Fermilab

$\bar{p}$ NOTE #442

An Analysis of Accumulator Ring Pressure Data

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This note summarizes and analyzes the Accumulator Ring's pressure data taken during the recent commissioning run (March-October, 1985) and during the three week interval immediately after the end of the commissioning run. Emphasis is placed upon the questions raised in reference [1], viz.:

1. What is the ultimate vacuum attainable?
2. How do we calculate the "effective-pressure" for beam lifetime estimates from the ion gauge data?
3. What is the required sublimation schedule to maintain adequate vacuum?

I. Historical Perspective

Throughout the TEV-1 commissioning run the mean pressure in the Accumulator Ring[2] was gradually reduced by sporadic leak-hunting, baking, and sublimating on a "catch-as-catch-can" basis. By the end of the run a mean pressure of 1.6×10^{-9} Torr. had been achieved - in contrast to the Design Report's average pressure of 3.0×10^{-10} Torr.

Early in October, 1985, at the conclusion of the commissioning run, the TEV-1 Vacuum Group began a program of systematic leak-checking and sublimating. After several weeks of painstaking work, the mean pressure in the Accumulator Ring had been reduced to 2.9×10^{-10} Torr. Shortly thereafter several sectors of the ring were let-up to atmosphere for equipment modification. Consequently, the analysis here concentrates on data taken after the conclusion of the commissioning run but before the ring was let-up to air.

II. Analysis of Ion Gauge Readings

The pirani, cold-cathode and ion pump readback instrumentation are intended primarily to monitor the progress of the Accumulator Ring pump-down; only the twenty-four ion gauges are available for measuring the pressure in the UHV design region. In attempting to understand the ion gauge readings, it is useful to separate the data into two categories - readings from ion gauges mounted on tanks vs. those mounted directly on the the chamber - since they sample fundamentally different environments.

1). Data from Gauges Mounted on the Chamber

The expected reading of any of these ion gauges relies upon a knowledge of the chamber geometry, the pumping speed(s) and the chamber's specific outgassing rate. While the Accumulator Ring's geometry and pumping speeds are well-known, reliable specific outgassing rates are, in general, notoriously difficult to assign. Data from the LEAR and AA Vacuum Group for unbaked UHV-treated stainless steel indicate specific outgassing rates between 2 x 10^{-9} and 7 x 10^{-12} Tℓ $sec^{-1}cm^2$ depending upon the length of time for which the system is pumped.[3]

Data on outgassing rates of UHV-treated stainless steel which is additionally baked in situ at low temperature are more confusing and appear to be less reliable. The results appear to depend upon a large number of parameters - including the time-integrated history of the material subjected to the low temperature in situ bake.[4] For UHV-treated stainless steel chambers baked in situ for 24-36 hours at 150°-300°C, recommended specific outgassing rates cover the range from 4 x 10^{-12} to 1 x 10^{-13} Tℓ $sec^{-1}cm^{-2}$. The "most popular" recommendation seems to be a value of 1 x 10^{-12} Tℓ $sec^{-1}cm^{-2}$ for UHV-treated systems baked to 300°C for 24 hours or more.

In view of (and in spite of) these uncertainties, we have elected to use the outgassing rates shown in Table 1.

Table 1. Assumed Outgassing Rates for Accumulator Ring Vacuum Chamber

Temperature at Which The Chamber was Baked (°C)	Specific Outgassing Rate (Tℓ $sec^{-1}cm^{-2}$)
100	2.0 x 10^{-12}
150	1.5 x 10^{-12}
200	1.0 x 10^{-12}

The choices shown in Table 1 are close to the values recommended in the literature and they accommodate the fact that different portions of the Accumulator Ring's vacuum chamber have been baked at different temperatures.

The data of Table 1, together with a pumping speed of 2000 ℓ.sec^{-1} for the TSP's, is sufficient to calculate the expected pressure at each ion gauge in the non-tank areas. The results, shown in Table 2, indicate:

1. The agreement between the calculated and measured pressures, given the major uncertainties in outgassing rates, is excellent. On average the ion gauge data is 50% higher than the calculated pressure.

