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Estimation of Helium Discharge Rates for RHIC ODH Calculations

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Brookhaven National Laboratory

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ABSTRACT

The helium discharge rate from RHIC magnets into the RHIC Magnet Enclosure (RME or Tunnel) during a hypothetical accident is estimated for the Oxygen Deficiency Hazards (ODH) study. The problem is simplified by assuming that helium from the magnet loop in one sextant is instantaneously released into the insulating volume of the RHIC cryostats. The insulating vacuum spoils instantly. Cold helium in the vacuum vessel warms at a rapid rate and vents into RME through the vacuum tank relief valves. The results obtained are conservative and are applicable to an ODH analysis.

I. INTRODUCTION

A detailed description of the RHIC cooling system is given in the RHIC Design Manual.[1] Briefly, there are two rings of magnet cryostats each containing five independent cold lines. The cooling system is divided into twelve segments, one for each sextant of the two rings. Between adjacent sextants, isolation valves and pressure relief valves are installed in Valve Boxes to control helium flow. For the magnet cooling line, pressure relief valves are also installed on the DX magnets. The pressure relief valves are set at 18.7 atm for each cold line. Low pressure vacuum tank reliefs, set at 0.2 atm, have been installed along the magnet cryostats to protect the tanks from over pressure. Both the pressure relief and tank relief valves have been sized for the loss of vacuum condition.[2,3]

For the ODH study, a serious failure is assumed to occur in one of the cooling lines causing cold helium to be released into the vacuum tank. As the vacuum deteriorates, the heat input to the helium increases drastically. To the intact cooling lines, the pressure will increase causing the pressure relief valves to open. Helium will be vented to atmosphere outside but not into the RME and does not cause an ODH problem. Some of the helium in the failed cooling line will also be vented to the atmosphere outside. The remaining helium, however, will flow to the insulating vacuum and subsequently through tank relief valves into the RME. Release of helium into the RME may create an ODH.

There are four separate insulating vacuum systems in a RHIC sextant. The helium release rate depends on which and where the cold line fails. As will be seen, the worst case has been identified as the failure of the magnet cooling loop in the regular arc region from considerations of helium inventory and heat inputs.

II. HELIUM VENTING PROCESS

The thermodynamic process of heating and venting helium from the vacuum tank has been illustrated in a previous study on Safety Relief for the RHIC Vacuum Tank.[3] Because the volume of the vacuum tank is much greater than that of the cold helium line, the initial pressure in the vacuum tank will be lower than the ambient pressure. Both the pressure and temperature increase through a constant density heating process. As the pressure reaches the relief setting 0.2 bar (3 psig), the tank relief will open to release helium into the RME followed by a constant pressure heating process. The heating and venting process in the vacuum tank is given below in Figure 1.

FAILURE OCCURS IN A COOLING LINE

-----> COLD HELIUM ENTERS VACUUM TANK

-----> VACUUM DETERIORATES

-----> HEAT INPUT INCREASES

-----> HEATING AT CONSTANT DENSITY

-----> PRESSURE REACHES RELIEF SETTING OF 1.2 ATM

-----> TANK RELIEF VALVES OPEN

-----> HELIUM ENTERS RME

Figure 1. Heating and venting process for the vacuum tank relief valves

The process of venting helium in response to heat input can be further illustrated by Fig. 2,[4,5] in which 1 refers to any thermodynamic state and x is an incremental state after constant pressure heat absorption. Given an initial condition, the venting of helium can be calculated from the heat input and volume for each step. Later, the RHIC vacuum tank relief valves can be shown to be sufficiently large as not to present a restriction to the release of helium into the RME. The process under consideration involves only single phase helium because the temperature is greater than 5.2 K. In Fig. 2, the effect of the thermal mass of the magnet is included and the iron york is assumed to be at the same temperature as the helium.

