PXIE VACUUM

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Project X Collaboration Meeting

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PXIE Vacuum
(outline)

- Vacuum Requirement
- Gas loads
- Pumping Scheme
- Practice of Low Particulate Vacuum
- Operational concerns
- R&D proposal
- Summary

PXIE Vacuum (requirement)

- Residual gas pressure
  - RT regions: 10^{-7} torr, driven by beam loss due to beam-gas interaction or required by specific instrument in order function properly
  - RT-Cold region: 10^{-10} torr, to limit the gas flux into CM
  - Cold region: $<10^{-11}$ torr (naturally achieved, due to 1.8K)
- Gas species sensitive
  - H_2, minimize N_2, H_2O, Ar, CO_2, hydrocarbons
- Low Particulate Vacuum required by SRF
  - Cleanroom class10, 100, 1000,…
  - how large the vicinity of SRF shall require low particulate vacuum
- Contamination control:
  - segmentation, migration, locations of pumping, venting
- Real-time monitoring
  - pressure gauges, pump status, partial pressure ratio(RGA)

PXIE Vacuum (requirement)

- Materials used in vacuum
  - Outgassing (rate and species)
  - Producing particles
- Design
  - Vacuum Seal design: brazing, welding, or flanged(metal or O-ring)
  - Avoiding virtual leak: blind screw; double joint; …
  - Avoiding producing particle: TSP, NEG, IP w/o shielding
- Procedures for QC:
  - Machining: cutting fluids …
  - Cleaning: material specific, Cu, SS, Al, …
  - Handling: groves, foils, tools, clean area,
  - Thorough leak check before major steps
  - Certified before installation in the system
- Management Policy
  - vacuum experts shall be involved in major design reviews

PXIE Vacuum
(Gas Loads)

- H^- Ion source (~10^{-1} torr.l/s)
  - H_2 introduce by pulse valve, in order to make H^-
- RFQ (~10^{-5} torr.l/s)
  - permeation thru O-rings, ~10^{-6} torr.l/s
  - surface outgassing, ~10^{-6} torr.l/s
  - gas flows from LEBT, ~10^{-6} torr.l/s (~10^{-3} torr, SNS)
  - Beam neutralization, ~10^{-5} torr.l/s (~10% beam loss)
- MEBT, Diagnosis lines and beam dump(~10^{-4} torr.l/s)
  - significant H_2 production from absorber, ~10^{-4} torr.l/s
  - outgassing from every devices exposed in vacuum, such as cavities, beamtubes, beam instrumentation… ~10^{-6} torr.l/s
- Cryomodules
  - Insulating vacuum: large and dirty, but low requirement (10^{-6} torr)
  - Coupler vacuum: ~10^{-7} torr.l/s, low particulate vacuum
  - Vaporization from condensation due to temperature rise(sensitive)
  - Cavity vacuum: flux from warm section(depends on pressure and conductance at entrance)

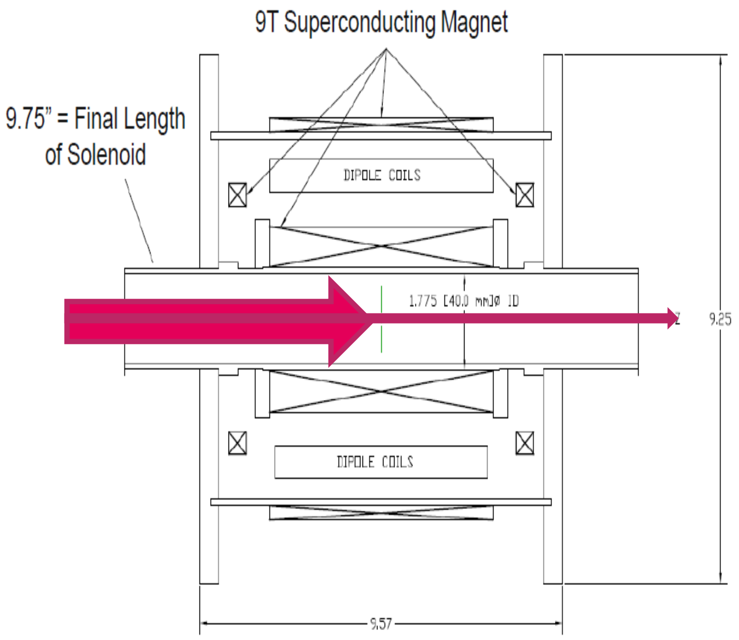
PXIE Vacuum
(Gas Loads)

Flux to CM: with 3E-10 torr at entrance of CM

- d1=40mm, l1=400mm
- Flux arrives at CM cavity:

  Q=~2×10^{-10} torr.l/s, or 6.6×10^{9} H_2/s
- monolayer time over Cavity($1000 cm^2$):~3.8 yrs
- Flux arrives at Solenoid tube:

  Q=~1.6×10^{-7} torr.l/s or 5.3×10^{12} H_2/s
- monolayer time over the tube: 25 days



We are still in discussions with vendors. This geometry is not final.

