1997 FERMILAB SUMMER STUDIES

EXAMINATION OF THE PROPOSED VLHC VACUUM SYSTEM

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During the Summer Studies period the "current thinking" for the Very Large Hadron Collider's (VLHC) vacuum system was reviewed. The basis for the "current thinking" was the papers by H. Ishimaru and W.C. Turner submitted to the Proceedings of the DPF/DPB Summer Study on New Directions for High-Energy Physics, Snowmass '96 and information obtained directly from Bill Foster, Mike May, and H. Ishimaru. The goal of this investigation was to identify areas where an R&D effort should be initiated, identify problems in the "current thinking", and comment on the validity of the current cost estimate. The following is a list of my questions, concerns, and recommendations.

1) How much will the channel between the elliptical chamber and the side pump channel collapse? Using the current chamber design section this can easily be determined using finite element analysis or by direct measurement.

2) If there are no bellows:
   a) What affect will thermal expansion and no bellows have on alignment?
      1) Beam pipe movement could cause alignment issues with the magnets.
      2) The lack of bellows will make it necessary to have very small incremental movement between magnets during alignment.
   b) Thermal expansion due to NEG conditioning could be significant.
   c) Full penetration welds will be needed to ensure structural integrity.

3) The use of dichloro-propane:
   a) Potential for chlorine to attack stainless steel components.
   b) Pump down will need to be discharged to outside or containment.

4) If internal pumping mechanism (NEG Strips) needs repair how do we do this?

5) Ishimaru's cost estimate of $11M seems low. The budget for the Main Injector (MI) and Recycler is about $5M which translates to about 0.777M$/km. If scaled, assuming the Pipetron as one vacuum system, that would put it at $23M. The MI bellows are only 10% of the total MI budget so, that would decrease the cost by $2.3M. Ishimaru's cost estimate makes a comparison to the Recycler at $1M. This is not the true cost of the Recycler because it makes use of components in the MI. Also, the Pipetron is two lines so if scaling were actually appropriate the cost would be closer to $40M. I do believe we can build the thing for less $/km than the MI but not by a factor of four. In general I think that the current cost estimate is off by at least a factor of two and possibly by four.

6) Roughing the system down.

Vacuum System parameters:

Gas is Air at 20 C
Camber Surface Area / meter = 3040 cm^2/m
Chamber Volume / m = 3002 cm^3/m = 3 l/m
Outgassing rate prior to degass = $6.3(10)^{-9}$ Torr-l/cm^2-s
Conductance / cm^{-1} = $1.8(10)^3$ l-cm/s
Pump Speed = 100 l/s

For pump spacing of 150 m and $q_D = 6.3(10)^{-9}$ Torr-l/cm^2-s:

Mid-point pressure = $3(10)^{-3}$ Torr
Delta P = $3(10)^{-3}$ Torr
Pressure at port = $3(10)^{-5}$ Torr

For pump spacing of 150 m and $q_D = 6.3(10)^{-13}$ Torr-l/cm^2-s:

Mid-point pressure = $3(10)^{-7}$ Torr
Delta P = $3(10)^{-7}$ Torr
Pressure at port = $1(10)^{-9}$ Torr

As can be seen by the above calculations if we want to have a pump spacing on the order of 150 m it is critical that we make the effort to degass the chamber prior to the conditioning of the NEG material. Whether this is done by bake-out, gas flow, or pumping over a long period of time has yet to be determined.

7) Recommendations for R&D efforts.

a) Engineering analysis of thermal effects on the vacuum chamber and magnet assembly. An analysis should be done on what affect a 500 C bake out would have on the chamber and magnet assembly. If it is possible to bring the system to this temperature for a long enough period of time to condition the NEG material it should be possible to eliminate the problems and cost of ceramic feed-throughs, stand-offs, processed NEG strips with conductors, and any repair problems associated with the NEG strips.

b) Whether the NEG material is heated from the outside or the inside, installation of the material in tubes of the length we are talking about will require considerable development work. It would be very useful to understand this up front so that the impact on cost and installation is understood.

c) It would be useful to have a working vacuum system mock-up. This would allow us to measure system parameters such as outgassing rates, pump spacing requirements, and system response times.

d) There will be numerous difficulties in working with tubes of extreme length. Examples would include initial cleaning and handling, machining at port locations and mating ends, straightening process, and transportation. Some R&D work up front here would go a long way towards eliminating bottlenecks and problems down the road.

As an R&D effort, a test set up of approximately 150 m should be initiated. This would allow us to investigate all of the above issues. The cost for equipment would be minimal due to the availability of existing Lab equipment. The main material costs would be the aluminum extrusions and the NEG material.

Cost Estimate for R&D Effort

Item	Quantity	Unit	Cost/unit ($/unit)	Cost ($)
Equipment:				
Vacuum				
RGA	1	each	N/A	0
Leak Detector	1	each	N/A	0
Ion Pumps/Controllers	8	each	N/A	0
Gauges/Controllers	8	each	N/A	0
Turbo Carts	1	each	N/A	0
Bake Out Controls	1	each	10,000	10,000
Misc. Parts (flange, gasket, valve, etc.)	1	each	6,000	6,000
Sub-Total				16,000
Materials:				
Aluminum Extrusion	200	m	100	20,000
NEG Material	150	m	50	7,500
Test Stands	20	each	200	4,000
Heat Tape	150	m	39	5,850
Sub-Total				37,350
Labor:				
Engineering	6	month	6,558	39,348
Technician	4	month	3,758	15,032
Alignment	1	month	3,758	3,758
Machinist	500	hr	40	20,000
Sub-Total				78,138
Grand Total				131,488