$$
\begin{array}{ccccc}
(MH)_{mag,1} & & (MH)_{mag,x} & & \\
 & & & & \\
m_1 & & m_x & & (m_1 - m_x) \\
P_1 & \rightarrow & P_x & + & P_x = P_1 \\
T_1 & & T_x & & T_1 \rightarrow T_x \\
h_1 & & h_x & & h_1 \rightarrow h_x \\
\rho_1 & & \rho_x & & \rho_1 \rightarrow \rho_x \\
 & & & & \\
\textit{State 1} & & \textit{State x} & & \textit{Helium Vented} \\
 & & & & \textit{Through Relief Valve}
\end{array}
$$

Figure 2 Heating process from state 1 to x with helium vented through relief valve.

where M is the mass of magnet
H is the enthalpy of magnet
P is the pressure
T is the temperature
m is the mass of helium
h is the enthalpy of helium
ρ is the density of helium
subscript mag refers to the magnet
and subscripts 1 and x refer to thermodynamic states 1 and x respectively.

The heat absorbed by the helium vapor, q , for any such incremental step can be approximated by equation 1. The heat absorbed per unit mass of helium leaving the container, L', is given by equation 2. The amount of helium to be vented $\dot{m}_{vent}$ equals the heating rate $\dot{Q}$ divided by the heat absorbing capability as shown in equation 3.

$$q = m_x\,(h_x - h_1) + (m_1 - m_x)\,\frac{(h_x - h_1)}{2} + [\,(MH)_{mag,x} - (MH)_{mag,1}\,] \tag{1}$$

$$L' = \frac{q}{(m_1 - m_x)} = \frac{(h_x - h_1)\,(m_1 + m_x)}{2\,(m_1 - m_x)} + \frac{[(MH)_{mag,x} - (MH)_{mag,1}]}{(m_1 - m_x)} \tag{2}$$

$$\dot{m}_{vent} = \dot{Q} \div L' \tag{3}$$

III. HELIUM INVENTORY

In order to identify the potential impact on the ODH, the amount of helium in the system must be known. The volume and mass of helium in a sextant at operating conditions for the five cold lines are given in Table 1. (Detailed calculations of the physical and thermal parameters used in this study are given in Appendix A.) In Table 1, helium in the magnet cooling loop and the supply line is assumed to be at 5 atm and 4.3 K. Helium in the return and the utility lines is in a 1.2 atm saturated vapor state. Helium in the shield line is at 15 atm and 55 K. The volume for the return line also includes the liquid helium in the recooler heat exchangers. The amount of helium contained inside the RHIC magnet cryostats of one sextant is very large. This helium, if fully vaporized, would amount to more than 270,000 standard cubic feet. The magnet loop contains the largest amount of helium, 775 kg or 155,000 standard cubic feet, and therefore could release more helium than the other four cold lines.

Table 1. Volume and mass of helium in the five cold lines in a RHIC sextant

Line	Volume Liters	Mass Kilo-grams	Volume at Standard Conditions Cubic Feet
Magnet loop	5653	775 kg	155,000 SCF
Supply line	2699	370 kg	74,000 SCF
Return line	2699	130 kg	26,000 SCF
Utility line	2699	54 kg	10,800 SCF
Heat Shield	1744	35 kg	7,000 SCF

IV. VACUUM SYSTEMS

The rate of helium release depends not only on the source of helium but also on the vacuum system the cold helium is released to. The initial state of the helium released is determined by the volume of the vacuum system. The heat input into cold helium system is proportional to the surface area of the vacuum system.

The four separate vacuum subsystems to be considered are those for: 1). the regular arc region between the quadrupoles Q4 and Q4, 2). the Triplet cryostat, 3). the DX magnet, and 4). the Valve Box. The volume, surface area and estimated heat input from loss of vacuum for each vacuum subsystem are summarized in Table 2. (See Appendix A for detailed calculations) Since the rate of helium release is proportional to the heat input, the failure of a cold line in the arc region will have the largest effect on the ODH. Thus the worst case for the ODH is identified as the failure of the magnet loop in the regular arc region.

