Role of IISc in the development of Cryopumps

S.Kasthurirengan

IISc, Bangalore

Plan

- **Need of UHV in fusion systems**
- **Cryosorption pump & its development**
- **IISc's Role towards the same**

  Experimental facility for adsorption characterization of activated carbons 4.5 K -77 K range & sample studies

  Pumping speeds measurements on scaled down panels & sample studies with cryopumps

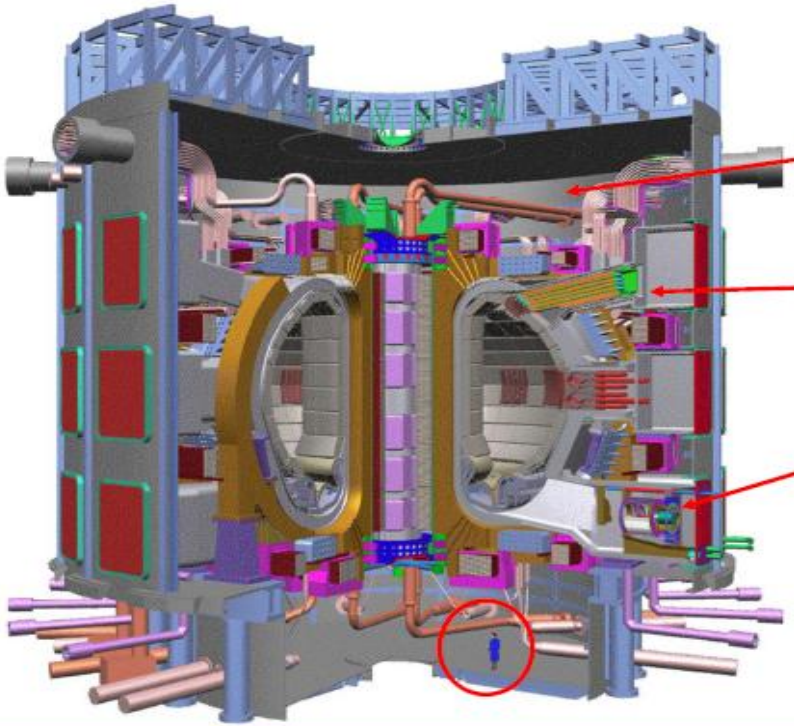
- **conclusion**

Ultra high Vacuum for Fusion Systems

- **Fusion - most promising technology for energy.**
- **Reaction plasma - confined in magnetic field using Tokomak**
- **Good vacuum & clean surface conditions critical for tokomak.**
- **Typical base pressures ~ 10^{-8} mbar (under fuel conditions)**
  ~10^{-10} mbar under for no-fuel conditions.
- **Need for non-contaminating ultra high vacuum pumping systems.**
- **In view of several aspects such as operation in time-varying magnetic fields, high pumping speeds,**
  Cryosorption Pumps are the only suitable ones.
- **He and H2 isotopes are adsorbed on cryopanels bonded with adsorber materials and cooled to LHe temperatures by LHe flow.**

ITER – Cryopuming systems

ITER´s large high vacuum systems



3 large cryopump systems

Cryostat pumping system
(~ 150 m³/s, 8500 m³)

Neutral Beam (NBI)
pumping system
(~ 5000 m³/s, 200 m³)

Torus exhaust
pumping system
(~ 8x80 m³/s, 1400 m³)

\+ *backing pump trains*

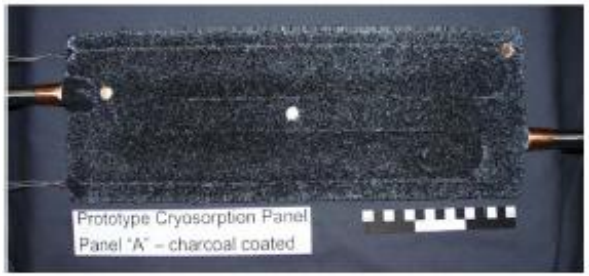
Major plasma radius 6.2 m	Plasma Volume: 840 m^3
Plasma Current: 15 MA	Typical Density: 10^{20} m^{-3}
Typical Temperature: 20 keV	Fusion Power: 500 MW

Cryosorption pumps

- **Activated carbon** adsorbent has **improved pumping speeds** when compared to other adsorbents.

- Experimental studies indicate the activated carbons of **Coconut shell charcoals** (of midsize range) produced the best performance [Christian Day, FZK, 2002]

1 m long x 0.2 m wide (3 parallel channels



Development Needs

- **Cryosorption pump development is now undertaken in IPR.**
- **This needs**
  (a) the right choice of the activated carbons
  (b) the right bonding agent (adhesive)
  for the cryopanels to adhere the activated carbons.
- **Commercial cryopumps – normally used for applications such as pumping of air, water vapour etc. cannot be directly used. Their performances for pumping He & H2 not known.**
- **Hence there is a need for performance data of activated carbons especially in the temperature range below 77K down to 4.5 K.**
- **Not available in the open literature .**

Role of IISc in the above

- **Creation of the knowledge base of performances of several types activated carbons from 4.5 K to 10 K by setting up the experimental setup for adsorption studies.**
- **Eevaluation of small size cryopanels in terms of pumping speeds.**
- **Manpower training in cryogenics and vacuum technology.**
- **Serve as interface between Industry and IPR.**

