SAFETY BULLETIN 40/23

Cryogenic Flat Bottom Tank Safety

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Cryogenic Flat Bottom Tank(FBT) Safety

Introduction

Flat bottom cryogenic storage tanks are commonly used at production sites for storing large volumes of Air Gases (viz. Oxygen, Nitrogen, Argon etc) in cryogenic liquid form. Though these tanks are very well designed with proper insulation and operate at near atmospheric pressure, but the constant evaporation of cryogenic liquid can cause pressure to rise, also vapor/liquid flow to and fro connected process could lead to pressure/liquid level to increase/drop. Proper venting system and Pressure Relief Devices together with periodic inspection and maintenance can protect these tanks from any over pressurization and possible rupture. However some major incidents involving flat bottom tank failures in some of the countries globally created a concern among the Industrial Gases Manufacturers and others associated with Gas Industry in the region. This has highlighted the urgent need to communicate the risks associated with Flat Bottom Storage Tanks and the importance of Safe Design and Operational Discipline, especially with the Pressure Management System and Overfill Protection System of the inner vessel and the necessity to educate all, including experienced engineers and operators who are involved in such activities.

Incident 1

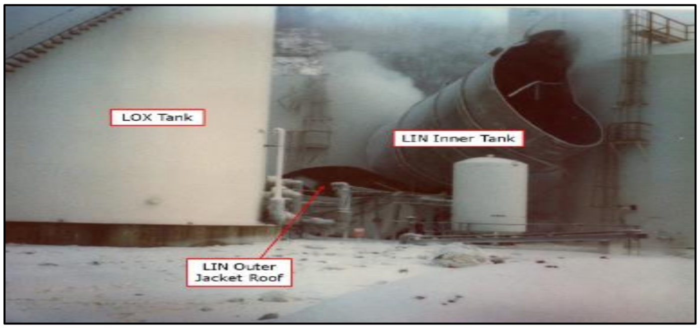
What happened?

FBT failure, liquid product spillage, massive release of perlite powder, 3 casualties involved.

Possible causes:

- Inner tank overpressure, pressure relief device (PRD) did not work.
- Bottom part of inner tank damaged and lifted off with outer tank.
- Lack of operational discipline (inner tank pressure monitoring) and periodic safety inspection on PRD.

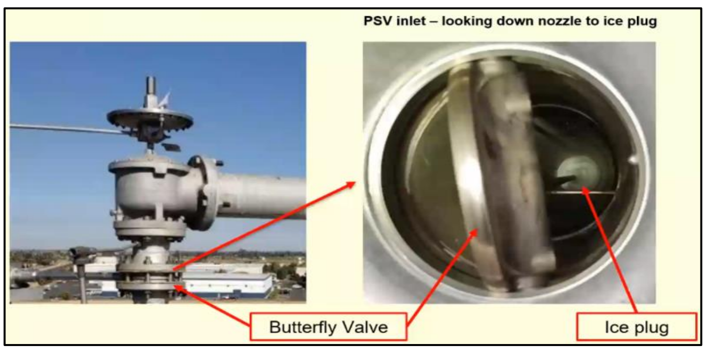
Incident 2



What happened?
FBT failure, liquid product spillage, massive release of perlite powder, adjacent O2 liquid line broken.

Possible causes:
- Single pressure indicator controller (PIC) failed LOW.
- Autovent valve CLOSED and Pressure build-up valve OPEN.
- Tank pressure rised and no pressure high alarm (PIC failed)
- Single PRD failed.

Incident 3

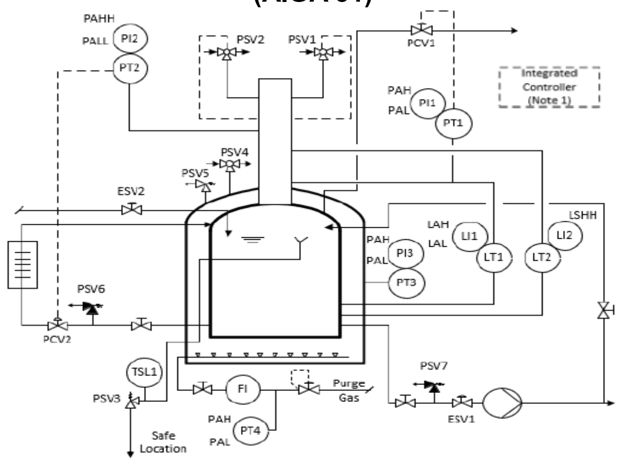


What happened?
Formation of ice in the nozzle at PRD inlet
Possible causes:
- Periodic operation of PRD at low pressure due to intermittent liquid transfer and pressure spike
- Pressure build-up system was inoperable.

