

CRYOGENIC ENGINEERING



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Lecture No - **1**

What is Cryogenics?

- Kryo – Very cold (frost)
- Genics – to produce
- Cryogenics is the science and technology associated with generation of low temperature below 123 K.

Course outline

- This course is aimed at students who are interested to study the science and technology of low temperatures.
- The purpose of this course is to give an introductory knowledge of Cryogenic Engineering.

Course outline

- The course is both theoretical as well as mathematical. It will engross the students.
- This course will interest students wishing to embark on a research career in Cryogenic Engineering.

Course prerequisite

- Engineering Mathematics.
- Heat Transfer.
- Thermodynamics.
- Refrigeration.

Points to remember

- Each lecture presentation ends with a self assessment test based on that particular lecture.
- The best knowledge is gained when the student solves the self assessment honestly and with proper understanding.
- A greater insight into the subject can be obtained by referring to the books specified.

Points to remember

- Assignments are included where ever necessary in order to have a clear understanding of concepts.
- Before each assignment, an example tutorial problem is solved with a detailed explanation.
- The best knowledge is gained when the student solves the assignment problems honestly and with proper understanding of concepts.

Books/References

Text books/References

- Randall F. Barron, "Cryogenics Systems", Second Edition, Oxford University Press, New York (1985).
- Timmerhaus, Flynn, "Cryogenic Process Engineering ", Plenum Press, New York (1989).
- Pipkov, " Fundamentals of Vacuum Engineering ", Mir Publishers, Moscow.

Books/References

Text books/References

- Thomas M. Flynn, "Cryogenic Engineering", second edition, CRC press, New York (2005).
- G.M Walker. "Cryocooler- Part 1 Fundamentals" Plenum Press, New York (1983).
- G.M Walker. "Cryocooler- Part 2" Plenum Press, New York (1983).

Books/References

Additional Readings

- Proceedings of Advances in Cryogenic Engineering.
- Proceedings of International Cryocooler Conference.
- Proceedings of International Cryogenic Engineering Conference and International Cryogenic Materials Conference.

Books/References

Additional Readings

- Cryogenics Journal.
- Indian Journal of Cryogenics.

Course syllabus

- The course syllabus is as follows.

Sr No	Topic
1	Introduction to Cryogenics and its Applications
2	Properties of Cryogenic Fluids
3	Properties of Materials at Cryogenic Temperature
4	Gas-Liquefaction and Refrigeration Systems
5	Gas Separation

Course syllabus (contd)

Sr No	Topic
6	Cryocoolers
7	Cryogenic Insulations
8	Vacuum Technology
9	Instrumentation in Cryogenics
10	Cryostat Design
11	Dilution Refrigerator and Adiabatic Demagnetization
12	Safety in Cryogenics

Applications – Space

Space

- Rocket propulsion
- Cooling of Infra-Red (IR) sensor
- Space simulation

Applications – Space

- Cryogenic engines are powered by cryogenic propellants.
- Liquid Hydrogen is used as a fuel to propel the rocket.
- Liquid Oxygen is used as an oxidizer.

Applications – Space

- Cooling of IR detectors, Telescopes, Cold probes, etc. are some of the major applications of cryogenics.
- Development of miniature and small cryocoolers for satellites for an improved accuracy and reliability of earth observation.
- Space simulations chambers are realistic environment for air craft. The cold space is simulated at cryogenic temperatures by use of LN_2 .

Applications – Space

- The levels of vacuum required in space simulation chambers are very high.
- This is achieved by the use of cryo pumps and turbo molecular pumps.

Applications – Mechanical

Mechanical

- Magnetic Separation
- Heat treatment
- Recycling

Applications – Mechanical

- Magnetic separation technique is used in variety of applications like enhancing the brightness of kaolin, improving the quality of ultra-high purity quartz etc.- Superconducting Magnet ensures proper separation.
- The lives of the tools, die castings & their dies, forgings, jigs & fixtures etc increase when subjected to cryogenic heat treatment.
- The life of guitar strings increases by 4 to 5 times with no need for tuning.

Applications – Mechanical

- Cryogenic recycling - turns the scrap into raw material by subjecting it to cryogenic temperatures.
- This is mostly used for PVC, rubbers.

Applications – Medicine

Medicine

- Cryosurgery
- Cell preservation
- Food preservation

Applications – Medicine

- Cryosurgery is a novel technique in which the harmful tissues are destroyed by freezing them to cryogenic temperature.
- Cryosurgery has shorter hospital stay, less blood loss, and small recovery time.
- It is generally used in patients with localized prostate and kidney cancer, skin disorders, retinal problems, etc.