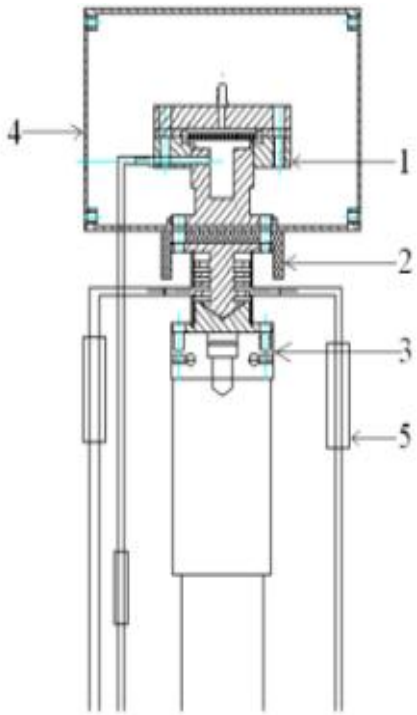
Experimental facility for characterization of adsorbents down to 4.2K

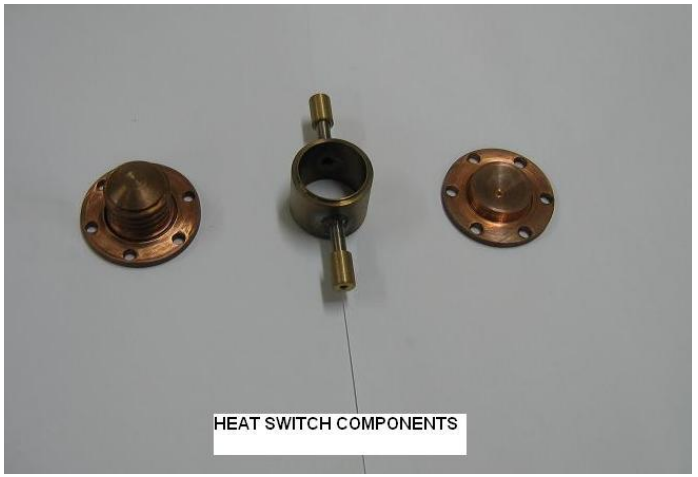

ASIQ in Operation


Cryocooler Mounted on base plate

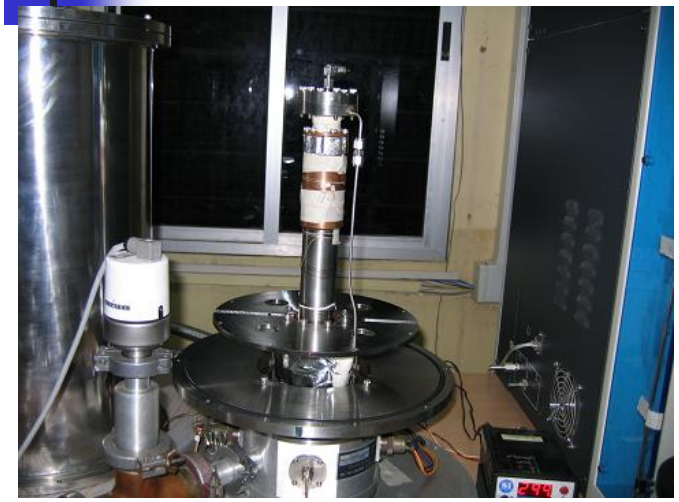
77K Micropore Analyser + 2 Stage GM Cryocooler

