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THE STRETCHER VACUUM SYSTEM

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Technical Note
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Kimo M. Welch and Joseph E. Tuozzolo

February 13, 1989

I. Introduction

The dipole magnets will be ≈ 7.33 m long. There will be 68 of these in the main Stretcher. Comparable dipole magnets are used to blend the geometries of the Stretcher and the AGS and vertically bend the beam to compensate for their different elevations. It is assumed an additional ten dipole magnets, with identical chambers, will serve these purposes. It is further assumed that, with the exception of the main seals of the Sector and Roughing Valves, the Stretcher will be an all-metal system.

The number and length of the dipole magnets are important in defining the width of the vacuum chamber. Use of a single segment vs multi-segment magnet doesn't impact on this width, as long as the field is near-uniform over the magnet length. Each chamber will be butt-welded in three sections. For reasons discussed in the following section, the chamber walls will have to be bowed to form an interference fit with the dipole magnet faces. It is not advisable to attempt to bend or shape the chambers to the beam radius of curvature, under these circumstances.

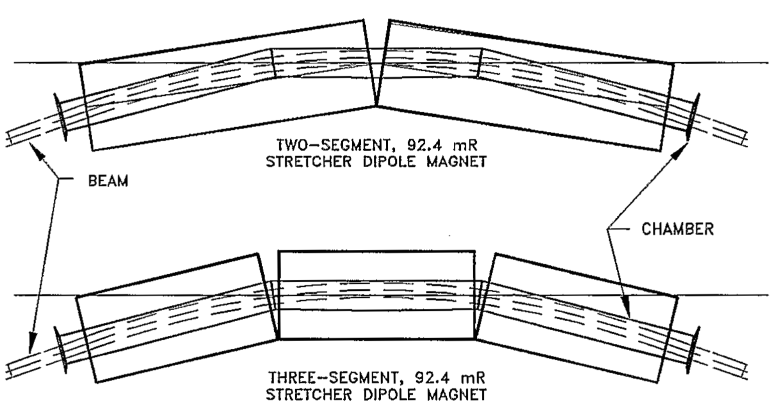


Figure 1. Three-Segement Beam Chamber In Multi-Segment Dipole Magnets.

II. Dipole Magnet Chamber Cross-Section

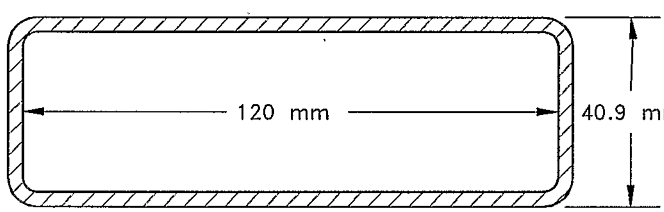
Because of the narrow vertical aperture (i.e., ≈ 41.3 mm), chambers in the dipole magnets will have to be prestressed. The equations for the wall deflection at the center of the chamber, **y**, and the maximum stress, **s**, of the major chamber width are as follows:

$$y = \frac{P}{E\,t^3}\left[\frac{5\,w^4}{32} + \frac{(h^3 + w^3)\,w^2}{8\,(w+h)}\right], \tag{1}$$

$$s = \frac{P\,(h^3 + w^3)}{t^2\,(w+h)}, \tag{2}$$

where, **t** = the wall thickness in inches,
y = wall deflection in inches, at the center of the chamber,
w = major width of the chamber,
h = the chamber height, in inches,
P = force/unit area in Lb/in^2.
E = the modulus of elasticity, Lb/in^2.

For a chamber of cross-section comparable to dimensions given in Fig. 2, and neglecting the effects of the radii at the corners, the maximum deflection at the center of the chamber, y_m, as a consequence of atmospheric pressure, and the stress, **s**, are given for a stainless steel chamber in Tables I & II, respectively, and for an Aℓ chamber in Tables III & IV.



The effects of external pressure on the chamber deflection is represented by strain in the chamber shown in Fig. 3. This assumes that the chamber is not pre-stressed. The maximum vertical aperture, A_V, is:

$$A_V = h - 2\,t - 2\,y_m. \tag{3}$$

Setting $\partial \mathbf{A_V}/\partial \mathbf{t} = 0$, we find the maximum vertical aperture by the relationship:

$$\mathbf{t} = 3\mathbf{y_m}. \quad (4)$$

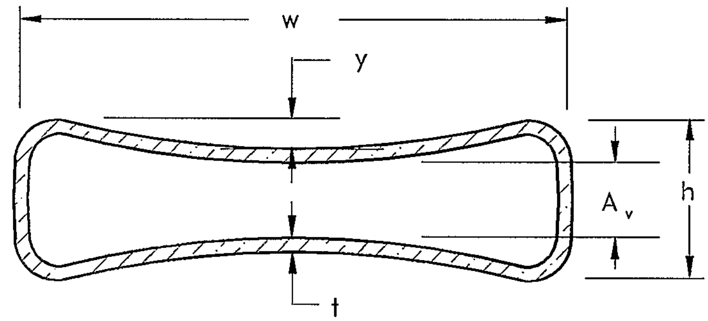


Figure 3. Strain In Dipole Chamber Due To Atmospheric Pressure

For the geometry given in Fig. 3, for $A\ell$, $\mathbf{A_V} \approx 30.2$ mm, and for stainless steel $\mathbf{A_V} \approx 32.6$ mm. This is unacceptable as the implication is that we have wasted ≈ 25% of the magnet gap with beam chamber deflection and thickness. Therefore, we must prestress the chamber in the dipole magnets, and seek a much thinner chamber wall, within the limits of the strength of the material chosen.

A chamber with a cross-section similar to that shown in Fig. 4 will deflect under atmospheric loading so as to just fit within the dipole gap. For a chamber of $\mathbf{t} \approx 1.5$ mm, the stress on the chamber will be $\mathbf{s} \approx 2.27 \times 10^5$ kN/m² (i.e., 33 kpsi). The chambers will be constructed of 304L stainless steel and not be annealed. Therefore, these numbers seem acceptable.

