Earlier Topics

- Introduction to Cryogenic Engineering
- Properties of Cryogenic Fluids
- Properties of Materials at Cryogenic Temperature
- Gas Liquefaction and Refrigeration Systems
- Gas Separation
- Cryocoolers
- Cryogenic Insulations
- Vacuum Technology
- Instrumentation in Cryogenics
Current Topic

Topic: Safety in Cryogenics

- Need for Safety
- Basic Hazards
- Protection from Hazards

- The current topic will be covered in 1 lecture.

- Tutorials and assignments are also included.
Outline of the Lecture

Topic: Safety in Cryogenics

- Introduction
- Basic hazards and their cause
- Protection from hazards
- Conclusion
Introduction

• As discussed in the earlier lectures, Cryogens are the liquefied gases, which are stored or transported at very low temperature.

• There exists various industrial as well as laboratory applications of some of the Cryogens.

• Few of the most commonly used cryogens are Helium (He), Nitrogen (N₂), Argon (Ar), Hydrogen (H₂) and Oxygen (O₂).
Introduction

- A video is shown, highlighting the effect of very low temperatures on
  - Materials like rubber
  - Organic materials like potato.

- The materials change their properties and become brittle at low temperature.

- They shrink at low temperatures. This may lead to material failure or may cause leaks in the system.
Introduction

- Sometimes due to the excessive boil-off, sudden pressure rise may occur.

- This sudden pressure rise may lead to accidents.

- Therefore, while handling cryogens, few important precautions have to be taken.
Basic Hazards

- Some of the most common hazards, that are encountered in a cryogenic environment are:

1. Extreme Cold or Low Temperature Hazard
2. Oxygen Deficiency Hazard – Asphyxiation
3. Oxygen Enrichment Hazard
4. Fire Hazard
5. Explosion
6. Material Embrittlement
1. Extreme Cold Hazard

- Bare skin, when exposed to cryogens or cold vapors, emanating due to continuous boil-off, can get subjected to thermal burn injuries.

- In certain cases, when the temperatures are very low, the time required for a thermal injury is as low as 5 seconds.

- Inhaling of extremely cold air or vapors can damage lungs.
1. Extreme Cold Hazard

- This exposure, damages the tissues of eyes, skin, hands, feet, etc. if proper care is not taken.

- The prolonged contact of the skin with cold surfaces causes frostbite.

- The skin, when not protected, can stick to the metal or pipe, that is cooled by a cryogen.

- In such situations, when pulled away, it tears the skin and adjacent tissues.
2. Oxygen Deficiency Hazard

• It is a known fact that the human body needs oxygen for survival.

• The minimum permissible oxygen content in breathing atmosphere for a normal human survival is around 19.5%.

• If human body is deprived of this minimum percentage for more than a few minutes, it may lead to choking/unconsciousness. In certain cases, it may also lead to death.

• This condition is called as Asphyxiation.
2. Oxygen Deficiency Hazard

- Oxygen Deficiency Hazard occurs when the oxygen in the atmosphere is displaced with another gas.

- Oxygen being, odorless and colorless, this is the most dangerous hazard that occurs without any warning.

- The expansion ratio of a normal cryogen is in the orders of 1:1000, when heated from boiling point to ambient condition.

- For example, one litre of LN2 displaces nearly 700 litres of air.
2. Oxygen Deficiency Hazard

- Apart from this, although the cryogen warms up a little and boils off, its temperature is very low as compared to ambient air.

- The low temperature heavier gas \( (N_2, A) \) displaces air, and thereby oxygen, in the nearby spaces.

- The situation is more critical in case of \( Ar \) and \( N_2 \), as these gases are heavier than air.
2. Oxygen Deficiency Hazard

• These heavier gases do not disperse well and accumulate in surrounding areas displacing air.

• Some of the lighter gases like Hydrogen and Helium, mix with the surrounding air and stratify. But, they still lead to oxygen deficiency hazard.