Table 2. The volume, surface area and estimated heat input from loss of vacuum for each separate vacuum subsystem in RHIC

System	Volume Liters	Surface Area cm^2	Heat Input kilo-watts
Q4 to Q4	97,000	9.3×10^6	500
Triplet	19,000	7.1×10^5	36
DX	1,685	1.3×10^5	6.7
Valve Box	14,700 to 20,000	4.2×10^5 to 4.8×10^5	24

V. LARGEST HELIUM DISCHARGE RATE

The largest helium discharge rate occurs when there is a failure of the magnet cooling loop in a regular arc region. The helium discharge rate is proportional to the heat input as shown in equation 3 above. The heat input in the regular arc region is estimated at 500 kW as shown in Table 2. A computer program was developed to calculate the venting of helium after cold helium is released into this region. This program calculates the pressure and temperature for the cold helium entering the vacuum tank, during the constant density heating process and during the constant pressure heating/venting process. The helium release rate is calculated from the heat input and the heat absorbing capacity of the system given by equations 2 and 3. The total amount of helium released after a given time is calculated from the density difference between the state at that time and the original density. The results of the calculation are given in Appendix B. The helium reaches about 0.6 atm and 4 K after being released to the vacuum tank. It takes about 50 seconds for the helium to be warmed to 1.2 atm and 7.7 K following the constant density heating process. Afterwards helium is discharged into the RHIC RME following the constant pressure heating process. The helium release rate and the total amount of helium released are given in Fig. 3 and 4. Due to the extremely large heat input, an initial discharge rate of 12.5 kg per second is calculated. However one minute later, the discharge rate decreases to 3 kg per second and the temperature of the helium reaches 20 K. The helium release rate decreases with increasing temperature as the thermal mass of the iron and the heat absorbing capability of helium increases. The major portion of the helium is released in just two minutes as shown in Figure 4.