Applications – Medicine

- Preserving food at low temperature is a well known technique.
- Cooling of sea foods, meat (sea export), milk products for long time preservation is achieved by use of LN₂.
- Systems are developed to preserve blood cells, plasma cells, human organs and animal organs at cryogenic temperatures.

Applications – Gas Industry

Gas Industry

- Liquefaction
- Separation
- Storage

Applications – Gas Industry

- The transportation of gases across the world is done in liquid state. This is done by storing the liquid at cryogenic temperature.
- The use of inert gases in welding industry has initiated higher demand for gas production in the recent past.
- Cryogens like LOX, LH₂ are used in rocket propulsion while LH₂ is being considered for automobile.

Applications – Gas Industry

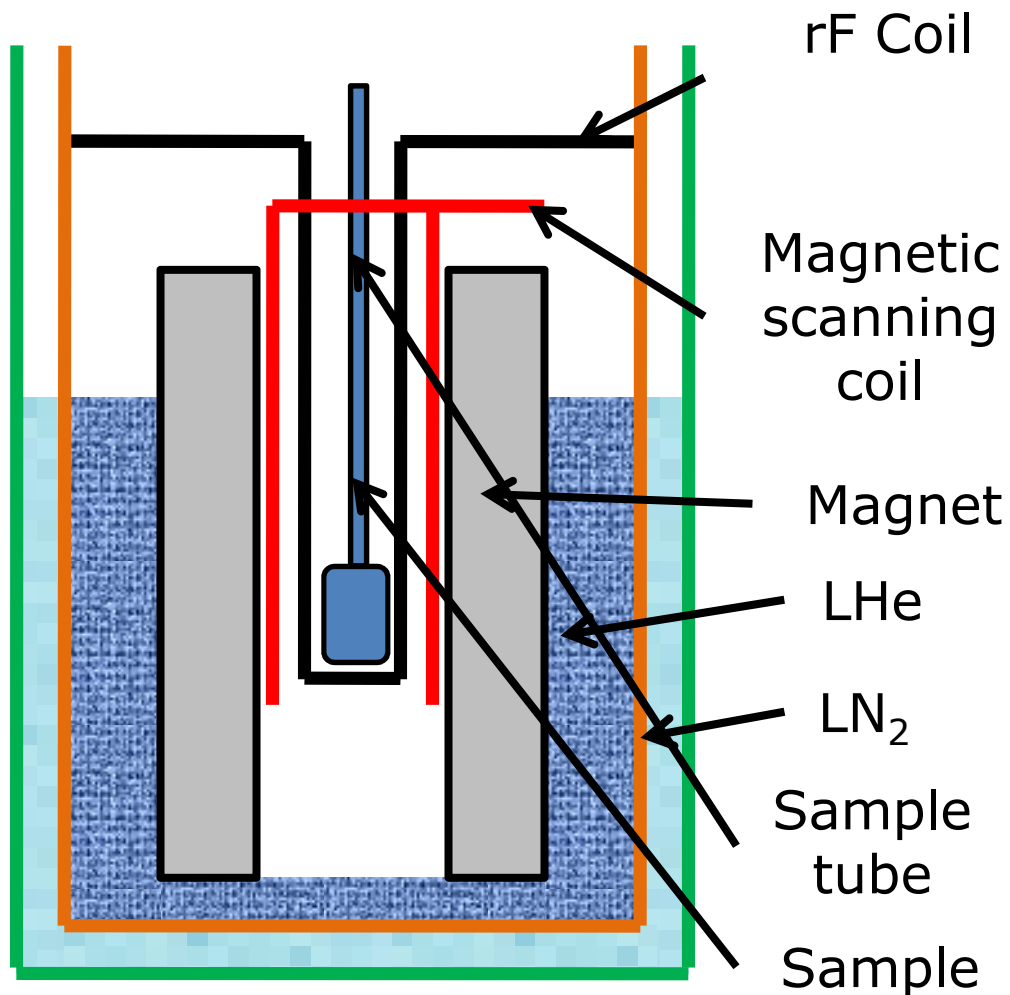
- Liquid nitrogen is used as precoolant in most of the cryogenic systems.
- Steel industry – Oxygen is used in the production of steel. Basic Oxygen Furnace (BOF) uses oxygen instead of air.
- Nitrogen and argon are primarily used to provide an inert atmosphere in chemical, metallurgical and welding industries.

Applications – Supercond.