• Unventilated or closed rooms are prone to hazards associated with large volumes of cryogens displacing oxygen.

• For example, the use of a portable dewar vessel in a small laboratory room.
3. Oxygen Enrichment Hazard

- It is not only the deficiency of the oxygen that is dangerous but also the enrichment of the oxygen.

- The temperature of boil-off gases like Liquid Helium, Liquid Nitrogen and Liquid Hydrogen are low enough to liquefy the surrounding air.

- This liquid air solidifies, when settled on non-insulated cryogenic pipes.
3. Oxygen Enrichment Hazard

- The latent heat of vaporization of Nitrogen is very small as compared to that of Oxygen.

- Due to this, the nitrogen evaporates more rapidly from the condensed air, leaving behind the oxygen rich component.

- This oxygen enriched gas, together with a flammable material can lead to fire hazards.
4. Fire Hazard

- Gases like hydrogen or oxygen are flammable and they exhibit the risk of fire hazard.

- For example, hydrogen is a colourless and an odorless gas.

- It is highly flammable or explosive, in presence of air or oxygen in right proportions.
4. Fire Hazard

• Also, hydrogen being lighter than air, it settles around the ceiling of a room or a laboratory.

• As the time proceeds, this gas accumulates near the corners and forms pockets of gas, which can lead to an explosion or fire hazard.

• In order to avoid the accidents, a flashing or rotating blue light is used as an indication.

• Placards indicating the possible risks and safety procedures to handle such situations are displayed.
5. Explosion

• Cryogenic vessels are insulated, closed containers. There is a continuous boil–off due to the various heat in leaks.

• Without adequate venting of the boil–off gases, the pressure build–up inside the container can lead to an explosion.

• The pressure rise could be sudden, in case of Nitrogen and Helium, due to low latent heat of vaporization and huge expansion ratios.
5. Explosion

- Unusual or accidental conditions such as, an external fire or a break in the vacuum insulation, may cause sudden pressure rise.

- This may lead to an explosion.

- The pressure relief valves and bursting discs are mounted on the closed containers to relieve the excess pressure.

- Electronic alarms are used to indicate the accidental pressure rise when relief valves malfunction or vent line is chocked.
6. Metal Embrittlement

• In the **Properties of Materials at Cryogenic Temperature** topic, we have seen the effect of low temperature on material properties.

• Most of the engineering materials that are used in Cryogenics have crystalline structure.

• The materials with Face Centered Cubic (FCC) structure remain ductile at cryogenic temperatures.

• The materials with Body Centered Cubic (BCC) structure become brittle at low temperatures.
6. Metal Embrittlement

- As a result, the piping or support structures break when subjected to small loads.

- The thermal stresses are developed, when metals are exposed to low temperatures.

- These stresses together with embrittlement can cause a rupture in a pipe line or break a support column.
Protection from Hazards

• It is necessary and imperative to use the personal protective equipment while handling cryogens. These include

  • **Goggles**: Eye protection must be used, whenever handling or transferring cryogens. Face shield and safety goggles should be used.

  • **Gloves**: Hands are to be protected with appropriate gloves. These should be designed to prevent cryogens from flowing into the glove.

  • **Safety Shoes**: It is mandatory to use high top shoes, while handling liquid cryogens.
Protection from Hazards

• **Overalls**: Lab coats or disposable overalls should be used. They provide a complete coverage of skin. All parts of the body must be protected from non-insulated pipes or vessels.

• Jewelry, watches, rings etc. should not be worn, as metals can get frozen onto the skin.
Protection from Hazards

• The new entrants and staff should be trained with implementation of standard operating procedures, safety measures and possible hazards.

• Only trained and qualified personnel are allowed to handle, transport or store liquefied gases.

• Overfilling of cryogenic containers is to be avoided.

• Apart from this, slow pouring or transferring of cryogen is preferred. It minimizes boiling and splashing.
Protection from Hazards

• All system vents must be directed away from personnel or designated work areas.
Oxygen Detectors

• Oxygen detectors are used in risk prone areas to indicate the oxygen level. These detectors usually operate in the range from 0% to 25%.

