

Recycler September 03 Shutdown Review  
Vacuum System

2003 SHUTDOWN  
RECYCLER RING VACUUM WORK REVIEW

Vacuum System Data

Terry Anderson

## **Objective**

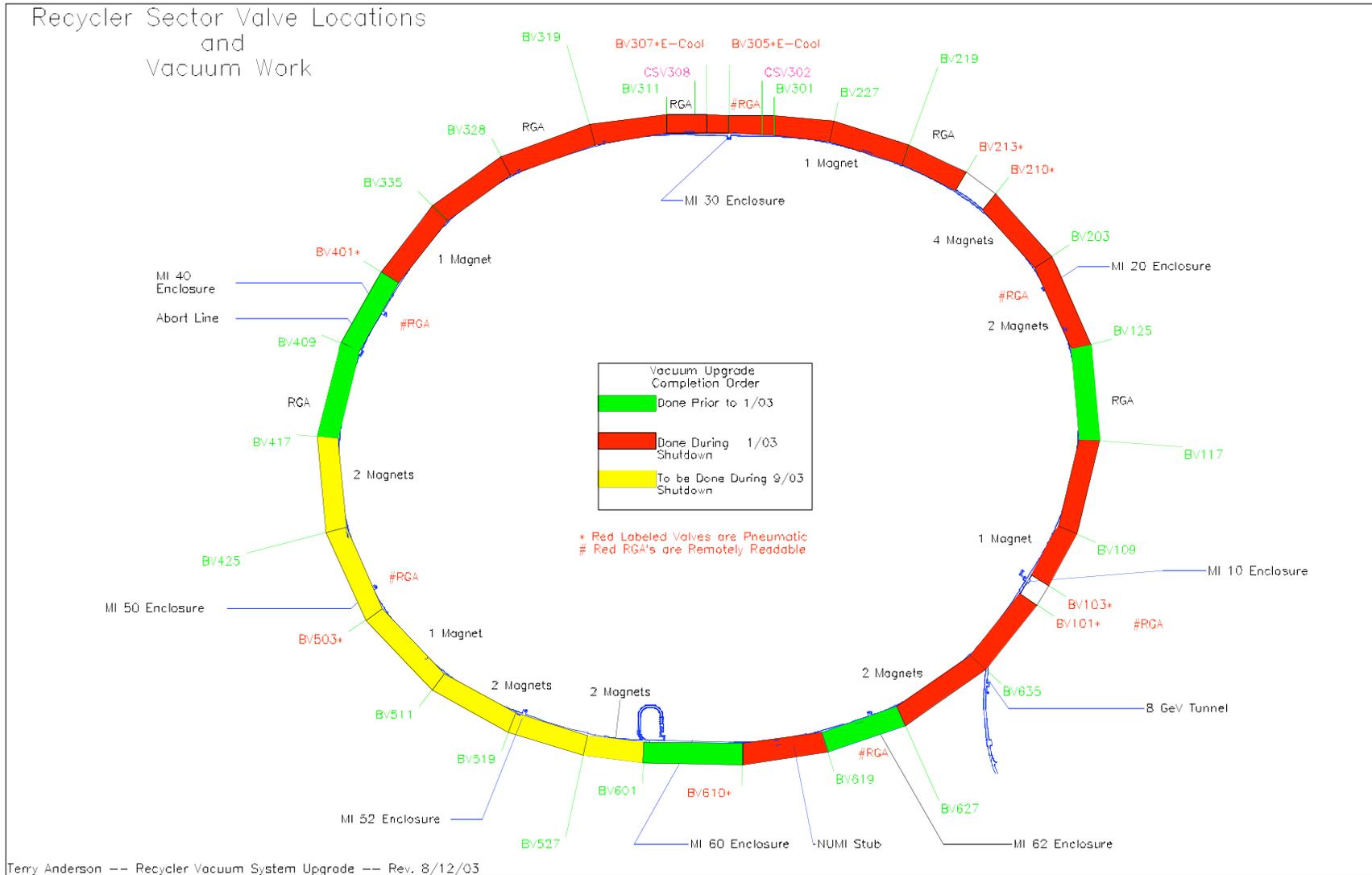
Present sufficient data so that the reviewer has a clear understanding of the current state of the Recycler vacuum system.

### **Issues That Continue To Confront The Recycler Vacuum System**

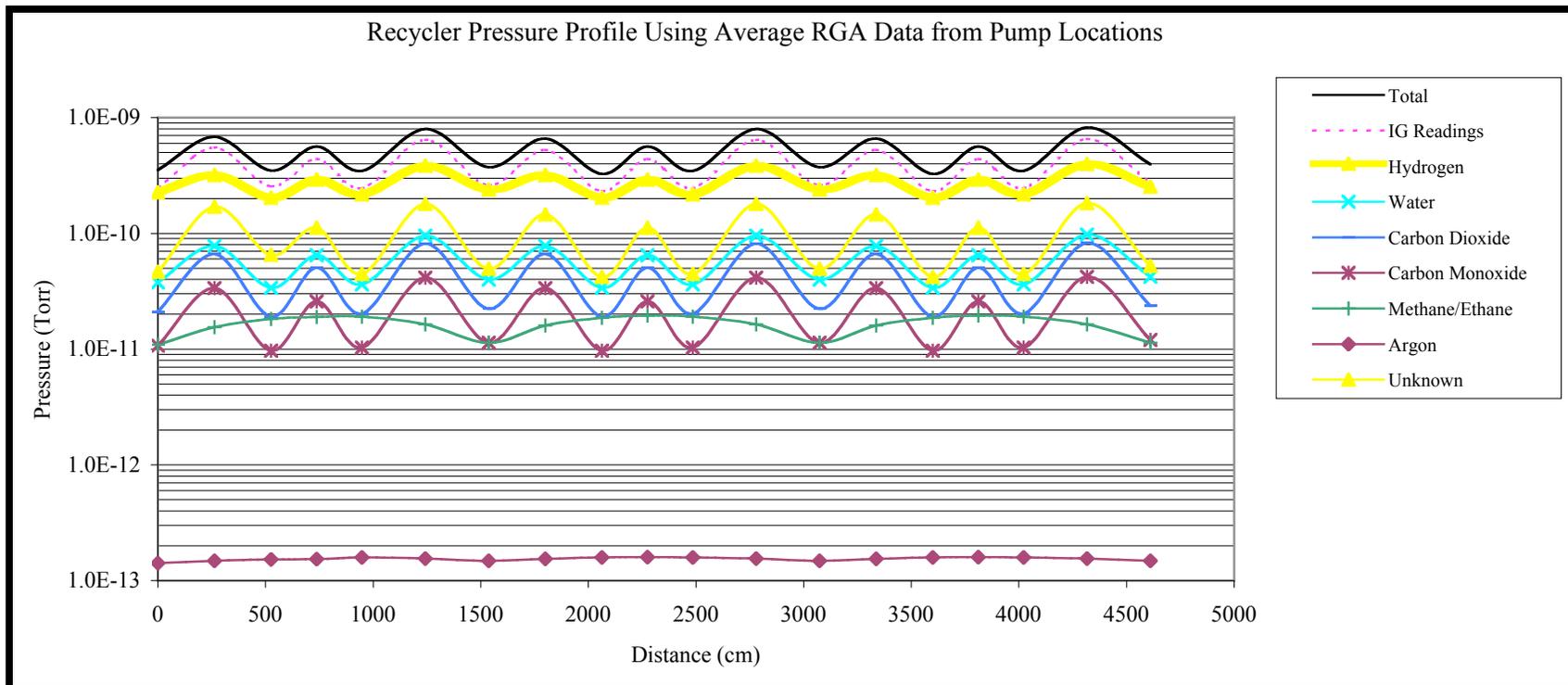
- 1) What is the make-up of the gasses in the Recycler beam tube?
- 2) Is there a reasonable understanding of the gas loads that the Recycler vacuum system sees?
- 3) Is there justification for the ongoing ion pump upgrade?
- 4) Is the Recycler vacuum gauging sufficient to determine conditions between gauges?
- 5) Does the Recycler vacuum gauging give a reasonable estimate as to the conditions in the beam tube?
- 6) Has there been an overall improvement in the Recycler vacuum since the January 03 shutdown?
- 7) What can be done to improve the Recycler vacuum system?

