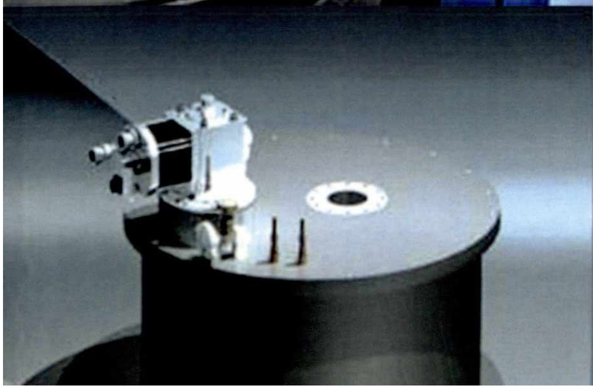

REPORT

ON

DATA BASE INFORMATION ON FACILITY AND HUMAN RESOURCES RELATED TO CRYOGENICS AND SUPERCONDUCTIVITY IN INDIA (PRESENT AND FUTURE TREND)

Prepared by

T S Datta & R G Sharma

INTER UNIVERSITY ACCELERATOR CENTRE
ARUNA ASAF ALI MARG
NEW DELHI- 110067

Sponsored by

DEPARTMENT OF SCIENCE AND TECHNOLOGY
NATIONAL SCIENCE AND TECHNOLOGY
MANAGEMENT INFORMATION SYSTEM
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Ref. No : DST/NSTMIS/05/84/20006-2007
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Dear Colleague,

We have compiled this report for DST after carrying out a study on the overall activity in India in the area of cryogenics which includes research activity in Low Temperature Physics, Superconductivity, Cryogenics, Experimental Facilities, Human Resource available and the Gas Industry. Looking at the vast scope of study this was an uphill task. Nevertheless we gathered as much information as possible through circulation of questionnaire, personal knowledge, contacts, visits and web pages. Still, this data may not be complete. There are bound to be pitfalls in an exercise of this nature and magnitude. We would therefore like to keep this data updating through your close cooperation. Kindly feel free to point out any factual omission or mistake or any additional information that you can provide. You can write to any one of us. We will post this report on the website of the ICC.

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PREFACE

Cryogenics became a buzz word with common man in India in 1990s when ISRO (Indian Space Research Organization) was denied the supply of Cryogenic Engine with technology by Russia. It's history in the country is, however, quite old. Great scientist and a visionary, Sir K.S. Krishnan, the Founder Director, National Physical Laboratory acquired a helium liquefier and established a competent group of physicists to start studies at low temperature down to 1 Kelvin. This culture of low temperature studies soon spread to other reputed institutes like TIFR Bombay, IISc Bangalore, DAE Centres, IITs and universities. This community, under the leadership of Prof. Akshay Bose of the Indian Association for the Cultivation of Science (IACS), formed Indian Cryogenic Council (ICC) in 1975 with its Head Quarter at Jadavpur University, Kolkata.

During 1980s use of cryogenic grew rather rapidly in application areas. NMR and MRI were the biggest promoter of the use of liquid helium. Production and use of liquid nitrogen (LN2) and liquid oxygen (LO2) saw a phenomenal growth primarily because of large expansion in fertilizer and steel industry respectively. During 1990s research institutions chalked out big projects, such as Accelerators at IUAC, New Delhi and TIFR Bombay, Fusion Reactor (SST-1) at IPR, Gandhinagar and Superconducting Cyclotron at VECC, Kolkata. These projects injected fresh blood in to the cryogenic activities in the country. Production of LHe and LN2 grew leaps and bound. Young scientists and engineers got involved in designing and fabricating complicated cryostats, large superconducting magnets and superconducting cavities and so on. These projects are bearing fruits today.

Department of Science and Technology (DST) too invested huge amount of money to support research in High Temperature Superconductors, Low Temperature and High Magnetic Field Facilities and other Infrastructural Facilities like Helium Liquefires, PPMS and so on.

During this golden period, however, ICC did not keep pace with changing situation vis-à-vis these large size cryogenic programmes. In 2006 the Cryogenic Community, however, got down with the task of rejuvenating ICC and drew a blue print for ICC. As a result ICC is now in good health and has new generation scientists & engineers and the industry as its enthusiastic Members and Fellows.

In spite of all these developments we did not have either a document or a desk from where we can ascertain information about the programmes and the facilities or the human resource available with these institutions. We decided to approach DST to grant us this project for preparing such document. DST very kindly agreed to the proposal.

The inputs came through our personal knowledge & contacts, through circulation of questionnaire, personal visits and discussions. Individual websites and internet facility have been used to collect data information wherever available. Classified information, was however, not available from certain organizations for obvious reasons. The response from institutions and individual was by and large good. Most were quite cooperative. Nevertheless there had been occasions when there was no response from certain quarters in spite of our repeated requests and phone calls.

We have done our best to analyze the raw data we collected under different heads in tabulated form. We have given a brief write up for important and well known institutions highlighting their areas of research. Major Measurement equipments available with different institutions are listed separately. There is a long list of scientists, engineers and technical personnel working at different centres. There is a separate list of retired scientists and professors who made a very significant contributions in a variety of ways. Even though, we tried our best to collect information as much as we could, yet there are bound to be many omissions particularly from places which might have started cryogenic activities in recent times and not joined the main stream. There are also possibilities of minor mistakes on individual data on qualification, age and some cases affiliation (those who has changed his job in last 1 year)

We take this opportunity and thank DST for having accepted our proposal and made funds available for this work. We thank Rakesh Chetal and Laxman Prasad of DST in particular for being very cooperative all along. We gratefully acknowledge the suggestions and help provided by the members of the Local Project Advisory Committee (LPAC) at the meetings. We thank Amit Roy, Director, IUAC for his keen interest and support to this work. We also had the privilege of the participation of two veterans, ESR Gopal and R Srinivasan who too participated in a meeting we organized at IISc and made valuable suggestions. We thank all the scientists, engineers and our friends from institutes and industries who found time to compile information and shared with us.

It will be impossible to list the names of all those, who directly or indirectly helped us to have wide range of technical information. However, we cannot but name the persons who made singular contribution to our efforts by taking us round their facilities, compiled data information from their organizations and shared their views. These are NK Gupta and SC Rastogi of ISRO, AK Majumdar (now at SNBNCBS) and RC Budhani of IIT Kanpur, S Jacob and Kasthuvirengan of IISc,VV Rao of IIT Kharagpur, RK Bhandari and Subimal Saha of VECC, Saswati Lahiri of IACS, B Sarkar of IPR, Faculty members of Mech. Engg. of LD College, Ahmedabad, Tushar Bhowmik of Stirling India, C Shanmugam of Air Liquide, P Kulkarni and M Pandey of Inox India, NR Jagannathan of AIIMS, N Khoosu of INMAS, PK Bose and S Deb of Gas Industry, CV Manjunath of Bruker India Ltd., A Mukhopadhyay and Amitava Roy of DST.

March 2010

T S Datta
R G Sharma

Title of the Project :	**Data Base Information on Facilities and Human Resources Related to Cryogenics and Superconductivity in India**
Principal Investigator :	**T S Datta & R G Sharma**
Implementing Agency :	**Inter- University Accelerator Centre (IUAC)** **Aruna Asaf Ali Marg.** **New Delhi-110067**
Date of Completion :	**March 2010**

EXECUTIVE SUMMARY

- This report is a document which covers growth of activity in the area of cryogenics, low temperature physics, superconductivity covering institutes and industries of India. Document lists the agency (Institutes, Industry, suppliers) with details of activity, facility and manpower. Document also presents statistics of man power, engaged in this exciting area in research institutes and the industry.

- The report is prepared on the basis of information provided by individuals in response to our questionnaire, compiled information on facilities provided by the heads of lab/ group/ center, through personal contacts, visiting facilities, internet searching and cross references. Response from individuals was not very effective and reason may be many folds like working on sensitive/ strategic projects in DAE and ISRO, busy schedule as many are holding responsible position, avoiding to declare about equipment and project status/ utility factor / outcome of project

- Total no of these agencies excluding gas industry comes about 85. Out of these 85 agencies 49 are are Scientific and Academic Institutes, 15 manufacturing industry and 21 are suppliers of cryogenic component, There are approximate 150 Gas Industries with 6 major industries like BOC- Linde, Air Liquide, Praxair, Industrial Oxygen, Goyal Gases and M/s Pure Helium. Out of 49 Institutes, 15 institutes belong to DAE and ISRO alone. Even though the no is 15, yet DAE and ISRO together account for a manpower 64 % out of a total 600

- Estimated man power in this field is 4100, including 3000 from gas industries. Out of 1100 man power from 85 agencies, estimated man power from scientific and academic institutes is 600. Rest 500 are from cryo manufactring industries and suppliers. It is also noted that exponential growth of man power in this field after 1995, when Govt took major projects like development of cryogenic engine by ISRO, superconducting Cyclotron at VECC. Kolkata, Superconducting Accelerator at IUAC.Delhi and TIFR Mumbai, Superconducting Tokamak at IPR. Ahmedebad. Earlier human resources was confined to only Basic research in superconductivity

- Majority of the Academic/ Scientific Institutes are involved in low temperature physics studies and superconductivity. Cryogenic engineering activity is limited to only 10 institutes. There are 12 Institutes with more than 20 personnel. Out of these 12 institutes DAE / ISRO account for 10.

- It is also noted out of 600 from Institutes, DAE and ISRO together accounts for 383, rest are from Academic Institutes and other scientific establishments under CSIR, UGC, DRDO etc.

- In spite of our best attempt, we are able to collect individual information from 375 out of 600. Majority of missing names are from ISRO establishment.

- It is noted that out of 375 who are working in this field, 180 are with Ph.D qualification, 50 with M.TechDegree, 120 with M.Sc./ B.Tech qualification.

- Out of 180 Ph. D, 32% are Ph.D in Cryogenic engineering and rest Ph.D in Science. It is noted Ph.D in science shares equally in Scientific and Academic Institutes, where as 80 % Ph. D in Engineering stays on Academic institutes

- Majority of Ph.D in Science is actively involved on basic research on Superconductivity and low temperature physics and less than 10 % are engaged on development Project. Development project in DAE, ISRO and other Scientific institutes are mainly managed by M.Tech and M.Sc/ B.Tech qualified personnel

- It is reported about 400 M.Tech (cryogenic Engineering) Students passed out from IIT. Kharagpur, LD College of Engineering and TKM College of Engineering. Data says that out of 200 passed out M.Tech Students from IIT. Kharagpur, 40 % are continuing their carrier in this line

- No of Ph.D in cryogenic Engineering is about 58 and more than 80% are from either IIT. Kharagpur or IIT. Mumbai. Out of 58, 45 are in Academic Institutes, 7 are in scientific lab, 3 are in private industries, 3 are settled in abroad.

CRYOGENIC FACILITY

- In this report, attempt is made to have information on Major facility like liquid Helium plant, Physical Property Measurement System (PPMS), Magnetic property Measurement System (MPMS), vibrating Sample Magnetometer, Cryo free Superconducting Measurement system etc. It is noted that significant growth on these facilities after 2000 because of liberal funding from DST under FIST programme and Low temperature high field facility Programme along with DAE funding.

- National Physical laboratory was the first in India to have acquired a liquid Helium Plant of capacity 4 litres/ hr. in 1952. The total no of Helium liquefiers/ refrigerators procured in last 50 years is 40 and out of which 21 are presently working with a total capacity 1475 litres/ hr. Out of these 21 operating liquefies, 6 are for major projects with a total capacity 920 litres/ hr. and 15 He-liquefiers with a total production capacity of 555 litres / hr. are dedicated to basic research on superconductivity. Again out of 21 liquefiers, DAE institutes (7) account for 13 liquefiers / refrigerators with total capacity 1170 litres/hr. Cost of a liquefier of capacity 20 litres/hr is in the range of 4- 5 Crore.

- There are 150 small capacity (10 - 40 litres / hr) liquid nitrogen plants in the institutes. Majority (90 %) of them are based on Stirling Cycle and 10 % on Linde Cycle. At present small users (100 litres / day) are preferring table top Nitrogen plant based on cryocooler technology, medium users (200 to 1000 litres/day) prefer either Sterling or Linde plant. Large Projects prefer external supply from gas industries and storing in large capacity storage vessels.

- Procurement of imported ready built ow temperature measurement facilities like Physical Property Measurement System (PPMS), Magnetic Property Measurement System (MPMS), SQUID Magnetometer and Cryo Free Magnet System rather than inbuilt cryostat is common now a days. Estimated number of total facilities are 73. Here also, like helium liquefiers DAE institutes (TIFR, RRCAT, SINP, IGCAR, and BARC) top the list with 40 % of these facilities. Other than DAE Institutes, these facilities are available only with a few selected academic institutes like IISC, UGC-DAE. CSR, Indore and Kolkata, IIT Bombay, IIT Delhi, IIT Kanpur, Hyderabad University, NPL and IACS . We observe a sharp jump in acquiring such expensive facilities since 2000. Funding to these institutes for such facilities has largely come from DST under Low – Temperature High Field Facilities and FIST Programme. Cost of such facilities vary from 1.00 crore to 4.00 crore

FUNDED PROJECT IN THIS FIELD

- Soon after the discovery of High Temperature superconductor, National Superconductivity Programme (NSP) was launched under the chairmanship of Prof. C. N. R Rao. Liberal funding to this programme came from DST, DAE and CSIR. This project lasted from 1988 to 1996. A total of Rs 50.00 crores was sanctioned under this PMB (Programme Management Board) Programme. DST shared 50% of this amount and the rest came from DAE and CSIR. A total of 135 projects were approved and funded to spread over 46 institutions. 87 projects were in Basic Research area and 48 in Application area.

- Low temperature High Field Facility programme was initiated by DST in 2003. Under this programme, DST sanctioned Rs 30.00 crore over a period of 5 years. This money was shared by 12 institutions and used for acquiring 14 major facilities. These facilities are supposed to be used as Users' Facilities. Institutes like IISc, UGC-DAE CSR, Hyderabad University, IITs got benefited and modernized their laboratories.

- Under the FIST Programme, many facilities like PPMS, VSM, Cryo free magnet, Helium / Nitrogen Liquefiers were added in institutes like IISc, and IITs. A total of Rs 27.00 crore was sanctioned during the period 2005- 2008. IISc. and IITs together shared about 80 % of the total DST funding. Another Major project on " SQUID

Based MEG system" was sanctioned by DST separately to IGCAR. Kalpakkam with a total funding of Rs 5.6 crore. (2002-03)

CRYOGENIC IN INDUSTRY AND MEDICAL FIELD

- Ever increasing demand for oxygen in steel industry, and nitrogen in fertilizer and petrochemical industry kept the production graph of LO2 and LN2 rising. This rise in the production of these two cryogenic liquids became very steep since around 1990. In 1980 for example the production capacity of these cryogens was merely 100 tons / day. This capacity now has grown to 50,000 tons / day. The concept of large capacity plants in place of small capacity plants is now well accepted in India. Large capacity plants are much more economically viable as the power cost is reduced very significantly. The largest capacity plant operating in India is 2500 Tons / day manufactured by Praxair India. Further, almost 90 % of the total demand of 50,000 tons / day, is controlled by just 5-6 Global Players in association with Indian counterparts like BOC India, Praxair India, Air liquide India, Inox Air products and some others. Only about 10 % of the total demand is met by approx. 150 small gas industries. These industries have production capacities ranging from 100 M^3 / hr to 1000 M^3 / hr. Big capacity plants (say 400 tons / day) too are manufactured by only 5-6 global big companies. Small capacity plants are manufactured by Indian Industries like Sanghi Oxygen and KVR International.

- First Superconducting MRI in India was installed at INMAS, New Delhi in 1986. Until 2000, India had less than 50 MRI units in the hospitals. The on going technology up-gradation (efficient cryostats and provision of re -liquefaction of evaporated helium) increased the refilling time to 9 months to one year. As a result, number of MRI units in the country increased manifold. The estimate shows that approx. 400 MRI units are operating in India at the present time. This number is expected to rise further and sharply. MRI units are now being installed in smaller town hospitals. The same is true for NMR Spectrometers. First Superconducting NMR unit was installed at IISc. Bangalore in the year 1976. NMR technique is used to study the structure of very complex molecules and finds application in all physics, chemistry and bio labs. It is an essential analytical tool in petrochemical and pharmaceutical Industry. In the early years the number of NMR units grew by about 2 units / year which has now jumped to 20 units / year. As on today there are about 200 NMR spectrometers working in India.

- Preservation of Blood using liquid nitrogen lost its momentum and it appears that no blood bank in India is using this technology. Whole blood continues to be preserved using conventional technique. On the contrary, stem cell preservation using liquid nitrogen is picking up all over India. Similarly Cryo-Surgery on skin is again limited to a handful hospitals. Animal Semen Preservation and distribution system in India has been going on in the country since 1965 and has a rather extensive network. This sector consumes large amount of liquid Nitrogen. Most of these preservation centres prefer to buy small capacity plants (5-10 litres/hr). Maintenance of these plants in the countryside is a big problem and therefore the down time is large. Majority of the plants are not working.

CRYOGENIC EDUCATION IN INDIA

- Superconductivity is taught in M.Sc (physics) as one of the subject in Solid State Physics in most of the university and IITs. Specialization in low temperature physics and superconductivity is carried out post M.Sc. either as a research fellow through their Ph.D. programme or after joining as scientist in DAE, ISRO, CSIR or some other scientific laboratories.

- IIT. Kharagpur was the first to start M.Tech Course in Cryogenic Engineering in 1980. After 1990, LD college of Engineering, Ahmedabad and TKM college of Engineering (Kerala) started M.Tech Progrmme mainly to facilitate the Scientists from IPR and ISRO to have M.Tech degree in cryogenic engineering. Since 1980 about 450 M.Tech students have passed out of these institutions. IIT. Mumbai, Mechanical Engineering Department also offers M.Tech (Thermal & Fluid Engineering) course. The syllabus covers many topics in Cryogenic Engineering. More recently, NIT, Rourkela and NIT (SVNIT), Surat have initiated few optional courses in cryogenics in their M.Tech programme.

- Ph.D. in Cryogenic Engineering has been limited to IIT, Kharagpur and IIT. Mumbai only. Now at least in a dozen institutes offer Ph.D. in cryogenic engineering albeit with limited experimental facilities. Majority of the students are pursuing research topics related to the design and fabrication of the cryocoolers.

- There is an acute shortage of technical assistants in this field. We don't have personnel to take care of liquefier operation and to maintain the costly measurement facilities like PPMS, SC Magnet system and so on.

SUMMARY OF CONCLUSIONS

1. Significant growth of man power and facility has taken place in this exciting area of cryogenics and superconductivity since 1995. Liberal funding from DST and others should continue. A separate Programme advisory committee in the field of Cryogenics and superconductivity may be constituted in DST for effective funding. No significant development of cryo equipment is being carried out in the country. Indian Cryogenics Council (ICC)can play a role on this.

2. Shortage of technical man power is however felt all around. A certificate course for B.Sc (Physics/ Chemistry) and Diploma in Engineering may be encouraged. Down time of costly equipments must be reduced

3. There are scope of improvement on quality education for M.Tech. Programme. Limited facilities in those institutes can be easily overcomed by close interaction with scientific institutes, having major facility and human resources

4. We strongly believe that a '**National Centre of Cryogenics and Applied Superconductivity** ' should be established in the country in the very near future. Only projects of applied nature should be pursued at this proposed centre.

Contents

Abbreviations

Abbreviation	Full Name
ADS	Accelerator Driven System
AIIGMA	All India Industrial Gas Manufacturing Association
AIIMS	All India Institute of Medical Sciences
BARC	Bhabha Atomic Research Centre
BHEL	Bharat Heavy Electricals Ltd.
BOC	British Oxygen Corporation
CCR	Closed Cycle Refrigerator
CRYO	Cryogenics
CSIR	Council for Scientific and Industrial Research
CT	Cryogenic Technology
CT/ CP	Cryogenic Technology/ Cryo Plant
CT/ LP	Cryogenic Technology/ Large project
DAE	Department of Atomic Energy
DST	Department of Science and Technology
DU	University of Delhi
FIST	Funds for Improvement of S&T
GSLV	Geo Stationary Launch vehicle
HGMS	High Gradient Magnetic Separator
HR	Human Resource
HTSC	High Temperature Superconductivity
HU	Hyderabad University
HWB	Heavy Water Board
IACS	Indian Association for the Cultivation of Sciences
ICC	Indian Cryogenics Council
IGCAR	Indira Gandhi Centre for Atomic Research
IISc	Indian Institute of Science
IITB	Indian Institute of Technology, Bombay
IITD	Indian Institute of Technology, Delhi
IITK	Indian Institute of Technology, Kanpur
IITKh	Indian Institute of Technology, Kharagpur
IITM	Indian Institute of Technology, Madras
ILC	International Linear Colloider
INMAS	Institute of Nuclear Medicines and Allied Sciences
IPR	Institute for Plasma Research
ISAC	ISRO Satellite Centre
ISRO	Indian Space Research Organization
ITER	International Thermonuclear Experimental Reactor
IUAC	Inter-University Accelerator Centre
LASTEC	Laser Science and Technology Centre
LD	LD College of Engineering
LH2	Liquid Hydrogen
LHe	Liquid Helium
LN2	Liquid Nitrogen

LNG	Liquefied Natural gas
LO2	Liquid Oxygen
LPAC	Local Project Advisory Committee
LPSC	Liquid Propulsion System Centre
LTP	Low Temperature Physics
LTP-SC	Low Temperature Physics- Superconductivity
MPMS	Magnetic Properties Measurement System
MRI	Magnetic Resonance Imaging
NMR	Nuclear Magnetic Resonance
NPL	National Physical Laboratory
PPMS	Physical Property Measurement System
RRCAT	Raja Ramanna Centre for Advanced Technology
SAC	Space Application Centre
SC	Superconducting
SCM	Superconducting Magnet
SINP	Saha Institute of Nuclear Physics
SMES	Superconducting Magnet Energy Storage
SQUID	Superconducting Quantum Interference Device
SSPL	Solid State Physics Laboratory
SST	Steady State Superconducting Tokamak
TIFR	Tata Institute of Fundamental Research
UGC -DAE CSR	UGC - DAE Consortium for Scientific Research
VECC	Variable Energy Cyclotron Centre
VSM	Vibrating Sample Magnetometer

Chapter 1

INTRODUCTION

1 INTRODUCTION TO CRYOGENICS & SUPERCONDUCTIVITY

1.1 Definition

Cryogenics is derived from the Greek word 'Cryo' which means ice. Cryogenics can perhaps best be defined as the branch of Physics and Engineering which deals with the production of 'freezing cold' and the study of materials at such low temperatures. There is no clear sharp dividing line where refrigeration ends and cryogenics starts. There is, however, a consensus that temperatures below -150^{0}C come under the definition of Cryogenics. Below this temperature all the permanent gases like argon, neon, nitrogen, oxygen, hydrogen and helium start condensing.

1.2 Liquefied Gases

Most convenient method to study materials at low temperatures is to have a refrigerant bath of a liquefied gas which provides the temperature range of interest. For example liquid nitrogen has a boiling point of 77 K and one can go down to 65 K by pumping over the bath. So the temperature range of 65 K to 300 K can be covered by liquid nitrogen (LN2). For still lower temperature one can use liquid hydrogen (LH2). Hydrogen has a boiling point of 20 K and freezes at 14 K. Thus the studies can be carried out from 77 K down to 14 K using LH2. The lowest temperature can be obtained by the liquefaction of helium gas. Helium boils at 4.2 K and can provide a temperature of 0.8 K by pumping vapours. Liquid helium (LHe) is thus widely used for studies from 1 K upwards by incorporating a heater and a temperature controller. Following are the milestones of the liquefaction of gases.

1872 Carl von Linde liquefies air using Joul-Thomson Expansion principle and regenerating cooling.
1877 Raoul Pictet and Paul Cailletet liquefy oxygen using two separate methods.
1895 Linde obtains patent for Hampson-Linde Liquefaction of atmospheric air and other gases
1898 James Dewar liquefies hydrogen by Regenerative Cooling Technique.
1905 Linde obtains pure oxygen and nitrogen
1908 Kammerlingh Onnes at Leiden liquefies helium – Kicking off an era of real Low Temperature Reseach and leading to new discoveries and technologies.
1911 Discovery of Superconductivity

Liquid nitrogen, liquid oxygen and liquid helium are by far the most widely used cryogens and are delivered at door steps. LO2 is used in steel factories and hospitals. LN2 is widely used in Fertilizer Plants and as a pre-cooling cryogen wherever LH2 and LHe are used. LO2 and LN2 are either stored in large vessels and are filled on site. Large size captive plants are installed where the usage is on a large scale.

1.3 Basic Principle of Liquefaction

The basic principle of liquefaction is always a combination of two processes, namely an isothermal compression followed by an adiabatic expansion using a series of heat exchangers.

Since helium gets liquefied at very low temperature (4.2 K) we use three steps of cooling. Compressed gas expands at two different temperature stages followed by a final expansion through a J-T Valve. The expanders can either be of piston type or a turbo type. Modern large capacity helium liquefiers are turbine based machines.

1.4 How Low the Temperature Can Go ?

Pumped LHe provides a minimum temperature of 0.8 K. A Dilution Refrigerator (DR) based on the principle of finite solubility of ^3He (6.4 %) in a mixture of liquid ^3He and ^4He, down to 0 K can go as low as 5 milli Kelvin (mK). Nuclear Adiabatic Demagnetization, using DR as a precooling stage produces temperature in the range of micro Kelvin (μK). Using cascade demagnetization stages a world record of spin temperature of 250 Pico Kelvin (pK, 10^{-12} K) had been achieved at the Low Temperature Laboratory, Helsinki University of Technology, Finland.

1.5 Applications of Cryogenics

1.5.1 ***Basic Research*:** Temperature, Pressure and Magnetic Field are three important parameters for studies, which can alter the behaviour of a material quite drastically. Whenever the temperature was reduced by a significant step some discovery or the other of fundamental importance took place. The physics at low temperature is extremely interesting and it is the physics of order. Lower the temperature, more subtle is the nature of this order. Superfluidity in the two liquids (liquid ^3He and liquid ^4He) and superconductivity in a large number of elements, alloys and compounds are two most striking examples of quantum behaviour of matter at macroscopic scale.

1.5.2 ***Superconductivity*:** Soon after the liquefaction of helium in 1908 Kammerlingh Onnes discovered the phenomenon of superconductivity wherein a number of metallic elements loose their electrical resistivity when cooled to a few degrees above absolute zero. Later the same behaviour was found in a vast number of alloys and compounds. The zero resistivity of these materials made them most attractive material for electro technical devices which are based upon a magnetic coil. The Joule heating in these materials is absent and thus save power. Superconductors are widely used for building magnets for a variety of applications. Superconducting magnets are used in research laboratories, High Energy Physics, Accelerators, Fusion Reactors, High Gradient Magnetic Separators, NMR Spectroscopy, Magnetic Resonance Imaging (MRI), Train Levitation, Superconducting Magnet Energy Storage (SMES) and many other applications. Materials called High Temperature Oxide Superconductors have been discovered which turn superconducting at LN2 (77 K) temperatures. Applications like Transmission Lines are thus expected to come around rather soon and very economical.

1.5.3 ***Space***

Cryogenic has two types of application in Space, namely as a Fuel and to cool the detectors below their operational temperatures. Hydrogen and oxygen are considered the best rocket propellants for space application because of their high specific impulse. Hydrogen is used as a fuel and oxygen as an oxidizer. They combine together in the combustion chamber and produce thrust. Both the gases being light need large volumes and therefore used in the form of liquids to conserve space. These liquids are stored in insulated vessels and transported to the combustion chamber through pipes, valves and turbo pumps. The entire assembly, called Cryogenic Engine has been developed and successfully tested by ISRO. The next GSLV Mark III is expected to be launched using this indigenous engine.

Many of the space missions use infrared, gamma ray, and x-ray detectors that operate at cryogenic temperatures. The detectors are cooled to increase their sensitivity. Astronomy missions often use cryogenic telescopes to reduce the thermal emissions of the telescope, permitting very faint objects to be seen. Vibration free Mini size cryo coolers are used to cool these detectors.

1.5.4 *Fuel*

The Liquefied Natural Gas (LNG), which is mostly methane, is considered to be an efficient and least polluting fuel. It turns in to a liquid at a temperature of 111 K and the volume is reduced by a factor of 600. LNG is transported by laying a pipeline. In case it is not feasible to lay a pipeline or it is too costly, the alternative is to transport LNG in special sea vessels. At the receiving terminal it is again converted in to gas and distributed. Hydrogen could become an important source of energy in the near future and thus liquid hydrogen will be widely used in many sectors other than Space.

1.5.5 *Industry*

(A) Steel Industry

Oxygen gas is used to enrich air and increase combustion temperatures in blast and open hearth furnaces. It also raises steel temperature and enhances recycling of scrap metal in electric arc furnaces. Oxygen replaces coke as the combustible material in steel making. Large size air separation plants are built at the steel manufacturing sites to meet oxygen requirement. The present trend is to give contract to gas manufacturers to erect the large air separation plants at the Steel industry site itself and ensure the supply of oxygen round the year. The manufacturer is allowed to sell the surplus oxyegen in the open market.

(B) Fertilizers

Compounds of nitrogen such as Ammonium Nitrate (NH_4NO_3) and Ammonium Sulphate $(NH_4)_2\ SO_4$ are essential for plant growth for making proteins. Plants however cannot take nitrogen from plentiful atmosphere but can absorb nitrogen from the soil water. Synthetic fertilizers are produced by combining nitrogen and hydrogen in to ammonia. Nitrogen needed for the the production of the fertilizers is again obtained by liquefying atmospheric air and separating nitrogen and oxygen.

(C) Petrochemicals

Industrial gases throgh their captive air separation plants are associated with petrochemical complex and fertilizer industry. Nitrogen is used for production of amonia, synthesis of amonia by washing with liquid nitrogen. Oxygen is used for production of Ethylene glycol by oxidation of ethylene. Pure nitrogen is used for blanketing and purging various eqipments in petrochemical complex.

(D) Deep Cryogenic Processing

Deep cryogenic processing is a standard technique to improve the Metallurgical and structural properties of a variety of materials, such as ferrous and non ferrous metals, metallic alloys, carbides, plastics and ceramics. The process need computer control, an insulated chamber and liquid nitrogen. Deep cryogenic process relieves internal stress, improves abrasive wear life and enhances the useful life of the tools and components. Added advantage of this process is that the treatment is not confined to the surface alone but the entire mass of the material. The enhanced strength of the material stays till the end and without affecting the hardness of the material.

(E) Cryo Grinding

Cryo grinding technique is widely used for all types of plastic products, rubber, pharmaceuticals, cosmetics and spices. The material becomes very brittle at cryogenic temperatures and can be grinded to fine size uniform particles. The physical and chemical characteristics of the material are preserved and there are no thermal damages or loss of volatile constituents.

1.5.6 *Medical*

Use of cryogenics in Medical Sector is very extensive and it serve the public at large. Magnetic Resonance Imaging (MRI), based upon the principles of Nuclear Magnetic Resonance (NMR) has become a very vital and useful diagnostic tool with all the hospitals across India. MRI needs a very stable magnetic field. Such stable field can only be provided by a superconducting magnet. Indeed MRI uses a large size superconducting magnet cooled by liquid helium. The magnet runs in persistent mode, wherein the magnet current flows persistently forever and without a power supply..

A new area of medical research, namely 'Magneto Encephalography' has started to map the brain functioning. The device uses an array of SQUIDS. A SQUID uses a pair of Josephson junctions and is operated at liquid helium temperature. Josephson junction consists of a pair of superconductors separated by a thin insulating barrier. The device is capable of measuring feeble magnetic field inside the brain, of the order of a femto Tesla (10^{-12} T).

Another application is in the area of cryo surgery of malignant tumors and ophthalmic surgeries. The device is popularly called 'Cryo Probe'. It instantly freezes the part to be operated upon and is a blood less surgery. The probe either uses a spray of LN2 or the tip of the probe is cooled in situ by a cooling process such as a J-T or Stirling. Most surgical tools are expensive and are invariably deep cryogenic processed to have longer life. Oxygen gas, produced by the cryogenic process, is one of the most vital item to be stocked by any hospital.

Yet another very important application of cryogenics is in the Cryo Preservation of human blood, sperms, semen, human eggs, human embryos, bone marrow or any other organ. The process usually involves a cryo protectant to counter the freeze damage and cooling to LN2 temperature (77 K). It is well established now that human blood (usually red cells) can be preserved for a very long time. A young donor can thus deposit his blood only to be used by him in old age. The cryo preserved blood is far superior in quality to the whole blood preserved by old techniques. Unfortunately this has not picked up in Indian hospitals.

1.5.7 *Large Scale Use of Cryogens & Superconductor*

The large scale application of cryogenics and superconductivity at liquid helium Temperature is found in High Energy Particle Accelerators and Fusion Programme. Superconducting magnets are universally used in particle accelerators for beam focusing and beam guidance. They are compact in size, light in weight and consume little energy. This saving in energy, in fact, more vthan off sets the cryogenic cooling cost.

Brookhaven National Laboratry was the first to use large no of Superconducting Magnets for Tevatron Accelerator The first superconducting dipole magnet (6 T, 200 Tons) was built by Argonne National Laboratory (ANL). The culture spread far and wide among the High Energy Community. A world recored was established by Lawrence Berkeley National Laboratory in 2004 when it made a dipole magnet producing a field of 16 T. Nb3Sn technology was used first time for an accelerator used by LBNL to build this magnet. Large Hadron Collider (LHC) at CERN is the accelerator which operates 1232 superconducting dipole magnets, 400 quadrupole magnets and several other magnets. All modern day accelerator use superconducting cavities to pump radio frequency power to the beam to boost energy as it cuts down the power dissipation. Accelerators thus stand out to day the biggest consumer LHe. TRISTON Project at KEK. Japan, LEP at CERN uses large no of RF Superconducting Cavity and many accelerator followed in the decade of 1990 International Linear collider is planned by using no of multicell superconducting cavities with a design goal of 31 MV/meter. In India several Accelerator facilities have come up during last fifteen years which use large amounts of LN2 and LHe. Similarly for Fusion programme, to confine the plasma, Superconding magnet is replaced by conventional magnet. Right now ITER programme is based on Superconducting technology, where India is also a partner of that International programme. A Steady State Superconducting Tokamak is under development at Gandhinagar.

1.5.8 *Superconducting Magnets and Systems*

The maximum use of superconductors have been in building magnets which are very compact, light in weight, produce intense field and consume very little power and as mentioned majority of them finds application in world accelerator programme. Other than accelerator and Tokamak programme, SC magnet is also used for the development of SC generator, Sc motor and SEMS system. Considering the difficulty on handling liquid helium for this application, demand of this equipment was restricted. But with the diccovry of High temperature superconductor, fresh efforts are initiated on these developments by using liquid nitrogen.

1.5.9 ***High Speed Transport***

Japan National Railways had pursued this programme during 1980s & 1990s and developed trains running at speed greater than 550 km / hour. Superconducting magnets operate on board and aluminum strips run along the track in a concrete slab. At a critical speed the eddy currents produced within the Al strips by the moving magnets is high enough to produce an opposing field which lifts the train above the track. The friction between the wheels and the rail disappears, train picks up high speed. Trains have, however, not been put to commercial use probably because of economical reason

1.5.10 ***Cryo Preservation of Food***

Most varieties of food items like meat, fruits, vegetables and marine products are perishable in nature. They deteriorate fast because of bacteriological, enzymatic, oxidative and other chemical reactions. Since most chemical reactions die down below minus 120^0C the self life of these products can be significantly enhanced by Instant Quick Freezing (IQF) Technique. The technique enables to preserve the taste, aroma, texture or the nutrition value of the food product. Shelf life of the products is increased dramatically. The cryo preservation of food and marine products for storage and exports has become an ever growing industry with large market share.

1.5.11 *Future Outlook*

Interesting developments are taking place and at a fast pace. Close Cycle Refrigerators or popularly known as Cryo Coolers of cooling power of 1.5 W are commercially available. Various equipments are designed and built to operate using these cryo coolers thus doing away with the use of LHe no more liquefaction of helium or recovery of the He-gas for recycling. Cry free superconducting magnets which are operated using cryo coolers and high temperature superconducting (HTSC) current leads have become very popular with researchers. There are high expectations from the HTSC materials. These superconductors are operated at LN2 temperature (77 K) and devices and systems based on these materials will be extremely economical. Power Transmission Line could be one such application which can be realized in near future. Once the problem of drop in critical current with magnetic field is resolved HTSC materials will replace almost all conventional superconducting devices and systems. Production of LO2 and LN2 is directly related to the industrial growth and is bound to go up at all times.

1.6 Objective of This Report

Although activity in the field of cryogenics/ Superconductivity started in India in the year 1952, yet it remained confined to a limited no of institutes carrying basic research in low temperature physics and some small capacity Air separation plants. Begining of 1990, major projects, involving use of large quantities of LHe and LN2, were initiated at a few places in India. Production and storage capacities of these two cryogenic liquids grew dramatically and so did the manpower in this area. DST provided large funds to a number of research institutions to acquire modern facilities and measuring equipments to encourage research at low temperature and under high magnetic field. We expect this trend to continue in future. Despite these developments there was no document with any agency in India which gives information on the cryogenic activities, the institute involved, the facilities and the human resource available. We at IUAC took up this task on ourselves and DST kindly came forward to support this attempt. Major objectives of this work are listed below

1. To collect data base information on human resource in this specialized field. There are four basic categories of personnels involved in cryogenic activities
   - (i) Scientists /Academicians working at low temperature physics (mostly with physics background)
   - (ii) Scientists / Academicians/ Engineers working on component development programme as well as running the cryogenic facilities
   - (iii) Scientists / Engineers working in major National Projects
   - (iv) Engineers / Managers working in Private Industry and Public Enterprises

2. To collect technical information about experimental facilities, which can be shared by outsiders to carry out basic research especially at very low temperature and high magnetic field
3. To collect information about new application of cryogenic technology in India
4. To have information of cryogenic industry including gas industries

5. To identify areas of common interest for developing cryogenic components, instruments, or systems like close cycle refrigerator, cryogenic instrumentation or magnet systems and take up joint programmes between different institutions or between institution and industry where by the best of the capabilities can be pooled together.
6. To list the major projects funded by Govt. Agencies

1.7 Methodology Adopted to Collect Information

A Local Project Advisory Committee (LPAC) was constituted by DST with expert members from the field of cryogenics and superconductivity for their advice and suggestions as the project progressed. Methodology to be followed to collect necessary information and to establish contacts with individuals, heads and the institute was the first item discussed in LPAC meeting. Consequently, around 1000 leaflets with two sets of questionnaires were distributed to a number of institutes, members ICC and known persons active in the field. Another sets of questionnaires were distributed to Heads of Institutes/ labs/ Department and Industries to gather a compiled list of facilities and human resources at their respective places. An advertisement to spread awareness about this project was also published in two leading national dailies. An appeal along with the leaflets was also put on the website of Indian Cryogenic Council. Many reminders had to be sent to many through email.

After receiving the preliminary feedback, we made few visits to different organizations and laboratories to have first hand information on their programmes and facilities available with them. At times we found face to face interaction very useful. Whenever we failed to get direct information we made serious efforts and spent much time to gether information from their respective websites and through search engines. General information from experts in specialized field from industries and suppliers were received.

After receiving the complete information, data were analysed and presented in various formats. Where data were not available, estimated data with close tolerance were fitted.

Leaflet and Questionary are inserted as annuxures

Chapter 2

CRYOGENICS IN INDIA

2.1 Brief History of Cryogenics & Superconductivity in India

Cryogenics became a buzz word in India only during 1980s when Russia refused to supply Cryogenic engines to ISRO for its space programme. Cryogenics, however, started in India as early as 1930 when a British company installed an Oxygen Plant. This was followed by IOL (now called BOC India Ltd.) which in 1938 established first air separation plant (30 M^3/hr) at Jamshedpur. This was, in fact, the beginning of Cryo Industry in India. To day Air Separation Plants of capacities of more than 1000 Tons / per day are being manufactured by several Indian and Multinational Companies in the country. These tonnage plants fall under the category of Gas Industries supplying gases like oxygen, nitrogen and argon to Steel Manufacturing Units, Fertilizers, Petrochemical Complexes and the Pharmaceutical Industry. Here the cryogenics is restricted to liquid nitrogen temperature, that is, 196^0C below the ice point.

Liquefaction of helium gas one hundred years ago in 1908 by a Dutch scientist, Kammerlingh Onnes pushed down the cryogenic temperature to 269^0C below the ice point. This opened a very fertile field` of research in Condensed Matter Physics and lead to several discoveries of fundamental importance. Superconductivity (vanishing of Resistance below a critical temperature) was first such discovery made within three years (1911) of the helium liquefaction by Kammerlingh Onnes himself. This phenomenon became and still continues to be the most sought after field of basic research. Superconducting magnets to day find application in research labs. NMR, MRI, fusion, accelerators and many such other areas..

Commercial helium liquefiers (Collins Type) became available around 1950 and one such liquefier was installed in India at National Physical laboratory (NPL) New Delhi in the year 1952. This liquefier had a capacity of 4 litres/ hr. This was the beginning of basic research at low temperature (down to 1 K) in India. During mid 1960s helium liquefaction facility started expending and many institutions started low temperature research. Tata Institute of Fundamental Research (TIFR), Bombay got its helium liquefier in the year 1962, Solid State Physics Laboratory (SSPL), Delhi and the University of Delhi in 1966. Many more institutes particularly from Department of Atomic Energy joined this exclusive club. Bhabha Atomic Research Centre (BARC), Bombay, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, Indian association for the Cultivation of Science (IACS) Kolkata and Indian Institute of Sciences (IISC), Bangalore established the liquid helium facility towards the end of 1970s. This was the era of cryostat using glass dewars filling liquid helium directly from the liquefier and carrying the cryostat to the fixed experimental stations. Storage of liquid helium had not started.

Oxygen generating plants were bought from World War disposals by NPL and IISc, converted them to liquid air plants. Liquid air was used for precooling purposes. Philips Liquid Nitrogen Plants, Model PLN 106 with 6 litres /hr and PLN 430 with 30 litres /hr rate of liquefaction became popular with the research laboratories to meet the demand of liquid nitrogen for pre cooling and other purposes. Towards the end of 1970s IBP Cryogenics Division initiated a programme on the development of small capacity (10 litres to 60 litres) liquid nitrogen aluminum superinsulated containers primarily to cater the requirement of Animal Husbandry Sector for artificial insemination. In fact 80% of small capacity Philips liquid nitrogen plants belong to Animal Husbandry Department. Similarly, BHPV also started developing indigenous air separation plants as well as high capacity storage vessels. By 1982 the Department of Science and Technology (DST) declared Cryogenics as a Thrust Area Programme and supported cryogenic activities in the country in a significant way. It supported many programmes on the development of superconducting wire and magnets.

The use of liquid helium spread during 1980s due to the popularity of high resolution Nuclear Magnetic Resonance (NMR) Spectrometers which invariably use superconducting magnets and need liquid helium for operation. NMR Spectrometer is a powerful tool for the study of the structures of complex molecules and is widely used as an analytical tool in Physical, Chemical, Biological and Pharma Laboratories. First Supercon NMR was installed at IISc. Bangalore and liquid helium filling (once in a week) was carried out by Central Cryogenic Facility Section of the IISc. Use of NMR units, however continued to be restricted to places only where helium liquefaction facility existed. Similarly, the first whole body Magnetic Resonance Imaging (MRI) Unit, a medical diagnostic tool was installed at INMAS, Delhi (DRDO), Delhi in 1985 along with a dedicated helium liquefier to maintain the supply of liquid helium. Soon in 1986, a private industry (Pure Helium) started importing large quantities of liquid helium in ship tankers and selling liquid helium to all these NMR and MRI units and helium gas to research laboratories to run their liquefiers. This easy availability of liquid helium within the country encouraged more and more hospitals to install MRI units. The Pharma and Petrochemical Sector too started buying high frequency NMR units.

Another development which took place during 1980-90 was that BARC established a full flagged facility to develop multifilamentary Cu-Ti wire. BARC also designed 1000 A Nb-Ti cable for use in Superconducting Cyclotron and presently engaged in developing Nb_3Sn conductor for being used for fusion reactor. At the same time NPL developed next generation multifilamentary superconductors, namely, Nb_3Sn and V_3Ga on a laboratory scale. NPL team made many 7 T and 11 T superconducting magnets and supplied to other institutions. BHEL (Bharat Heavy Electricals Ltd.) Hydrabad in collaboration with NPL produced India's first Superconducting High Gradient Magnetic separator (SC-HGMS). BHEL also developed a 200 KVA superconducting generator in collaboration with NPL, IISC etc. Both of these were the first ever industrial applications of superconductivity in the country.

Many liquid helium cryostats with and without superconducting magnets were fabricated by laboratories and also were imported from abroad. M/S Oxfords instruments UK did good business. During 1980s and 1990s many laboratories like BARC, Bombay; IGCAR, Kalpakkam; IIT, Madras; IISc, Bangalore; IIT, Kanpur; TIFR, Mumbai, IACS and SINP, Kolkata and NPL acquired larger capacity helium liquefies and were equipped with expensive instruments for a variety of measurements. The money was liberally provided by DST to encourage research in High Temperature Cuperates Superconductors. A high powered Planning Management Board (PMB) under the leadership of Prof. CNR Rao was constituted by the DST to implement this national effort. During the same period private industries like Vacuum Technique and Hind High Vacuum entered the field of fabricating large size SS superinsulated cryostats for housing superconducting magnets in participation with the concerned research lab. / centre.