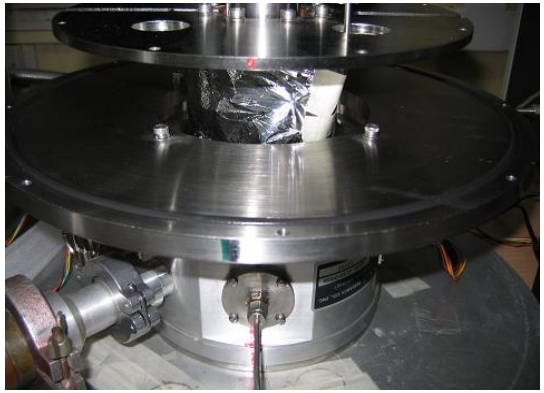
Sample chamber & Heat Switch





System Assembly

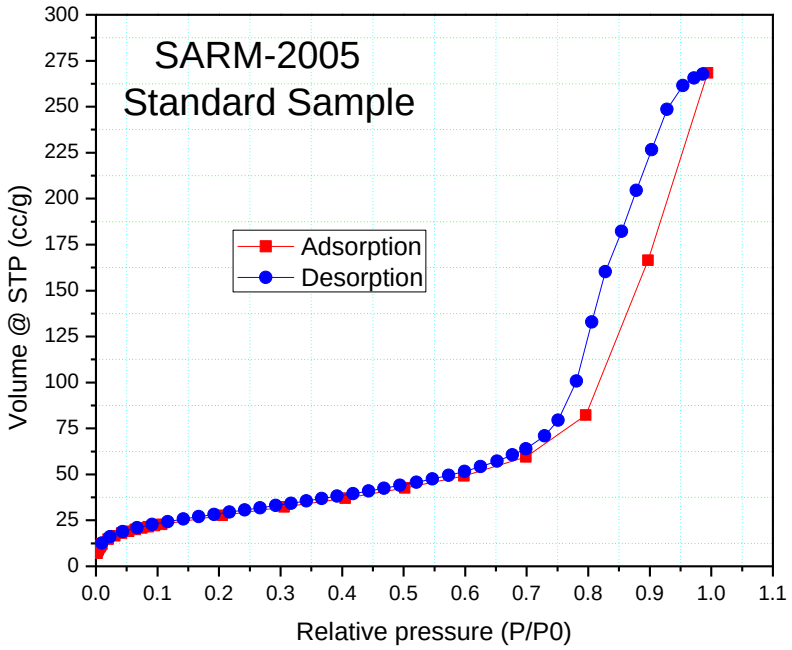




....Contd.