PXIE Vacuum
(Pumping Schemes)

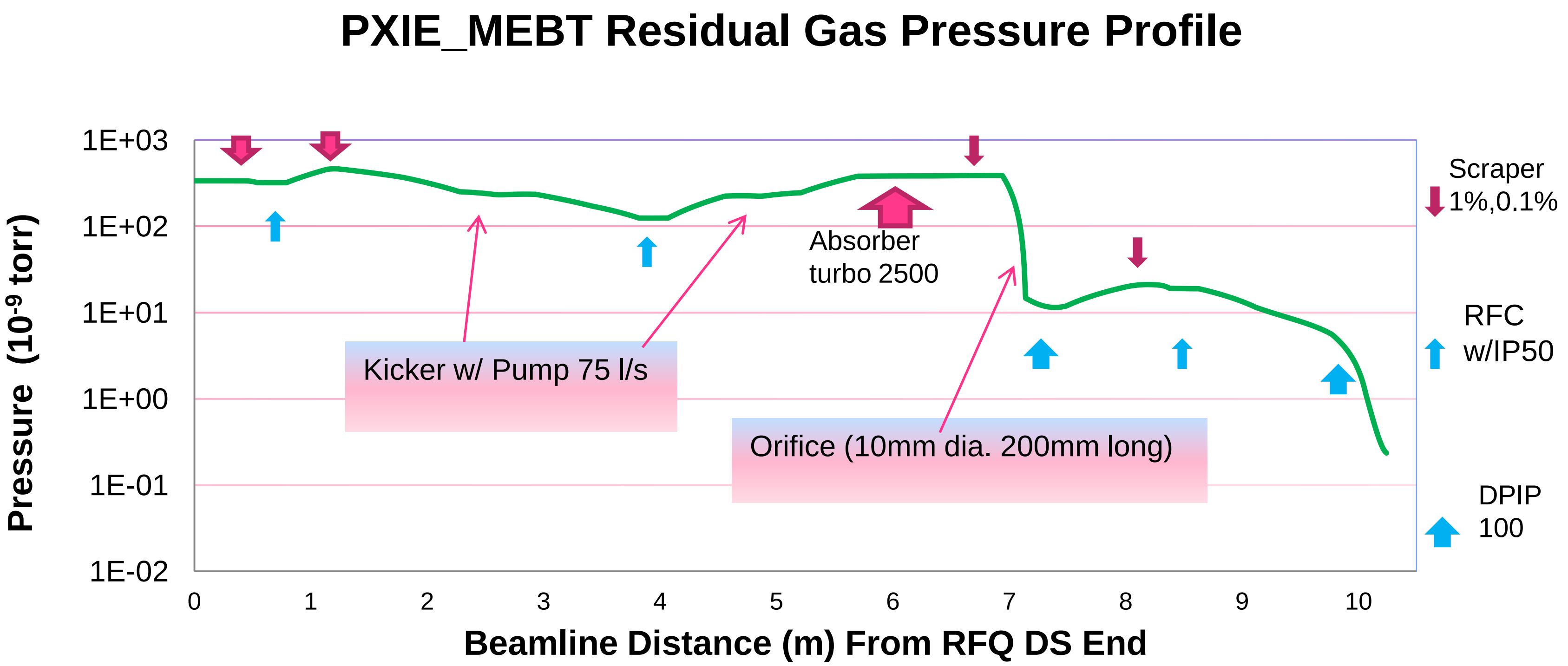
- H^- Ion source (10^{-4} torr @ plasma chamber, 10^{-6} torr @ extraction)
  – Two Turbo pumps (1930 l/s H_2)backed by mechanical dry pump with filter
- RFQ (10^{-8} ~10^{-7} torr)
  – Four Turbo pumps(900 l/s H_2) backed by mechanical dry pump with filter
- MEBT (10^{-7} torr), Diagnosis lines & beam dump
  – distributed ion pump w/ shield + turbo pumps with filter@ absorber+differntial pumping near CM
  – achieve 10^{-10} torr where near CM
- Cryomodules (<10^{-10} torr)
  – Beam vacuum, Pumped 10^{-7} torr by turbo pumps until cooled down (dry pump with filter)
  – Insulating vacuum: pumped down 10^{-4} torr by turbo before cool down, maintained by turbo as needs. Self-sustained10^{-6} torr at cold.
  – Coupler vacuum: pump down by turbo and maintained with ion pump.
- All venting (except insulating vacuum) shall be slow and with filters.
  – control mas flow to <40 torr.l/s until pressure< 1 torr. according to DESY
  – Design venting locations so that particle migrates not toward CM
  – Controlled venting/pumping system with mass flow controllers currently being developed by NML

