BNL-35121
INFORMAL REPORT

NOTICE
PORTIONS OF THIS REPORT ARE ILLEGIBLE.
It has been reproduced from the best
available copy to permit the broadest
possible availability.

X-ray ring performance after spring shut down

Henry J. Halama

NATIONAL SYNCHROTRON LIGHT SOURCE

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Under Contract No. DE-AC02-76CH00016 with the

UNITED STATES DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

X-RAY RING PERFORMANCE AFTER SPRING SHUT DOWN

Henry J. Halama

July 1984

Research Supported by the
OFFICE OF BASIC ENERGY SCIENCES
U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C.

NATIONAL SYNCHROTRON LIGHT SOURCE DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Under Contract No. DE-AC02-76CH00016 with the
U.S. Department of Energy

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

Abstract

This report covers vacuum studies carried out over 4 months' period April - July 1984 including some comments on the shut down. The data relies heavily on partial pressure analysis which is used to calculate beam lifetimes. Discrepancies between these calculated values and the real lifetimes are also discussed and some explanations suggested. An attempt is made to measure synchrotron light desorption and the pumping speed of the distributed ion pumps which appears to be very small at low pressures. Finally I will outline a possible course of action to improve the pumping speed as well as the beam current and its lifetime. At present the lifetimes routinely achieved are 1 hr for 50 - 60 mA and several hours 20 - 30 mA at 1.7 - 2 GeV. Fast beam drop-outs are not directly pressure related but are caused by other mechanisms. They present a serious problem and vary greatly with day to day operation. Equipment failure may be an important contributor to this problem.

I. SHUT-DOWN

During the shut down the following tasks were performed:

- a. The entire X-ray ring was thoroughly leak checked and all leaks were repaired. A few inaccessible leaks in welds as well as a few small leaks that developed during the bake out were sprayed with Celvaseal manufactured by CVC. The ring was left leak free using detectors with sensitivity of 1×10^{-10} Torr L s^{-1} or better. All leaky flanges and bellows were replaced.
- b. The entire ring was baked out above 100°C ($\sim 120^{\circ}\text{C}$ average), stainless tubes and ion pumps were baked to higher temperatures ($150 - 200^{\circ}\text{C}$). Hot nitrogen from LN_2 boil-off was bled through the ring

during the warm up time (~ 4 hours) and the purging continued for ~ 1 hour after the equilibrium bake out temperature was reached.

The purge was then stopped, the ring was evacuated and the bake was continued for more than 24 hours.

- c. All filaments in Ti sublimation cartridges were conditioned i.e. degassed to 50 A.
- d. All DIP's and SIP's were conditioned (turned on at high pressure and operated for ~ 1 min.; DIP's showing high leakage currents were "spark-knocked".
- e. 2 BA gauges and 2 mass spectrometers were calibrated and installed before the bake out.

After the bake out the pressure in the X-ray ring was $\sim 5 \times 10^{-10}$ Torr (N_2 equivalent) as read on the 2 calibrated gauges. 1 day after sublimation the pressure dropped below 1×10^{-10} Torr and remained there. Residual gas spectra confirmed that the bake out was a success, showing hydrogen content of ~ 90%. The remaining 10% were due to CO, CO₂ and H₂O in that order. It should be pointed out that the gauges are mounted above the combination of ion and Ti sublimation pump where the pressure is at minimum.

II. PARTIAL PRESSURE ANALYSIS

In a leak-free, well baked out system the pressure depends on the gas load due to synchrotron radiation which in turn is determined by the surface condition of the vacuum chamber and the installed pumping speed. From equation 1 in Ref. 1 the gas load for our conditions should increase linearly

with current and more strongly with energy through η_{ph} (photoelectron yield per photon), and η_e (molecular yield per photoelectron).

From our data the gas evolution dependence on current, appears to be less than linear. Due to a large scatter in the data for different runs this dependence cannot be quantitatively determined. Fig. 1 shows the results from a run on 6/28. Partial pressures at 750 MeV and 1.7 GeV are shown in Fig. 2 for 2 different orbits in the vacuum chamber. Fig. 3 depicts the conditioning of the good port orbit in the X-ray ring and shows a better than factor of 3 improvement between the beginning of May and the end of June.

A substantial amount of conditioning primarily of the good port orbit as well as spark-knocking of all DIP's were carried out between June 28 and July 17 when another 8 hours vacuum study took place. The CO and CO₂ contents were lowered by 45 and 50% respectively resulting in total decrease of desorption by a factor of 5 for the above 2 gasses during the time between the shut down and July 20. The largest gain in lowering the desorption was due to conditioning at 2.05 GeV, since the desorption is much stronger at high energy. (Fig. 4) Lifetimes have also been improved proportionately. General appearance of mass spectra indicates a leak free, reasonably clean baked out vacuum system similar to other electron storage rings.

