



EXPERIENCE WITH CRYOGENICS SAFETY, PROBLEMS AND SOLUTIONS

Rajiv Sharma and Cryogenic Division SST-1 IPR, Gandhinagar

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- Introduction
- Cryogenic safety Hazards and Its Causes
- Protection and Prevention Measures
- Personals Protective Equipments
- Cryogenic Safety in IPR
- Practical Problems Experience and Solution
- Cryogenic Safety Guidelines
- Actions at Emergency Conditions
- Summary
- Acknowledgments



Introduction



 The branches of Physics and Engineering that involve the study of very low temperature below 123 K. Low temperature are achieved by the liquefaction of gases.

Some Typical Temperature	Temperature (° C)	Absolute (K)	Liquid to gas Expansion
Tropics	45	318	
Human Body	37	310	
Room Temperature	20	293	
Ice Point	0	273	
Home Refrigerator	-18	255	
Antarctic water	-50	223	
Solid Carbon-dioxide	-78	195	
Liquid Oxygen	-183	90	1 to 860
Liquid Nitrogen	-196	77	1 to 696
Liquid Helium	-269	4	1 to 757
Absolute Zero	-273	0	

Cryogenic Effects on Materials and Accountability in Design

- The mechanical and electrical properties change of many materials very dramatically when cooled to 100 K or lower. (for example plastic, rubber extremely brittle)
- Freezing/Glassing (Liquids, Oil, Greases)
- Condensation/Liquefaction (Gases)
- Stainless steel (304,316), Cu, Al, Ag, and Brass are characterize very good mechanical properties at Cryogenic temperature.
- The thermal contraction typically 3 to 5 mm/m for common structural materials between 300 K and 77 K (little additional change occurs < 77 K)
- Joints and supports must be able to handle induced thermal stresses and transitions between various materials
- An uneven cool down will create large thermal stresses within a vessel

(Pipeline example: 30 m stainless steel pipeline would contract 8.4 cm on cool down to 77K)





[1] <u>Asphyxiation</u>:

A condition of severely deficient supply of oxygen to the body that arises from being unable to breathe normally.

It is due to released cryogens can displace oxygen in a room.

(i) Oxygen deficiency is defined as <19.5% oxygen (OSHA)

(ii) The symptoms of oxygen deficiency are :

- 19% 15% pronounced reduction of reaction / response speed
- 15% 12% deep breaths, fast pulse, co-ordination difficulties
- 12% 10% vertigo, false judgment, lips slightly blue
- 10% 8% nausea, vomiting, unconsciousness
- 8% 6% : death within 8 minutes, 4-8 minutes brain damage
- < 4% coma within 40 seconds, no breathing, death

[2] Cold Contact Burn/Frostbite:

<u>Contact Burns</u> – skin exposure to cold liquid, gas or surface, Similar to heat burns; can cause localized tissue damage can lead to frostbite

<u>Frostbite</u> – freezing of skin or body parts resulting from exposure to low temperature





The causes of cold burns and Frostbite are:

- Cause of frostbite to the hands and body is contact with cold metal surfaces
- Especially when the skin is moist can lead to permanent damage
- Prolonged exposure to cold vapor can damage lungs and eyes
- Handling open cryogen containers, especially when cooling down warm vessels or objects
- De-choking vents/drains of cryogen handling system
- Doing connections/disconnection of piping /hoses.

[3] Over pressurization and physical explosion

- Cryogen liquids do expand by a factor of 500 to 800 when evaporated and warmed up to room temperature.
- Heat input lead to significant pressure build-up to bursting of the cryogen container.