PXIE Vacuum
(pumps choice for RFQ)

Pump Choice For RFQ (2000 l/s total effective speed)							
Style	Configuration	Cost	Operation cost	Fermilab operation experience	hours until major maintenance	Particulate generation	absorbing gas burst
Turbo Pumping	4 sets of 900 l/s turbo pump with dry rougher	$ 116,000	Med., rougher maintenance yearly	yes	>30,000	low	good
Cryo Pumping	3 set of CTI CRYO-Torr 8 cryopump(2000 l/s) with gate valve, dry rougher; prefer to have 3 sets for continous regeneration	$ 99,000	Med., regeneratoins every 3-6 Months	no	na	medium, particlates from sieve material such as cocnut charcoal	good
Ion Pumping	4 set of 800 l/s(16000l/s,H_2) Ion Pump and one turbo carts for initial pumpdowm	$ 68,000	low	yes	~40,000 hr	high, due to spurting	poor

Turbo Pumping is favored for better meeting the system requirement at reasonable cost

Vacuum Simulation
to optimize design spec



beam tube has 1.37” id.

PXIE Vacuum
(Low Particulate Vacuum Practice)

- The risk of particle migration is a great concern near CM, shall we apply Low particulate vacuum practice to entire PXIE beamline since all devices are with 20m (DESY experience) of CM. the cost of low particulate vacuum is much higher than UHV since time consuming and technical limitations. A fine tuned requirement from SRF is desired.
- Handling and assembly procedures include.
  - all preassembly/assembly work done in Class 10 or 100 cleanrooms
  - open beamline work always to be done in a portable cleanroom
  - stricter gowning requirements
  - blow down all parts/hardware as being assembled according to procedure

PXIE Vacuum
(Low particulate Requirement)

- System design considerations:
  - Minimze the amount of particle, avoid using TSP, NEG; add shielding to IPs
  - Add fast acting(10 ms) gate valves next to CM, to protect in certain cases of catastrophic failure in RT regions
  - Add pumping as close as possible to gas load to reduce the gas movemnet
  - Add some sort of ‘dust collector’, such as in Absorber
  - Continue investigating…

PXIE Vacuum
(Operational Consideration)

- Dataloging the status of all vacuum devices, necessary for operation and analysis
- Interlocking fast valves at both ends of CM
- Realtime RGA, try to detect slow leaks, R&D needs
- Gauging: double gauges will be used to reduce access time and increase system reliability
- Operating procedures to reduce human errors, such never venting coupler vacuum when CM is cold, etc.
- Vacuum Training:
  - Human error is always major risks in Vacuum practice

PXIE Vacuum
(Operational Consideration)

When we have no direct eyes on cold vacuum:

- No gauge at cold, but
  - Thermal transpiration: Knudsen relation at zero molecular flow region

    $N_{cold}=(T_{warm}/T_{cold})^{1/2}N_{warm}$

    $P_{cold}=(T_{cold}/T_{warm})^{1/2}P_{warm}$

- Signal of pressure wave delays significantly due to condensation
  - Up to 40 hours at leak rate of 10^{-6} torr.l/s at 2K, as at DESY, So Cold leak might not be noticed before RF or Cryo reactions
  - d=4.3cm,L=75.3m (@CERN)
    - $t=4.01\times10^{-2}Q^{-0.9595}$ @1.9K