# Recycler September 03 Shutdown Review Vacuum System

## Recycler Vacuum System Map

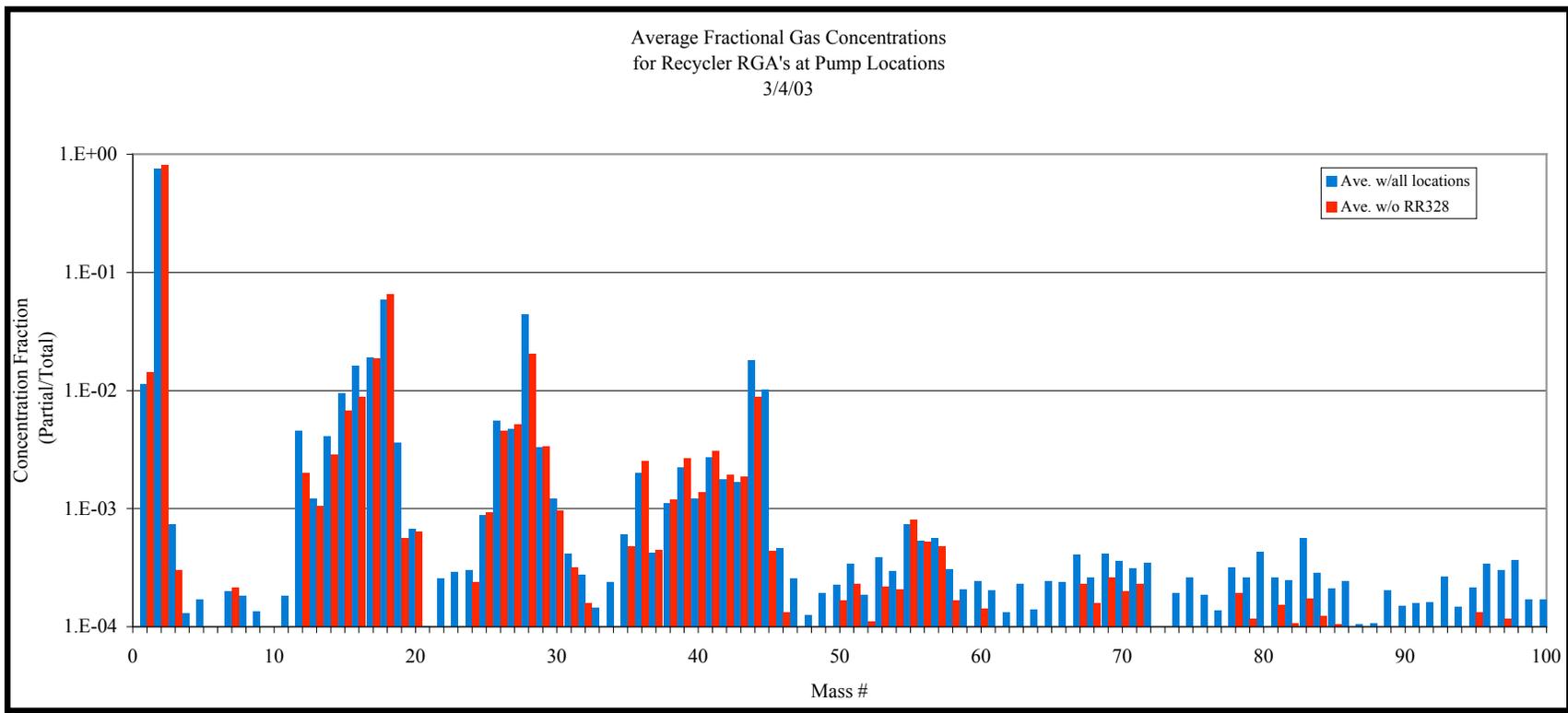


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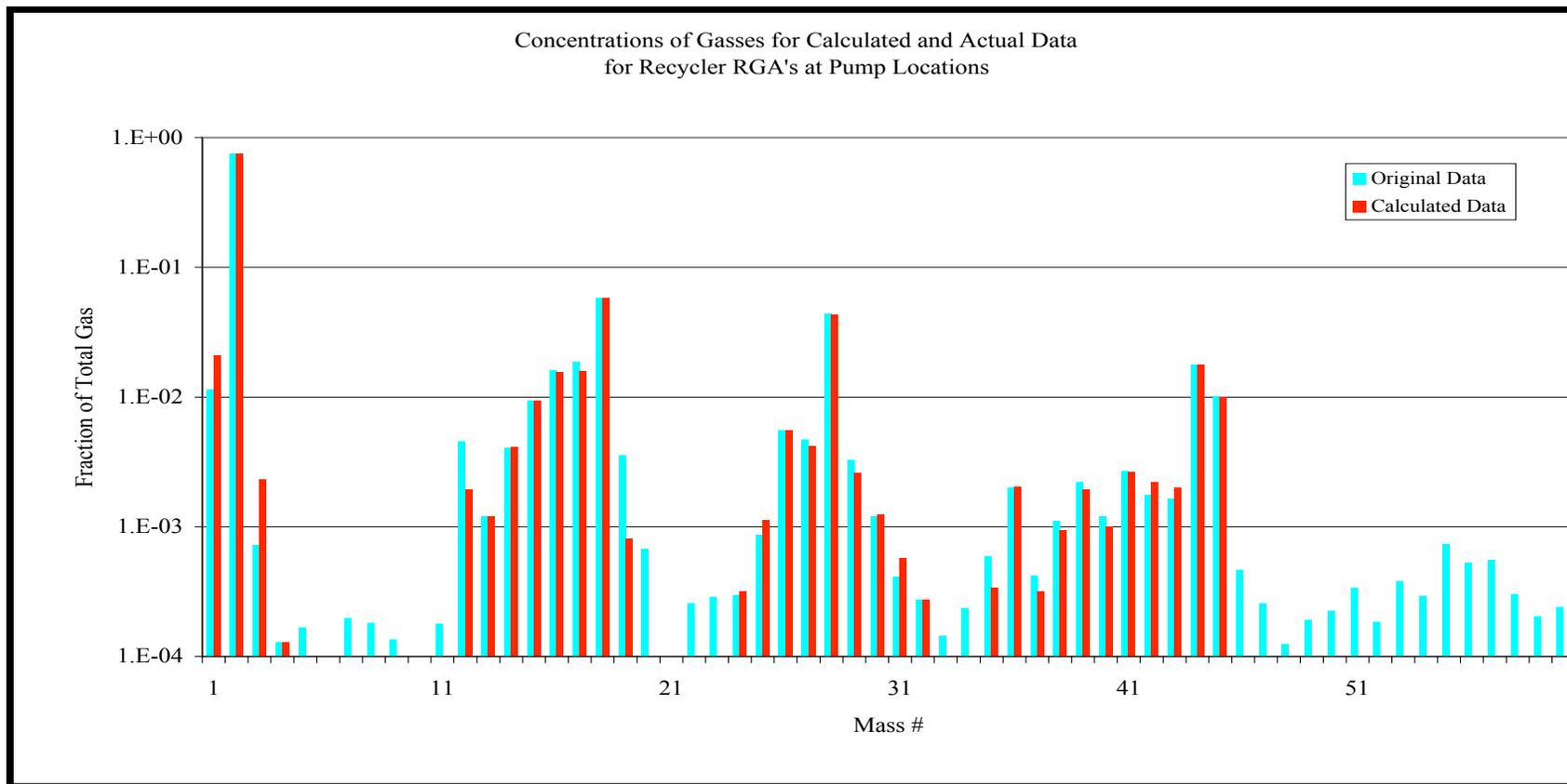
This plot shows what the Recycler pressure profile should be using the average RGA data from the pump locations and a 5% TSP efficiency factor. I principal this is the best guess as to how the Recycler vacuum system is performing. There is a significant “Unknown” quantity in this data. It is unclear whether this is real or just a local problem having to do with the hot filament of the RGA. For calculation purposes the unknown quantity is treated as N<sub>2</sub> in the model.

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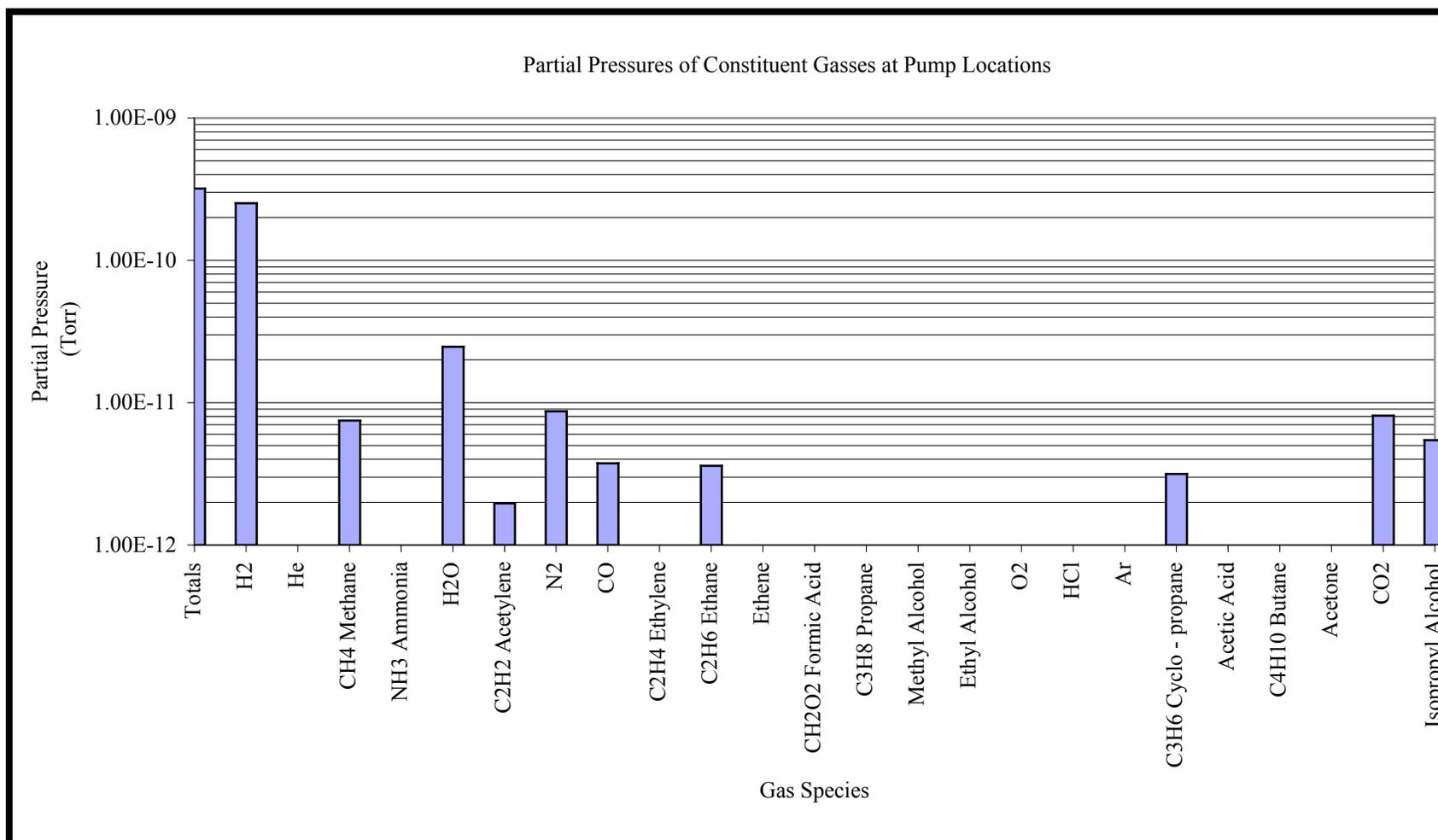
This plot shows the average fractional concentrations of the various peaks on the RGA's at RR121, RR219, RR328, and RR413. The average ion gauge value in the sectors that contain the RGA's was  $2.2 \times 10^{-10}$  Torr. The data from the RR328 location has the biggest impact on the average, especially on masses 12, 14, 15, 16, 19, 28, 44, 45, and 50+ peaks. The RGA's are located directly on the pump assemblies and the pumps are between the RGA's and the System. The ion pumps are 20 L/s DI pumps and the TSP's are standard Recycler TSP's.

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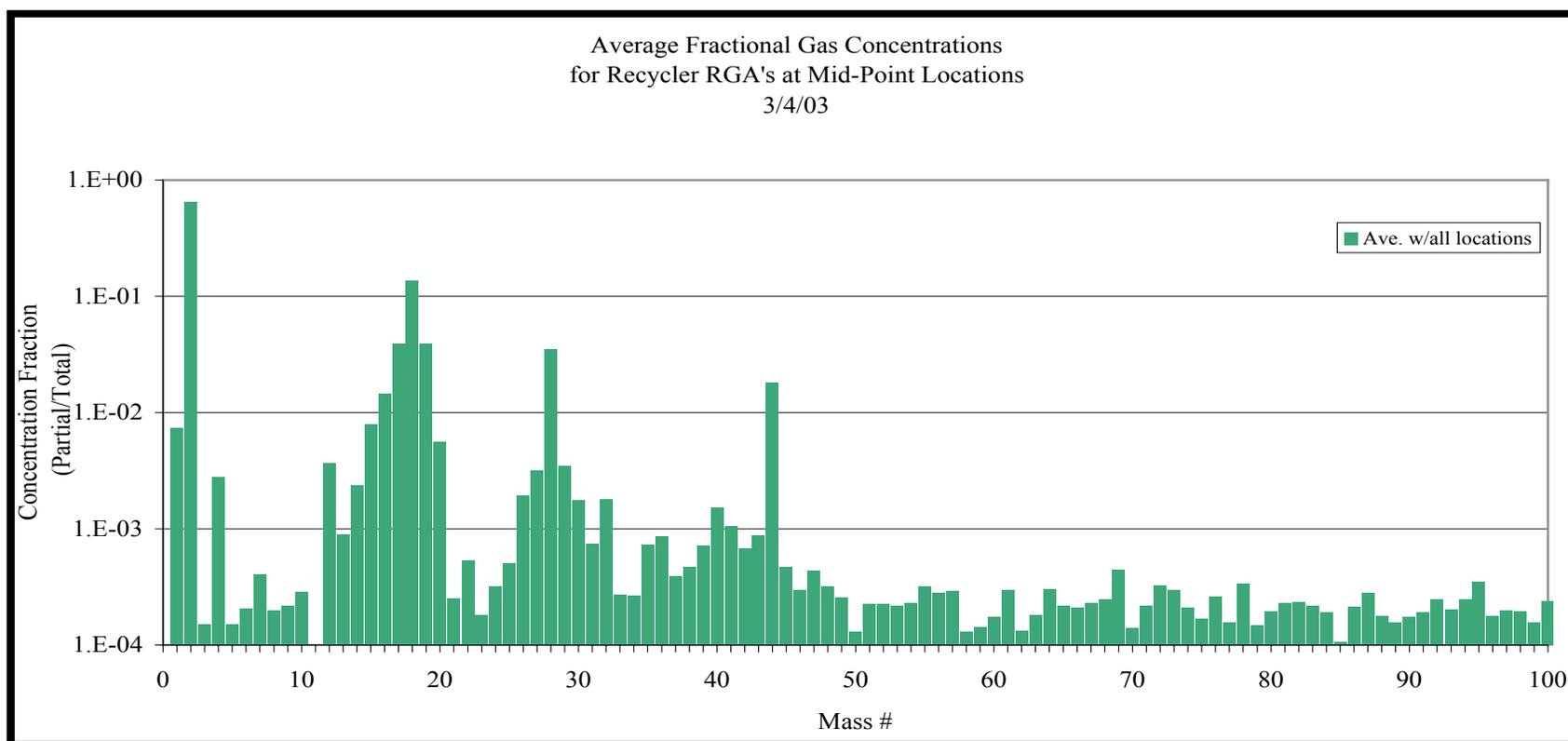
This plot shows the original data (previous plot) and calculated data for assumed known gas species. The gasses that are assumed are shown in the next plot. The gas species responsible for the peaks greater than mass 45 are unknown at this time. They could be a hydrocarbon contaminate or just noise.