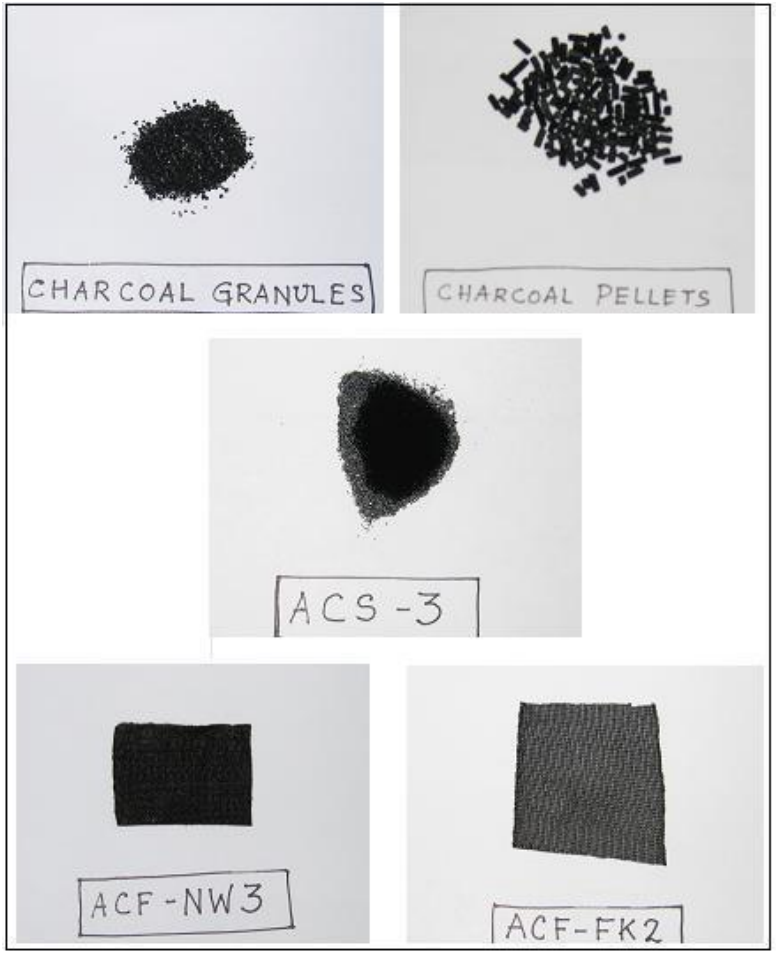
Total System

Experimental Studies at 77K with ASIQ

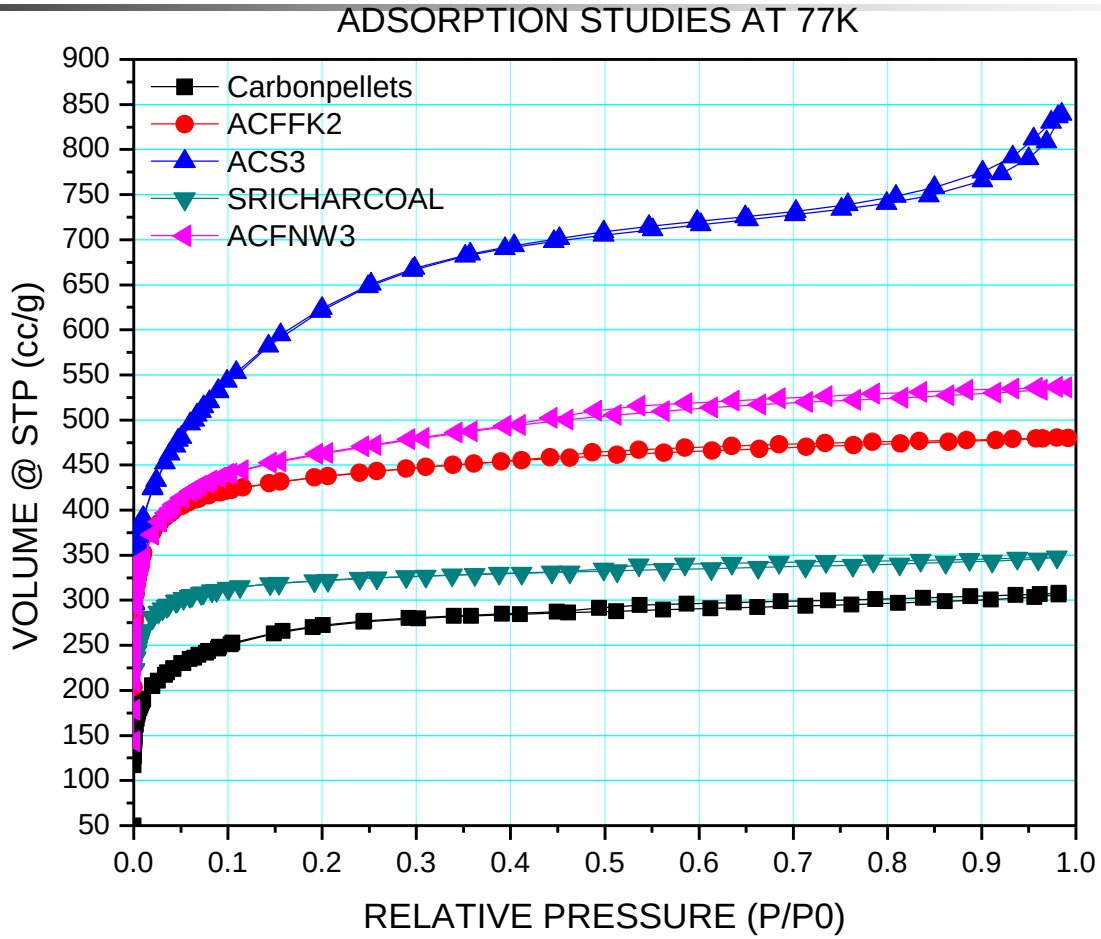


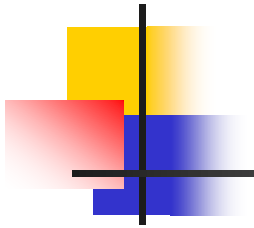