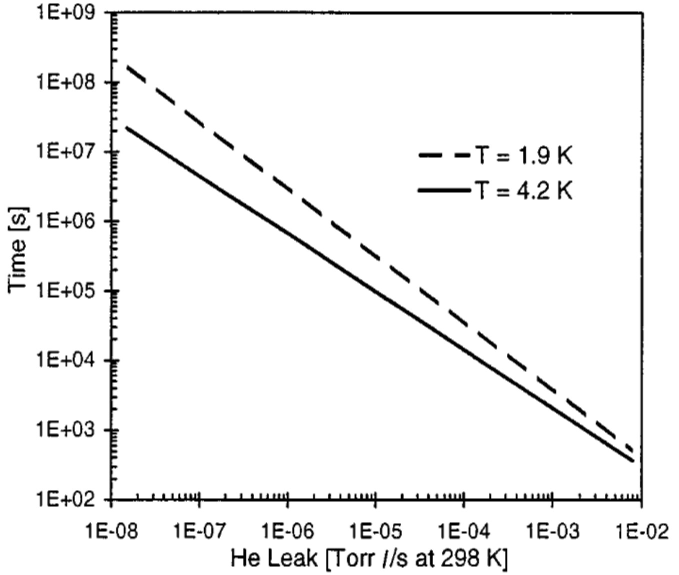


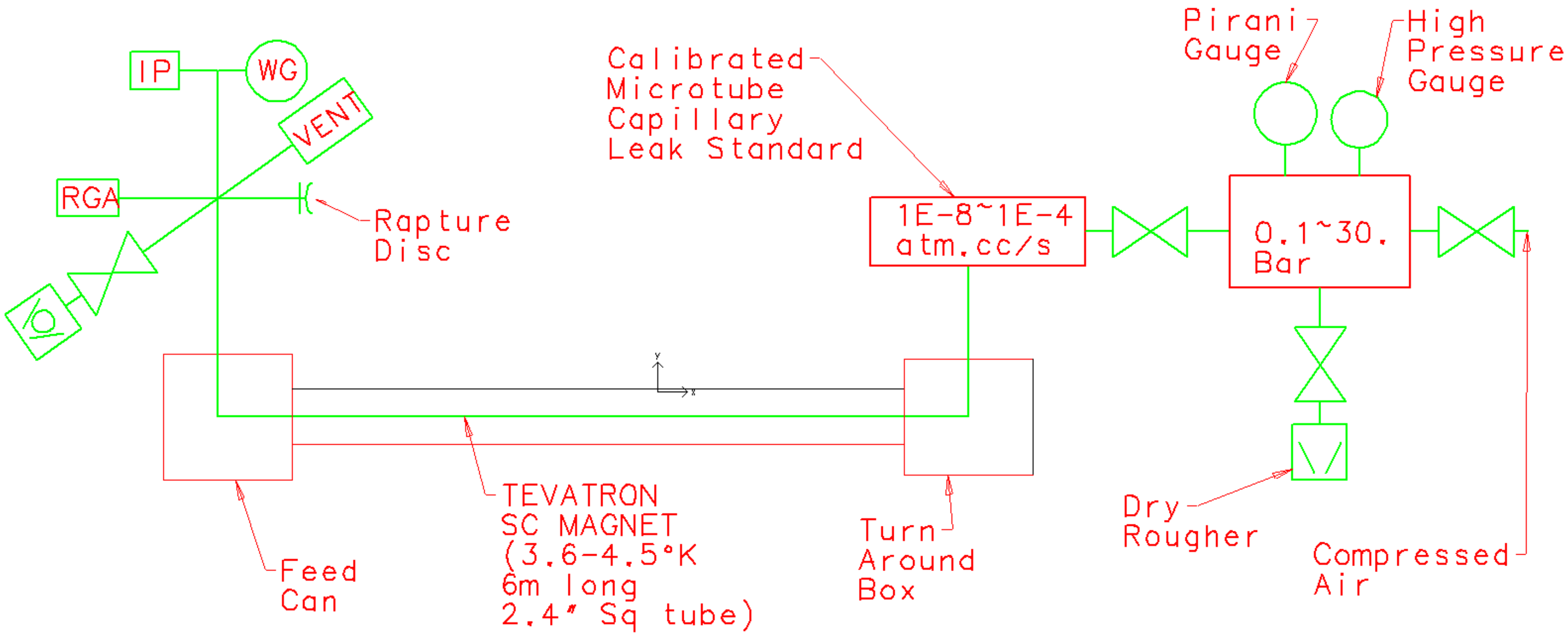
FIG. 6. Predicted time needed for the He pressure front to reach the instruments at the distant end with the cold bore tube at 1.9 and 4.2 K as a function of the leak rate in Torr ℓ/s at 298 K.

E. Wallen, J. Vac. Sci. Tech A15(6)1997

PXIE Vacuum
(R&D proposal)

- leaks covered by huge cryo pumping of cavities, total pressure does not show problem, so different mean needed
- Most experiment about cold leaks were done 10 years ago, and with total pressure gauge, 10^{-10}~10^{-11} torr
- Changes of partial pressure ratio will indicate vacuum environment status evolving. So, It may be possible to take preemptive measure before big failure occurs
- No isotherm data @1.8K for H_2, Air
- modern RGA is much more sensitive (10^{-14}~10^{-15} torr partial pressures), less outgassing and inexpensive
- Then it is possible to realtime monitoring the vacuum environment with RGA

PXIE Vacuum
(R&D proposal)