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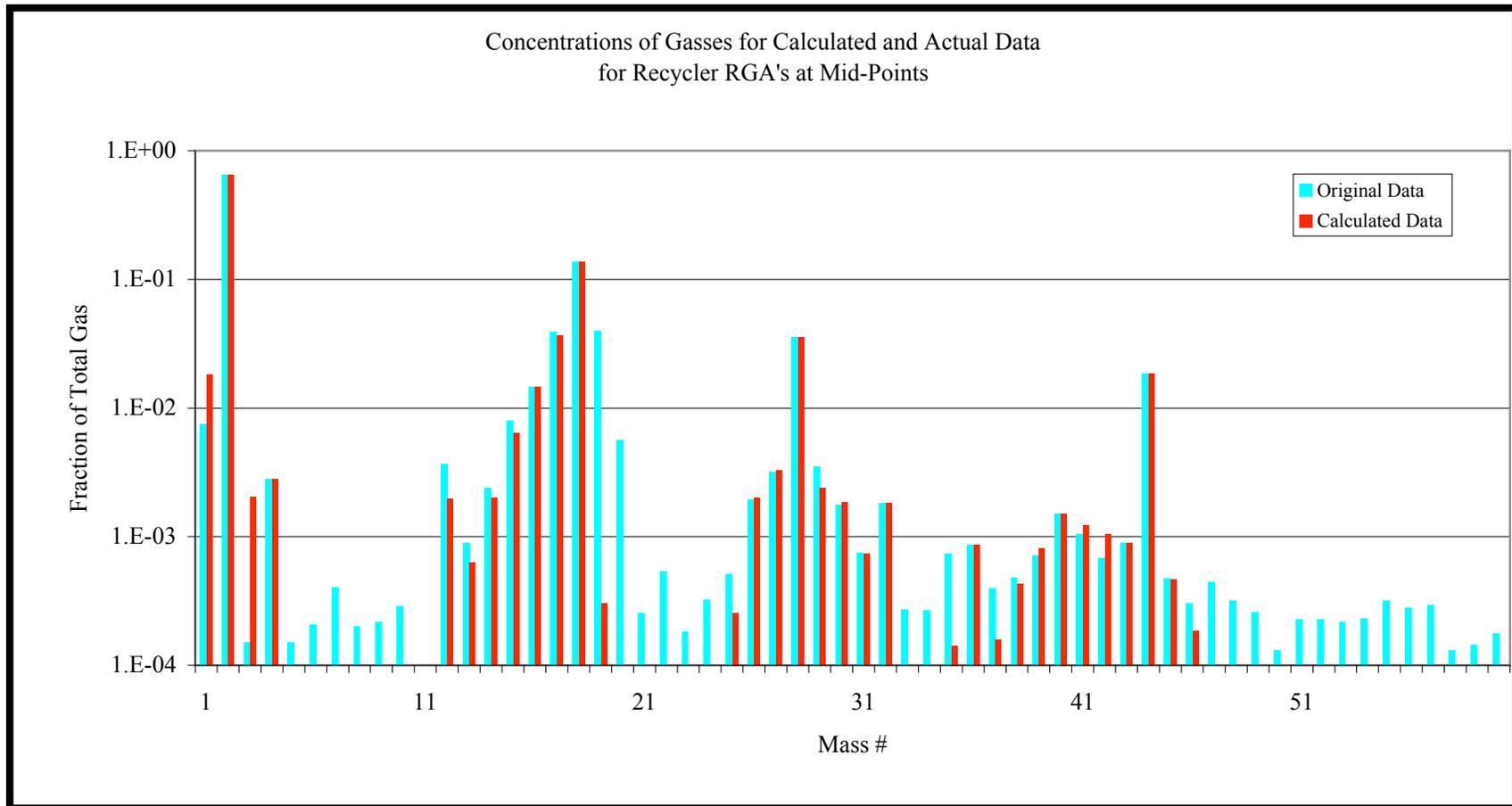
This plot shows the assumed gas species used in the previous plot. The partial pressures shown are calculated using an average ion gauge pressure of 2.2E-10 Torr. The partial pressures are adjusted to reflect the true partial pressure, not a pressure normalized to N<sub>2</sub>.

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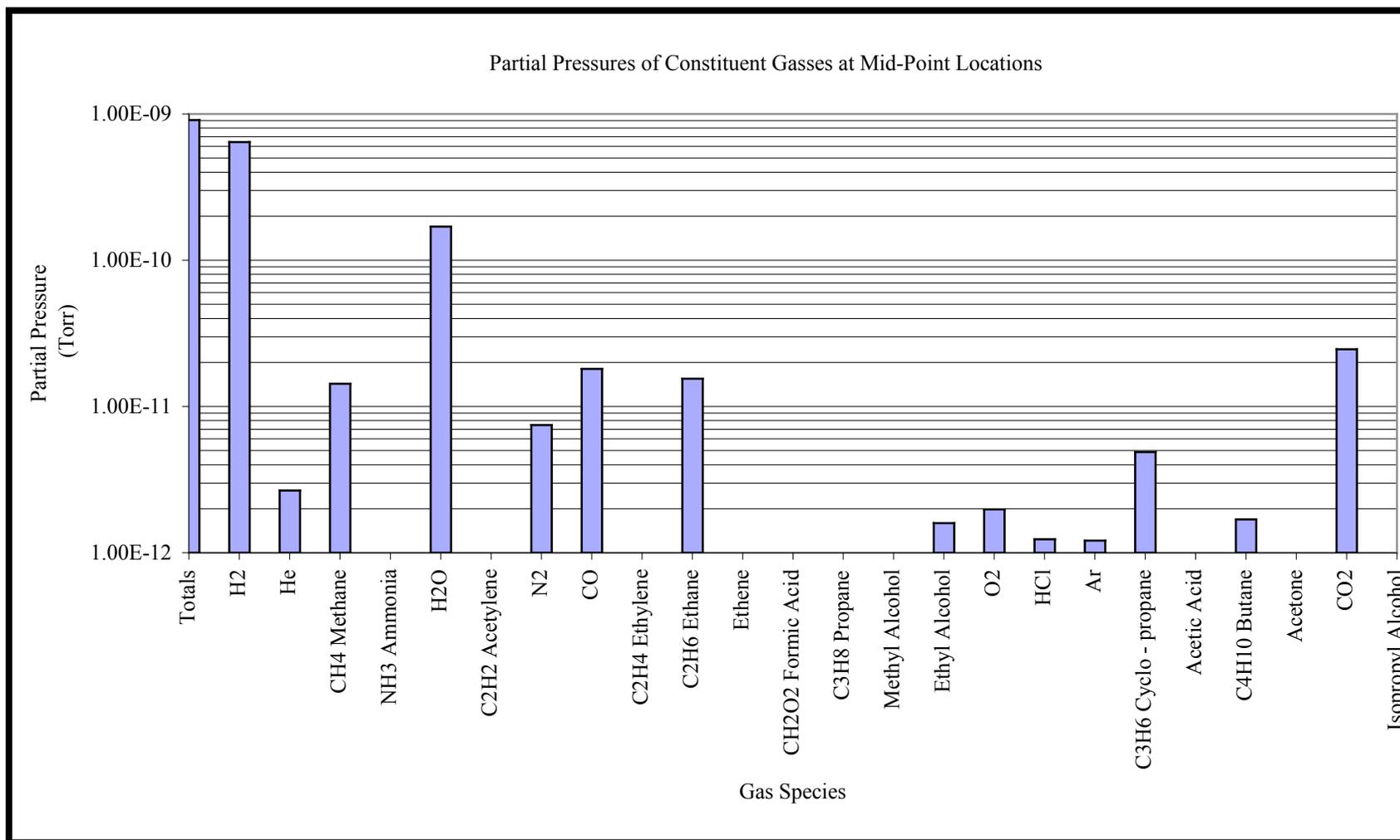
This plot shows the average fractional concentrations of the various peaks on the RGA's at RR10, RR30, and RR62. The average ion gauge value in the sectors that contain the RGA's was  $1.5 \times 10^{-10}$  Torr. The data from the RR62 location is the source for the large 19 peak and the 20 peak is dominated by the data at RR30. The methane (14, 15, & 16) peaks are most influenced by the scan at RR30. The peaks greater than 50 are most influenced by the scan at RR10. The helium (4) peak is almost entirely due to the scan at RR10 and is due to the Cooling Tanks in that location. The RGA's are located between TSP assemblies. There is an ion pump on one of the TSP assemblies at the 10 and 62 locations and ion pumps on both TSP assemblies at the 30 location. The average distance between the two pump locations is about 5 meters.

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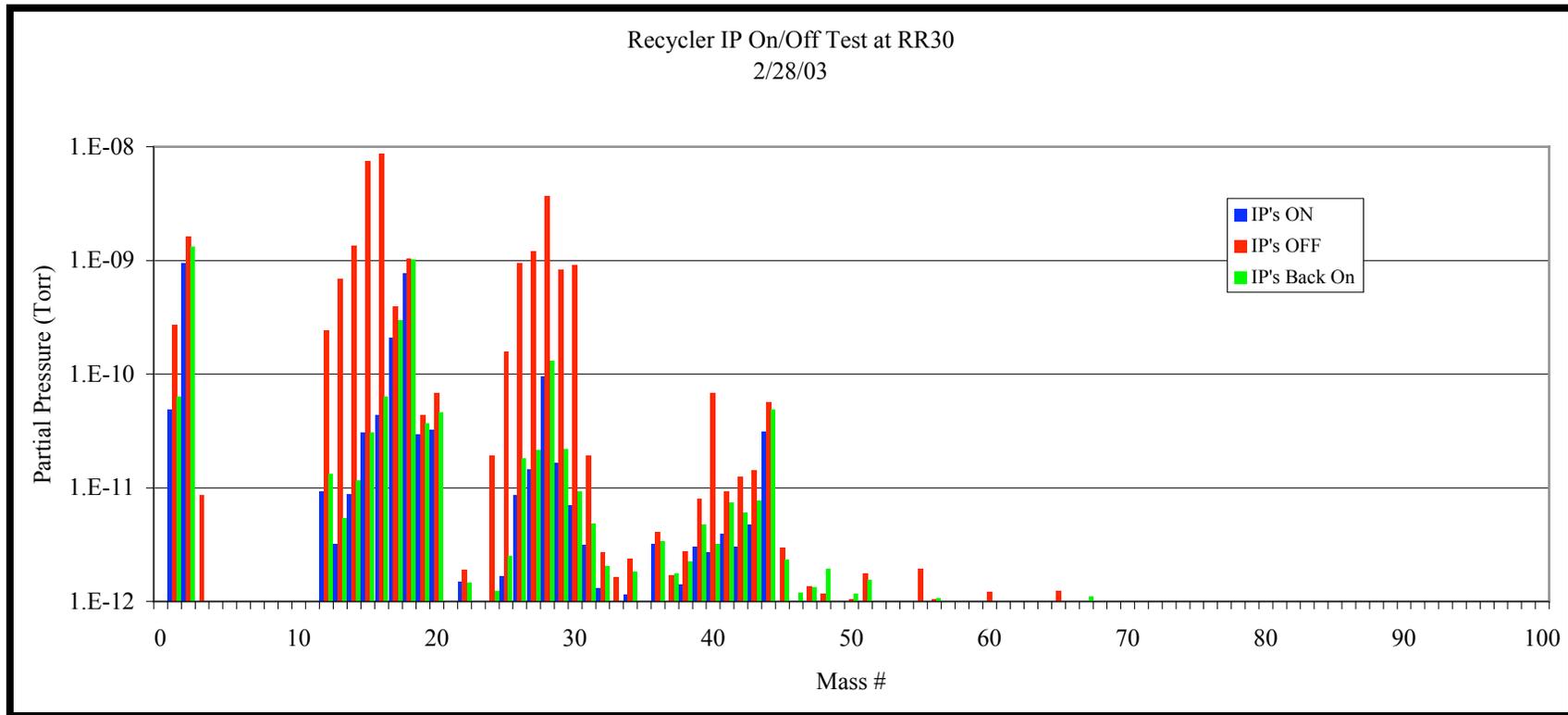
This plot shows the original data (previous plot) and calculated data for assumed known gas species. The gasses that are assumed are shown in the next plot. The gas species responsible for the peaks greater than mass 45 are unknown at this time. They could be a hydrocarbon contaminate or just noise. The high 19, and 20 peaks are not understood at this time and are limited to the RR62 location. It is believed that these are not common through the system, but are a local phenomenon to that RGA.