III. BEAM LIFETIME

In this chapter the lifetime is calculated¹ from partial pressure data recorded at one location only, i.e. at XIBM1. Besides a systematic error in the MS calibration, other parts of the ring as for example the RF cavity, can have considerably higher pressures. These two effects may change the absolute

value of lifetime by a factor 2 or 3. Nevertheless the relative values of the calculated lifetimes as a function of energy and beam current should be much closer and should provide a reasonable basis for comparison.

Lifetimes, τ_c , are calculated using Eq. 4 and 5 from Ref. 1 and are compared with the measured lifetime τ_m in Table I.

TABLE I. Comparison of measured and calculated lifetimes

day	I	P(M=28)	Fig.	τ_c	τ_m	E	τ_c/τ_m		Ring
	mA	10^{-9} Torr		min		GeV			
5/5	50	4	3	84	35	1.7	2.4	good port	X
6/28	51	1.2	1+3	264	51	1.7	5.17	good port	X
6/28	54	0.8	1	536	71	1.7	7.9	inj.	X
6/28	22	0.72	1	500	86	1.7	5.8	good port	X
5	200	4.2		132	120	750	1.1		UV

Disregarding the previously mentioned errors one can notice that the τ_c/τ_m ratio increases with decreasing current thus suggesting other mechanisms such as ion trapping etc. may play an important role.

IV. DISTRIBUTED ION PUMPS, DIP

A. Pumping Speed

It is a well known fact that the pumping speed of ion pumps decreases drastically below 10^{-9} Torr range. In many cases the speed approaches zero or may even become negative i.e. the pumps generate

gasses which were previously pumped. In systems where H_2 is the predominant gas, the pumping speed is reduced due to poor sputtering of Titanium by H_2 ions. In order to maintain high pumping speed in 10^{-9} and 10^{-10} Torr ranges, chemical pumping such as Ti sublimation or solid getters must be used.

In order to measure the pumping speed of the distributed ion pump (XIDP1) a calibrated mass spectrometer was mounted behind X1BM1 magnet and partial pressures were recorded. Since the combination of ion (SIP) and Ti sublimation pumps are located ~ 115 cm from the edge of the magnet the pumping speed with DIP off at this point is determined by the gas conductance of the beam tube which is

26 l/s for CO, N_2 ($M = 28$)

100 l/s for H_2 ($M = 2$)

21 l/s for CO_2 ($M = 44$)

and the pumping speed of SIP - Ti combination. The total speeds in the magnet for CO, CO_2 and H_2 are < 50 l/s < 40 l/s and < 150 l/s respectively due to adjacent pumps. By switching the DIP on and off, partial pressures can be compared and the speed of the DIP can be estimated. Several experiments were run with the pressure varying from below 5×10^{-10} to 5×10^{-9} Torr from which the following observations could be made:

- a) N_2 equivalent pressure of $\leq 1 \times 10^{-9}$ torr is required to ignite the pump at both 750 MeV and 2 GeV. The pumping speed below this pressure is zero.

- b) Pumping speed at 750 MeV is lower than at 2 GeV possibly by a factor of 1.5 or 2.
- c) as the gas load increases due to desorption thus increasing the discharge current density, the pumping speed for CO increases from $< 20 \text{ l/s}$ at above 1×10^{-9} torr to considerably higher levels.
- d) the pump appears to be clean i.e. no large gas loads are observed when the pump ignites.

In order to confirm that the speed is indeed very low, both the DIP's and SIP's were turned off and their effect on beam lifetime, τ , was observed as shown in Table II.

TABLE II.

	I mA	τ min
All pumps on	36	57
50% DIP's off	32	53
100% DIP's off	27	53
All pumps on	39	50
50% ring SIP's off	35	56
100% ring SIP's off	32	56
100% + Front End SIP's off	30	56
+ 50% DIP's	25	29
All pumps off	20	18
All pumps on	7.5	132

During the above experiment with SIP's and DIP's off, only slight changes were observed in the partial pressures of the active gasses (H_2 , CO, CO_2) which agrees with the pumping speed measurements and confirms the fact that most of the pumping speed for active gasses is due to the Titanium sublimation pumps. With all ion pumps off, the methane and argon peaks increase rapidly and destroy the beam. Similar experiments were performed on 6/28 with higher currents (~ 50 mA). Pumping speed measurements were unchanged but a larger drop in the lifetime was observed when the DIP's were turned off. After all DIP's have been spark-knocked during the 4th of July maintenance period a noticeable improvement was measured in pumping speed of 1DIP1. The effect on the lifetime by switching DIP's off is shown in Table III.