PXIE Vacuum
(Summary)

- System will be engineered to satisfy the requirement and cost effectively
- QC is critical for achieving a reliable vacuum system, procedures for UHV and low particulate will be closely followed
- Preliminary analysis shown that it is necessary to add differential pumping next to CM; and 10^{-10} torr @CM entry is achievable
- The need of low particulate practice is discussed
- work in near future
  - Design the vacuum system in detail
  - Optimize the location and pumping scheme to reduce the risk of particle creation and migration
  - R&D shall take place when engineering resource allocated

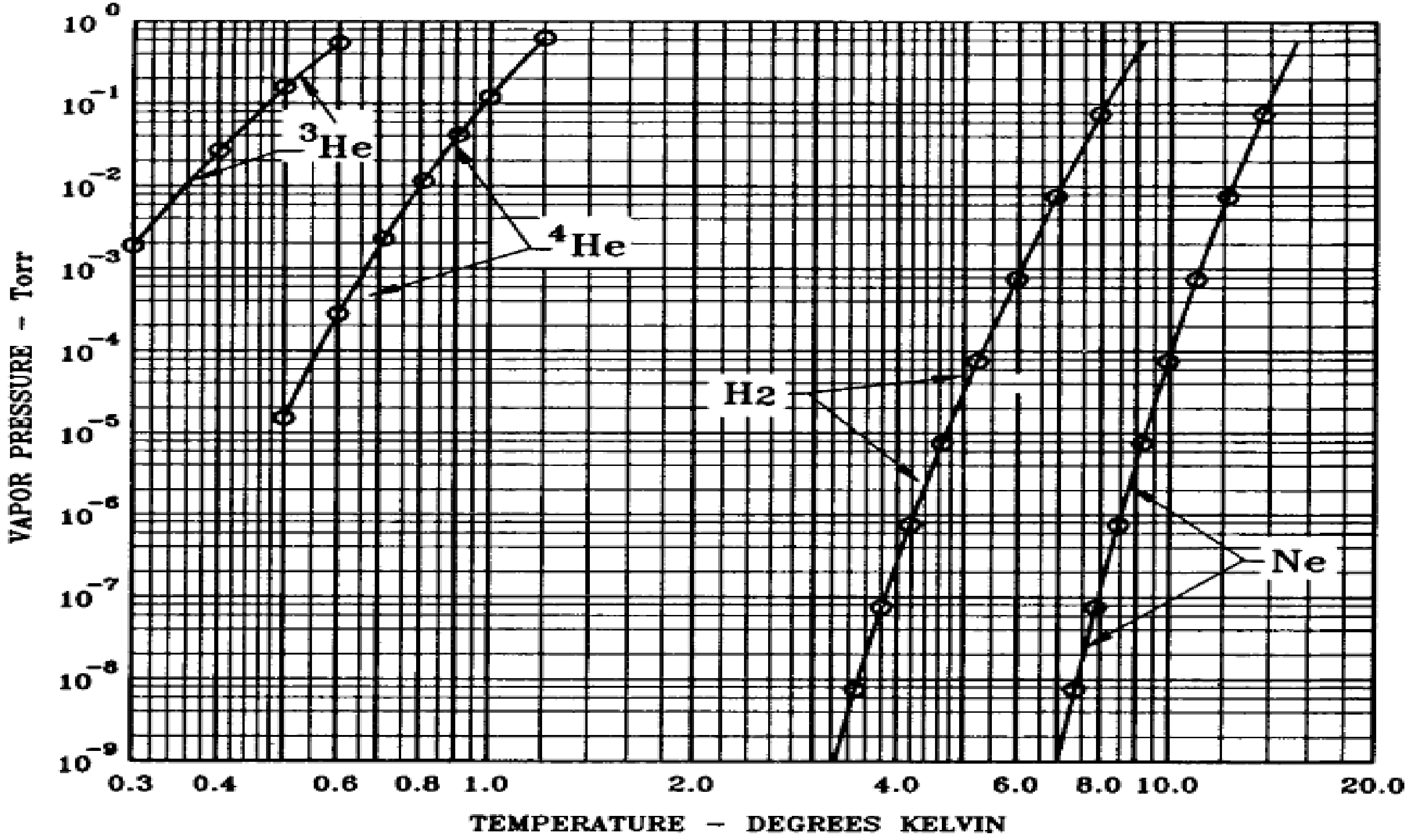
Project X

Ref: recommended machining fluids

Relton A-9	Rapid Tap
Tap Magic	Trim Tap
Tapmatic #1 or #2	RD2-195
"Pearl" Kerosene by Chevron Chem CO	Dip Kool 868
"Tool Saver" by Do All Corp.	DIP Kool 862
Cutzol EDM 220-30	Dip Kut 819H
Sunnen Man-852 Honing Oil	No Sul #6871
Vytron Concentrate	Kool Mist #88
Rust-Lick G-25-J	Cimcool 5 Star 40
Wheelmate #203	Cimperial # 1011
Aqua Syn 55 by G-C Lubricants CO	Haloform CW-40
Cold Stream Coolant by Johnson Wax CO	Trim Sol
"Acculube" by Lubricating Systems Inc.	Trim9106CS
Micro Drop "Advanced System Lubricant" by Trico	CINDOL 3102
Micro Drop "New Vegetable Based" by Trico	PenWalt #DP 1131

Accelerator Vacuum Engineering
By Louis R. Bertolini, LLNL

Ref: Vapor Pressures of H_2, He



Ref: Outgassing Rates of some materials

Metals and Glasses	Desorption Rate (mBar-l/sec- cm^2 x 10^{-10}) 1 hr @ vacuum	4 hrs @ vacuum
Aluminum	80	7
Copper (mech. polished)	47	7
OFHC Copper (raw)	266	20
OFHC Copper (mech. polished)	27	3
Mild Steel, slightly rusty	58,520	199
Mild Steel, Cr plate (polished)	133	13
Mild Steel, Ni plate (polished)	40	4
Mild Steel, Al spray coating	798	133
Molybdenum	67	5
Stainless Steel (unpolished)	266	20
Stainless Steel (electropolished)	66	5
Molybdenum glass	93	5
Pyrex (Corning 7740) raw	99	8
Pyrex (Corning 7740) 1 mo. At Atm.	16	3