Standard Alumina Sample

Activated Carbons studied



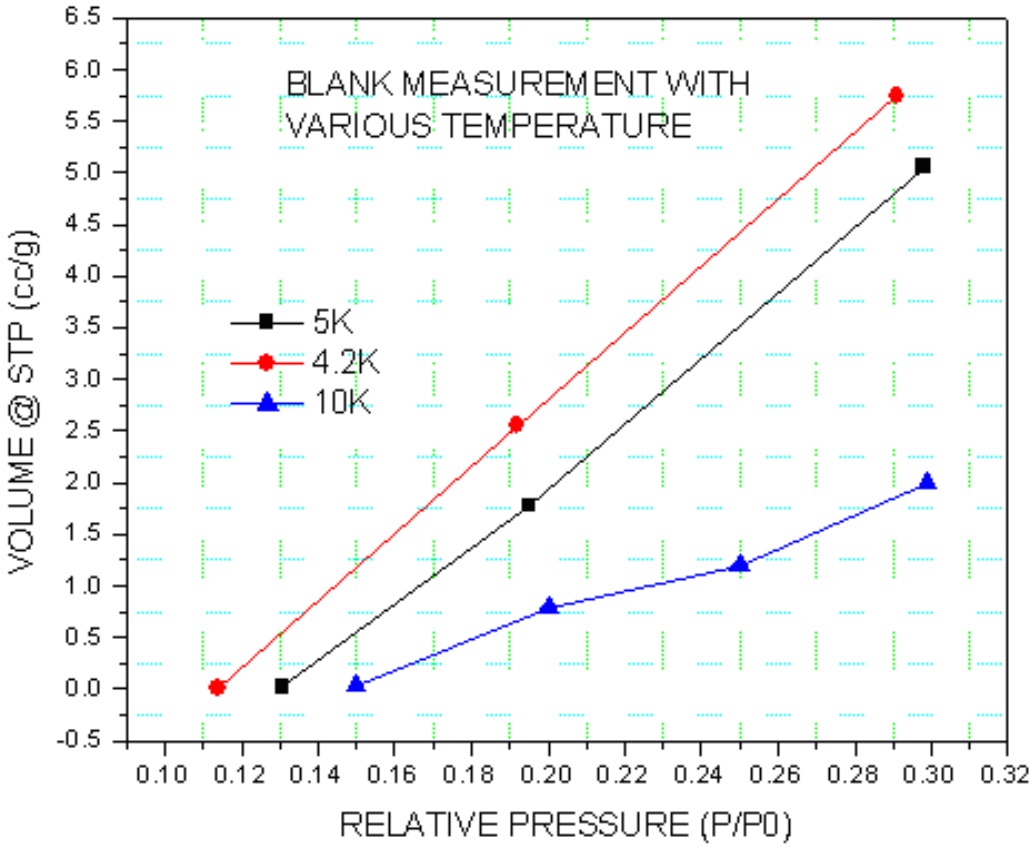
Performance @ 77K for activated Carbon samples