2. A small, residual leak <u>may</u> still exist in the vicinity of A1Q4.

3. A pumping speed of 2000 $\ell.sec^{-1}$ seems to be appropriate for the TSP's.

2). Data from Gauges Mounted on Tanks

The calculated pressure for the stochastic cooling tanks and the injection and extraction kickers uses as input a total gas load of 8.9 x 10^{-7} Tℓ sec^{-1} for a typical tank in the A20 straight section.[5] The gas loads for tanks in the A10, A30 and A60 sectors were scaled to those of A20 by the ratio of tank lengths. In addition, the gas load in the A60 tanks was increased by 20% to account for outgassing from the cryoshields.[6]

Table 3 contains a comparison of the measured and calculated pressures for the Accumulator Ring tanks.

One notes:

1. There is a strong suggestion of a leak at or near tank A514A at the time this data was taken (Oct. 21, 1985).

2. On average, the agreement between the ion gauge data and the calculated pressures for the stochastic tanks is about a factor of two worse than (the agreement) for the non-tank areas. To some extent one might have expected that the tanks would outgass somewhat more than one calculates; however, the measured pressures in the injection and extraction kicker - components with gas loads comparable to those of the stochastic cooling tanks - agree with the calculation rather well.

III. Accumulator Ring Average Pressure

During the commissioning run the index which was used to monitor the Accumulator Ring's pressure was the mean (i.e., arithmetic average) ion gauge pressure. This index bears virtually no relationship to the average ring pressure for two reasons: (1) It weights each gauge equally (e.g., the two-foot-long tanks in the A10 straight section are weighted as heavily as the entire A40 straight section); and (2) It does not take into account that some gauges are located at positions where the pressure is below the average while others are located at places where the pressure is above average. To "unfold" an average ring pressure from the ion gauge data requires the application to each ion gauge reading of a weight which accounts for these effects. The appropriate weight-factors for each gauge are given in Table 4, together with the mean pressure by sector and the average pressure by sector.

Table 4 illustrates, as expected, that the average pressure is much more uniform, sector-to-sector, than the arithmetic mean of the ion gauges. The (anomalously) high values for the average pressure in sectors A10 and A60 can be "explained" by the suspected leaks at A1Q4 and Tank A514A.

IV. "Ultimate" Accumulator Ring Pressure

The comparisons made in Tables 2-4 suggest the presence of small leaks near A1Q4 and Tank 514A. Assuming that such leaks actually exist and can be found and eliminated, an average ring pressure of about 4.9×10^{-10} Torr. should result.

One will be hard-pressed to improve the Accumulator Ring pressure much beyond this. Table 3 indicates that the stochastic cooling tanks, on average, outgass about 3.5 times more than expected. However, there is very little to be gained by attempting to lower the outgassing rate of the stochastic cooling tanks. For example, reducing the outgassing rate of the cooling tanks in the A30 sector - the sector in which the stochastic cooling tanks present the greatest path-length to the beam - by a factor of 3, would reduce the average pressure in sector A30 by only 25%; i.e., for a leak-free ring, the average ring pressure is strongly dominated by the specific outgassing rate of the chamber.

Table 2 indicates that the bare chamber outgassing rate is about what one should expect. Improvements could be made by baking most of the ring to a higher temperature than has been used in the past (100-200°C). Given, however, that a high temperature bake is an <u>intrinsically</u> high-risk procedure, it is unattractive to rely on such a recourse as Standard-Operating-Procedure.

Should it ever be necessary to make a dramatic improvement in the Accumulator Ring's average pressure, a significant increase in the net pumping speed (by the addition of more pumps) would be the most direct approach.

V. Sublimation Schedule

The appropriate sublimation schedule has been calculated to be approximately once every 3 months.[7] Since the residual gas pressure in the ring is 3-4 times higher than what was used in these calculations, the TSP's should be sublimated more often - approximately once every 3 weeks.