Ref. "Modern Vacuum Practice", Nigel Harris, pg 240

Ref: Hydrogen Isotherm

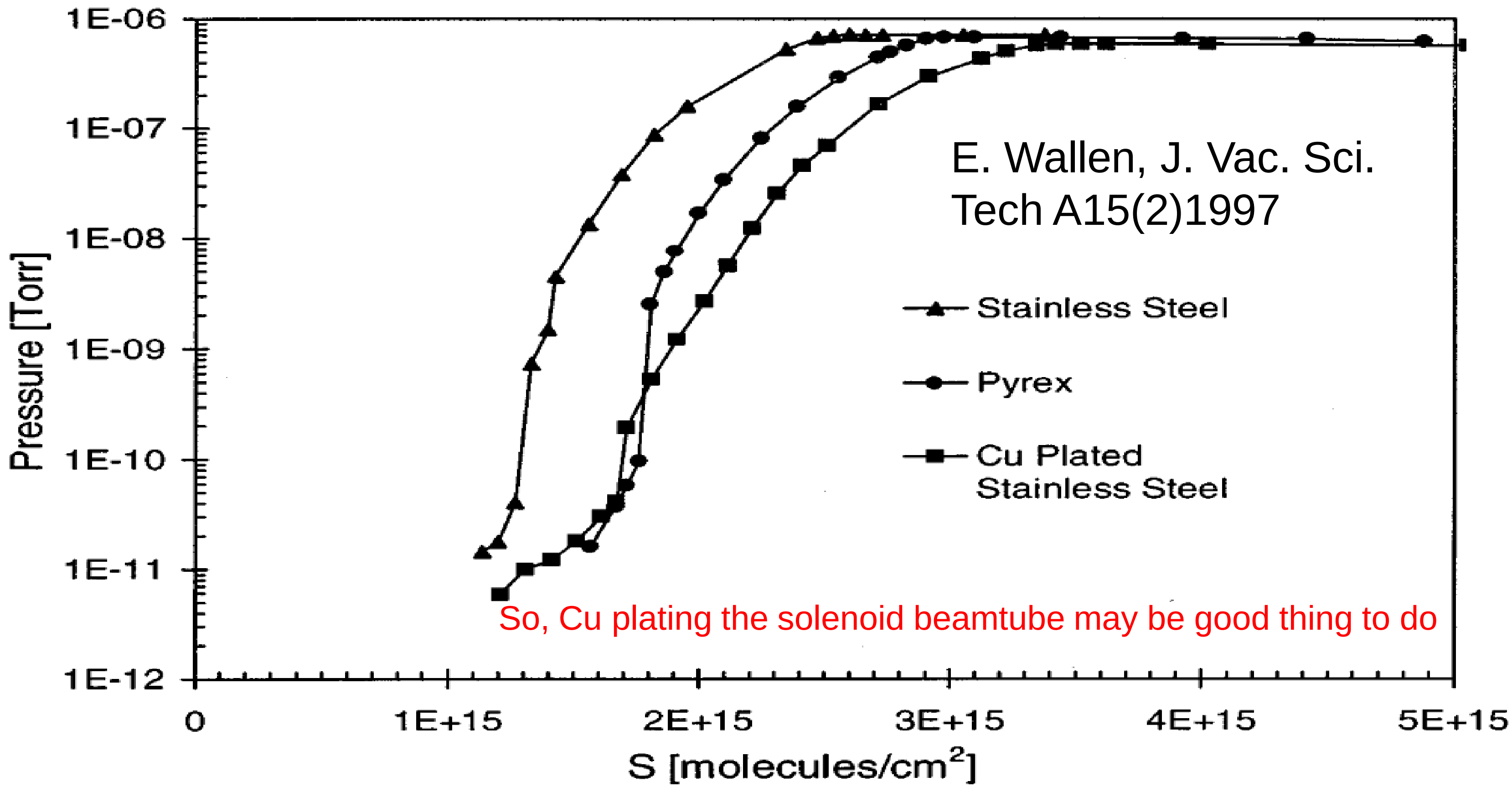
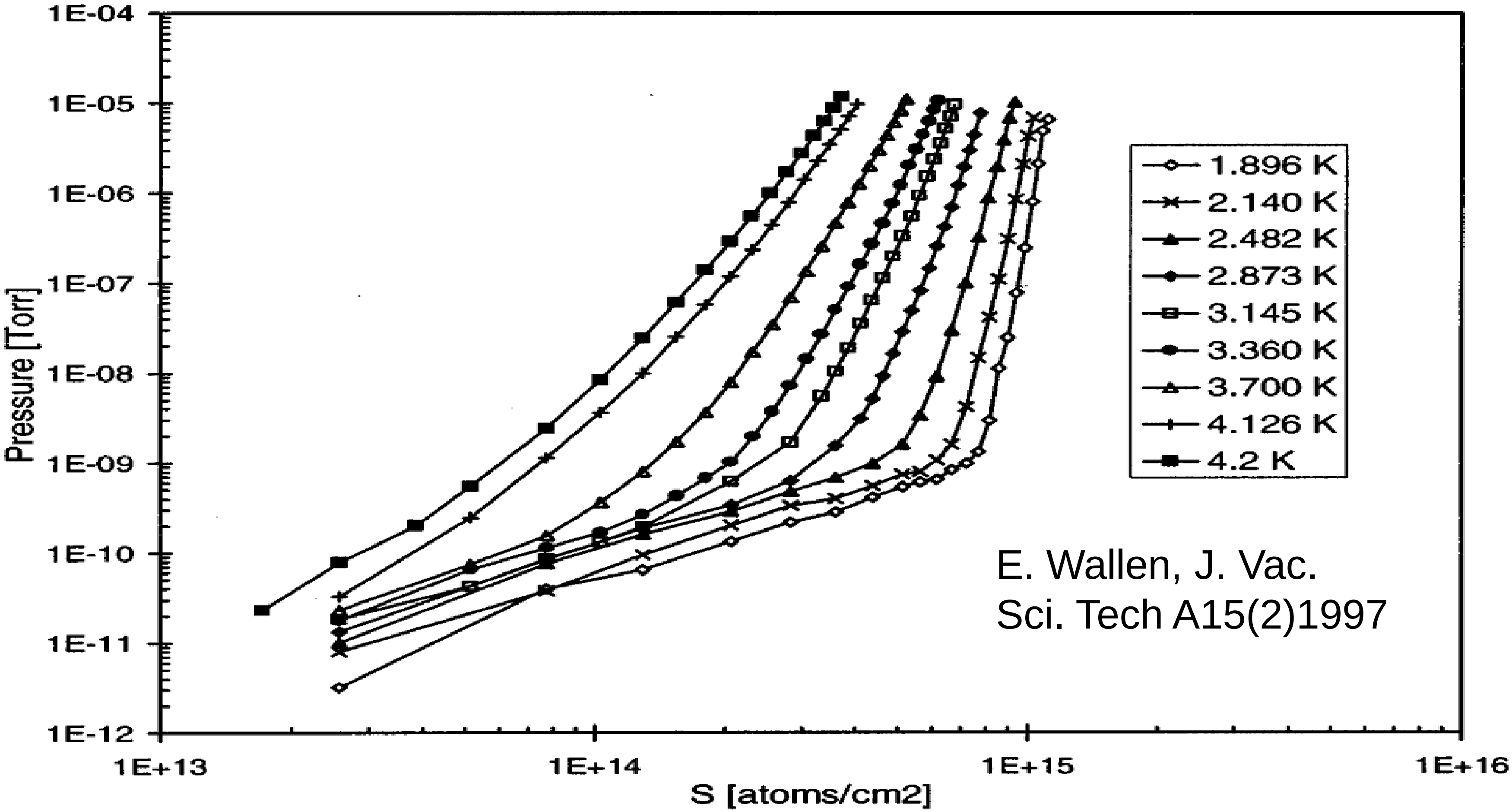
