CRYOGENIC ENGINEERING

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Lecture No - 42

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 ($\mathbf{N_2}$), Argon (**Ar**), Hydrogen ($\mathbf{H_2}$) and Oxygen ($\mathbf{O_2}$).

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.

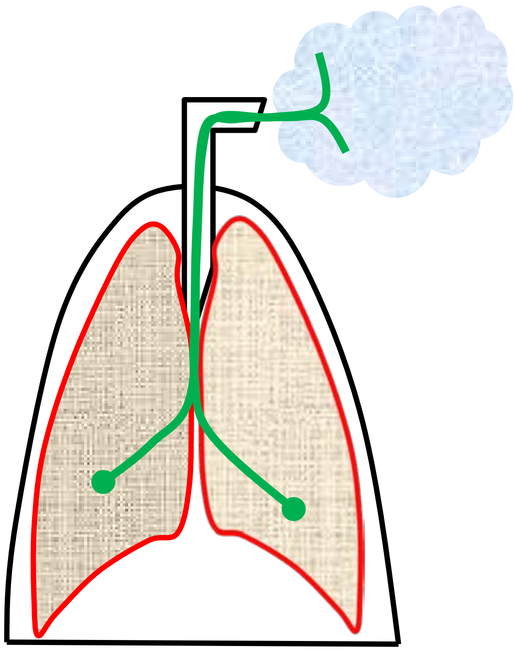
Basic Hazards

- 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.

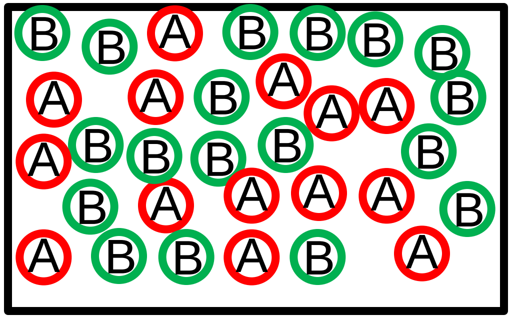
2. Oxygen Deficiency Hazard

- 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 chocking/unconsciousness. In certain cases, it may also lead to death.
- This condition is called as **Asphyxiation**.

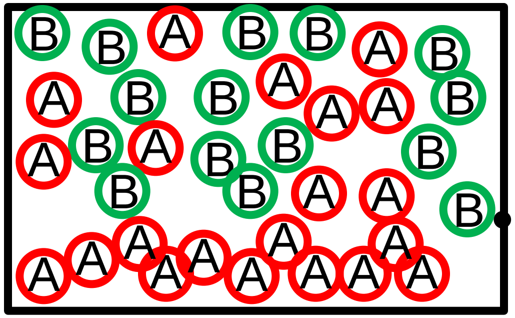
2. Oxygen Deficiency Hazard

- 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 liter of **LN2** displaces nearly 700 liters 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.

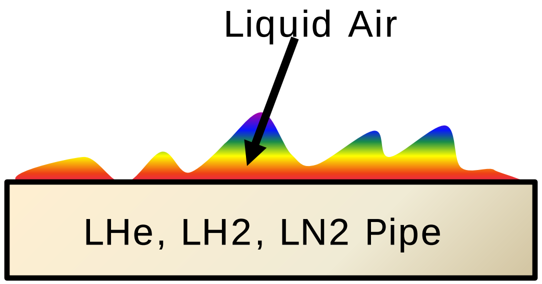
- The situation is more critical in case of **Ar** and **N_2**, as these gases are heavier than air.

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.

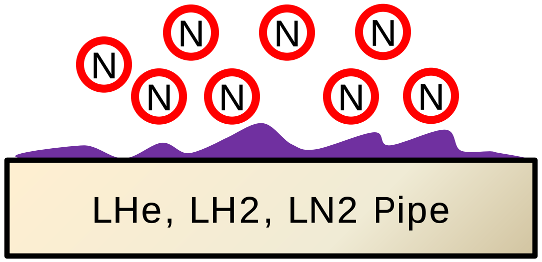


- The temperature of boil – off gases like Liquid Helium, Liquid Nitrogen and Liquid Hydrogen are low enough to liquefy the surrounding air.

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

- This oxygen enriched air, 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 colorless 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.

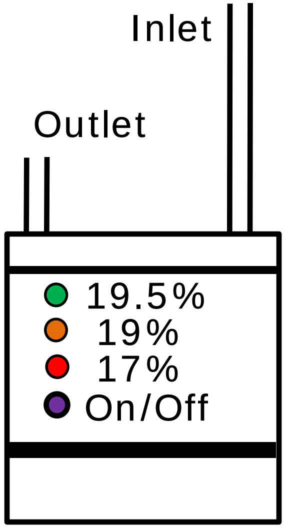
- Overfilling of cryogenic containers is to be avoided.