Possible reasons for an elevated heat input are:

1. Fast cool down of components or cryogenic installations

- 2. Large heat production within the object to be cooled during a quench
- 3. Loss of the insulation vacuum,

(LHe has very low latent heat of vaporization (1/10th that of LN_2) so it will evaporate rapidly/explosively when heated)

[4] Air Condensation (Fire Hazards)

- Condensation of air/O2 on combustible liquids or materials can create flammable/explosive mixture
- At temperatures < 82 K, metal surfaces will condense oxygen and form enriched air (50% O2 and 50% N2) to drip and pool on surfaces
- Un insulated pipelines provide this surface
- Air boils at 78 K (at 1 atm pressure) in a 6% O2-94% N2 vapor mixture, enriching the O₂ content

[5] <u>ICE PLUGS</u>

 Frozen plugs can form in Dewar plumbing if the cryogenic system is exposed to air





- Moisture in air can also block lines, vent lines path to relief valves from releasing pressure from the Dewars as the cryogen vaporizes
- Over time this will result in a pressure build up that can cause structural failure of the Dewar

[6] ICE BUILD UP:

- Ice build up on uninsulated areas can cause damage to surrounding equipment
- Potentially embrittle sensitive materials
- Ice build up can block relief valves
- Ice build up can freeze O-rings and compromise insulating vacuums



Protection and Prevention Measures



- Cryogenic liquids must be handled in well ventilated areas to prevent excessive concentrations of gas in enclosed spaces.
- Oxygen level detectors to be installed in enclosed spaces
- In case of splash in the eyes flush continuously for at least 15 minutes.
- Any unprotected part of the body must never be allowed to touch uninsulated pipes or vessels containing liquefied gases.
- When pouring liquefied gases from one container to another, the receiving container must be cooled gradually to prevent thermal shock.
- To reduce air condensation is by applying an insulating material on system components.
- To eliminate high-pressure releases of cryogenic vapors, containment systems with special pressure- relief devices and rupture "Burst Disks" to allow over pressures to release safely

 ⁽LHe Dewar: 2 relief valve (0.5 psi and 10 psi) and 2 no. rupture disc set at 35 psi, LN₂ Dewar: 1 relief valve 22 psi and rupture disc 9 180 psi)







- Portable trolleys must be used for moving large containers of cryogens.
- Frost spots may appear in case of loss of insulating vacuum. A vessel in this condition must be removed from service
- Safety glasses and face shield should be used for eye and face protection.
- Cryo hand gloves, Apron must be worn when handling cryogenic liquids.
- Dewars must be kept covered with a loose fitting cap to prevent air or moisture from entering the container, and to allow build up pressure to escape.
- Make sure that no ice accumulates in the neck or on the cover and causes a blockage and subsequent pressure build up.
- Always store and handle liquid helium under positive pressure or in closed systems to prevent the infiltration and solidification of air or other gases.