Large scale use of cryogenic liquids, namely, liquid hydrogen and liquid oxygen started in India by ISRO during 1980- 90 to boost their geo-synchronous satellite launch vehicle programme. This Launch vehicle in its final stage has a cryogenic engine using hydrogen as fuel and oxygen as an oxidizer. Liquid Propulsion Space Centre at Valiamala and Mahendrogiri is dedicated for this Cryogenic Engine Development Programme. Remarkable facilities for the design, development and testing of Cryogenic Engine have been established at the Centre. More than 200 Scientists, Technologists and Technicians are working at this centre.

Beginning 1990, India entered a new phase of large scale of cryogenic application to the delight of the cryogenic community. It embarked on major projects involving usage of large quantities of liquid helium and liquid nitrogen. The projects initiated were particle accelerators at Nuclear Science centre (now IUAC), at New Delhi and at TIFR at Mumbai both using superconducting cavities and liquid helium for refrigeration, Tokomak Fusion Reactor (SST-1) at IPR (Institute for Plasma Research) Gandhinagar and Superconducting Cyclotron at VECC (Variable Energy Cyclotron Centre) Kolkata. All these projects are either successfully completed and in operation or at an advanced stage of completion. Department of Atomic Energy (DAE) has embarked recently on an ambitious programme, namely Accelerator Driven System (ADS) Reactor. Indian industry like BHEL, BOC, Vacuum Techniques, INOX India Ltd. and many other associated industries actively participated and contributed to the success of these projects. These projects led to the commissioning of helium liquefiers of larger capacities in the range of 300 litres/hr.

It is only now with the success of these projects that India is respected by the international cryogenic community. The recognition came soon when India was chosen as a member state of the ITER (International Thermo Nuclear Experimental Reactor) Programme.

Although cryo preservation of Blood technique is a well established technique in many countries and is over 20 years old. Indian medical fraternity has neglected this area almost completely. Their argument that there is not enough blood to be preserved is untenable. If the long term preservation of blood is assured most young people will like to deposit their blood to be withdrawn when needed at the old age. This is the meaning and also the function of a Blood Bank. Blood preserved in India by conventional technique has a self life of about a month. Recently few private parties started long term preservation of Stem Cells / cord cells using liquid nitrogen as refrigerant.

There are other applications of cryogenics, like cryo treatment of tools, Cryo grinding of spices but has not been strongly pursued in India.

Commercial availability of Closed Cycle Refrigerators or the so called croycoolers of cooling capacity of 1- 1.5 W (@ 4.2 K) has made the low temperature research very popular and cost effective at most of the universities and small research institutions. One can now dispense with liquid helium requirement. The so called Cryo-Free high field superconducting magnets are marketed by many companies and find ever increasing demand in India. This is one instrument for which the DST gets maximum requests from researchers in India. All this, because cryo coolers have done away with the hassles of procuring and handling liquid helium. IUAC, New Delhi has recently taken up a programme of developing a Cryofree superconducting magnet inhouse.

Similarly, for a laboratory, where liquid nitrogen requirement is not more than 100 litres/ day table top nitrogen generators using either GM cooler or Stirling cooler has become a better choice. Stirling or Linde make nitrogen liquefiers are preferred where the requirement varies between 100 and 500 litres / day. For higher consumptions it is more economical and hassle free to buy commercial liquid nitrogen and store in large capacity external storage vessels. No need of maintaining a liquefier and the operating staff and the liquid is available round the clock. Supply of liquid nitrogen by Gas Industries in India is available at door step in the present times.

Focus on research at low temperature and superconductivity has shifted from in house development of cryostats for measurements to imported ready built experimental systems with all attachments and instruments incorporated. Foreign suppliers like Quantum Design, Cryogenics, Jainis etc. have a field day in India these days. Culture to build indigenous system for physical property measurements has just disappeared. With generous money available from the funding agencies in India people are competing to buy expensive systems like PPMS, MPMS, VSM, SQUID Magnetometer.

The slow but sustained growth of cryogenics in India attracted the attention of the international community wherein it was asked to become a part of ITER Collaboration Project and contribute by way of supplying cryo lines and the cryostat for ITER. Earlier too, RRCAT (Raja Ramanna Centre for Advanced Technology) had contributed to the European LHC (Large Hadron Collider) Project and supplied a large number of superconducting multi pole corrector magnets to CERN. Hopefully in the near future many of our institutions such as RRCAT, IUAC, VECC, BARC and TIFR will be partners in a yet another prestigious International Project called ILC (International Linear Collider) project and will be supplying Cryo Modules and superconducting cavities

2.2 DST, the Prime Mover of Cryogenic Development in India

As early as 1982 DST identified Cryogenics as a Thrust Area and had a separate PAC (Programme Advisory Committee) on Cryogenic. This PAC sanctioned money for several research projects (big and small) in cryogenics. It also launched some big programme of national importance with varying degree of success. Its special programme on National Project on Development of Helium Liquefier however did not succeed. PMB's high profile programme on HTSC led by Prof C.N R Rao was a heavily funded programme. It created a wave for years, resulted in unprecedented number of publications and Ph.D.s but not much on technology or material. Under the same programme, however, NPL and BHEL developed a Superconducting High Gradient Magnetic Separator which was a success and first ever industrial application of superconductivity in India. Another successful programme was the development of a superconducting 200 KVA generator by BHEL.

After the PMB era DST once again rose to the occasion to boost cryogenic activity around 1999 in so far as it declared IISc, Bangalore, UD-CSR and University of Hydrabad (NPL was kept on hold in the absence of inhouse liquid helium facility) as the Centres for Low Temperature and High Magnetic Field and gave liberal grants of Rs. 3-4 Crores, a good amount at that point of time. New PAC was formed to implement and monitor the development of these centres. These centres are supposed to function as Users' Facilities for all across the country. In addition to these centres DST also sanctioned high value equipments and facilities to many other university departments and IITs to spread the cryogenic culture far and wide. We hope the centres and PIs live up to the expectations.

Under yet another programme, called 'FIST' for improving the infrastructure in research laboratories, DST sanctioned expensive machines like helium liquefiers to a number of institutions.

BRNS & NFPB also encourages Cryogenic engineering programme like Development of Helium Compressor, Purifier, Sc magnet/ Cable, Cryocooler etc

2.3 Human Resource in Cryogenics

Until 1990, cryogenics was confined in low temperature laboratories pursuing mainly basic research and development of cryogenic systems like SC magnets and LN2 vessels and small LN2 liquefier. These programmes, however, were led mostly by physicists who had great expertise in low temperature physics and carried out developmental work out of passion. Thus the man power by and large had basic qualification as M.Sc. with or without Ph.D. Limited no of personnel with B.Tech. (mostly mechanical) used to manage low temperature facilities (Liquid Helium and Liquid Nitrogen Plants) with few operators either with diploma in Engineering or ITI qualification. Gas industries by and large preferred to have fresh engineering graduates from Mechanical, Chemical, Electronics or Instrumentation discipline. Major projects in the field of Cryogenics and Superconductivity demands higher qualifications like M.Sc. / B.Tech. along with M.Tech. Cryogenic or Thermal Engineering or with Ph.D. in Cryogenic Engineering or Applied Superconductivity. M.Tech. degree with Cryogenic specialisation was started at IIT Kharagpur in the year 1980 Later, the TKM College of Engineering at Kollam. Kerala started an M.Tech. course in Industrial refrigeration and Cryogenic Engineering in 1990 and the LD College of Engineering, Ahmedabad started a course in Cryogenic Engineering in 1992. On an average only 15- 20 M.Tech. Students passed out every year with either M.Sc. or B.Tech. as the background qualification. In today's scenario this number is utterly inadequate and the syllabus of the existing centres imparting cryogenic courses need to be overhauled. Majority of Ph.D in Science continue on basic research on superconductivity and magnetism and limited (less than 5 %) no is on development project. Similarly Ph.D in cryogenic engineering confined themselves in teaching institute. Detailed breakup is discussed in Human Resources part.

We strongly feel that India needs around this time a full fledged Institute for Cryogenics and Applied Superconductivity for development work along with generating good number of technical staff in this field.

Executive Summary of Institutes and Industry Engaged in Cryogenics/ Superconductivity / Low Temperature Physics

2.4 Indian Cryogenics Council (ICC)

Indian Cryogenics Council is the apex professional society of personnel of Cryogenics and Low Temperature Physics and is popularly known as ICC. The aim of ICC is to promote education, advancement and application of cryogenics in India through various activities such as organizing seminars and workshops, training courses and publication of books and journals on Cryogenics, Low Temperature physics and Superconductivity.

On the proposal of NCIIR, a National Convention of Cryogenists was held at IIT, Kharagpur on May 24-25, 1975. The convention took a decision to set up a professional body of largely eminent cryogenists in Indian and some eminent honorary cryogenists from abroad. This professional body was named as the "Indian Cryogenics Council (ICC)" with its registered office at Jadavpur University, Kolkata. Professor A. Bose became the Founder President of Indian Cryogenics Council. At Present, Dr. Amit Roy, Director.IUAC is the President of Indian Cryogenics Council

Office Address

Registered Office : Jadavpur University. Kolkata –32

President Office : Inter – University Accelerator Centre, New Delhi- 110067

Zonal Office :

1. *West Zone : Mechanical Engineering Department, IIT, Mumbai.*
2. *South Zone : CCT, Indian Institute of Science, Bangalore –12*
3. *East zone : VECC, Kolkata – 64*
4. *North Zone : NPL, New Delhi – 110012*

Members: At present ICC has about 500 Members/ Fellow on its roll. There had been an stagnation in the Membership since 1990 until 2006 when a new membership drive was launched and 160 active members were inducted in the fold. Interestingly, this was the period when large scale cryogenic projects were initiated in the country.

Indian Journal of Cryogenics: This journal is being published since 1975 regularly. Last volume (35) is already out this year (2010) as a special issue (Part B) on Proceeding of the 22nd National Symposium on Cryogenics, held at Bangalore during December 4-6, 2008. ICC is trying on improving the quality through stricter peer review of each paper by at least two independent referees.

National Symposium on Cryogenics: Scientific/ Academic institutes organize these Symposia on cryogenics once in two years in collaboration with Indian Cryogenics Council. The venue of symposia is rotated among the four zones, North South, East and West Zone.

National Symposium on Cryogenics (NSC) held in Recent Past

Year	Name of Symposium	Organised by	Venue	Chairman / Convener
2008	NSC-22	CCT, IISc	Bangalore	S. Jacob
2006	TFNSC	NPL	Delhi	Vikram Kumar/ A K Gupta
2005	TNSC 2005	SVNIT	Surat	A.K Dave / H B Naik
2003	NNSC 2003	IACS/JU	Kolkata	S N Ghosh/ B. K Choudhury
2001	ENSC-2001	NPL	Delhi	K.Lal/ R G Sharma
1999	SNSC-99	Priyadarshini College	Nagpur	B.E Chopne/ S Prasad
1997	SNSC-97	IIT. Kharagpur	Kharagpur	S Sarangi / K. Choudhury
1995	FNSC- 95	NPL	Delhi	ESR Gopal / A K Gupta
1993	TNSC-93	Shivaji University	Kohlapur	S H Pawar
1991	ENSC-90	IIT. Kharagpur	Kharagpur	S Sarangi

In the year 2000, International Cryogenic Engineering Conference (ICEC-18) was held at IIT. Mumbai and organised by Prof K.G Narayankhedkar, the then President of ICC.

ICC details available at: **http://www.iuac.ernet.in/iccwebsite/icc.html**

Chapter 3

Executive Summary of Institutes and Industries Engaged in Cryogenics/ Superconductivity/Low Temperature Physics

3.1 INSTITUTES

TABLE. A –1 :

SL.NO	*INSTITUTE NAME*	*NATURE OF PROGRAMME*	*MAJOR FACILITIES*	*MAN POWER*		
				SCIENTIFIC/ ACADEMIC	*TECHNICAL*	*TOTAL*
DAE Institutes						
A-1-1	**BARC Mumbai**	LTP- SC, Dev. of 4K Refrigerator, ADS	LHe& LN2 Plant, SQUID Magnetometer	15	12	27
A-1-2	**IGCAR, Kalpakkam**	LTP-SC, Dev of SQUID, Cover Gas Purification	LHe plant, LN2 Plant, VSM,Cryostat	17	7	24
A-1-3	**IPR, Gandhinagar**	Steady State Superconducting Tokamak	LHe Plant, LN2 Storage Vessel	20	8	28
A-1-4	**ITER- INDIA (Part of IPR)**	Cryo Distribution line, Cryo Module		6		6
A-1-5	**RRCAT Indore**	LTP_ SC, Dev of Cryocooler/ He Liquefier, SC Cavity / Magnet	LHe Plant, LN2 Plant, PPMS, SQUID, Cryostat	20	12	32
A-1-6	**SINP Kolkata**	LTP_ SC, Helium Recovery Project	LHe, LN2 Plant, MPMS Helium Purifier, SQUID	6	4	10
A-1-7	**TIFR Mumbai**	LTP- SC, SC Linac	LHe & LN2 Plant, PPMS, SQUID, ULT, NMR	15	10	25
A-1-8	**VECC. Kolkata**	SC Cyclotron, Helium Recovery, SC Magnet /SEMS Programme	LHe Plant, LN2 Storage Vessel	30	10	40
A-1-9	**Heavy Water Board**	Heavy Water Distillation	Cold Box	5		5
		Total under DAE		**134**	**62**	**196**
Institutes under ISRO						
A-1-10	**LPSC, Valiamala**	R& D Activities on Cryo Engine, Cryo Component Testing	Component Testing Facility	40	15	55

A-1-11	**LPSC, Mahendragiri**	Design, Development of Cryo Engine, Testing of Cryo Engines	LH2 Plant, LN2 Storage Vessel, Thurst Test	40	20	60
A-1-12	**LPSC Bangalore**	Cryo Engine		4	3	7
A-1-13	**ISAT, Bangalore**	Satelite, Passive Cryo cooler, Space Similtation at 80 K	LN2 Storage Vessel, 20 K Refrigerator,	15	10	25
A-1-14	**SAC, Ahmedabad**	Space Simulation at 80 K	Simulation chamber of Different Capacity	8	7	15
A-1-15	**SHAR Sriharikota**	Launching Satelite by using LH2 and LO2	LH2, LO2 Storage vessel, Transfer line	5	20	25
		Total Under ISRO		**112**	**75**	**187**
Other Scientific Institutes						
A-1-15	**NPL. New Delhi**	LTP- SC, Superconducting Magnet Development,	LN2, LHe (Old), PPMS (First Helium Liquefier in India)	17	6	23
A-1-16	**IUAC, New Delhi**	SC Linac Programme, SC Magnet/ SC Cavities	LHe & LN2 Plant, Storage Vessel, ECR SC Magnet	19	4	23
A-1-17	**UGC-DAE CSR, Indore**	LTP- SC LT Measurement Users'Facilities	LHe&LN2 Plant, High Field LT Facility.ULT	10	6	16
A-1-18	**IUC- Kolkata**	Users' Facility	Moissbur Spectrometer at 10 K, PPMS	1		1
A-1-19	**IACS Kolkata**	LTP- SC	PPMS,MPMS,VSM, SQUID Magnetometer LN2 Plant	5	4	9
A-1-20	**SNBSC-Kolkata**	LTP- SC	VSM	4		4
A-1-21	**RRL, Trivandrum**	HTSC Current Lead Development		1		1
A-1-22	**JNCAR Bangalore**	LTP_ SC	High Field Cryo Free Magnet	2	1	3
Total Under Other Scientific Institutes				**59**	**21**	**80**

Academic Institutes						
A-1-23	**IISc Bangalore**	LTP-SC, Cryo Technology,	LHe & LN2 Plant, NMR, PPMS, High Field LT Facility	12	8	20
A-1-24	**IIT Chennai**	LTP-SC, Mixed JT Cooler, Heat Exchanger	MPMS, LN2 Plant, NMR	6	3	9
A-1-25	**IIT Kanpur**	LTP- SC	LHe & LN2 Plant, SQUID Magnetometer, PPMS	5	4	9
A-1-26	**IIT Mumbai**	Cryogenic Engineering (Cryo cooler), LTP- SC. M.Tech	LHe & LN2 Plant, VSM, NMR	7	8	15
A-1-27	**IIT Delhi**	LTP- SC	MPMS, LN2 Plant	4		4
A-1-28	**IIT Kharagpur**	Cryo Engineering, LTP- SC. M.Tech Programme	LN2, Cryo Free Magnet	10	5	15
A-1-29	**NIT Surat**	Cryo Cooler	LN2 Plant	2		2
A-1-30	**NIT Rourkela**	Cryo Engineering, Purifier, Compressor	LN2 Plant	3		3
A-1-31	**LD College Ahmedabad**	Teaching M.Tech		5		5
A-1-32	**T.K.M College. Trivandrum**	Teaching M.Tech		6		6
A-1-33	**NIT Calicut**	Theoretical Analysis		1		1
A-1-34	**JNU New Delhi**	LTP_ SC	Cryo Free Magnet	3		3
A-1-35	**BHU Varanasi**	LTP_ HTSC		2		2
A-1-36	**Jadavpur University**	LTP- SC, Applied Cryogenics		2		2
A-1-37	**Anna University Chennai**	Cryo Treatment of Tools		1		1
A-1-38	**Bharati Darshan University, Chennai**	LTP_ SC, LT with High pressure Facility	PPMS	1		1
A-1-39	**Hyderabad University**	LTP_ SC	LHe & LN2 Plants, Cryostat with Magnet, PPMS	5	2	7

A-1-40	**Shivaji University Kolapur**	LTP_ SC		1		1
A-1-41	**VIT Vellore**	Cryo Engineering		2		2
A-1-42	**Nirma University. Ahmedabad**	Cryo Engineering		1		1
A-1-43	**Singhania University. Rajasthan**	Cryo Grinding		2		2
A-1-44	**Walchand College. Sangli**	Cryo Cooler Technology		2		2
Total under Academic Institutes – 21				**76**	**28**	**104**
		Other Institutes Under Defence/ Medical				
A-1-45	**SSPL. New Delhi**	Miniature Cryo cooler	LN2 Plant	3	4	7
A-1-46	**LASTECH Delhi**	Miniature JT Cooler	LN2 Plant	2		2
A-1-47	**AIIMS New Delhi**	NMR & MRI Clinical Use & Research	NMR, MRI	2	1	3
A-1-48	**INMAS, Delhi**	Research with MRI Clinical Use and research	MRI	2	2	4
	Total Under Defence/ Medical – 4			**9**	**7**	**16**
	Total Under Institutes			**381**	**193**	**574**
3.2 Public Sector Enterprises						
A-1-48	**BHEL(R & D) Hyderabad**	Industrial Applications of SC HGMS, Generator, Transformer	LHe Plant	4	2	6
A-1-49	**IOL/IBP Nasik**	R&D on Cryo container		4	2	6
	Total Under Public Sector			**8**	**4**	**12**

TABLE A-2: INDUSTRIES & SUPPLIERS

SL. NO	INDUSTRY	NATURE OF ACTIVITY	PRODUCTS/ REMARK	ESTIMATED MAN POWER		
				ENGINEER / OFFICER	TECHNICAL	TOTAL
			GAS Industry			
A-2-1	**M/s Air Liquide India Holding Pvt Ltd. New Delhi-44**	Captive / Merchant Oxygen/ Nitrogen Gas Plants, Large apacities		75	50	125

A-2-2	**M/S BOC india Ltd. Kolkata-88**	Captive / Merchant Oxygen/ Nitrogen Gas Plants, Large Capcities	Now it is BOC - LINDE	350	250	600
A-2-3	**M/s Paraxair India**	Captive / Merchant Oxygen/ Nitrogen Gas Plants, Large Capcities		300	200	500
A-2-4	**M/s Inox Air Products Ltd. Mumbai-18**	Captive / Merchant Oxygen/ Nitrogen Gas Plants, Large Capcities		50	50	100
A-2-5	**M/s Pure Helium India**	Supply of Liquid/ Gas Helium	Aquired by M/s Air Liquide	6	8	14
A-2- 6	**M/s Goyal Gases**	Supplier of LO2 & LN2 and O2 & N2 Gases & Captive Plant		20	20	40
Total Major Gas Industries and Gas Suppliers – 6 ***Other than these major gas Industries, there are about 150 Gas manufacrtuting industries which produce Oxygen, Nitrogen, Argon in smaller quantities. The technical manpower is about 10 persons / gas industry and they have either Engineeing or Technical qualifications.***						
3.3 Manufacturing Industry						
A-2-7	**M/S Sanghi Oxygen, Mumbai**	Manufacturing O2 / N2 Plants		15	25	40
A-2-8	**M/S Titan Engineering co. (P) Ltd, Durgapur**	Manufacturing O2/N2 plants		2	5	7
A-2-9	**M/s Sanghi Organization, Mumbai**	Manufacturing 02 / N2 plants		20	30	50
A-2-10	**M/S KVK Corporation, Mumbai**	Manufacturing O2 / N2 Plants		10	20	30
A-2-11	**M/S Inox India Ltd. Vadodora**	LN2, LO2 Storage Vessel, Super Insulated Piping		20	30	50
A-2-12	**M/S Indian Oil Corporation Ltd. Mumbai**	LN2, LO2 Storage Vessels		10	10	20
A-2-13	**M/S BHPV**	Air Separation Plants		5	10	15
A-2-14	**M/s Super Cryogenic Systems Pvt. Ltd. Noida**	LN2, LO2 Storage Vessels		5	6	11

A-2-15	**M/S Shell- N-Tube Pvt. Ltd. Pune**	Vaporisers, Super Insulated piping		5	5	10
A-2-16	**M/s Indian Compressors Ltd. New Delh**	Cryogenic Pumps and Compressors		5	8	13
A-2-17	**Air Liquide Engineering India (P) Ltd, Hyderabad**	Air and Gas Separation plants of Higher Capacity		200	50	250
A-2-18	**M/S Vacuum Technique, Bangalore**	Cryostats		4	6	10
A-2-19	**Don Bosco Institutes New Delhi**	Cryostats		2	6	8
A-2-20	**Cryoquip India Vadodora**	Vaporizer				
A-2-21	**Cryolor Asia Pacific Chennai**	Storage Vessel				
	Total Under Manufacturing Industry : 15			**303**	**215**	**518**
3.4 Suppliers And Services						
A-2-22	**M/s Sterling Cryogenics India, New Delhi**	Liquid Nitrogen Plant	Part of Sterling Cryogenics, Netherland	10	10	20
A-2-23	**M/s Linde India Ltd, Vadodora**	Liquid Helium and Nitrogen Plant	Representative of M/s Linde	15	05	20
A-2-24	**M/s Paul Enterprises New Delhi**	Liqid Helium Plant	Representative of M/S Air Liquide DTA, France	2	1	3
A-2-26	**M/s Con-Serv, Mumbai**	Temp Controller, Cryostat, Magnet, Cryo Cooler	Representative of Lake Shore, Jainis,	1	2	3
A-2-27	**M/s Vico Sales. Delhi**	Cryostat, Cryo Free Magnet	Representative of Cryogenics. UK	1	1	2
A-2-28	**M/s Good Will Cryogenics, Mumbai**	LHe Container, Cryo Instrumentation, CCR	Representative of CryoFab, Cryo Mech,	1	2	3

A-2-29	**M/S Specialise Instruments & Marketing Company, Mumbai**	PPMS, MPMS	Representative of Quantum Design	3	3	6
A-2-30	**M/s Bruker India Scientific Pvt Ltd. Bangalore - 80**	NMR	Representative of Bruker	10	10	20
A-2-31	**M/s Siemens Health Care Diogistics Ltd, Baroda - 19**	MRI	Representative of M/S Siemens	10	10	20
A-2-32	**M/s Wipro-GE Health Care System. Bangalore -67**	MRI	Representative of M/S Wipro Health Care	10	10	20
A-2-32	**M/s Philips Medical System (India) Ltd**	MRI	Representative of M/S Philips Medical	5	8	13
A-2-33	**M/s Tinsley Group Ltd (India)Delhi**	Temp Sensor,, Cryostats	Representative of Tinsles,	1	1	2
A-2-34	**M/s Spry Technology. Delhi**	Table Top LN2 Plants	Representative of M/s Kelvin International	1	1	2
A-2-35	**M/s Amil Sales (P) Ltd. Delhi**	Cryostats, Magnets	Representative of M/S Oxford Instruments.	1	1	2
A-2-36	**Anargaya Innotech**	SC Magnet	Representative of M/s Scientific Magnet	1		1
	Total No. of Suppliers and Services – 14			**72**	**65**	**137**

Chapter 4

4. MAJOR RESEARCH INSTITUTIONS IN CRYOGENICS AND SUPERCONDUCTIVITY

4.1 National Physical Laboratory, New Delhi

The National Physical Laboratory (NPL) has the distinction of being the first research centre in the country to have started research at low temperature down to 1 K. It was Sir, K.S. Krishnan, the founder director of NPL, who bought an ADL make helium liquefier and an ADL large electromagnet (3.2 T) for NPL in the year 1952. He also invited Prof. D. Shoenberg, FRS from Cambridge Uni, UK in 1952 to laid the foundation for Low Temperature Physics Research at NPL.

Besides pursuing various basic research problems NPL made a significant contribution to the development of A- 15 Multifilamentary Superconductors, and SC magnets for basic research and for other applications. NPL was also active on other applications like development of Cryo Containers and Cryo Probes for cryo surgery. The old helium liquefier was replaced in 1980 by a turbo machine from BOC with a rate of 20 l / hr. This machine worked until 1996. NPL is now running an old He liquefier (capacity 15 litres/ hr) brought from INMAS, Delhi.

The laboratory has the following major facilities and measurement systems:

1. Helium liquefier, Nitrogen Liquefier (Stirling make, (2003), capacity 45 l / hr)
2. Superconducting Magnets, 11 T, 7 T, insert magnet 3.5 T all home made
3. 14 T superconducting magnet from Oxford Instruments, working bore 50 mm.
4. Josephson Voltage Standard system, 10 volts Josephson device
5. Quantum Hall Effect Device for Resistance Standard
6. Resistivity and AC susceptibility measurements 4.2 to 300 K and 0–7 T field
7. A PPMS has just arrived

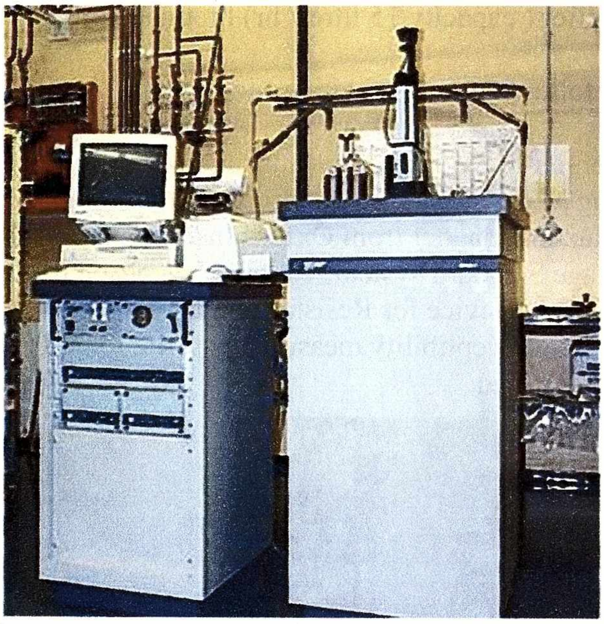
Collins He Liquefier at NPL in 1952

SC Magnet Developed at NPL

4.2 Indian Association for the Cultivation of Sciences (IACS), Kolkata

IACS started low temperature research in 1953 by Prof. A. Bose. IACS developed a cryostat based mini He liquefier using J-T expansion technique. They used liquid air and liquid hydrogen as a pre cooling stages. They could go to about 2 K. A Collins type commercial He liquefier was procured around 1968. It must have been a Coch Process machine. A Philips He liquefier was installed some times in 1981 which served IACS until 1998. No liquid helium is produced for several years. Following major facilities are available with the IACS at the moment:

1. Nitrogen Liquefiers PLN-108, MNP-9/01 and SPC-1 (15 l/hr)
2. An 8 T Superconducting Magnet (bought in 1990s from Oxford Instruments)
3. PPMS (Quantum Design) with a Cry Cooled 9T SC magnet, installed in 2007, 2K – 300 K, is used for resistivity, DC and AC susceptibility measurements by various groups. SK De looks after the unit. Presently used for studies on DMS (dilute magnetic semiconductors, Perovskites and CMR and GMR materials
4. Mini VSM, 2 – 1000 K with cryo cooled 5 T Superconducting Magnet
5. MPMS (Quantum Design) 1.5 to 300 K with 5 T cryo cooled Superconducting Magnet



MPMS at IACS

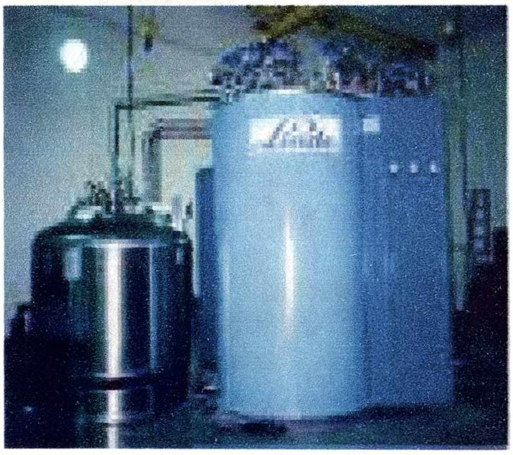
4.3 Tata Institute of Fundamental Research (TIFR), Mumbai

After National Physical Laboratory, TIFR too acquired liquid helium facility in 1961 and continued with front line basic research and extending the range of temperature down to 50 mK range. The institute has a plan to extend the temperature range further down to µK range. In the early years low temperature research continued as a group activity under the leadership of Prof. Girish Chandra. This activity, however, became a part of the much broader Department of Condensed Matter Physics and Material Sciences (DCMP & MS) which came up in 1968.

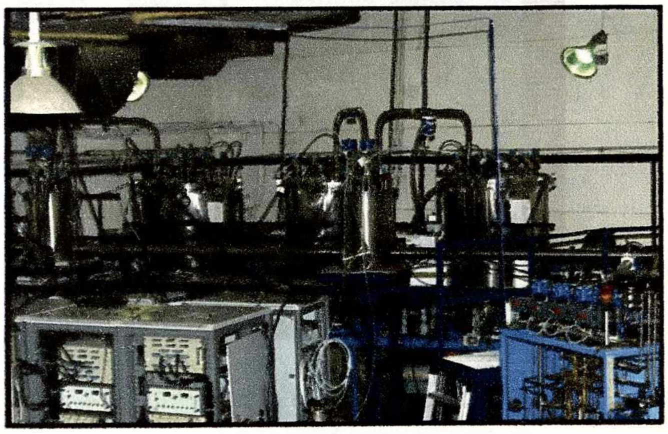
The main users of liquid helium are the DCMP & MS, the National Facility for High Field NMR and the Pelletron Accelerator. The Pelletron Accelerator has a separate helium refrigerator **(Linde Model TCF 50) with a refrigeration capacity of 300 W at 4.2 K** to cool down the LINAC superconducting cavities in close loop. Linac Group indigenously developed cryomodules and liquid helium transfer line with the help of Indian industry. The institute is credited with the discovery of superconductivity in quaternary Y-Ni-B-C system. More recently, Point Contact Spectroscopy has been set up and is used to establish the two band superconductivity in Y-Ni-B-C. It has also been used to study the particle size dependence of the superconductivity in Nb nano particles as well as the degree of spin polarization in several rare earth alloys and oxides.

Following is the list of major equipment related to Cryogenics and superconductivity:

1. NMR Spectrometers, 800 MHz, 600 MHz and 500 MHz
2. DC Magnetic Property Measurement System (DC MPMS)
3 SQUID Magnetometers (3 nos.)
4. Physical Property Measurement System (PPMS)
5. Vibrating Sample Magnetometer (VSM)
6. Dilution Refrigerator (mK Range)
7. Adiabatic Demagnetization Refrigerator (mK Range)
8. Tunneling Point Spectrometer,. Point Contact Spectrometer, Photo Electron Spectrometer
9. Liquid Helium Plant and Liquid Nitrogen Plant



New Liquefier (200l/hr) installed at TIFR



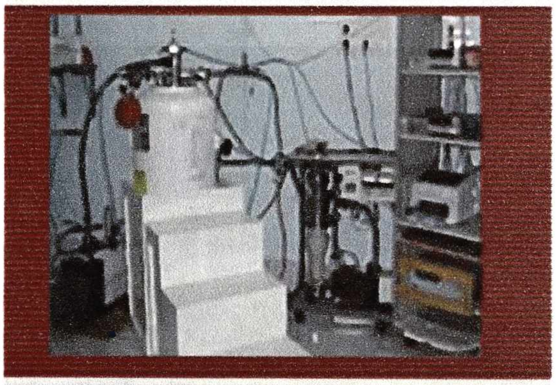
SC LINAC at TIFR

4.4 Indian Institute of Science (IISc), Bangalore

A Philips helium liquefier, PL He-210 with a capacity of 10 l / hr was installed in 1976 primarily for running the NMR spectrometer which needed continuous supply of LHe This helium liquefier was replaced with a Koch Process 1401 liquefier. This machine is still serving the institute well. A new helium liquefier again reciprocating engine type is being procured with a rated capacity of 70 l/hr. These Cryogenic Facilities, are part of the **"Centre for Cryogenic Technology" (CCT)** which takes care of the LN2 and LHe supply to all the groups and departments of the IISc. IISc also has an NMR Centre operating 7 NMR spectrometers ranging from 300 MHz to 700 MHz Spectrrometers

Following is the list of Major Low Temperature Measurement Systems with various Departments and Groups which need continuous supply of Cryogenic Liquids..

1. Janis 12 T Superconducting Magnet Cryostat for Magneto-Transport Studies (Measurements 2-300 K and up to 12 T), **(DST National Facility)**
2. Bruker IFS 66V Optical Spectrometer with Oxford CFV Continuous Flow Optical Cryostat for Reflectivity and Transmittivity Measurements (2-300 K) in 20 cm-1 to 50,000 cm-1 range, **(DST National Facility)**
3. Cryomach Closed Cycle He Refrigerator for Transport Measurements (4-300 K) with **(Semiconductor Laboratory)**
4. LHe Bucket Dewar with Optical Window for photoluminescence Measurements at 4 K (with Semiconductor Laboaratory)
5. ^{3}He-HHV System up to 280 mK along with 8 T Superconducting Magnet from Jenis
6. Displex Closed Cycle He-Refrigerator for Optical Measurements 15-300 K (With Semiconductor Laboratory)
7. Dilution Refrigerator (MNK-500) Facility from Leiden Cryogenics, The Netherlands, Base Temperature 7 mK with 14 T Superconducting Magnet (from American Magnetics) (With Low Temperature Laboratory)
8. AC Susceptometer with Liquid Nitrogen Dewar (With Physics Department)



NMR at NMR Centre of IISc

Cryogrinding facility developed at IISc.

4.5 Indian Institute of Technology, Madras (IITM)

The foundation for Low Temperature research at IITM was laid by Prof. R. Sriniwasan in mid 1970s when an old helium liquefier was donated by the Frie Uni. Germany. The liquefier had a liquefaction rate of 4 l / hr. Good facilities were created for physical properties measurements between 4 K and 300 K. The lab. got its new liquefier Koch Process model 1401 in 1989 with 10 l / hr liquefaction capacity. Even though most work was confined to basic research some development work was also carried out on mini coolers based upon J-T expansion process for IR detector application. Major studies were carried out on High Temperature Superconductors, Intermetallic Compounds, CMR and Magnetic Refrigeration Materials.

The Refrigeration and Air Conditioning Laboratory of the IIT has carried out development work on Compact Heat Exchanger, Mixed Refrigerant J-T cryocoolers and Mixed Refrigerant Nitrogen Mini Liquefier.

IITM also offers courses on " Low Temperature Physics" for PG and Ph. D. students. It also provides Minor Stream Course on "Superconductivity and its Applications" to M.Sc., M.Tech. and B.Tech. students. (~50 students take this course every year. The "Cryogenic Course" to M.Sc. students has however now discontinued.

The Low Temperature Laboratory has the following Facilities / Major Equipments:

1. Helium Liquefier Koch Process System Inc. 1410 model, procured 1989, capacity 10 l / hr, presently not working
2. Nitrogen Liquefier Koch MNP 25, procured 1990, capacity 25 l / hr annual production ~1,00,000 l
3. MPMS Magnetometer with SC Magnet 5.5 T, (Quantum Design), procured 1988, presently not working
4. Specific Heat & Electrical Transport system with 5 T SC Magnet (Cryogenic Consultant), procured 199

4.6 Indian Institute of Technology, Kharagpur (IIT Kh)
(Cryogenic Engineering Centre)

Cryogenic Engineering Centre (CEC) was established in the year 1976 under the leadership of Prof. S.K. Datta Roy to teach cryogenic technology to engineering students at the IIT. The Centre offers a four semester course to M.Tech. students and several electives in cryogenic applications at the B. Tech level. The Centre is the unique and first of its kind in the country to have started teaching programme in Cryogenics. The pass outs from the Centre have spread far and wide in the country in all important organizations like ISRO, DRDO, DAE and others. Its faculty is involved in basic and applied research in several areas of cryogenics and superconductivity like superconducting Magnet Energy Storage (SMES), gas separation and purification, air separation technology, food processing, liquefaction of gases, natural gas and hydrogen energy, refrigeration & liquefaction cycles and turbine cooling technology..

The Centre acquired its helium liquefier BOC make with a liquefaction capacity of 17 l/hr with LN2 precooling and worked for about 4 years. This liquefier is, however, not working since that time and the low temperature research is primarily carried out using closed cycle refrigerator systems. The Centre has the following major facilities:

1. Nitrogen Liquefier Stirling make (1995), capacity 12 l/hr producing about 40,000 l in a year
2. SMES (Superconducting Magnet Energy Storage) System (3T / 365 mm) developed in house during 1990s
3. Cryofree SC Magnet System (5 T, 50 mm) from Janis Research Inc.
4. Transport properties measurement facilities down to 10 K using Closed Cycle Refrigerators

Cryogenic Engineering Centre at IIT Kharagpur

4.7 Indian Institute of Technology, Bombay (IITB), Mumbai

Until very recently, cryogenic activity at IITB, started by Prof. KG Narayankhedkar, remained confined to the Department of Mechanical Engineering. The initial thrust was on the development of nitrogen liquefier based upon Stirling Cycle. A proto type 5 l / hr nitrogen liquefier was developed at the institute. The department continues to work on Cryo Coolers based upon Stirling and Pulse Tube Techniques. This programme helped training young students in this area and also led to Ph.D. degrees.

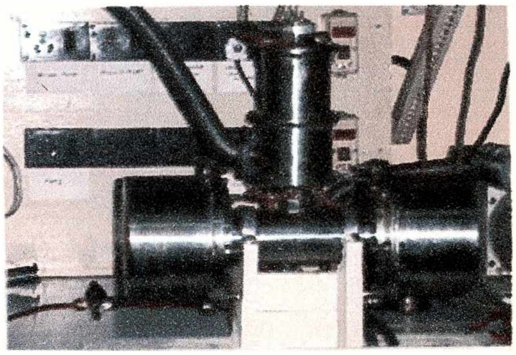
Low Temperature activity has just begun in the Department of Physics at IIT. It has recently acquired a helium liquefier Linde BOC with a liquefaction capacity of 15 l / hr. It already has a liquid nitrogen machine from Cryomech, USA producing 32 litres / day of LN2. The department has a VSM and a Superconducting Magnet System (Quantum Design) allowing measurements like magneto resistance, heat capacity and such other measurements. DST has also granted funds for a Torque Magnetometer with Scanning Hall Probe Microscope / Magnetometer with a superconducting magnet. Transport properties and magnetic measurements on oxides and and intermetallic compounds are presently going on. The facilities above are supposed to be used as Central Facilities. The major facilities available with IITB are :

With Mechanical Engineering Department:

1. Philips / Stirling PL-430 nitrogen liquefier (30 l/hr)
2. Koch Process helium liquefier (10 l / hr), 1992

With Physics Department:

1. Linde / BOC helium liquefier (15 l / hr)
2. Cryomech nitrogen liquefier (32 l / day)
3. VSM and PPMS (Quantum Design) with superconducting magnet
4. Torque Magnetometer with Scanning Hall Probe Microscope / Manetometer with



Pulse Tube Cooler developed at IIT Mumbai

4.8 Bhabha Atomic Research Centre (BARC), Bombay

BARC launched Low Temperature Research activity under the leadership of Dr. NS Satyamurthy during 1974-75 by acquiring a Philip Helium Liquefier with 10 l / hr LHe capacity. This machine was replaced in 1990 by a Koch Process Liquefier. The facility was by and large used for basic research and for the characterization of multifilamentary (MF) Cu/Nb-Ti wires developed by the Atomic Fuel Division (AFD) during 1980s. The development of these MF wire was an important event in so far as long lengths, tens of Km good enough to wind laboratory magnets with excellent critical current were produced in the country. The AFD group also produced Cu /Nb-Ti cables with critical current in excess of 1000 A.

In recent years, ambitious programme has been launched on the high energy charged particle accelerators used in ADS (Accelerator Driven Critical System). This requires large number of Superconducting RF Cavities which need liquid helium temperature for operation. BARC has successfully developed a turbo based 1 kW @ 20 K Helium Refrigerator also plans to develop a turbo based 100 l /hr capacity Helium Liquefier.

BARC has the following major facilities:

1. Koch Process Helium Liquefier with 25 l / hr capacity
2. Indigenously developed 1Kw class Helium refrigerator
3. SQUID Magnetometer
4. A Superconducting Magnet 7.4 T (home made)
5. A Superconducting 14 T Magnet (Oxford make)
6. Critical Current Measurement Facility

4.9 UGC – DAE Consortium for Scientific Research (UD-CSR), Indore

In recent times UD – CSR, Indore has emerged as the Major Centre in the country for Low Temperature Research and measurements catering to a large number of students and faculty from across the Indian universities. It's own faculty interacts with many national level research laboratories and the institutes and provide low temperature and high magnetic field measurement facilities. Major facilities were made available to the Centre by the DST under its Low Temperature and High Magnetic Field Facility Programme.

The Indore Centre has an excellent Cryogenic Infrastructure and Major Low Temperature Measurement Facilities. These are detailed below:

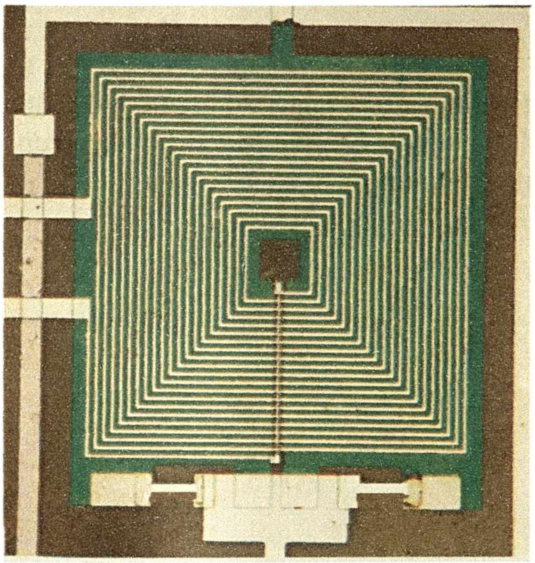
1. Helium Liquefier with a capacity of 20 l/hr with LN2 pre cooling, Linde make, Model TCF–10 and procured in the year 2000.
2. Nitrogen Liquefier with a capacity of 40 l/hr with PSA Philips make Model STIRLING – 4 procured in the year 2006.
3. 14 T / 0.3 K PPMS, Quantum Design for Resistivity and Specific Heat Measurements
4. 14 T VSM, Quantum Design, 1.9 K to 400 K and 14 T longitudinal field
5. 10 T Magneto Resistance, 1.4 K to 310 K, (0 to 10 T field) can measure 16 samples at a time
6. Specific heat, Magneto Specific Heat and Magneto Chloric Effect Temp. Range 2.2 K to 310 K, Field 0 – 10 T, 4 samples at a time, sample 50 mg to 1 gm. Online output on monitor
7. General Purpose VTI (Variable Temperature Insert) for 60 l LHe storage Dewar, Temp. Range 1.4 K to 310 K, Sample space dia. 37 mm. LHe consumption 3-4 l/day
8. Dielectric Constant and AC Resistivity Measurement Set-Up, frequency Range, 100 Hz to 13 MHz, Temp. range 80 K to 300 K and 300 K to 700 K
9. AC Susceptibility Apparatus, Up to 100 Oe AC and 300 Oe Superimposed DC Field, Temperature range 80 to 300 k and 300 k to 700 K
10. VSM (Vibrating Sample Magnetometer), up to 1.5 KOe, Temp Range 80 to 300 K, sensitivity better than 5 x 10^{-6} emu
11. VSM, 7 T American Magnetics, 1997

4.10 Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam

IGCAR was established as Reactor Research Centre at Kalpakkam in the year 1971. All its research activities have been directed towards the development of Fast Breeder Reactor (FBR). Its Material Science Division (MSD) started low temperature research facility in the year 1977-78 by acquiring a Koch Process helium liquefier of 10 l /hr capacity (with LN2 pre cooling). The facility has been used for the characterization of a variety of materials with respect to their properties down to 4.2 K. Since around 1990 the group developed the technology of making Nb based Josephson junctions which led to the development of SQUID magnetometer based NDT (Non Destructive Testing) set up.