TABLE III (July 17) E = 1.7 GeV

	I(mA)	τ min
All DIP's on	55	70
8 DIP's off	48	61
8 DIP's off	46	63
All DIP's off	41	63
All DIP's off	37	73
All DIP's on	30	102

5 mA were lost during the DIP's turn on.

B. Leakage Current

The total X-ray ring pressure is read by averaging all DIP currents and this reading depends intrinsically on the leakage current, which has been increasing from the shutdown values and by the end of June reached in some pumps values 2 orders of magnitude higher, thus

invalidating all pressure readings displayed on the TV screen. Especially X7DP1, X7DP2 and X8DP1 reached more than 5×10^{-9} Torr with beam off. After these pumps were "spark-knocked" the dark currents returned to their original values. This event is recorded in Fig. 5A, 5B and 5C.

V. ION PUMPS

The pumping speed of these pumps is difficult to measure since they contain a titanium sublimator which cannot be switched off. Largest peculiarity is an almost 2 order difference in current reading between two adjacent pumps mounted in the front Ends. Some difference should exist due to different conductances which depend on the length of the connection between the beam tube and the pump. (Fig. 7).

VI. RF CAVITY

The pressure in the cavity is determined by the surface condition and by the temperature of the walls and is nearly independent of beam current. With ~ 10 kW in the cavity (1.7 GeV operation) the pressure stays usually in high 10^{-9} Torr or low 10^{-8} Torr range but with 40 - 50 kW of rf power the pressure in the cavity goes occasionally into 10^{-7} Torr range increasing the pressure in the entire sector which then constitutes a limit on the beam lifetime.

The distance between the adjacent pumps including the cavity length is about 7 m and the pressure decays parabolically to the pump pressure in that distance. If multipactoring occurs, approximately 7 m of the ring rises to a high pressure and could cause a sharp decrease in the beam current. In addition high pressure may extend to the entire superperiod as is shown in

Fig 6A and 6B. Several similar events were recorded at different powers. After this occurrence the pressure takes many minutes to come down. There are many possible explanations i.e. multipactoring, local heating, and poor pumping speed. We are presently working on reducing the outgassing both due to high power rf input and due to multipactoring. Since RF conditioning does not seem to eliminate multipactoring barriers.

VII. CONCLUSIONS COMMENTS AND SUGGESTIONS

- a. The pumping speed of the distributed ion pumps in the low 10^{-9} and 10^{-10} Torr ranges is vanishingly small and should be increased before significant improvement in the beamlife x current product can be realized. Pumping speed improves rapidly with higher gas loads. In general the low pressure pumping speed of ion pumps is improved by a high temperature bake (500°C), by glow discharge in air or by "spark-knocking" if field emission is present. Measurements carried out by C. Foerster on a DIP (half the size of those used in the X-ray ring) confirmed that glow discharge in N_2 at room temperature raised the pumping speed at $1 \times 10^{-7} - 10^{-8}$ Torr close to the pumping speed at 10^{-6} Torr which was approximately 100 l/s. Prior to this September shut down I suggest we measure the speed in 10^{-6} Torr range and implement at least cold glow discharge with N_2 . It is not clear how permanent this cure will be.
- b. At present, the major pumping at low pressures is provided by the existing titanium sublimation pumps, which is the situation in many UHV application elsewhere. The ion pumps are pumping primarily CH_4 and Ar . It is suggested that ample pumping speed be provided in

future front ends and special devices by inexpensive Ti cartridges mounted in 6 - 8" cylinders and combined with a 20 - 30 l/s ion pumps. (Memo to Hank Hsieh and Joe Schuchman, dated 6/15/84). These units will also help to make up for low pumping speed of DIP's and at these locations 20 l/s ion pumps can be eliminated altogether.