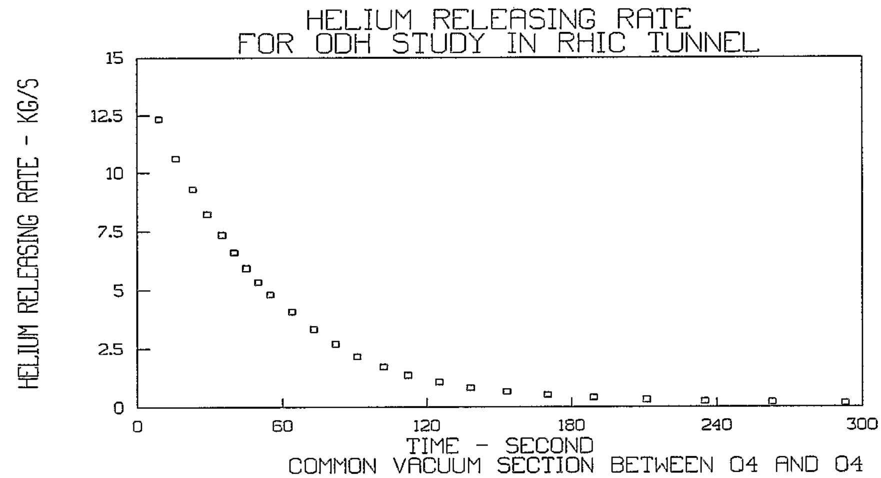

Figure 3 Helium release rate in a RHIC arc

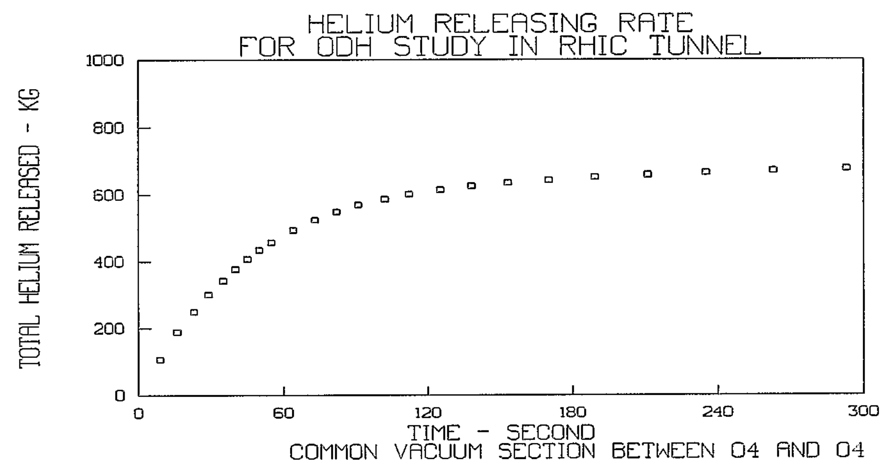

Figure 4 Total helium released in a RHIC arc

Because there are uncertainties in estimating heat input, parametric studies have been performed at lower heat inputs to investigate the release rate. The helium release rate and total amount of helium released at heat rates of 300, 400 and 500 kW are given in Figure 5 and 6. As expected, the helium release rate decreases with time. The initial helium release rate decreases with the heat input. But at lower heat inputs, the discharge of helium is spread over a longer time duration. The helium release rate at 300 kW become larger than that at 500 kW approximately one minutes after the relief valves open. The major portion of the helium is released in the first few minutes with the largest release corresponding to the largest heat input. These results have been used for ODH calculations,[5,6,7] and no differences in the ODH classifications have been found.