For last few years the Group has taken up a most ambitious project, funded by DST, on the Magneto Encephology (MEG) system using an array of Nb SQUIDs to map the human brain. SQUID has the capability of measuring magnetic field as low as 10^{-15} T. The low temperature laboratory has the following experimental facilities:

1. Helium Liquefier, Linde make (2002) with a capacity of 40 l / hr,
2. Nitrogen Liquefier, Stirling Cryogenic make, capacity 36 l / hr,
3. 12T Superconducting Magnet, 32 mm working bore, temperature range for measurements 4.2 K to 300 K
4. 6 T Superconducting Magnet, 50 mm working bore, home-made
5. Experimental facilities for resistivity measurements 1.2 K to 300 K
6. Resistivity under pressure up to 7.5 GPa and in a temperature 4.2 K to 300 K using a dip stick LHe cryostat
7. Specific Heat measurements using quasi adiabatic calorimetry in the temperature range of 4 K to 300 K
8. Heliox Cryostat (Oxford make) capable of reaching temperature down to 0.3 K



SQUID Sensor Developed at IGCAR

4.11 Indian Institute of Technology, Kanpur (IITK)

Liquid helium activity started at IIT Kanpur in the later half of 1960s in Physics Department. The history of old liquid helium activity is somehow not available and we believe that it must have been a Collins type machine with 4 l / hr rate of liquefaction. A new helium liquefier, Koch Process System Model No. 1410 was acquired in 1993 with a liquefaction rate of about 20 l / hr with precooling and two compressors. The major activity at the institute had been confined to basic research.

The major facilities available with the Physics department are:

1. Helium Liquefier, Linde Model 1610 Series ,30 litres/hr 9 (Installed in 2009)
2. Stirling make Nitrogen Liquefier (PSA), 2 cylinder, 20 l /hr
3. Quantum Design MPMS XL with a 60 l helium cryostat, Temp. Range 1.7 K- 350 K,
4. Quantum Design PPMS, Model 6700 with 16 T Mag. Field and 100 l He-Cryostat, Temperature Range down to 0.3 K using 3He- Evaporator
5. X-Ray Diffraction PANalytical X Pert PRO with LN2 Attachment, Temp. Range 77 K – 300 K

The measurement facilities are available for researchers from all over India on payment basis

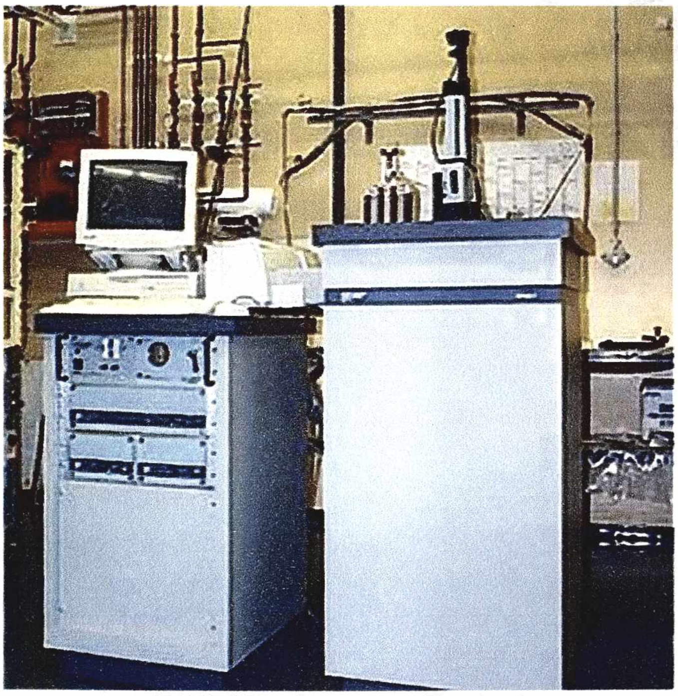
Measurement Facilities at Kanpur

4.12 Saha Institute for Nuclear Physics (SINP), Kolkata

Low temperature research has been a part of the Condensed Matter Physics Group. The institute installed its first He liquefier based upon reciprocating expansion engines in the year 1975-76. A new He liquefier Linde make model TCF 10 was installed during 2003-04. It has a liquefaction capacity of 40 l / hr with LN2 pre cooling. SINP in collaboration with VECC are actively engaged on Helium Recovery project from Thermal Spring The institute carries basic studies on inter metallic compounds, complex magnetic materials (bulk and nano), microstructre, magneto crystalline anisotropy, domain wall motion and pinning, down to 1K. The institute is equipped with the following facilities.

1. Helium Liquefier Linde TCF 10, capacity 40 l / hr with LN2 pre cooling
2. Nitrogen Liquefier Stirling make, PSA based, capacity 20 l / hr
3. A 14 T high homogeneity (0.01%) Superconducting Magnet (Oxford Instru.) with large bore of 77 mm for high pressure work has recently been installed
4. An 8 T field Oxford make cryostat used for magneto resistance measurements
5. An 8 T magnet with 0.1 % homogeneity with persistent mode operation used for resistivity, specific heat and time dependence of resistivity
6. An harmonic Thermo Electric Power Dewar Oxford Instrum. Make
7. A Quantum Design Magnetic Property Measurement System (MPMS) for ac and dc susceptibility studies
8. A 2 T and a 0.5 T electromagnet for general purpose applications
9. A 300 MHz Bruker Nuclear Magnetic Resonance (NMR)

The SINP also interacts with VECC, located in the same campus, in their K-500 SC Cyclotron Project.

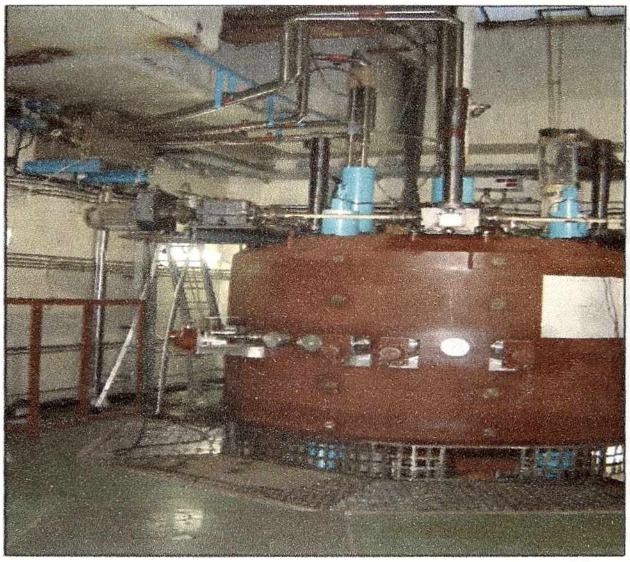


(MPMS – Quantum Design)

4.13 Variable Energy Cyclotron Centre (VECC), Kolkata

VECC Kolkata, a premier R & D Institution of the DAE devoted to Accelerator Science and Technology Development has been operating a K-130 class cyclotron using normal iron-electromagnets since 1980 and making high energy beam available to users from across the research institutions and universities. During 1990s VECC planned to build a K-500 class of cyclotron using superconducting magnet producing a field of 5.5 T. It is a complex machine with critical components like the large size Superconducting Coils, the Cryogenic Cooling System, the Cryo Panels and the RF all built by its scientists.

To keep the magnet and the cryostat cool at 4.2 K. the cryogenic system consists of a Helial-50 Air Liquide machine with a liquefaction rate of 100 l / hr. New refrigerator of 450 W at 4.2 K is procured recently. The Centre has a storage capacity of about 16,500 l of LN_2. Magnet was cooled down as early as Dec. 2004 and was energized up to 550 A current repeatedly since then. The magnet produces a field of 4.8 T. The complete integration of the cyclotron is nearing completion and beam line will be available to the users soon. In the wake of building this SC Cyclotron, the Centre has establish some R & D facilities like critical current measurements up to 9 T field and 1500 Amp current. The Centre has a 7 T SC magnet and also a wide bore (20 inches) 9T magnet for Jc characterization. During XI Plan the Centre proposes to build a 1 MW Superconducting Magnet Energy Storage System (SMES) and also a Helium Purification System for the impure helium recovered from natural sources through a cascaded PSA Adsorption Technique.



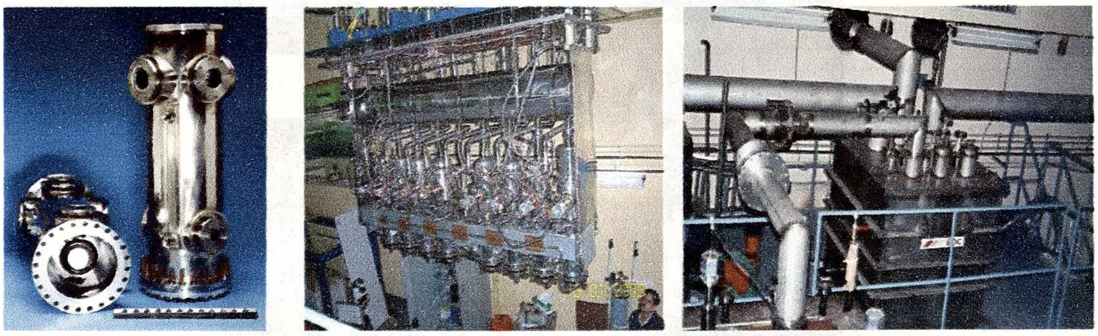
Superconducting Cyclotron Cryostat at VECC

4.14 Inter-University Accelerator, (IUAC), New Delhi

Inter- University Accelerator Centre, formerly known as Nuclear Science Centre is the first inter university centre established by UGC in 1984. This centre has a 15 UD Heavy Ion Pelletron Accelerator for research in Nuclear and Condensed Matter Physics since 1990. A decision to enhance the beam to cover a wider mass range by adding a superconducting linac booster was taken in 1992-93.. The Linac Booster has three modules each having 8 bulk Nb RF cavities operating at 97 MHz. These cavities operate at a temperature of 4. 2 K. Cryogenic activities thus started at the Centre to operate the linac boosters. The centre bought a helium liquefier with a liquefaction capacity of 150 litre / hr. and a 5000 W capacity Nitrogen refrigerator in 1997. IUAC designed and fabricated three large size cryo modules.. IUAC, first time laid a liquid helium distribution network to transfer liquid helium from the plant room to cryo modules in the vault area. IUAC also established a complete facility for in house development of niobium cavities and to characterize them for their “Q” values. First Linac module was installed in the beam line with a buncher and a rebuncher and tested successfully in 2004. Other two linac modules are getting ready and are expected to become operational in 2010. Helium Purifier, Cryogenics Control and Data Acquisition System were also developed at IUAC

Along with SC cavity programme, IUAC has recently initiated SC magnet programmes. It built a 7 T SC magnet of insert type with a standard bore of 50 mm. It is also developing a HTSC magnet for ion source for High Current Injector and a Cryo Free SC Magnet with a Warm Bore. It is also building a SC Quadrupole Magnet for the beam line. The centre has the flowing Cryogenic Facilities.

1. A helium liquefier (reciprocating engine type) with a capacity of 150 l / hr
2. Sterling Semi close loop LN2 liquefiers with capacity 150 litres/hr
3. LN2 storage vessels of 5000 L and 20,000 L capacity
4. An ECR ion source with High Tc superconducting Cryo Free magnets
5. An 8 T Superconducting (Oxford Instruments) Magnet
6. Large size Linac cryomodules and test cryostat, Presently used for Nb-cavities



(RF Cavity Linac Cryomodule and Liquid Helium Valve Box)

4.15 Institute for Plasma Research (IPR), Gandhinagar

Institute for Plasma Research (IPR) at Gandhinagar is an autonomous Physics research institute, involved in research in various aspects of plasma science including basic plasma physics, research on magnetically confined hot plasmas and plasma technologies for industrial applications. In 1994 IPR started the development of a Steady State Superconducting Tokamak (SST-1). Superconducting toroidal field and poloidel field coils are deployed in SST-1 for plasma confinement and shaping. The coils are to be operated at 4.5K . A closed cycle liquid helium plant of capacity 400 W refrigeration at 4.5 K and 200 litres / hr liquefaction was installed and commissioned in 2002. An integrated liquid helium distribution system is designed, fabricated and commissioned for the distribution of liquid helium in magnet coils and the current leads. In 2006, IPR also installed a separate helium refrigeration plant of capacity 100 W at 3. 8 K plant for cryo pumping of Neutral Beam Injector. IPR also developed a large network of liquid Nitrogen system to cater to the need of LN2 for various systems. This network includes 3 x 35000 litres storage vessel and a vacuum jacketed line of 300 m length with branching. Today, IPR has the largest infrastructure of LHe and LN2 in the country.

The cable in conduit conductor(CICC) is used for all these magnets. Magnets and cryostats are designed and developed at IPR. The Magnet Group of IPR together with M/s Hitachi Cable, Ltd; Japan is engaged in the design of a state-of-the-art Cable-in-Conduit (CIC) superconductor to be used in the Tokamak (SST-1) Toroidal and Poloidal coils. IPR is also developing the winding technology for large size superconducting magnets in association with M/s Bharat Heavy Electricals Limited, Bhopal. It has completed the manufacturing of all the coils, 17 superconducting Toroidal coils, 9 superconducting Poloidal coils and 7 resistive magnets. In-house development and validation of low resistive joints involving CICC has been worked out.

IPR is also leading the Indian team supposed to supply 8 subsystems that include cryoline & cryo distribution boxes, cryostats and vacuum vessels etc. to the International Thermo Nuclear Experimental Reactor (ITER) Programme.

4.16 Cryogenics In Indian Space Research Organization

Large scale use of cryogenic liquids started in India in the beginning of 1980s with the establishment of the LPSC (Liquid Propulsion System Centre) when ISRO embarked upon an ambitious programme of developing GSLV class of launch vehicles using cryo-engines with liquid hydrogen (LH2) and liquid oxygen (LO2) propollants. The main centre of LPSC is located in Mahendragiri in southern part of the country. The objectives of the centre are limited to develop technology, design, fabrication and testing of the components used in the launch vehicles. Measurement facilities relate mostly to thermal properties, thermo-vacuum behaviour, fluid flow and control, thermal insulation down to 20 K and 4.2 K. Stringent tests are carried out on the fluid components at 77 k under extreme pressure conditions (300 bar and above).

The centre has an Integrated Liquid Hydrogen Plant (ILHP) based on J-T expension process with a liquefaction capacity of 300 l per hour (0.5 ton per day) and a cold box of 30,000 l. A total storage capacity of 1,25,000 l is available with the centre. Tankers with capacity of 10,000 l to 40,000 l are used for transporting LH2 from the centre to the launching pads. Hydrogen gas used for liquefaction is produced in house by Naphtha cracking process. At peak time the plant runs for 4-5 months continuously.

Large quantities of LO2 and LN2 (~ 10 tons / day) are produced by a air separation plants (Linde Germany) which run 365 days in a year.

Testing of Cryo engine is going on for last ten years starting with 1 ton engine in 1987-88. Thrust tests are carried out at the Thrust Chamber Test Facility (TCTF) which is completely indigenous. It has LH2 tank of $9M^3$ capacity at 200 bar pressure and a LO2 tank of 4 M^3 200 bar pressure. Both the types of test that is, sea level as well as high altitude tests are carried out. LO2 is pressurized by LN2 and LH2 by H gas. He gas at 250 bars operates engine valves. Present 7.5 ton class Cryoengines needing 12 tons of propellants produce a thrust of 20 tons. Work is in progress on the development of a C-25 stage 12 ton class engine supposed to produce a thrust of 25 tons.

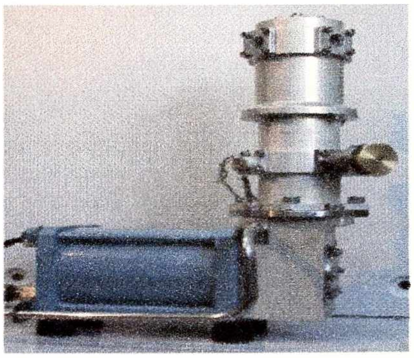
ISRO's ambitious programme includes Chandrayan already launched in Oct., 2008. It envisages orbiting a 1300 Kg space craft at a height of 100 Km in polar orbit around the moon for physical and chemical mapping. Another such programme is the development of GSLV Mark III which will have 3 stages, a solid state (2 x S200), a liquid stage (L-110) followed by cryogenic C25 stage. The vehicle lift off mass is around 630 Tons. Major activity related to cryo engine programme are at LPSC , Valiamala and at Mahendragiri. Satellite Passive and active cooler programme is well established at ISAT Bangalore. Space simulation thermo vacuum chamber activity is primarily carried out at SAC. Ahmedabad and ISAT. Bangalore.

4.17 Raja Ramanna Centre for Advance Technology (RRCAT), Indore

Raja Ramanna Centre for Advanced Technology was established by the Department of Atomic Energy, India to expand the activities carried out at Bhabha Atomic Research Centre (BARC), Mumbai, in two frontline areas of science and technology namely Lasers and Accelerators. Construction of laboratories and houses began in May 1984. synchrotron radiation sources Indus-1 and Indus-2 are being built at RRCAT. Indus-1 is a 450 MeV synchrotron radiation source with a critical wavelength of 61 angstroms. It was commissioned in June 1999. Indus-2 will be a synchrotron radiation source of nominal electron energy of 2.5 GeV and a critical wavelength of about 4 angstroms. Liquid Helium Facility (Koch 1400) with production rate 10 l/hr was installed in in 1989. Capacity augmented with Linde TCF 20 liquefier to support the Magnet collaboration programme with CERN for LHC. RRCAT developed around 1200 Superconducting corrector magnet. RRCAT has successfully developed single stage and two stage cryocolooler with minimum temperature of 10 K. The Magnetic & Superconducting Materials Activity at RRCAT has been conducting research on various classes of magnetic materials and superconductors including A15, heavy fermion and high temperature superconductors. Recently RRCAT is active on SC linac programme for ADS. RRCAT is establishing a facility for development of multi cell niobium cavity.

Experimental facilities

1. SQUID magnetometer (MPMS 5, Quantum Design, USA): for dc magnetization measurements in the temperature range 1.8-400 K, and in the presence of magnetic fields up to 5.5 Tesla.
2. Vibrating sample magnetometer (VSM, Quantum Design, USA): for dc magnetization measurements in the temperature range 2-300 K, and in the presence of magnetic fields up to 9 Tesla.
3. 16 Tesla Cryo-magnet (Oxford Instruments, UK) with variable temperature insert (2K to 300K) for magneto-transport measurements.
4. Thermal properties (specific heat, thermal conductivity, thermoelectric power) measurements system (PPMS, Quantum Design, USA) in the temperature range 2-300 K and in the presence of magnetic fields up to 9 Tesla.
5. Home made ac-susceptibility measurement system in temperature range down to 77K. This facility is now being extended to 4.2K using a new helium cryostat.
6. Temperature dependent electrical conductivity measurements down to 35K using a locally made closed cycle refrigerator.



GM Cooler Developed at RRCAT

Chapter 5

5 ANALYSIS OF INSTITUTE / INDUSTRY ACTIVITY

5.1 Over All Statistics

A	Total no of Scientific / Academic Institutes, which are directly or indirectly associated with Cryogenics/ Superconductivity Activity	**49**
B	Total no of Gas industries (Big and Small) in India	**160**
C	Total No. of other Manufacturing Industries Associated with Cryogenics	**15**
D	Total No. of Cryogenic Equipment Suppliers and Services	**20**
E	Total No. of Animal Husbandry units handling Liquid Nitrogen or having their own LN2 Plants	**45**
F	Total No. of Hospitals / Scanning Centres with Superconducting MRI Facility (Superconducting Magnet cooled by Liquid Helium)	**400**
G	Total No. of Institutes / Pharmaceutical / Petro Chemical R &D etc. having NMR with SC Magnet :	**150**

5.2 Organisation wise Institute Break up

Institute	DAE	ISRO	Other Scientific	Academic Institutes	DRDO/ Medical	Public Sector	Total
Number	**9**	**5**	**8**	**21**	**4**	**2**	**49**

5.3 Activity Wise Institute Break-Up

1.	Engaged in Basic Research only	**35**
2.	Engaged in Research on Cryogenic Engineering only	**20**
3.	Engaged in both Cryogenic Engineering and Basic Research on Superconductivity	**10**
4	Engaged in Major Projects:	**7**
5	Engaged in Teaching of Cryogenic Engineering	**6**

5.4 Break up with reference to no of personnel in this Field

1.	Single Institute with more than 50 persons	**2**
2.	Institute with more than 20 persons	**10**
3.	Institute with 10- 20 persons	**5**
4.	Institute with 5-10 persons	**10**
5.	Institute with less than 5 persons	**22**

Chapter 6

6. MAJOR FACILITIES RELATED TO CRYOGENICS AND SUPERCONDUCTIVITY AVAILABLE

In this section we highlight information on Major Facility like Helium and Nitrogen Liquefier and low temperature versatile Measurement Facility with and without Superconducting Magnet. Not able to include simple cryostats and cryogen storage vessels as there are many in number. Superconducting NMR and MRI part is presented in separate chapter.

6.1 Helium Liquefaction Facility (Old and New) in India

Year	Institute	Model	Supplier	Capacity (l / hr)	Status	Type	Key Person/ Remark
1952	NPL	ADL-50	ADL	4	W.U 1980	Reciprocating	First Plant in India : KG Ramanathan
1961	TIFR	ADL-50	ADL	10	W.U1980	Reciprocating	Girish Chandra
1962	IIT (K)	ADL-50	ADL	10	W.U	Reciprocating	R Ray & TM Srinivasan
1966	SSPL	1400	Koch	10	W.U1980	Reciprocating	AK Sridhar
1966	DU		Old Russian	5	NW		KD Choudhuri
1975	BARC	Pl-212	Philips	12	NW	Sterling	NS Satyamurthy
1975	IISc	Pl-212	Philips	12	W.U	Sterling	R Srinivasn
1977	IGCAR	1400	Koch	10	2000/WU	Reciprocating	TS Radhakrishnan
1978	IACS	Pl-212	Philips	12	W.U 1997	Sterling	A Bose
1979	TIFR	1410-S	Koch	28	W.U 2000	Reciprocating	S C Agrawal
1980	NPL		BOC	20	1996	Turbine	First Turbine plant
1980	Hyderabad University		BOC	10	NW	Turbine	
1980	IIT -Kgp		BOC	10	NW	Turbine	S K DuttaRoy
1986	IISc	1400	KOCH	20	Working	Reciprocating	S Jacob
1986	INMAS		Linde	26	W.U 2000 (to NPL)	Reciprocating	First Liquefier for MRI
1988	RRCAT	1400	KOCH	10	Working	Reciprocating	M. Thirumaleshwar
1989	IIT Madras		KOCH	10	NW	Reciprocating	R Srinivasan

Year	Institute	Model	Supplier	Capacity (l / hr)	Status	Type	Key Person/ Remark
1991	TIFR	1610S	KOCH	70	Working	Reciprocating	3rd plant in TIFR
1992	BARC	1400	Koch	20	NK	Reciprocating	
1993	BHEL	1610	Koch	40	NK	Reciprocating	For SC Generator
1993	IUC-Indore	1400	Koch	20	Working	Reciprocating	Gifted ?
1993	IIT- K	1400	KOCH	20	NW	Reciprocating	A K Mazumder
1995	IIT-Bombay	1400	KOCH	10	NK	Reciprocating	K.G Narayan Khedkar
1997	NSC/IUAC		CCI	150	Working	Reciprocating	SC Linear accelerator
2000	TIFR	TCF 50S	Linde	120	Working	Turbine	SC Linear accelerator
2000	RRCAT	TCF20	Linde	40	Working	Turbine	CERN Project
2000	IUC-indore	TCF10	Linde	20	Working	Turbine	V Ganesan
2001	IGCAR	TCF 20	Linde	40	Working	Turbine	Y Hariharan
2001	ISAT/ISRO Bangalore	1400/1600	KOCH	20	NK	Reciprocating	
2001	VECC	Helial	Air liquide	100	Working	Turbine	SC Cyclotron
2001	IPR	Helial	Air liquide	300- 400	Working	Turbine	Largest Capacity
2003	SINP	TCF 10	LINDE	20	Working	Reciprocating	Ranganathan
2004	Hyderabad Uni.	1400	KOCH	20	Working	Reciprocating	DST Funded
2005	IPR	3.8 K	**Air Liquide**	100 W	Working	Turbine	For NBI
2008	TIFR	L280	Linde	200	Working	Turbine	Commissioned on 11th July, 2008
	NW : Not working, NK : No Knowledge, WU : Wound Up						
6.2 New plants Installed recently or to be installed Shortly (Order placed)							
2009	IIT, Mumbai	1400/1600	KOCH/ Linde	20		Reciprocating	C. V Tommy
2009	IIT-Kanpur	1600	KOCH/ Linde	20		Reciprocating	R C Budhani
2009	IISc	1600	KOCH/ Linde	40		Reciprocating	3rd Plant

Year	Institute	Model	Supplier	Capacity (l / hr)	Status	Type	Key Person/ Remark
2009	VECC	Helial	Air liquide	415 W		Turbine	To be installed
2009	BARC	L280	Linde	100		Turbine	To be installed
2010	IUAC			750 – 1000 W		Turbine	Action Initiated

6.3 Installed Liquid Nitrogen Plant in Institutes

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
	NORTH					
	DELHI					
1	N.P.L, DELHI	PLN 106	Stirling	1971		WRITTEN OFF
2	N.P.L., DELHI	PLN 430	Stirling	1979		WRITTEN OFF
3	NPL, DELHI	STIRLIN-4	Stirling	2003	40	
4	I.I.T., DELHI	PLN 108S	Stirling	1990		
5	I.I.T., DELHI	PLA 433	Stirling	1973		WRITTEN OFF.
6	I.I.T, DELHI	Conv. PLN	Stirling	2006	40	
7	S.S.P.L., DELHI	PLA 433	Stirling	1973		NOT IN USE
8	S.S.P.L., DELHI	PLN 430S	Stirling	1987		NOT IN USE
9	S.S.P.L., DELHI	PLN 106	Stirling	1972	NO	WRITTEN OFF
10	SSPL, DELHI	STIRLIN -4	Stirling	2002	40	
11	N.I.I., DELHI	PLN 106S	Stirling	1985		WRITTEN OFF
12	N.I.I., DELHI	MNP 6/1/500/C	Stirling	1994	NO	WRITTEN OFF
13	N.I.I, DELHI	STIRLIN-2	Stirling	2004	20	
14	A.I.I.M.S., DELHI	PLN 108S	Stirling	1989	NO	WRITTEN OFF
15	AIIMS, DELHI	MNP 10/1/300/C	Stirling	2001	10	
16	AIIMS, DELHI	MNP 10/1/300/C	Stirling	2001	10	
17	N.S.C., DELHI	RLS 80 PROJ.	Stirling	1996		CONV. TO OPEN LOOP
18	NSC, DELHI	Upgrade RLS 80	Stirling	2006	150	UNDER AMC
19	DRDE, GWALIOR	PLN 106	Stirling	1976		WRITTEN OFF
20	INMAS, DELHI	PLN 430	Stirling	1986	40	

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
21	MRC,DELHI	STIRLIN-1C	Stirling	2005	10	
22	LASTEC, DELHI	STIRLIN-4	Stirling	2007	40	WARRANTY
23	LASTEC, DELHI	LINIT-25	Linde	1991		WRITTEN OFF
24	IOP, DELHI	STIRLIN ECO	Linde	2007		
25	DELHI UNIV.	PLN 430	Linde	1977		WRITTEN OFF
26	Delhi. Univ.	LINIT-25	Linde	1991	25	
27	NBPGR, New Delhi	LINIT-10	Linde	1998	10	
	HARYANA					
28	USIC, KURUKSHETRA	PLN 106	Stirling	1981		WRITTEN OFF
29	RSIC, CHANDIGARH	2 X PLN 106S	Stirling	1983		WRITTEN OFF
30	RSIC, Chandigarh	LINIT-10	Linde	1998		
31	IMT, CHANDIGARH	108S	Stirling	1989		WRITTEN OFF
32	C.S.I.O., CHANDIGARH	MNP 10/1/300/C	Stirling	1997	10	
33	CSIO, CHANDIGARH	STIRLIN2G	Stirling	2004	20	
34	PUNJAB UNI, CHANDIGARH	STIRLIN 1	Stirling	2009	10	TO BE INSTALLED
35	IMT, CHANDIGARH	STIRLIN-2	Stirling	2001	20	
	UTTARPRADESH					
37	S.G.P.G.I., Lucknow	MNP 25/2	Stirling	1989	20	
38	ALIGARH MUS UNI.	PLN 106	Stirling	1979		WRITTEN OFF
39	I.I.T, KANPUR	MNP 20/2/500/C	Stirling	1998	20	
40	DMSRDE, KANPUR	PLN 106	Stirling	1985		WRITTEN OFF
41	BHU, CHEMISTRY	PLN 106	Stirling	1978		WRITTEN OFF
42	BHU CHEMISTRY	PLA 107	Stirling	1971		WRITTEN OFF
43	BHU METALLURGY	PLN 106	Stirling	1981		WRITTEN OFF
44	BHU, PHYSICS	PLN 106	Stirling	1970		WRITTEN OFF

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
45	BHU PHYSICS	MNP 6/1/500/C	**Stirling**	1990	10	
46	BHU MOL. BIO	PLN 108S	**Stirling**	1990	10	
47	BHU, PHYSICS	STIRLAB 200	**Stirling**	2008	2	WARRANTY
48	BHU, ANATOMY	STIRLAB 200	**Stirling**	2008	2	WARRANTY
49	BHU, SCIENCE	STIRLIN ECO	**Stirling**	2009	5	WARRANTY
50	USIC, ROORKIE	PLN 106	**Stirling**	1976		WRITTEN OFF
51	LUCKNOW UNI.	PLN 106	**Stirling**	1975		WRITTEN OFF
52	C.D.R.I, LUCKNOW	PLA 107	**Stirling**	1972		WRITTEN OFF
53	C.D.R.I, LUCKNOW	PLN 108S	**Stirling**	1978		WRITTEN OFF
54	C.D.R.I, LUCKNOW	MNP 9/1	**Stirling**	1988	10	
55	IIT, ROORKEE	STIRLIN-1C	**Stirling**	2004	10	
56	IRDE, D'DUN	MNP 10/1/300/C	**Stirling**	1999	10	
57	OPTO ELEC., DEHRADUN	STIRLIN-1C	**Stirling**	2005	10	
58	IRDE, DEHRADUN	PLN 106	**Stirling**	1973		WRITTEN OFF
59	I.I.P, DEHRADUN	PLN 106	**Stirling**	1973		WRITTEN OFF
60	I.I.P, DEHRADUN	PLN 108S	**Stirling**	1990		WRITTEN OFF
61	ORD,FTY, DEHRAD	PLN 106	**Stirling**	1981		WRITTEN OFF
62	OPTO ELEC., DEHRADUN	MNP 50/2/E/C	**Stirling**	1991	40	
63	I.P.E, DEHRADUN	PLN 106	**Stirling**	1984		WRITTEN OFF
64	G.B. PANTH UNIV.	PLN 106	**Stirling**	1985		WRITTEN OFF
65	DRDE, GWALIOR	PLN 106	**Stirling**	1968		WRITTEN OFF
66	DRDE, GWALIOR	MNP 10/1/300/C	**Stirling**	1999	10	
67	CIMAP, LUCKNOW	MNP 10/1/300/C	**Stirling**	2000	10	
68	CDRI, LUCKNOW	STIRLIN-1 EXT.	**Stirling**	2003	10	

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
69	ALLAHABAD UNI.	STIRLIN ECO	Stirling	2006	5	
	RAJASTHAN					
70	CEERI, PILANI	PLN 106S	Stirling	1978		WRITTEN OFF
71	USIC, JAIPUR	PLN 106S	Stirling	1985		WRITTEN OFF
72	DL, JODHPUR	STIRLAB 200	Stirling	2006	2	WARRANTY
	PUNJAB					
73	GNDU, AMRITSAR	PLN 106/MNP1 0	Stirling	1998/99	10	
74	USIC, PATIALA	PLN 106	Stirling	1978		WRITTEN OFF
	HIMACHAL PRADESH					
75	CRI, KASAULI	PLA 107	Stirling	1972		WRITTEN OFF
76	IIAP, HANLEH	MNP 5/1	Stirling	1999	10	
77	IHBT,PALAMPUR	STIRLIN-1C	Stirling	2005	10	
	JAMMU & KASHMIR					
78	NRL, SRINAGAR	PLN 106	Stirling	1978		WRITTEN OFF
79	R.R.L, JAMMU	PLN 106S	Stirling	1981		WRITTEN OFF
80	R.R.L, JAMMU	STIRLIN-1	Stirling	2002	10	
	SOUTH					
	CHENNAI					
81	I.I.T., MADRAS	PLN 106	Stirling	1971	NO	WRITTEN OFF
82	I.I.T, MADRAS	MNP 25/2/2000/C	Stirling	1992	20	
83	I.I.T, MADRAS	PLN 108S	Stirling	1987		WRITTEN OFF
84	IGCAR, KALPAKKAM	PLN 106	Stirling	1977		WRITTEN OFF
85	IGCAR, KALPAKKAM	SPC-01 UPGRADE	Stirling	2005	10	
86	IGCAR, KALPAKKAM	MNP 50/2/200/C	Stirling	1990	20	
87	AC COLLEGE	PLN 106	Stirling	1979		WRITTEN OFF

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
88	TANUVAS	MNP 10/1/300/C	**Stirling**	2000	10	
	TAMILNADU					
89	NPCIL, KUDANKULAM	2 X STIRLIN-4	**Stirling**	2008	80	WARRANTY
	ANDHRA PRADESH					
90	SV UNI. TIRUPATI	PLA 107	**Stirling**	1965		WRITTEN OFF
91	SV UNI. TIRUPATI	**PLN**	**Stirling**	1998	10	
92	DMRL, HYDERABAD	PLN 106	**Stirling**	1972		WRITTEN OFF
93	DMRL, HYDERABAD	STIRLIN-1C	**Stirling**	2006	10	
94	ECIL, HYDERABAD	PLN 430	**Stirling**	1975		WRITTEN OFF
95	NGRI, HYDERABAD	PLA 107	**Stirling**	1977		WRITTEN OFF
96	CCMB, HYDERABAD	PLN 106S	**Stirling**	1984		WRITTEN OFF
97	CCMB, HYDERABAD	STIRLIN-1E	**Stirling**	2003	10	
98	IICT, HYDERABAD	STIRLIN-2	**Stirling**	2006	20	
99	CMC, VELLORE	STIRLIN-1E	**Stirling**	2006	10	
100	SRICHITRA	STIRLAB 200	**Stirling**	2006	2	
101	HYDERABAD UNI.	STIRLIN-2	**Stirling**	2007	20	
102	HYDERABAD Uni.	PLN 106	**Stirling**	1978		WRITTEN OFF
103	HYDERABAD UNI.	LINIT-25 & LINIT-10	**Linde**	1990	30	
104	NIN, HYDERABAD	STIRLIN ECO	**Stirling**	2007	5	
105	INDIA-SWISS PROJECT, Kurnool	LINIT-10	**Linde**	1989	10	Not Known
106	INDIA-SWISS PROJECT, Medak	LINIT-10	**Linde**	1989	`10	Not Known
107	INDIA-SWISS PROJECT, Nalgonda	LINIT-10	**Linde**	1989	10	Not Known
108	OSMANIA UNI. HYDERABAD	MNP 6	**Stirling**	1992	10	

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
109	ANDHRA UNI. VISAKHAPATNAM	PLN 108S	Stirling	1992	NO	WRITTEN OFF
	KARNATAKA					
111	CFSB, H'GHATTA	PLN 106	Stirling	1977		WRITTEN OFF
112	CSCC, HEBBAL	PLN 106	Stirling	1977		WRITTEN OFF
113	CMPU, MANIPAL	PLN 106	Stirling	1979		WRITTEN OFF
114	IVRI, BANGALORE	PLN 106	Stirling	1979		WRITTEN OFF
115	KMF, BANGALORE	PLN 430S	Stirling	1985		WRITTEN OFF
116	DHARWAR MILK	PLN 430	Stirling	1979		WRITTEN OFF
118	N.J.F, OOTY	PLN 106	Stirling	1979	6	
119	I.I.SC., BANGALORE	PLN 106	Stirling	1960		WRITTEN OFF
120	I.I.SC., BANGALORE	PLN 430	Stirling	1972		WRITTEN OFF
122	I.I.SC., BANGALORE	STIRLIN-4	Stirling	2001	40	
123	ISRO, BANGALORE	PLN 106	Stirling	1972		WRITTEN OFF
124	GULBARGA UNIV	PLN 108S	Stirling	1996		WRITTEN OFF
	KERALA					
125	CALICUT UNIV	PLN 106	Stirling	1974		WRITTEN OFF
126	T.B.G.R.I, PALODE	P. PLN	Stirling	1998	NO	
127	RGC, TRIVANDRUM	MNP 10/1/300/C	Stirling	2001	10	
128	RRL, TRIVANDRUM	STIRLIN COMPAC T	Stirling	2007	10	
129	SRICHITRA INST	STIRLAB 200	Stirling	2007	2	
	WEST					
	MUMBAI					
130	C.R.I., PAREL	PLN 106S	Stirling	1982	NO	WRITTEN OFF
131	C.R.I, PAREL	MNP 10/1/300/C	Stirling	2000	10	

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
132	TIFR, MUMBAI	PLN 106	Stirling	1968		WRITTEN OFF
133	TIFR, Mumbai	LINIT-25	Linde	1989		WRITTEN OFF
134	BARC, MUMBAI	PLN 430	Stirling	1982		WRITTEN OFF
135	BARC, MUMBAI	PPG 102	Stirling	1985		WRITTEN OFF
136	BARC, MUMBAI	PLHe	Stirling	1980		WRITTEN OFF
137	RAPP, TARAPUR	PLN 108S	Stirling	1981		WRITTEN OFF
138	UDCT, MATUNGA	PLN 108S	Stirling	1985		WRITTEN OFF
139	UDCT, MATUNGA	STIRLIN ECO	Stirling	2008	5	WARRANTY
140	IIT, POWAI-ELEC	STIRLIN-1 ECONOMY	Stirling	2005	10	
141	IIT, POWAI-CHEM	STIRLAB-200	Stirling	2006	2	
142	IIT, POWAI SAIF	STIRLIN COMPACT	Stirling	2007	10	
143	IIT, POWAI	PLN 106S	Stirling	1972		WRITTEN OFF
144	IIT, POWAI	PLN 430	Stirling	1978		WRITTEN OFF
145	IIT, POWAI-MET	STIRLIN ECO	Stirling	2009	5	TO BE INSTALLED
146	IIT, POWAI, MECH	STIRLIN 4	Stirling	2009	40	TO BE INSTALLED
147	MUM UNIVERSITY	STIRLIN ECO	Stirling	2009	5	TO BE SHIPPED
	MAHARASHTRA					
150	M'WADA UNIV.	PLN 106S	Stirling	1971		WRITTEN OFF
151	NCCS, PUNE	STIRLIN-1	Stirling	2009	10	TO BE Installed
152	NCCS, PUNE	MNP 6/1	Stirling	1994	10	OWN SERVICE
153	M.C.C, PUNE	STIRLIN-1	Stirling	2002	10	
155	PUNE UNI.	PLN 106	Stirling	1969		WRITTEN OFF
156	PUNE UNI.	MNP 10/1/300/C	Stirling	1996	10	
157	N.C.L., PUNE	PLN 106S	Stirling	1985		WRITTEN OFF

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
158	N.C.L., PUNE	PLN 106	**Stirling**	1968		WRITTEN OFF
159	N.C.L., PUNE	MNP 10/1/300/C	**Stirling**	1996	10	OWN SERVICE
160	TELCO, PUNE	MNP 10/1/300/C	**Stirling**	1998	10	
	GUJARAT					
161	HCPL, NADIAD	PLN 106S	**Stirling**	1971		WRITTEN OFF
162	P.R.L, AHMEDABAD	PLN 106	**Stirling**	1968		WRITTEN OFF
163	CSMCRI, BHAVNAGAR	MNP 9/1	**Stirling**	1985	10	
164	SICART, ANAND	PLN 108S/C	**Stirling**	1998	10	
165	NIT,SURAT	STIRLIN-ECO	**Stirling**	2009		TO BE INSTALLED
	GOA					
166	NIO - GOA	StirLIN-1 Economy	**Stirling**	2005	10	
167	NCAOR - GOA	StirLIN-1 Economy	**Stirling**	2006	10	
	MADHYA PRADESH / CHHATTISGARH					
168	RAIPURENGG. COLL.	PLN 108S	**Stirling**	1992	10	
169	CAT, INDORE	MNP 25/2/DF/C	**Stirling**	1991	20	
170	CAT, INDORE	LINIT-50	**Linde**	2007	50	
171	IUC, Indore	LINIT-25	**Linde**	1987	20	FROM NSC
172	IUC, INDORE	STIRLIN-4	**Stirling**	2006	40	
173	IUC, INDORE	PLN 106	**Stirling**	1994		WRITTEN OFF
174	SREE SYNTHETICS	PPG 102	**Stirling**	1988		WRITTEN OFF
175	SREE SYNTHETICS	PPG 102	**Stirling**	1989		WRITTEN OFF
176	RMRCT, JABBALPUR	STIRLIN ECONOMY	**Stirling**	2008	5	WARRANTY
	EAST					
	WEST BENGAL					
177	IACS, KOLKATA	SPC01 UPGRADE	**Stirling**	2005	10	

S.No	Institute name	Model	Supplier	Year	Capacity Litres/hr	Remarks
178	IACS, KOLKATA	PLN 106	**Stirling**	1973		WRITTEN OFF
179	IACS, KOLKATA	MNP 9/1	**Stirling**	1988	10	AMC
181	SINP, KOLKATA	PLN 106	**Stirling**	1972		WRITTEN OFF
182	SINP, KOLKATA	MNP 9/1-2	**Stirling**	1996	10	AMC
183	VECC,	PLN 430	**Stirling**	1976	NO	NOT IN USE
183	VECC		**PCI**	2002	40	Not working
184	USIC, KOLKATA	PLN 106S	**Stirling**	1990		
185	USIC,KOLKATA	CONV PLN	**Stirling**	2006	10	
186	SN BOSE INST	STIRLAB 200	**Stirling**	2008	2	WARRANTY
187	IIT, KHARAGPUR	PLN 106	**Stirling**	1976		WRITTEN OFF
188	IIT, KHARAGPUR	PLN 430	**Stirling**	1983		WRITTEN OFF
189	IIT, KHARAGPUR	MNP 12/1/1000/ C	**Stirling**	1994	10	
190	BURDWAN Uni.	LINIT-05	**Linde**	1993	5	
	BIHAR /ORISSA/ ASSAM/ MEGHALAYA					
191	SAIL, RANCHI	PLN 106	**Stirling**	1984		NK
192	INST. OF PHYS., BHUVANESHWAR	PLN 108S	**Stirling**	1991	10	
193	RRL, BHUVANESHWAR	STIRLIN ECONOM Y	**Stirling**	2008		WARRANTY
194	DIBRUGARH UNIV	STIRLAB 200	**Stirling**	2008		WARRANTY
195	N.E.H.U, SHILLONG	PLN106S/ MNP10	**Stirling**	1984/99	10	
197	NBDC, BHUTAN	STIRLAB 200	**Stirling**	2008		TO BE INSTALLED

6.4 Low Temperature Measurement System PPMS/ VSM/

S.No	Institute	Equipment/ Model/ Supplier	Main Features	Contact Person	Supplier
West Zone					
1	**RRCAT Indore**	MPMS5, SQUID Magnetometer	1.8K- 400K, 5.5 T	S. B Roy	Quantum Design, USA
		PPMS-9	2-300K, 9 T		Do
		VSM	2-300 K, 9 T		Do
		Home made Cryostat	4.2 K- 300K		
		Cryostat with magnet	16 T SC Magnet		Oxfords, UK,
2	**UGC-DAE CSR. Indore**	PPMS- 14 LH	1.9- 400K,14 T	V Ganesan	Quantum Design,2005
		P-525 VSM	14 T	A. Baneerjee	Do
		Mossbauer Spectrometer	7 T, 1.5- 300K	A K Gupta	M/s Jainis
		Cryostat	5K- 300K		Home Made
		AC Susceplibility	80 K- 300 K		
		ULT Facility	50 mK		Gifted by G. Klipping
3.	**TIFR, Mumbai**	PPMS-9	2-300K, 9T	A. K. Nigam	Quantum Design
		MPMS-XL7		A. K. Nigam	Do
		PPMS-14LH		Sampathkumaran	Do
		MPMS SQUID		A. K Grover	2007
		MPMS 5		PL Paulose	Do
		Dilution Refrigerator	mK Range		
		Adiabatic De Mag Ref	Below 1 mK		Being Built
		Cryostats with magnet			
4	**BARC, Mumbai**	SQUID Magnetometer MPMS 5	1.8- 400K, 5.5 T	Ravikumar	Quantum Design
		VSM			
		14 Tesla Cryostat	4.2 – 300 K, 14 T		Oxford, UK
		7 T Cryostat	4.2- 300*, 7 T		Home Made
5.	**IIT Mumbai**	PPMS-9 P525VSM Torque Magnetometer	1.8- 400K, 9T	C V Tomy	Quantum Design,2006
6	**UGC-DAE CSR, Mumbai**	Cryo Free Sc Magnet for Neutron Scattering	7T		Cryogenics UK