- c. From the data accumulated the beam lifetime seems to depend more on various other phenomena, such as various instabilities, rf problems, bucket size, beam size, ion trapping, etc than on the pressure. Sharp drops in intensity are not due to gas present in the ring. Likely causes are fast instabilities, ion trapping, multipactoring, equipment failure, dust particles,² etc.
- d. Substantial beam conditioning has already occurred in the X-ray ring and the beam tube appears to be reasonably clean. Recently the beam was brought to the same current and lifetime product after a week's pause with only 1 or 2 fills. This fact assures us also that no significant leaks have opened in the X-ray ring. To reach a few hundred mA for a few hours, some conditioning of the chamber will be required. We are studying O₃ scrubbing and N₂ glow discharge, on a spare magnet chamber. If these tests are successful we will be ready to implement the above cleaning methods later this year.
- e. To eliminate large pressure rises in RF cavities a simple N₂ glow discharge will be tried first. This process will clean the surface by ion bombardment and will thus decrease the desorption during

multipactoring. Hopefully it will also lower the secondary electron coefficient and prevent the multipactoring. If the glow discharge is not sufficient, the surface of the cavity will be nitrided.

- f. Only a very limited investigation was carried out on the UV ring. The main difference between the mass peaks is a higher content of water and a rather large argon peak. Argon is completely absent in the X-ray ring. Only Ar is significant for beam lifetime and can be eliminated by the bake out and pump conditioning during September shut down. Calculated lifetime agrees well with the measured one (Table I) at least in two cases compared. Between May and July partial pressure decreased by about 50%. It is recommended that the same treatment be given to the UV ring in September as was given to the X-ray ring in the Spring. Ion pump conditioning should be lengthened to improve pumping speed by N₂ glow discharge during the bake out.

ACKNOWLEDGEMENT

I would like to thank all who worked hard and long hours during the shut down. They deserve much of the credit for the significant improvement in the performance of the X-ray ring. In particular I thank Jim Briggs and his group for eliminating all leaks, Ernie Lange who supervised the bake out, Chris Lanni and Phil Stattel who calibrated the BA gauges and mass spectrometer. Fruitful discussions with T. S. Chou, C. Foerster, S. Krinsky and J. Shuchman are gratefully acknowledged. Last but not least I would like to thank A. Mathewson for his critical reading of the manuscript and his helpful suggestions.

REFERENCES

1. H. J. Halama, Vacuum and Lifetime in Electron Storage Rings, NSLS Informal Report BNL-34177.
2. A. W. Maschke, Heavy Ion Fusion Tech Note No 84-1 (1984) on abrupt life shortening in electron storage ring.

Note added in proof.

The number 3 cavity was assembled, leak checked and all leaks were repaired. After bake out RF power was fed into the cavity where many multipactoring barriers were observed starting at a few watts and continuing all up to 3 kW, which was the power level limited by the existing coax cable. After more than a day of conditioning no progress was made and I decided to glow discharge the cavity using the following parameters:

Voltage	540 V
Current	300 mA
Pressure	$5 - 10 \times 10^{-3}$ torr N_2
Temperature	$> 100^\circ \text{ C}$

After a dose of $< 1 \times 10^{18}$ ions/cm² the glow was stopped, the cavity was reassembled for RF power tests and baked out. No multipactoring could be observed even with CW power introduced into the cavity which constituted the most stringent condition. This is the first time multipactoring has been eliminated in a NSLS RF cavity. One can say with cautious optimism that a new, simple method has been developed to overcome this bothersome phenomenon. As soon as the 70 kW feed line is completed, full power will be introduced into the cavity and final extensive tests will be run. The same treatment will also be given to cavity number 4, the assembly of which is in progress. After the above is completed a full description of this method will be published.

FIGURE CAPTIONS

1. X-ray ring beam current at 1.7 GeV vs partial pressure.
2. X-ray ring partial pressure of main gas components at different energies.
3. Beam conditioning of the X-ray ring; Partial pressure vs time.
4. Partial pressure of CO, CO₂ and CH₄ vs energy in the X-ray ring on July 13 (good port orbit.)
5. Current readings for ion pumps with no beam
 - A. 5/07/84
 - B. 7/02/84
 - C. 7/10/84
6. Pressure Bump around the RF Cavity X3D1IP
 - A. 3 kW of RF, no beam most likely multipactoring.
 - B. 40 kW of RF no beam.
7. Front End pump currents at 10 mA 2 GeV.

Fig 1

Fig 2

Fig 3

Fig 4

No
beam

X_RAY ION AND DISTRIBUTED PUMPS RACKS 2&

FIG 5A

No Beam

FIG 5C

7 02/84 11 58:37

No beam
3 kW

RAY ION AND DISTRIBUTED PUMPS RACKS 0&

6A

No beam

40 kW
RF

X-RAY ION AND DISTRIBUTION PUMP'S PRESSURE

6B

10 mA
2 GeV

02 04 11 +6.50

UMP =

RAY FRONT END PUMPS

FIG 7