Some sort of coating should be put on the dipole magnet pole faces to protect the beam chambers from the Fe used as pole material. If the chambers are rubbed or scratched against the pole faces, they will cease to be "stainless" and will be subject to corrosion.

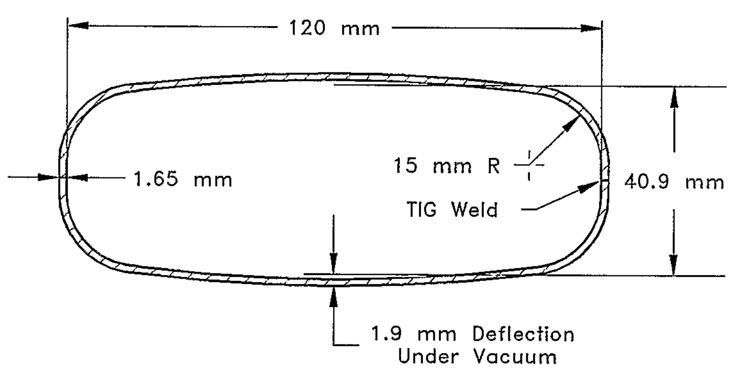


Figure 4. Required Dipole Chamber Shape For Maximum Verticle Beam Aperture When Chamber Is Strained By Vacuum Loading

III. Chamber Pumping During Beam Operation

Several options exist for pumping the dipole magnet chambers. These include:

1. Use of distributed NEG pumps, and a "scattering" of small sputter-ion pumps around the stretcher to pump noble gases and the saturated hydrocarbons (i.e., gases not pumped by NEG pumps).

2. Use of sputter-ion pumps (only) between each of the dipole magnets.

3. Use of distributed sputter-ion pumps making use of the fringing field of the dipole magnets.

Option 1 would probably be too costly if we were to use st. stl. dipole chambers. It would have efficacy, were we able to use extruded $A\ell$ dipole chambers. For reasons including chamber longitudinal impedance considerations, it would be advisable to extrude a separate channel, parallel with the beam chamber, to house the NEG strip. The chamber's major wall dimension would be too broad for a single chamber.

Transverse (i.e. to the beam) holes could be drilled between the two chambers for conductance coupling. Also, because of NEG bakeout requirements, a third water cooling chamber would have to be extruded, parallel with the NEG and beam chambers. This would have to be done because of the poor hot strength of $A\ell$, as excessive chamber temperatures which would result from NEG bakeout. These considerations and findings of Section II, make use of Option 1 questionable.

Option 3 is "clever" and has found wide application in electron storage rings where one needs to pump gas desorbed by synchrotron radiation along a dipole magnet chamber. However, it presents unnecessarily complex fabrication problems (i.e., in our application), the need of electrostatically shielding the beam from the pump anode arrays, and makes difficult the servicing of the distributed sputter-ion pumps.

Option 2 is adopted for use in the Stretcher. Assume that these pumps are separated by a length 2ℓ, where 2ℓ is the length of one half-cell. It can be shown that the pressure along an outgassing half-cell is given by:

$$P(x) = P_p + \frac{\pi q}{2kD^2}(2x\ell - x^2) \tag{5}$$

where P_p = the pump pressure, Torr,
q = chamber outgassing rate, Torr-ℓ/sec-cm^2,
ℓ = length from the pump to the center of magnet, cm,
D = equivalent diameter of the chamber, cm, and
k = is a constant relating to the molecular weight and temperature of the numerical value of 12.1, assuming an amu of 28, and that the gas is at 293° K.

The average pressure in a sector (and the complete Stretcher), $P_{avg.}$, is then just:

$$P_{avg.} = \int_0^{\ell} P(x)\, dx$$

$$= P_p + \left[\frac{\pi\, q\, \ell^2}{3\, k\, D^2} \right], \qquad (6)$$

Assuming that $D = 2\left((h - 2t)(w - 2t)/\pi\right)^{\frac{1}{2}}$, in (6), (i.e., the rectangular chamber has an equivalent diameter, D), is accurate to within $\approx$ 15%.

If	w	=	12.0 cm,
	h	=	4.0 cm,
	t	=	0.23 cm, the chamber wall thickness,
then	D	$\approx$	7.0 cm.

Assuming a fairly clean system, an outgassing rate of $q \approx 10^{-11}$ Torr-ℓ/sec-cm^2 is within reason, after 10^3 hours of pumping. Use of 60 ℓ/sec sputter-ion pumps will result in an average Stretcher pressure of $\approx 7\times10^{-9}$ Torr after 10^3 hours of pumping.

For optimum longitudinal beam impedance, a smooth, beam-tube transition is desirable between the magnet chambers and the straight sections. For cost reasons, the transition is accomplished at each of the dipole chamber ends. This "keeps us out of a mill" in the manufacture of most of the Stretcher flanges.

IV. Sector Roughing Stations

We have assumed that there will be no stretcher vacuum roughing stations resident in the "ring". There is some evidence that roughing stations resident in the AGS are not essential to machine operation, and cause problems when improperly operated. For example, there was no instance in FY'88 where use of the resident "turbo" roughing stations saved experimental machine time. However, there is considerable evidence that their improper use, in times of emergency, resulted in serious hydrocarbon contamination of the AGS.

For this reason, and to eliminate unnecessary costs, portable Sector Roughing/Leak Checking Carts be constructed for use during maintenance and on those rare occasions when the sputter-ion pumps need augmentation. In the latter case, vacuum technicians will be "called in" to position and set up the portable roughing carts.

In determining the length of each vacuum sector, we must address only one issue: "How long are we willing to wait from the start of a sector pump-down until machine turn-on?" Each time a vacuum sector is vented to atmospheric pressure, the walls of the chambers and components are contaminated with gas. Were this gas exclusively N_2, on subsequent pumpdown, the walls would outgas very rapidly (i.e., in a matter of minutes), and the ion pumps could be quickly restarted. Unfortunately, this usually is not the case; that is, though an AGS sector may be vented to pure N_2, air, including H_2O, gets inside of the vented sector. As a consequence, it usually takes hours to pump down a sector to the point where the ion pumps can be turned on. After this, it takes an hour or so to "condition" the pumps.