S.No	Institute	Equipment/ Model/ Supplier	Main Features	Contact Person	Supplier
SOUTH ZONE					
7	**IISC. Bangalore**	SC Magnet Cryostat	1.3- 325 K	Venkatraman	Janis,2004
		Optical Spectrometer/ Oxford Cryostat	2-300K		Bruker/ Oxford 2004
		He3- HHV System	280mk,8T		Janis
		Dilution Refrigerator(MN K-500)	7mk,14 T		Leiden Cryogenics
		MPMS XL5		Vasudevan	Quantum Design
		Cryostat with CCR	4-300K		Cryo Mech
8	**IIT. Madras**	MPMS 5	1.8- 400K,5.5T	M.S R Rao	QD- 1998
		Cryostat with Magnet	300mk, 5T		CCI- 1992
		Cryostat with CCR	12K-300		Jainis
9	**IGCAR. Kalpakkam**	VSM	16T, 2-300K	Bharthi	Cryogenics UK-2008
		Heliox Cryostat	0.3-300K		Oxford
		Cryostat for Sp Heat, AC Susceptibility			Home Made
10	**Hyderabad University.**	PPMS		Nano Technology Cell	QD- 2009
		VSM-9T			
		Continuous Flow Cryostat			Jainis-2009
		8T Magnet Cryostat	4.2- 300 K, 8T	Physics Department	Cryogenics. UK
		Cryostat	1.3- 300 K		CIA, USA
		Cryostat	1.3 – 300 K,8T		AMI
10.a	**Bharathidasan University.**	Cryostat with Sc Magnet and VTI	8T, Cryo free	S Arumugam	2008
11	**CLCR. Bangalore**	MPMS XL5	Evercool		QD
12	JNCAR, Bangalore	PPMS-9	Evercool	Sunderasan	QD
		Cryo Free Sc Magnet			Jainis

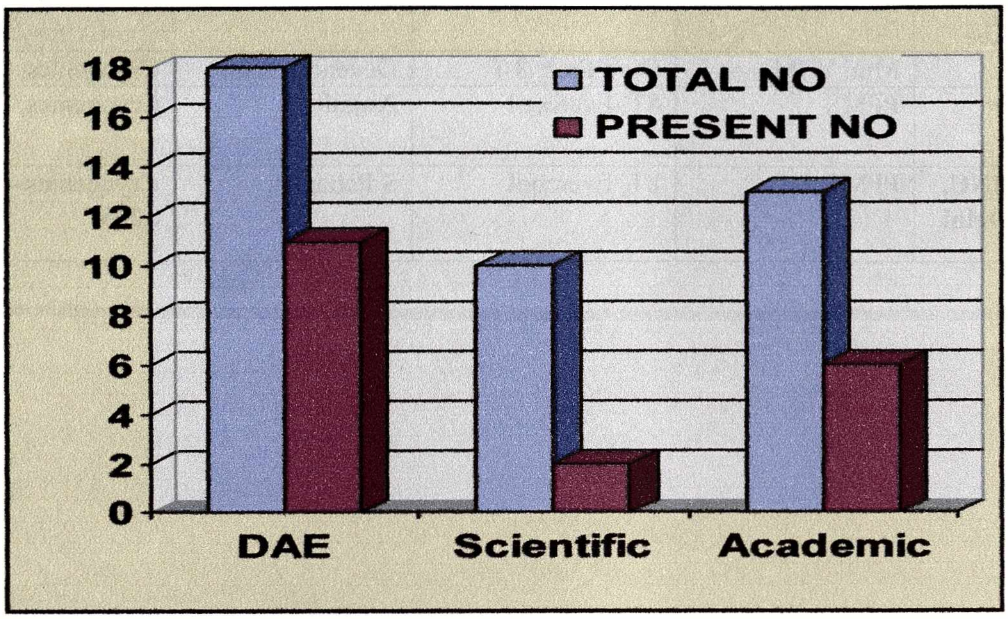
S.No	Institute	Equipment/ Model/ Supplier	Main Features	Contact Person	Supplier
EAST ZONE					
13	**IACS Kolkata**	MPMS-5	Evercool	D Chakrabarthy	QD-2007
		Mini VSM	4T, 2-100K	S Mazumder	Cryogenics.UK
		PPMS (Cryofree)	9T, 1.8- 300K	S. K Dey	Cryogenics. UK,2007
		Cryostat with Magnet	8T		Oxford- 1988
		Cryo Free Sc Magnet	**16 T**	D D Sharma	Cryogenics UK,2009
14	**SINP Kolkata**	Susceptometer	1.8K- 325		Cryobird
		Cryostat with Magnet	8T		Oxford
		MPMS XL7	7T	Podder	OD, 2004
		MPMS XL7	Evercool, 7 T	Milan Sanyal	QD
		Cryostat with Magnet	14T,1.5- 400K		Oxford
15	**JU. Kolkata**	Cryo Free Magnet System	7T	K Chattapadhyay	Cryogenics
16	**UGC-DAE CSR. Kolkata**	PPMS	15T (CryoFree)	Dipankar Das	Cryogenics,2009
		SQUID Magnetometer	7T		Cryogenics,2009
		Mossbaur spectrometer	16K		
17	**SNBSC. Kolkata**	PPMS		P. K. Mukhopadhyay	Cryogenics, 2009
		Magnet with Cryostat			Home Made
18	**IIT. Kharagpur**	PPMS	8T, Cry Free	T K Nath	2008
		Cryo Free Magnet	5T, 50 mm Bore		Jainis 2006
19	**IIT, Guahati**	VSM		A Srinivasan	2008
NORTH ZONE					
20	**IIT. Kanpur**	MPMS XL5	5 T	R.C Budhani	QD- 2002
		PPMS – 14 LH	14		QD- 2002
		Dilution refrigerator	30 mk		
		Mossbeur Spectrometer			
		Cryostats			Home Made
21	**NPL. Delhi**	Cryostat with Magnet	7T, 11 T		Home made
		PPMS	Evercool		Ordered, QD

S.No	Institute	Equipment/ Model/ Supplier	Main Features	Contact Person	Supplier
22	**IIT. Delhi**	Squid Magnetometer	Evercool 7T	R. Chatterjee	QD, 2009
23	**IIT Roorkee**	MPMS XL7	7 T	Ramesh Chandra	QD,
		Mini VSM	Cryo Free, 8 T	Devendra Kaur	Cryogenics, 2009
24	**Jaipur Uni.**	PPMS	8T, Evercool	Anjali	Cryogenics, 2008
25	**SPS, JNU. New Delhi**	PPMS	8T, Evercool	S Pattanaik	Cryogenics - 2005

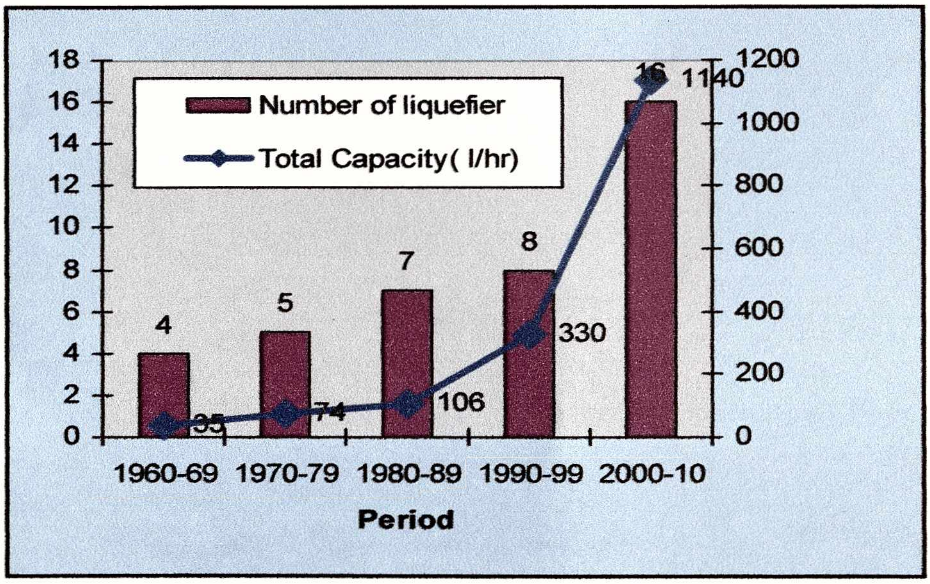
6.5 Graphical Representation of Major Facility

A. Helium Liquefier/ Refrigerator;

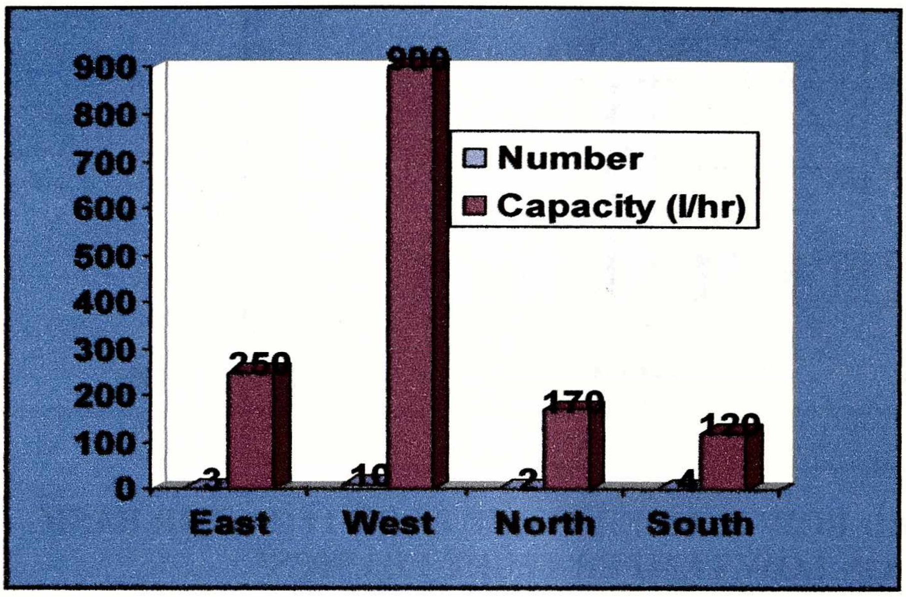
i) Total no of Helium liquefier/refrigerator installed since 1952 and at present operational and to be installed together



ii) Growth of Helium Liqefier/ Refrigerator (Added during the Period)



iii) **Zone Wise Distribution of Presently Operating Liquefier/ Refrigerator with Capacity**

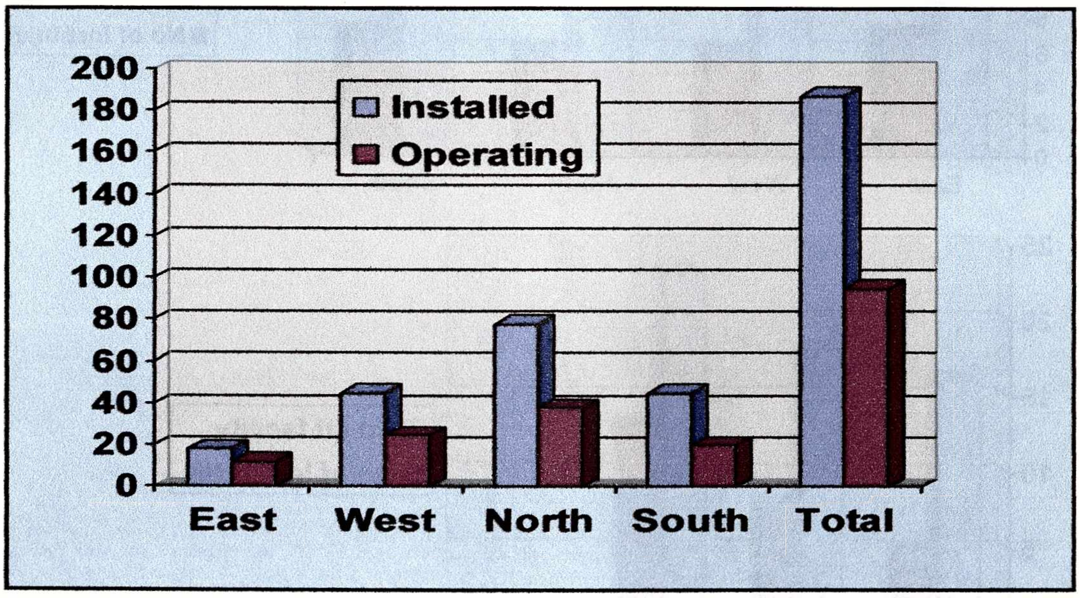


iv) **Present Operational Liquefier : Total 19 with Capacity 1180 Litres/hr.**

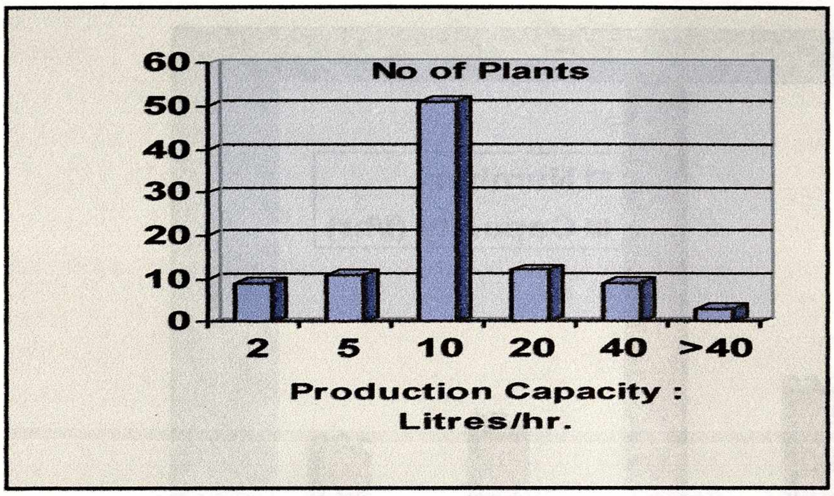
A. **Major Project : 6 with Capacity 930 litres/hr (IPR + VECC + IUAC+ TIFR LINAC)**
B. **For Basic Research & NMR : 13 (250 litres/hr)**

B. LIQUID NITROGEN PLANT IN INSTITUTES *(Excluding Animal Husbandry)*

i) Total no of installed plants and presently operating plants



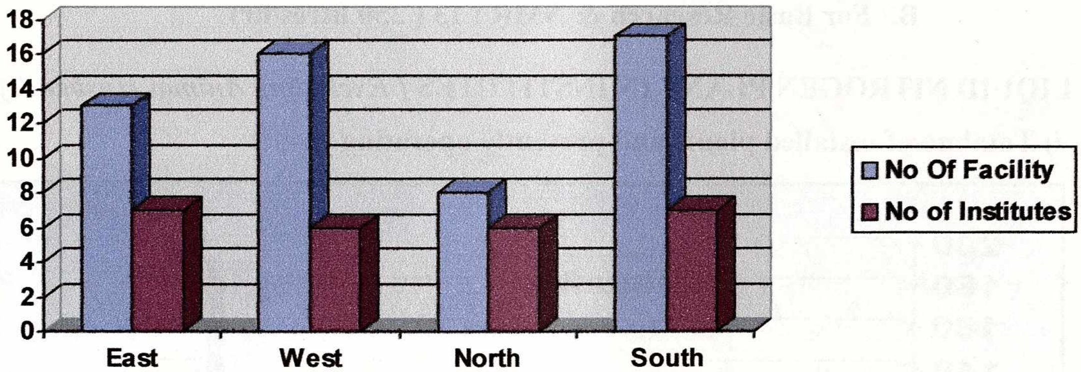
ii) Production Capacity (Litres/ hr.) distribution

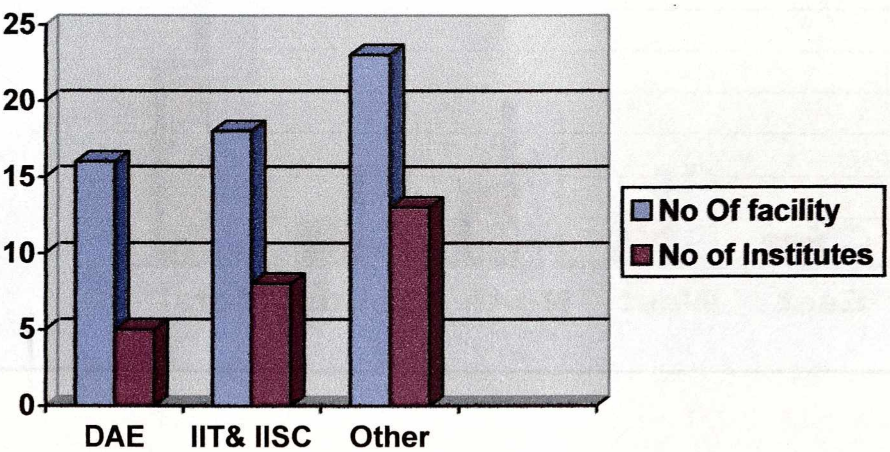


C. IMPORTED LOW TEMPERATURE FACILITIES FOR BASIC RESEARCH ON LOW TEMPERATURE PHYSICS/ SUPERCONDUCTIVITY AND MAGNETISM.

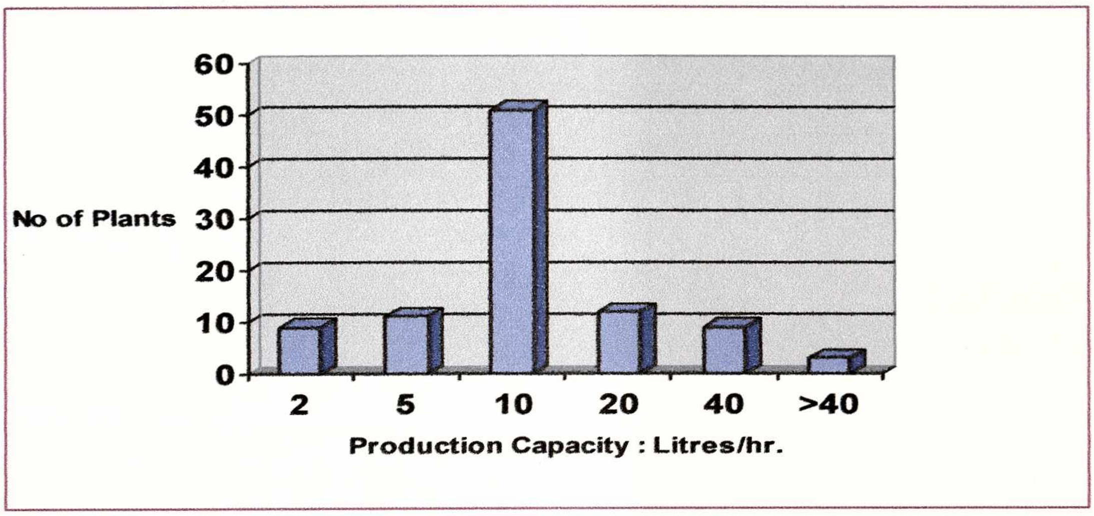
(PPMS, MPMS, SQUID MAGNETOMETER, VSM, CRYO FREE MAGNET)

i) Distribution of Major facilities in Zone wise and institute wise





Production Capacity (Litres/hr.) distribution



Chapter 7

7. INFORMATION ON ACTIVITIES IN MAJOR INSTITUTES

7.1 Cryo Engineering / Technology, Cryo Component Development :

7.1.1 *IISc. Bangalore*

Cryogenic Technology Centre (CTC), Indian Institute of Science, Bangalore was, some years ago, involved with the design development of Cryotanks for special application for ISRO, the Cryo Grinding Technique and worked on other such application projects. More recently they they have established a laboratory for the development of Cryocoolers (GM and Pulsed tube) and linear motor. This centre along with Mechanical Group are closely associated with ISRO programmes.

7.1.2 *IIT Bombay*

The Thermal Laboratory of Mechanical Engineering Department, IIT Bombay was involved in the development of Stirling based nitrogen liquefier and Quick Freezing of marine products. It is presently engaged in the indigeneous development of Stirling Cryo Coolers, Pulse Tube Cryo Coolers and Cryogenic Insulation.

7.1.3 *IIT Kharagpur*

Cryogenic Engineering Centre, IIT Kharagpur was the first institute in the country to have started work on cryogenic engineering. They established a Heat and Mass Transfer Laboratory and mainly Concentrated on the performance analysis of Cryogenic Heat Exchangers and Turbines. The focus had been to bridge the gap between gas industries and Academics.

7.1.4 *RRCAT Indore*

Raja Ramanna Centre for Advance Technology (RRCAT), Indore had a Cryogenic Section right from its inception, led by Dr. Thirumalleswar. This Centre has developed successfully GM coolers and used them in the laboratory. A project on the Development of Reciprocating Expansion based Helium Liquefier was also initiated and is at advance stage of completion. RRCAT also fabricated a large number of superconducting sextupole magnet and supplied them to CERN.

7.1.5 *BARC Mumbai*

Around 1995 BARC created a new division called 'Cryogenic Technology Division' for the indigeneous development of KW class 20 K and 4.2 K Refrigerators. BARC also established a multifilamentry Superconducting NB- Ti wire development facility.

7.1.6 *IIT Madras*

The Refrigeration Department of IIT Madras is engaged on Mixed Refigeration systems.

7.1.7 *IGCAR kalpakkam*

IGCAR, Kalpakkam had in the past successfully developed a Helium Gas Purifier. They have also successfully developed SQUID. Reactor group is engaged on Cover gas purification project to purify Argon from radioactive contaminant

7.1.8 *NIT Rourkela*

NIT Rourkella initited Cryogenic Engineering Programme after Dr Sunil Sarangi took over as Director. Development of Helium Compressor and Helium Purifier are the current range of activity. NIT also intitated a programme on Cryo Cooler Development and Thermal Analysis.

7.1.9 *NIT Surat*

NIT surat under Mechnical Engineering Department has initiated on Cryocooler development and analysis programme. They are also taking part on ITER and IPR Development Programme

7.1.10 *DRDO*

Solid State Physics Laboratory (SSPL),Delhi & LASTEC under DRDO are involved in the development of Miniature Coolers primarily for cooling IR detectors.

7.1.11 *NPL New Delhi*

NPL was engaged earlier on the development of Superinsulated Cryocontainers, a J-T based Air Liquefier and Crypo Probes. In the later years NPL produced a good number of superconducting magnets (7 T and 11 T)

7.1.12 *ISRO*

LPSC (Valiamala, Mahendragiri and Bangalore) are engaged on Development of Cryoenginc Engine and assicated components, ISAT Bangalore on satelite similation chamber and active cooler. SAC, Ahmedabad on development of 80 K simulation chamber.

In addition, many institutes like Walchand College of Engineering, LD College of Engineering, Ahmedabad, TKM College of Engineering, Trivandrum, Vellore Institute of Technology, NIT Calicut, Nirma Institute of Technology too are engaged in small scale activities in their Mechnical Engineering Departments.

7.2 Institutes Engaged on Basic Research at Low Temperature & Superconductivity

At present there are good number of Institutes, which are actively engaged on low temperature activities. Earlier days there were limited no of instittes as liquid helium was rare comodity. Today with the discovery of HTSC and availability on Cryofree system along with ready built measurement facility prompted many scientist/ academics to work in this field. Not possible to report on Research work at different institutes in this report. Institutes here classified in two catagories, A. where no of facilities as well as no of personnel working are significant and B. Whwere activity is with limited man power and facility C. Newly established programme based on individual level

A. TIFR. Mumbai, IISC. Bangalore, UGC- DAE CSR. Indore, RRCAT. Indore, SINP, Kolkata, NPL. Delhi, IIT. Kanpur, Hyderabad University, IACS. Kolkata, IGCAR. Kalpakkam

B. IIT. Kharagpur, IIT Chennai, IIT Mumbai, BARC. Mumbai,VECC Kolkata

C. IIT. Delhi, JNU. Delhi, IUC- Kolkata, JNCAR, Bangalore, SNBSC. Kolkata, BharthiDarshan University, Trichur, IIT Roorkee, IIT Guwati, IUAC. Delhi

7. 3 Institutes with Major Development Programme in This Field

1. IPR. Gandhinagar: The iinstitute was established by DST to carry out Fusion based Research Programme. Aditya tokamk was indigeneously developed. During mid 90, IPR embarked on major nationnal programme on Steady State Superconducting Tokamak. Largest capacity Helium refrigerator of approx capacity 1.3 KW at 4.2 K was installed in 2002. IPR is engaged on large SC magnet, cryostat, cryoline, cryopump etc. At present ITER- INDIA a section of IPR is taking part on primary work on Complete cryo distribution line for ITER and Cryostat

5. IUAC. DELHI: Activity on Cryogenics started here with the programme on Development of Superconducting Linear Accelerator in mid 90. Expertise are available on Superconducting Cavity, Cryo Distribution line, Cryomodule, Cryo instrumetation and large helium liquefier of capacity 150 litres/ hr. They have also started development work with SC magnet like cryo free magnet, quadrupole magnet. IUAC is using HTSC based cryo free magnet for ECR source.

6. LPSC. Valiamala : Primary engaged on design of cryo engine and component develoment and testing at low temperature

7. LPSC. Mahendragiri: Engaged on assembly of cryoengine, simulation testing of thurst by using liquid hydrogen and liquid oxygen, prior to attache on launching vehicle.

8. TIFR. Mumbai: For Development of Superconducting linear accelerator TIFR has developed expertise on Lead coated copper cavity, cryo line and cryomodules.

9. VECC. Kolkata: Superconducting Cyclotron project was approved by DAE in the beginning of 1990. Expertise available on large SC magnet, cryostat, cryoline etc. Quadrupole magnet, SEMS along with SC cavity programme were alsi initiated.

Chapter 8

8. MAJOR PROJECTS FUNDED BY GOVT AGENCIES

8.1 National Superconductivity Programme

Soon after the discovery of critical temperature above liquid nitrogen tempeartiue for Yittrium – barrium- cuprate in 1986, Scientist from all over world engaged in further research and application of this type of High Temperature Superconductor (HTSC). In India, National Superconductivity Programme (NSP) was launched in 1987 under the chairmanship of Prof. C. N R Rao. The programme management Board under NSP sanctioned no of projects in basic research and applications in two phases. A Total amount of 50.00 crores was provided for NSP from 1987 to 1996. Three funding agencies namely DST, DAE and CSIR were involved in the implementation programme. In this report it is not possible to list all projects details as the number is more than 100. Summaries of the NSP are given below. Other than NSP programme, few major project details (Project cost more than Rs. 30,000,00) in this field are listed under different catagories

Funding Agencies	NSP Phase –1 (1988- 1991)			NSP, Phase 2 (1991- 1996)		
	No of Institutes	Project on Basic Research	Project on Application	No of Institutes	Project on Basic Research	Project on Application
DST	24	34	12	26	37	16
DAE	6	5	7	6	7	7
CSIR	3	2	3	4	2	3
Total	33	41	22	36	46	26

Thus Total no of Projects in Phase 1 and Phase 2 135
No. of Projects on Basic Research : 87
No. of Projects on Application: 48
Funding Details under NSP Programme;

S.No.	Organization	Funding Rs. (in crore)
1	DST	24
2	DAE	16
3	CSIR	10
	TOTAL	50

Under the Basic Research Category, projects were sanctioned in the area of High Temperature Superconductors (HTSC) under the subheads:

1. **Theory of Superconductivity**
2. **Synthesis of New superconductors**
3. **Physical measurement and**
4. **Characterisation (Major Fraction).**

Under Application Category, projects were sanctioned on both, Low Temperature Superconductors (LTSC) as well as on HTSC. On LTSC major projects were sanctioned on the Development of Multifillamentry Nb- Ti wire, SC magnets, Superconducting High Gradient Magnetic Separators (SC-HGMS), Superconducting Generators, Thin Film Dc SQUID, Josephson Series Array Voltage Standard, SC Energy Storage Devices etc. In HTSC catgory projects were sanctioned for Purification of Material, Development of HTSC Powders and Targets, Substrates, Thin Films, Tapes and Wires. Projects were also sanctioned for making HTSC Josephson and SQUID Devices, SC- FET, HTSC and Microwave Devices.

Major Institutes involved in HTSC:

DAE : BARC, RRCAT, TIFR, IGCAR, SINP, IMSC

CSIR : NPL, NCL, CEERI, RRL(Trivandrum)

Public Sector Enterprises: BHEL, ECIL, IRE Ltd.

Universities and Academic Institutions : All IITs (5), IISc, IACS, SNBSC and Universities (Anna, BHU, Marthwada, Rajasthan, Pune, Shivaji, Hyderabad, Osmania, Madras)

8.2 Projects Other than NSP

S.No	Date of Funding	PI & Institute	Major Equipments	Equipments Cost (Rs) in crores	Total Cost (Rs)
	A. FUNDING BY DST UNDER LOW TEMPERATURE HIGH FIELD FACILITY				
1	12-Feb-2003	**S.V. Subramanyam** IISc Banglore	* Optical Cryostat with Split Coil Superconducting Magnet, * FT-IR_VIS-UV Spectrophotometer * 7T SC Magnet	2,65,00,000/-	3,00,00,000/-
2	08-March-2002	**B. A. Dasannacharya** UGC- DAE CSR Indore	* 12T Vibrating Sample Magnetometer, * 14T at 4.2 K and 0.3 K Magnet System with He-3 Inserts	2,02,00,000/-	3,67,28,000/-
3	26-Feb-2003	**A. K. Bhatnagar** University of Hyderbad	* Helium Liquefier System * 8T Superconducting Magnet	3,79,85,000/-	4,11,59,000/-
4	21-Nov-2001	**G. Rangarajan** IIT Madras	* Upgradation of SQUID Magnetometer	50,41,800/-	64,62,8000/-
5	22-Nov-2007	**T. K. Nath** IIT Kharagpur	* 8Tesla Cryofree SC Magnet * Variable Temperature Insert	1,04,18,000/-	1,27,07,000/-
6	26-Dec-2007	**Dr. C. V. Tomy** IIT Powai, Bombay	* Cryostate with Superconducting Magnet, * Torque Magnetometer	1,01,00,000	1,32,53,000/-

S.No	Date of Funding	PI & Institute	Major Equipments	Equipments Cost (Rs) in crores	Total Cost (Rs)
7	13-Nov-2007	**Dr. A. K. Raychaudhuri** SN Bose National Centre for Basic Science, Kolkata	* Magnet Bucket Dewar	81,00,000/-	1,43,37,000/-
8	07-Sep-2007	**Dr. Ajit K. Sinha** UGC-DAE CSR Kolkata	* 15T Cryogen Free Magnet, * Integrated VTI, RnX AC Susceptibility, * SQUID Magnetometer	4,06,44,000/-	4,89,60,000/-
9	22-Oct-2007	**Dr. Subash Jacob** IISc Bangalore Hybrid Cryocooler)	* Power Meter & Accessories * D.C. Power Supply, Function Generators, * CFIC Q-Drive Twin Star Dry Compressor &Accessories * LVDT Gauss Meter Helium Crystal	94,00,000/--	1,50,00,000/-
10	19-Sep-2007	**Dr. A. Srinivasan** IIT, Guwahati	* VSM System with Cryostate, * High Temp, LHe Storage Dewar	1,26,37,000/-	1,44,07,000/-
11	22-May-2007	**Dr. Kalyan Mandal** SNBSC Kolkata	* Superconducting Magnet	11,00,000/-	22,50,000/-
12	30-Jan-2008	**Dr. S. Arumugam** Bharathidasan University Truchirappalli	* Cryogen Free Superconducting 8T Magnet, * VTI, Ac Susceptibility Attachement, * Zoom Stereo Microscope System, * Modified Bridgman-Anvil Pressure Cell	1,71,60,000/-	1,95,31,000/-
13	27-July-2007	**Dr. Ratanamala Chatterjee** IIT Delhi	* MPMS-XL7 Quantum Design	2,57,94,000/-	2,96,74,000/-
14		**Dr. U. Syamaprasad** RRl, Trivandrum NIIST	* PPMS with 9T Magnet A/C, D/C		1,30,00,000/-
B. MAJOR PROJECTS FUNDED BY DST UNDER FIST PROGRAMME					
				Rs. in crores	
15	2007	Centre for Cryogenic Technology, **IISC. Bangalore**	* Helium Liquiefier	4.5	
16	2007	Dept of Physics. **IIT Madras**	* MPMS Squid Magnetometer and Table top Helium Plant	3.0	

S.No	Date of Funding	PI & Institute	Major Equipments	Equipments Cost (Rs) in crores	Total Cost (Rs)
17		Dept of Chemistry, **IIT Madras**	* VSM	2.0	
18	2006	Dep. Mechanical Eng. **NIT. Surat**	* Liquid Nitrogen plant	1.0	
19	2006	Solid state Chemistry Unit **IISc. Bangalore**	* MPMS SQUID	2.0	
20	2007	Dept of Metallurgy, **IISc. Bangalore**	* Thermal & Electrical Properties Analyser	4.0	
21	2006	Dept of physics **IIT. Kanpur**	* Helium Liquefier	4.5	
22	2006	Department of Chemical engineering, **IIT. Mumbai**	* Liquid Nitrogen Plant	1.0	
23	2005	Department of chemistry **IIT. Mumbai**	* VSM	1.5	
24	2006	School of Physical Science, **JNU. Delhi**	* Cryo Free Magnet	0. 60	
25	2006	**M.L Sukhodia University**, Jodhpur	* VSM	1.0	
26	2006	Dept of Physics, **NIT Trichi**	* VSM	0.5	
27	2007	Cryogenic Engineering Centre. **IIT. Kharagpur**	* High Field Magnet	1.0	
28	2008	Dept of Physics **Shimla University**	* VSM	1.0	
29	2008	Dept Inorganic chemistry **Madras university**	* VSM	1.0	

C. MAJOR PROJECTS FUNDED BY VARIOUS AGENCIES

	YEAR	P.I and Institute	Name of The Project	Funding agency	Project cost in crore
31	1991	**R. Srinivasan** National Project (Multi institute)	Development of Cold Box For Helium Liquefier	DST	1.0
32	1987	**K.G Narayan Khedkar.** IIT Mumbai	Development of Stirling Cryogenerator to produce 10l/hr LN2	DST	0.35
33	1990-	**P Sen/ D Ghosh** SINP. Kolkata	Recovery of Helium Gas From Thermal Spring	DST	Not Known
34	2006	**N. Das & P. Sen,** VECC & SINP	Helium Gas from Natural Gas	ONGC + DST	Not Known
35	1984	**T S Radhakrishnan,** IGCAR Hanumanth Rao, BARC	Helium Recovery from Monazite Sand	DAE + IRE	Not known

S.No	Date of Funding	PI & Institute	Major Equipments	Funding Agency	Total Cost (Rs)
36	1991-95	**K.G. Narayan Khedkar IIT. Mumbai**	Thurst area Programme in Cryogenic engineering	MHRD	0.53
37	1995-1999	**K.G Narayan Khedkar** IIT. Mumbai	Development of Cryogenic IQF Tunnel for Freezing of Sea Food	MHRD	1.0
38	2000-2005	**Subhash Jacob.** IISc. Bangalore	Vortex Tube Liquid Oxygen Separation	DRDO	0.37
39	2003	**Subhash Jacob**	Solid State optical Cryocooler	DRDO	0.45
40	2004	**M.P Janawadkar** IGCAR. Kalpakkam	SQUID Based MEG System for studies human brain	DST	5.59
41	2004	**K.G Narayan Khedkar**	Advance technology Development of Two-Stage Cryocooler for IRS Programme	ISRO	0.67
42	2004	**H B Naik.** NIT Surat	Development of Pulse Tube Nitrogen Liqefier (1 l/hr)	DST	0.35
43	2005	**K.G Narayankhedkar**	Development of Two Stage pulse Tube cryocooler for 20 K Using Linear Compressor	BRNS	0.46
44	2006	**Subhash Jacob**	Development of Pulse Tube Cryocooler	DOS	0.42
45	2007	**T S Datta,** IUAC	Development of Cryo free SC Magnet	DST	0.40
46		**V.V Rao** IIT. Kharagpur	Development of UPS Based SEMS	DST	0.40
47	2006	**S. K Sarangi,** NIT Rourkella	Development of helium purifier	BRNS	0.35
48	2007	**VV Rao**	Computational evaluation for SC Cables	BRFS	0.4
49	2007	**Kanhan Choudhury,** IIT Kharagpur	Helium Liquefier Optimization	BRFS	

Chapter 9

9. CRYOGENICS IN GAS INDUSTRIES

9.1 History and Present Status

The application of cryogenic in industry came through Cryogenic Distillation of liquid air to manufacture pure oxygen gas. This technology of separation of oxygen gas from air was invented by a German Scientist, Carl Von Linde in 1885.

In India, Cryogenic Gas Industry (CGI) started around 1935. It started with the production of Oxygen and Acetylene (non cryogenic) at Kolkata, Jamshedpur and Mumbai by Indian Oxygen and Acetylene Co Ltd. This company was promoted by British Oxygen Company (BOC). The plant capacity was, however, only 30 M^3/hr. The second company which entered in the business of gas production was Asiatic Oxygen. It established an air Separation Plant at Howrah in collaboration with Air Products of USA in 1941. Between 1940 and 1960 a number of Industries like Industrial Gases Ltd, Modi Vanaspati, KT Steel, Om Mumbai, Sanghi Oxygen, and Hindusthan Gas started producing industrial gases. By 1960 the total production of oxygen rose to 21 MCM (million cubic meter) and to 44 MCM by 1970. During the period of 1935- 1960, oxygen was mainly used for welding & cutting of steel, lancing / flame enrichment in steel making and for medical application. The capacity of the largest size plant was 400 M^3/hr. This period could be termed as "Merchant Era of Gas Industry"

The first captive air separation plant was installed at Rourkela Steel Plant in 1959- 60. Many more plants were installed later by SAIL at their different locations in the country. Similarly, first captive air separation plant for Fertilizer Industry was put up at Sindri Fertilizer Plants. Many plants with capacity in the range of 500- 1000 M^3/hr came up during 1960-70 at different locations. ASU at Gorakhpur Fertilizer plant was the first one to have Argon gas recovery unit in 1978.

Till 1970 most of our plants were imported. There were about one dozen manufactures of these separation plants mostly in Europe and USA. Prominent among the manufacturers were Airproducts, UK, L'Air, Liquide France, VEW, East Germany, BOC, UK and Techno- Export, USSR. During 1971, four Firms were given licence to manufacture plants in India and they are

1. Bharat Heavy Plate & Vessels Ltd. Visakhapatnam
2. Indian Oxygen Ltd. Kolkata (IOAL, IOL, BOC India)
3. Industrial Cryogenic and Chemicals Plants Ltd., Lucknow
4. Sanghi Oxygen, Mumbai

Later, manufactures like Inox, Air Products, Asiatic Oxygen Ltd and Titan Engineering started manufacturing small capacity (~ 400 M^3/hr) Air Separation Plants in India.

During the Period (1960- 1990) Tonnage LO2 and LN2 plants were commissioned for captive use in Steel Plants, Fertilizer Plants, Petrochemical Complexes etc. Lower capacity plants for Merchant Market are controlled by the old Gas Industries as well as by the new entrants. This is, in fact, the period of coexistent of the Captive and the Merchant Plants.

In recent times there has been a significant increase in the demand for oxygen in steel industry. This was caused by the massive programme of capacity enhancement as well as modernization of the existing plants. The new manufacturing processes demand larger quantities of oxygen. Similarly, demand for nitrogen gas and liquid nitrogen shot up in Fertilizer Industry, Petroleum Industry, Pharmaceutical Industry and the Semiconductor Industry. Until around 1995 steel industry used to have their own air separation plants, and operate & maintain them through their own technical force. Trends have now changed to what is called the B.O.O. (Built, Owned and Operate) mode. Under this scheme Gas Industries establish the required capacity Plant at Steel or Fertilizer site and commit the supply of large quantities of LO2 and LN2 for 10- 15 years. Surplus LO2 and LN2 is released by the industry in the open Merchant Market.

With the opening of Indian economy in 1991 a new phase started in the cryogenic gas industry too. During the period 1991 – 2005 Indian market was opened to global players. This started an era of reorganization and merging of existing gas industries with Multinational Companies (MNCs).

Major Global Cryo- Gas Industries, who are active in India today are

1. BOC- Linde
2. M/S Paraxair Ltd
3. M/S Air Liquide
4. M/S Air Products with INOX
5. Messers with Goyal Gases

Praxair began business operations in India in 1995 through a joint venture with Jindal Steel Works. It built one of the largest air separation plants (2500 Tons / day) in the world in Bellary, Karnataka in 1998. In the same year BOC India Ltd also installed a 1250 Tons/ day plant at Jamshedpur. At present many high capacity Tonnage plants are operating in Steel / Fertilizer / Petrochemical industry based on B.O.O model by Cryogenic Gas Industry. Estimated installed capacity with all the above major Industries in collaboration with Indian companies is approximately 50,000 tons / day. There are about 50 Public Sector Units with large capacity Tonnage Air Separation Units for their in house use. In addition to this Tonnage plants, there are about 250 small capacity Air separation plants (Max Production rate 400 M^3/hr) are operating to meet the demand of small industries by supplying gas in cylinders. This adds a capacity 0f 10,000 tons/day.

Along with the small capacity plants, the global gas industry also establishes tonnage plants to take care of users on regional basis. The demand of smaller quantities of LN2 by the scientific laboratories and Animal Husbandry for low temperature research and for cattle breeding is met by 10 litres / hr to 100 litres / hr capacity nitrogen liquefiers marketed by M/S Stirling Cryogenics India (P) Ltd and Linde. More recently, table-top nitrogen liquefier with a production rate of 20 litres / day to 100 litres /day are being procured by scientific laboratories.

Old air separation plants were mainly used for oxygen production. With technology upgradation it became possible to extract Nitrogen and Argon as well. High pressure air compressors have been replaced with low pressure compressors which reduces power and maintenance cost. Similarly Distillation Columns were redesigned with packed type of columns. Another important technology upgradation is the compression of LO2 and LN2 by Pumps.

9.2 AIIGMA

All India Industrial Gases Manufacturer's Association (AIIGMA) is the sole representative body of the entire industrial gases industry in India. Members include manufacturers of oxygen, nitrogen, argon, helium, dissolved acetylene, carbon-dioxide, hydrogen, etc. in India as well as allied equipment manufacturers. Foreign companies have direct or indirect relation with the industrial gas industry in India.