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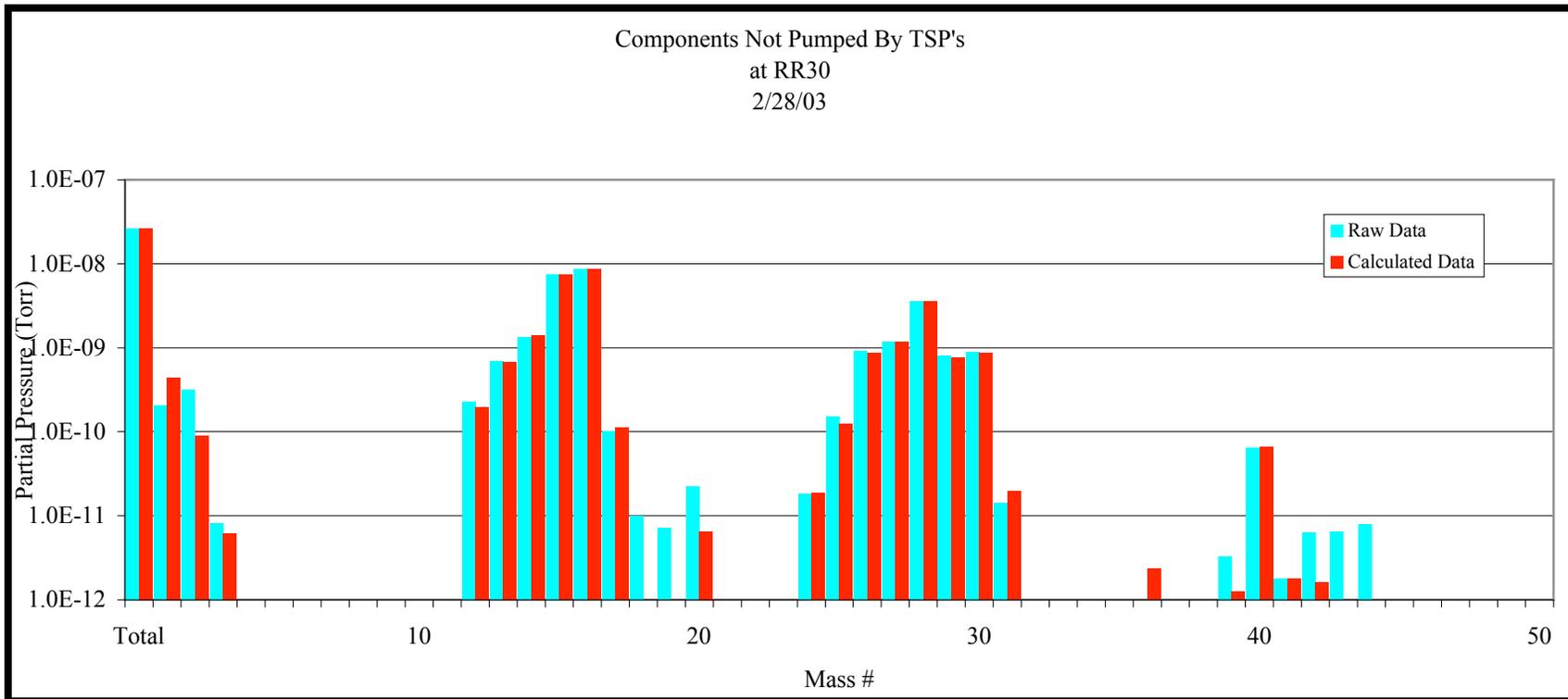
This plot shows the assumed gas species used in the previous plot. The partial pressures shown are calculated using an average ion gauge pressure of  $6.4\text{E-}10$  Torr. The partial pressures are adjusted to reflect the true partial pressure, not a pressure normalized to  $\text{N}_2$ .

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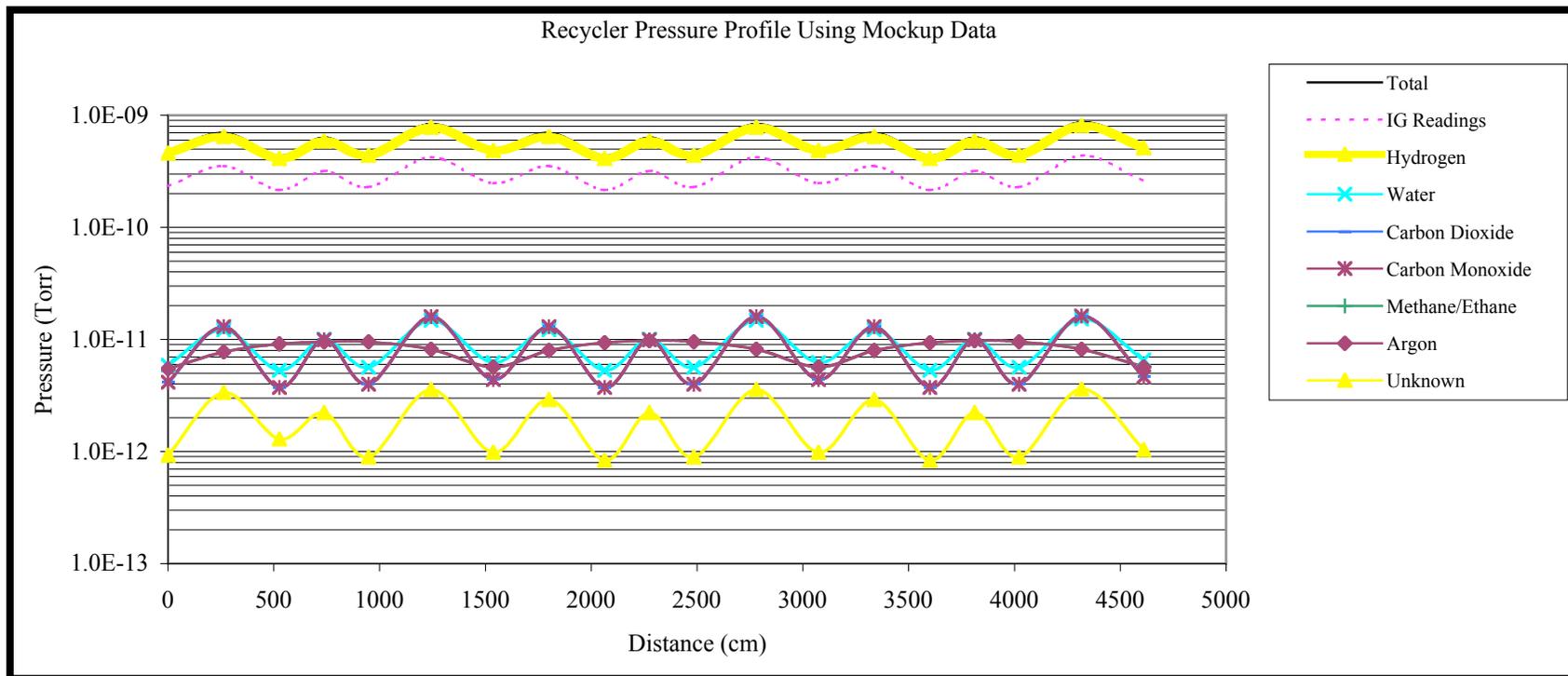
This plot shows what happens when a sector is isolated and the ion pumps are turned off. The red peaks show the gasses that are not pumped by the TSP's. These gasses for the most part in the Recycler are methane, ethane, and argon.

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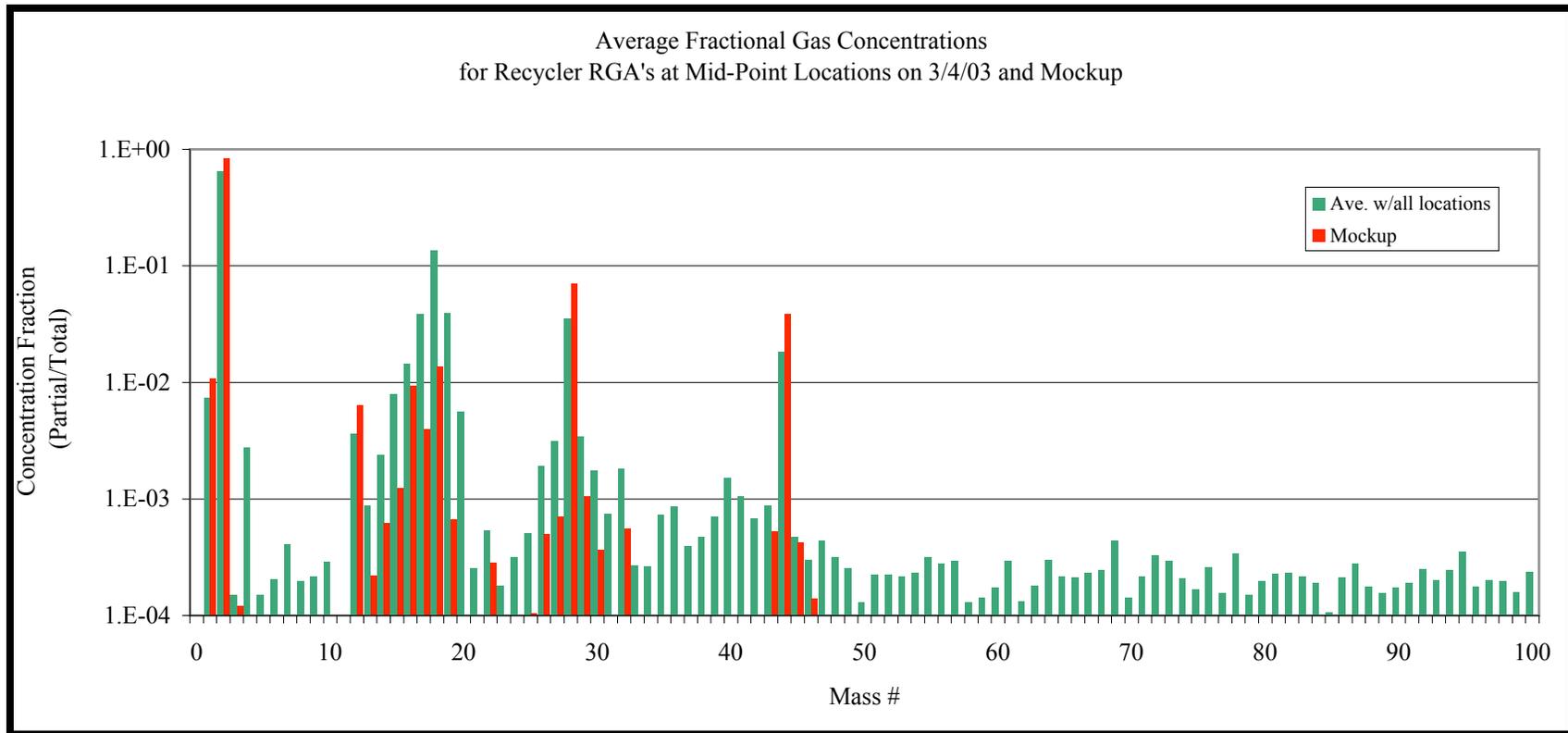
This plot shows the difference between the ion pumps off and the ion pumps on in the previous plot and how that data correlates to methane, ethane, and argon.