Cryogenic Personnel Protective Equipments in IPR







Pressure safety device in LHe Trolley for LN₂ Dewar movement Dewar

Face shield



Cryo hand gloves



Safety goggle



Cryo Apron¹¹

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Fire Alarm System



O₂ Sensor and Monitor

IN CASE OF FIRE / F CRYOGENIC HAZARD INFORMATION कायोजनिक के खतर्ग की जानकार आग लगने/फायर अलाम बजने की स्थिति में Material Propertylat 1 bar, 15'C टार्थ तवा उनके गण (1=15°C) Don't get panic. Don't use Lif Name of chemica 2. Liquid HELJUM (२) रखेव धीलव • घवराए नहीं। लिफ्ट/एलिवेटर का उपयोग न करें। Gas density (Kol 0.14 आग से प्रभावित क्षेत्र में काम कर रहे लोगों को चेतावनी दें। Alert people working in the af 269'C 196'C फायर अलाम की घंटी सक्रिय नहीं होने की स्थिति में सबसे नजदीक टव में मैम का फैमात 678 **गणा** Pull the nearest Manual Call Point to ac 739 time के मैनुअल कॉल पॉइन्ट को खींचें। alarm, if not activated. AZARDS & PRECAUTIONS खतरे तथा सावधानिय • सावधानी पूर्वक आग को बझाने का प्रयास करें। Attempt to extinguish fire cautiously Splashing of liquid Nitrogen or liquid Helium causes cold burn or frost bite. १. इतित नाइट्रेबन या इतित होतियम के फैलने के कारण कोल्ड बर्न तथा फ्रोस्ट बाईट का सतव उत्पन्न हो बाता है • स्थान खाली करने के लिए सबसे नज़दीक के आपातकालीन रास्ते का Use appropriates Personal Protective Appliances like Asbestos/Chrome उत्पुका व्यक्तिगत मुखात्मक उत्करणे हेसे - एस्वेस्टम, निकल, बमझ के दास्ताने, साखा-दासे Use nearest Emergency Exit to evacuate प्रयोग करें। leather hand-gloves, Safety goggles, Face shield, etc. म्राहे आरे का उसकेन करें। Flush affected body part with running water. Do not rub affected part आगे के निर्देश मिलने तक इकट्ठा होने के सबसे नज़दीक स्थान Assemble at nearest Assembly Point namely स्रोर के को हर पर मानिस्राधने हने। को हर पर को लदे थी। इमलि महि को कुले रव like affected person in fresh air & give emergency Owners therapy, तने स्व में हे को क्री क्रारवारी? जेक्सीकर दिवास है : चीक स्वते की विदेश में क्रुपिय Admin. Porch, Circle near APPS area, Behind SST-(एसेम्बली पॉइन्ट) जैसे प्रशासन पोर्च, एपीपीएस क्षेत्र के नजदीक का Give antificial respiration if not breathing. Seek medical help immediately सारे तुन विकासी साथ तनम का 1 building near spiral stair-case and on road near सर्कल, एसएसटी-। बिल्डिंग के पीछे स्पाइरल/घुमाबदार सीढी के पास overhead water tank till further instructions. और ऊपरि पानी की टंकी के पास रास्ते पर एकत्रित हो। are of Winger or Helium gas cause should ashould lack of Owner ् से य में स्वर्थित में मुद्दे में दे दिन के कि में बताता में सीमा की कोई स्वर्थ है। this tanding in contined or closed work area. आपातकालीन स्थिति में इन्हें सुचित करें. Always ensure proper ventilation and for any doubt confirm Quoge होता तन्त्र संदरन ही बहान ही किसी में के कारे में का कार में प्रसंग ही साम की form in case of emergency, bility prior to entering any confined spacesiclosed room जेमोरा हो उस्तम्य ही बंच हा है। सेक्युरिटी डेस्क 2041/2273 (079) 23962041/2273 urity Desk 2041/2273 (079) 23962041/227 nce of moisture in vessel/pipe causes ice-blocking and render सेक्युरिटी अधिकारी ३. अवसा मुखा - टावरणे को गालवे में आर्टत के कारण बर्फ का बमाव हो जात है और रखे का ecurity Officer 2255/2266 (079) 23962255/226 \$4299 65520 2255/2266 (079) 23962255/2266 94299 65520 devices inoperative, which leads to physical explosion due to over विससे उच्चदबाव बनने के कारण भौतिक विस्फोट होने का खतर रहता है। afety Officer 2152 (079) 23962155 9898074775 सुरक्षा जयिकारी (079) 23962152 98988 74775 Idmin Officer 2013 (079) 23962013 98253 33220 Ensure moisture removal from the pipes/vessels by proper purging / उरकरणों में द्वीवत बाइट्रोबन या हीतियम प्रबाहित करने से पूर्व उनकी नालनों या पत्रों में नयी द्वाकी प्रज्ञासनिक अधिकार (079) 23962013 venting before charging liquid Nitrogen or liquid Helium. ire Station (Gandhinagar) (079) 2322 2100 / 2322 274 सभी सरक्षा उपकरणों का उनकी कार्य प्रण Ensure periodic inspection and testing of all safety gadgets for its working फावर स्टेशन (गांधीनग

Display Information about System, Cryogenic Hazards and Fire Alarm System in IPR ¹²

