PHENIX RICH LEAK DOWN TEST PROCEDURE IN 1008

procedure name

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Leak and Pressure Test Report for the PHENIX West Arm RICH Detector

Version 1.0
October 19, 1998
Edited by Thomas K. Hemmick and Anthony D. Frawley

1.0 Purpose

The PHENIX RICH detector is one of the major detector systems of the PHENIX experiment at RHIC. As is true for all detectors delivered to RHIC, the RICH must conform to all RHIC and PHENIX safety regulations as well as meet criteria specified for the RICH by the RHIC Experimental Safety Committee (ESC). Among the safety action items for the RICH is the requirement that it pass leak inspection and window overpressure tests to the level specified by the RHIC ESC. This document details the results of these tests and demonstrates conformance to the leak rate criteria required for the RICH.

2.0 Leak Criteria

The PHENIX experiment is allotted a maximum overall leak rate of 1.0 cubic feet per hour (CFH) of flammable gas into the PHENIX Experimental Hall (PEH). Internally to PHENIX, 1/12 of this (0.083 CFH) was set as the maximum leak rate allowed for each of the two RICH detectors.

3.0 Leak Check Procedure

The RICH Leak Check Procedure (PHENIX Procedure No. PP-2.5.2.7-01) was approved on October 2, 1998 and details the method of leak checking of the vessel. The leak check involves the following major steps:

- Check for catastrophic leaks
- Calibrate the Pressure-Volume Curve for the RICH.
- Measure Leak Rate & Repair all leaks found until detector meets leak spec.
- Cycle windows to 3X operating pressure.
- Perform final leak rate measurement.

4.0 Diary of Leak Check Results

4.1 Check for Catastrophic Leaks.

Catastrophic leaks are indicated if it is found to be impossible to pressurize the vessel at all (necessary for pressure-volume curve measurement). The RICH pressurized sufficiently on its first attempt that no action was necessary to search for catastrophic leaks.

4.2 Calibrate Pressure-Volume Curve for RICH

The RICH is not a constant volume device due to its flexible windows. For this reason, its volume is greater at higher pressure. If this effect were to be ignored, leak rates would be underestimated at constant barometeric pressure and temperature, and corrections for variations in barometric pressure and temperature could not be made.

To calibrate the vessel's pressure volume relation, we attached a vacuum vessel of known volume (0.0860 m^3) to the RICH. Bleeding gas from the RICH into the vacuum vessel removed a known number of moles of gas from the RICH, determined from the rise in vacuum pressure in the vacuum vessel. At each step, the new differential pressure of the RICH, external barometric pressure, and temperature were recorded. It was found that the temperature was constant over the short time interval required for the calibration measurements.

We used the following equations to solve for the volume of the RICH during the first three pump-down intervals:

$$P_1V_1 = n_1RT$$

$$P_2V_2 = (n_1 - \Delta n_1)RT$$

$$P_3V_3 = (n_1 - \Delta n_1 - \Delta n_2)RT$$

$$V_2=(V_1 + V_2)/2$$

Where P_1, V_1 and n_1 are the RICH pressure, volume and number of moles of gas at the initial (highest) pressure. P_2 and V_2 are the RICH pressure and volume after the first release of gas into the vacuum chamber. The number of moles removed from the RICH during the first and second releases of gas into the vacuum chamber are Δn_1 and Δn_2. The pressures were obtained by adding the barometric pressure (obtained from the BNL meteorological station to an accuracy of 0.1 mbar) to the window differential pressure. Here, the volumes at each pressure and the initial number of moles of gas are four unknowns. The fourth equation follows the assumption that at the highest pressures (after window sag is removed) the volume changes linearly with pressure. Solutions to these equations produce a total volume which is a few % higher than a calculation assuming no window billowing, and are believed to be accurate.

Using these results, the volume at each pressure can be calculated from the measured data. The result of this calibration is shown in Figure 1. We find (as expected) that at low differential pressures, the windows are billowing and the volume rises rapidly with differential pressure. At higher pressures, the rate of rise slows since the window has become taut.