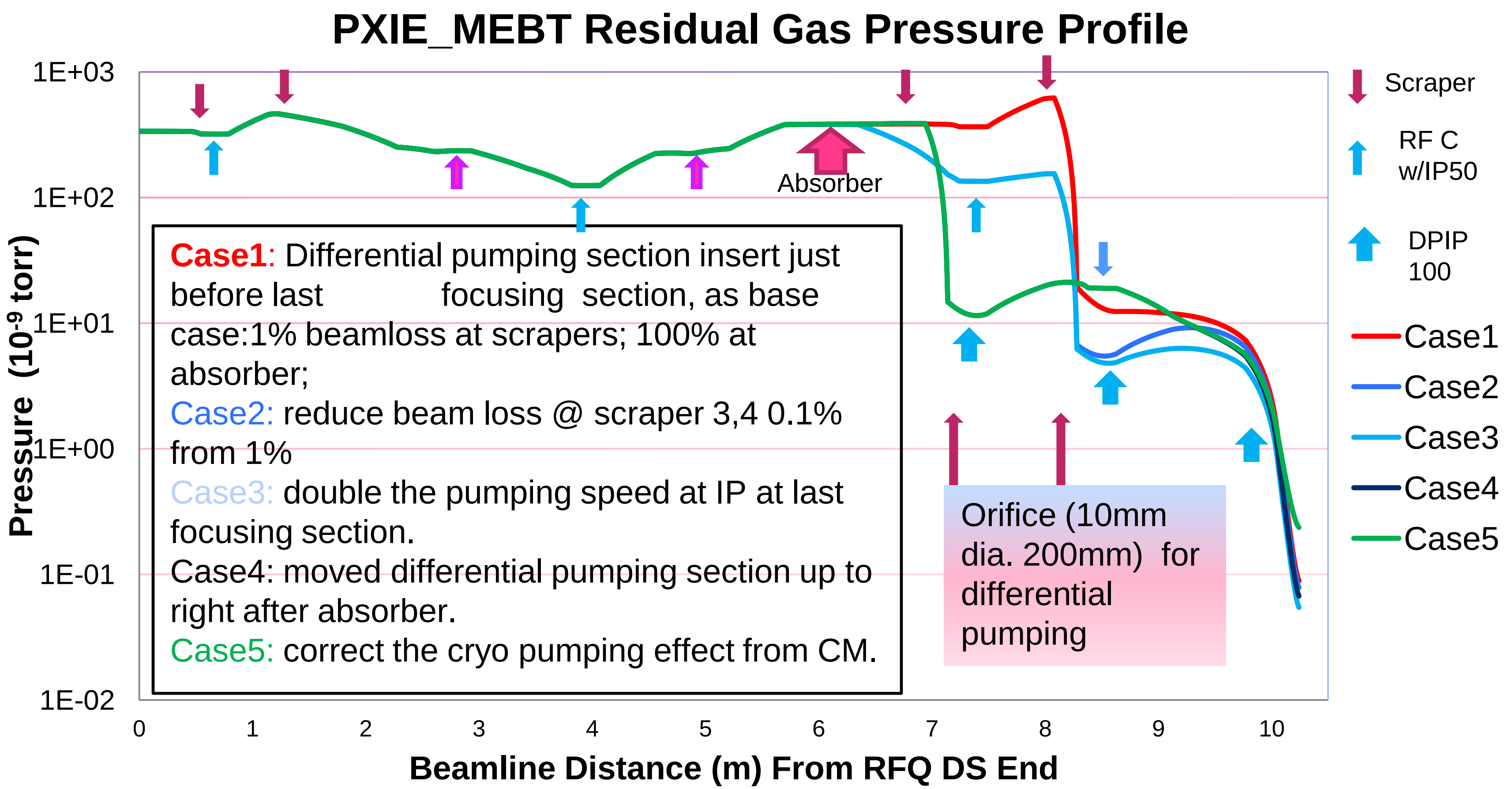


FIG. 2. H_2 adsorption isotherms at 4.2 K on Pyrex, stainless steel, and Cu plated stainless steel (Ref. 20).

Ref: Helium Isotherm 1.9-4.2K



PXIE Vacuum
(pressure profile in MEBT)



PXIE Vacuum
(pressure in Ion Source)