A new ion pump, pumping on a "clean and dry" system, is easily started at an N_2 pressure of a few miliTorr. However, these are unrealistic conditions. If a pump and system has been exposed to air, starting the pump can be "tricky" business. To minimize pump maintenance and facilitate reliable starting, it is best to follow certain starting procedures. This involves initially turning on the pumps at a pressure of $\approx 5 \times 10^{-5}$ Torr; leaving them on for 10 minutes; shutting them off for 10 minutes; etc. This is called "conditioning" the pumps. Actually, the process involves controlling the desorption of surface gases on the pump elements, while avoiding both glow discharge in the pumps and thermal run-away.

Assume that the Stretcher is divided into Vacuum Sectors, each of which is isolated by in-line sector valves. Assume that each of these sectors is divided into $2\mathbf{n}$ half-cells, and a half-cell is 2ℓ meters long. The pressure profile in an outgassing sector may be expressed by the following equation:

$$\mathbf{P}(\mathbf{x},\mathbf{t}) = \mathbf{P}_p + \frac{\pi\, \mathbf{q}(\mathbf{t})}{2kD^2}(2\mathbf{x}\mathbf{L} - \mathbf{x}^2), \tag{7}$$

where $\mathbf{L} = 2\mathbf{n}\ell$. Assuming that $\mathbf{q}(\mathbf{t}) \neq f(\mathbf{P})$, the pressure at the ion pump furthest removed from the sector roughing cart is simply:

$$\mathbf{P}(\mathbf{L},\mathbf{t}) = \mathbf{P}_r + \frac{\pi\, \mathbf{q}(\mathbf{t})}{2kD^2}\mathbf{L}^2 . \tag{8}$$

The pressure at the portable roughing pump, $\mathbf{P}_r$, is simply the outgassing rate of one complete vacuum sector, divided by the rough pump speed. Substituting this into (8), results in a quadratic equation in **L** having only one root, which makes physical sense:

$$\mathbf{L} = -\frac{4kD^3}{2\mathbf{S}_r}\left[1 - \left[1 + \frac{\mathbf{P}(\mathbf{L})(\mathbf{S}_r)^2}{4\pi \mathbf{q}(\mathbf{t})kD^4}\right]^{\frac{1}{2}}\right], \tag{9}$$

where, $\mathbf{P}(\mathbf{L})$ = the tolerable starting pressure of an ion pump located distance **L** form the roughing pump,

and $\mathbf{q}(\mathbf{t})$ = the outgassing rate in Torr-ℓ/sec-cm^2 as a function of time.

Assuming $\mathbf{q}(500\text{hr.}) \approx 2.5 \times 10^{-11}$ Torr-ℓ/sec-cm^2, and that the source of outgassing is metal walls, rather than elastomers, plastics, etc., $\mathbf{q}(\mathbf{t})$ may be approximated by the following equation:

$$q(t) \approx q(500hr.) \left[\frac{t}{500hr}\right]^{-m} \tag{10}$$

where $m \approx 0.9$, and $t > 1.0$ hr. Using (10) in (9), and assuming different the ion pump starting pressures, we can calculate, with (9), the time it will take to pump on a sector, prior to starting the ion pumps, as a function of the speed of the turbo-pump, S_r, and the length, L, of a half-sector. These results are given in Fig. 5, assuming use of a 100 ℓ/sec roughing pump. It appears, with a clean system, with $n = 2$, conditioning of the sputter-ion pumps may be started in two to three hours. The benefits of proper system venting, and maintaining a clean system are dramatically illustrated in Fig. 5.

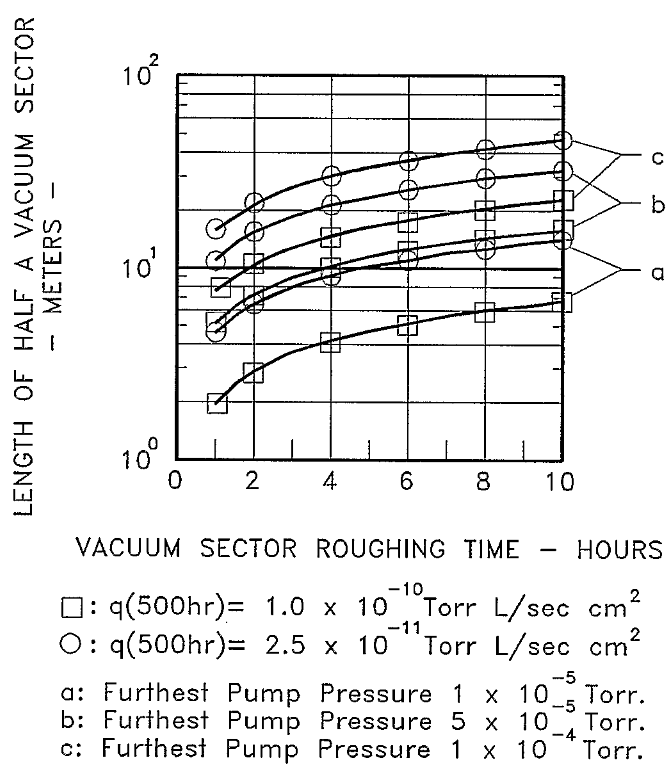


Figure 5. Pressure at the Sputter–Ion Pump Furthest Removed From the Sector Roughing Pump as a Function of Time and Assumed Beam Pipe Outgassing Rates.

This analysis indicates that Sector Valves should be located every other cell (i.e., $\approx$ 37.5 m apart). Roughing Valves and Vacuum Instrument "Trees" will be placed at the mid-point between the Sector Valves. An example of a straight section configuration between two dipole magnets is shown in Fig. 6. Sector Valves and Instrument Trees will never be located in the same straight section. However, between each dipole magnet, the single 317.5 mm straight section, shown to the right in Fig. 6, must be reserved for some form of vacuum equipment.