General Hazards

Inner Tank Overpressure / Vacuum	Outer Tank Overpressure/ Vacuum
Inner Tank Liquid Overfill / Low Level	Liquid Spillage

Example of a FBT Storage System (AIGA 31)



Legend			
PSV1, PSV2	Inner tank overpressure-vacuum protection devices (5.4.2 and 5.4.4)	LAL	Level alarm low
PSV4, PSV5	Outer tank overpressure-under pressure protection device (5.4.5 and 5.4.6)	LI1, LI2	Level indicator
PSV3	Overflow protection (5.4.7)	LT1, LT2	Inner tank level measurement device (5.4.7)
PSV6, PSV7	Thermal relief valve	TSL1	Switch, overfill line low temperature
PCV1, PCV2	Inner tank pressure control valve (5.4.1)	PAH	Pressure alarm high
PI1, PI2, PI3	Pressure indicator	PAHH	Pressure alarm high high
PT1, PT2, PT3, PT4	Pressure transmitter	PAL	Pressure alarm low
ESV1, ESV2	ESVs (5.5.1)	PALL	Pressure alarm low low
LAH	Level alarm high	FI	Flow indicator

[1] Alternative to separate pressure controllers, an integrated pressure controller with PT1 and PT2 can be used.

Safeguards

Design:

General

- Should include Warning/Alarm for any abnormal process readings monitored.
- Appropriate equipment sizing for gas venting.
- Prevent PRDs from rain ingress and blockage of foreign matter.
- Anchorage of tanks is cast in the underside of the foundation.
- The weakest point of the inner tank is at roof-to-shell joint
- Monitor pressure or flow of seal gas supply to the annular space.
- Prevent corrosion by excluding moisture between the bottom of the outer tank and the foundation.
- PRDs and PCVs vent gas to safe location, minimises fogging, avoid localised oxygen enrichment or deficiency, avoid contact with carbon steel which could lead to cold embrittlement.
- Ensure flexibility of liquid piping and install anchor point to guard against rupture caused by excessive stress on piping.
- For LOX storage tanks, prevent the accumulation of hydrocarbons by boiling in dead-end connections.

Inner tank pressure control

- Independent pressure controller (including pressure sensing lines, root valves, and pressure transmitters) of pressure control valves for venting and pressure build-up.

Inner and outer tank protection from overpressure and Vacuum

- Redundant pressure relief devices. Tank is protected from all abnormal pressure cases if one malfunctions or is removed for maintenance.
- Avoid perlite plugging at upstream of outer tank PRDs.

Inner tank liquid level monitoring and protection

- Minimum 2 independent level measurement devices are installed (normal level monitoring and input to safety systems to prevent overfilling or low level)
- For overfilling protection, high level trip to close all tank filling valves or activate overflow line to maintain the liquid level within maximum limit.
- For low level protection, low level trip to close all liquid withdrawal valves.

Liquid Spillage

- Minimum 2 independent isolation valves for each liquid line connected to inner tank below maximum liquid level.
- Emergency shutoff valve with remote operation is available at all liquid lines (≥ 50mm nominal bore).

Operation & Maintenance:

- Ensure comprehensive installation dossiers are available, including operating instructions to define safe operating limits of the system and procedure required.
- Ensure emergency procedures are readily available to address cryogenic liquid spills, with regularly practised and checked periodically.
- Provide specific training to all personnel directly involved in the operation & maintenance and keep records.
- Ensure continuous supply of seal gas to tank annular space for maintaining positive pressure and dry state of insulation.
- Ensure pressure in the annular space is always less than the actual pressure in the inner tank.
- Carry out periodic inspection of PRDs to ensure they are free of ice.
- Carry out mitigation measures to prevent ice formation and build-up at discharge of pressure control valve for gas venting.
- Ensure no more than one PRD be taken out of operation at a time.
- Carry out periodic maintenance with functional test and results documented:
  - PRDs set pressure in accordance with MAWP of tank
  - Instrumentation, controls, and safety systems, for low liquid level and overfill protection loops.
- It may be necessary to replace bursting disk elements periodically.
- Carry out periodic external integrity checks of tank.
- Follow MOC (Management of Change) procedure for any modification and change of service.
- Issue work permit before any maintenance or modification carried out.
- Ensure liquid releases are mitigated by directing the spill to a safe location.

Reference:

- AIGA 031, *Bulk Liquid Oxygen, Nitrogen And Argon Storage Systems At Production Sites,* www.asiaiga.org
- AIGA 032, *Perlite Management,* www.asiaiga.org
- AIGA Safety Bulletin SB/22, *Safety Inspection Check Lists of ASUs and Cryogenic Liquid Storages at Plant Sites,* www.asiaiga.org