

**The Recycler vacuum system overview**  
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the Recycler Ring shutdown vacuum work review  
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**The ring**

The Recycler is an 8.9-GeV/c fixed energy storage ring for antiprotons (reverse protons), which uses primarily permanent magnets.

Circumference	3320 m
Average beta	40 m (both planes)
Max. beta	55 m (vert. 85 m in two locations)
Transition gamma	20.7
Transverse acceptance (measured)	60 $\pi$ $\mu$ m (normalized horizontal) 40 $\pi$ $\mu$ m (normalized vertical)
Momentum aperture (measured)	+/- 0.3%
Emittance growth rate (design)	2 $\pi$ $\mu$ m/hr (95%, norm)
Initial lifetime (design)	greater than 200 hrs

It has been reported that the measured beam lifetime and the emittance growth rate (immediately prior to the previous shutdown of Jan. 2003) were:

Emittance growth rate (measured destructively)	5 $\pi$ $\mu$ m/hr (95%, norm, antiprotons)
Antiproton beam lifetime with cooling	180 hrs

Present values (measured with protons only):

Emittance growth rate (scrapers and Schottky)	10 $\pi$ $\mu$ m/hr (95%, norm)
Proton beam lifetime (initial, pencil beam)	90 hrs

**The vacuum system**

*The vacuum chamber*

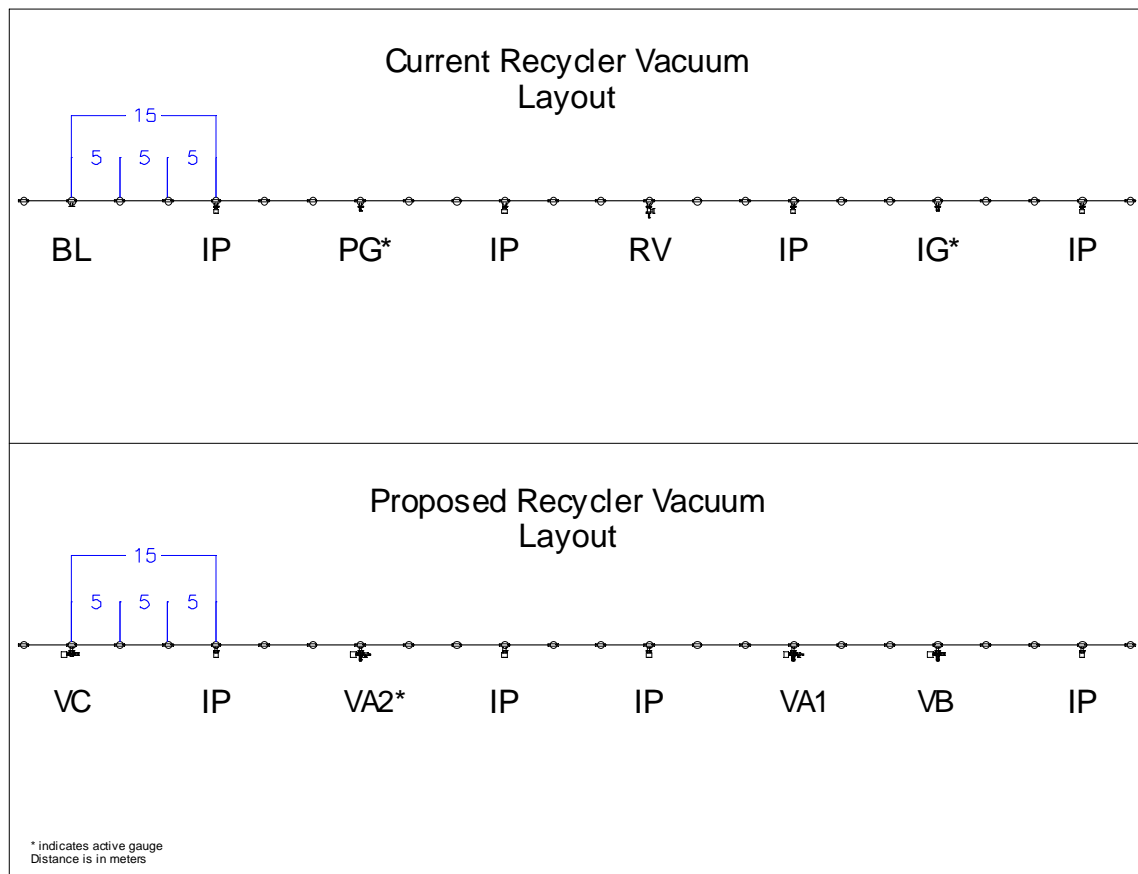
The Recycler vacuum chamber is an elliptical 100mm x 48mm (width and height), stainless steel tube (316L). Most of the tube sections in the tunnel are welded. There are a few flanged connections in some special locations (27 gate valves and 10-15 other locations). The tube was not electropolished, neither was it ultrasonically cleaned. The tubes were washed by a mild acidic soap, rinsed and then baked to 500C for 12 hours

under vacuum ( $10^{-5}$  Torr). Upon venting the tubes were wiped with acetone and/or alcohol, dried and capped.