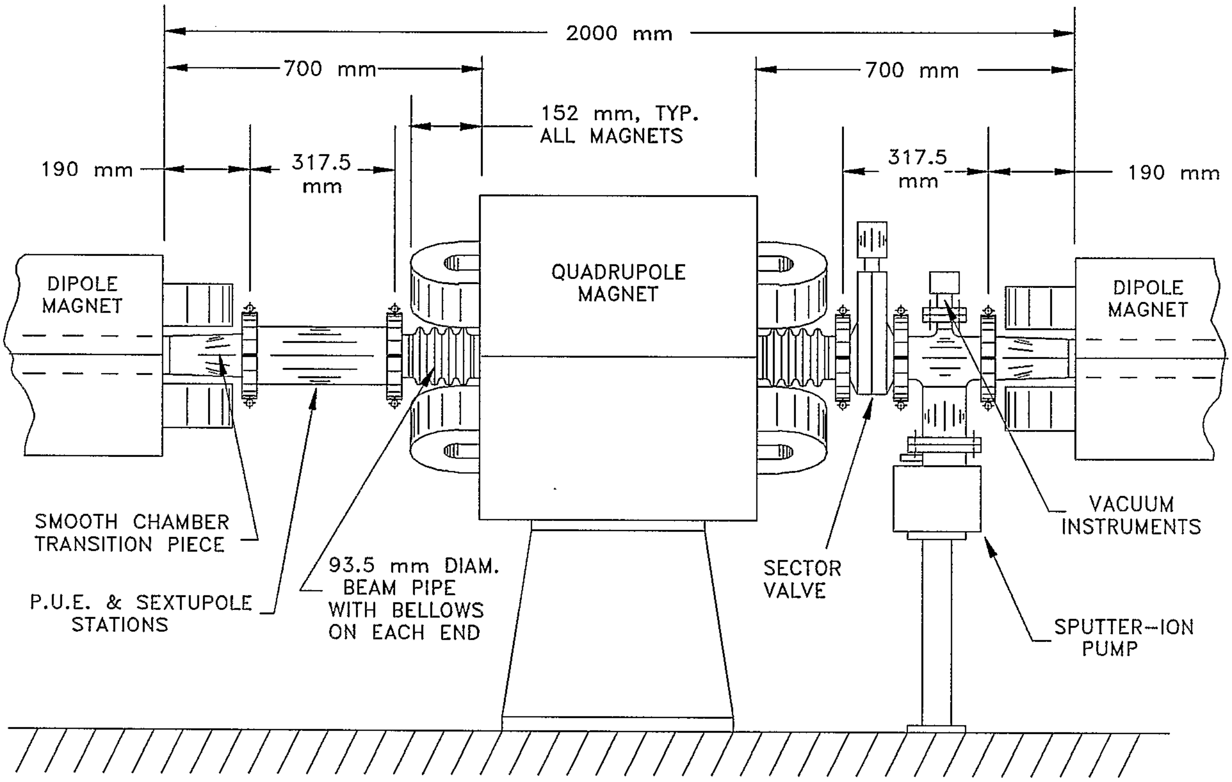


Figure 6. A half-Cell Straight Section Including Possible Sector Valves, Instrument "Trees" and Sector Roughing Valves (not shown) in 317.5 mm Position.

V. Vacuum System Instrumentation and Controls

A vacuum instrumentation & control system architecture similar to that presently used in the AGS will be adopted in the Stretcher. A functional block diagram of the Stretcher I&C system is shown in Fig. 7. Commercial sputter-ion pump power supplies, and ionization and Pirani gauge controllers will be purchased. Products presently are offered in the marketplace with RS-232 interface features. Engineering will be dedicated to designing interface "boxes" which allow communications between the commercial equipment and controllers, of the type presently existing in the various AGS "houses". Similar controllers will be located in three or four Stretcher "houses".

No permanent electronic hardware chassis will be resident in the tunnel. However, a form of ring communications buss will be installed. It is important that there be 20-30 bus access ports about the Stretcher, though only two or three would ever be simultaneously used during maintenance work. It was suggested by R. Frankel that it would be possible to communicate with an Apollo equivalent by using a simple coaxial cable for this bus. Data would be communicated by frequency modulating carrier frequencies unique to two or three local, transportable controllers (LTCs). In this manner, the simultaneous communications from more than one LTC would be possible during maintenance periods.