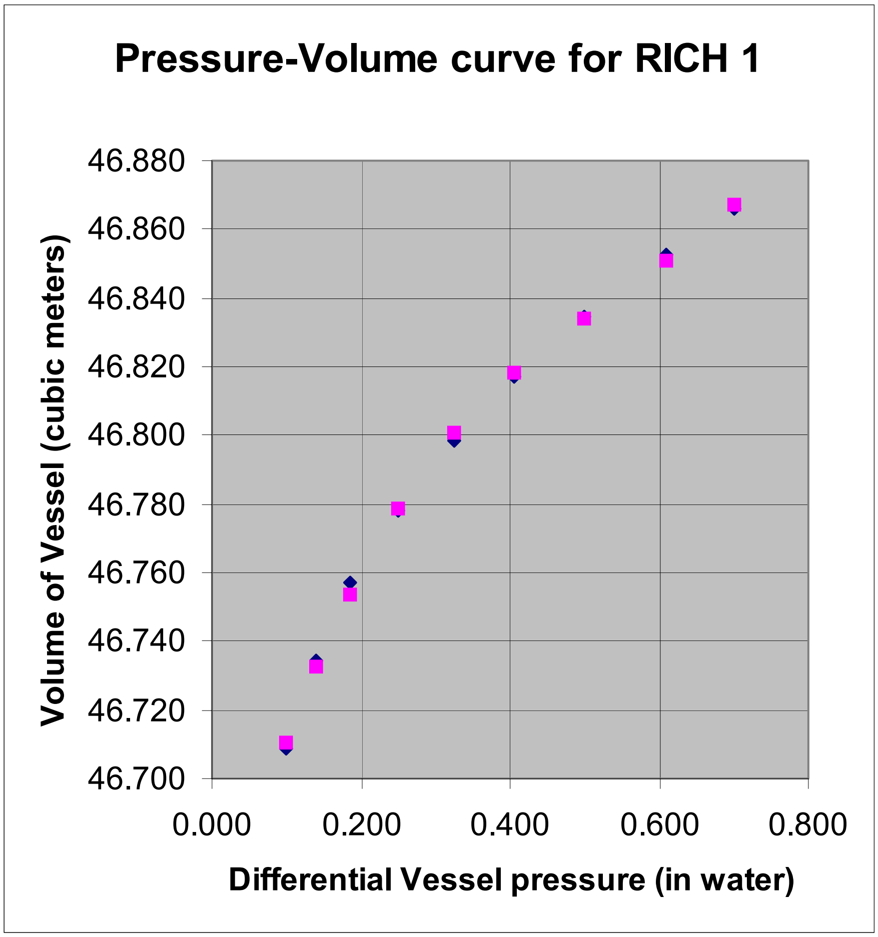

FIGURE 1: RICH Pressure-Volume curve. Blue diamond points are measured data. Pink square points are a cubic fit used for interpolation.

During the week of leak testing, this curve was measured a second time. There the absolute volume of the RICH was found to be 2.7% higher, and the slope of the curve in the leak measurement interval (near the 0.5” nominal RICH pressure) was 4.9% higher. We consider the later result to confirm our initial result to within the necessary accuracy for the leak-down test.

4.3 Measure Leak Rate, Repair Leaks

The measurement of leak rate was accomplished by pressurizing the RICH, sealing off the vessel, and measuring barometric pressure, vessel overpressure, and temperature inside the vessel as a function of time. The vessel overpressure was used to determine the vessel's volume using a parameterization of the curve shown in Figure 1. For each measurement, the number of moles of gas contained inside the vessel was calculated. The molar content of the vessel was converted to a volume at STP so that leak rates would be expressed in cubic feet per hour (CFH). For the initial stage of leak checking, the difference in volume between the first and last measurements was used.

Initially, the RICH was found to leak significantly so that each leak-down measurement was quick enough that vessel temperature and atmospheric pressure variations did not significantly affect the calculations. As leaks were repaired, the leak tests took longer times and a high precision method of measuring RICH gas temperature was required. For this purpose, the readout from one of the temperature monitors mounted on the PMT array was used. The temperature sensor was read to a precision of 0.01^{0} C

The table below summarizes all steps of the leak tests done prior to the window overpressure test:

Date	Leak (CFM)	Action
10/6/98	6.00?	Repair several HV hatch welds
10/7/98	4.00	Repair entrance window gasket seal, (bolt-heads binding, bad gasket seam)
10/8/98	3.25	Repair two feedthrough cards
10/9/98	1.62	Repair more feedthrough cards
10/10/98	0.32	Torque entrance window to 20 ft-lbs
10/11/98 – 10/13/98	-0.09	End of initial test.