Superconductivity

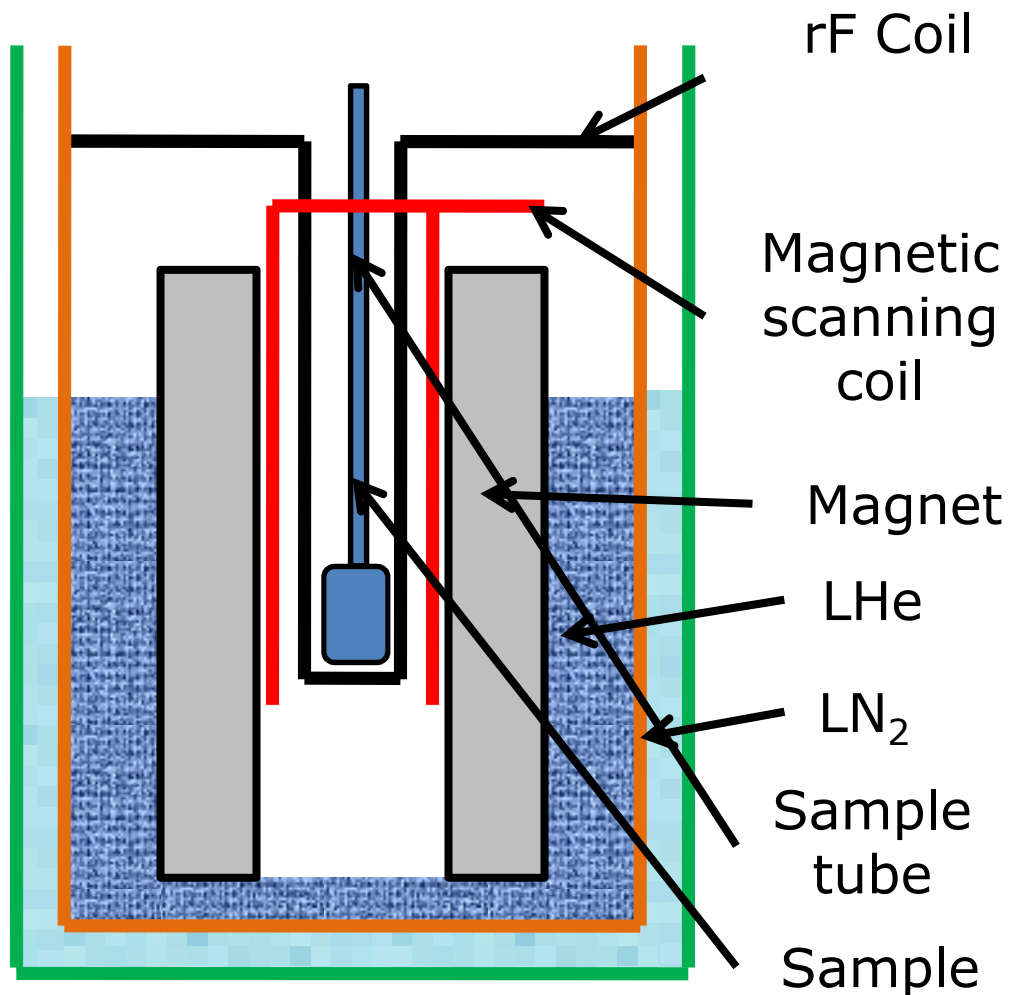
- NMR, MRI
- Maglev Locomotion
- Transformer & Generators

Applications – Supercond.



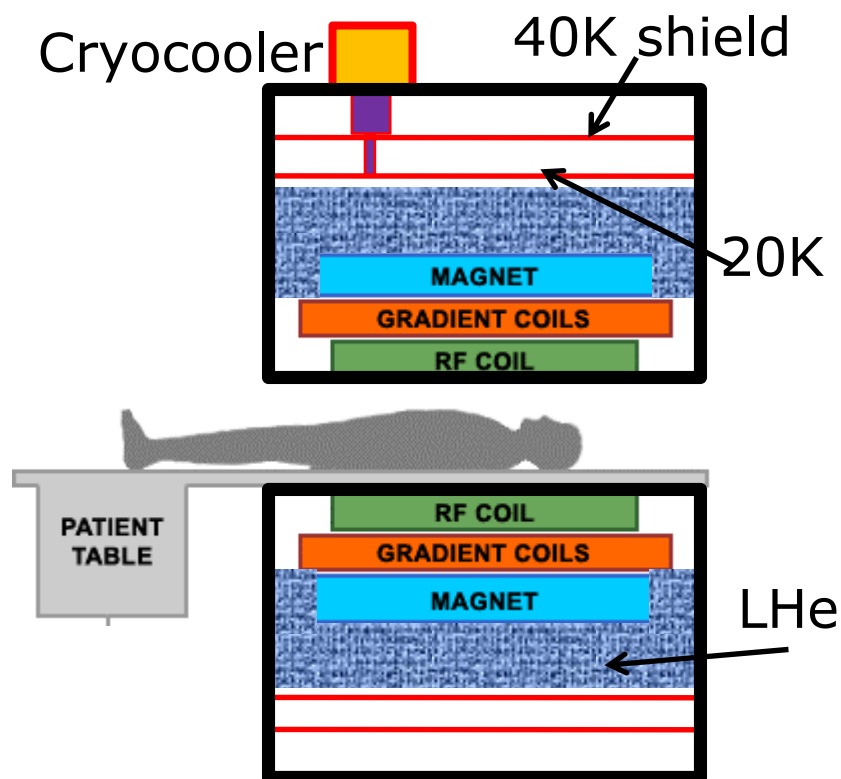
- The NMR (Nuclear Magnetic Resonance) is used by the pharmaceutical industry to study the molecular structure.