9.3 Estimated Installed Capacity of O2 / N2

Year	Merchant Plant Capacity	Captive plant (Tons/day)
1960	28 Million M^3/ year	
1970	74	3560
1980	139	14,000
1991	226	20,000
2005	~250	50,000

I Ton/day ~ 30 NM^3/hr. Oxygen gas Production

9.4 List of Cryogenic Gas industries(Gas production and air separation plants manufacturing)

Ref: AIIGMA Directory

S.No.	Company Name	Place	Manufacturer
1	Aarti Steels Limited	Ludhiana	OXYGEN, NITROGEN
2	Adarsh Gases	Rourkela	OXYGEN GASES
3	Adarsh Gases & Techno Industries	Udaipur	OXYGEN GAS FOR INDUSTRIAL USE,
4	Aditya Air Products Pvt. Ltd.	Nagpur	INDUSTRIAL OXYGEN, MEDICAL OXYGEN,
5	Aims Industries Ltd.	Vadodara Dist.	OXYGEN, NITROGEN, DISSOLVED ACETYLENE
6	Air Liquide Engineering India	Hyderabad	AIR & GAS SEPARATION PLANTS
7	Air Liquide India Holding Pvt. Ltd.	New Delhi	LIQUID & GASEOUS OXYGEN, NITROGEN,
8	AISCO Group of Companies	Aden	STEEL, INDUSTRIAL AND MEDICAL GASES,
9	Ajmer Gases	Ajmer	INDUSTRIAL AND MEDICAL OXYGEN,
10	Anand Gases (India) Pvt Ltd	New Delhi	INDUSTRIAL/MEDICAL OXYGEN GAS,
11	Anand Indl.Gases Ltd.	Bhubaneshwar	INDUSTRIAL OXYGEN, MEDICAL OXYGEN,
12	Ankita Air Products Pvt. Ltd.	Jharsuguda	INDUSTRIAL OXYGEN, NITROGEN & MEDICALOXYGEN

S.No.	Company Name	Place	Manufacturer
13	Annapurna Gases	Varanasi	INDUSTRIAL / MEDICAL OXYGEN GAS
14	ANS Oxygen Pvt. Ltd.	Chennai	OXYGEN GAS, NITROGEN GAS & LIQUID,
15	Arasan Air Products Pvt. Ltd.	Tuticorin	INDUSTRIAL OXYGEN, MEDICAL OXYGEN,
16	Arun Oxygen Ltd	Jagadhari	OXYGEN, MEDICAL OXYGEN, NITROGEN GAS
17	Asiatic Gases Limited	Mumbai	OXYGEN, NITROGEN, MEDICAL OXYGEN
18	Assam Air Products Pvt. Ltd.	Guwahati	OXYGEN GASEOUS, MEDICAL OXYGEN, NITROGEN
19	Attar Indl. Gases Pvt. Ltd.	New Delhi	OXYGEN, NITROGEN, CARBON DIOXIDE,
20	Atul Gases	Agra	COMPRESSED OXYGEN GAS
21	Atul Oxygen Company	Bhilai	INDUSTRIAL & MEDICAL OXYGEN, LIQUID NITROGEN
22	Bansal Indl. Gases (Bihar) Ltd.	New Delhi	OXYGEN Gas, NITROGEN GAS
23	Baroda Industrial Gas Pvt. Ltd.	New Delhi	OXYGEN GASEOUS, NITROGEN
24	Best Air Products	Pondicherry	INDUSTRIAL OXYGEN, MEDICAL OXYGEN,
25	Bhagawati Gases Ltd.	NOIDA	GASEOUS/LIQUID OXYGEN, NITROGEN, ARGON
26	Bhagawati Oxygen Limited	Kolkata	LIQUID & GASEOUS OXYGEN, NITROGEN & ARGON
27	Bhagirathi Industrial Gases Pvt. Ltd.	Faridabad	INDUSTRIAL, MEDICAL OXYGEN & NITROGEN GAS
28	Bhavya Gases	Kanpur	OXYGEN GAS
29	Bhilwara Gases Pvt. Ltd.	Bhilwara	INDUSTRIAL & MEDICAL OXYGEN LIQUID NITROGEN
30	Bhuruka Gases Ltd.	Bangalore	LIQUID OXYGEN, LIQUID NITROGEN,
31	Bihar Air Products Ltd.	Gamharia	OXYGEN,MEDICAL OXYGEN,,
32	Bihar Hydro Carbon Products (P) Ltd.	Delhi	CO2 GAS PLANTS,
33	BOC India Limited	Kolkata	INDUSTRIAL GASES, MEDICAL & SPECIAL
34	Bombay Oxygen Corpn. Ltd.	Mumbai	LIQUID & GASEOUS OXYGEN
35	Chirayu Air Products (P) Ltd.	Bhopal	COMPRESSED OXYGEN, NITROGEN
36	Crown Gases Ltd.	Nairobi	ARGON, OXYGEN, NITROGEN,

S.No.	Company Name	Place	Manufacturer
37	Devi Industrial Gases Pvt. Ltd.	Kolhapur	INDUSTRIAL OXYGEN & NITROGEN
38	Durgapur Oxygen Pvt. Ltd.	Kolkata	OXYGEN GASEOUS
39	Earnest Gases Pvt. Ltd.	Udaipur	OXYGEN,
40	Ellenbarrie Industrial Gases Ltd.	Kolkata	OXYGEN MEDICAL OXYGEN,
41	Essem Gases Pvt. Ltd.	Jalna	OXYGEN GAS, NITROGEN GAS
42	Fusion Air Product Pvt Ltd	Chennai	INDUSTRIAL OXYGEN GAS
43	Gautam Engineers Ltd.	Kolkata	OXYGEN GASEOUS
44	Geldhof Limited.	Mumbai	COMPRESSED OXYGEN & NITROGEN
45	Govind Poy Oxygen Ltd.	Salcete	OXYGEN, MEDICAL OXYGEN,NITROGEN
46	Goyal Air Products	Mandi Gobindgarh	ULTRA HIGH PURE GASES,ARGON,
47	Goyal MG Gases Pvt. Ltd	New Delhi	OXYGEN, NITROGEN, ARGON
48	Guljag Gases Pvt. Ltd.	Jodhpur	INDUSTRIAL/MEDICINAL OXYGEN GAS NITROGEN GAS
49	Gupta Industrial Gases Pvt. Ltd.	Hisar	OXYGEN GASEOUS, NITROGE
50	Gupta Oxygen Pvt. Ltd.	Hisar	OXYGEN, MEDICAL OXYGEN, NITROGEN &LN2
51	Gwalior Air Products Ltd.	Morena Distt.	OXYGEN GASEOUS, MEDICAL OXYGEN,
52	Hari Oxygen	Kashipur	OXYGEN, NITROGEN,
53	Harpreet Gases	Ludhiana	OXYGEN, NITROGEN
54	Hingorani Air Products Pvt. Ltd.	Vadodara	OXYGEN, OXYGEN I.P, NITROGEN, ARGON & MIXTURES
55	Hitech Industries Limited	Mohali	INDUSTRIAL & MEDICAL GASES,OXYGEN
56	Howrah Gases Ltd.	Kolkata	INDUSTRIAL OXYGEN, MEDICAL OXYGEN
57	Indessa Gases Pvt Ltd	Howrah	INDUSTRIAL/MEDICAL OXYGEN, NITROGEN, CARBON DIOXIDE
58	India Glycols Ltd.	New Delhi	LIQUID CARBON DIOXIDE, ARGON,NITROGEN & OXYGEN
59	Indian Gases	Jalandhar	DISSOLVED ACETYLENE GAS,COMPRESSED OXYGEN GAS
60	Indo Gulf Fertilisers	Sultanpur	LIQUID ARGON

S.No.	Company Name	Place	Manufacturer
61	Inox Air Products Ltd.	Mumbai	INDUSTRIAL GAS - OXYGEN, NITROGEN,ACETYLENE, ARGON
62	International Indl. Gases Ltd.	Howrah	INDUSTRIAL OXYGEN, MEDICAL OXYGEN, NITROGEN
63	J. K. Enterprises	Hoshiarpur	OXYGEN, NITROGEN, MEDICAL OXYGEN &
64	Jalan Gases & Allied Inds. Pvt.Ltd	New Delhi	OXYGEN, NITROGEN, UHP N2, ZERO AIR
65	Jindal Praxair Oxygen Co. Pvt. Ltd.	Dist: Bellary	OXYGEN, NITROGEN & ARGON
66	Jindal Stainless Limited	Hisar	OXYGEN. NITROGEN & ARGON GAS
67	K S Air Products	Trichy	INDUSTRIAL OXYGEN GAS
68	K V K Corporation	Mumbai	OXYGEN/NITROGEN GAS PLANT
69	Kalyan Oxygen Pvt. Ltd.	Madurai	OXYGEN GAS, MEDICAL OXYGEN, LIQUID NITROGEN
70	Kanak Cryo Sales Service &	Sihor	OXYGEN & NITROGEN GAS PLANT
71	Karnatak Industrial Gases Pvt. Ltd.	Dharwad	OXYGEN GASEOUS
72	KCA Enterprises	Mandi Gobindgarh	OXYGEN, NITROGEN GAS
73	Kirloskar Pneumatic Co. Ltd.	Pune	AIR & GAS COMPRESSORS
74	Kolhapur Oxygen & Ace Pvt Ltd	Kolhapur	INDUSTRIAL & MEDICAL OXYGEN GAS, LN2
75	Kruhad Airogas Pvt. Ltd.	Ahmedabad	OXYGEN NITROGEN GASES
76	Kumar Oxygen Limited	Distt. Udham Singh Nagar	OXYGEN GASEOUS, MEDICAL OXYGEN, LN2
77	Lupin Gases Pvt. Ltd.	Raipur	INDUSTRIAL OXYGEN GAS,
78	M T C (India) Gases P. Ltd.	Siliguri	INDUSTRIAL OXYGEN/ NITROGEN, MEDICAL
79	Malwa Oxy & Indl. Gases Pvt. Ltd.	Ratlam	OXYGEN,
80	Mandav Air Industries	Mandi	INDUSTRIAL OXYGEN, MEDICAL OXYGEN, LIQUID
91	Manorama Oxygen Pvt Ltd	Kochi	INDUSTRIAL/ MEDICAL OXYGEN, & LIQUID NITROGEN
82	Mapro Industries Ltd.	Mumbai	OXYGEN, ARGON, ARGON MIXTURE

S.No.	Company Name	Place	Manufacturer
83	Maruti Gases P. Ltd.	Dist Panchmahal	MEDICAL/INDUSTRIAL & HIGH PURE NITROGEN
84	Mayur Air Products Pvt. Ltd.	New Delhi	INDUSTRIAL OXYGEN, MEDICAL OXYGEN & NITROGEN GAS
85	Mayur Gases	Navi Mumbai	OXYGEN / NITROGEN GAS MEDICAL OXYGEN & DRY AIR
86	Mayur Gases Private Limited	Dist. Sant Kabir Nagar	MEDICAL OXYGEN, NITROGEN GASEOUS,
87	Medical Engineers (India) Ltd.	Mumbai	OXYGEN GASEOUS, NITROGEN, ACETYLENE
88	Meesha Air Products (P) Ltd.	Navi Mumbai	DISSOLVED ACETYLENE GAS
89	Messer Industrial Gases (Pvt) Ltd.	Sapugaskan da	OXYGEN, MEDICALOXYGEN, HIGH PURITY NITROGEN
90	MSPL Gases Limited	Hospet	INDUSTRIAL /MEDICAL OXYGEN, NITROGEN GAS, LN2
91	Munjal Gases	Ludhiana	OXYGEN, NITROGEN MEDICAL GAS,COMPRESSED AIR
92	N. S. Corporation	Mumbai	INDUSTRIAL OXYGEN & MEDICAL OXYGEN
93	Nagpal Gases Pvt. Ltd.	New Delhi	OXYGEN & NITROGEN
94	National Fertilizers Limited	Dist. Gautam Budh Nagar	LIQUID OXYGEN, LN2 CARBON DIOXIDE,ARGON
95	National Oxygen Limited	Chennai	LIQUID OXYGEN/ NITROGEN, GASEOUS OXYGEN/NITROGEN,
96	Niket Udyog Ltd.	Kolkata	LIQUID OXYGEN/NITROGEN, GASEOUS OXYGEN /NITROGEN
97	Noble Gas Ltd.	Bhubaneswar	OXYGEN GAS
98	Northeast Gases Pvt. Ltd.	Chirang Distt.	INDUSTRIAL OXYGEN GAS, INDUSTRIAL NITROGEN GAS
99	Nova Industrial Gases Pvt. Ltd	Vadodara	OXYGEN, MEDICAL OXYGEN, NITROGEN GASES
100	NU-Carbonic Gas Industries (P) Ltd.	Jamshedpur	CARBON DIOXIDE GAS, ARGON GAS & ARGON - CO2 MIXTURE
101	Orissa Air Products Pvt. Ltd.	Dhenkanal Distt.	OXYGEN, NITROGEN, MEDICAL OXYGEN
102	Pamarox Pvt. Ltd.	Mumbai	INDUSTRIAL OXYGEN, NITROGEN, HIGH PURITY NITROGEN

S.No.	Company Name	Place	Manufacturer
103	Pankaj Oxygen Limited	Kolkata	OXYGEN, NITROGEN
104	Paradeep Oxygen Pvt. Ltd.	Cuttack	INDUSTRIAL & MEDICAL OXYGEN GAS
105	Paras Gases Pvt.Ltd.	Rohtak	INDUSTRIAL & MEDICAL OXYGEN GAS, LN2
106	Pavan Industrial Gases (P) Ltd.	Mehsana - Distt.	INDUSTRIAL OXYGEN, NITROGEN, MEDICALOXYGEN & LN2
107	Peenya Industrial Gases (P) Ltd.	Bangalore	OXYGEN, NITROGEN,
108	Pioneer Oxygen	Hyderabad	OXYGEN, NITROGEN GASEOUS
109	Pravan Air Products Pvt. Ltd.	Vadodara	INDUSTRIAL GASES, VAPORISERS,MANIFOLDS, SKIDS
110	Praxair India Pvt. Ltd.	Bangalore	ATMOSPHERIC AND SPECIALTY GASES
111	Pure Helium India Pvt. Ltd.	Mumbai	HELIUM GASEOUS, LIQUID HELIUM, GAS MIXTURE
112	Pushpavalli Engineering Works	Salem	OXYGEN, NITROGEN GAS
113	Raigad Oxygen Pvt. Ltd.	Raigad Dist.	OXYGEN, NITROGEN, MEDICAL OXYGEN, UHP NITROGEN, LN2
114	Rajasthan Air Products Pvt. Ltd.	Jaipur	INDUSTRIAL AND MEDICAL OXYGEN GAS
115	Rajhans Industries	Bhavnagar	INDUSTRIAL OXYGEN GAS
116	Ravindra Oxygen Co. Pvt. Ltd.	Nashik	INDUSTRIAL & MEDICAL OXYGEN GAS
117	Refrigeration & Oxygen Ltd.	Safat	INDUSTRIAL & MEDICAL GASES
118	Regent Air Products (P) Ltd.	New Delhi	OXYGEN, NITROGEN, ARGON & CALIBRATION GASES
119	Rewa Gases Pvt. Ltd.	Distt.Sidhi	INDUSTRIAL OXYGEN GAS
120	Rohit Gases	Visakhapatn am	DISSOLVED ACETYLENE GAS
121	Rukmani Metals & Gaseous Ltd.	Nagpur	OXYGEN GAS, MEDICAL OXYGEN, NITROGEN GAS,
122	S. E. Gases Pvt. Ltd.	Visakhapatn am	OXYGEN, NITROGEN, ARGON, CARBON DIOXIDE
123	S. M. Process Plant (P) Ltd.	Ramgarh Cantt.	INDUSTRIAL OXYGEN, MEDICAL OXYGEN,GASEOUS & LN2
124	Sachdev Engineering Works Pvt. Ltd.	Jamshedpur	COMPRESSED OXYGEN GAS,
125	Saket Industrial Gases Ltd.	Raipur	OXYGEN GAS, NITROGEN GAS

S.No.	Company Name	Place	Manufacturer
126	Salasar Air Products	Bilaspur	INDUSTRIAL OXYGEN GAS, MEDICALOXYGEN GAS
127	Sanghi Organization	Mumbai	OXYGEN/NITROGEN PLANTS 40 TO 1000 CU.M/HR
128	Sanghi Oxygen (Bombay) P. Ltd.	Mumbai	OXYGEN/NITROGEN/ ARGON GASES
129	Sarthak Metals Marketing Pvt. Ltd.	Bhilai	INDUSTRIAL OXYGEN GAS
130	Saurashtra Oxygen Pvt. Ltd.	Gandhidham , Kutch	OXYGEN, NITROGEN
131	Sethi Indl.Gases (Guj.) Pvt.Ltd.	Ahmedabad	OXYGEN, NITROGEN GASEOUS, LN2
132	Seven Hills Oxygen Company	Hyderabad	INDUSTRIAL & MEDICAL OXYGEN,NITROGEN & DRY AIR
133	Shankar Gas Industries Pvt. Ltd.	Raiganj P.O	OXYGEN (INDUSTRIAL & MEDICAL) NITROGEN
134	Shanti Nath Gases	Silchar	OXYGEN/MEDICAL
135	Sharang Plastengg Pvt. Ltd.	Lucknow	OXYGEN, NITROGEN & NITROUS OXIDE
136	Shree Alang Gases & Air Prod. Pvt. Ltd.	Mumbai	OXYGEN, NITROGEN, LN2
137	Shree Hari Gases Pvt. Ltd.	Jaipur	INDUSTRIAL/MEDICAL OXYGEN GASEOUS,NITROGEN GASEOUS, LIQUID NITROGEN
138	Six Sigma Gases (India) Pvt. Ltd.	Navi Mumbai	ARGON GAS, CARBON DIOXIDE, NITROGEN GAS, MIXTURE GASES & CALIBRATION GASES
139	Sky Acetylene Co. Pvt. Ltd.	Vadodara	GASEOUS & LIQUID OXYGEN
140	Sri Kakinada Oxygen Gases	Kakinada	OXYGRN GAS
141	Sri Rambalaji Gases Pvt. Ltd.	Erode	ACETYLENE, OXYGEN, NITROGEN, MEDICALOXYGEN, ARGON GAS
141	Sri Sai Krishna Gases Pvt. Ltd.	Hyderabad	INDUSTRIAL OXYGEN GAS, NITROGEN,MEDICAL OXYGEN
142	Sri Venkateswara Oxygen Pvt.Ltd.	Coimbatore	OXYGEN, NITROGEN, ARGON
143	Sunny Industrial Sales Pvt. Ltd.	Nasik	INDUSTRIAL OXYGEN GAS, NITROGEN GAS & LN2
144	Super Gases & Appliances Pvt. Ltd.	Kharagpur	COMPRESSED OXYGEN, DISSOLVED ACETYLENE
145	Super Oxytech Pvt. Ltd	Howrah	OXYGEN, NITROGEN

S.No.	Company Name	Place	Manufacturer
146	Superb Gases Pvt. Ltd.	Surat	NITROGEN, ARGON, ARGON BASE MIXTURE
147	Tamilnadu Air Products Pvt. Ltd.	Chennai	OXYGEN, NITROGEN, LN2
148	Thane Industrial Air Products Pvt. Ltd.	Navi Mumbai	OXYGEN & NITROGEN
149	The Eastern Oxygen & Ace. Pvt.	Dhanbad	OXYGEN GASEOUS, ACETYLENE AND NITROGEN
150	The Southern Gas Limited	Margao	OXYGEN, NITROGEN,
151	Ultra Pure Gases (India) Pvt. Ltd.	Baroda	ULTRA HIGH PURE GASES, ARGON,ARGON MIXTURES
152	Universal Air Products Pvt. Ltd.	Bangalore	INDUSTRIAL & MEDICAL OXYGEN
153	Urmi Oxygen Co.	Vadodara	OXYGEN, NITROGEN & LN2
154	Usha Air Products Ltd.	Patna	INDUSTRIAL & MEDICAL OXYGEN & NITROGEN GAS
155	Uttam Air Products Pvt. Ltd.	New Delhi	OXYGEN, MEDICAL OXYGEN, NITROGEN,NITROUS OXIDE
156	Vadilal Chemicals Limited	Ahmedabad	INDUSTRIAL GAS MIXTURES, ZERO AIR, VCL GRADE-I
157	Vaideeswara Oxygen (P) Ltd.	Trichy	INDUSTRIAL OXYGEN, MEDICAL OXYGEN L
158	Venus Industrial Gases Pvt. Ltd.	Kurukshetra	HIGH PURITY OXYGEN & NITORGEN GAS
159	Vijay Kumar Gases (P) Ltd.	Salem	OXYGEN, OXYGEN I.P
160	Vimal Dyes & Gas Industries P. Ltd.	Mumbai	INDUSTRIAL & MEDICAL OXYGEN,NITROGEN
161	Vinayak Air Products Pvt. Ltd.	Sonepat	OXYGEN GAS, NITROGEN
162	Vindhyachal Air Prod. (P) Ltd.	New Delhi	INDUSTRIAL OXYGEN, MEDICAL OXYGEN,& NITROGEN GASES
163	Viral Oxygen Pvt. Ltd.	Bhavnagar	INDUSTRIAL OXYGEN GAS, NITROGEN GAS & LN2
164	Yateem Oxygen	Manama	OXYGEN - INDUSTRIAL & MEDICAL
165	Zambad Gases Ltd.	Aurangabad	INDUSTRIAL OXYGEN, UHP OXYGEN

Chapter 10

10 CRYOGENICS IN CHEMISTRY AND MEDICINES

(Status of NMR and MRI Systems in India)

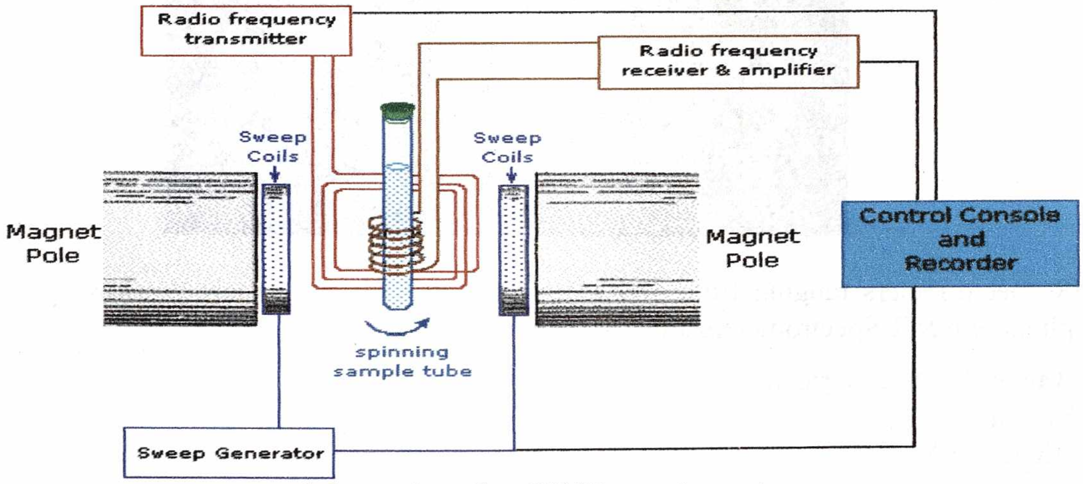
10.1 NMR

Nuclear Magnetic Resonance, or popularly known as NMR and discovered in 1945 is based upon the absorption and emission of a RF pulse by a nucleus, having a nuclear magnetic moment in presence of high magnetic field. An NMR spectrum is obtained by keeping the field constant and sweeping the RF. For a given field the sample shows a resonance at a particular frequency. This resonant frequency is proportional to the field. For example a proton frequency 100 MHz frequency corresponds to 2.35 Tesla field. The NMR spectrometry is used in the study of the structure of complex molecules. Higher the frequency higher is the resolution in the spectrum. Spectrometer with 1000 MHz (1 GHz) corresponding to 23.5 T field has just been commercialized. NMR spectrometer is a popular analytical tool for structural studies in physical, chemical, and biological systems. Its use has spread far and wide in pharmaceutical sector.

NMR technique has replaced x-ray crystallography for the determination of protein structure. Time domain NMR spectroscopic techniques are used to probe molecular dynamics in solutions. Solid state NMR spectroscopy is used to determine the molecular structure of solids..

NMR Hardware Overview

An NMR spectrometer must be tuned to a specific nucleus which in most cases is the proton. The spectrum is usually obtained in continuous wave (CW) mode. A typical CW-spectrometer is shown in the following diagram. A solution of the sample in a 5 mm glass tube is kept in a superconducting magnet. The tube is spun to average any magnetic field variations, as well as tube imperfections. The sample is subjected to an RF radiation of appropriate frequency using an antenna coil (coloured red). A receiver coil (in purple colour) surrounds the sample tube, and the emission of absorbed rf energy is monitored by dedicated electronic devices and a computer. An NMR spectrum is acquired by varying the frequency of the RF radiation while holding the external magnetic field constant.



Schematics of an NMR spectrometer

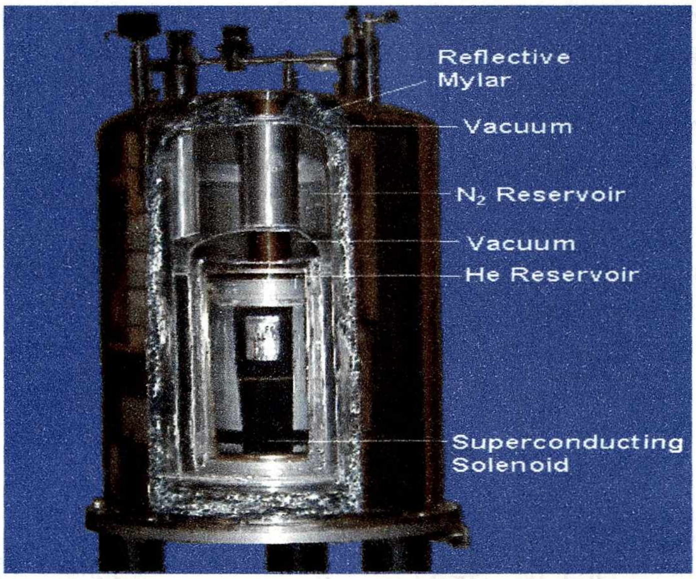
Cryogenics in NMR

Other than the RF power supply, the transmission and receiver system, the control system two most vital parts of an NMR spectrometer vis-à-vis cryogenics are the Superconducting Magnet and a Helium Cryostat.

The Superconducting Magnet is used for two basic reasons. One that for high resolution NMR needs as high field as possible. We know well that beyond 2 T we have to use superconducting magnet only. It has been possible to produce a record field of 23.5 T by using a combination of materials like Nb-Ti, Nb3Sn and HTSC like Bi(2223) and operating them at 4.2 K or even below. An equally important reason why a superconducting magnet is used is that NMR needs very high field stability. These superconducting magnets are operated in persistent mode whereby the two terminals of the magnetic coil are short circuited after the coil is charged to required level via a persistent switch. The current through the magnet continues to flow persistently without degradation. The magnet power supply is now removed. Since there is no power supply there is no fluctuation in the magnet current.

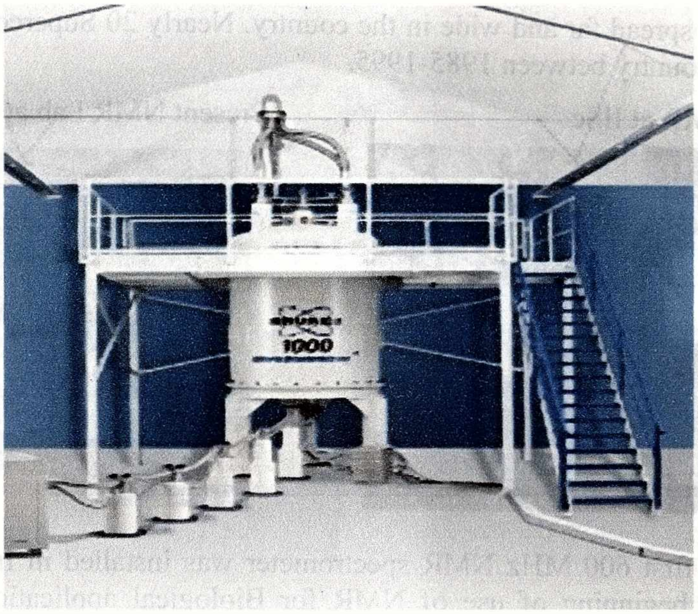
Since NMR and MRI units are required to operate at locations where helium liquefaction or storage facilities are not possible. Helium cryostats for NMR are thus designed in such a way, using vapour shields and superinsulation and so on, that the helium evaporation is so small that the liquid helium transfer is needed every ten months. The modern NMR units carry cryocooler based recondensers which reliquefy evaporated helium within the cryostat extending further the refill time.

The figure below is a cut view of the NMR cryostat



NMR spectrometers ranging from 300 MHz to 1000 MHz are in use Worldwide. The Major Suppliers of NMR Spectrometers are

1. Bruker, USA & Germany
2. Varian
3. JEOL, USA



The World's first Highest Frequency (1GHz) NMR spectrometer has been Supplied by Bruker is AVANCE 1000 System (23.5 T) to 'Centre de RMN à Très Hauts Champs' in Lyon, France in July 2009. In India we have NMR system with a maximum proton frequency of 800 MHz at TIFR.

NMR Scenario in India

In India till most part of 1960's, commercially available CW NMR Spectroscopy was used for structural studies employing permanents magnets. Nearly 25 electromagnet FT NMR spectrometers in the frequency range of 80-100 MHz were installed till late 1980,s. In the meantime, development of high frequency FT NMR Systems continued and by mid 1970, FT NMR spectrometers working at 200, 270 and 300 MHz became commercially available. All these spectrometers used Superconducting magnets.

In India, the first Supercon 270 MHz NMR spectrometer was made operational at IISc Bangalore largely because IISc had its own cryogenic facility. Helium gas evaporating from the cryostat was recovered and reliquefied. This was a national facility and samples, submitted from all corners of India, were analysed. The cryostat required liquid helium refilling once in a week and was therefore difficult to maintain in other parts of the country.

During early 70's, NMR manufacturers were able to design efficient helium cryostats with longer liquid helium re-filling intervals. Four more supercon NMR systems in the frequency range of 300 to 500 MHz were added in 1983. These units were again installed at places supported either by in-house or close-by cryogenic facilities.

During 1980s, a few private entrepreneurs started importing liquid helium in the country and the distribution too was streamlined. At this time around, a few NMR vendors started selling 200, 300 and 400 MHz NMR systems with liquid helium hold time of one year. This encouraged not only Government Research Institutes to go in for high field NMR spectrometers but also Private

Research Institutes spread far and wide in the country. Nearly 20 Supercon NMR Spectrometers were added in the country between 1985-1995.

First SC NMR at IISc

Present NMR Lab at IISc

In mid-1990s, the first 600 MHz NMR spectrometer was installed in India at TIFR, Mumbai. This heralded the beginning of use of NMR for Biological applications including peptides, proteins etc. In 2005 TIFR bought a 800 MHz NMR Spectrometer (with the superconducting wire maintained at 2K with ultrastabilised technology) was made available in TIFR and this further boosted NMR applications to biological systems. For proteins, NMR is now seen as an alternative to structure determination by X ray since NMR, in general, requires less tedious sample preparation.

More advancements were made available for biologists and natural product chemists working on 2D/3D experiments with limited sample quantities. Cryoprobe / Chilliprobe is one such innovation. Radiofrequency coil and 1H, 2H preamplifiers were cooled to 20K thereby reducing noise in the electronics. Since 2003, there are 8 NMR spectrometers (500 - 800 MHz) in India which are equipped with Cryo / Chilliprobes

Microimaging is another field of NMR which is fast catching up in the country. The first microimaging NMR in IISc was installed in 1990 on a vertical 400 mm wide bore magnet capable of handling samples (such as mice) for sizes upto about 4cms. There are now half a dozen such systems in the country with one of them using a 500 MHz narrow bore magnet and can take sample sizes upto 1 cm. These samples can be temperature controlled, and various sensors can not only monitor the health of the animal during the experiment but also trigger various NMR acquisitions. One of the microimaging setups in India was used mainly for material research. One can reach resolutions down to a few tens of microns with these systems and can not only do nearly all NMR imaging experiments (similar to MRI) but also spectroscopy. There are also two miniimaging NMR systems in the country and one of them was established way back in 1993 at AIIMS. These have horizontal bore magnets handling bigger animals. One of these magnets requires only an yearly top-up of liquid helium and requires no liquid nitrogen filling.

About 250 NMR spectrometers were bought and installed in the country (since mid 1970). Out of these 250 NMRs, BRUKER alone has supplied approx 200 and the rest by Varian and JEOL.

A rough breakup of these spectrometers, in various disciplines, is as follows:

S.No.	Institution	No. of NMR
1.	Universities	40
2.	R & D Institution like, IISc, TIFR, IITs, DRDO, ISRO	60
3.	Pharma and Chemical Industry	110
4.	CSIR	40

Frequency-wise breakup of NMR Spectrometers Installed since mid 1970:

Frequency	No. of Spectrometer	Frequency	No.of NMR
800 MHz	1	400 MHz	96
700 MHz	2	300 MHz	97
600 MHz	6	270 MHz	1
500 MHz	24	200 MHz	23

In the last 5 years, at least 20 NMR systems were added every year in India.

Present NMR with upgradation technology reduces liquid helium consumption from earlier filling frequency of once in a month to once in 4-6 months with topping of approx 100-litres. Nitrogen filling frequency almost remains same once in a week. Estimated amount of liquid Helium required to maintain these units at 4.2 K is more than 75,000 litres annually..

It is estimated that by 2015, India will have approx 1000 NMR units and majority of them will be in Pharmaceutical, Petrochemical industry and biological laboratories.

Today most of the the NMR units are maintained by the suppliers through AMCs that include liquid helium supply and filling. This methodology has helped many institutes to operate NMR Spectrometers at places where liquid helium and liquid nitrogen are not available. In fact, institutes like TIFR and IISC, where cryogenic facilities are available, too feel comfortable with AMC mode of operation. Cost of NMR units varies from 1.2 to 5.00 Crores depending upon the operating frequency.

Presently, IISc and TIFR are called the National NMR Centres. The National Centre at TIFR is slated to be shifted to a new location at Hyderabad University.

10.2 MRI

Magnetic Resonance Imaging (MRI) is an imaging technique used primarily in medical settings to produce high quality images of the inside of the human body. It is based on the principles of nuclear magnetic resonance (NMR).. The technique was called magnetic resonance imaging rather than Nuclear Magnetic Resonance Imaging (NMRI) because of the negative connotations associated with the word Nuclear. MRI started out as a tomographic imaging technique, that is it produced an image of the NMR signal in a thin slice through the human body. MRI has now advanced beyond a tomographic imaging technique to a volume imaging technique.

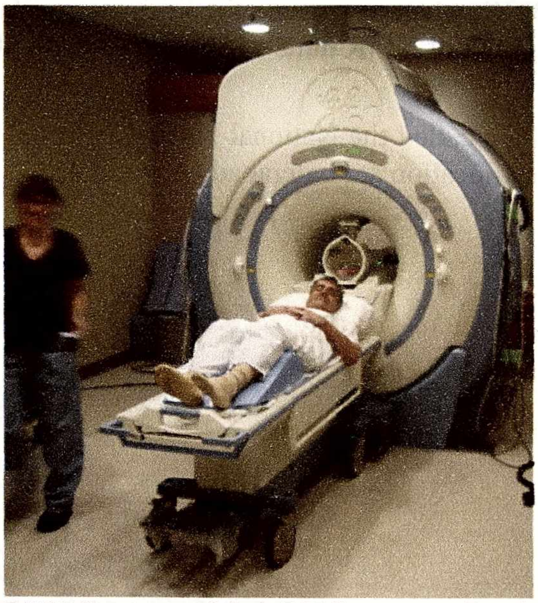
In 2003, there were approximately 10,000 MRI units worldwide, and approximately 75 million MRI scans per year were performed. As the field of MRI continues to grow, so do the opportunities in MRI.

Currently, there are approximately six major clinical MRI original equipment manufacturers (OEMs). In addition to these clinical OEMs, there are two major experimental MRI OEMs. Other MRI related subsystem manufacturers include RF coil, contrast agents, compatible devices, RF amps, and magnets. The following tables contain the names of some of the major manufacturers of these devices.

List of MRI manufacturer

1. GE Medical System
2. Philips Medical System
3. Siemens Medical System
4. Fonar
5. Hitachi Medical Systems
6. Toshiba Medical Systems

The imaging magnet is the most expensive component of the magnetic resonance imaging system. Most magnets are of the superconducting type. This is a picture of a 1.5 Tesla superconducting magnet from a magnetic resonance imager.



A Typical MRI System with 1.5 T Superconducting Magnet

Like in NMR, superconducting magnets in MRI run in persistent mode. Once a current is caused to flow in the coil it will continue to flow at the same level as long as the coil is kept at liquid helium temperatures Some losses do occur over time due to infinitely small resistance of the coil. These losses are of the order of a ppm of the main magnetic field per year. The typical volume of liquid Helium in an MRI cryostat is 1700 liters. In early magnet designs, this He-dewar was typically surrounded by a liquid nitrogen (77.4K) dewar which acts as a thermal buffer between the room temperature (293K) and the liquid helium. In later cryostat designs, the liquid nitrogen enclosure was replaced by a radiation shields cooled by a cryocooler or a refrigerator. This design eliminates the need to transfer liquid nitrogen to the cryostat. In more recent models the unit is equipped with another closed cycle refrigerator to reliquefy cold evaporated helium gas back in to the cryostat. This reduces the filling frequency from 6 times in a year to just once a year with topping of approx 200- 400 litres liquid helium. It is expected that cryocoolers for the helium reservoir will soon be available.

MRI In India

The first MRI unit was installed in the country at INMAS (Institute for Nuclear Medicines and Allied Sciences), Delhi, a DRDO establishment, through the efforts of N. Lakshmipathy in the year 1986. This was a 1 T MRI, model Magnetom GBS-I supplied by Siemens on a turn key basis. To keep the magnet at 4.2 K, a helium liquefier of capacity 30 l / hr too was installed at INMAS. We believe that this was the first MRI in South East Asia at that time. The second MRI machine again from Siemens and on turn key basis came to Breach Candy Hospital, Bombay in 1987. INMAS machine has been used for clinical and as well as for spectroscopic studies for Bio Medical Research. Dr Harsh. Mahajan established his own MRI Centre in Delhi in 1992. This was a 0.5 T machine and the first one supplied by Wipro GE. In 1997 Another machine 1.5 T from Wipro GE. SGPGI (Sanjay Gandhi Post Graduate Institute), Lucknow installed a similar 1.5 T Siemens Magnetom SP model MRI unit in 1989. Another important development took place at AIIMS (All India Institute of Medical Sciences) Delhi, when an MRI Centre was started there in 1992 started with a Siemens 1.5 T machine for clinical purpose and a small bore 4.7 T smaller machine for research on animals. This 4.7 T machine was built by Varian and Bruker together. AIIMS added yet another 1.5 T machine again from Siemens in the year 2003. The first old machine too was replaced by Siemens under a buy-back scheme in 2004. Both the machines have reliquefaction provision and the refill time of liquid helium now is one year. AIIMS has one more 1.5 T MRI with its Trauma Centre. So AIIMS at the moment operates three 1.5 T MRI machines.

The rise in the number of MRI Centres in the country has been rather phenomenal. It is estimated that the total number of MRI units in India is about 700. Out of them 450 units are superconducting magnet based. Single individual like Mahajan already has 6 Centres in Delhi alone and has a plan to have 50 such imaging centres all over India. Most of the MRI machines are either from Siemens or GE. Quite a number of them are also from Philips. Hitachi and Toshiba have also been able to make inroads. 3T MRI Systems are getting popular now and Philips has supplied the largest number so far. Siemens, GE and Philips put together have supplied so far about 3 T MRI units in the country. INMAS is going to replace its 11 years old 1.5 T machine by a 3 T MRI before the end of 2009. There are about 20 MRI systems with 3 T magnets already operating in India. The maximum number of them about 8 have been supplied by Philips and the rest by Siemens and GE. A 7 T Bruker Animal MRI with a bore of 15 cm too is being procured by INMAS Delhi. Even 7 T MRI has been declared safe for human application.

It appears that in a total of 450 Supercon MRI units in India about 125 are operating in Delhi and Mumbai alone. Out of these 450 Supercon MRI units about 400 units are from Siemens and Wipro GE together and the rest by Philips and others. We understand that each machine needs on the average about 500 litres of liquid helium in a year. Thus all the MRI units in India require about 3,50,000 litres of liquid helium annually. Present MRI at INMAS requires filling every four months with a total requirement of about 500 litres/ year. MRI no more require a captive helium liquefier.

Cost of MRI

MRI	Cost in Rs.
1.5 T	~7 Crore
3 T	~12 Crores
7 T	20 – 25 Crores

Korea and China are now in the MRI manufacturing business. India with a potentially large market must enter this field sooner than later. MRI is a combination of three scientific Discoveries, viz; Liquefaction of Helium, Superconductivity and NMR and one technology which went straight to the benefit of mankind.

Chapter 11

11. CRYO PRESERVATION CRYOTREATMENT

11.1 Cryo Preservation in Animal Husbandary

What is Artificial Insemination ?

Cryogenics is playing an important role in the field of animal husbandry (AI). Artificial insemination of cows and buffalos has become a normal method of breeding quality cattles using frozen semen from quality sires. This technique of artificial insemination is particularly useful in a country like India where the paucity of quality sires has been the main hurdle in the way of cattle improvement programme. Although the storage of semen for 3 to 4 days may be satisfactory for day to day requirements of an AI centre, yet difficult to maintain its fertility for long. This causes a serious wastage of semen from valuable sires. The majority of AI activity today is performed with frozen semen. Freezing has permitted semen to be collected, processed and used anywhere for years afterwards. Cryo preservation is the most advanced in the bovine species and has served as a basic model for other species.

The diluted semen is filled in straws which are then racked horizontally or vertically and before being frozen in liquid nitrogen vapours at -120 to -130^0 C for 9 – 18 minutes. These straws are then transferred in to a container filled with liquid nitrogen and maintained at -196^0 C. For use, the straws are thawed by placing them into a 37^0C water bath for 30 to 60 seconds. The first scientific research in artificial insemination of domestic animals was performed on dogs in 1780 by the Italian scientist, Lazanno Spalbanzani. His experiments proved that the fertilizing power reside in the spermatozoa and not in the liquid portion of semen.

Artificial insemination is not merely a novel method of bringing about pregnancy in females but a powerful tool employed for livestock improvement. In artificial insemination the germplasms of the bulls of superior quality can be effectively utilized with least regard for their location in far away places

Frozen Semen

The use of frozen semen for AI in cattles in the tropics was introduced in the sixties. The Regional Semen Banks play a vital role in maintaining the quality of frozen semen during storage and transportation. It supplies semen of different genetic groups as per the stipulations of the state breeding programme and ensures accountability. The Board supplies frozen semen to the A.I. centers as per the indent. The Board also markets frozen semen in a few other states like Tamilnadu, West Bengal, Rajasthan, Maharashtra, Assam, J&K, Andhra Pradesh and the Union Territory of Pondichery and Lakshadweep.

Role of the Department of Animal Husbandry, Dairying & Fisheries

(AHDF) (Ministry of Agriculture, Govt. of India)

Animal Husbandry is a state subject and the State Governments are primarily responsible for the growth of this sector. The Department of Animal Husbandry, Dairying & Fisheries has been operating 30 Central Livestock Organizations and allied Institutions for production and distribution of superior germplasms to the State Governments for cross breeding and genetic upgradation of the stocks. Besides, the Department has been implementing 11 Central Sector and

Centrally Sponsored Schemes for the development of requisite infrastructure and supplementing the efforts of the State Governments for achieving the accelerated growth of animal husbandry sector.

Central Frozen Semen Production and Training Institute (CFSP&TI) Hessarghatta, Bangalore

The Institute at Hessarghatta, Bangalore was established by the AHDF as Frozen Semen Bank in 1969 with the following objectives:

1. Production of quality semen from superior exotic, crossbred and indigenous breeds of cattles and some important breeds of buffalo.
2. To serve as a Central Depot of Frozen Semen from outstanding imported bulls for the distribution within the country for breeding the nucleus exotic herds.
3. To organize training, workshops, seminars in the field of frozen semen technology and allied subjects.

In 1980, it was renamed as Central Frozen Semen Production and Training Institute (CFSP&TI) with the addition of training component in the field of frozen semen technology. Institute is also accredited for testing of indigenously manufactured equipments related to frozen semen technology.

National Project for Cattle & Buffalo Breeding

The Objectives of the scheme is to arrange delivery of vastly improved artificial insemination service at the farmers doorstep which involves

(a) Streamlining storage and supply of Liquid Nitrogen by sourcing supply from industrial gas manufacturers and setting up bulk transport and storage systems for the same.

(b) Istitutional restructuring by way of entrusting the job of managing production and supply of genetic inputs as well as Liquid Nitrogen to a specialized autonomous and professional State Implementing Agency.

A Typical Example (Tamilnadu) is given below:

Artificial Insemination Centres	3258
Frozen Semen Production Stations	3
Liquid Nitrogen Plants	6
Cattle Breeding & Fodder Development Units	20
Frozen Semen Banks	12

LIQUID NITROGEN PLANTS FOR ANIMAL HUSBANDARY

To meet the liquid nitrogen requirement of the Semen Banks, many State and Central Husbandry Centres installed liquid nitrogen plants of capacity 5- 10 litres/ hr The total number of these plants are 250- 300 and majority of them are by M/ Stirling (model PLN 106) and few are from Linde (model LINIT 5- 10). Installation of these plants started in 1965. Out of these 250 installed plants, only 50 are working condition and meeting the demand of the respective semen centres. Remaining AI centres manage preservation by procuring liquid nitrogen from external sources.

In recent past the demand for liquid nitrogem plants in North East States and in Kashmir has increased as no external supply is available in these regions.