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

Protection from Hazards

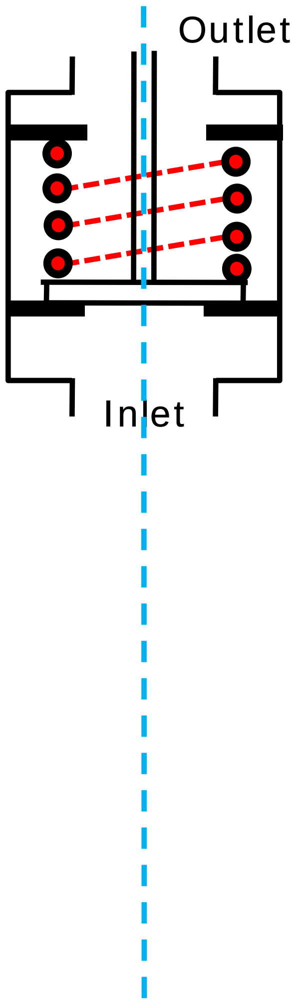
- All system vents must be directed away from personnel or designated work areas.

Oxygen Detectors



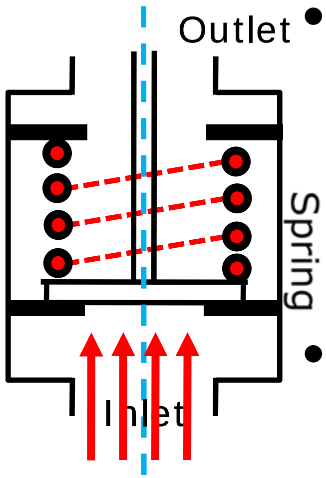
- Oxygen detectors are used in risk prone areas to indicate the oxygen level. These detectors usually operate in the range from **0%** to **25%**.
- The detector system gives a primary stage warning, when the oxygen level in the atmosphere falls below **19**%.
- A second danger alarm is given at **17%**.
- This enables the user to take the quick action, in order to avoid asphyxiation.

Pressure Relief Valve



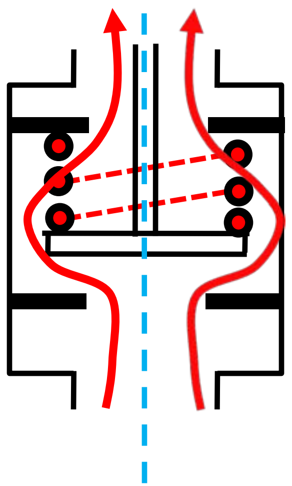
- A pressure relief valve is a mechanical device, which is used to control or limit the pressure in a closed vessel.
- The schematic of a pressure relief valve is as shown in the figure.
- It has an inlet for an high pressure gas on the lower side. The outlet is provided on the upper side.

Pressure Relief Valve



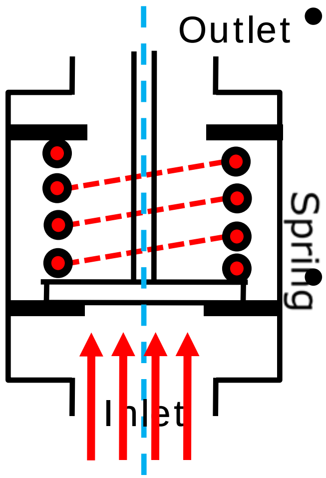
- It consists of a spring, whose stiffness can be adjusted to operate the closing and opening of the valve.

- 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.

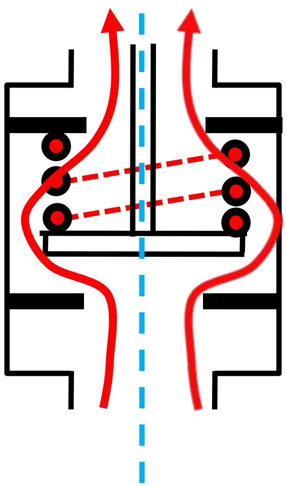


- When the pressure in closed vessel exceeds the set pressure, the valve opens to release the excess pressure. This is the open position of the valve.

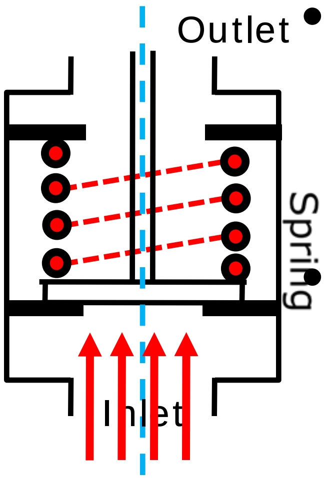
Pressure Relief Valve

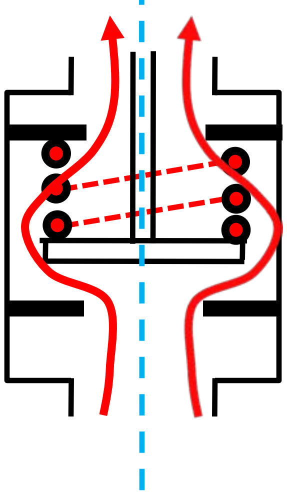


- The process of releasing excess pressure is called as Blow Down.
- The set pressure or Blow Down pressure is usually between 2 to 20 % of maximum allowable pressure inside the vessel.
- The released high pressure gas is often vented into an open atmosphere using a duct.