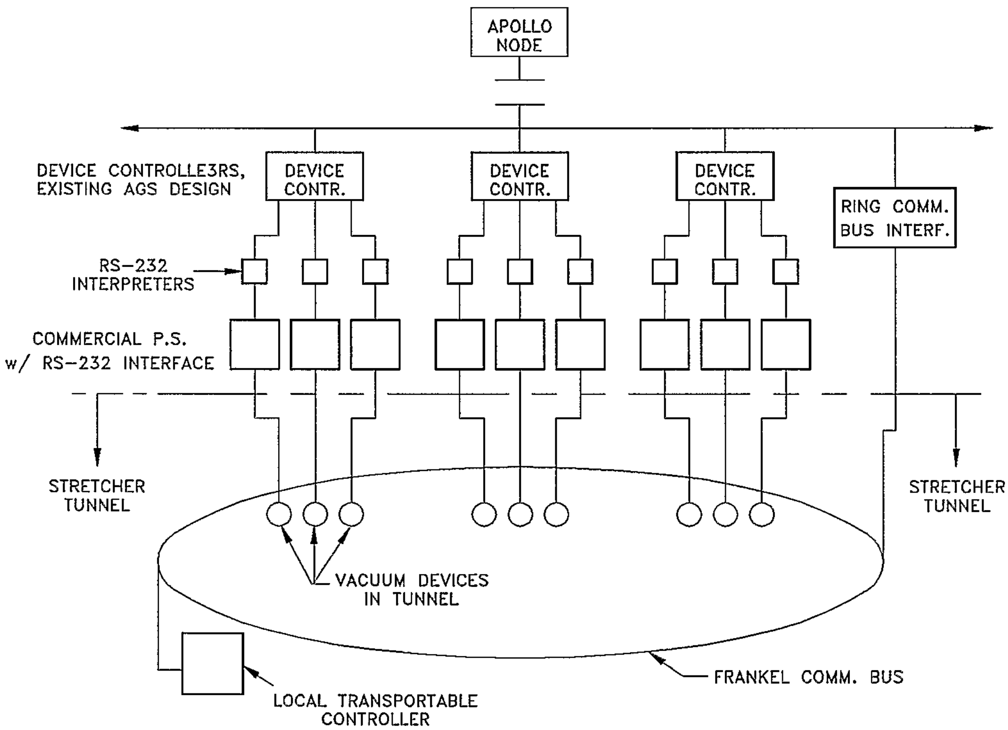


Figure 7. Stretcher Vacuum Instrumentation and Control System

VII. System Costs

System costs are summarized in the attached Tables V - IX. We were able to draw extensively from recent AGS vacuum component development work in estimating costs for the Stretcher vacuum system. Much of the hardware used in the Stretcher will be common to both the AGS and the Stretcher. Approximations made in these estimates include use of $\approx$9.37 m straight sections, each paired with shorter straight sections/bellows assemblies identical to the one shown captured in the quadrupole in Fig. 6. Also, straight sections will be divided into sectors comparable in length and with similar equipment as the Stretcher "ring" is configured (i.e., sputter-ion pumps, gauges, roughing ports, etc.).

Pressure:1.47E+01 psi
Mag Gap:1.62E+00
Height:1.61E+00 inches
Modulus 2.77E+07 (stainless: 27.7 X 10^6; aluminum: 10.3 X 10^6)

Tuozzolo/Welch
February 3, 1989

TABLE I

Maximum Chamber Deflection At Center, Stainless Chamber

thickness "t" mm	inches							
width in mm ---->		9.00E+01	1.00E+02	1.10E+02	1.20E+02	1.30E+02	1.40E+02	1.50E+02
width in inches ---->		3.54E+00	3.94E+00	4.33E+00	4.72E+00	5.12E+00	5.51E+00	5.91E+00
4.70E+00	1.85E-01	3.31E-03	5.06E-03	7.43E-03	1.06E-02	1.46E-02	1.98E-02	2.61E-02
4.44E+00	1.75E-01	3.91E-03	5.97E-03	8.78E-03	1.25E-02	1.73E-02	2.33E-02	3.09E-02
4.19E+00	1.65E-01	4.66E-03	7.13E-03	1.05E-02	1.49E-02	2.06E-02	2.78E-02	3.69E-02
3.94E+00	1.55E-01	5.62E-03	8.59E-03	1.26E-02	1.80E-02	2.49E-02	3.36E-02	4.45E-02
3.68E+00	1.45E-01	6.87E-03	1.05E-02	1.54E-02	2.20E-02	3.04E-02	4.10E-02	5.43E-02
3.43E+00	1.35E-01	8.51E-03	1.30E-02	1.91E-02	2.72E-02	3.76E-02	5.08E-02	6.73E-02
3.17E+00	1.25E-01	1.07E-02	1.64E-02	2.41E-02	3.43E-02	4.74E-02	6.40E-02	8.48E-02
2.92E+00	1.15E-01	1.38E-02	2.10E-02	3.09E-02	4.40E-02	6.09E-02	8.23E-02	1.09E-01
2.67E+00	1.05E-01	1.81E-02	2.76E-02	4.06E-02	5.78E-02	8.00E-02	1.08E-01	1.43E-01
2.41E+00	9.50E-02	2.44E-02	3.73E-02	5.49E-02	7.81E-02	1.08E-01	1.46E-01	1.93E-01
2.16E+00	8.50E-02	3.41E-02	5.21E-02	7.66E-02	1.09E-01	1.51E-01	2.04E-01	2.70E-01
1.90E+00	7.50E-02	4.96E-02	7.59E-02	1.12E-01	1.59E-01	2.20E-01	2.97E-01	3.92E-01
1.65E+00	6.50E-02	7.62E-02	1.17E-01	1.71E-01	2.44E-01	3.37E-01	4.56E-01	6.03E-01
1.40E+00	5.50E-02	1.26E-01	1.92E-01	2.83E-01	4.02E-01	5.57E-01	7.52E-01	9.95E-01
1.14E+00	4.50E-02	2.30E-01	3.51E-01	5.16E-01	7.35E-01	1.02E+00	1.37E+00	1.82E+00

TABLE II

Maximum Chamber Stress, Stainless Chamber

thickness "t" mm	inches							
width in cm ----->		9.00E+00	1.00E+01	1.10E+01	1.20E+01	1.30E+01	1.40E+01	1.50E+01
width in inches ------>		3.54E+00	3.94E+00	4.33E+00	4.72E+00	5.12E+00	5.51E+00	5.91E+00
4.70E+00	1.85E-01	4.06E+03	5.05E+03	6.17E+03	7.43E+03	8.83E+03	1.04E+04	1.20E+04
4.44E+00	1.75E-01	4.53E+03	5.64E+03	6.90E+03	8.31E+03	9.86E+03	1.16E+04	1.34E+04
4.19E+00	1.65E-01	5.10E+03	6.35E+03	7.76E+03	9.34E+03	1.11E+04	1.30E+04	1.51E+04
3.94E+00	1.55E-01	5.78E+03	7.19E+03	8.80E+03	1.06E+04	1.26E+04	1.47E+04	1.71E+04
3.68E+00	1.45E-01	6.60E+03	8.22E+03	1.01E+04	1.21E+04	1.44E+04	1.68E+04	1.95E+04
3.43E+00	1.35E-01	7.62E+03	9.48E+03	1.16E+04	1.40E+04	1.66E+04	1.94E+04	2.26E+04
3.17E+00	1.25E-01	8.88E+03	1.11E+04	1.35E+04	1.63E+04	1.93E+04	2.27E+04	2.63E+04
2.92E+00	1.15E-01	1.05E+04	1.31E+04	1.60E+04	1.92E+04	2.28E+04	2.68E+04	3.11E+04
2.67E+00	1.05E-01	1.26E+04	1.57E+04	1.92E+04	2.31E+04	2.74E+04	3.21E+04	3.73E+04
2.41E+00	9.50E-02	1.54E+04	1.91E+04	2.34E+04	2.82E+04	3.35E+04	3.93E+04	4.55E+04
2.16E+00	8.50E-02	1.92E+04	2.39E+04	2.92E+04	3.52E+04	4.18E+04	4.90E+04	5.69E+04
1.90E+00	7.50E-02	2.47E+04	3.07E+04	3.76E+04	4.52E+04	5.37E+04	6.30E+04	7.31E+04
1.65E+00	6.50E-02	3.29E+04	4.09E+04	5.00E+04	6.02E+04	7.15E+04	8.38E+04	9.73E+04
1.40E+00	5.50E-02	4.59E+04	5.71E+04	6.99E+04	8.41E+04	9.98E+04	1.17E+05	1.36E+05
1.14E+00	4.50E-02	6.85E+04	8.53E+04	1.04E+05	1.26E+05	1.49E+05	1.75E+05	2.03E+05

