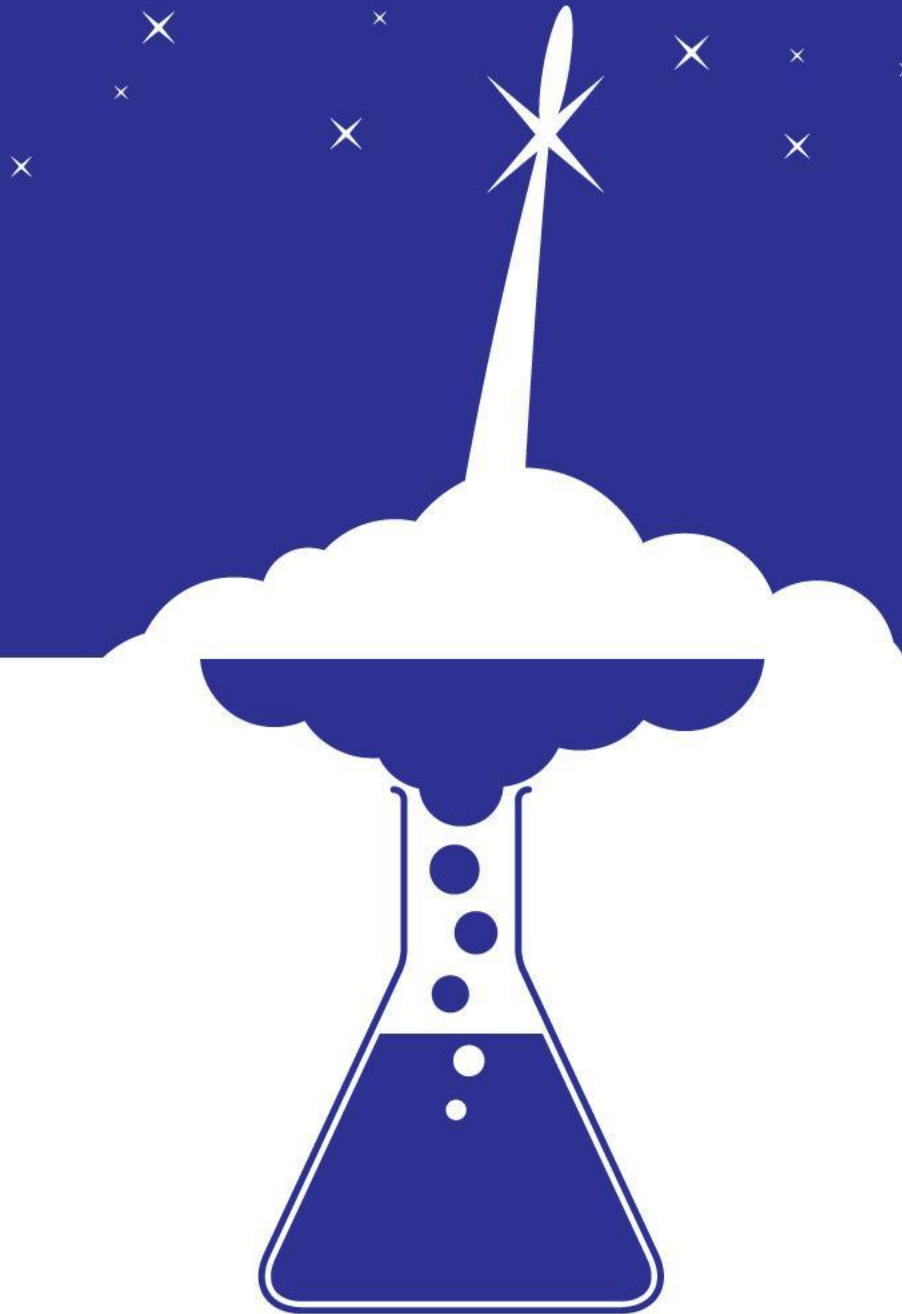


Pressure System Safety

By Mark Holthaus

1/23/2023

ACADEMIC-INDUSTRY
LIQUID ROCKET SYMPOSIUM **2023**



Mark Holthaus' Background

- BS Electrical Engineering, University of Detroit
- MS Electrical Engineering, University of Southern California
- 10-Year RADAR Transmitter Electrical Design, Hughes Aircraft
- 10-Years Space Shuttle Avionics Reliability, Rockwell International

- 23-Years System Safety and Flight Termination, Boeing, Retired
- 25-Years Amateur Liquid Rocketry
- 20-Years Founder, Treasurer, and Pyrotechnic Operator Lead, Friends of Amateur Rocketry

Safety Concerns

- Burst (Shrapnel, Overpressure)
- Jetting
- Venting (Burns, Asphyxiation, Toxicity)
- Rocketing-Kinetic Impact
- Leaking (Fire, Explosion)
- Burns
- Asphyxiation
- Toxicity

Commercial Versus Experimental Tanks

- Commercial tanks

- ASME rated
 - Designed by a licensed engineer
 - Built by a licensed company
 - Safety factor 4
 - Lot sampled burst testing
- Used at or below their pressure rating

- Experimental tanks

- Self-manufactured
 - Not ASME rated
 - Safety factor < 4
 - No lot sampled burst testing
- Commercial tanks used above their pressure rating

Tank Testing

- **Proof Testing**
 - Test to a pressure above the maximum expected operating pressure
 - Does not cause deformation
- **Burst Testing**
 - Test to a pressure where the tank deforms and bursts
- **Leak Testing**
 - Testing plumbing joints with a soap solution at a pressure $\frac{1}{4}$ the maximum expected operating pressure (MEOP) to find leaky joints

Tank Pressure Burst Protection

- Overpressure causes a tank to burst
 - Pressure blast
 - Shrapnel
- Causes of overpressure
 - Regulators
 - Fails to lock up at set pressure
 - Locked up cryogenics
 - Warming cryogenics builds vapor pressure
- Overpressure protection
 - Use relief device
 - Relief valves
 - Commercial burst disks only
 - Set to below proof pressure
 - Continuous remote pressure monitoring
 - Remote controlled vents to depressurize
 - Maintain safe distance/protective shelter

Other Hazards

- Inadvertent Activation
 - Tank Pressurization
 - Main Valve Open
 - Ignition
 - Use Single Key Lockout
- Pressure System Burst due to Damage
 - Fire
 - Scrape
 - Dent
 - Impact
 - Too Many Pressure Cycles
 - Protect from Damage
 - Don't Use If Damaged
- Venting Nitrogen, Helium, Methane, Propane are Asphyxiants
 - Use Open Air Operations
- Pressure Venting Injury
 - Hearing
 - Use Ear plugs
 - Eyes
 - Use Safety Glasses

Use Safety Provisions and Be Safe

- Check Pressure System For Damage
- Proof Test Tank
- Don't Use a Damaged Tank
- Use Relief Devices
- Use Remote Pressure Monitoring
- Use Remote Vent Valves
- Use Single Key Lockout

- Use Open Air Operations
- Use Eye Protection
- Use Hearing Protection
- Keep Personnel Safe Distance