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This plot shows what the Recycler pressure profile should be if the out-gassing rates from the Mockup Test are used. In principal this is the best that we can achieve with the Recycler vacuum. The biggest problem that is noted with this data is that the H<sub>2</sub> out-gassing rate is larger than what the model typically shows using RGA data from the ring.

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This plot shows the difference between what we see at the mid-point location RGA's and the Mockup RGA. We can see that the water content in the Mockup is about an order of magnitude less than in the Recycler. The methane and ethane concentrations are also significantly less in the Mockup. Carbon monoxide, carbon dioxide, and hydrogen are slightly higher in the Mockup. There is also evidence of helium, oxygen, and argon in the Recycler. The peaks less than 1E-3 and larger than mass 44 may or may not be real.

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Recycler Out-Gassing Rates From Various Tests

	%	Original	%	RR121	%	RR219	%	RR328	%	RR413	%	Tunnel Average	%	Mockup
H2	69	7.7E-13	60	4.20E-13	85	6.70E-12	54	2.00E-12	80	9.30E-13	70	2.51E-12	97	5.57E-12
H2O	20	2.2E-13	13	9.50E-14	7	6.60E-13	6	2.10E-13	7	8.00E-14	8	2.61E-13	1	5.47E-14
CO	3	3.7E-14	2	1.05E-14	1	2.00E-13	12	3.50E-13	0	3.50E-15	4	1.41E-13	1	4.75E-14
Ar	0	2.1E-16	0	2.60E-18	0	1.35E-17	0	1.10E-17	0	1.17E-18	0	7.07E-18	0	1.59E-21
CH4	1	9.1E-15	0	1.15E-15	0	4.70E-15	0	1.35E-14	0	1.50E-15	0	5.21E-15	0	4.00E-15
CO2	6	7.2E-14	4	2.30E-14	4	5.50E-13	16	4.50E-13	1	8.00E-15	6	2.58E-13	1	4.91E-14
Unknown	1	9.7E-15	20	1.20E-13	3	5.00E-13	11	2.80E-13	12	1.15E-13	11	2.54E-13	0	1.29E-14
Total	100	1.12E-12	100	6.70E-13	100	8.61E-12	100	3.30E-12	100	1.14E-12	100	3.43E-12	100	5.74E-12

This table shows the various out-gassing rates that have been obtained from RGA measurements on the Recycler system and Mockup test. The units are Torr-L/s-cm<sup>2</sup>.

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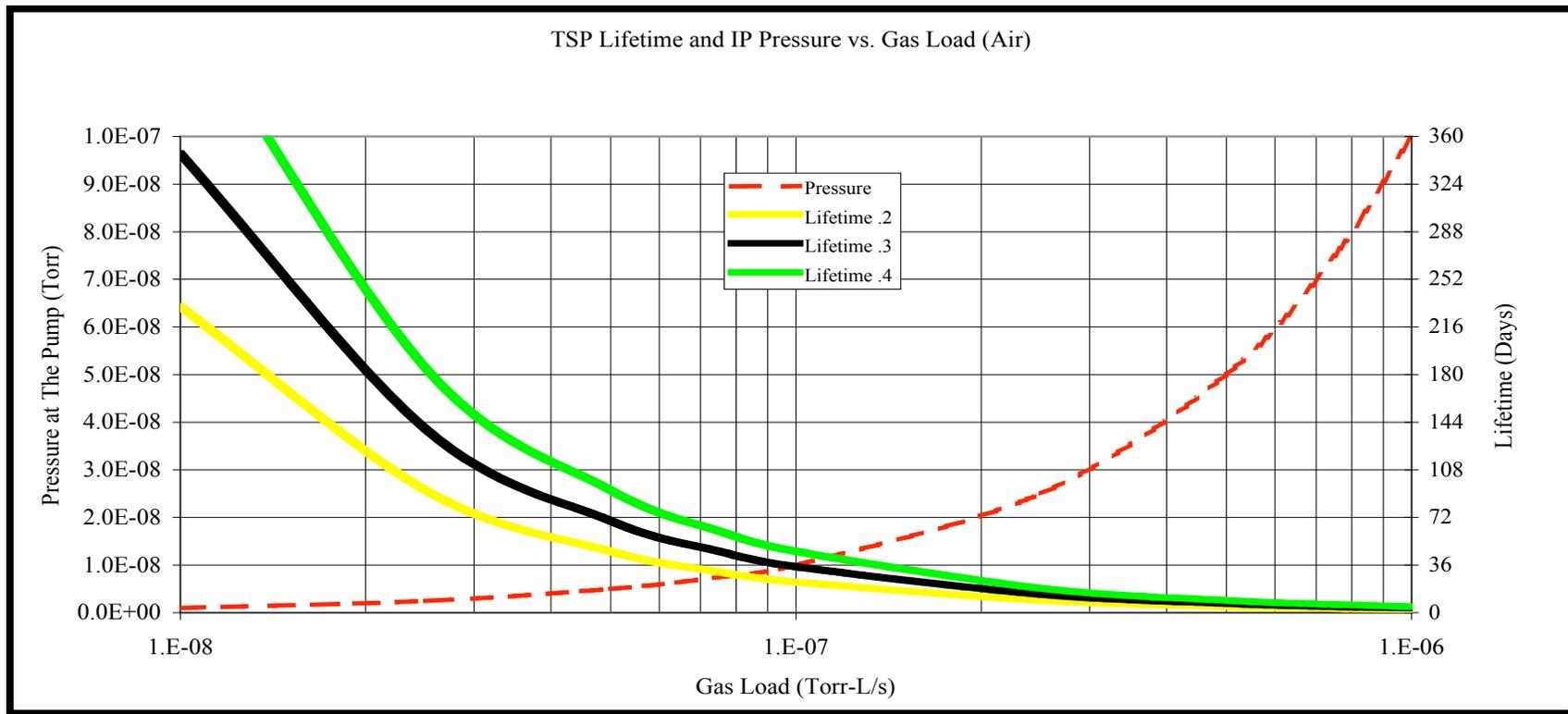
Recycler Mid-Point Pressures From Various Tests

Gas	Mid-Point Values from Pump Location Model	Fractional Contribution	Mid-Point Values from RGA's @ RR10, 30, & 62	Fractional Contribution	Mid-Point Values from Mockup Model	Fractional Contribution
H <sub>2</sub>	3.84E-10	0.48	6.42E-10	0.71	7.79E-10	0.93
H <sub>2</sub> O	9.52E-11	0.12	1.70E-10	0.19	1.49E-11	0.02
CO/N <sub>2</sub>	4.15E-11	0.05	2.56E-11	0.03	1.31E-11	0.02
Ar	1.55E-13	0.00	1.21E-12	0.00	3.53E-17	0.00
CH <sub>4</sub> /C <sub>2</sub> H <sub>6</sub>	1.64E-11	0.02	2.98E-11	0.03	8.20E-12	0.01
CO <sub>2</sub>	8.13E-11	0.10	2.46E-11	0.03	1.60E-11	0.02
Unknown	1.80E-10	0.23	1.41E-11	0.02	3.57E-12	0.00
Total	7.99E-10	1.00	9.07E-10	1.00	8.34E-10	1.00

Gas	Mid-Point Values from RR121 Model	Fractional Contribution	Mid-Point Values from RR413 Model	Fractional Contribution	Mid-Point Values from RR219 Model	Fractional Contribution	Mid-Point Values from RR328 Model	Fractional Contribution
H <sub>2</sub>	6.47E-11	0.45	1.46E-10	0.68	4.54E-10	0.76	1.87E-10	0.57
H <sub>2</sub> O	2.88E-11	0.20	2.48E-11	0.12	5.86E-11	0.10	2.57E-11	0.08
CO/N <sub>2</sub>	3.27E-12	0.02	1.12E-12	0.01	1.18E-11	0.02	2.86E-11	0.09
Ar	6.47E-14	0.00	2.92E-14	0.00	2.31E-13	0.00	2.61E-13	0.00
CH <sub>4</sub> /C <sub>2</sub> H <sub>6</sub>	2.60E-12	0.02	3.40E-12	0.02	5.39E-12	0.01	2.15E-11	0.07
CO <sub>2</sub>	8.42E-12	0.06	3.00E-12	0.01	3.84E-11	0.06	4.33E-11	0.13
Unknown	3.73E-11	0.26	3.67E-11	0.17	2.96E-11	0.05	2.29E-11	0.07
Total	1.45E-10	1.00	2.15E-10	1.00	5.98E-10	1.00	3.30E-10	1.00

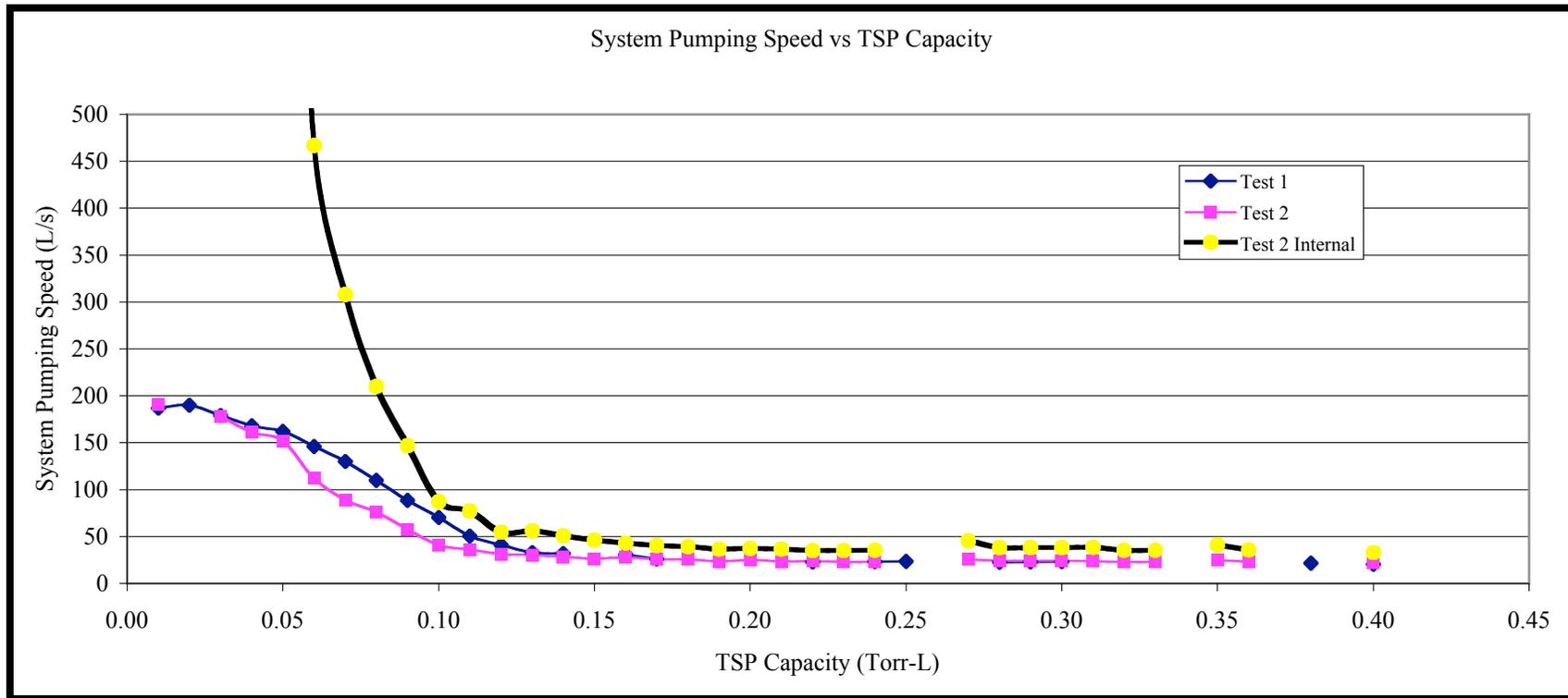
These tables show the predicted mid-point (maximum) pressures for the various gasses using the model and RGA data at different locations.