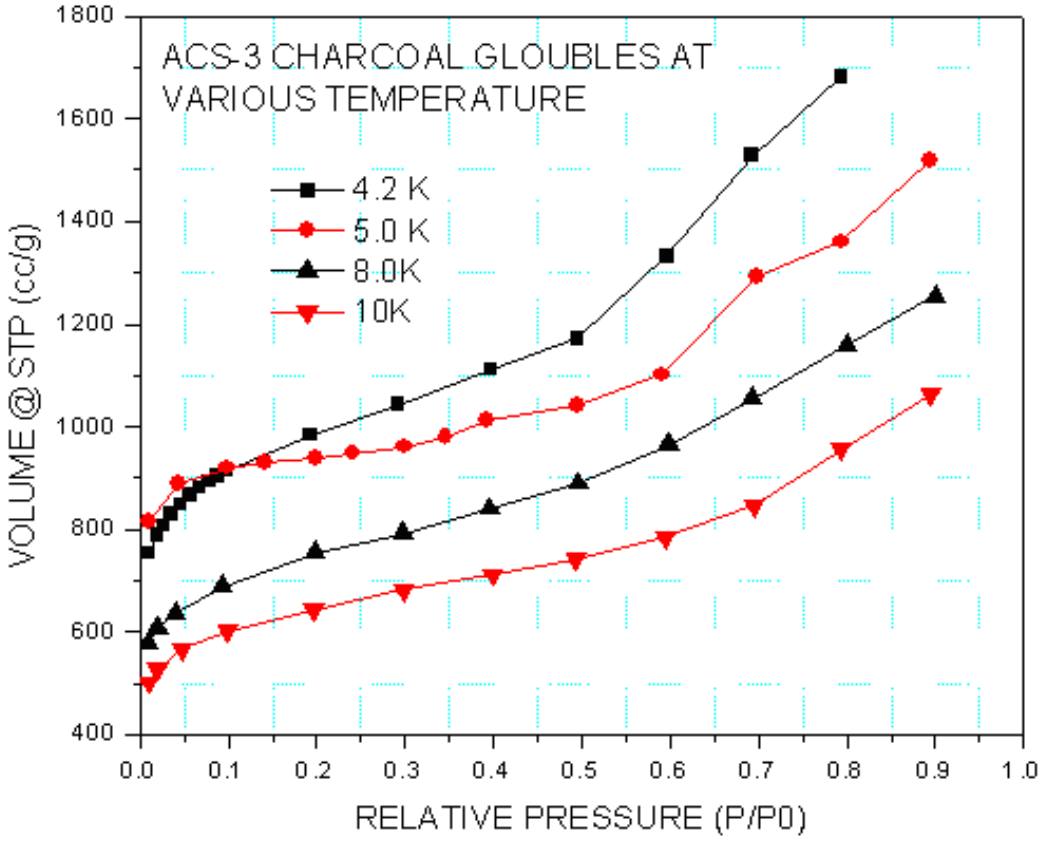


Studies from 4.5K to 10 K

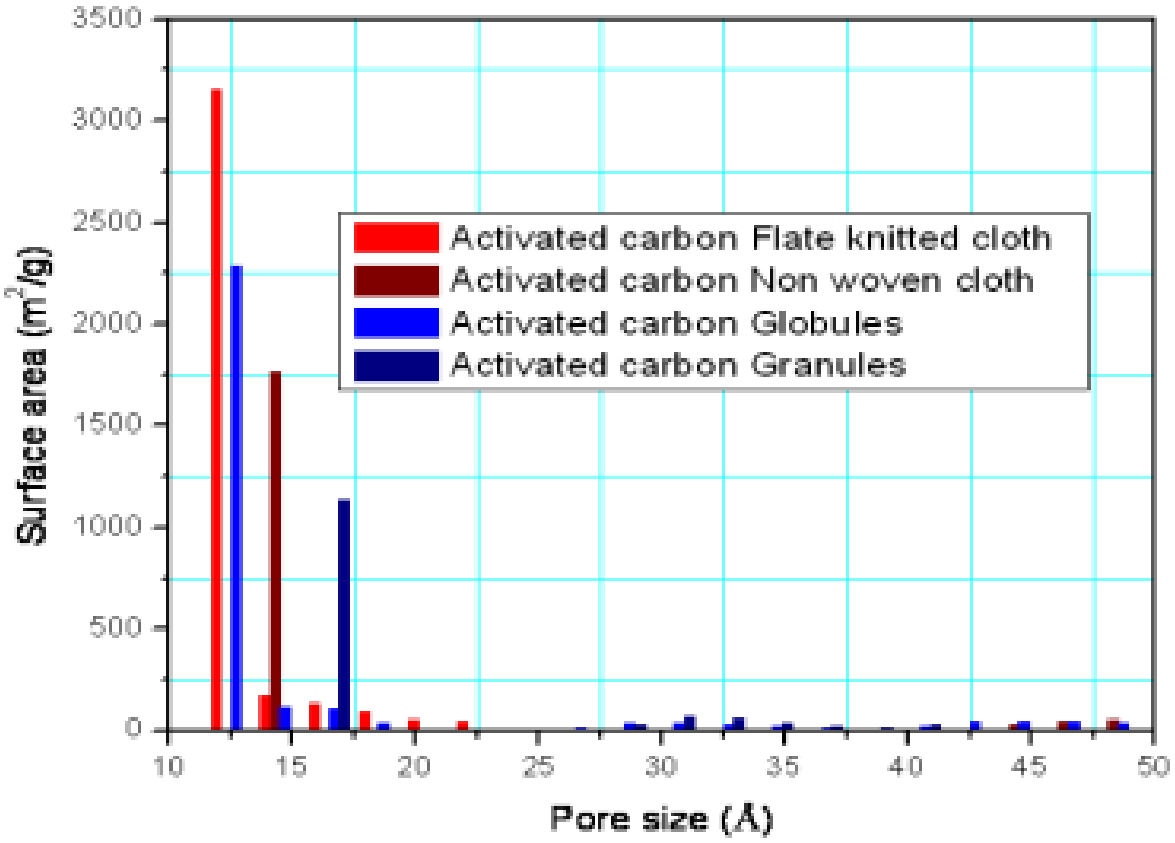
Blank Measurements



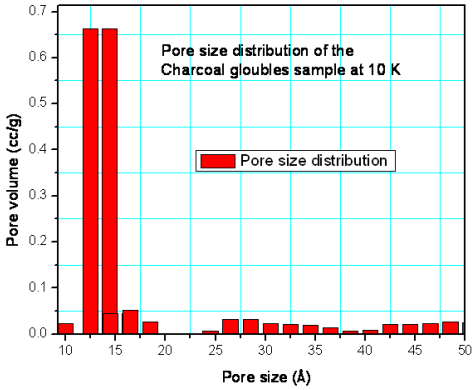
ACS-3 Globules

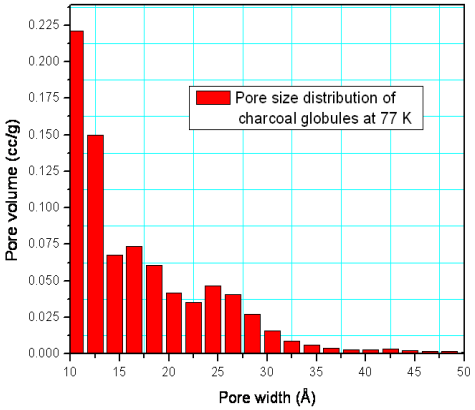


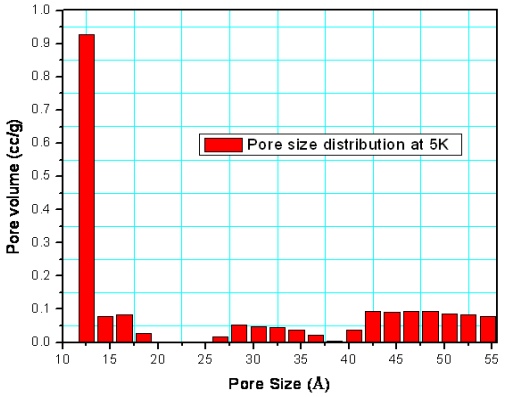
Pore size distribution of various charcoal at 4.2K with He