Table 2. Comparison of Calculated Pressures and Ion Gauge Readings (Non-Tank Areas)

Sector	Ion Gauge	Gauge Pressure (10^{-10} Torr .)	Assumed Outgassing Rate (10^{-12} Tℓ sec^{-1} cm^{-2})	Calculated Pressure (10^{-10} Torr)	Ratio of Measured to Calculated Pressure
A10	IG603	0.29	2.0	0.30	1.0
	IG104	1.44	2.0	0.35	4.1
A20	IG109	0.44	2.0	0.36	1.2
	IG207	0.36	2.0	0.26	1.4
A30	IG204	1.70	1.0	0.90	1.9
	EG303	3.97	1.0	3.00	1.3
	IG305	0.47	1.0	0.18	2.6
A40	IG414	0.89	2.0	0.44	2.0
	IG409	0.56	2.0	0.36	1.6
A50	IG405	0.50	1.5	0.26	1.9
	IG404	2.42	1.5	4.70	0.5
	IG500	3.76	1.5	1.20	3.1
	IG505	0.41	1.5	0.26	1.6
A60	IG509	0.10	2.0	0.36	0.3
	IG609	0.19	2.0	0.36	0.5

Table 3. Comparison of Calculated Pressures and Ion Gauge Readings for Accumulator Ring Tanks

Sector	TANK	Gauge Pressure (10^{-10} Torr .)	Calculated Pressure (10^{-10} Torr)	Ratio of Measured to Calculated Pressure
A10	A600	2.0	1.1	1.8
	A100	3.8	1.1	3.5
A20	A114A	1.2	0.73	1.6
	A114B	5.8	1.3	4.5
	A214B	4.4	1.3	3.4
	A214A	1.1	0.73	1.5
A30	A200B	3.3	1.1	3.0
	A200A	2.8	1.5	1.9
	A300	1.8	1.2	1.5
A60	A514A	18.3	1.1	16.6
	A514B	8.0	1.3	6.2
	A614B	6.0	1.2	5.0
	A614A	5.2	1.1	4.7

Table 4. Measured Ion Gauge Data, Ion Gauge Weight-Factors and Average Pressure by Sector in Accumulator Ring

Sector	Gauge	Gauge Pressure (10^{-10} Torr.)	Mean Sector Pressure (10^{-10} Torr.)	Gauge Weight Factor *	Average Sector Pressure (10^{-10} Torr.)
A10	IG603	0.29	1.90	7.41	9.64
	IG600	2.05		.033	
	IG100	3.83		.033	
	IG104	1.44		5.07	
A20	IG109	0.44	2.22	2.87	5.43
	IG114A	1.18		.27	
	IG114B	5.85		.20	
	IG214B	4.36		.20	
	IG214A	1.12		.27	
	IG207	0.36		4.03	
A30	IG204	1.70	2.35	1.03	5.81
	IG200B	3.31		0.26	
	IG200A	2.85		0.22	
	IG300A	1.80		0.26	
	IG303ℓ	3.97		.048	
	IG305	0.47		4.07	
A40	IG414	0.89	0.73	2.64	3.95
	IG409	0.56		2.86	
A50	IG405	0.50	1.77	2.03	4.37
	IG404	2.42		0.17	
	IG500	3.76		0.23	
	IG505	0.40		5.15	
A60	IG509	0.10	6.30	2.87	10.11
	IG514A	18.3		0.33	
	IG514B	8.00		0.084	
	IG614B	5.96		0.14	
	IG614A	5.24		0.33	
	IG609	0.19		2.91	

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* For example, the average pressure in sector A10 is:

$$\langle P\rangle_{A10}=7.41\,P_{Gauge}((IG603)+0.033\,P_{Gauge}(IG600)$$
$$+\,0.033\,P_{Gauge}(IG100)+5.07\,P_{Gauge}(IG104)$$

References

1. G. Dugan, TEV-1 Analysis Tasks, Oct.23, 1985 (unpublished).

2. Herein, "Mean Pressure" is the Arithmetic average of a number of ion gauge readings. "Average Pressure" is the (true) spatial average of the pressure, determined as described in Section III.

3. A. Poncet, PBAR Note #297, May 20, 1983.

4. J. F. O'Hanlon, A User's Guide to Vacuum Technology, John Wiley and Sons, New York, 1980.

5. A. Poncet, PBAR Note #303, June 4, 1983;
   S. Mtingwa, PBAR Note #294, May, 1983.

6. J. Marriner, private communication.

7. A. Poncet, PBAR Note #296, May 23, 1983.