Leaks were found using an Ar leak sniffer, the Matheson Leak Hunter Model # 8066. Both feedthrough card and weld leaks were repaired using DP190 flexible epoxy to create the seal.

Obviously a negative leak rate is not possible, so we concluded that our leak rate was now consistent with zero within the accuracy of the measurement. Improvements were made to the procedure for the leak check that was made following the overpressure tests, to improve the accuracy of the final result. The improvements to the procedure will be described later.

4.4 Window Overpressure Tests

The RICH normally runs with an internal pressure of 0.5” of water above the room pressure. We tested the window to triple this pressure, 1.5” of water. Measurements of the entrance window support beam deflection were made as a function of the RICH overpressure, and the results are shown in Figure 2.0. The deflection of 0.100” at nominal operating pressure (0.5”) was predicted from stress calculations and verified by these measurements. This level of deflection will not mechanically interfere with neighboring detectors and is 50 times smaller than the estimated breaking point of the support bars (a deflection of roughly 5”). Measurements of the deflection of the exit window support beams were found to be unnecessary because the exit window did not touch the support beams, even at 1.5” pressure.

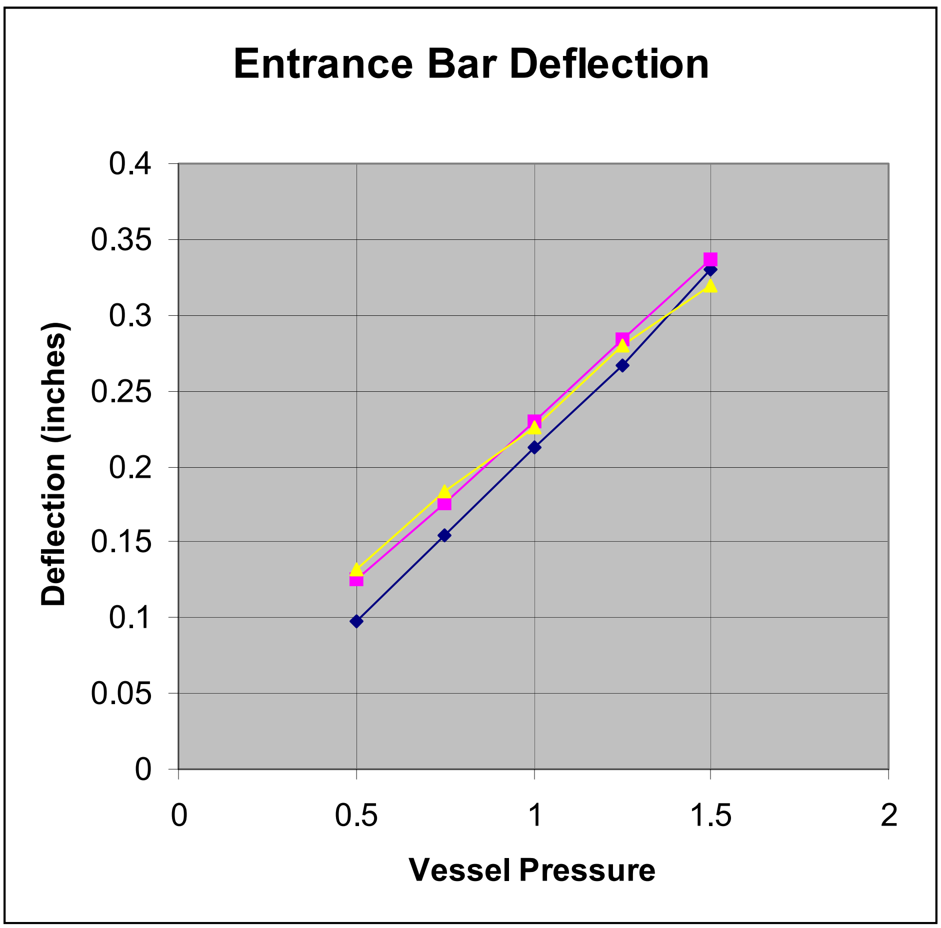

Figure 2. Deflection at the center of the middle inner window support beam under overpressurized conditions. Blue diamonds are the first measurement, pink squares the second, and yellow triangles the third. It is evident that there was some stretching of the window during the first pressure cycle, but there does not appear to be any during the second cycle.