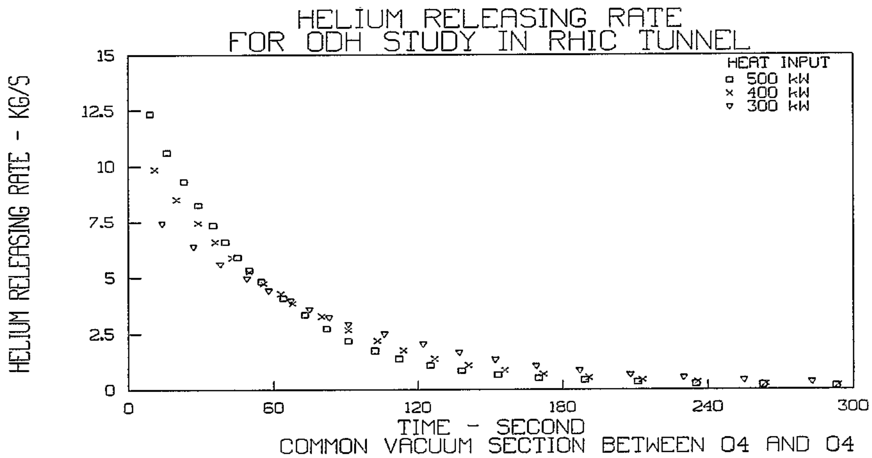

Figure 5 Helium release rate in a RHIC arc at three heat inputs

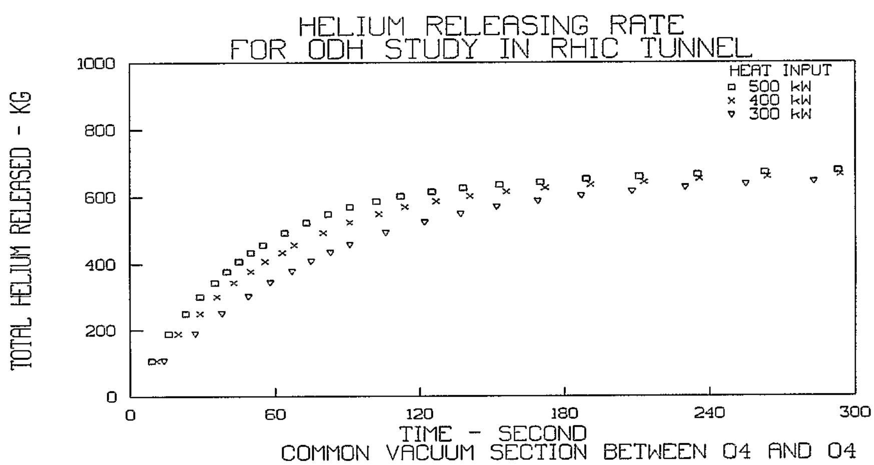

Figure 6 Total helium released in a RHIC arc at three heat inputs

VI. DISCHARGE OF HELIUM AT VALVE BOX, Triplet and DX Magnet

The vacuum tank volumes for the Valve Box, the Triplet and the DX magnet are smaller than the vapor volume of cold helium contained in a sextant. When there is a rupture of the magnet cooling line in this region, liquid helium will be formed and two phase helium will exist when the relief valve opens at 1.2 bar (3 psig). The amount of helium discharged can be calculated by dividing the heat input by the latent heat of vaporization.

The heat inputs to the Valve Box, the Triplet and DX magnet are estimated at 36, 6.7 and 24 kW respectively. Assuming the heat of vaporization for helium equals 20 joules per gram, then the maximum helium discharge rates for the Valve Box, the Triplet and Dx magnet equal to 1800, 335 and 1200 grams per second respectively. These values are smaller than the 12,000 grams per second peak rate from the regular arc region.

VII. SUMMARY

The helium released rates from RHIC into the RME during a hypothetical accident have been estimated for the ODH study. The worst case is identified as the failure of the magnet cooling loop in the regular arc region. While the peak discharge rate is 12,000 grams per second of helium, or 150,000 SCFM, the discharge rate decreases rapidly with time. In one minutes, the discharge rate reaches 3,000 grams per second. Depending on the heat input, majority of helium will be discharged into the RHIC RME in two to five minutes. The results presented are very conservative because it assumes all the helium will enter the vacuum tank instantly. If the leakage from the magnet to the insulating vacuum is smaller, then the helium discharge rate will be less than reported. The discharge rate of 12,000 grams per second of helium from the magnet cooling loop to the vacuum tank would require a hole 3.2 cm in diameter in the loop.

ACKNOWLEDGEMENT

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REFERENCES:

1. H. Hahn, Editor, RHIC Design Manual. Brookhaven National Laboratory, Revised October, 1994.
2. K. C. Wu, "Pressure Relief for RHIC Cryogenic System", RHIC Project Technical Note AD/RHIC/RD-64, December 1993.
3. K. C. Wu, "Safety Relief for RHIC Vacuum Tank", RHIC Project Technical Note AD/RHIC/RD-71, August, 1994.
4. R. H. Kropschot, B. W. Birmingham and D. B. Mann, "Technology of Liquid Helium", National Bureau of Standards, Monograph 111, Oct. 1968.
5. M. Iarocci, "Calculation of Oxygen Deficiency Hazard Classes for RHIC", Technical Note AD/RHIC/RD-72, August, 1994.
6. D. P. Brown, "Calculated Volume for the RHIC Magnet Enclosure", RHIC Project Technical Note AD/RHIC/RD-78, November, 1994.
7. M. Iarocci, Private Communication.

Appendix A: System Parameters

1). Length from Q4 to Q4

The dimensions used in the present study are based on the lattice at 5/6 o'clock.[1]

a). Length from Q4 to Q9

End of Vacuum to Center of Q4	4.28 m
Center to center	
Q4 - Q5	5.33 m
Q5 - D5	5.06 m
D5 - Q6	5.11 m
Q6 - D6	7.48 m
D6 - Q7	6.90 m
Q7 - Q8	8.32 m
Q8 - Q9	21.78 m
Total	64.3 m

b). Regular Arc Q9 to Q9

The center to center dimension from quadrupole to dipole equals 7.4 m. The length from the center of Q9 to the center of Q9 equals 48 times 7.4 m (about 355 m).