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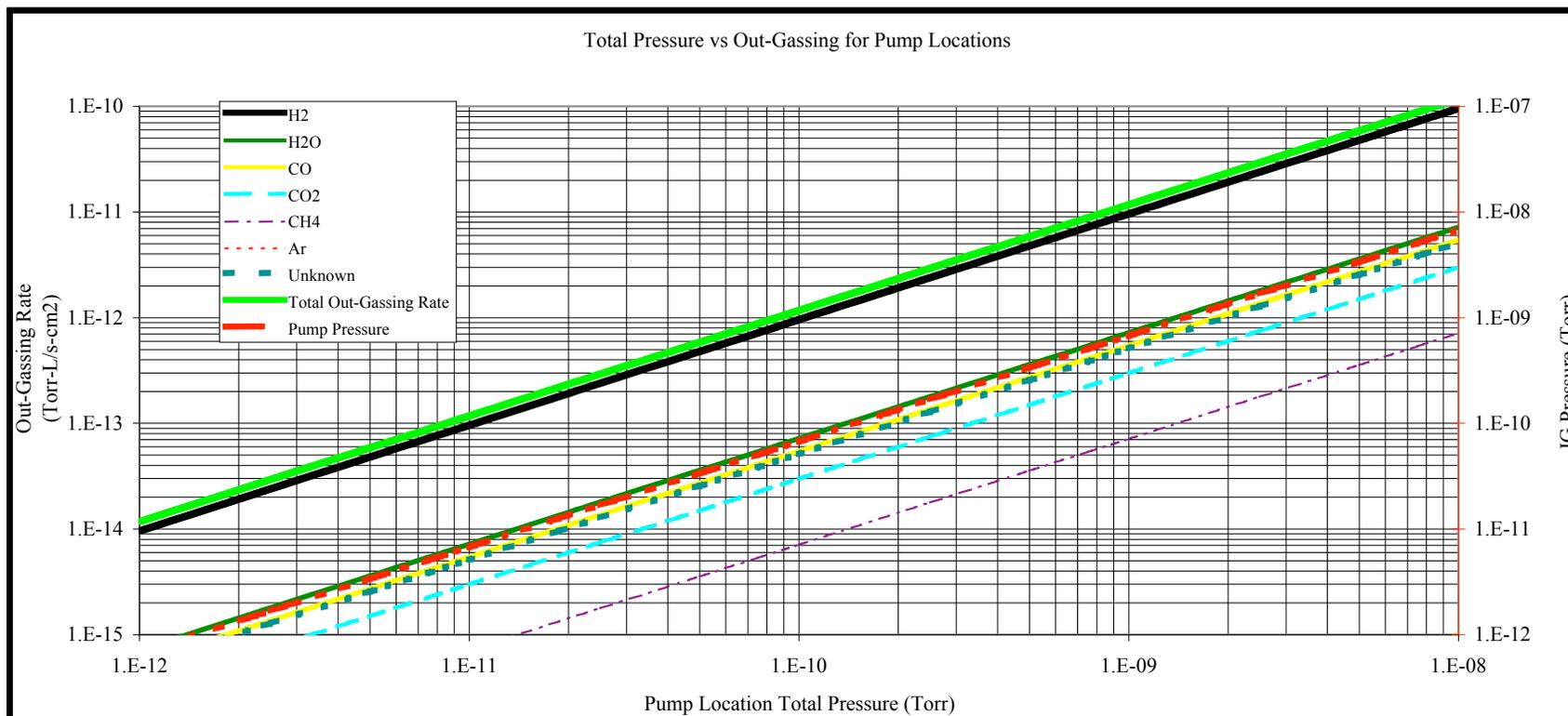
The solid black line in this plot shows the lifetime of a Recycler TSP for various air gas loads assuming a pumping capacity of 0.3 Torr-L, the green and yellow lines show the same thing for a capacity of 0.4 and .2 Torr-L. The dashed red line shows what the ion pump pressure would be after 3 TSP's closest to an ion pump have been depleted for the same gas load. What we have seen in the Recycler is that the TSP's need to be fired every six months to a year (assuming that there is not a leak or some other problem). This would imply that the normal gas load for the Recycler is less than  $3 \times 10^{-8}$  Torr-L/s at the pump locations. The Recycler vacuum model indicates a total out-gassing rate of something between  $7 \times 10^{-13}$  and  $9 \times 10^{-12}$  Torr-L/s-cm<sup>2</sup>. The standard pump spacing is 5 m and the inside perimeter of the beam tube is 23 cm. This gives a total gas load at the pump of  $8.1 \times 10^{-9}$  to  $1.0 \times 10^{-7}$  Torr-L/s. This is of course not air as the gas but the gas species shown in the previous tables.

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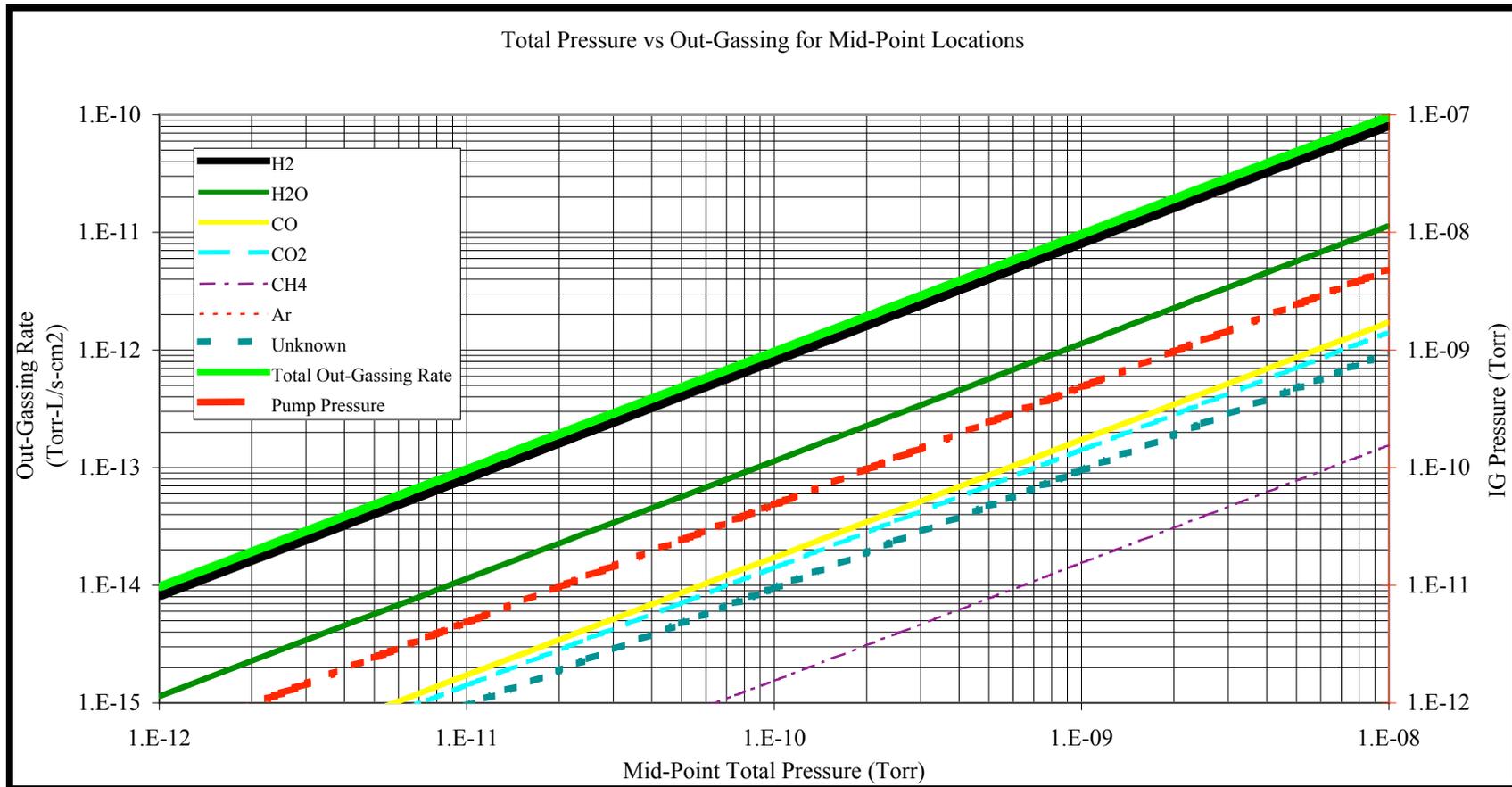
This plot shows the results of some tests that were done to determine the N<sub>2</sub> capacity of the Recycler TSP's. Nitrogen was introduced to the system with a freshly fired TSP and a 20 L/s ion pump. The nitrogen flow rate varied from a few E-6 to a few E-5 Torr-L/s. The black line is the internal pumping speed of the TSP and IP; the other lines are the system pumping speed of the test setup.

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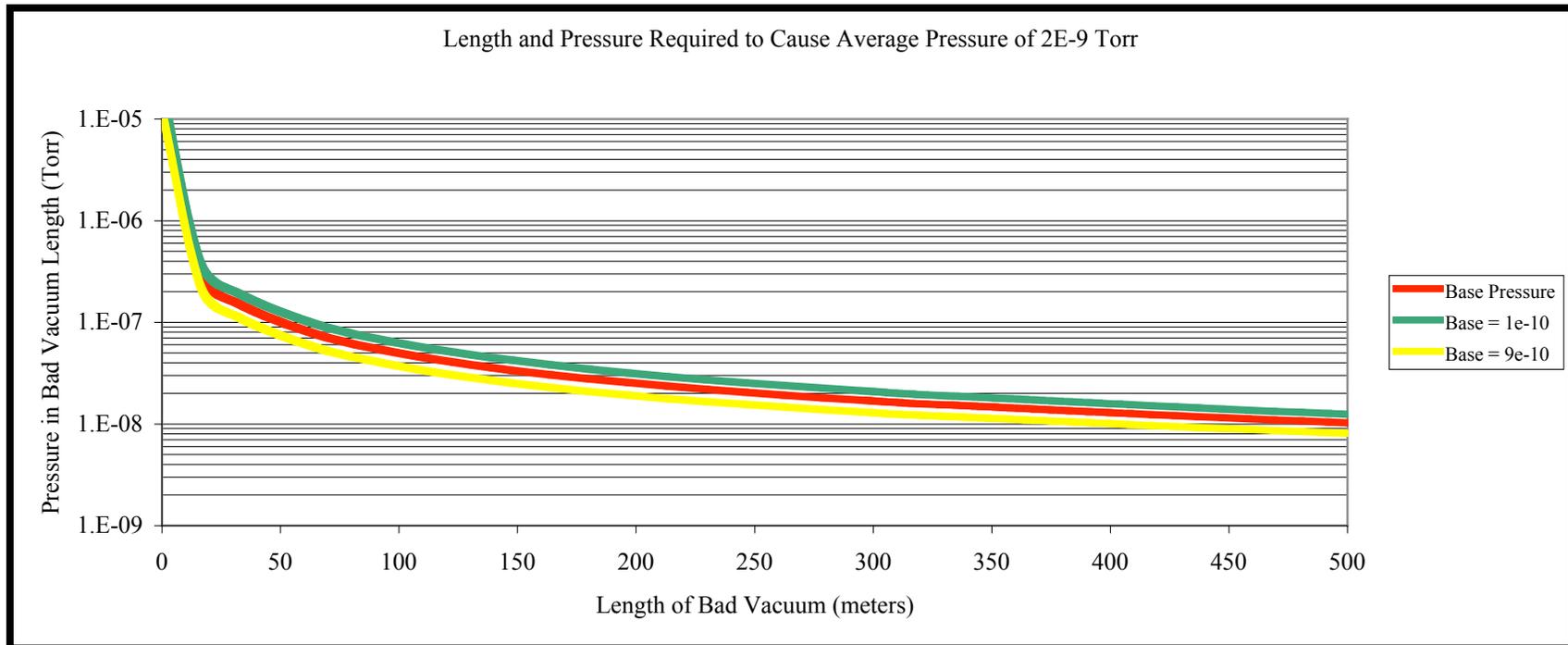
This plot shows the out-gassing rates for the various gas species as a function of the total pressure at the pump locations using the average pump location RGA data. The right hand axis and the red dashed line show the ion gauge equivalent for a given total pressure. The basis for the plot is  $P_p = q_D B L_p / S$ , where  $P_p$  = pump pressure (Torr),  $q_D$  = specific out-gassing rate (Torr-L/s-cm<sup>2</sup>),  $L_p$  = pump spacing (cm),  $B$  = tube inside perimeter (cm).