The nominal beam pipe bakeout temperature is 100 - 120C. The Recycler vacuum chamber is presently NOT 100% bakeable. First, there are sections of beam pipe in the magnets that had the heater tape removed in the past. These sections will be cut out during this coming shutdown, re-equipped with a new bake-out tape, and then welded into the vacuum system. Second, the ring has about 420 BPMs (30 cm long each) and similar number of bellows, which have never been baked. They will be baked during this shutdown.

### *The pumps*

The majority of pumping in the Recycler is performed by TSPs. The TSPs are spaced at 5 m as shown in Fig. 1. The original design called for a small 30-L/s diode ion pump to be installed every 30 meters (Fig. 1, top). It was later decided to upgrade the pumping system by doubling the number of ion pumps (Fig. 1, bottom).

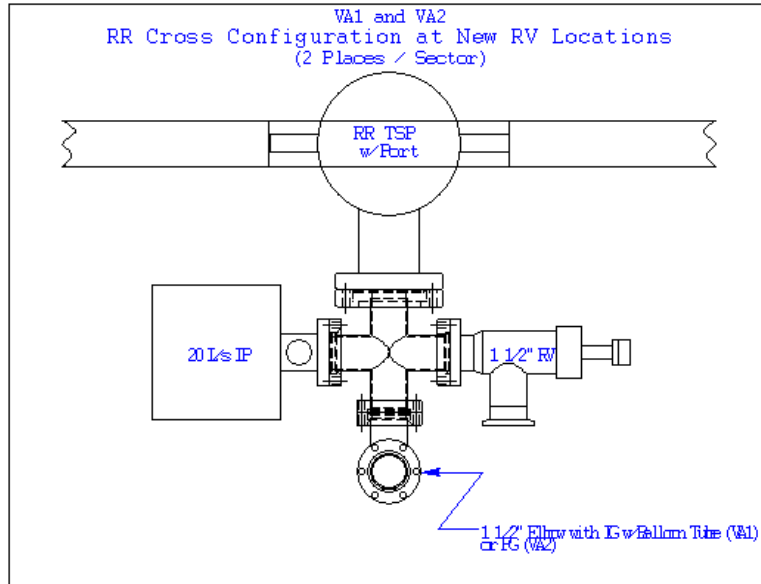


**Figure 1:** Schematic representation of the original (top) and proposed (bottom) Recycler vacuum layouts. Shown are TSPs (every 5 meters), ion pumps (IP), ion gauges (IG), Pirani gauges (PG), roughing valves (RV), blank-offs (BL), and newly added crosses with ion pumps (VA, VB, VC). Scale is in meters.

About 120 of 20-L/s ion pumps, capable of pumping argon, were procured from BNL. It is unknown to me if these pumps were new or used. Close to 90 of these pumps were

installed in the Recycler during the Jan., 2003 shutdown. After this coming shutdown there will be a total of about 240 ion pumps in the Recycler.

With the exception of nine ion pumps installed directly on a beam pipe in special locations, all of the new 20-L/s ion pumps are installed on a TSP can as shown in Figure 2. The “old” 30-L/s pumps are installed in a similar manner.

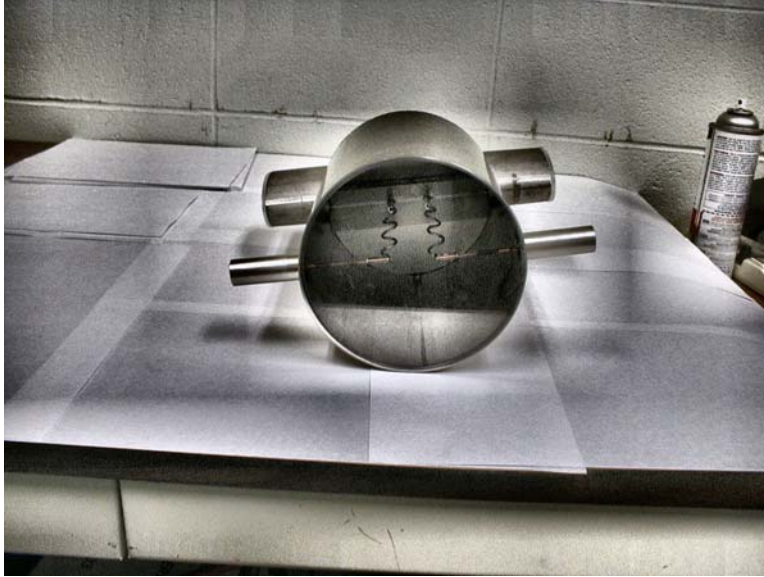


**Figure 2:** An example of VA1/VA2 vacuum cross configuration.

The Recycler TSP has about 1200 cm<sup>2</sup> of internal active pumping area. We believe it has a pumping speed of 170 L/s for CO/N<sub>2</sub> at the beam pipe. Figures 3 and 4 show the TSP can with its back side cut open.