Detailed of Liquid Nitrogen plants for Animal Husbandry are listed below. Capacity of these plants in the range of 5- 10 litres/hr

S.NO	NAME & LOCATION OF ANIMAL HUSBANDARY	YEAR	SUPPLIER	REMARKS
	NORTH			
	HARYANA/ UP/ RAJASTHAN/ PUNJAB/ H.P/J&K			
1	I.C.D.P., GURGAON	1975	**Stirling**	WRITTEN OFF
2	I.C.D.P., SIRSA	1981	**Stirling**	NOT IN USE
3	IACBP, HISSAR	1980	**Stirling**	NOT IN USE
4	IACBP, HISSAR	1981	**Stirling**	NOT IN USE
5	I.D.A, ROHTAK	1986	**Stirling**	NOT IN USE
6	LAK. FARM, ROHTAK	1986	**Stirling**	NOT IN USE
7	NDRI, KARNAL	1974	**Stirling**	NOT IN USE
8	AH, Karnal	1990	**Linde**	
9	AH, KAITHAL	1996	**Stirling**	NOT IN USE
10	AH, Jaghadri	1990	**Linde**	
11	D.F.S., NIBLET	1991	**Stirling**	
12	D.F.S., GORAKHPUR	1988	**Stirling**	NOT IN USE
13	D.F.S., LAKHIMPUR	1988	**Stirling**	NOT IN USE
14	D.F.S., FAIZABAD	1989	**Stirling**	
15	D.F.S., MUJJAF'NGR	1990	**Stirling**	
16	D.F.S., BALIA	1991	**Stirling**	
17	D.F.S., SULTANPUR	1989	**Stirling**	
18	D.F.S., BABUGARH	1991	**Stirling**	
19	D.F.S., PILLIBHIT	1987	**Stirling**	NOT IN USE
20	F.S.B, AJAMGARH	1988	**Stirling**	NOT IN USE
21	F.S.B., ORAI	1987	**Stirling**	NOT IN USE
22	D.F.S., BARIELLY	1987	**Stirling**	NOT IN USE
23	I.V.R.I, Bareilly	1987	**Linde**	NOT IN USE
24	I.V.R.I., IZZATNAGAR	1976	**Stirling**	NOT IN USE
25	F.B. DAIRY, MERRUT	1983	**Stirling**	NOT IN USE
26	F.B. DAIRY, V'NASHI	1981	**Stirling**	NOT IN USE
27	C.C.B.F., ANDESH'NGR	1992	**Stirling**	
28	F.F.H.C, MORADABAD	1977	**Stirling**	WRITTEN OFF
29	AH, KUCKNOW	1975	**Stirling**	NOT IN USE
30	AH, BASTI	1997	**Stirling**	NOT INSTALLED
31	AH, JHANSI	1997	**Stirling**	
32	AH, Barabanki	1990	**Linde**	

S.NO	NAME & LOCATION OF ANIMAL HUSBANDARY	YEAR	SUPPLIER	REMARKS
33	AH, Chakgaria	1990	Linde	
34	AH, RISHIKESH	1985	Stirling	NOT IN USE
35	AH, PAURI	1983	Stirling	NOT IN USE
36	AH, PAURI	1989	Stirling	NOT IN USE
37	AH, ALMORA	1977	Stirling	NOT IN USE
38	AH, ALMORA	1988	Stirling	
39	RAU, VALLABHNAGAR	1981	Stirling	NOT RUNNING
40	RCDF LTD, JAIPUR	1985	Stirling	WRITTEN OFF
41	RCDF LTD, JODHPUR	1986	Stirling	WRITTEN OFF
42	RCDF LTD, BHILWARA	1987	Stirling	WRITTEN OFF
43	URDUS LTD,BIKANEER	1981	Stirling	WRITTEN OFF
44	RCDF LTD, BASSI	1979	Stirling	NOT IN USE
45	AH, BASSI	1985	Stirling	WRITTEN OFF
46	AH, JALWAR	1985	Stirling	WRITTEN OFF
47	AH, BANSWARA	1985	Stirling	WRITTEN OFF
48	AH, NAGOUR	1985	Stirling	WRITTEN OFF
49	AH, BUNDI	1985	Stirling	WRITTEN OFF
50	CCBF, SURATHGARH	1992	Stirling	WRITTEN OFF
51	ICDP, AMRITSAR	1976	Stirling	WRITTEN OFF
52	P.A.U., LUDHIANA	1976	Stirling	WRITTEN OFF
53	P.M.P., LUDHIANA	1980	Stirling	WRITTEN OFF
54	P.M.P., BHATINDA	1981	Stirling	WRITTEN OFF
55	AH, BHATINDA	1976	Stirling	WRITTEN OFF
56	AH, NABHA	1976	Stirling	WRITTEN OFF
57	AH, PATIALA	1976	Stirling	WRITTEN OFF
58	AH, SANGRUR	1976	Stirling	WRITTEN OFF
59	AH, Kapurthala	1988	Linde	NOT IN USE
60	FSB, MANDI	1978	Stirling	
61	FSB, MANDI	1985	Stirling	NOT RUNNING
62	FSB, SOLAN	1985	Stirling	
63	FSB, CHAMBA	1991	Stirling	
64	ICDP, GANAHATTI	1985	Stirling	
65	ABC, SALON	1976	Stirling	WRITTEN OFF
66	I.L.I.P., PALAMPUR	1976	Stirling	NOT IN USE
67	AH, PALAMPUR	1997	Stirling	
68	AH, PALAMPUR	2002	Stirling	
69	AH, MANDI	1997	Stirling	
70	FSB, SRINAGAR	1981	Stirling	NOT IN USE
71	FSB, SRINAGAR	1986	Stirling	NOT IN USE
72	ICDP, JAMMU CANTT.	1981	Stirling	NOT IN USE
73	AH, BELICHARANA	1993	Stirling	

S.NO	NAME & LOCATION OF ANIMAL HUSBANDARY	YEAR	SUPPLIER	REMARKS
74	AH, HAKKAL	1996	**Stirling**	
75	AH, UDHAMPUR	1996	**Stirling**	
76	AH,RAJOURI	1996	**Stirling**	
77	AH, BARAMULLA	1994	**Stirling**	
78	AH, ANANTNAG	1995	**Stirling**	
79	AH, BADGAON (S'GAR)	1998	**Stirling**	
80	AH, KARGIL	2001	**Stirling**	
81	AH, HANDWARA	2001	**Stirling**	
82	AH, PULWAMA	2002	**Stirling**	
83	AH, DODA	2003	**Stirling**	
	SOUTH			
A	**TAMILNADU ANDHRA PRADESH/ KERALA/ KARNATAK**			
84	M/S VETY COLLEGE	1973	**Stirling**	NOT IN USE
85	AH, SYDAPET	1983/96	**Stirling**	
86	T.N. MILK, VELLORE	1978	**Stirling**	NOT IN USE
87	T.N. MILK, ERODE	1978	**Stirling**	NOT IN USE
88	D.M.P.F, MADURAI	1978	**Stirling**	NOT IN USE
89	D.L.F., ABHISEK'PATTI	1988	**Stirling**	NOT IN USE
90	D.L.F., ABHISEK'PATTI	1988	**Stirling**	NOT IN USE
91	ECBF, E'KOTTAI	1983	**Stirling**	NOT IN USE
92	ECBF, E'KOTTAI	1989	**Stirling**	NOT IN USE
93	ECBF, E'KOTTAI	1989	**Stirling**	NOT IN USE
94	ECBF, E'KOTTAI	1989	**Stirling**	
95	AH, HOSUR, TN	1998	**Stirling**	
96	AH, EACHENKOTTAI	1998	**Stirling**	
97	AH, Ooty	1991	**Linde**	
98	FSB, NANDYAL	1979	**Stirling**	NOT IN USE
99	CSCC, GANNAVARAM	1986	**Stirling**	OWN SERVICE
100	CSCC, WARRANGAL	1986	**Stirling**	OWN SERVICE
101	CSCC,KAKKINADA	1987	**Stirling**	OWN SERVICE
102	CSCC, T,PALLIGUDAM	1987	**Stirling**	OWN SERVICE
103	CSCC, KOVUR	1987	**Stirling**	OWN SERVICE
104	CSCC, NIZAMABAD	1988	**Stirling**	OWN SERVICE
105	CSCC, KARIMNAGAR	1989	**Stirling**	OWN SERVICE
106	CSCC, SRIKAKULAM	1978	**Stirling**	NOT IN USE
107	S. DAIRY, VAD'MURI	1980	**Stirling**	WRITTEN OFF
108	IND-SWS PJT., VIZAG	1968	**Stirling**	NOT IN USE
109	IND-SWS PJT., VIZAG	1987	**Stirling**	OWN SERVICE
110	IIL, HYDERABAD	1989	**Stirling**	NOT IN USE

S.NO	NAME & LOCATION OF ANIMAL HUSBANDARY	YEAR	SUPPLIER	REMARKS
111	IDL CHEM (IIL)	1976	Stirling	WRITTEN OFF
112	CFSB, H'GHATTA	1977	Stirling	NOT IN USE
113	CSCC, HEBBAL	1977	Stirling	NOT IN USE
114	CMPU, MANIPAL	1979	Stirling	NOT IN USE
115	IVRI, BANGALORE	1979	Stirling	NOT IN USE
116	KMF, BANGALORE	1985	Stirling	NOT IN USE
117	DHARWAR MILK	1979	Stirling	NOT IN USE
118	N.J.F, OOTY	1979	Stirling	NOT IN USE
119	IIAP, KOVULUR	1998	Stirling	
120	IND-SWS PJT, M'KERA	1968	Stirling	NOT IN USE
121	IND-SWS PJT, MUNNAR	1968	Stirling	NOT IN USE
122	IND-SWS PJT, P'MADI	1968	Stirling	NOT IN USE
123	KLD&MMB, M'KERA	1973	Stirling	NOT IN USE
124	KLD&MMB, K'PUZA	1992	Stirling	OWN SERVICE
125	KLD&MMB, K'PUZHA	1974	Stirling	NOT IN USE
126	KLD&MMB, M'PATTI	1974	Stirling	NOT IN USE
127	KLD&MMB, CAN'NORE	1990	Stirling	OWN SERVICE
128	KLD&MMD, CAN'NORE	1975	Stirling	NOT IN USE
129	KLD&MMB, PUTH'PDY	1976	Stirling	NOT IN USE
130	KLD&MMB,PALGHAT	1975	Stirling	NOT IN USE
131	KLD&MMB, PALGHAT	1985	Stirling	NOT IN USE
132	KLD&MMB, CH'KUDI	1977	Stirling	NOT IN USE
133	KLD&MMB, M'KERA	1985	Stirling	NOT IN USE
	WEST			
A	**MAHARASHTRA/ GUJARAT / MP & CHHATTISGARH**			
134	K.D.C., GOREGAON		Stirling	NOT IN USE
135	K.D.C., GOREGAON	1982	Stirling	NOT IN USE
136	BAIF, PUNE	1983	Stirling	NOT IN USE
137	BAIF, PUNE	1984	Stirling	NOT IN USE
138	BAIF, PUNE	1985	Stirling	NOT IN USE
139	BAIF,WAGHOLI	1986	Stirling	NOT IN USE
140	AIC, KHIDKI, PUNE	1980	Stirling	NOT IN USE
141	AH, JALGAON	1980	Stirling	NOT IN USE
142	AH, PARBHANI	1984	Stirling	NOT IN USE
143	AH, NANDED	1985	Stirling	NOT IN USE
144	AH, NAGPUR	1985	Stirling	NOT IN USE
145	AH, NAGPUR	1985	Stirling	
146	AH, AURANGABAD	1985	Stirling	
147	AH, OSMANABAD	1985	Stirling	

S.NO	NAME & LOCATION OF ANIMAL HUSBANDARY	YEAR	SUPPLIER	REMARKS
148	AH, SOLAPUR	1987	**Stirling**	NOT IN USE
149	AH, NASIK	1986	**Stirling**	
150	AH, MIRAJ	1987	**Stirling**	NOT IN USE
151	AH, AMARAVATI	1985	**Stirling**	NOT IN USE
152	AH, AMBIKAPUR	1992	**Stirling**	NOT IN USE
153	AH, RAJKOT	1987	**Stirling**	NOT IN USE
154	AH, RAJKOT	1987	**Stirling**	NOT IN USE
155	AH, RAJKOT	1997	**Stirling**	NOT IN USE
156	AH, MEHSANA	1989	**Stirling**	NOT IN USE
157	AH, HIMMATNAGAR	1995	**Stirling**	NOT IN USE
158	MEHSANA DAIRY	***	**Stirling**	NOT IN USE
159	S.A.J., BIDAJ	1983	**Stirling**	NOT IN USE
160	S.A.J., BIDAJ	1972	**Stirling**	NOT IN USE
161	CHALALA DAIRY	1988	**Stirling**	NOT IN USE
162	A.I.C., JAMNAGAR	1989	**Stirling**	NOT IN USE
163	AH, BHOPAL	1971	**Stirling**	OWN SERVICE
164	AH, BHOPAL	1985	**Stirling**	OWN SERVICE
165	AH, SEONI	1987	**Stirling**	NOT IN USE
166	AH, CHINDWARA	1987	**Stirling**	NOT IN USE
167	AH, BILASHPUR	1986	**Stirling**	NOT IN USE
168	AH, RAJNANDANGAON	1985	**Stirling**	OWN SERVICE
169	AH, NARSINGPUR	1986	**Stirling**	NOT IN USE
170	AH, BHANUP'PUR	1990	**Stirling**	NOT IN USE
171	AH, SHAHDOL	1983	**Stirling**	NOT IN USE
172	AH, AMBIKAPUR	1987/92	**Stirling**	OWN SERVICE
173	AH, AMARAWATI	1988	**Linde**	NOT IN USE
	EAST			
A	**WEST BENGAL/ BIHAR/ ORISSA**			
174	AH, BELGACHIA	1992	**Stirling**	
175	AH, BELGACHIA	1994	**Stirling**	NOT IN USE
176	AH, JALPAIGURI	1995	**Stirling**	NOT IN USE
177	AH, BURDWAN	1997	**Stirling**	NOT IN USE
178	AH, MALDAHA	1997	**Stirling**	NOT IN USE
179	AH, KAKDWEEP	1997	**Stirling**	NOT IN USE
180	AH, HARINGHATA	1997	**Stirling**	
181	AH, SALBONI	1997	**Stirling**	
182	AH,BISHNUPUR	1997	**Stirling**	NOT IN USE
183	HIMUL, SILIGURI	1980	**Stirling**	NOT IN USE
184	BAMUL, BERHAM'PR	1979	**Stirling**	NOT IN USE

S.NO	NAME & LOCATION OF ANIMAL HUSBANDARY	YEAR	SUPPLIER	REMARKS
185	MIMUL, MIDNAPUR	1973	Stirling	NOT IN USE
186	FSB, PATNA	1979	Stirling	NOT IN USE
187	FSB, RANCHI	1989	Stirling	NOT IN USE
188	FSB, MUZZAFARPUR	1989	Stirling	NOT IN USE
189	FSB, DUMKA	1980	Stirling	NOT IN USE
190	FSB, ARA	1980	Stirling	NOT IN USE
191	FSB, DALTONGAUNGE	1980	Stirling	NOT IN USE
192	FSB, CHAIBASA	1980	Stirling	NOT IN USE
193	AH, Purnea	1988	Linde	NOT IN USE
194	AH, Gaya	1989	Linde	NOT IN USE
195	FSB, CUTTACK	1979/97	Stirling	NOT IN USE
196	FSB, CUTTACK	1989	Stirling	NOT IN USE
197	FSB, CHIPLIMA	1996	Stirling	NOT IN USE
198	FSB, CHIPLIMA	1997	Stirling	NOT IN USE
199	FSB, CHIPLIMA	1988/96	Stirling	NOT IN USE
200	FSB, PHULBANI	1986	Stirling	NOT IN USE
201	FSB, BOLANGIR	1986/97	Stirling	NOT IN USE
202	FSB, KORAPUT	1986	Stirling	NOT IN USE
203	FSB, BHAWANIPATNA	1986	Stirling	NOT IN USE
204	FSB, BHAWANIPATNA	1987	Stirling	NOT IN USE
205	FSB, KHURDA	1986	Stirling	NOT IN USE
206	FSB, RAIGADA	1999	Stirling	NOT IN USE
207	CCBF, KORAPUT	1988	Stirling	NOT IN USE
E	**ASSAM / MEGHALAYA/ MANIPUR/MIZORAM/**			
208	DFSB, JORHAT	1982	Stirling	NOT IN USE
209	ICDP, KHANAPARA	1983	Stirling	NOT IN USE
210	ICDP, KHANAPARA	1983	Stirling	NOT IN USE
211	ICDP, HOWLY	1987	Stirling	OWN SERVICE
212	ICDP, KOKRAJHAR	1987	Stirling	OWN SERVICE
213	ICDP, SILCHAR	1987	Stirling	OWN SERVICE
214	ICDP, Tezpur		Linde	
215	AH, Jorhat	1991	Linde	
216	AH, Silchar	1991	Linde	
217	AH, Manja		Linde	
218	ICDP, SHILLONG	1992	Stirling	
219	AH, MEGHALAYA (TURA)	2000	Stirling	
220	ICDP, IMPHAL	1990	Stirling	
221	ICDP, KAKCHING	1993	Stirling	
222	ICDP,PORAMPET	2001	Stirling	

S.NO	NAME & LOCATION OF ANIMAL HUSBANDARY	YEAR	SUPPLIER	REMARKS
223	AH, AIZWAL	1988	**Stirling**	WRITTEN OFF
224	AH, Aizwal	2000	**Linde**	
225	AH, Lungley	2001	**Linde**	
E	**NAGALAND/ TRIPURA/ SIKKIM/ARUNACHAL PRADESH/ ANDAMAN**			
226	FSB, WOKHA	1988	**Stirling**	AMC
227	FSB,KOHIMA	2002	**Stirling**	
228	AH, AGARTALA	1987	**Stirling**	AMC
229	AH, AGARTALA	1986	**Stirling**	AMC
230	AH, AGARTALA	2002	**Stirling**	AMC
231	AH, AGARTALA	2007	**Stirling**	
232	AH, AGARTALA	2009	**Stirling**	WARRANTY
233	SIMUL, GANGTOK	1982	**Stirling**	ON CALL
234	AH, Gangtok	1987	**Linde**	
235	AH, Jorethang	1993	**Linde**	
236	AH, Jorethang	1996	**Linde**	
237	AH,NIRJULI	1991	**Stirling**	AMC
238	AH, PASIGHAT	2004	**Stirling**	AMC
239	AH, DIRANG	2009	**Stirling**	TO BE INSTALLED
240	NAIP, BHUTAN	1988/2002	**Stirling**	AMC
241	NAIP, BHUTAN	2007	**Stirling**	AMC
242	NAIP, BHUTAN	2008	**Stirling**	WARRANTY
243	AH, KATHMANDU	1976	**Stirling**	ON CALL
244	AH, KATHMANDU	1976	**Stirling**	ON CALL
245	AH PORT BLAIR	1997	**Stirling**	AMC

11.2 Human Blood Preservation

The frequent requirement of Blood Transfusion in a variety of surrgical operations, pernicious anaemia patients and during war time calls for storage of human blood red cells. Traditionally most hospitals in India store whole blood usually in ACD (Acid-Citrate-Dextrose) or in CPD (Citrate-Phosphet-Dextose) solutions. The self life of this blood is about 21 days and is generally refered to as '21-day Tyranny'. More often than not patients need red cells only and whole blood is certainly not ideal. Cryopreservation technique offers an ideal way of storing red cells at cryogenic temperature for a long durations. In fact the very idea of blood bank is that you can deposit several units of blood when you are young and healthy and can withdraw it when needed at an old age or if you undergo a surgery. Nothing can be better than your own blood.

Broadly speaking, there are two methods employed in the freeze preservation of human blood red cells. The first method involves the use of high concentration (45 W/V %) intercellular cryo-protective agent (glycerol) and slow freezing (-80^{0}C). In the second method one uses low concentration of glycerol (14 W/V %) and rapid freezing to LN2 temperature (-196^0 C). In the first technique glycerolized red cells are frozen and stored at -80^{0}C in a mechanical refrigerator whereas in the second technique these glycerolized red cells are frozen quickly in the LN2 bath and are either stored at LN2 temperature or in the vapour phase at -150^{0}C. In both the techniques the frozen cells are thawed at 37^{0}C in a vibrator, washed thoroughly under suitable media to below two per cent glycerol level before being transfused. The IMCR gyuidelines however say the red cells preserved at -80^0 C have a self life of 10 years and those preserved at – 196^0 C have a self life of only three years. This is somewhat in contradiction with our earlier belief that the red cells preserved by these techniques will have a self life of many many years or even indefinite period.

The above techniques are prevalent in many countries with excellent results. In India, no hospital is using this cryogenic technique to preserve human blood or the red cells. We visited several hospitals and blood nanks, like AIIMS, Apollo, Army Referral and Research Hospital, Armed Forces Transfusion Centre and so on in Delhi. Whole blood is still stored at + 4^0 C by traditional technique. The self life of such blood is about one month.

11.3 Stem Cell and Cord Cell Preservation:

With over 26 million births being registered every year in India, the number of Stem cell banking companies in India are on the rise.

Enterprises ranging from India's largest corporate player like Reliance Life Sciences to local non-government organizations (NGOs) are making early investments in setting up stemcell and umbilical cord blood banks across the country. While Cryobanks International, LifeCell, and Reliance have already established themselves in the cord blood and stem cell banking space, regional players are seeing this as a futuristic business option. This year alone has witnessed the setting up of two companies.

The Reliance Life Sciences offers stem cell banking services under the "Reli Cord" brand and is known to have direct presence in more than 30 locations. Cryobanks has established its facility in Gurgaon with an investment of Rs 35 crores. The company operates in over 25 cities and was able to harvest about 6,000 units during 2008. The Cryobanks International India increased the number of offices from 25 to 50 by March 2008 and the client base from 1,500 to 6,000. It plans to set up about four banks across India in the next three to four years. One would be in Delhi, one in Calcutta, one in Mumbai or Pune and one in South or whichever place suits. Life Cell, in collaboration with Cryo-Cell International, USA facilitates the cryogenic preservation of stem cells at its unique facility in Chennai. Life Cell has set up a 21,000 sq ft laboratory at the cost of Rs 14 crores in the outskirts of Chennai and has more than 30 centers. The company has centers in Dubai and Sri Lanka and plans to open centers in other countries as well. Life Cell has recently inaugurated its area office and collection centre in Indore and the company plans to have more than 50 centers during 2009 to cater to the growing Indian market for stem cell banking. The facility has a capacity to store over 1 lakh samples and conforms to the standards of American Association of Blood Banks and US FDA.

The other players operating in this space include Cord Life Biotech, Cryo Stem Cell, and Karnataka Stem Cell. Chennai-based Jeevan Blood Bank is also setting up Jeevan Stem Cell Bank. The main source of stem cells will be umbilical cord blood. IQRA Biotech Services, claimed to be the first human DNA banking company based in Lucknow, UP, also proposes to setup an umbilical cord blood bank by 2008-09.

Cryo-Save India is headquartered in Bangalore with a state-of-the art fully automated adult stem-cell storage facility. The facility at Bangalore covers 10,000 square feet with a storage capacity of 1,50,000 samples extendable to 3,00,000.

The Potential and the Trend

India, having a very high birth rate, presents a lucrative opportunity for stem cell banking business. With more than 26 million births a year, India is poised to be the largest source for umbilical cord blood in the world. Leading cell banking companies are keenly eyeing India for the potential it carries in this segment and are contemplating to enter the Indian market preferably via joint ventures with local companies.

According to industry observers, India has all the essential ingredients to emerge as a key repository of cord blood for companies across the globe. Leveraging the well developed logistics infrastructure, leading companies can create huge storage capacities for their global and Asia-Pacific operations in India. Most of the cord-cell banking companies are increasingly looking at fostering links with medical institutes, hospitals, research institutions and biotechnology companies to aid in stem sell research. Many of the stem-cell banking companies have also been focusing on stem cell therapy centers. TRICell is an affiliate of LifeCell and has a therapeutics facility to provide clinical applications under stem cell therapy. It has been set up in association with Sri Ramachandra University, Chennai. Cyrobank is also in the process of establishing a therapy center by the end of this year.

At present, lack of awareness among the common people about the huge potential to be gained from the storage of cord blood stem cells and highly technical nature of the process is the key reason for a small customer base in the country. However, the market has tremendous potential that could be tapped by initiating an awareness campaign and a customized marketing plan.

Stem Cell Banks in India

Sr. No.	Name of the Stem Cell Bank	Location
1.	Relience Life Science	Mumbai
2.	Life Cell	Chennai
3.	Cryo Bank International	Gurgaon
4.	Jeevan Stem cell Bank	Chennai
5	Karnataka Stem Cell	Bangalore
6	Cryo Stem Cell	Bangalore
7	Cord Life Biotech	Pune
8	Appolo Hospital	Hydrabad
9	Advanced Cell Therapatics	Mumbai
10.	IDRA Biotech Services	Lucknow
11.	Cryo Save India	Bangalore

11.4 Human Semen Preservation

M/s Cryo-genie India (P) Ltd.
New Delhi- 110016
www.cryogenie.com

11.5 Cryo Pulverising / Cryo Grinding

Cryogenic Grinding is a method of powdering herbs, size reduction of polymers, pharmacheticals by cryo technique at liquid nitrogen temperature. The herbs are frozen with liquid nitrogen as they are being ground. The process does not damage or alter chemical composition of the plant in any way. Normal grinding process which do not use a cooling system can reach up to 200^0 F. These high temperature can reduce Volatile components and heat sensitive constituents in herbs. The Cryogenic Grinding process starts with air dried herbs, rather than freeze dried herbs. Solid materials are pulverised by way of hammer mills, attriation mills or other equipment. A smaller particle size is usually needed to enhance the further processing of the solid as in mixing with other materials. However many materials are either very soft or very tough at room temperature. By cooling to cryogenic temperature with liquid nitrogen, these may be embrittled and easily fractured into small particles

Companies involved in Cryo-Grinding:

M/S Swasan Globalised
8 Rajdeep, Sheffield Society Lokhandwala Complex
Andheri (W) Mumbai- 53

M/s Kaps Enginners
831, GIDC Makarpura
Vadodora-390001

11.6 Cryo Treatment of Tools

Cryogenic traetment can improve the performance and life of HSS (high Strengh Steel) or carbide cutting tools, blades, knives and dies up to 400%. This is achieved by control cooling of tools using liquid nitrogen in a chamber. Research work on the cryotreatment of tools is being carried out at 2-3 places like Anna University, IISc, Bangalore and at IIT Kharagpur.

The company involved in cryotreatment of tools:

M/s Spectra Cryogenic Systems (P) Ltd
E-132, Road No 5
Kota Rajasthan – 324005

11.7 Cryo Surgery

Cryosurgery or sometimes called cryotherapy is the application of extreme cold to destroy abnormal or diseased tissues like warts, moles, skin tags or treat small skin cancer. Several internal disorders, liver cancer, prostate cancer lung cancer, oral cancers and cervical disorders can also be treated by cryoprobes effectively provided the disease is localized. Cryosurgery uses the destructive power of freezing temperatures on cells. At low temperatures, ice crystals form inside the cells, which can tear them apart. More damage is caused when blood vessels to the diseased tissue freeze.The most common method of freezing lesions is to use liquid nitrogen spray or the so called cryojet. Another alternative is to use a tip cooled to nearly LN2 temperature using the principle of Joule-Thomson Expansion. This gives physicians excellent control of the ice, and minimizing complications using ultra-thin 17 gauge cryoneedles. Cryosurgery is a minimally invasive procedure, and is often preferred to more traditional kinds of surgery because of its minimal pain, scarring, and cost; however, as with any medical treatment, there are risks involved, primarily that of damage to nearby healthy tissue. Damage to nerve tissue is of particular concern.Cryosurgery is the most common of methods, for it causes very little pain to the patient, and is relatively quick.

Proto type cryoprobes were developed at National Physical Laboratory, New Delhi during 1970s for the cataract operation and for treating malignant tumors. These probes used J-T expansion technique. Probes were successfully test demonstrated.

Cryosurgery at Ganga Ram Hospital, New Delhi
The department utilises liquid nitrogen for cryosurgery, which is useful for a variety of benign and malignant skin conditions including:

- Warts
- Molluscum
- Naevi
- Acne (for both inflammatory and scars)
- Keloids
- Leukoplakia
- Actinic keratosis
- Basal cell carcinoma

Chapter 12

EDUCATION IN CRYOGENIC ENGINEERING

There are number of Institutes and universities, offering a course on superconductivity in M.Sc (Physics). Limited institutes offering courses on Cryogenic Engineering. Table lists few colleges offering cryogenic Education

Sl No	Institute	Department	Degree Offered	Starting year
1	IIT. Kharagpur	Cryogenic Engineering Centre	M.Tech (Cryogenic engineering) Ph.D	1980
2	IIT. Mumbai	Mechnical Engineering Department	M.Tech (Thermal & fluid engineering) Ph.D	
3	LD College of Engineering	Mechanical department	M.Tech (Cryogenic Engineering)	1990
4	TKM College of Engineering	Mechanical Department	M.Tech (Industrial Refrigeration and cryogenic Eng	1992
5	IISc. Bangalore	Centre for Cryogenic Technology	Ph.D	
6	NIT. Rourkella	Dept of Mechanical	B.Tech : Elective Subject Ph.D	2004
7	NIT. Surat	Dept of Mechanical	Ph.D	

Complete course on Cryogenics and Superconductivity together is offered only at IIT. Kharagpur and faculty of mixed nature Ph.d in Science and Engineering. Rest of the Institutes, cryogenic Engineering is attached to Mechanical Engineering Department. IIT mumbai offers M.Tech in Thermal and Fluid Engineering where two subjects are on Cryogenic engineering.

LD College of Engineering and TKM College of Engineering offers M.Tech in Cryogenic engineering and Industrial Refrigeration and Cryogenic engineering respectively. Faculty fromLD College are all M.Tech qualified where as TKM has few Ph.D. Both the colleges have limited cryogenic facilities

IIT, Kharagpur was the First to have separate Centre for M.Tech Teaching. We report here structure & profile of passed out students.

Cryogenic Engineering Centre at IIT Kharagpur was established in 1976 on the recommendation of Nayudumma Committee for the advancement of cryogenics and cryogenic engineering. The objective of creating an advanced center like Cryogenic Engineering with inputs from three major disciplines, namely, Physics, Mechanical Engineering, and Chemical Engineering, was to generate expert manpower in this advanced field of science and technology through teaching and research.

In teaching, the Centre offers a four-semester M.Tech. course in Cryogenic Engineering. Besides, it offers several electives related to cryogenics and cryogenic engineering at the B.Tech. level.

Major research areas pursued at the center include Superconductivity and superconducting devices, Vacuum Technology, Gas Separation and Purification, Refrigeration and Liquefaction of Gases, Cryogenic Food Processing, Natural Gas and Hydrogen Energy, Air Separation Technology, Cryogenic Process Engineering, Nitrogen Liquefiers, Cryogenic Instrumentation etc.

Core Subjects on M.Tech courese

1. Cryogenic System : Basic thermodynamics, Liquefaction Cycle, Properties of Cryogenic fluid.
2. CryoPhysics : Matter at low Temperature and Superconductivity
3. Cryo Mass Transfer and separation system : Basic Mass transfer, varios separation process, Adsorption, distillation
4. Superconducting Materials an, magnets and Devices : Basic Superconductivity and Preparation of Sc materials
5. Cryo Heat Transfer : Various types of Heat Transfer, Cryogenic insulation, Two phase flow
6. Cryo fuel System : Deals with Liquid Hydrogen and LNG.
7. Vacuum technique : Various tupes of pump, Characteristics, Leak Detection, Measuring instrumennts
8. CAD Of Cryogenic process
9. Design of Cryo equipment and Acessories : Compressor, heat exchanger, Expansion Machines
10. Cryogenic Air Separation process ; Deals with Industrial gas Production
11. Cryogenic Rocket Propulsion : Deals with Cryo Engine

Faculty Strength : At present total 10 Numbers, 30 % on Physics Background and 70 % with Engineering Background. 3-4 Faculty members had their Ph.D in the Subject of Cryogenic engineering and all from IIT Kharagpur.

M Tech : Total 192 students have got their Post graduation in Cryogenic Engineering. Estimated 40 % students continued their carrier in this Field. 30% have changed the track based on their Basic qualification. No information about 30 %
It is also estimated that 60 % of 40 % preferred to have their carrier in academic/ Scientific Institutes.. and Balance 40 % in gas industries or Cryogenic industry. (There is a scope of improvement on recruitment by gas industries)
Ph.D : Approximate 35 Ph. D have received their degree from this institute, and out of this 80 % in Engineering. Ph.D in Cryogenic Engineering prefers academic institution and limited number are working in scientific lab/ Industry.

Chapter 13

13. HUMAN RESOURCE

13.1 In Research Institutions, IITs and Universities

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
1	S. B. Roy	M.Sc/Ph.D	RRCAT	Scientist(Phy)	40- 50	LTP-SC
2	P. K. Kush	M.Sc	RRCAT	Scientist(Tech)	40-50	CT/Cryocooler
3	B. Datta Gupta	B.Tech/M. Tech	RRCAT	Scientist(Tech) Eng	40- 50	CT
4	R C. Sharma	B.Tech	RRCAT	Scientist(Tech)	50- 60	CT/ CP
5	Prabhat Gupta	B.Tech/ M. Tech	RRCAT	Scientist(Tech)	30- 40	CT/ CCD
6	S Gilankar	B.Tech /M. Tech	RRCAT	Scientist(Tech)	30- 40	CT/Cryopump
7	R. Ghosh	B.Tech	RRCAT	Scientist(Tech)	30- 40	CT /CCD
8	R S. Doohan	B.Tech	RRCAT	Scientist(Tech)	30- 40	CT/ CP
9	M KChattapadhyay	M.Sc/Ph.D	RRCAT	Scientist(Phy)	30- 40	LTP-SC
10	Anand Jadav	M.Sc	RRCAT	Scientist(Phy)	30-40	LTP-SC
11	M. A Manekar	M.Sc	RRCAT	Scientist(Phy)	30-40	LTP-SC
12	K.J.S.Sokhey	M.SC/Ph.D	RRCAT	Scientist(Phy)	40-50	LTP-SC
13	A. Chouhan	M.Sc	RRCAT	Scientist(Phy)	30-40	LTP-SC
14	P. Sachdeba	M.Sc	RRCAT	Scientist(Phy)	30-40	LTP-SC
15	S.C Bapna	M.Sc	RRCAT	Scientist(Tech)	50- 60	CT/Cryostat
16	A. Puntumbekar	B.Tech	RRCAT	Scientist(Tech)	40- 50	CT/ SCM
17	P. Khare	B.Tech	RRCAT	Scientist(Tech)	30- 40	CT/SCM
18	S. C Joshi	B.Tech	RRCAT	Scientist(Tech)	40- 50	CT/SC Cavity
19	J. Diwedi	B.Tech	RRCAT	Scientist(Tech)	40- 50	CT/ SC Cavity
20	R. K. Bhandhari	M.SC/Ph.D	VECC	Scientist(Tech)	>60	CT/ LP
21	R Dey	B.Tech	VECC	Scientist(Tech)	>60	CT/ CP
22	S. Saha	B.Tech	VECC	Scientist(Tech)	50- 60	CT / SCM
23	J. Choudhuri	B.Tech	VECC	Scientist(Tech)	50-60	CT/ Cryostat
24	G.Pal	B.Tech	VECC	Scientist(Tech)	40- 50	CT/ Cryoline
25	Tamal Bhattacharya.	B.Tech	VECC	Scientist(Tech)	30-40	CT/ Cryo control
26	C. Nandi	B.tech	VECC	Scientist(Tech)	30- 40	CT/ Cryo line
27	Tanmoy Das	B.Tech	VECC	Scientist(Tech)	30-40	CT/ Cryo line

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
28	Sanjay Bajirao	B.tech	VECC	Scientist(Tech)	20-30	CT/Cryo line
29	Santosh Mishra	B.Tech	VECC	Scientist/ Eng	20-30	CT
30	Trijit Maity	B.Tech/ M.Tech	VECC	Scientist(Tech)	30-40	CT/ Purifier
31	Abani. Mukherjee	B.Tech	VECC	Scientist(Tech)	30-40	CT/ CP
32	U Panda	B.Tech	VECC	Scientist(Tech)	30-40	CT/ CP
33	U De	M.SC/Ph.D	VECC	Scientist(Phy)	50-60	LTP-SC
34	S.K. Bandyopadhyay	M.Sc/Ph.D	VECC	Scientist(Phy)	50-60	LTP-SC
35	P Barat	M.SC/Ph.D	VECC	Scientist(Phy)	50- 60	LTP-SC
36	D Hajra	B.Tech	VECC	Scientist(Tech)	50-60	CT/ SCM
37	A. Sur	B.Tech	VECC	Scientist(Tech)	50-60	CT/ Vacuum
38	A Pradhan	M.Sc/ M.tech	VECC	Scientist(Tech)	30-40	CT/ SC Magnet
39	U Bhuinya	M.Sc/ M.tech	VECC	Scientist(Tech)	30-40	CT/ SEMS
40	N Das	M.Sc/Ph.D	VECC	Scientist(Tech)	40-50	CT/ Helium Gas
41	Anjan Datta Gupta	B.Tech	VECC	Scientist(Tech)	30-40	CT/ Cryostat
42	Zamal A Naseer	B.Tech/M.Tech	VECC	Scientist(Tech)	30-40	CT
43	S. K. Mitra	B.Tech	VECC	Scientist(Tech)	50-60	CT/ Cryo Plant
44	Parmita Mukherjee	M.SC/Ph.D	VECC	Scientist(Phy)	40- 50	LTP-SC
45	N Datta	DE	VECC	Engineer	30-40	CT/CP
46	C Malik	M.SC/Ph.D	VECC	Scientist(Phy)	50-60	CT/ Magnet
47	M. Ahmed	B.Tech	VECC	Scientist(Tech)	30-40	CT/ Cryostat
48	R. K. Ranganathan	M.Sc/Ph.D	SINP	Academics	50-60	LTP-SC
49	P. Sen	M.Sc/Ph.D	SINP	Academics	>60	CT/ Helium Gas
50	D. Ghosh	M.Sc/Ph.D	SINP	Scientist(Tech)	>60	CT/ Helium Gas
51	C. Mazumdar	M.Sc/Ph.D	SINP	Academics	40-50	LTP-SC
52	A. Poddar	M.Sc/Ph.D	SINP	Academics	50-60	LTP-SC
53	Indranil Das	M.Sc/ Ph.D	SINP	Academics	40-50	LTP-SC
54	M Sanyal	M.Sc/ Ph.D	SINP	Academics	50-60	LTP-SC
55	Sailan Das	M.Sc/ Ph.D	SINP	Academics		LTP-SC
56	P.Mandal	M.Sc/ Ph.D	SINP	Academics		LTP-SC
57	Mr Trilok Singh	B.Tech	BARC	Scientist(Tech)	>60	CT/ Refrigerator
58	A. Chakravarty	B.Tech/Ph.D	BARC	Scientist(Tech)	30-40	CT/ Refrigerator

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
59	Mukesh Goyal	B.Tech	BARC	Scientist(Tech)	30-40	CT/ Refrigerator
60	Naseem Ahmed	B.Tech	BARC	Scientist(Tech)	30-40	CT/ Refrigerator
61	Piyush Prasad	B.Tech	BARC	Scientist(Tech)	20-30	CT/ Refrigerator
62	Mohannand Jadav	B.Tech	BARC	Scientist(Tech)	20-30	CT/ Refrigerator
63	S. Rajendran	B.Tech	BARC	Scientist(Tech)	40-50	CT/ Refrigerator
64	M.R Singh	M.SC/Ph.D	BARC	Scientist(Tech)	40-50	CT/ CP
65	S K Das	B.Tech	BARC	Scientist(Tech)	40-50	CT / Cryo Distilation
66	S B Narwaria	B.Tech	BARC	Scientist(Tech)	40-50	CT/Cryo Distillation
67	J.V Yakmi	M.Sc/Ph.D	BARC	Scientist(Phy)	60	LTP-SC
68	Ravi Kumar	M.Sc/Ph.D	BARC	Scientist(Phy)	40-50	LTP-SC
69	A.Y Dangore	B.Tech	BARC	Scientist (Tech)	>60	CT/Cryo Distillation
70	S K Gupta	M.SC/Ph.D	BARC	Scientist(Phy)	50-60	LTP-SC
71	S. M Yusuf	M.SC/Ph.D	BARC	Scientist(Phy)	40- 50	LTP-SC
72	Amitava Das	M.SC/Ph.D	BARC	Scientist(Phy)	40- 50	LTP-SC
73	A K Rajarajan	M.SC/Ph.D	BARC	Scientist(Phy)	40- 50	LTP-SC
74	S K Mittal	M.Sc/Ph.D	BARC	Scientist(Tech)	50-60	CT/ SC Cavity
75	S.A. Ghodke	B.Tech	BARC	Scientist(Tech)	30-40	CT/ SC cavity
76	Y.C Saxeana	M.Sc/Ph.D	IPR	Academics	>60	CT/ LCP
77	S. Matto	M.Sc/Ph.D	IPR	Academics	>60	CT/LCP
78	S. Pradhan	M.SC/Ph.D	IPR	Scientist(Tech)	40- 50	CT/ LCP
79	V. Tanna	M.SC/Ph.D	IPR	Scientist(Tech)	30- 40	CT/ LCP
80	J.C Patel	B.Tech/M.Tech	IPR	Scientist(Tech)	40- 50	CT/ CP
81	Ch. Chakrapani	B. Tech	IPR	Scientist(Tech)	30- 40	CT/CP
82	Manoj Gupta	B.Tech/M.Tech	IPR	Scientist(Tech)	30- 40	CT/CP
83	B. Sarkar	M.SC/Ph.D	IPR/ITER	Scientist/ Eng	40- 50	CT/LP
84	Hiten Vaghela	B.Tech	IPR/ITER	Scientist(Tech)	30- 40	CT/ Cryolines
85	Satish Badjigar	B.Tech	IPR/ITER	Scientist(Tech)	20- 30	CT/Cryolines
86	Nitin Shah	B.Tech	IPR/ITER	Scientist(Tech)	20-30	CT/Cryolines
87	Riten Bhattacharya	B.Tech	IPR/ITER	Scientist(Tech)	20- 30	CT/Cryo Control
88	D D Sivagan	M.Sc/Ph.D	IPR/ITER	Scientist (Tech)	30-40	CT/ Cryolines
89	N.C Gupta	B.Tech/ M. Tech	IPR	Scientist(Tech)	30-40	CT/Cryolines

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
90	Arun Chakrabarty	M.Sc	IPR / ITER	Scientist(Tech)	40- 50	CT/ Cryopump
91	Jignesh Tank	B.Tech	IPR	Scientist(Tech)	20-30	CT/Cryo Control
92	Rohit Panchal	B.Tech	IPR	Scientist(Tech)	30- 40	CT/Cryo Control
93	Pradip Panchal	B.Tech	IPR	Scientist(Tech)	30- 40	CT/Cryo Control
94	Rakesh Patel	B.Tech	IPR	Scientist(Tech)	20-30	CT/Cryo Control
95	GL N Srikanth	B.Tech	IPR	Scientist(Tech)	20-30	CT/ Cryostat
96	Dasarath Sonara	B.Tech	IPR	Scientist(Tech)	30-40	CT/ Cryo Inst
97	Rajiv Sharma	B.Tech/M Tech	IPR	Scientist(Tech)	30- 40	CT/ Cryostat
98	Manoj Singh	B.Tech	IPR	Scientist(Tech)	20-30	CT/Cryo Instr
99	Ranjana	M.Sc	IPR	Scientist(Tech)	40-50	CT/Cryo Pump
100	Amardas	M.Sc	IPR	Scientist(Tech)	40- 50	CT/Cryo analysis
101	A. N Sharma	M.Sc	IPR	Scientist(Tech)	30-40	CT/SC Magnet
102	Kalpesh Desai	B.Tech	IPR	Scientist(Tech)	30-40	CT/ Cryo Control
103	Upendra	M.Sc	IPR	Scientist(Tech)	30-40	LTP-SC
104	A K Sahu	B.Tech/M.Tech	IPR/ITER	Scientist(Tech)	30-40	CT/LP
105	P. K.Nayak	M.SC/Ph.D	IPR	Academics	30-40	LTP-SC
106	Amit Roy	M.SC/Ph.D	IUAC.	Scientist(Tech)	50- 60	CT/ CLP
107	T.S Datta	M.Sc/ M.Tech	IUAC.	Scientist(Tech)	40- 50	CT/ CLP
108	D Kanjilal	M.SC/Ph.D	IUAC.	Scientist(Phy)	50-60	LTP-SC
109	PN Prakash	M.Sc	IUAC.	Scientist(Tech)	40-50	CT/ SC Cavity
110	S Ghosh	M.Sc	IUAC.	Scientist(Tech)	40-50	CT/ SC Cavity
111	R Mehta	M.Sc	IUAC.	Scientist(Tech)	40-50	CT/SC Cavity
112	Anup Choudhuri	M.Sc	IUAC.	Scientist(Tech)	30-40	CT/ Cryoline
113	Jacob Chacko	DE	IUAC.	Engineer	50-60	CT/ Cryostat
114	Soumen Kar	M.Sc	IUAC.	Scientist(Tech)	30-40	CT/ Magnet
115	S. Babu	DE	IUAC.	Engineer	40-50	CT/ CP
116	GK Choudhury	DE	IUAC.	Engineer	30-40	CT/ Cryopump
117	Manoj Kumar	DE	IUAC.	Engineer	30-40	CT/ CP
118	Joby Antony	B.Tech	IUAC.	Engineer	30-40	CT / Cryo Control
119	A. Rai	M.Sc	IUAC.	Scientist(Tech)	30-40	CT/ SC Cavity
120	B.K Sahu	M.Sc	IUAC.	Scientist(Tech)	30-40	CT/SC cavity

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
121	Ravi Kumar	M.SC/Ph.D	IUAC.	Scientist(Phy)	40-50	LTP-SC
122	G. Rodriguez	M.Sc	IUAC.	Scientist(Tech)	40-50	CT/ Magnet
123	D. Kabiraj	M.SC/Ph.D	IUAC.	Scientist(Phy)	40-50	LTP-SC
124	P.N Patra	M.Sc	IUAC.	Scientist(Tech)	20-30	CT/ SC Cavity
125	A. Pandey	M.Sc	IUAC.	Scientist(Tech)	30-40	CT/SC Cavity
126	Hari Kishan	M.Sc/Ph.D	NPL	Scientist (Phy)	50-60	LTP-SC
127	R B Saxena	M.Sc	NPL	Scientist(Tech)	50-60	CT/ Magnet
128	S S Verma	B.Tech	NPL	Scientist(Tech)	50-60	CT/CP
129	S K Agrawal	M.SC/Ph.D	NPL	Scientist(Phy)	>60	LTP-SC
130	Ratan lal	M.SC/Ph.D	NPL	Scientist(Phy)	50-60	LTP-SC
131	Anurag Gupta	M.Sc/Ph.D	NPL	Scientist(Phy)	40-50	LTP-SC
132	V.P.S Awana	M.Sc/Ph.D	NPL	Scientist(Phy)	40-50	LTP-SC
133	Puspa Upadhyay	M.Sc/Ph.D	NPL	Scientist(Phy)	50-60	LTP-SC
134	H.K Singh	M.Sc/Ph.D	NPL	Scientist(Phy)	40-50	LTP-SC
135	R.K Kotnala	M.Sc/Ph.D	NPL	Scientist(Phy)	50-60	LTP-SC
136	M.A Ansari	B.Tech	NPL	Scientist(Tech)	30-40	CT/ Magnet
137	Ashok Kumar	M.SC/Ph.D	NPL	Scientist(Tech)	30-40	CT/Magnet
138	V.N Ojha	M.SC/Ph.D	NPL	Scientist(Phy)	40-50	LTP-SC
139	Jokhan Ram	B.Tech	NPL	Engineer	40-50	CT/ CP
140	Anjana	M.Sc/Ph.D	NPL	Scientist(Phy)	30-40	LTP-SC
141	R.S Meena	M.Sc	NPL	Scientist(Tech)	30-40	Cryogenics
142	JP singh	Diploma	NPL	Engineer	40- 50	Cryo Plant
143	R G Sharma	M.SC/Ph.D	NPL	Scientist(Tech)	>60	CT/SC Magnet
144	A. K Gupta	M.SC/Ph.D	NPL	Scientist(Tech)	>60	CT/ SQUID
145	R.C Budhani	M.SC/Ph.D	IIT. Kanpur	Academics	40-50	LTP-SC
146	K.P Rajeev	M.SC/Ph.D	IIT. Kanpur	Academics	40-50	LTP-SC
147	Anjan Gupta	M.SC/Ph.D	IIT. Kanpur	Academics	30-40	LTP-SC
148	Zakir Hossain	M.SC/Ph.D	IIT. Kanpur	Academics	40-50	LTP-SC
149	Satyajit Banerjee	M.SC/Ph.D	IIT. Kanpur	Academics	30-40	LTP-SC
150	Rajeev Sharma	B.Sc	IIT. Kanpur	Engineer	20-30	Cryo Plant
151	Sanjay Singh	M.Sc	IIT. Kanpur	Engineer	30-40	Cryo plant
152	S.Jacob	B.Tech/ Ph.D	IISc.	Scientist(Tech)	50-60	CT