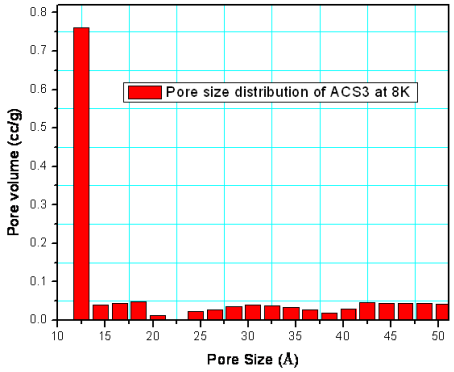


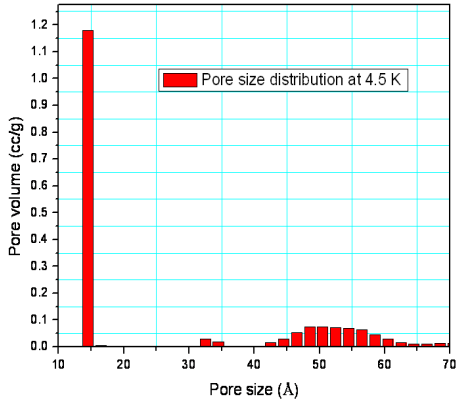
Pore size distributions











Surface areas of activated carbons

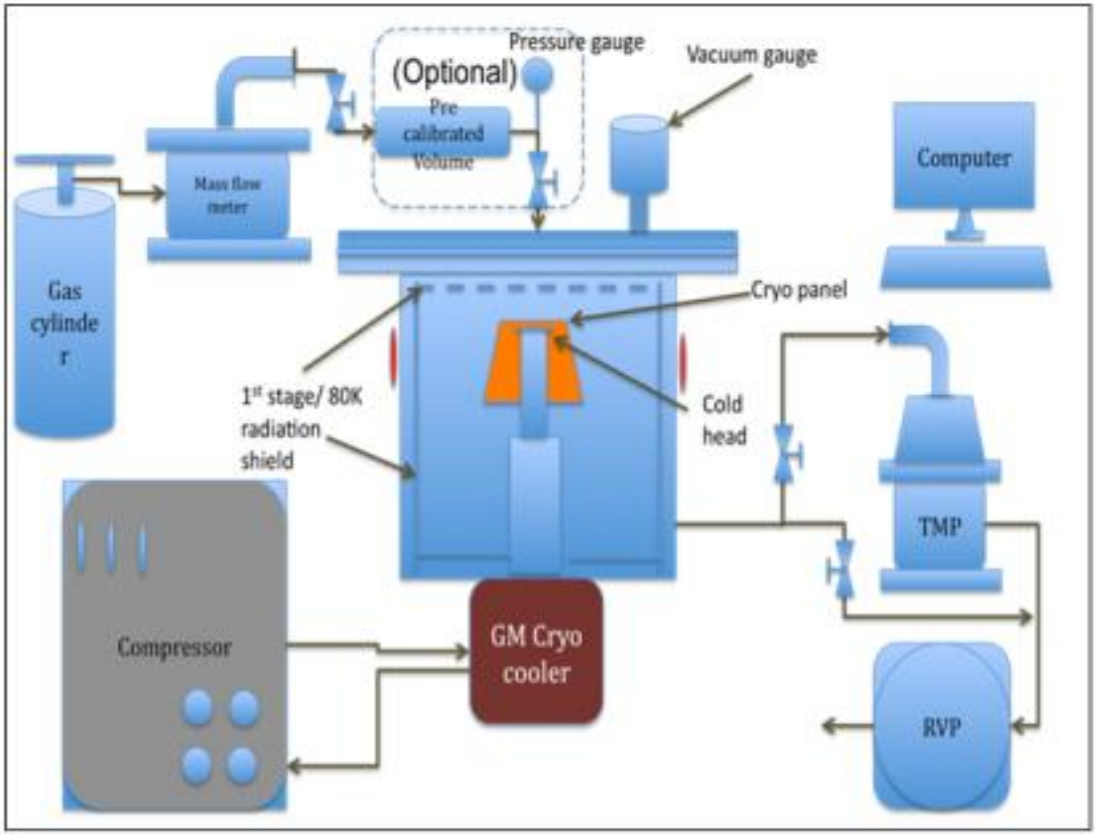
SAMPLES	SURFACE AREA MEASUREMENT –(m^2/g)				
	77K (Nitrogen adsorbate)	4.2K (Helium adsorbate)	5K (Helium adsorbate)	8K (Helium adsorbate)	10K (Helium adsorbate)
BLANK	0.00	0.12	0.00	0.00	0.00
CARBON PELLETS	1003.1	1465.1	1031.5	894	887.2
ACS3	2038.2	2700.3	2639.45	1963.4	1736.8
ACFNW3	1773.2	1951.01	1924.1	1589.3	1335.2
Srilanka Charcoal	1364.5	1801.2	1797.6	1188.5	1069.2
ACF- FK3	2230	---	2697.2	2582.6	2014.9
ACS3 +SS plate+ adhesive	1927	2600.7	2424.4	1831.2	1516.44
Charcoal granule Coarse	1126.74	1668.00	1576.5	1374.5	1235.61

Studies with adhesives

Sample under study	Surface area in 77K with N_2 (m^2/g)	Average pore size in 77K with N_2 (A^0)	Surface area in 4.5K with He(m^2/g)	Average pore size in 4.5K with He (A^0)
ACS-3	2031.6	7.60	2700.1	6.21
SS sheet	0.00	0.00	0.00	0.00
SS coated with Adhesive	0.00	0.00	0.00	0.00
SS with Adhesive and ACS-3	1978.00	12.3	2600.7	11.81

Pumping Speed studies of scaled down cryopanels down to 11K

Schematic

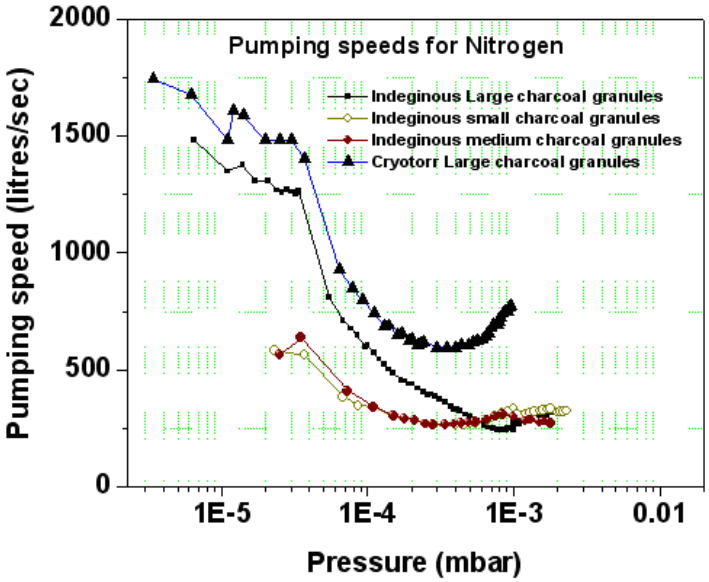

(Optional)
Pre calibrated Volume
Pressure gauge
Vacuum gauge
Mass flow meter
Gas cylinde r
Computer
Cryo panel
1st stage/ 80K radiation shield
Cold head
TMP
Compressor
GM Cryo cooler
RVP