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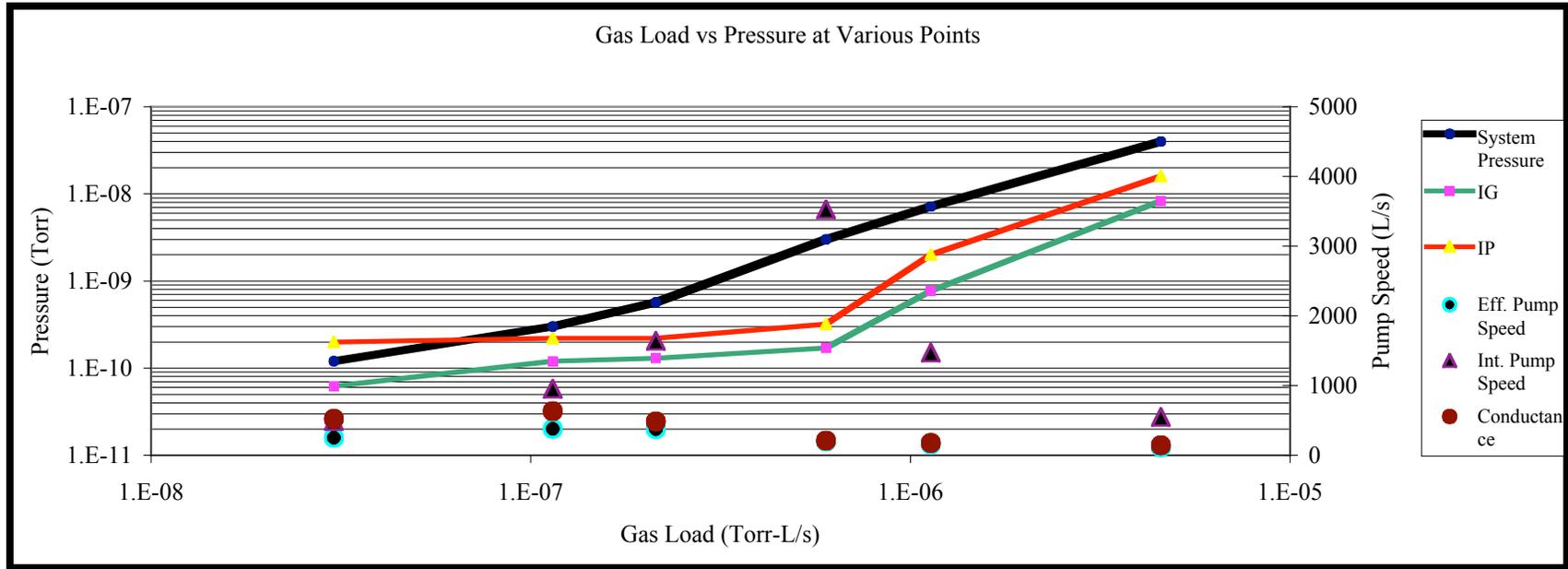
This plot shows the out-gassing rates for the various gas species as a function of the total pressure at the mid-point locations using the average mid-point location RGA data. The right hand axis and the red dashed line show the ion gauge equivalent at the pump for a given mid-point total pressure. The basis for the plot is  $P_m = q_D B L_p (1/S + 1/(4C))$ , where  $P_m$  = mid-point pressure (Torr),  $q_D$  = specific out-gassing rate (Torr-L/s-cm<sup>2</sup>),  $L_p$  = pump spacing (cm),  $B$  = tube inside perimeter (cm), and  $C$  = tube conductance (L/s).

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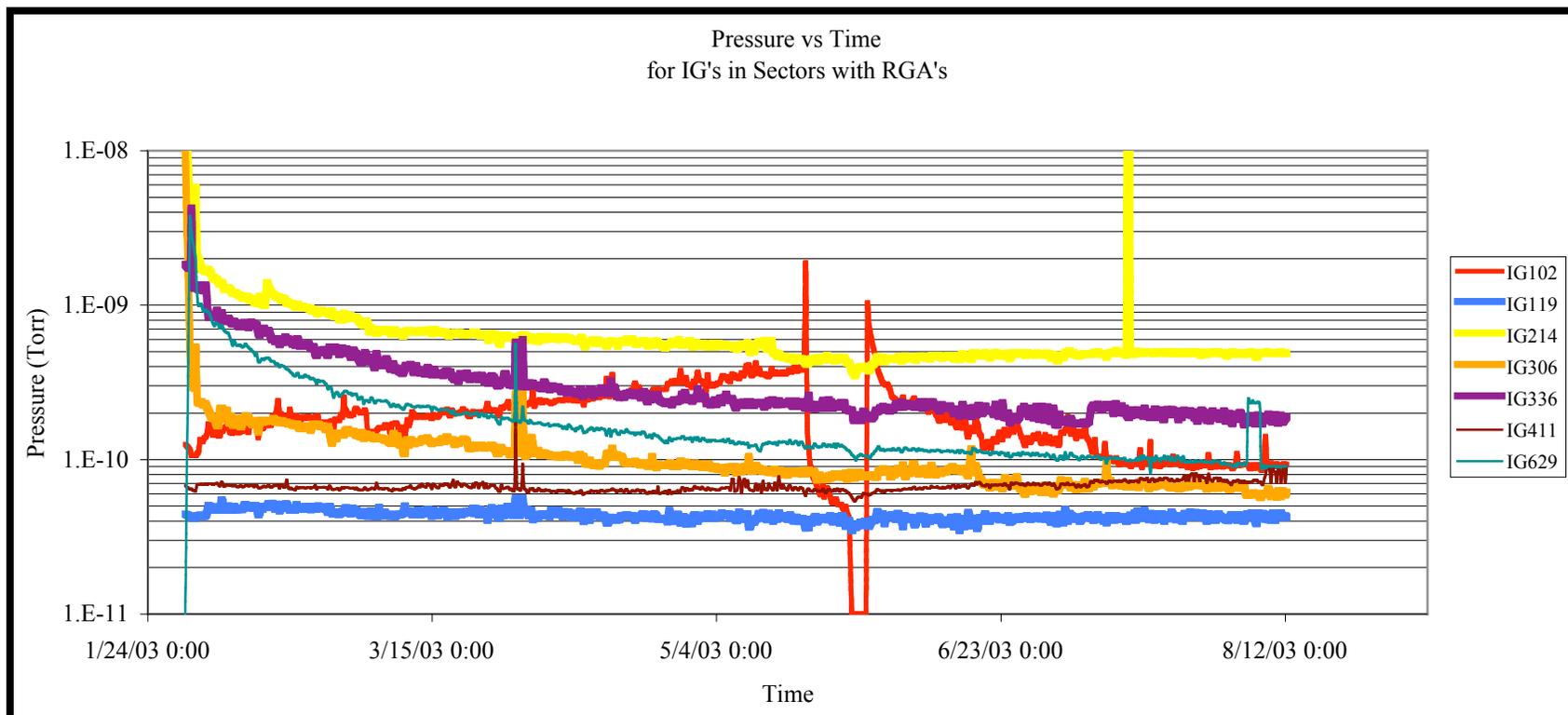
This plot shows how much of the Recycler vacuum chamber has to have poor vacuum, relative to some base pressure (5E-10 Torr in this case), in order to cause the average ring vacuum to be 2E-9 Torr. For example, if there is some section of the system that has an average pressure of 1E-8 Torr the total length of the poor vacuum needs to be about 500m to cause the average to be 2E-9. If that poor vacuum section has an average pressure of 1E-7 the length needs to be 50m.

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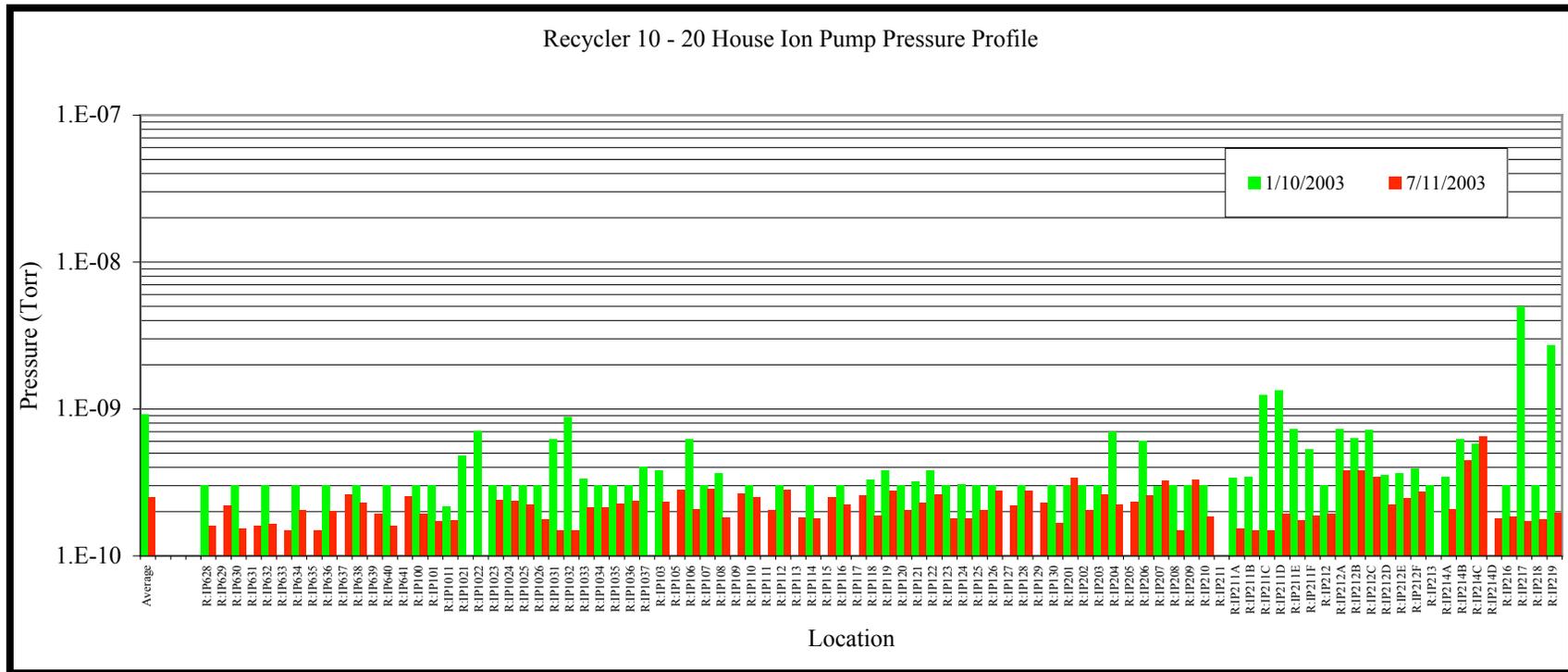
This plot is of test data that shows the relationship between the ion gauge pressure near the throat of the TSP (system side) and the ion gauge pressure on the backside of the TSP (IP or gauge side) for various flow rates.