Applications – Supercond.



- It has a superconducting magnet (10 T ~ 25 T) and the accuracy of measurement increases with field strength.

Applications – Supercond.

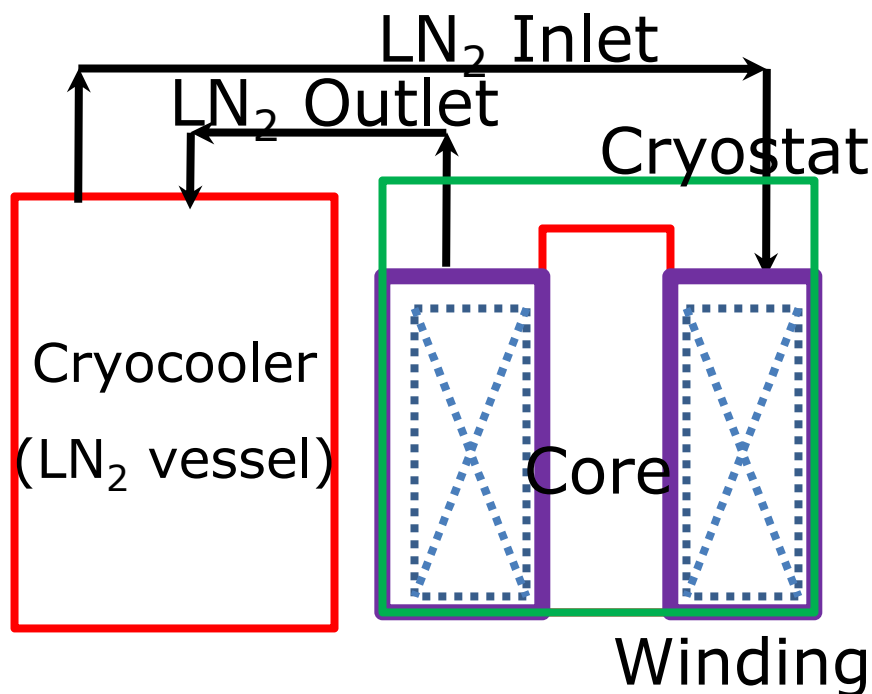


- The MRI (Magnetic Resonance Imaging) machines are used for body scanning.
- The SC magnets for both NMR and MRI machines are cooled by liquid Helium.

Applications – Supercond.

- Maglev Train runs on the principle of Magnetic Levitation.
- The train gets levitated from the guide way by using electromagnetic forces between superconducting magnets on the vehicle and coils on the ground.
- This results in no contact motion and therefore no friction.

Applications – Supercond.



- Superconducting transformers and generators have coils (and cores sometimes) maintained at low temperature to minimize the I^2R (copper) losses.

Applications – High E Physics

High Energy Physics

- CERN
- ITER

Applications – High E Physics

- CERN is an European organisation for nuclear research which was founded in 1954.
- It consists of a 27Km accelerator ring with four detectors.
- All the magnet systems (SC) and its accessories are kept at 1.9 K using the liquid helium.

Applications – High E Physics

- A liquid nitrogen layer (77 K) is used as shielding for liquid helium.
- It is an experiment seeking answers to Big Bang theory and collision of atomic particles.

Applications – High E Physics

- ITER (International Thermonuclear Experimental Reactor) is an engineering project for nuclear fusion reactor.
- The superconducting magnets are maintained at 4 K by liquid helium.
- The experiments are carried out to enable mankind to generate energy for future.

Applications – Summary

Space

- Rocket propulsion
- Cooling of IR sensor
- Space simulation

Medicine

- Cryosurgery
- Cell preservation
- Food preservation

Gas Industry

- Liquefaction
- Separation
- Storage

Mechanical

- Magnetic Separation
- Manufacturing
- Heat treatment
- Recycling

High Energy Physics

- ITER
- CERN

Superconductivity

- NMR, MRI
- Maglev Locomotion
- SC Transformer & Generator

Thank You!