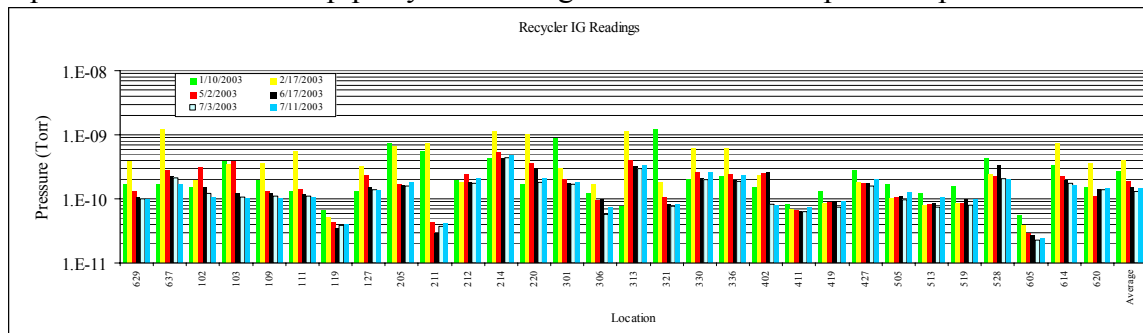
**Figure 3:** A photo of the TSP assembly with a beam pipe.



**Figure 4:** The TSP can with its back side cut open. One can see two Ti filaments attached to home-made current feed-thrus. This TSP can does not have a port for the ion pump as shown in Fig. 2.

#### *The gauges and RGAs*

There are 30 actively reporting ion gauges in the ring. Each of these ion gauges is installed on a TSP can as shown in Fig. 2. Their biggest drawback is that they are separated from the beam pipe by a TSP. Figure 5 shows the IG pressure profile.



**Figure 5:** The Recycler IG pressure profiles before (1/10/03) and after the Jan, 2003 shutdown.

There are 8 RGAs in the Recycler of which 3 are installed between the TSPs, while the remaining 5 are installed like ion gauges in Fig. 2. The majority of the residual gas content (as expected) is hydrogen, with more than 10% of water, CO and CO<sub>2</sub>.

## **The shutdown plan**

During the previous Jan 2003 shutdown 20 out of 27 vacuum sectors were vented with nitrogen (pressure bottle and/or dewar boil-off) to install new ion pumps under a small positive N2 pressure. Of these 20 only 5 were baked in situ. Of these five, three were vented and not baked since. The goals for this coming shutdown is to make the entire ring bakeable, to add diagnostics, to add the remaining ion pumps and to bake the entire ring at a max. possible temperature. Below is a list of tasks (not final) for the shut down work.

Duration of Recycler Work: 10 weeks (50 days)

Recycler tasks to be completed:

- Remove/Reinstall Heater Tape from 18 Gradient magnets
- Install Heater Tape in 30 Quad half-cells (60 magnets)
- Install Cooling tank 10 (Horizontal 2-4 GHz) tank
- Replace approx 170 feet of beam pipe in the 620 Region
- Install Flying Wires at Q619 and Q620
- Ion pump upgrade of remaining 5 vacuum sectors
- Installation of pneumatic gate valve at Q503 location
- Bake 27 of 27 vacuum sectors
- Replace 13 LEP correctors (9 vertical, 4 Horizontal)
- Relocate 2 LEP correctors @Q305 Region
- Remove IPM from Q404 and Q405
- Install Ion gauge @522
- \*Install RGA's in the 20, 40 and 50 house
- Complete cables pulls for:
  - 503-gate valve
  - IP 319
  - IG 623
  - IG 522
  - IG 227
  - IG 305
  - IG 307
  - IG 101
  - Back pull cable IG519 to upstream sector @524
  - Back pull cable IG127 to upstream sector @201
  - Back pull cable IG306 to upstream sector @305
  - Back pull cable IG402A to upstream sector @403
  - Back pull cable IG427 to upstream sector @430
- \*Install Remote readable RGA at the 20, 40 and 50 house

## **Acknowledgements**

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