Pumping Speed Measurements

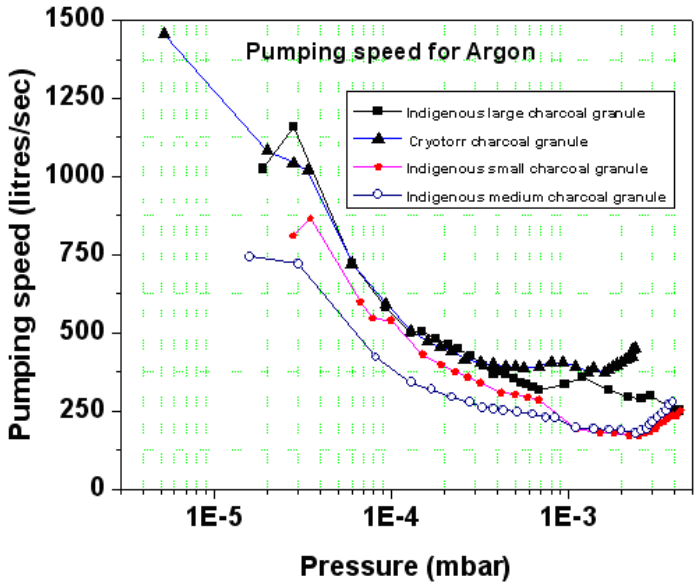
Experimental Setup

Small size Activated carbon coated Cryopanels

Pumping speeds for N2 & Ar

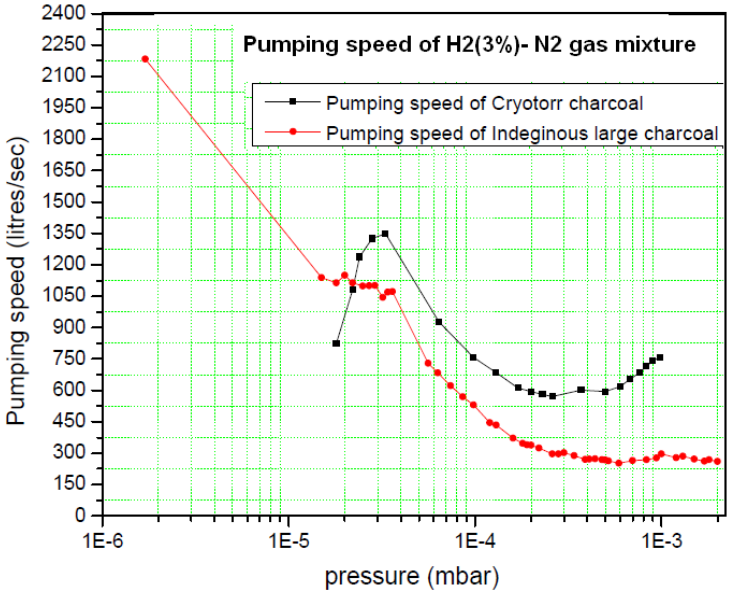


Pumping speed Vs pressure for Nitrogen gas for different panels

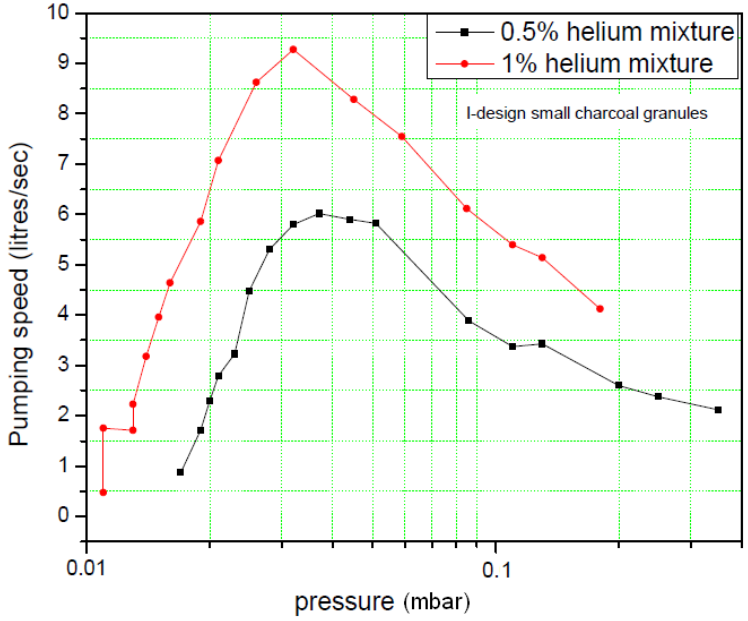


Pumping speed Vs pressure for Argon gas for different panels

Pumping speeds for H2 & He



Pumping speed Vs pressure for H2 gas for different panels



Pumping speed Vs pressure for Helium gas for different panels

Pumping speed comparison of different charcoal panel

Panel	N_2	Ar	H_2^+	He
Panel without Act. Carbons	192	127	50	0.1
CryoTorr7 Act. Carbon panel	1450	1135	250.2	0.2
Small Granule Act. Carbon panel	600	825	100.8	0.14
Medium Granule Act. Carbon panel	575	720	155.3	0.08
Large Granule Act. Carbon panel	1370	1129	215.3	0.16

Conclusion

- **The experimental setup has been established to characterize the performances of activated carbons down to 4.5 K.**
- **It is being used to arrive at the right choice of the activated carbon for the end application.**
- **The pumping speed measurements of scaled down sizes of cryopanels using cryocoolers are useful to know effect of different adhesives and the overall performances of the panels.**
- **The work has resulted in both in the knowledge base as well as manpower training in cryogenics & vacuum technology.**
- **Fruitful collaboration has been established between industry , R&D institution (IISc) and the end user (IPR).**

Thank You

for your kind attention!