Pressure:1.47E+01 psi
Mag Gap:1.62E+00
Height:1.61E+00 inches
Modulus 1.03E+07 (stainless: 27.7 X 10^6; aluminum: 10.3 X 10^6)

Tuozzolo/Welch
February 3, 1989

TABLE III

Maximum Chamber Deflection At Center, Aluminum Chamber

thickness "t" mm	inches	9.00E+01	1.00E+02	1.10E+02	1.20E+02	1.30E+02	1.40E+02	1.50E+02
	width in mm ---->	9.00E+01	1.00E+02	1.10E+02	1.20E+02	1.30E+02	1.40E+02	1.50E+02
	width in inches ---->	3.54E+00	3.94E+00	4.33E+00	4.72E+00	5.12E+00	5.51E+00	5.91E+00
4.70E+00	1.85E-01	8.89E-03	1.36E-02	2.00E-02	2.84E-02	3.93E-02	5.31E-02	7.03E-02
4.44E+00	1.75E-01	1.05E-02	1.61E-02	2.36E-02	3.36E-02	4.65E-02	6.28E-02	8.31E-02
4.19E+00	1.65E-01	1.25E-02	1.92E-02	2.82E-02	4.01E-02	5.54E-02	7.49E-02	9.91E-02
3.94E+00	1.55E-01	1.51E-02	2.31E-02	3.40E-02	4.83E-02	6.69E-02	9.03E-02	1.20E-01
3.68E+00	1.45E-01	1.85E-02	2.82E-02	4.15E-02	5.90E-02	8.17E-02	1.10E-01	1.46E-01
3.43E+00	1.35E-01	2.29E-02	3.50E-02	5.14E-02	7.32E-02	1.01E-01	1.37E-01	1.81E-01
3.17E+00	1.25E-01	2.88E-02	4.41E-02	6.48E-02	9.22E-02	1.28E-01	1.72E-01	2.28E-01
2.92E+00	1.15E-01	3.70E-02	5.66E-02	8.32E-02	1.18E-01	1.64E-01	2.21E-01	2.93E-01
2.67E+00	1.05E-01	4.86E-02	7.44E-02	1.09E-01	1.55E-01	2.15E-01	2.91E-01	3.85E-01
2.41E+00	9.50E-02	6.57E-02	1.00E-01	1.48E-01	2.10E-01	2.90E-01	3.92E-01	5.19E-01
2.16E+00	8.50E-02	9.17E-02	1.40E-01	2.06E-01	2.93E-01	4.06E-01	5.48E-01	7.25E-01
1.90E+00	7.50E-02	1.33E-01	2.04E-01	3.00E-01	4.27E-01	5.90E-01	7.97E-01	1.06E+00
1.65E+00	6.50E-02	2.05E-01	3.13E-01	4.61E-01	6.55E-01	9.07E-01	1.23E+00	1.62E+00
1.40E+00	5.50E-02	3.38E-01	5.17E-01	7.61E-01	1.08E+00	1.50E+00	2.02E+00	2.68E+00
1.14E+00	4.50E-02	6.18E-01	9.45E-01	1.39E+00	1.98E+00	2.73E+00	3.69E+00	4.89E+00

TABLE IV

Maximum Chamber Stress, Aluminum Chamber

thickness "t" mm	inches							
	width in cm ----->	9.00E+00	1.00E+01	1.10E+01	1.20E+01	1.30E+01	1.40E+01	1.50E+01
	width in inches ------>	3.54E+00	3.94E+00	4.33E+00	4.72E+00	5.12E+00	5.51E+00	5.91E+00
4.70E+00	1.85E-01	4.06E+03	5.05E+03	6.17E+03	7.43E+03	8.83E+03	1.04E+04	1.20E+04
4.44E+00	1.75E-01	4.53E+03	5.64E+03	6.90E+03	8.31E+03	9.86E+03	1.16E+04	1.34E+04
4.19E+00	1.65E-01	5.10E+03	6.35E+03	7.76E+03	9.34E+03	1.11E+04	1.30E+04	1.51E+04
3.94E+00	1.55E-01	5.78E+03	7.19E+03	8.80E+03	1.06E+04	1.26E+04	1.47E+04	1.71E+04
3.68E+00	1.45E-01	6.60E+03	8.22E+03	1.01E+04	1.21E+04	1.44E+04	1.68E+04	1.95E+04
3.43E+00	1.35E-01	7.62E+03	9.48E+03	1.16E+04	1.40E+04	1.66E+04	1.94E+04	2.26E+04
3.17E+00	1.25E-01	8.88E+03	1.11E+04	1.35E+04	1.63E+04	1.93E+04	2.27E+04	2.63E+04
2.92E+00	1.15E-01	1.05E+04	1.31E+04	1.60E+04	1.92E+04	2.28E+04	2.68E+04	3.11E+04
2.67E+00	1.05E-01	1.26E+04	1.57E+04	1.92E+04	2.31E+04	2.74E+04	3.21E+04	3.73E+04
2.41E+00	9.50E-02	1.54E+04	1.91E+04	2.34E+04	2.82E+04	3.35E+04	3.93E+04	4.55E+04
2.16E+00	8.50E-02	1.92E+04	2.39E+04	2.92E+04	3.52E+04	4.18E+04	4.90E+04	5.69E+04
1.90E+00	7.50E-02	2.47E+04	3.07E+04	3.76E+04	4.52E+04	5.37E+04	6.30E+04	7.31E+04
1.65E+00	6.50E-02	3.29E+04	4.09E+04	5.00E+04	6.02E+04	7.15E+04	8.38E+04	9.73E+04
1.40E+00	5.50E-02	4.59E+04	5.71E+04	6.99E+04	8.41E+04	9.98E+04	1.17E+05	1.36E+05
1.14E+00	4.50E-02	6.85E+04	8.53E+04	1.04E+05	1.26E+05	1.49E+05	1.75E+05	2.03E+05