Pressure Relief Valve



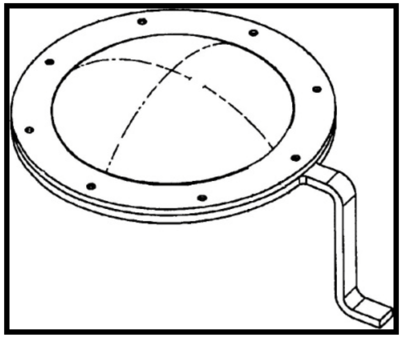


- Periodic checks for the working of pressure relief valve is necessary.
- One of the disadvantage of these valve is that, once pressure is released, the valve may not sit back to the original set value.
- In the recent developments, electronic open – close valves are used.
- These devices not only monitor the system pressure but also function as pressure relief valve.

Bursting Disc

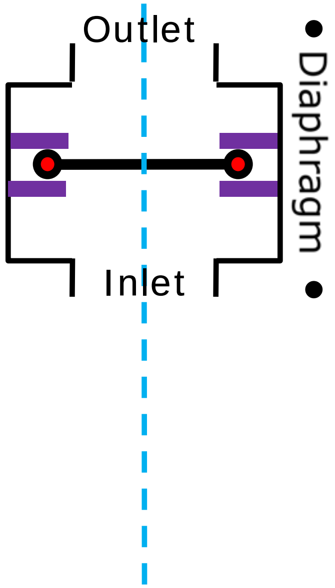
- A Bursting Disc or a Rupture Disc is a non – self closing pressure relief device.

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



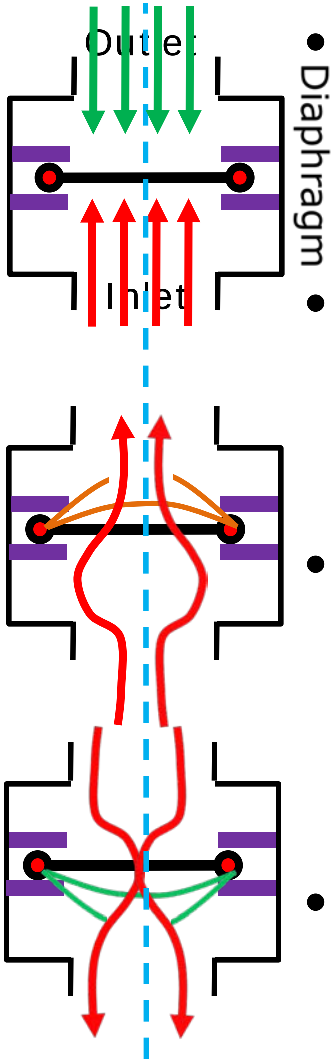
- It is a sacrificial device and has only one – time – use during a positive pressure or a vacuum.

Bursting Disc



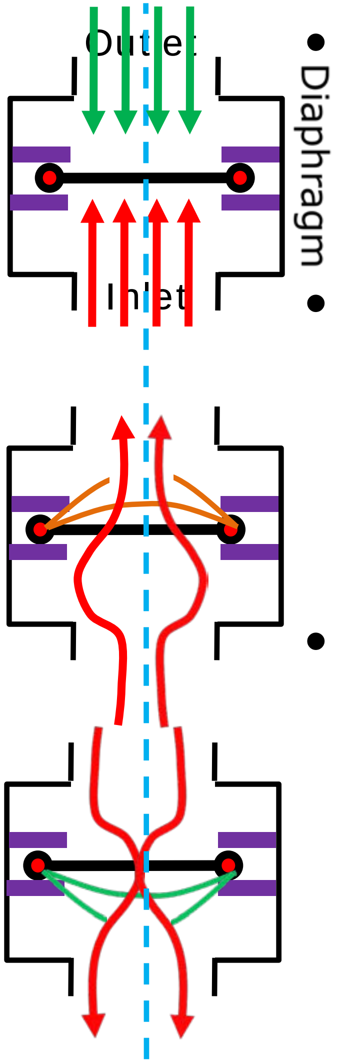
- The schematic of a Bursting Disc is as shown in the figure.
- It consists of a diaphragm which divides the inlet and the outlet portions as shown in the figure.
- This is the normal position of the disc.
- Usually, the diaphragm is made of metal. However, any material or different materials in the 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.

Course Syllabus

- The course syllabus covered is as follows.

Topic		
1	Introduction to Cryogenics & its Applications	1
2	Properties of Cryogenic Fluids	3
3	Properties of Materials at Cryogenic Temperature	3
4	Gas-Liquefaction and Refrigeration Systems	10
5	Gas Separation	8
6	Cryocoolers	7
7	Cryogenic Insulations	3
8	Vacuum Technology	3
9	Instrumentation in Cryogenics	3
10	Safety in Cryogenics	1

Course Syllabus

- The other topic which is covered under **Cryogenic Engineering** is

	Cryostat Design	

- A self assessment exercise is given after this slide.

- Kindly asses yourself for this lecture.

Self Assessment

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!