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.