(STRETCH$2) 49 49 49 49 28 34 34 46 46 39 <---- LABOR RATES ARE IN 1989 DOLLARS, INCLUDE FRINGE, BUT EXCLUDE OVERHEAD.

TABLE V

December 19, 1988
Rev. B

STRETCHER VACUUM SYSTEM COST ESTIMATE
CHAMBERS

Kimo M. Welch
Joseph Tuozzolo

ITEM NO.	ACTIVITY OR ITEM	MANAGE hours	M.E. hours	E.E. hours	VACSUP hours	DESDRF hours	VACTEC hours	ELCTEC hours	MACH'T hours	WELD hours	RIG'G hours	BCTECH hours	QUANT	COST EA. $	LABOR ($) & A.P. ($K) AGS LABOR	OUTSIDE LABOR	A.P. $K	CONTRACT DRAFTING
1	INITIAL PLANNING, DESIGN AND SCHEDULING	1200	1200	240		1200									129360	0	0	33600
2	DIPOLE CHAMBERS, STANDARD	80	240	-	80	160	350	-	-	-	160	-	78	7435	31500	6240	580	4480
3	DIPOLE CHAMBERS, SPECIAL	170	225	-	20	160	64	-	-	-	-	-	8	15000	22511	0	120	4480
4	STRAIGHT SECTIONS, (9.37 m)	40	160	-	20	160	160	-	-	160	80	-	41	1710	16220	10480	70	4480
5	TRANSITIONS (SEXTAPOLE/PUE'S).	10	60	-	15	120	130	-	-	-	-	-	79	1128	8585	0	89	3360
6	TUBE/BELLOWS ASS'Y, QUADS	10	80	-	15	80	130	-	-	-	-	-	135	1000	9565	0	135	2240
7	CROSS, 4-INCH, IP, ROUGHING AND BEAMLINE.	40	120	120	28	160	280	90	-	-	-	-	28	2670	27672	0	75	4480
8	TEE'S, 60 L ION PUMPS	40	120	80	105	160	525	80	-	-	-	-	105	1606	37475	0	169	4480
	SUBTOTALS --->	1590	2205	440	283	2200	1639	170	0	160	240	0	474	30549	282888	16720	1238	61600

TABLE VI

Rev. B

STRETCHER VACUUM SYSTEM COST ESTIMATE
PUMPS

ITEM NO.	ACTIVITY OR ITEM	MANAGE hours	M.E. hours	E.E. hours	VACSUP hours	DESDRF hours	VACTEC hours	ELCTEC hours	MACH'T hours	WELD hours	RIG'G hours	BCTECH hours	QUANT	COST EA. $	LABOR ($) & A.P. ($K) AGS LABOR	OUTSIDE LABOR	A.P. $K	CONTRACT DRAFTING
9	PUMP, 60L/sec SPUTTER-ION	80	160	-	50	16	470	-	-	-	-	-	135	1200	30190	0	162	448
10	PUMPS, 200 L/sec SPUTTER-ION (2/BEAM COMPONENT CHAMBER)	8	16	-	8	-	48	-	-	-	-	-	12	4000	3200	0	48	0
11	PORTABLE ROUGHING AND LEAKCHECKING SYSTEMS	80	160	40	8	160	40						3	16000	15472	0	48	4480
	SUBTOTALS --->	168	336	40	66	176	558	0	0	0	0	0	150	21200	48862	0	258	4928

TABLE VII

December 19, 1988
Rev. B

STRETCHER VACUUM SYSTEM COST ESTIMATE
HARDWARE

Kimo M. Welch
Joseph Tuozzolo

ITEM NO.	ACTIVITY OR ITEM	MANAGE hours	M.E. hours	E.E. hours	VACSUP hours	DESDRF hours	VACTEC hours	ELCTEC hours	MACH'T hours	WELD hours	RIG'G hours	ECTECH hours	QUANT	COST EA. $	LABOR ($) & A.P. ($K) AGS LABOR	OUTSIDE LABOR	A.P. $K	CONTRACT DRAFTING
12	VALVES, SECTOR	8	80	20	12	16	64	-	-	-	-	-	32	2600	8056	0	83	448
13	VALVES, ROUGHING (USING NEW AGS MODEL)	8	16	20	12	-	64	-	-	-	-	-	30	1200	4920	0	36	0
14	VALVES, BEAM COMPONENT ISOLATION	8	80	20	12	16	64	20	-	-	-	-	12	3600	8736	0	43	448
15	CLAMPS, 7-1/2" MARMIN, (NEW AGS IP DESIGN)	20	24	-	20	-	262	-	-	-	-	-	526	250	12044	0	132	0
16	GASKETS, 7-1/2" MARMIN	2	16	-	16	-	56	-	-	-	-	-	526	68	3570	0	36	0
17	CLAMPS, 13" FLANGES (EXISTING NEW DESIGN)	8	16	-	4	-	54	-	-	-	-	-	27	750	3208	0	20	0
18	GASKETS, 13" FLANGES	2	16	-	4	_	54	-	-	-	-	-	27	110	2914	0	3	0
19	SUPPORT STANDS, STRAIGHT SECTIONS	16	120	-	8	160	-	-	-	-	320	-	80	600	7056	12480	48	4480
20	SUPPORT STANDS, SPUTTER-ION	16	80	-	8	120	-	-	-	-	540	-	135	400	5096	21060	54	3360
21	TOOLING (ITEMS NOT AMORTIZED IN PARTS)	40	240										3	25000	13720	0	75	0
	SUBTOTALS ---)	128	688	60	96	312	618	20	0	0	860	0	1398	34578	69320	33540	530	8736