• The detector system gives a primary stage warning, when the oxygen level in the atmosphere falls below 19%.

• A second danger alarm is given at 17%.

• This enables the user to take the quick action, in order to avoid asphyxiation.
Pressure Relief Valve

- A pressure relief valve is a mechanical device, which is used to control or limit the pressure in a closed vessel.

- The schematic of a pressure relief valve is as shown in the figure.

- It has an inlet for a high pressure gas on the lower side. The outlet is provided on the upper side.
Pressure Relief Valve

- It consists of a spring, whose stiffness can be adjusted to operate the closing and opening of the valve.

- This spring together with valve disc, is used to divide the inlet and the outlet portions as shown in the figure. This is the closed position of the valve.

- When the pressure in closed vessel exceeds the set pressure, the valve opens to release the excess pressure. This is the open position of the valve.
Pressure Relief Valve

• The process of releasing excess pressure is called as Blow Down.

The released high pressure gas is often vented into an open atmosphere using a duct.
Pressure Relief Valve

• Periodic checks for the working of pressure relief valve is necessary.

One of the disadvantages of this valve is that, once pressure is released, the valve may not sit back to the original set value.

• In the recent developments, electronic open – close valves are used.

• These devices not only monitor the system pressure but also function as pressure relief valve.
Bursting Disc

- A Bursting Disc or a Rupture Disc is a non-self closing pressure relief device.

- This device, unlike pressure relief valve, is used to vent the entire system to atmosphere in both,
  - Excess pressurization
  - Excess vacuum

- It is a sacrificial device and has only one-time use during a positive pressure or a vacuum.
Bursting Disc

- The schematic of a Bursting Disc is as shown in the figure.

- It consists of a diaphragm which divides the inlet and the outlet portions as shown in the figure.

- This is the normal position of the disc.

- Usually, the diaphragm is made of metal. However, any material or different materials in the form of layers can be used.
Bursting Disc

- In case of excess pressure on the inlet side, the diaphragm deforms.
- Finally, it bursts to vent the system to atmosphere as shown in the figure.
- In case of vacuum on the inlet side, the diaphragm deforms inwards as shown in the figure.
- The diaphragm bursts and breaks the excess vacuum inside the system.
Bursting Disc

- These discs are generally used as a backup device for pressure relief valves.
- The released high pressure gas is often vented into an open atmosphere using a duct.
- One of the major advantages of the Bursting Discs as compared to pressure relief valves is its leak tightness and cost.
Conclusion

- Few of the common hazards that occur in a cryogenic environment are Extreme Cold Hazard, Asphyxiation, Oxygen Enrichment Hazard, Fire Hazard, Explosion and Material Embrittlement.

- The minimum permissible oxygen content in breathing atmosphere for a normal human survival is around 19.5%.

- Oxygen detectors, relief valves, bursting discs are used to avoid accidents.
Conclusion

- It is always necessary and imperative to use the personal protective equipment while handling cryogens.

- These include, thermal insulated gloves, face shields, long sleeve overalls and safety shoes.
The course syllabus covered is as follows.

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• A self assessment exercise is given after this slide.

• Kindly assess yourself for this lecture.
1. Most materials change their properties and become ____ at low temperature.
2. Bare skin, when exposed to cryogens causes ____ hazard.
3. The minimum permissible oxygen content in breathing atmosphere for human survival is ____.
4. The density of cold gas is ____ than hot gas.
5. The latent heat of vaporization of Nitrogen is ____ as compared to that of Oxygen.
6. ____ is highly flammable in presence of oxygen.
7. In an oxygen detector, a second alarm is at ____.
8. The process of releasing excess pressure is ____.
Answers

1. Brittle
2. Cold temperature
3. 19.5%
4. Higher
5. Small
6. Hydrogen
7. 17%
8. Blow Down
Thank You!