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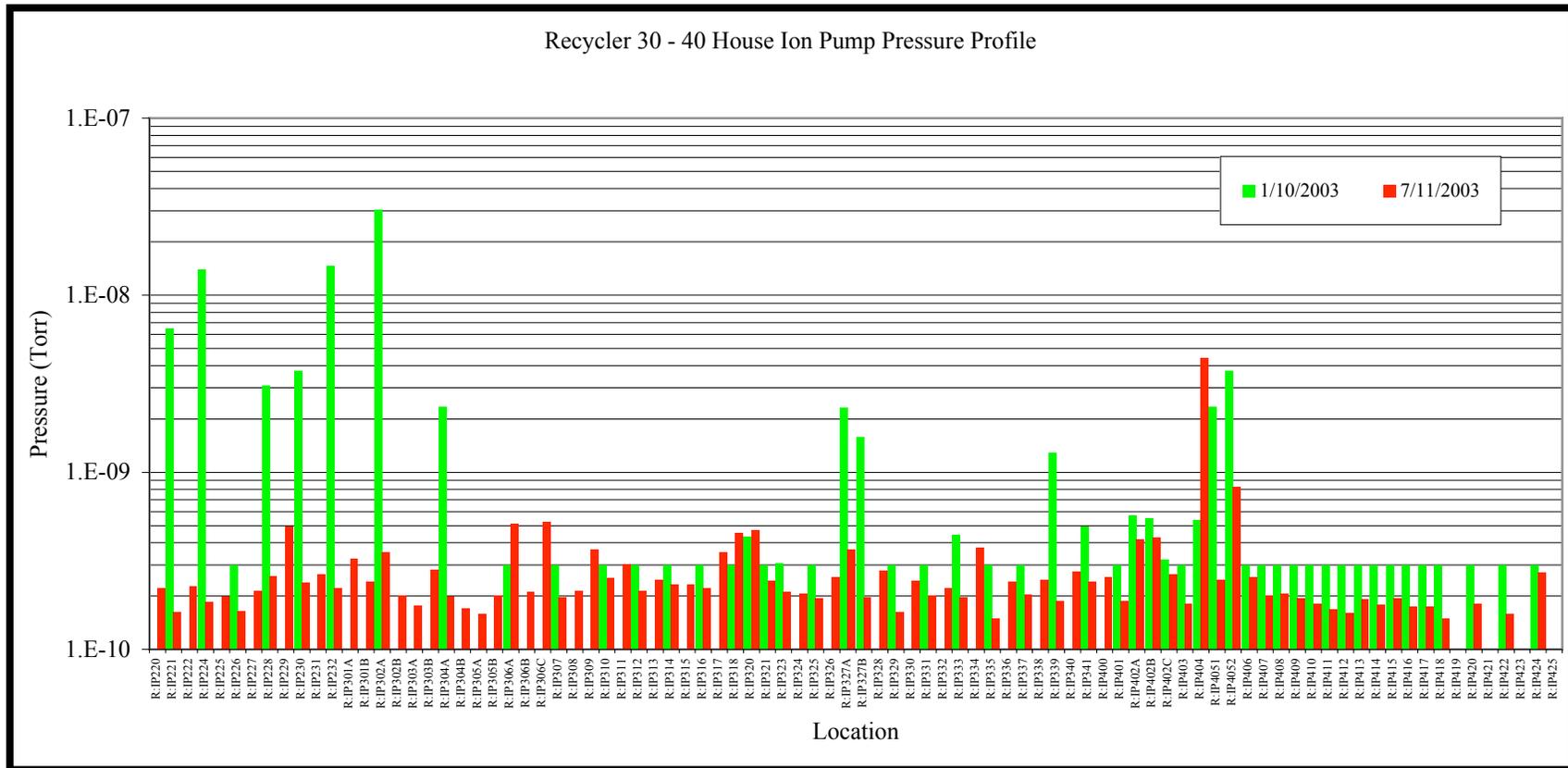
This plot shows the ion gauge history in the sectors that have RGA's. The plot starts at the time the TSP's were fired during the January 03 shutdown. The RGA data used in these notes was taken on 3/4/03.

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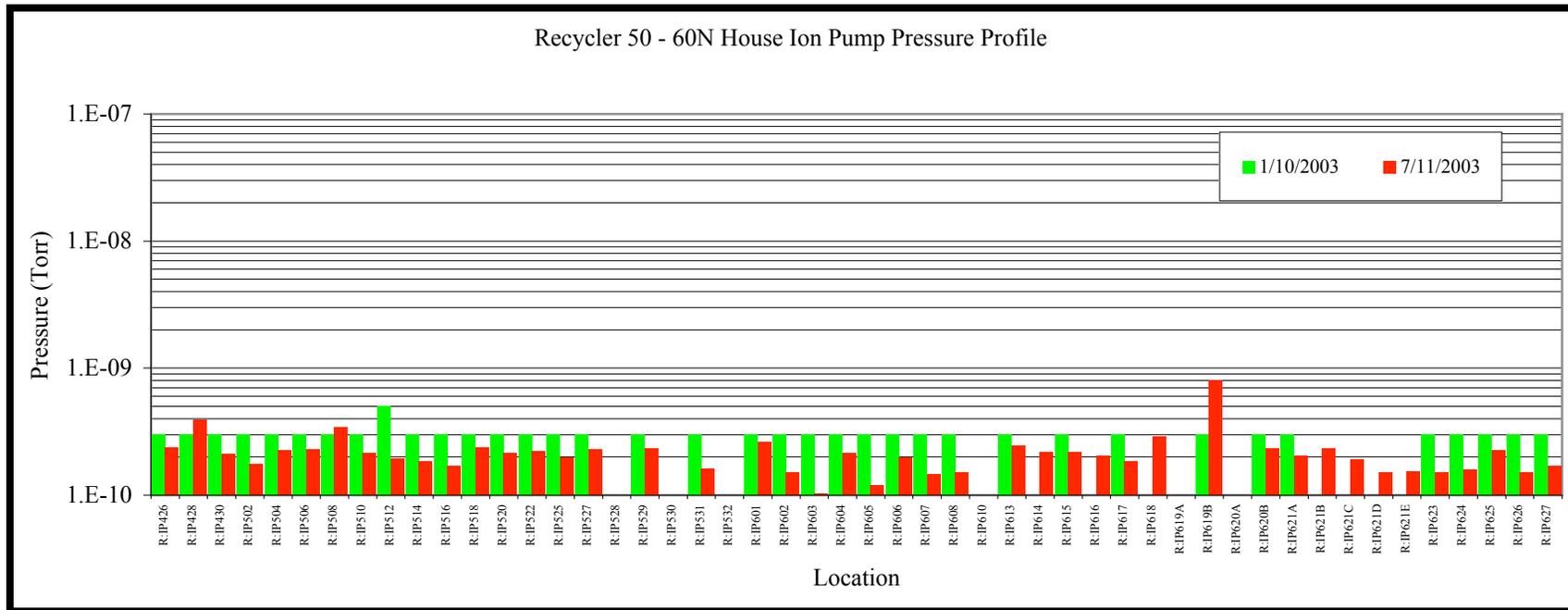
This is a plot of the Recycle ion pump profiles in the 10 and 20 houses before the January '03 shutdown and about six months after the shutdown. The average shown is for the entire Recycler ring and there is clearly an improvement between then and now.

## Recycler September 03 Shutdown Review Vacuum System



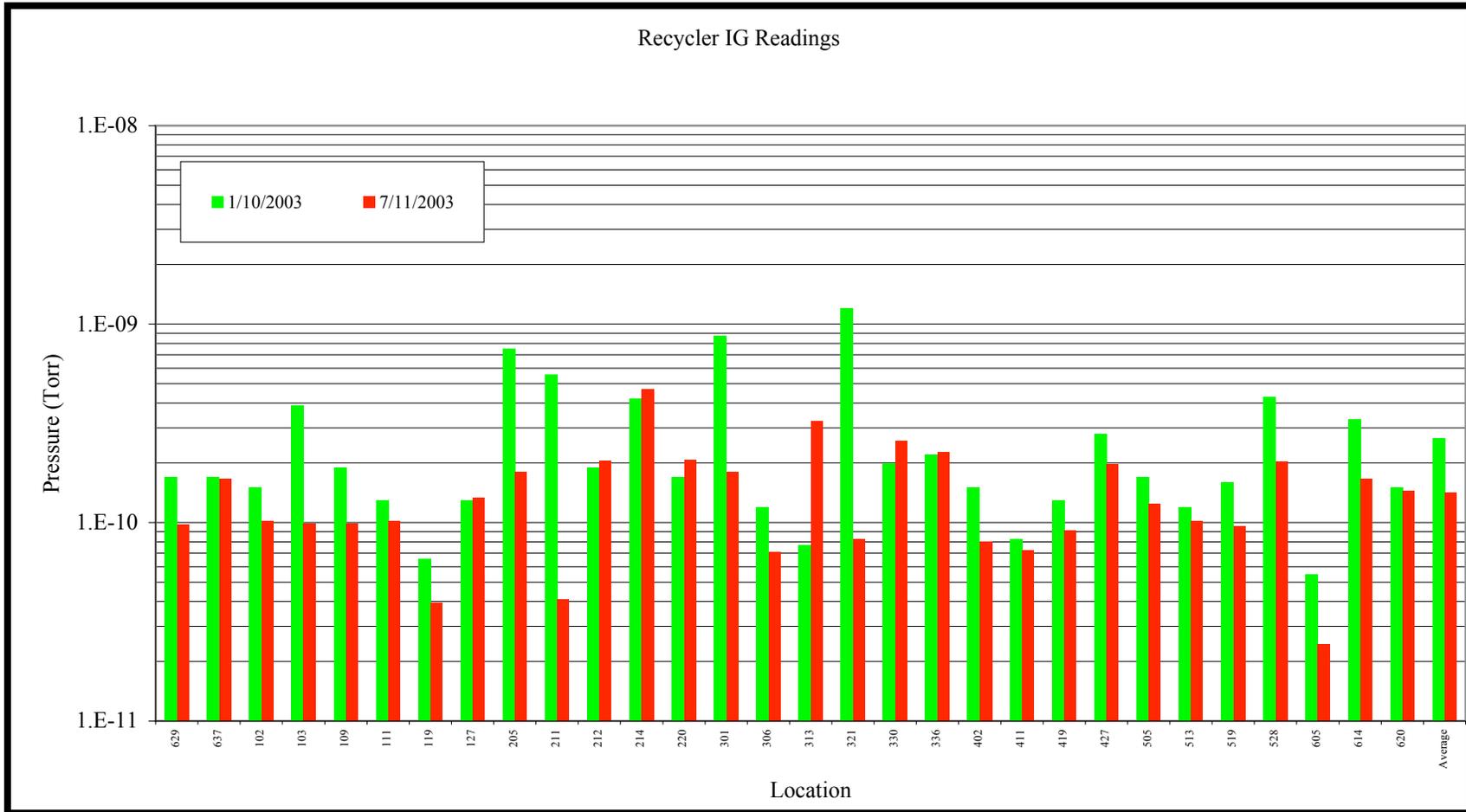
This is a plot of the Recycle ion pump profiles in the 30 and 40 houses before the January '03 shutdown and about six months after the shutdown. The high pressures at IP404 and IP4052 are the IPM locations and are known high gas loads. The TSP's in this location were fired on 7/2. It is suspected that the IP404 and IP4052 readings have a high leakage current at this time.

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This is a plot of the Recycle ion pump profiles in the 50 and 60 houses before the January '03 shutdown and about six months after the shutdown. The high pressure at IP619B is from the Flying Wire contamination.

## Recycler September 03 Shutdown Review Vacuum System



This is a plot of the Recycle ion gauge profiles for the entire ring before the January '03 shutdown and about six months after the shutdown. As can be seen by the average there has been improvement between then and now.