Emergency Shower & Breathing Set



Cryogenics Safety at IPR



- LHe and LN₂ cryogens are used for the cooling of superconductive magnets, 80K thermal shields of vacuum vessel, cryostats, Purifier of SST-1 machine and experimental test facilities.
- LHe produce in Helium Refrigerator and Liquefier Plant in IPR
- 2200 l/hr of LN₂ consumption, transfer from 105 kL cryogenic LN₂ tanks through ~ 270 meter long vacuum jacketed cryogenic transfer lines.
- Spring loaded safety valves in 2 stages, pressure relief valves, rupture disc, cryogenic bellows to take care of high pressure, thermal contraction and induced thermal stresses in the system.
- Cryogenic experimental Dewars of 50, 100, 150, 250 L capacities in Labs.
- Transfer siphon for liquid helium transfer, LN₂ withdrawal pressure device
- Follows the Cryogenic safety protocols and procedures, permit to work systems, equipped with cryogenic personal protective equipments, First aid treatment kit, information about the systems, emergency procedure and important contacts details have displayed on wall at the required locations in case of an emergency/accident. 33rd DAE Safety & Occupational Health Professionals Meet at IPR, Gandhinagar



Practical Problems Experience and Its Solution

[1]<u>Repairing of Main LN2</u> <u>Cryogenic Transfer line of LN2</u> <u>Distribution of SST-1</u>

- Huge frosting and condensation observed on a long section of transfer line
- Loss of cryogens and risk of cryogens falling down on personals working
- Damage to the equipments due to LN₂ dripping on
- In-house repaired and carried out the performance test at operating conditions of LN₂ transfer line
- Vacuum, multilayer insulation wrapping, welding, helium leak test and assembly in congested space and safety aspect at 12 meter height.



Leaked Line section







[2]<u>Replacement of Old Insulation</u> and Vacuum of Cryogenic <u>Transfer Lines of 80 K</u> <u>Distribution System</u>

- The ice blocks and water drops were falling down in the working area which was not safe for the system and personals
- Replaced old mineral glass wool insulation to Polyurethane insulation (PUF) of Cryo grade class P
- Vacuum in cryogenic transfer lines degraded to > 500 mbar
- Evacuation of transfer lines level up to 10⁻³ mbar
- Thermal performance of the LN₂ systems enhanced up to 80-90%.



Glass wool insulation

Frosting on vent line



PUF insulation





[3] <u>Rectification and Mitigation of</u> <u>Helium leaks in Cryogenic</u> <u>Systems</u>

- Leaks localized, mitigated and repaired in cryogenic systems at high pressure 14 bar pressure in safety valves, rupture discs, hand valves of high pressure helium gas storage vessels.
- Replaced developed mixed metal (AL+PTFE) seals, elliptical type O ring and PTFE gasket as per standard B16.
- Helium gas losses were reduced significantly and prevented the risk of high pressure gas bursting at any leaked location.
- Helium leak hunting and repairing at 12 meter height @ 100 bar, Helium leak rate
 achieved <10⁻⁶ mbar l/s



Rupture disc on high pressure helium gas vessels



Cryogenic Safety Guidelines



The general cryogenic safety checks must be followed by the personals working and responsibility to ensure by the management and safety Incharge.

- Safety extraction equipment is available and ready to use
- Personnel are trained and certified for cryogenic tasks
- Have a checklist and use it for any task
- Ensure adequate warning signs are posted
- Complete a JSA and review with team operations and procedures prior to doing job
- Always work as a team of two or more
- Developing a written policy to show commitment and assign responsibility at every level
- Identifying and evaluating all hazardous substances in the workplace date MSDS for them
- Implementing safe work procedures and appropriate administrative and engineering controls, educating workers about labels, MSDS, safe handling, storage, disposal and emergency response
- Identifying required personal protective equipment and educating workers in its care and use





- The personnels who are working in cryogenic plant must be aware of system information, cryogens information, PPEs, condition and type of cryogenic hazards or danger signs and what procedure should be followed in case of an accident or emergency conditions.
- Inform control room, identified personnel regarding emergency, safety In-charge for any accident, activation of emergency services like rescue, transportation of victims and calling fire brigade if necessary as a part of disaster management.



Summary



- The employer should show commitment towards safety and health practice and give full priority to promote and enforce the safety culture and health rules in workplace.
- At IPR, we are adopting and following the cryogenic guidelines and established procedures.
- By applying this practice results the safe long working in cryogenic environment without meeting any emergency condition.

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Thanks to All

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