While holding 1.5” overpressure, the entrance and exit windows were inspected for leaks using the leak sniffer. No response of the leak sniffer at all was found at the exit window. At the entrance window, small responses were noticed at the corners, however these responses were two orders of magnitude lower than the leaks found in the previous step, consistent with meeting the overall RICH leak criteria.

4.5 Final RICH Leakdown Tests

Following the window overpressure test, leak down tests of the vessel were repeated. The first test followed the original procedure and yielded a result of –0.039 CFM. This result again is negative, which means consistent with zero to the accuracy of our method.

One last measurement was made in an attempt to improve the accuracy of the final result. It was believed that the primary source of uncertainty in the measurement of RICH volume was due to the temperature measurement. When temperature was changing with time at a measurable rate, it was suspected that the measured PMT array temperature was lagging the actual gas temperature. The PMT array is electrically and thermally isolated from the aluminum RICH vessel, and is thus warmed and cooled primarily by the gas. A temperature sensor was mounted on the skin of the RICH gas vessel and the readout from this sensor was added to the data. It was expected that the vessel skin temperature would be closer to the actual gas temperature. Additionally, measured quantities of gas were added to the vessel to keep the overpressure in the range 0.20” to 0.5” as the atmospheric pressure and temperature shifted, keeping the RICH overpressure inside the range for which the volume versus pressure calibration is valid.

The table below shows the results of the final leak tests. For each measurement, two volumes are calculated , one using the PMT array temperature and the other using the vessel skin temperature. Note that a net amount of 112 liters of gas was added between the measurements at 21:29 and 22:11. This has to be taken into account when calculating leak rates.

Time	Barometric Pressure (mbar)	RICH pressure (inches water)	PMT array temp. (Celsius)	Volume at STP (liters)	RICH skin temp. (Celsius)	Volume at STP (liters)
17:07	1018.5	0.520	20.35	43841.1	20.02	43890.4
17:19	1018.8	0.510	20.37	43848.5	20.13	43884.4
17:40	1019.1	0.505	20.40	43855.7	20.26	43876.6
18:08	1019.7	0.460	20.46	43861.1	20.36	43876.0

19:05	1020.6	0.340	20.53	43854.4	20.40	43873.9
19:27	1020.9	0.320	20.56	43856.0	20.42	43877.0
19:52	1021.1	0.295	20.58	43852.6	20.43	43875.0
20:17	1021.5	0.260	20.60	43853.1	20.42	43880.0
21:13	1021.9	0.205	20.60	43845.6	20.41	43874.0
21:29	1022.1	0.180	20.64	43835.7	20.40	43871.5
22:11	1022.2	0.485	20.65	43946.5	20.39	43985.4
22:34	1022.7	0.460	20.65	43961.5	20.40	43998.9
22:57	1022.7	0.440	20.65	43956.2	20.39	43995.2
23:30	1022.7	0.405	20.66	43945.1	20.38	43987.0
23:59	1022.9	0.380	20.66	43946.3	20.42	43982.3
00:08	1023.0	0.360	20.66	43944.5	20.42	43980.4

Measured leak rates were estimated by taking all combinations of the first four and the last four measured volumes calculated using the RICH skin temperature. The use of the RICH skin temperature gave a substantially smaller spread of leak rates, indicating that it was tracking the gas temperature more closely. For each combination, the final volume was subtracted from the starting volume and the difference was divided by the relevant difference in time. Note that the starting volume had to be increased by 112 liters to account for the net amount of gas added between 21:29 and 22:11, and the times were reduced by the interval of 42 minutes during which gas was being added. The best estimate of the leak rate was obtained by averaging the results. It is 1.26 liters/hour, or 0.045 CFH. This is below the specification set internally within PHENIX of 1/12 of the maximum leak rate allowed for PHENIX.

5.0 Conclusions

The RICH detector for the West Arm of PHENIX has successfully met the leak rate specification required by the RHIC safety committee, and has passed the prescribed pressure cycling tests.

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