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REVIEW ARTICLE

CRYOGENICS AND ITS APPLICATIONS

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Cryogenics and Its Applications

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INTRODUCTION

Cryogenics means the production of cold. Conventional refrigeration operates from - 30 C upwards. By definition cryogenics deals with temperatures in the range -150 C (123 K) downwards. Absolute zero is the lowest temperature one may approach. The temperature of melting ice in the centigrade scale is zero. Its temperature on the absolute scale is 273 K.

PRODUCTION OF CRYOGENIC TEMPERATURES:

Temperatures in the cryogenic range are produced by liquefaction of so called permanent gases ie gases which have a critical temperature below melting ice. A gas will liquefy only at a temperature below its critical temperature. Sulfur dioxide, Ammonia, and Freon have a critical temperature above room temperature. So they are used in refrigerators in which they liquefy under compression. But Nitrogen, Argon, Krypton, Oxygen, Neon, Hydrogen and Helium have critical temperatures much below room temperature. They have to be cooled below their critical temperature and then liquefied.

Liquefaction of air was achieved more than 120 years ago. Since then the other permanent gases were liquefied. Machines to produce liquefied gases contain compressors, expansion engines, heat exchangers and Joule-Thomson valves. We will not go into the liquefaction of gases.

The normal boiling point of a liquid is the temperature at which it boils less than one atmosphere pressure. The normal boiling points of some liquefied gases are given below:

Liquid oxygen	90 K	-183	C
Liquid nitrogen 77 K	-196	C	
Liquid Hydrogen	20 K	-253	C
Liquid Helium	4.2 K	-268.8	C

WHY GO TO LOW TEMPERATURES?

1. Because of the scientist's desire to reach as close to absolute zero as possible.

2. Because properties of materials change drastically as the temperature is reduced.

3. New phenomena are discovered:

Example: **Superconductivity.**

Super fluidity Quantum Hall Effect and Fractional

Quantum Hall Effect

Bose-Einstein Condensation

1. Variety of useful applications

A whole branch of engineering called cryogenic engineering has come into vogue.

APPLICATIONS OF CRYOGENICS:

1. Production of Oxygen gas for industrial applications

Oxygen is produced by liquefying air and by fractional distillation.

Oxygen is needed in the steel industry in blast furnaces, in welding industry, in hospitals and in space rockets.

2. Production of nitrogen gas for industrial applications

Nitrogen gas is produced by liquefaction of air and by fractional distillation

Nitrogen gas is used in production of ammonia based fertilizers

It is used for blanketing chemical reactors

3. Applications of liquid nitrogen

In Artificial insemination of cattle to increase milk production

In food preservation

In preservation of cells and tissues

In destruction of diseased cells - Cryosurgery

4. Applications of liquid hydrogen

Hydrogen is a clean fuel. Hydrogen burning in oxygen produces water which does not pollute.

Hydroigen is inexhaustible as hydrogen is produced by electrolysis of water. Water is abundant in the oceans. Hydrogen is the fuel of the future.

Hydrogen is used as fuel in rockets carrying a very heavy payload. Example: Saturn

Rockets to launch Apollo missions..

Hydrogen produces maximum thrust per unit mass of fuel.

Hydrogen and oxygen are carried as liquids in the rocket.

India has built such a cryogenic engine and has tested it successfully. It will be used for GSLV.

5. Applications of liquid helium

For producing clean ultra-high vacuum ($<10^{-9}$ mbar) needed for manufacture of semiconductor chips and for testing scaled down version of satellites.

For cooling superconducting magnets. These magnets can produce high magnetic fields (up to 20 T) and are light in weight.

Superconducting magnets are used in magnetic resonance imaging. This technique is superior to CAT scan as (1) the images have a higher resolution, (2) flowing blood can be seen and (3) there is no radiation damage.

Superconducting magnets are used in high energy particle accelerators for making these charged particles to move in circles of large diameter. Such accelerators are the cyclotrons, synchrotrons and the Large Hadron collider. India is building a variable energy cyclotron with SC magnets in Kolkata and a 2.5 GeV synchrotron at Indore. India has supplied a large number of poloidal field magnets for focusing the beams in the large Hadron collider in CERN, Geneva.

Superconducting magnets are required to confine plasma of hydrogen in a fusion reactor. India is building a superconducting Tokomak in Ahmedabad and will participate in the International Thermonuclear Reactor project in France by designing and supplying liquid helium cooling systems for the superconducting magnets.

Superconducting magnets can be used to levitate a train and facilitate high speed travel. Such trains are running in Japan..

The demand for electrical power varies with time of the day. Generally it is low at night time and high during day time. Power is generated at a constant rate. So one needs to store the excess power when the demand is low and release it when the demand is high. Such storage can be accomplished using a superconducting magnet.

A thin insulating layer sandwiched between two superconductors is called a Josephson junction. One can send by quantum mechanical tunneling of the Cooper pairs a small current from one superconductor to another without a voltage appearing across the insulator. This is called the DC Josephson effect. If a small DC voltage of 1 microvolt is applied across the junction it produces electromagnetic waves at 496 MHz. This is called the AC Josephson effect.

The DC Josephson effect is used to measure small magnetic fields (10^{-11} Tesla) and is used in non-destructive testing of materials, in geological prospecting and in study of currents in the brain due to sensory impulses. The AC Josephson effect is used as a voltage standard.

CONCLUSION

Cryogenics is a typical example of how research in basic physics leads to wide ranging applications. Research on liquefying permanent gases and studying material properties at low temperatures has led to a whole range of practical applications in which suitably trained engineers are involved.