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
153	S. Kasthurirengen	M.SC/Ph.D	IISc.	Scientist(Tech)	50-60	CT
154	R. Karunanithi	M.SC/Ph.D	IISc.	Scientist(Tech)	50-60	CT
155	Nadig	B.Tech/M.Tech	IISc.	Scientist(Tech)	40-50	CT
156	U.Behera	B.Tech/M.tech	IISc.	Scientist(Tech)	40-50	CT
157	G.Narasimham	B.Tech/ Ph.D	IISc.	Academics	40-50	CT
158	S. Subramanian	M.SC/Ph.D	IISc.	Academics	>60	LTP-SC
159	Arindam Ghosh	M.SC/Ph.D	IISc.	Academics	30-40	LTP-SC
160	V. Prasad Bhotia	M.SC/Ph.D	IISc.	Academics	30-40	LTP-SC
161	V.Venkataraman	M.SC/Ph.D	IISc.	Academics	40-50	LTP-SC
162	R Ganesan	M.SC/Ph.D	IISc.			LTP-SC
163	E.S. Rajagopal	M.SC/Ph.D	IISc.	Academics	>60	LTP-SC
164	T.S.Radhakrishnan	M.SC/Ph.D	IGCAR	Re -Scientist	>60	CT/ SQUID
165	Y. Hariharan	M.SC/Ph.D	IGCAR	Re- Scientist	>60	LTP-SC
166	A.Bharathi	M.SC/Ph.D	IGCAR	Scientist(Phy)	50-60	LTP-SC
167	M.P Janwadkar	M.Sc	IGCAR	Scientist(Tech)	50-60	CT/ SQUID
168	R Bhaskaran	M.Sc	IGCAR	Scientist(Tech)	40-50	CT/ SQUID
169	Vaidyanathan	M.SC/Ph.D	IGCAR	Scientist(Tech)	40-50	CT/ SQUID
170	Nagendran	M.Sc/ M.Tech	IGCAR	Scientist(Tech)	40-50	CT/ SQUID
171	S. Kalavathy	M.Sc	IGCAR	Scientist(Phy)	40-50	LTP-SC
172	Awadesh Tiwari	M.SC/Ph.D	IGCAR	Scientist(Phy)	40-50	LTP-SC
173	Geetakumari	M.SC/Ph.D	IGCAR	Scientist(Phy)	40-50	LTP-SC
174	K. Gireesan	M.SC/Ph.D	IGCAR	Scientist(Tech)	40-50	CT/ SQUID
175	A T Satyanarayan	M.Sc/Ph.D	IGCAR	Scientist(Phy)	30-40	LTP-SC
176	N. Ghosh	M.Sc/Ph.D	IGCAR	Scientist(Phy)	30-40	LTP-SC
177	D.K Baisnab	M.Sc	IGCAR	Scientist(Tech)	30-40	CT/ SQUID
178	C Parasakthi	M.Sc	IGCAR	Scientist(Tech)	20-30	CT/ SQUID
179	S Sengottuvel	B.Tech	IGCAR	Scientist(Tech)	20-30	CT/ SQUID
180	Vibek. Nema	B.Tech	IGCAR	Scientist(Tech)	30-40	CT/Purifier
181	B. Muralidharan	B.Tech	IGCAR	Scientist(Tech)	40-50	CT/Purifier
182	P. Dhairypalsingh	B.Tech	IGCAR	Scientist(Tech)		CT/Purifier
183	K. Ganasekharan	B.Tech	IGCAR	Scientist(Tech)	50-60	CT/CP

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
184	S. A Krishnan	B.Tech	IGCAR	Scientist(Tech)	30-40	CT/ CP
185	S. Srinivasmurthy	B.Tech/ Ph.D	IIT.M	Academics	>60	CT/ Mixed Ref
186	G. Venkatratnam	B.Tech/Ph.D	IIT.M	Academics	40-50	CT/ Mixed Ref
187	V. Sankaranarayanan	M.SC/Ph.D	IIT.M	Academics	50-60	LTP-SC
188	G. Ranga Rajan	M.SC/Ph.D	IIT.M	Academics	>60	LTP-SC
189	K. Sethupathi	M.SC/Ph.D	IIT.M	Academics	40-50	LTP-SC
190	M.S. R Rao	M.SC/Ph.D	IIT.M	Academics	40-50	LTP-SC
191	N. Harish Kumar	M.Sc/Ph.D	IIT-M	Academics	40-50	LTP-SC
192	D. Mohanlal	M.Sc/Ph.D	Anna	Academics	40-50	CT/ Cryo Treatment
193	A. Senthil Kumar	B.Tech/Ph.D	VIT	Academics	40-50	CT/ Insulation
194	C.N R. Rao	M.Sc/Ph.D	JCAR	Academics	>60	LTP-SC
195	A Sundarshan	M.SC/Ph.D	JCAR	Academics	40-50	LTP-SC
196	N. Kumar	M.SC/Ph.D	RRU	Academics	>60	LTP-SC
197	T.K Dey	M.SC/Ph.D	IIT- KG	Academics	50- 60	LTP-SC
198	V.V Rao	M.SC/Ph.D	IIT- KG	Academics	50-60	CT/Magnet
199	K. Choudhuri	B.Tech/ Ph.D	IIT- KG	Academics	50-60	CT/ Refrigerator
200	T. K. Nandi	B.Tech / Ph.D	IIT- KG	Academics	40-50	CT/CCD
201	P.S Ghosh	B.Tech/Ph.D	IIT- KG	Academics	30- 40	CT/ CCD
202	Indranil Ghosh	B.Tech/ Ph.D	IIT- KG	Academics	30- 40	CT/CCD
203	V Adyam	M.SC/Ph.D	IIT- KG	Academics	30- 40	LTP-SC
204	S K. Ghatak	M.SC/Ph.D	IIT- KG	Academics	>60	LTP-SC
205	T.K Nath	M.SC/Ph.D	IIT- KG	Academics	30- 40	LTP-SC
206	S Ghosh	B.Tech/ Ph.D	IIT- KG	Academics	30-40	CT/CCD
207	A.K Saha	B.Tech/ Ph.D	Haldia	Academics	40-50	CT/ Separation
208	R Khadatakar	B.Tech/Ph.D	IIT-Gauhati	Academics	30-40	CT/Preservation
209	V.R Kalvey	M.SC/Ph.D	IIT- KG	Retired	>60	LTP-SC
210	S. Bandyopadhyay	B.Tech/Ph.D	IIT- KG	Academics	50-60	CT/ Separation
211	S Pattanayak	B.Tech/Ph.D	IIT- KG	Retired	>60	CT/ preservation
212	V Narasimham	B.Tech	IIT- KG	Retired	>60	CT/CP
213	A. K. Ray Choudhuri	M.SC/Ph.D	SNBSC	Academics	50-60	LTP-SC
214	P.K Mukhopadhyay	M.SC/Ph.D	SNBSC	Academics	40-50	LTP-SC

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
215	Kalyan Mandal	M.SC/Ph.D	SNBSC	Academics	30-40	LTP-SC
216	A.K. Mazumder	M.SC/Ph.D	SNBSC	Retired	>60	LTP-SC
217	S.K Dey	M.SC/Ph.D	IACS	Scientist(Phy)	50-60	LTP-SC
218	S.Lahiri	M.Sc/Ph.D	IACS	Scientist(Phy)	50-60	LTP-SC
219	B.K Choudhuri	M.Sc/Ph.D	IACS	Scientist(Phy)	50-60	LTP-SC
220	D D Sharma	M.Sc/Ph.D	IACS/IISC	Scientist (Phy)	50-60	LTP-SC
221	D Chakravarthy	M.Sc/Ph.D	IACS	Scientist(Phy)	>60	LTP-SC
222	Dipankar Das	M.SC/Ph.D	IUC-Kolkata	Scientist(Phy)	50-60	LTP-SC
223	K Chattapadhyay	M.Sc/ Ph.D	JU	Academics		LTP-SC
224	Tapas Middya	M.SC/Ph.D	JU	Academics		LTP-SC
225	Ajay Ghosh	M.Sc/Ph.D	JU	Academics		LTP-SC
226	Sunil Sarangi	B.Tech/ Ph.D	NIT/ Rourkella	Academics	50- 60	CT/CCD
227	D Behera	M.SC/Ph.D	NIT/ Rourkella	Academics	50- 60	LTP-SC
228	K.A Reddy	M.Sc/Ph.D	NIT/ Rourkella	Academics		
229	R.K Sahu	B.Tech/ Ph.D	NIT/ Rourkella	Academics	50-60	CT/CCD
230	Dipali Banerjee	M.SC/Ph.D	BE College	Academics		LTP-SC
231	S C Sarkar	B.Tech/ Ph.D	CRCT/JU	Academics	40-50	CT/ Separation
232	D. Bhattacharya	B.Tech/Ph.D	CRCT/JU	Academics	40-50	CT/ Preservation
233	Dipten Bhattacharya	M.Sc/Ph.D	CGCRI	Scientist(Phy)	40-50	LTP-SC
234	P. Chaddah	M.Sc/Ph.D	UGC-DAE	Scientist(Phy)	50-60	LTP-SC
235	A Gupta	M.Sc/Ph.D	UGC-DAE	Scientist(Phy)	50-60	LTP-SC
236	V Ganesan	M.SC/Ph.D	UGC-DAE	Scientist(Phy)	40-50	LTP-SC
237	Alok Banerjee	M.SC/Ph.D	UGC-DAE	Scientist(Phy)	40-50	LTP-SC
238	A. M Awasthi	M.SC/Ph.D	UGC-DAE	Scientist(Phy)	40-50	LTP-SC
239	M P. Saravanan	B.Tech	UGC-DAE	Engineer	30-40	CT/CP
240	G S Okram	M.Sc/Ph.D	UGC-DAE	Scientist(Phy)	40-50	LTP-SC
241	Rajeev Rawat	M.Sc/Ph.D	UGC-DAE	Scientist(Phy)	30-40	LTP-SC
242	A.V Narlikar	M.SC/Ph.D	UGC-DAE	Scientist(Phy)	>60	LTP-SC
243	Archana Lakhani	M.Sc/Ph.D	UGC-DAE	Scientist(Phy)	30-40	LTP-SC
244	Ramjane Choudhary	M.Sc/Ph.D	UGC-DAE	Scientist(Phy)	30-40	LTP-SC
245	A. K Rastogi	M.SC/Ph.D	JNU	Academics	50-60	LTP-SC

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
246	S Patnaik	M.SC/Ph.D	JNU	Academics	30-40	LTP-SC
247	S. Ghosh	M.SC/Ph.D	JNU	Academics	40-50	LTP-SC
248	O.N Srivastava	M.Sc/Ph.D	BHU	Academics	40-50	LTP-SC
249	Ratnamala Chatterjee	M.SC/Ph.D	IIT. Delhi	Academics	50-60	LTP-SC
250	Sujeet Choudhuri	M.SC/Ph.D	IIT. Delhi	Academics	40-50	LTP-SC
251	Neeraj Khare	M.SC/Ph.D	IIT. Delhi	Academics	50-60	LTP-SC
252	Manmohan Singh	B.Tech/ M.Tech	SSPL	Scientist(Tech)	40-50	CT/Cryocooler
253	S. Sachdeb	B.Tech	SSPL	Scientist(Tech)	40-50	CT/Cryocooler
254	H.L. Chatwal	B.Tech	SSPL	Scientist(Tech)	>60	CT/Cryocooler
255	R.K. Dewakar	B.Tech	SSPL	Scientist(Tech)	30-40	CT/Cryocooler
256	P.N Dheer	M.Sc/Ph.D	Delhi-U	Scientist(Phy)	>60	LTP-SC
257	G.L Bhalla	M.Sc/Ph.D	Delhi-U	Scientist(Phy)	>60	LTP-SC
258	Agni Kumar	M.SC/Ph.D	Delhi U	Academics	40-50	LTP-SC
259	Maitreyee Nanda	M.SC/Ph.D	Lastech	Scientist(Tech)	40-50	CT
260	Raveesh Kumar	B.Tech/ MTech	Lastech	Scientist(Tech)	50-60	CT
261	P.L. Paulose	M.SC/Ph.D	TIFR	Academics	40-50	LTP-SC
262	E.V Sampath Kumar	M.Sc/Ph.D	TIFR	Academics	40-50	LTP-SC
263	A.K. Nigam	M.SC/Ph.D	TIFR	Academics	50-60	LTP-SC
264	S Ramakrishnan	M.Sc/Ph.D	TIFR	Academics	50-60	LTP-SC
265	S. K. Dhar	M.SC/Ph.D	TIFR	Academics	40-50	LTP-SC
266	A. K Grover	M.SC/Ph.D	TIFR	Academics	>60	LTP-SC
267	K B Maiti	M.SC/Ph.D	TIFR	Academics	40-50	LTP-SC
268	P. Roy Choudhuri	M.SC/Ph.D	TIFR	Academics	40-50	LTP-SC
269	R Nagarajan	M.SC/Ph.D	TIFR	Retired	>60.	LTP-SC
270	L.C Gupta	M.SC/Ph.D	TIFR	Retired	>60	LTP-SC
271	R Pinto	M.SC/Ph.D	TIFR	Retired	>60	LTP-SC
272	R G Pillay	M.SC/Ph.D	TIFR	Academics	50-60	CT/ CLP
273	SS Jangam	M.Sc	TIFR	Engineer	30-40	CT/CP
274	K.V. Srinivasan	M.Sc/ M. Tech	TIFR	Engineer	30- 40	CT/CP
275	S C Agrawal	M.Sc/ M.tech	TIFR	Retired	>60	CT/CP
276	K.S Jaisan	B.Tech	TIFR	Engineer	30-40	CT/CP

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
277	B.Srinivasan	M.Sc	BARC	Scientist(Tech)	40-50	CT/SC Cavity
278	S.C Bapat	B.Tech/Ph.D	IIT. Mum	Academics	50-60	CT/Cryocooler
279	M.D Atrey	B.Tech/ Ph.D	IIT. Mum	Academics	40-50	CT/Cryocooler
280	C.V Tommy	M.SC/Ph.D	IIT. Mum	Academics	40-50	LTP-SC
281	K.G Suresh	M.SC/Ph.D	IIT. Mum	Academics	40-50	LTP-SC
282	A. V. Mahajan	B.Tech/Ph.D	IIT. Mum	Academics	40-50	LTP-SC
283	L.S Mombasawala	B.Tech/M.Tech	IIT. Mum	Engineer	50-60	CT/ CE
284	M.M. Lele	B.Tech/Ph.D	VIIT, Pune	Academics	30-40	CT/ Cryocooler
285	K.G Narayankhedkar	B.Tech/Ph.D	VJTI	Academics	>60	CT/Cryocooler
286	P.V Nathu	B.Tech/ Ph.D		Academics	40-50	CT/ Cryocooler
287	B.S Gawli	B.Tech/ Ph.D	Walchand	Academics	40-50	CT/ Cryocooler
288	N.S Walimbe	B.Tech/Ph.D		Academics	30-40	CT/ Cryocooler
289	H.B Naik	B.Tech/Ph.D	NIT, Surat	Academics	50-60	CT/ Cryocooler
290	K.P Desai	B.Tech/Ph.D	NiT, Surat	Academics	40-50	CT/ Cryocooler
291	D.C Solanki	B.Tech/M.Tech	LD	Academics	>60	Cryo Teaching
292	B.V Dave	B.Tech/M.Tech	LD	Academics	50-60	Cryo Teaching
293	J.M Patel	B.Tech/M.Tech	LD	Academics	40-50	Cryo Teaching
294	N V Bora	B.Tech/M.Tech	LD	Academics	30-40	Cryo Teaching
295	AN Prajpati	B.Tech/M.Tech	LD	Academics	30-40	Cryo Teaching
296	R R Patel	B.Tech/M.Tech	LD	Academics	30-40	Cryo Teaching
297	Paliwal	B.Tech	LD	Academics	40-50	Cryo Teaching
298	S.N Kaul	M.Sc/Ph.D	HU	Academics	50-60	LTP-SC
299	R. Singh	M.Sc/Ph.D	HU	Academics	50-60	LTP-SC
300	Raaram	M.Sc/Ph.D	HU	Academics	40-50	LTP-SC
301	A K Bhatnagar	M.Sc/Ph.D	HU	Academics	>60	LTP-SC
302	Arumugam	M.Sc/Ph.D	Bharthi. U	Academics	40-50	LTP-SC
303	Bizu T.Kuzhiveli	B.Tech/Ph.D	NIT. Calicut	Academics	40-50	CT/ Analysis
304	G.C Joshi	B.Tech	HWB	Scientist(Tech)		CT/ Distillation
305	M. Bhaskaran	B.Tech	HWB	Scientist(Tech)	40-50	CT/ Distillation
306	Manoj Kumar	B.Tech	HWB	Scientist(Tech)	50-60	CT/ Distillation
307	T.K Halder	B.Tech	HWB	Scientist(Tech)	50-60	CT/ Distillation

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
308	Susheel Kalia	M.SC/Ph.D	Singhania	Academics	40-50	CT/ Tools
309	Rajesh Gehlot	Btech/m Tech	IBP	Enginner		
310	Zafar A. Shaikh	B Tech /M.Tech	L&T	Engineer		
311	S H Pawar	M.Sc/Ph.D	Shivaji	Academics	>60	LTP-SC
312	J.L Bhattacharya	B.Tech	BHEL	Scientist(Tech)	50-60	CT/ SC Generator
313	ShyamaPrasad	M.Sc/Ph.D	RRL	Scientist(Tech)	50-60	CT/ HT Current Lead
314	S. Ravi	M.Sc/Ph.D	IIT. G	Academics	40-50	LTP-SC
315	T.Goswami	B.Tech/ Ph.D	IIT. Kg	Academics	40-50	CT/ Preservation
316	N Brahma	B.Tech	IIT. Kg	Scientist	50-60	CT/ Preservation
317	Ramesh Chandra	M.Sc/Ph.D	IIT. Roor	Academics		LTP-SC
318	Devendra Kaur	M.Sc/Ph.D	IIT. Roor	Academics		LTP- SC
319	Anjali	M.Sc/Ph.D	Jaipur U	Academics		LTP-SC
320	Harsh Mahajan	MD	Own centre	Doctor	50-60	MRI
321	N Jagannathan	M.Sc/ Ph.D	AIIMS	Academics	50-60	NMR/MRI
322	S. Khushu	M.Sc/ Ph.D	INMAS	Scientist	40-50	MRI
323	K.Madhusoodan Pillai	B.Tech/M.Tech	TKM	Academics		Teaching
324	M Jose Prakash	B.Tech /Ph.D	TKM	Academics		Teaching
325	K K Abdul Raseed	B.Tech/ Ph.D	TKM	Academics		Teaching
326	N.K Mahamud sajid	M.Tech	TKM	Academics		Teaching
327	H Thlakan	M.Tech	TKM	Academics		Teaching
328	S Sreyasunath	M.Tech	TKM	Academics		Teaching
329	R M Khadetkar	M.S	EMCO	Engineer		SC Transformar
330	Nissan	M.Tech	TKM	Academics		Teaching
13.2 In Space Programme						
1	Mohammed Muslim		LPSC/ Mahen	**Scientist (Tech)**	50-60	CT/ Cryo Engine
2	L Muthu		LPSC/ Mahen	**Dy. Director**	>60	
3	T Jayabalan	B.Tech/ M.Tech	LPSC/ Mahen	**Sientist/Engineer-SE**	40-50	
4	Ponraj Pondi	B.Tech	LPSC/ Mahen	**Dy. Manager, TF**	40-50	
5	B Chelladurai	B.Tech	LPSC/ Mahen	**Sientist/Engineer-SG**	40-50	

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
6	R santhanam	B.Tech	LPSC/ Mahen	**Engineer-SF**	40-50	
7	P Sangeet Kumar	M.Tech	LPSC/ Mahen	**Sientist/Engineer-SC**	20-30	
8	K Murgha Das	B.Tech	LPSC/ Mahen	**Sientist/Engineer-SD**	30-40	
9	P Jothi Raj	M.Tech	LPSC/ Mahen	**Sientist/Engineer-SC**	30-40	
10	C Nagarajan		LPSC/ Mahen			
11	K Allagavelu	M.Tech	LPSC/ Mahen		40-50	CT/ LH2
12	R Radhakrishnan		LPSC/ Mahen		40-50	
13	C. G Balam	M.Tech	LPSC/ Vali		50-60	
14	N K gupta	M.Tech	LPSC/ Vali		50-60	
15	Raikrishna Kumar		LPSC/ Vali	**Scientist/ Engineer-SF**		
16	V M Deepak	M.Tech	LPSC/ Vali		40-50	
17	T John Thakaran	B.Tech/ Ph. D	LPSC/ Vali	**Deputy Divisional Head FAL/PRS**	40-50	
18	K Ashok Kumar	B.Tech/ Ph. D	LPSC/ Vali	**Scientist/ Engineer**	40-50	
19	Varghesse Mathew	M.Tech	LPSC/ Vali	**Engineer-SF**	30-40	
20	G Ayappan	M.Tech	LPSC/ Vali	**Dy. Project Director Liquid Stages,GSLVM K-III**	50-60	
21	V Balachandramn	M.Tech	LPSC/ Vali	**Dy. Project Director GSLV Project**	50-60	
22	N Jayan	M.Tech	LPSC/ Vali	**Engineer-SF**	40-50	
23	B Subromonian	B.Tech/ Ph.D	LPSC/ Vali		50-60	
24	B Satish Kumar	M.Tech	LPSC/ Vali	**Dy. Division Head CSUSD,**	40-50	
25	P Jothi Raj	M.Tech	LPSC/ Vali	**Scientist/Engineer-SC**	30-40	
26	S C Rastogi	M.Tech	ISAC	**Head Thermal System Div.**	50-60	CT/ Passive cooler
27	A Ramasaamy	M.Tech	ISAC	**Scientist/ Engineer-SG**	50-60	CT/ Passive cooler
28	P P Gupta	M.Tech	ISAC	**Head, TTD/TSG**	>60	CT/ Passive cooler
29	S Akkimaradi	M.Tech	ISAC		40- 50	CT/ Passive cooler

S. No	Name	Qualification	Affiliation	Profession	Age	Specialization
30	H Anantha Krishna	M.Sc	ISAC	Scientist	30-40	CT/ Cryo Test
31	Dinesh Kumar	B.tech	ISAC			CT/ Cryo Test
32	Madhu Prasad	M.Sc/ Ph.D	ISAC		50-60	CT/ Passive cooler
33	Sant Ram	DE	ISAC			CT/ Passive cooler
34	Subramanya	M.Tech	ISAC	Senior Engineer		CT/ Passive cooler
35	P N rajendran		ISAC			CT/ Cryo Test
36	V Ramakrishnan	B.Tech	ISAC		40-50	CT/ Passive cooler
37	C.S Guru Datt	M.Sc/ Ph.D	ISAC			CT/ Passive cooler
38	Padmanabhan	B.Tech	ISAC			CT/ Space Simulator
39	P Govindan		ISAC			CT/ Space Simulator
40	D P Karnik		ISAC			CT/ Space Simulator
41	N K Mishra		ISAC			CT/ Space Simulator
42	R S Praveen		VSSC	Engineer		CT/ Cryo Property
43	N Narasimhan	M.Tech	SAC		>60	CT/ Cryo simulation
44	M. Keshav Kamani	B.Tech	SAC	Engineer-SF	40-50	CT/ Cryo simulation
45	Nilesh Soni	M.Tech	SAC	Scientist/ Engineer-SE	50-60	CT/ Cryo simulation
46	D G Rathod	DE	SAC	Engineer-SD	50-60	CT/ Cryo simulation

Vali : Liquid Propulsion Systems centre, ISRO, Valiamala, Thiruvanantpuram
Mahen: Liquid Propulsion Systems centre, ISRO, Mahendragiri
SAC: Space Applcation Centre, Ahmedabad
ISAC: ISRO Stellite Centre, Bangalore

13.3 Persons from Industry Interacting with Research Institutes

S.No.	Name	Affiliation	Qualification	Specialization
1	H M Bengani	BOC	B.Tech	ASP Plant
2	Shankar Ghosh	Shell N Tube	B.Tech	Cryo Project
3	Tushar Bhowmick	Stirling India	Ph.D	Liquid Nitrogen Plant
4	D Navalkale	Conserv Ent.	Ph.D	Cryo Instrumentation
5	V Chopra	Goodwill Cryogenics	Ph.D	Cryo Equipment
6	S. Deshpande	Specialise Instruments		PPMS
7	M Pandey	GE	M.Tech	Cryo Project

S.No.	Name	Affiliation	Qualifi cation	Specialization
8	Manjunath	Brucker India	Ph.D	NMR
9	S D Paul	Paul Ent.	Ph.D	LHe Plant
10	P Kulkarni	INOX India	B.Tech	Cryo Vessel
11	K. Desai	Linde India	B Tech	LHe and LN2 plant
12	Ranga Rao	Vacuum technique	M.Sc	Cryostat
13	Bhattacharya	Vacuum Technique	Ph.D	Cryostat
14	Mathew	Don Bosco	B.Tech	Cryostat
15	Pramad Kumar	Vico Sales	B.Tech	SC Magnet

13.4 M.Tech (Cryogenic Engineering) Students from IIT Kharagpur

1982

1. Alak Bhattacharya
2. Bikash Kumar Guha (DAE)
3. Tapash Kumar Bhattacharyya
4. J. Radhakrishna (BOC)
5. K. R Chandana Tejonarasimham
6. Atish Banerjee

1983

1. Avuthu Venkata Reddy
2. Raveesh Kumar(LASTEC, Delhi)
3. A. R. Rama Chandra Murty (BHPV)
4. Alok Kumar Choudhury
5. Kirity Bhusan Khan (BARC)
6. Tapan Kumar Bhowmik
7. B. T. Vijaya Raghava Reddy

1984

1. Sujit Sen Gupta (Canada)
2. Chandra Chatterjee
3. Maitreyee Panda (LASTEC, DELHI)
4. Tripti Sekhar Datta (IUAC. DELHI)
5. T. Venkata Rami Reddy (IOL)
6. Sisir Kumar Chakraborty (BOC)
7. Nandella V.S. Rao (ISRO)
8. Santa Kumar Paul (IOL/ Cryo)

1985

1. Biswanath Dutta Gupta (RRCAT)
2. Vulavala Ramesh
3. Sudhanshu Sekhar Mahato(NTPC)
4. Narra Gopala Krishna
5. Kota V. L. Naganandini

1986

1. Biswanath Roy
2. A B K Anand
3. Vaddamani Srinivasu
4. Reghunatha Pillai K C
5. Amar Nath Thakur
6. G. Venkatarathnam (IIT. Madras)
7. Prabal Kanti Chakraborty

1987

1. Dipak Kumar Ghosh
2. Kudaravalli Venkata Ravikumar (USA)
3. Nadig Durgesh Shrikantaiah (IISC)
4. S. Krishnamoorthy (ISRO)
5. Tushar Bhowmick (Stirling)
6. Thimothy Francis C (ISRO)

1988

1. Injeti Nanaji Niranjan Kumar
2. Kagita Venkata Suryanarayana

1989

1. Aithal P Swameesha R
2. Chaudhury Saikat Subodh
3. Panda Papa (IIT,M)
4. Sreekumar N
5. Sreemany Monjoy
6. Vasantaraju Cherukonda

1990

1. V. Vijayalakshmi
2. K. Radha
3. Deshmukh Shashank Chintaman
4. V. Narayanan (ISRO)
5. M. Xavier (ISRO)

1991

1. Ramkrishna Das (BARC)
2. Dipen Bhattacharya (CGCRI)
3. R. Subramanian (USA)

1992

1. Akshaya Kumar Padhi
2. Debashish Dutta (BARC)
3. N. Meyyappan

1993

1. Garimella Gouri Shankaram
2. K. Kamatchi
3. Sreedhar R
4. N V S Somayajulu
5. Ashim Kumar Sahu
6. Sridhar Panigrahi (BHPV)
7. Nirmal Kanti Mukhopadhyay
8. A. Sathyanarayana

1994

1. Chandan Kumar Dutta
2. Sankar S. A.
3. Atri Chakrabarti
4. Maneesh Kumar Pandey (INOX/ GE)
5. Atchyutuni Sesha Srinivas
6. Moravineni Balaji Babu

1995

1. Parthasarathi Ghosh (IIT. KGP)
2. Dinesh Tripathi (NIT,R)
3. Niranjan Behera
4. Papiya Biswas (USA)
5. Sanjeeb Kumar Pandey (Canada)
6. Ashish Kumar Baral
7. Indranil Ghosh (IIT. KGP)
8. Ananta Kumar Sahu (ITER, France)
9. Probir Kumar Ghoshal (Oxford Instruments, UK)

1996

1. K. K. Himabindu
2. Jedidiah Pradhan (VECC, Kolkata)
3. Chalapareddy Venkateswara Rao
4. Yenneti Kalyana Chakravarthi
5. Upendra Behera (IISc. Bangalore)
6. P. Veera Raghava Prasad

1997

1. Indigibilli Satyanarayana
2. B. N. Srinivas
3. Vaddiparthi Venkata Rajsekhar
4. Alapati Arun Kumar
5. CH Ramakrishna (BARC)
6. Gurmeet Singh

1998

1. Raja Banerjee (Usa)
2. Madey Amurutha Kumar

3. C Venkata Rami Reddy

4. Syed Mahammad Asif

5. Debkumar Maity (GE, Bangalore)

6. K. V. Krishna Rao

1999

1. V. S. Raja Raman

2. Pydikondala Venkata Suresh Babu

3. Ghodekar Nilesh Vitthal

4. Amlan Kusum Maiti

5. Manish Mohan Shrivastava

6. Sarmita Pradhan (USA)

2000

1. Kaza Sree Venu Madhav

2. Poulomi Dhole

3. Rohit Sharma

4. Jirgale Vinay Ashok

5. Sanjit Karmakar

6. Uttam Bhunia (VECC. Kolkata)

7. Agam Prakash Vajpeyi

2001

1. Sridhara Vijaya Srinivas

2. Panse Pushkar Mohan

3. Reena Satyanarayan Baheti

4. Jyotindra Kumar Kesherwani

5. Amit Kumar

6. Diganta Hatibaruah

7. Dondapati Kalpana

2002

1. Sonjoy Mondal

2. Sajal Biring

3. Prasanta Mandal

4. Gandhi Darpankumar Dipakkumar

5. Anand Kumar Tiwari

6. Birsa Munda

7. Salumuri Sarva Lingeswara Rao

2002

1. Rajat Kumar Bhuyan (ISRO)

2. Manik Pradhan

3. Md Zamal Abdul Naser (VECC)

4. Anil Kishan P

5. Ranu Mahdelay

6. Dhananjay Kumar Singh

2003

1. Abhijit Majumder, IIT (K)

2. Purushottam Lal Koshti

3. Shah Tejaskumar Hargovindbhai

4. Suresh Kumar Raghuvanshi

2004

1. S. Karthikeyan (BOC)

2. Pankaj Somani

3. Guru Prasad Mandal. [RS, IIT (KG)

4. Sumit Kumar (USA)

5. Arpita Mondal (USA)

6. Manas Mondal : (VECC)

2005

1. Ashwani Kumar Maloo (INOX)

2. Daya Shankar Patel

3. Kaushik Kumar Jatua

4. Ramanuj Mishra (Praxair)

5. Sumana Ghosh RS, IIT(KG)

6. Vinod Kumar V

2006

1. Chandra Bhal Singh

2. Kripa Shankar Gupta (BOC)

3. Manas Kumar Dutta (BOC)

4. Muddasani Raju(Essar)

5. Sai Sreekanth K

6. Sudipta Naskar (B N Dastur)

7. Y. R Kauleshwar Kevla

2007

1. Bhaskar Rahul Nandi

2. Binay Kumar

3. Jaya Prakash Bollavaram

4. Khade Nilesh Suresh (Revomax)

5. Mone Mandar Ramesh

6. Phanikumar D (USA)

7. Rajesh Rajabhaktula

8. Sandeep Kumar Lakhera (USA)

9. Sanjoy Basak (BOC)

10. Shyam

11. Surajit Kumar Swain

2008

1. Akshat Kholia

2. Ashok Kumar Dewangan

3. Chowkekar Detan Divakar (IPR)

4. Kapil Gupta

5. Monoj Tripathi : RS. IIT(D)

6. Nikhil Kumar

7. Raveendra Reddy

13.5 Personnels with Ph.D in Cryogenics

This list restricts Ph.D in Engineering in the field of cryogenics. List of personnel holding Ph.D in Science in the field of basic research on Superconductivity and low temperature research with basic qualification M.Sc (Physics), M.Sc (Chemistry) or M. Sc (material science) are in large numbers from many institutes and hence separate list is not prepared.

Sl. No	Name	Ph.D From	Year	Present Position
1	K G Narayankhedkar	IIT. Mumbai	1974	Director VJTI, Mumbai
2	Sunil Sarangi	Stony Brok	1974	Director, NIT. Rourkela
3	Subash Jacob	IISc.Bangalore	1987	IISc. Bangalore
4	M. B Jain	IIT. Bombay	1980	No More
5	A. B Fakolawala	IIT. Bombay	1981	Retired
6	N Nagaraja	IIT. Bombay	1983	No Information
7	Kanchan Choudhury	IIT. Kharagpur	1984	IIT Kharagpur
8	R K Sahoo	IIT Kharagpur	1984	NIT. Rourkella
9	B.M Domkundwar	IIT. Bombay	1986	Retired
10	P R Tailor	IIT. Bombay	1985	NIT, Surat
11	TP Lukose	IIT. Bombay	1986	Prof. Kerala
12	T. K Goswami	IIT. Kharagpur	1987	IIT. Kharagpur
13	M Prakash Malya	IIT Bombay	1988	IIT. Madras
14	MD Atrey	IIT. Bombay	1990	IIT. Bombay
15	Rangan Baneerjee	IIT. Bombay	1990	IIT. Bombay
16	K.V Ravi Kumar	IIT. Kharagpur	1991	USA
17	L N Patel	IIT Bombay	1991	Director, Engg. College. Gujarat

Sl. No	Name	Ph.D From	Year	Present Position
18	G Venkatratnam	IIT. Kharagpur	1992	IIT. Madras
19	Tushar Bhowmick	IIT. Kharagpur	1992	Stirling Cryogenics
20	Tapas Kumar Nandi	IIT. Kharagpur	1992	IIT. Kharagpur
21	Bizu T Kuzhiiveli	IIT. Bombay	1994	NIT. Calicut
22	S. J Antony Samy	IIT. Kharagpur	1994	Not Known
24	A K Saha	IIT. Kharagpur	1994	Eng College
25	Ramkrishna Das	IIT. Kharagpur	1995	BARC
26	A S Gaunakar	IIT. Bombay	1996	Singapore
27	P.V Natu	IIT. Bombay	1996	Eng College
28	P. K Sahoo	IIT, Kharagpur	1996	IIT. Roorkee
29	Ford Farhani	IIT. Kharagpur	1996	IRAN
30	K K Abdul Rasheet	IIT. Kharagpur	1997	TKM College. Kerala
31	Amarjot Kaur Dhami	IIT.Kharagpur	2001	IISc. Bangalore
32	Anindya Chakravarthy	IIT. Kharagpur	2001	BARC
33	Maitreyee Nanda	IIT. Kharagpur	2001	LASTEC
34	S S Nagappa	IIT. Kharagpur	2002	Pune College
35	Abhijit Tarafdar	IIT. Kharagpur	2002	Switzerland
36	P. S Ghosh	IIT. Kharagpur	2002	IIT. Kharagpur
37	Abhijit Ray	IIT. Kharagpur	2003	Indian Petroleum Uni
38	Dipak Kumar Maity	IIT. Kharagpur	2003	General Motor
39	S Kanagraj	IIT. Kharagpur	2004	IIT. Gauwati
40	Bishnu Pada Mandal	IIT. Kharagpur	2004	IIT. Gauwati
41	Madhushree Kundu	IIT. Kharagpur	2004	NIT. Rourkella
42	A. B Datya	IIT. Bombay	2005	Eng College
43	B S Gawali	IIT. Bombay		Eng College (Walchand)
44	Indranil Ghosh	IIT. Kharagpur	2006	IIT. Kharagpur
45	Sanoj Kumar	IIT. Kharagpur	2006	IIT. Gauwati
46	M M Lele	IIT. Bombay	2006	VIIT, Pune
47	A. K Shrivastava	IIT. Bombay	2006	ISAC Bangalore
48	Arun Samanta	IIT. Kharagpur	2008	College
49	V. K Bhojwani	IIT.Bombay	2008	Scientist
50	R. K Ramalingam	IIT. Mumbai	2008	FZK. Karlsruhe
51	N.S Walimbe	IIT. Mumbai	2008	VIT, Pune
52	A.S Senthil Kumar	IISc.Bangalore	2005	VIT. Vellore
53	Prabal Chakroborty	IISc.Bangalore	1995	
54	M Jose Prakash			TKM College
55	M Shiva Sankar	IIT. Madras	2008	
56	Subrata Kr ghosh	IIT. Kharagpur	2006	ISM Dhanbad
57	H B Naik			
58	K P Desai	IIT. Mumbai		NIT, Surat

There are approx. 55- 60 Ph.D in Cryogenic enginnering and majority (45) are in Academic/ Teaching institutes. 7- 8 nos are in Scientific lab, 2- 3 are in Private industries. 3 are settled in abroad after completion of Ph.D In India.

13.6 Students with M.Tech. in Cryogenic Engineering

M.Tech From Cryogenic Engineering Centre (IIT. Kharagpur) : 190
M.Tech from LD College of Enginnering : 128
M.Tech From TKM College of Engineering : 100
Total : 418

No of M.Tech Students from IIT. Kharagpur continuing their carrear in the field of Cryogenics : 40 %. M.Tech received from LD college and TKM College and working in the field of cryogenics are mainly sponsored candidate from respective institutes like IPR, ISRO, RRCAT,TIFR etc.