TABLE VIII

Rev. B

STRETCHER VACUUM SYSTEM COST ESTIMATE
ELECTRONICS

ITEM NO.	ACTIVITY OR ITEM	MANAGE hours	M.E. hours	E.E. hours	VACSUP hours	DESDRF hours	VACTEC hours	ELCTEC hours	MACH'T hours	WELD hours	RIG'G hours	ECTECH hours	QUANT	COST EA. $	LABOR ($) & A.P. ($K) AGS LABOR	OUTSIDE LABOR	A.P. $K	CONTRACT DRAFTING
22	POWER SUPPLIES (IP w/ RS-232)	80	20	160	16	40	36	120	-	-	-	-	147	1700	18828	0	250	1120
23	DEVICE CONTROLLERS (MODIFIED AGS; INCLUDES SOFTWARE)	40	-	1120	20	240	20	320	-	-	-	-	6	5000	69380	0	30	6720
24	DEVICE INTERFACE BUCKETS (GAUGE, SECTOR VALVES, ETC)	120	20	1040	160	480	96	2040	-	-	-	-	235	600	138284	0	141	13440
25	RS-232, STRETCHER, TUNNEL BUS	80	80	320	4	320	-	320	-	-	-	-	1	20000	34596	0	20	8960
26	CABLING, ION PUMP	16	-	80	20	40	80	882	-	-	-	-	147	515	38392	0	76	1120
27	PIG CABLING	4	-	40	4	480	96	341	-	-	-	-	28	335	17210	0	9	13440
28	TC GAUGE CABLING	4	-	40	4	240	36	341	-	-	-	-	28	335	15170	0	9	6720
29	TC GAUGE CONTROLLERS (RS-232 INTERFACED) & GAUGES	20	-	320	4	-	-	-	-	-	-	-	28	1690	16856	0	47	0
30	PIG CONTROLLERS (RS-232 INTERFACED) & GAUGES	20	-	320	4	-	-	-	-	-	-	-	28	1690	16856	0	47	0
31	ELECTRONIC EQUIPMENT "HOUSE" (I.E. RACKS, AIR, POWER, ETC.)	120	320	1000	4	480	96	4000	-	-	-	-	2	30000	210020	0	60	13440
	SUBTOTALS ---)	504	440	4440	240	2320	460	8364	0	0	0	0	650	61865	575592	0	690	64960
	GRAND TOTAL ---)	2390	3669	4980	685	5008	3275	8554	0	160	1100	0	2672	148192	976662	50260	2715	140224

(STRETCH3)

TABLE IX

ABREVIATED SCHEDULE OF MANPOWER LOADING FOR A GIVEN
PROJECT AS A FUNCTION OF JOB CLASSIFICATION
(rounded to integers)

PROJECT NAME: STRETCHER MANPOWER ALLOCATION , Rev. 8

Kimo M. Welch
Dec. 22,1988

JOB FUNCTION --->	49.0 MAN'GR	49.0 M.E.	49.0 E.E.	80.8 SFTWRE	49.0 VACSUP	TOTAL HRS OF 49.00 ITEMS	TOTAL $ OF 49.00 ITEMS	34.0 VACTEC	34.0 ELCTEC	34.0 BCTECH	TOTAL HRS OF 34.00 ITEMS	TOTAL $ OF 34.00 ITEMS	46.0 MAC'ST	46.0 WELDER	TOTAL HRS OF 46.00 ITEMS	TOTAL $ OF 46.00 ITEMS	39.0 RIG'NG	TOTAL $ OF 39.00 ITEMS	SUM AGS $	SUMSHOP $
TOTAL PROJECT FUNCT'N HOURS	2390.0	3669.0	4980.0	0.0	685.0			3275.0	8554.0	0.0			0.0	160.0			1100.0			
PLAN & SCHEDULE:																				
% ALLOCATED	45.0	15.0	15.0	15.0	10.0			5.0	5.0	5.0			-	-			5.0			
PERSON HOURS	1075.5	550.4	747.0	0.0	68.5	2441.4	119626.2	163.8	427.7	0.0	591.5	20109.3	0.0	0.0	0.0	0.0	55.0	2145.0	139735.5	2145.0
DESIGN																				
% ALLOCATED	20.0	40.0	40.0	55.0	5.0			-	-	-			-	-			-			
PERSON HOURS	478.0	1467.6	1992.0	0.0	34.3	3971.9	194620.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	194620.7	0.0
ACQUISITION:																				
% ALLOCATED	25.0	25.0	25.0	10.0	10.0			10.0	10.0	10.0			100.0	100.0			-			
PERSON HOURS	597.5	917.3	1245.0	0.0	68.5	2828.3	138584.3	327.5	855.4	0.0	1182.9	40218.6	0.0	160.0	160.0	7360.0	0.0	0.0	178802.9	7360.0
INSTALLATION:																				
% ALLOCATED	10.0	20.0	20.0	20.0	75.0			85.0	85.0	85.0			0.0	0.0			95.0			
PERSON HOURS	239.0	733.8	996.0	0.0	513.8	2482.6	121645.0	2783.8	7270.9	0.0	10054.7	341858.1	0.0	0.0	0.0	0.0	1045.0	40755.0	463503.1	40755.0
																			976662.0	50260.0

NOTE: ASSUMED USE OF CONTRACT DRAFTING.

LABOR COSTS	TOTALS $K
PLANNING & SCHEDULING	141.9
DESIGN (W/ CONTRACT DRAFT.) ...	334.8
ACQUISITION	186.2
INSTALLATION & TEST	504.3
GRAND TOTAL $K	1167.1