13.7 Retired Scientists / Professors / Engineers

	Name	Past Affiliation	Specialization	Present Status and Remarks
1	KG Ramanathan	NPL	LTP	Not known, migrated to USA
2	MSR Chari	NPL	LTP	Retired 1977, Died 2008
3	TM Srinivasan	NPL / IITK	LTP & Tech	Settled in Chennai
4	PN Dheer	NPL / DU	LTP	Settled in Delhi
5	RG Sharma	NPL	LTP / Magnet	Still Active, Project Sc. IUAC
6	AV Narlikar	NPL	LTP	Still Active at UGC_DAE CSR
7	A P Jain	NPL	Cryo-Tech	In Delhi
8	A. K Gupta	NPL	SQUID	
9	Y. S.Reddy	NPL	Cryo - Tech	No Information
10	Girish Chandra	TIFR	LTP	Settled in Mumbai
11	R. Nagarajan	TIFR	LTP_ SC	Active at CBS- DAE, Mumbai
12	M.B. Kurup	TIFR	SC LINAC	No More
13	S C Agrawal	TIFR	Cryo Plant	Active with TIFR
14	R. Pinto	TIFR	HTSC	No Information
15	R Vijayraghavan	TIFR	LTP- SC	No Information
16	J.Ray	TIFR	LTP-SC	No Information
17	L. C Gupta	TIFR	LTP-SC	No Information
18	S K Mullick	TIFR	LTP-SC	No Information
19	R Srinivasan	IITM	LTP / Cryo Tech	Still Active, Settled in Mysore
20	G Subba Rao	IITM/CECRI	HTSC	No information
21	G Rangarajan	IITM	LTP	No Information
22	C. N. R Rao	IISC/ JNCAR	HTSC	Still active at JNCAR
23	R Srinivasan	IISc	LTP / Cryo	Died in Service,
24	S. V. Subramoniun	IISC	LTP-SC	Active at IISC
25	E.S R Gopal	IISC	LTP-SC	Active at IISc Bangalore
26	Krisnamurthy	IISC	Cryo Tech	He was in VIT, Vellore
27	SK Datta Roy	IITKh	LTP(Magnetism)	No More
28	S C Pattyanayak	IIT Kh	Cryo Tech	Settled in Kharapur

	Name	Past Affiliation	Specialization	Present Status and Remarks
29	Narashimhan	IIT Kh	Cryo Plant	Settled in AP
30	V.R.Kalvey	IIT Kh	LTP-Sc	No Information
31	A Bose	IACS / JU	LTP(Magnetism)	No More, Founded ICC
32	P Sengupta	JU	Cryo technology	No More
33	D Chakrabarthy	IACS	LTP-SC	Active at IACS
34	A K Pal	IACS	Cryo technology	No Information
35	S Chatterjee	IACS	LTP	No Information
36	J K N Sharma	IACS	LTP	Settled in delhi
37	A K Pal	IACS/	LTP	Settled in Kolkata
38	PK Bose	IOL/JU	Cryo / Gas	Settled in Kolkata
39	TS Radhakrishnan	IGCAR	LTP / Cryo	Still active at IGCAR
40	Y Hariharan	IGCAR	LTP/Cryo	Not well
41	T Suryanarayana	BHEL(R&D)	SC Generator	No Information
42	KD Chaudhary	DU	LTP/ Cryo	No More
43	A K Mazumder	IITK	LTP / Cryo	Active at SNBSC
44	Rajat Ray	IITK	LTP/Cryo	Settled in Delhi
45	ES Raja Gopal	IISc / NPL	LTP	Active at IISc Bangaluru
46	AK Sreedhar	SSPL	LTP	No Infornation
47	H. S Chotwal	SSPL	Cryo Technology	No Information
48	M. Thirumaleswar	RRCAT	CryoTechnology	No Information
49	M G Karmakar	RRCAT	Cryo Technology	At Indore. CERCN Collaborator
50	N. S. Satyamurthy	BARC	LTP/Cryo	No More
51	Y.Dande	BARC	Cryo Technology	No Information
52	D.L Bongirwar	BARC	Cryo Preservation	At Mumbai
53	M. K Mallik	BARC,	SC Wire	No Information
54	N.C Bhattacharyay	VECC	SC Technology	Settled at Kolkata
55	D. Ghosh	VECC	Helium Gas	Active at SINP
56	P Sen	SINP	Helium Gas	Active at SINP
57	B Ghosh	SINP	LTP-SC	No information
58	P Kishore	AOL	ASP	No More
59	S M K A Gurukul	BHPV	ASP	No Information
60	Venkatraman	BHPV	ASP	No Information
61	A K Bhatnagar	HU/PU	LTP-Sc	Active at Hyderabad university
62	A. Kalanidhi	Anna Uni.	Cryo- Tool	No Information
63	O.M Srivastava	BHU	HTSC	No Information
64	S H Pawar	Shivaji Uni.	LTP-Sc	Active at Shivaji university
65	M. B. Jain	LD College	Cryo Technology	No More
66	A. D. Damodoran	RRL	HTSC	No Information
67	EVS Namboodriry	ISRO	Cryo Engine	Sttled in Trivandrum
68	S C Ghosh	ISRO	Cryo Engine	Sttled in Trivandrum
69	K Ramamurthy	ISRO	Cryo Engine	No Information
70	L. Vedhachalam	ISRO	Cryo Engine	No Information
71	Ganna Gandhi	ISRO	Cryo Engine	Active at LPSC
72	A K. Gupta	IBP	Cryo vessel	No information
73	V K Mishra	DST	Cryo Project	No information
74	N.D Das	DST	Cryo Project	Settled in Delhi

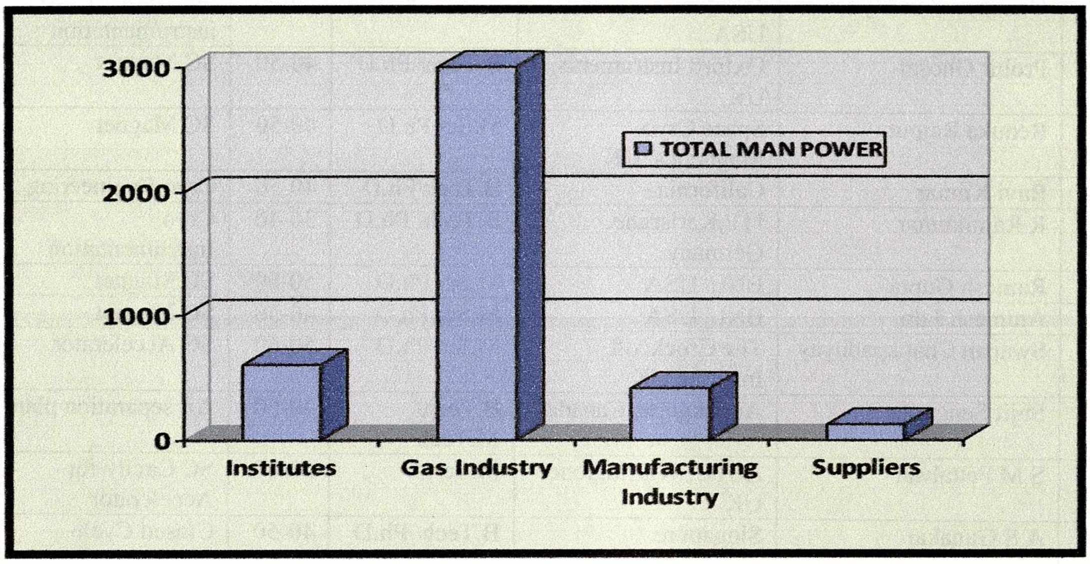
13. .8 Indians Working Abroad in Cryogenics/Superconductivity

Sl No	Name	Affiliation	Qualification	Age	Specialization
1	Venkata Rao Ganni	Jefferson Laboratory, USA	B.Tech/ Ph.D	50-60	Helium Refrigerator
2	Ganapati Rao Myneni	Jefferson Laboratory, USA	M.Sc/ Ph.D	50-60	SC Cavity, Cryo instrumentation
3	Probir Ghosal	Oxford Instruments. UK	B.Tech/ Ph.D	40-50	SC Magnet
4	Renuka Rajput	Space Cryo Magnetics, UK	M.Sc/ Ph.D	40-50	SC Magnet
5	Ravi Kumar	California	B.Tech/Ph.D	40-50	Cryo Engineering
6	R Rajnikumar	ITP,Karlsruhe. Germany	B.Tech/ Ph.D	30-40	Cryo Instrumentation
7	Ramesh Gupta	BNL. USA	M.Sc/ Ph.D	50-60	SC Magnet
8	Animesh Jain	BNL. USA	M.Sc/ Ph.D	40-50	SC Magnet
9	Swapan Chattapadhyay	The Crockcoft Institute.UK	M.Sc/ Ph.D	50-60	SC Accelerator
10	Sujit Sengupta	Air Liquide, Canada	B.Tech/ M.Tech	40-50	Air separation plant
11	S M Pattalwar	ASTC. Warringtone. UK	M.Sc	50-60	SC Cavity for Accelerator
12	A S Gunakar	Singapore	B.Tech/ Ph.D	40-50	Closed Cycle refrigerator
13	C P Dhard	Max Plunk	M.Sc/ Ph.D	40-50	Cryo Engineering
14	Ashis Chourasia	American SC. USA	M.Sc/ Ph.D	40-50	SC Magnet
15	U Balachandran	ANL.USA	M.Sc/Ph.D	50-60	Superconductivity
16	A K Sahu	ITER, France	B.Tech/M. Tech	30-40	Cryogenic Heat Transfer
17	Abhijit Tarafder	Switzerland	B.Tech/ Ph.D	30-40	Cryo Technology
18	Manjusha Battabyal	EMPA, Switzerland	M.Sc/ Ph.D	30-40	LTP-SC
19	A.K Gangopadhyay	University of Washington	M.Sc/Ph.D	50-60	LTP-SC
20	S Chakraborty	University of Lousille	M.Sc/Ph.D	40-50	LTP-SC
21	Pradeep Kumar Khatua	Israel	M.Sc/Ph.D	30-40	LTP-SC

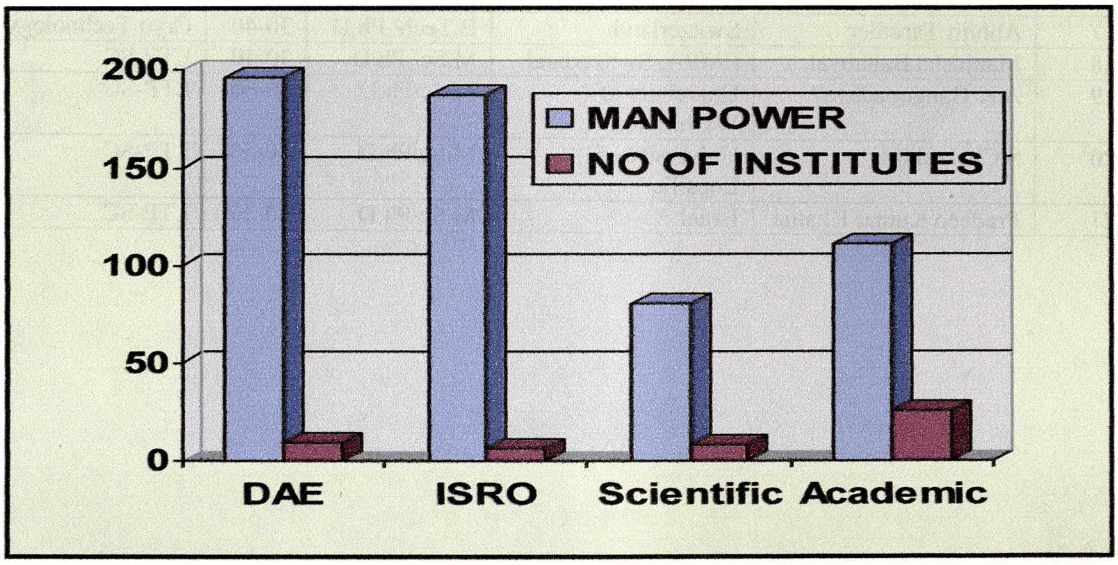
13.9 Human Resource Statistics in Graphical Form

1. Total Man Power

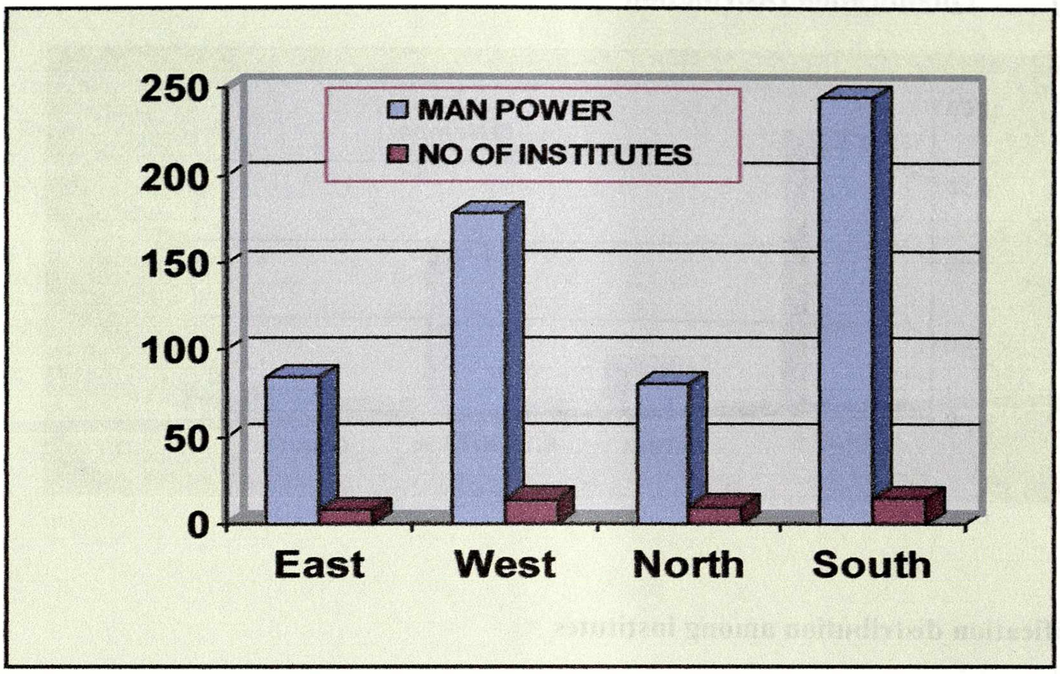
Institutes: 600, Gas Industry : 3000, Manufacturing Industry ; 410, Supplier & Services : 126



2. ***Institute Man Power : DAE : 196 (9), ISRO : 187 (6) , Scientific Institutes : 80 (8), Academic : 111 (23)***

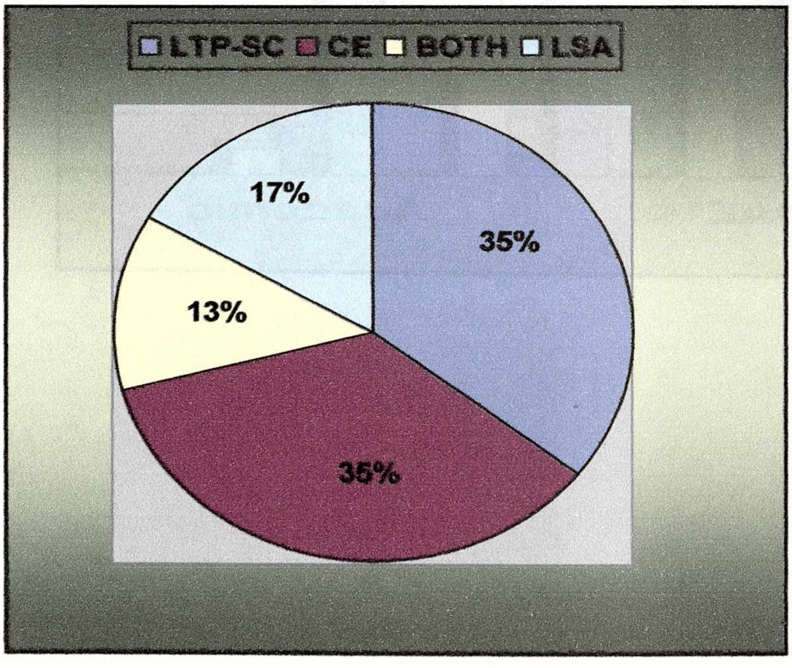


3. **Institute Man power Distribution Zone basis : West Zone : 178 (14), South Zone; 245 (15), North Zone :80 (10), East Zone : 84 (8)**



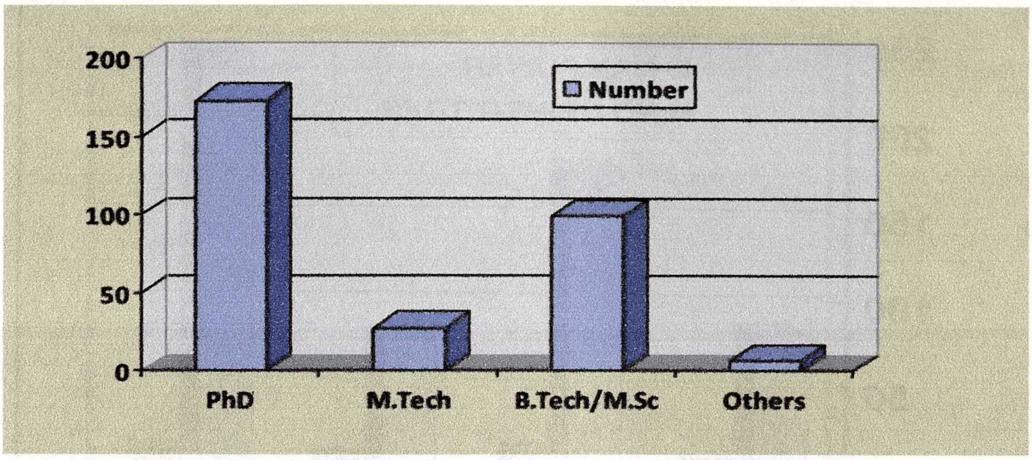
4. **Activity wise Institute Break up**

   i) Only basic research on Superconductivity: LTP-SC (17) ii) Cryogenic Engineering only: CE (17) iii) Both Basic Research and Cryo Engineering: (6) iv) Large scale Application: LSA (8)

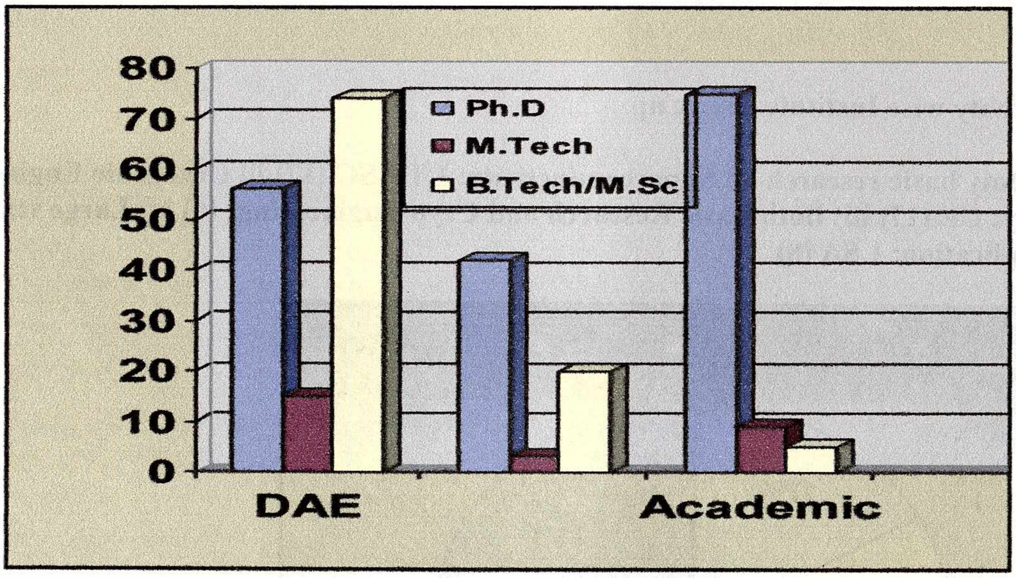


5. Scientific Academic Institutes other than ISRO

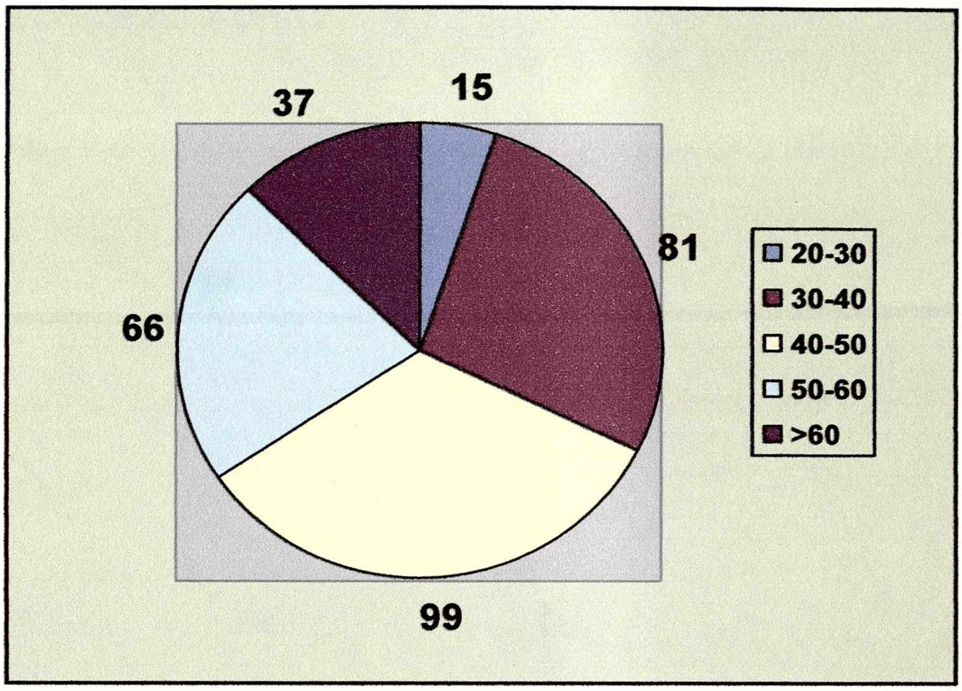
i) Qualification Distribution



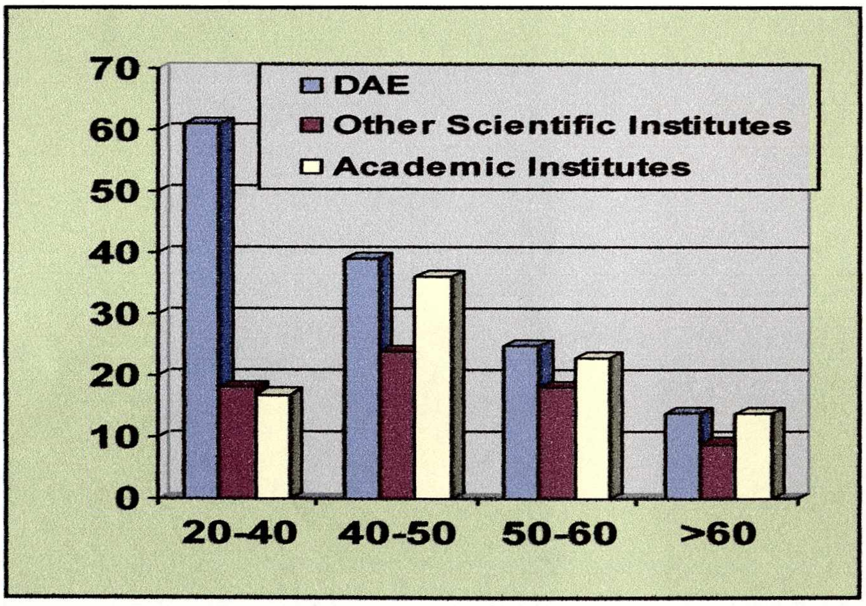
6. Qualification distribution among institutes



7. Age wise Distribution of Scientific Manpower



8. Age pattern in Institutes



Chapter 14

CONCLUSIONS AND RECOMMENDATIONS

1. Indeed Cryogenics and Superconductivity is no longer confined to research institutes and laboratories in the country. During last two decades activities have spread far and wide. Impetus came from large-scale applications of superconductivity (RF cavities and magnets) in particle accelerators which came up at IUAC, TIFR and VECC and in Tokamak which came up at IPR.

2. Use of cryogens (LN2 and LO2) shot up because of large scale expansion of steel, fertilizer and gas industries. Development of Cryo Engine by ISRO added a new dimension to the production of LH2 in the country.

3. Man power too increased manifold since 1995 on embarking with major national projects and specifically with engineering background, which was miniscale earlier. Other than IIT Kharagpur few colleges like LD college of Engineering and TKM College of Engineering offers M.Tech in Cryogenic Engineering and on average 20 students pass out every year. Except IIT.Kharagpur, all other colleges are not equipped with necessary minimum facility and that prevents practical training on this field. Minimum facility along with qualified faculty will certainly improve quality of manpower. Other option is deputing M. Tech students in National Laboratory/ Industry for 3-6 months. Students will develop tremendous confidence and will in turn be an asset to the National Cryogenic Programmes and the Cryo-Industry.

4. We find a trend in the research institutions in acquiring very expensive imported readymade measurement systems like PPMS and MPMS. The earlier concept of developing cryostats and measuring systems has just vanished during the last decade. Few industries, which came forward to develop multi purpose cryostats and other cryo components slipped in to the background. In today's scenario, scientists and technicians are not willing to take even minor maintenance on these imported equipments. We have no option for servicing except to depend heavily on Foreign Service engineers at a hefty cost. We strongly feel that the funding agencies need to have a relook on their policy of granting large funds for sophisticated measuring systems. For example, one can buy the basic system but can develop different probes for different measurements

5. Indian representatives of foreign companies do not have facilities and expertise to provide any after sales services. The suppliers of these equipment's have no network of service centres or maintenance obligation. As a result, the down time of these expensive equipments is very high. The funding for such equipments has come mostly from DST and DAE. Lack of trained manpower is cited as one reason by these representatives.

6. To overcome the shortfall of technical man power, there should be a certificate course (1-2 years) in cryogenics and superconductivity and can be offered by a new centre dedicated for cryogenic component development. Such policy can be framed by a joint committee consisting of experts from DST, Cryo-Industry (involved in large cryogenic cryostats and LN2 & LO2 tankers), the Gas Industry, the Indian Cryogenic Council (ICC)

and the MHRD. Till that time the similar type of course can be offered by Institutes like IUAC, VECC, IPR, RRCAT etc. Minimum qualification should be B.Sc. (Physics) or Diploma in Engineering.

7. We have also found that at several places (other than DAE and large national centres) liquid nitrogen and liquid Helium plants are run by technical staff but without having proper qualification or adequate training. It is highly desirable that there should be at least one person (B.Sc. or Diploma in Engineering) for Nitrogen Plant and two persons for each Helium Plant (one M.Sc/ B.Tech and another B.Sc/ Diploma) to have better utility factor of these plants.
8. In most places liquid helium plants are not run to their full capacity. Take for example a helium liquefier with a production capacity of 20 l / hr. If run even five days a week or just 20 days in a month and at an efficiency of only 60 % it can produce a total of 5700 litres of LHe in a month. This quantity of LHe is good enough to support 20 experimental systems with a daily loss of (static and dynamic) LHe of 10 litres.
9. The same holds good for liquid nitrogen plants. For example a nitrogen plant with a capacity of 10 litres /hr can easily produce a total quantity of 4600 litres /month (here transfer loss is taken 20 % and running 24 days in a month).
10. Simple estimates that can be used to select the type and capacity of the plant required to meet the users' requirements from a institute can be like this:
    - If the requirement is less than 2000 litres /month, a table top plant based on cryocooler is good enough without any additional man power.
    - For requirement of 2000 to 4000 litres /month : 10 litres capacity plant is suitable. Alternatively one can opt for external supply.
    - For requirement 4000 to 8000 litres /month : 20 litres capacity plant may be procured.
    - For more than 8000 litres / month it is preferable to have external supply only. A 10000- 20000 litres capacity storage vessel should be installed at the site.
    - External supply however depends on the location whether a source is available within a reasonable distance and the transportation is possible.
11. All the Academic Institutes offering M.Tech. may initiate close interaction with laboratories/ Institutes, which are engaged in major Cryogenics programmes. Students can work on projects in these institutes and experts from laboratory may deliver lectures on particular application to all these Academic institutes.
12. Gas industries should come forward to recruit these M.Tech students from these institutes. Once this happens, quality of students joining M.Tech courses will improve.
13. Funding agencies should encourage and fund programmes aiming at the development of devices, cryo systems and technologies. Joint programmes between Institutes and Industries should be supported in particular.

Summary of the Conclusions / Recommendations

1. Significant growth of man power and facility has taken place in this exciting area of cryogenics and superconductivity since 1995. Liberal funding from DST and others should continue. A separate Programme advisory committee in the field of Cryogenics and superconductivity may be constituted in DST for effective funding. ICC can play a role on this.

2. Shortage of technical man power is however felt all around. A certificate course may be encouraged.
3. No significant development of cryo equipment is being carried out in the country.
4. We strongly believe that a **'National Centre of Cryogenics and Applied Superconductivity'** should be established in the country in the very near future. Only projects of applied nature should be pursued at this proposed centre.

March 2010

T. S. Datta
R. G. Sharma

ANNEXURES

Annexure 1

CONTACT PERSONS IN INSTITUTES AND INDUSTRY

Institutes

SL No	Institute	Address	Contact Person
1	**AIIMS**	All India Institute Of Medical Sciences, Dept of NMR. & MR.I New Delhi - 110029	N.R Jagannathan Jagan1954@hotmail.com
2	**Anna University**	Dept of Mechanical Engg. Sardar Patel Road, Chennai - 600 025	Mohan Lal mohanlal@annauniv.edu
3	**BARC**	Bhabha Atomic Research Centre, Cryo Technology Division Trombay, Mumbai - 400 085	Trilok Singh tsingh@magnum.barc.gov.in Ravi Kumar(Physics)
4	**BE College**	**Bengal Engineering and Science University,** P.O : Shibpur Howrah. Pin - 711103. West Bengal	Dr. Dipali Banarjee Physics Department
5	**Bharathi Dashan University**	Bharathidasan University Dept. of Physics.Tiruchirappalli - 620 024, Tamil Nadu,	S. Aramugam saramugam1963@yahoo.com
6	**BHEL**	BHEL Corporate R&D Balanagar,Hyderabad-502093	J.L Bhattacharya Jayant@bhelrnd.co.in
7	**BHU**	Banaras Hindu University, Varanasi-221005, U.P.,India.	
8	**CGCRI**	**Central Glass & Ceramic Research Institute** 196 Raja S C Mullick Road, Kolkata-700032	Dipen Bhattacharya
9	**CRCT/JU**	Centre for Rural and Cryogenic Technology, Jadavpur University Kolkata-32	S.C. Sarkar scs@cal2.vsnl.net.in Dr. D Bhattacharya
10	**Delhi University**	University Of Delhi, Delhi - 110 007, India	
11	**Heavy Water Board**	Heavy Water Board Vikram Sarabhai Bhavan, Anushakti Nagar, Mumbai - 400 094	T. K. Haldar tkhaldar@mumbai.hwbdae.in
12	**Hyderabad University**	University of Hyderabad School of Physics Hyderabad-500046, A.P	R. Singh rssp@uohyd.ernet.in S. N. Kaul Kaul.sn@gmail.com
13	**IACS, Jadabpur**	Indian Association for Cultivation of Science. 2a&2b Raja S C Mullick Road, Kolkata 700032	Dr.. B. K. Choudhuri sspbke@rediffmail.com Dr.. S. K. De msskd@iacs.res.in
14	**IGCAR**	**Indira Gandhi Centre for Atomic Research** Material Science Group Kalpakkam-603102 Tamilnadu	Dr.. C.S Sunder css@igcar.gov.in
15	**IISC. Bangalore**	Indian Institute of Science Centre for Cryogenic Technology Bangalore- 560012	Prof. S. Jacob jacob@ccf.iisc.ernet.in Prof. S kasturirengan kas@ccf.iisc.ernet.in

SL No	Institute	Address	Contact Person
16	**IIT Kanpur**	IIT Kanpur Kanpur-208016, Up India	Dr. R. C. Budhani rcb@iitk.ac.in
17	**IIT- Delhi**	Indian Institute Of Technology Delhi Hauz Khas, New Delhi - 110 016. India	Dr. Ratnamala Chaetterjy ratnamalac@gmail.com
18	**IIT- Kharagpur**	Indian Institute Of Technology Cryogenic Engineering centre Kharagpur - 721302, India	V. V. Rao vvrao@hijli.iitkgp.ernet.in
19	**IIT. Guwahati**	Indian Institute Of Technology Guwahati 781039 Assam, India	Dr.. S. Kanakraj kanakraj@iitg.ernet.in
20	**IIT. Mumbai**	Indian Institute of Technology Bombay Powai, Mumbai - 400076, India	Prof. Milind D. Atrey matrey@iitb.ac.in Prof. C.V. Tommy
21	**INMAS, Delhi**	INMAS (DRDO), Brig. S. K. Mazumdar Marg, Timarpur, Delhi 110054	S. Khushu skhushu@yahoo.com
22	**IPR**	Institute for Plasma Research Bhat, Gandhinagar, Gujrat, India-382428	V. L. Tanna vipul@ipr.res.in S. Pradhan pradhan@ipr.res.in
23	**ISAT, Bangalore**	ISRO Satellite Centre HAL Airport Road, Vimanapura, Banaglore – 560017	S. C. Rastogi rastogi@isac.gov.in
24	**ITER- INDIA Ahmedabad**	ITER-India Institute For Plasma Research Bhat, Gandhinagar – 382 428.	B. Sarkar bsarkar@iter-india.org
25	**IUAC, New Delhi**	Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110 067, India	T S Datta tsdatta@iuac.res.in
26	**Jadavpur University**	Jadavpur University Kolkata-700032	Dept of Physics
27	**JNCASR**	Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore-560 064	A. Sundaresan sundaresan@gncasr.ac.in
28	**JNU**	Jawaharlal Nehru University. New Mehrauli Road, New Delhi 110067	S. Patnaik Spatnaik@mail.jnu.ac.in
29	**L&T**	L&T House, Ballard Estate Mumbai – 400 001	
30	**LASTEC**	Laser Science & Technology Centre, Metcalfe House.Delhi -110054	Maitreyee Nanda maitreyee_n@hotmail.com
31	**LD College of Engineer, Ahmedabad**	L. D. College Of Engineering Dept of Mechanical Engg. Ahmedabad 380 015 India	Bharti Vipin Dave msbharti@rediffmail.com
32	**LPSC, Mahendragiri**	LPSC, ISRO, Mahendragiri,Thirunelveli-District Tamilnadu-627133	Mohammad Muslium m_muslim@lpsc.gov.in
33	**LPSC, Bangalore**	LPSC, HAL Second Stage Bangalore- 560008	M. V. N. Prasad mandyaprasad@gmail.com
34	**LPSC, Valiamala**	LPSC/ISRO Valiamala P.O Trivandrum-695 547	N. K. Gupta nkgupta1950@yahoo.com C.G. Balan cg_balan@lpsc.gov.in

SL No	Institute	Address	Contact Person
35	**Nirma Institute of Technology**	Nirma Institute of Technology Post : Chandlodia, Via : Gota, Ahmedabad - 382 481. Gujarat,	Nilesh Bhatt nmbhatt@nirmauni.ac.in
36	**NIT, Calicut**	National Institute of Technology Mechanical Engg. Department *NIT* Campus P.O., Calicut - 673 601.	Bizu. T. Kuzhiveli btkuzhiveli@nitc.ac.in
37	**NIT, Surat**	National Institute of Technology Mechanical Engineering Department Surat-395007	H.B Naik hbn@med.svnit.ac.in
38	**NIT/ Rourkella**	National Institute Of Technology Rourkela Orissa, India, Pin-769008	Prof. Sunil Sarangi sarangiskr@nitrkl.in
39	**NPL. New Delhi**	National Physical Laboratory Dr. K.S. Krishnan Marg New Delhi - 110012 India	Hari Kishan hkishan@mail.nplindia.ernet.in
40	**RRCAT Indore**	Raja Ramanna Centre For Advanced Technology Indore 452013 (M.P), India	S. B. Roy(Physics) sbroy@rrcat.gov.in P.K. Kush(Engineering) kush@rrcat.gov.in
41	**RRL, Trivandrum**	National Institute for Interdisciplinary Science & Technology(Nist) Trivandrum - 695 019. Kerala	V. Shyama Prasad syam@csmftrd.ren.nic.in
42	**SAC, Ahmedabad**	Space Applications Centre Jodhpur Tekra, Ambawadi Vistar P.O.Ahmedabad – 380015	N. Narashimhan narasimhan@sac.isro.gov.in
43	**Shivaji University**	Shivaji University Vidyanagar, Kolhapur-416 004 Maharashtra,	Physics Department
44	**Singhania University**	Singhania University Address: V.P.O. - Pacheri Bari, Dist. Jhunjhunu, Rajasthan - 333 515	Susheel Kalia Susheel_kalia@yahoo.com
45	**SINP**	Saha Institute of Nuclear Physics 1/AF, Bidhannagar Kolkata - 700 064	R. Ranganathan r.ranganathan@iuac.res.in
46	**SNBSC, Kolkata**	SN Bose Science Centre JJ Block. Salt Lake. Kolkata	A. K. Raychoudhuri arup@bose.res.in
47	**SHAR Centre ISRO**	Sriharikota Range Andhra Pradesh 524124	pga@shar.gov.in
48	**SSPL. Delhi**	Solid State Physics Lab,Lucknow Road, Delhi-110054	Manmohan Singh manmohon.f@sspl.drdo.in
49	**T.K.M College. Kollam, Trivandrum**	TKM College Of Engineering Mechanical Engg. Dept. Kollam-5 Kerala	M. S. Pillai madhutkmce@rediffmail.com
50	**TIFR, Mumbai**	Tata Institute of Fundamental Research Homi Bhabha Road, Mumbai 400005, India	S. Ramakrishnan ramk@mailhost.tifr.res.in
51	**UGC-DAE CSR, Indore**	UGC-DAE.CSR. Indore University Campus, Khandwa Road, Indore-452017, M. P	Praveen Chaddah chaddah@csr.ernet.in
52	**UGC-DAE CSR, Kolkata**	UGC-DAE CSR, Kolkata Centre Sector III / Plot LB -8 Bidhan Nagar Calcutta 700 098	Dipankar Das ddas@alpha.iucres.in

SL No	Institute	Address	Contact Person
53	**VECC. Kolkata**	Variable Energy Cyclotron Centre 1/AF, Bidhan Nagar, Kolkata-700064	R. K. Bhandari bhandari@veccal.ernet
54	**VJIT, MUMBAI**	Veermata Jijabai Technological Institute, Mumbai- 400019	K.G Narayankhedkar director@vjti.ernet.in
55	**VIIT, Pune**	Mechanical Engineering Department Pune	M Lele
56	**VIT, Vellore**	VIT University. Mechanical Department Vellore - 632 014 Tamilnadu	A. Senthil Kumar as_kumar68@hotmail.com
57	**Walchand College of Engineering**	Walchand College Of Engineering, Mechanical Dept Vishrambag, Sangli - 416 415	B. S. Gawli
Gas Industry			
58	**Air Liquide India Holding Pvt Ltd.**	Air Liquide India A-36, 1st Floor Mohan Co-Operative Ind. Estate Mathura Road, New Dehli 110 044	Satish Kochhar Sales.india@airliquide.com
59	**BOC India Ltd.**	Oxygen House, P-43, Taratala Road, Kolkata, West Bengal, India -88	H.N. Bengani h.bengani@boci.co.in
60	**Paraxair India**	"Praxair House" No. 8, Ulsoor Road Bangalore - 560 042	Gaganan Nabar info@praxair.com
61	**Inox Air Products Ltd.**	Ceejay House Dr Annie Besant Road. Worli Mumbai-400018	
62	**M/s Goyal MG Gases Pvt. Ltd**	A-38, Mohan Co-operative Industrial Estate. Mathura Road New Delhi-44	Suresh Goyal Scgoyal@goyalgroup.com
63	**Pure Helium India Pvt. Ltd**	Pure Helium India (P) Limited B-301, Balarama, Bandra (East) Mumbai 400051, Maharashtra	Anand Mehta
Manufacturing Industry			
71	**Cryolor Asia Pacific**	1/238,Old Mahavalipuram Road, Semmencherry,Chennai-6000119	Ravin Mirchandani ravin.mirchandani@cryolor.com
70	**Cryoquip India**	454,GIDC, NH-8, Por-Ramagandi Vadodora-391243	sales.in@cryoequip.com
72	**Indian Compressors Ltd.**	Indian Compressors Ltd. 35, Okhla, Industrial Estate, New Delhi - 110020, INDIA	Hemant Didwania sales@didwania.com
67	**Indian Oil Corporation Ltd.**	Business Group Cryogenics Sewri East.Mumbai - 400015	Samit Kr. Roy Bhowmicks@indianoil.co.in

SL No	Institute	Address	Contact Person
66	**Inox India Ltd.**	ABS Tower,4th Floor.Old Padra Road Vadodara,- 39007 Gujarat	Parag Kulkarni pkulkarni@inoxindia.com
65	**Sanghi Organization**	Seth Mahal. G Sanghi Marg Worli. Mumbai-400018	Vaibhab Sanghi mail@sanghioverseas.com
64	**Sanghi Oxygen, Mumbai**	Mani Mahal, 11/21 Mathew Road Opera House, Mumbai - 400004 (India)	R. K. Sanghi sanghioxygen@gmail.com
69	**Shell- N- Tube Pvt. Ltd.**	Shell-N-Tube Pvt. Ltd. 3, Gulmohar Orchids, Lullanagar, Pune 411 040, Maharashtra, INDIA	Munjal Mehta munjal.mehta@shell-n-tube.com
68	**Super Cryogenic Systems**	Super Cryogenic Systems Pvt. Ltd. C-18,19, Sector-8, Noida-201301	Deepak Rajotia mail@supercryo.com
73	**Air Liquide Engineering India (P) Ltd**	Air Liquid Engineering Mallapur, Nacheram Hyderabad-76	C. Shanmugam c.shanmugam@airliquide.com
74	**K. V. K. Corporation**	A-1 Trishul Building Andheri(East)Mumbai-93	Vineet Chandgothia kvkcorp@vsnl.net
75	**Vacuum Technique (P) Ltd**	#36A, AGS Layout, MSR Nagar, Bangalore - 560 054 Karnataka	Ranga Rao rangarao@vtvacuumtech.in
76	**Don Bosco Technical Institutes**	DON BOSCO TECHNICAL INSTITUTE. Okhla Road. New Delhi-25	Mr Mathew
	Suppliers and Services		
80	**Con-Serv, Mumbai**	Con-Serv, Enterprises B-202, Ani Raj Tower, Bhandup(W) Mumbai-400078	Navalkale conserve@vsnl.com
82	**Good Will Cryogenics,**	M/s Good Will Cryogenics, Mumbai 213 Nariman Building, Sector 17, New Mumbai--400703	Vinod Chopra gce_cryo@vsnl.net
78	**Linde India Ltd, Vadodora**	Linde Engineering India Pvt. Ltd. 38, Nutan Bharat Society, Alkapuri, Vadodara - 390007, Gujarat, India.	Kamlesh Desai Kamlesh.desain@linde-le.com
79	**Paul Enterprises**	Paul Enterprises, 232A, Okhla Industrial Estate, Phase-III New Delhi-110020	S. D. Paul paulprise@airtelmail.in
90	**Aimil Ltd.**	Aimil Ltd. A-8, Mohan Co-operative Industrial Estate. New Delhi - 44	Mr Arvind Verma
91	**Anarghya Inotech**	32, 7th 'A'Main Road, Muthyalanager Mathikere, Bangalore -54	Info@anarghyainnotech.com
84	**Bruker India Scientific Pvt Ltd.**	522,Rajmahal Vilas Extn. 11A Cross. Sadashivanagar Bangalore-80	C.V. Manjunath cv.manjunath@brukerbiospin.in
85	**Siemens Health Care**	Siemens Health Care Diagonistics Ltd. Baroda - 19	

SL No	Institute	Address	Contact Person
83	**Specialise Instruments Marketing Company**	18th Fort View Road No-1, Sior(East) Mumbai-22	S. D. Deshpande specmcoi@vsnl.com
89	**Spry Technolgies**		K.V Gopal
77	**Stirling Cryogenics India**	6th Floor, Ambadeep Building, No. 14, Kasturba Gandhi Marg New Delhi - 110 001	Tushar Bhowmick Tushar.bhowmick@stirlingindia.com
87	**The Tinsley Group Ltd**	304, Plot No7 Mahajan Tower.LSC Shreshtha Vihar,Delhi- 110092	Sandeep Sharma tinsley@ndf.vsnl.net.in
88	**Velan India**		Giridhar velanindia@yahoo.com
81	**Vico Sales, Delhi**	M/S Vico Sales, Delhi W-8, Main Patel Road West Patel Nagar, New Delhi - 110 008	Pramad Kumar pkumar@vicosales.com
86	**Wipro - GE Health care**	Bangalore- 67	
92	**BHPV**	BHPV Ltd. Visakhapatnam- 530012 A.P	md@bhpvl.com

Annexure 2

The Local Programme Advisory Committee (LPAC)

List of Members

1. Amit Roy	(Director IUAC)
2. R. Chetal	(Adviser, DST)
3. A.K. Rastogi	(JNU)
4. Harikishan	(NPL)
5. Tushar Bhowmick	(M/S Stirling)
6. Maitreyee Nanda	(LASTEC)
7. Manmohan Singh	(SSPL)
8. NR Jagannathan	(AIIMS)
9. Ratnamala Chatterjee	(IIT Delhi)
10. R.G. Sharma	(IUAC, Co-PI)
11. T.S. Datta	(IUAC, PI)

Annexure 3

Leaflet circulated amongst the Cryogenic Community

An appeal for providing us with complete information on the activities pursued at your laboratory / institute / company / industry in the areas of Low Temperature Physics / Superconductivity / Cryogenics and the availability of human resource for compilation and data bank

Dear Sir,

We have been assigned by DST to prepare a comprehensive report on "**Data base information on facility and human resources related to Cryogenic & Superconductivity in India (Present & Future trend)**"

The purpose of preparing this document is two fold. One, that a glance through the report should tell us about all the ongoing activities related to low temperature physics, basic studies and applications, work on superconductivity, basic or applied, major facilities available at various centres for measurements and large scale usage and production of cryogenic fluids like LN2, LH2 and LHe in research institutions and the industry. Two, to know the state of human resource availability and future requirement. The data so collected will enable us to forecast our major requirements in terms of infrastructure and human resource for future. This is crucial, for India is going to participate in global programmes like ITER and ILC.

Surely, to prepare such report we need your help, support and cooperation. We will appreciate receiving information with regard to the nature of activities, their present status, the infrastructural facilities, the measuring equipment(s) available at your centre. Accordingly, we have prepared a data sheet which is in two parts. First one pertains to personnels working in this field and second is related to facilities available. Information of cryogenic industries in India is also very important and we intend to collect all possible data from them..

We request you to kindly fill up the data sheet and forward it back to us. You may also like to give extra information about the activities at your centre not covered by this data sheet. Please also attach photographs of some of your important facilities / equipment. We might come back to you for additional information that we might like to include in the report. At some point of time we might visit your laboratory for personal interaction. If you so desire you may suggest the name with full contact address, whom you think should be contacted directly. Your cooperation is once again solicited.

Thanking you and with best regards

T.S. Datta **R.G. Sharma**

A. Data base information on Personel working on Cryogenics/ Superconductivity/ Low temperature Physics

(Project funded by DST: DST/ NSTMIS/05/84/2006-07)

1. Name
2. Date of Birth
3. Age on 1st January 2008.
4. Qualification

Degree	*Specialization*	*Year*	*Institute*	*State*

5. Present Profession

a) Occupation (Service / Business) :
b) Service Type (Govt / Private/ Public enterprise) :
c) Designation ;
d) Type of Job : Academic/ R&D/ Industry/ Sales & Marketing/ Medical

7. Past Experience

Year	*Name of Company*	*Type of Job*	*Designation*	*Reason for leaving*

7. Experience Details on Cryogenics / Superconductivity/ low temperature physics/ low temperature biology/ Medical application / Industry / others connected to low temperature
   a) Broad field among the above :
   b) Working Experience : up to 77 K/ up to 20 K / up to 4. 2 K /below 4.2 K
   c) Experience on handling : liquid Nitrogen, liquid oxygen, liquid hydrogen, liquid Helium, LNG
   d) Nature of Work : Please mark it, which are appropriate
      i) Development of Cryogenic Component
      ii) Major Superconductivity/ Cryogenic programme Running Cryogenic Facility
      iii) Maintenance of Cryogenic Equipment/ Facility

iv) Cryogenic Instrumentation
v) Measurement at low temperature
vi) Design of Component
vii) Teaching on Cryogenics/ Superconductivity/ Low Temperature Physics
viii) Application of Cryogenic in Medicine
ix) Application of Cryogenic in other special application
x) Using Equipment related to Cryogenics/ superconductivity
xi) Cryo Preservation

e. Brief description abour your work and your expertise with key words and telex format

8. Your experience in other lab/ university outside india in this field

9. Your Comment & Suggestion on Growth of Cryogenics/ Superconductivity in India

10. Have you assigned a Project Funded by DST or other Agency :
    1. Title
    2. Funding Amount/ Agency / year
    3. Status :

11. Please inform us about name and email address of four perss, working in the field of cryogenics/ Superconductivity/ low temperature physics/ etc.

    1. Name :
    2. Address
    3. Tel No :
    4. Email :

B. Data base information on Equipment / Facility related to Cryogenics/ Superconductivity/ Low temperature Physics

(Project funded by DST: DST/ NSTMIS/05/84/2006-07)

1. Name of Person :
2. Institute Name
3. Address;
4. Department :
5. Email address :
6. Main work at the Institute:
7. For what Cryogenics / Superconductivity is persued at the centre.
8. Facility Availavle at your centre. And Status :

A. Do you have Helium / Hydrogen / Nitrogen Liquefier :

1. Make
2. Capacity
3. Year of Procurement:
4. Main user
5. Yearly average production
6. Demand
7. Present capacity
8. Augmentation
9. If written of Reason :

B. Do you have Superconducting Magnet & Cryostat

1. Make :
2. Field / Bore dia :
3. Year of Procurement:
4. Main user
5. Yearly Utility
6. Demand
7. Present Field
8. Upgradation
9. If written of Reason :

C. Do your lab is equipped with Closed Cycle Refrigerator

1. Make :
2. Capacity/ Min Temp:
3. Year of Procurement:
4. Main user
5. Yearly Utility
6. Demand
7. Present Capacity
8. Upgradation
9. If written off Reason :
10. Application

D. How many Cryogenic Storage Vessel (LN2/ LH2/ LN2)

Capacity, Type, year of procurement, Evaporation rate, Make, present status etc.

E. Please inform us about Cryogenic Temperature Controller

Range, Accuracy, Make, year of procurement, used with equipment, present status

F. NMR Status

Field, Bore, Frequency, Cryogen free/ with cryogen, Filling freqency, Services by , Make, year of procurement, Cost and use

G. MRI

Field, Bore, Frequency, Cryogen free/ with cryogen, Filling freqency, Services by, Make, Year of procurement, Cost and use

H. Cryofreezer

Application, Temperature range, Make, year of procurement, cost

I. Any other Cryogenic Equipment