Total length of the common vacuum space from Q4 to Q4 equals

$$Length\ (Q4\ -\ Q4) = 65 + 355 + 65 = 485\ meters \tag{4}$$

2). Surface Area for the Vacuum Vessel Q4 to Q4

The surface area for the vacuum tank from Q4 to Q4 equals to

$$\begin{aligned} Surface\ Area &= \pi \times d \times L \\ &= \pi \times (24\times 2.54) \times (485\times 100)\ cm^2 \\ &= 9.28 \times 10^6\ cm^2 \end{aligned} \tag{5}$$

3). Cross Sectional Area of the Vacuum Vessel

Net cross sectional area for the vacuum space equals that of the vacuum tank less that of the magnet and various pipes. A description of each component in the cryostat is summarized below and the net cross sectional area is given in equation 6.

Component	Dimensions	Cross Sectional Area - cm^2
Vacuum Tank	d_0 = 24" t_w= 1/4 " d_i= 23.5"	0.785 x (23.5 x 2.54)^2 = 2798 cm^2
Magnet (Cold Mass)	d = 11"	0.785 x (11 x 2.54)^2 = 613 cm^2
Supply, Return Utility Pipe	d_o = 2.875"	0.785 x (2.875 x 2.54)^2 = 42 cm^2
Heat Shield Pipe	d_o= 2.375"	0.785 x (2.375 x 2.54)^2 = 29 cm^2
Aluminum Heat Shield	d ~ 21" t ~ 0.1"	3.14 x (21 x 2.54) x (0.1 x 2.54) = 43 cm^2

$$\begin{aligned}&\textit{Net Cross Sectional Area for Vacuum Space}\\&\sim 2798 - 613 - 3 \times 42 - 29 - 43\\&\sim 1987\ cm^2\end{aligned} \tag{6}$$

4). Vacuum Tank Volume Q4 to Q4

The vacuum tank volume equals the cross sectional area multiplied by the length.

$$\begin{aligned}Vac.\ Tank\ Vol. &= 1987 \times 48500 / 1000\ L\\&\sim 97000\ L\end{aligned} \tag{7}$$

5). Weight of Vacuum Vessel Q4 to Q4

The weight for the vacuum tank from Q4 to Q4 equals to

$$\begin{aligned}
Vac.\ Tank\ Weight &\sim \pi \times d \times t \times L \times \rho \\
&\sim \pi \times 0.25 \times 24 \times \frac{48500}{2.54} \times 0.28\ lb \\
&\sim 100778\ lb \\
&\sim 45800\ kg
\end{aligned} \tag{8}$$

6). Thermal Capacity of Vacuum Vessel Q4 to Q4

The thermal capacity for the vacuum tank from Q4 to Q4 equals to

$$\begin{aligned}
Thermal\ Capacity &\sim M \times C_p \\
&\sim 45800\ kg \times 0.44\ \frac{j}{g\text{-}K} \\
&\sim 20000\ \frac{kj}{K}
\end{aligned} \tag{9}$$

7). Estimation of Heat Load during an Accident for Vacuum Vessel Q4 to Q4

The heat input is obtained from introducing warm helium into the vacuum tank for a RHIC dipole. Neglecting the aluminum heat shield and the cooling pipes, this study assumes the helium and magnet absorb the entire heat input. The heat input is calculated to be about 500 kW from 1) the temperature change of 1.5 K per minute rate for the vacuum tank as shown in equation 10 and 2) the heat load of 0.05 watts per square cm for the outer vessel as given in equation 11. If one assumes some per cent of heat input is absorbed by the heat shield and the cooling pipes, the heat input could be as low as 400 or 300 kW.

$$\begin{aligned}
Heat\ Load &\sim M \times C_p \times \frac{dT}{dt} \\
&\sim 20000\ \frac{kj}{K} \times 1.5\ \frac{K}{\text{min}}\ /\ 60\ \frac{\text{sec}}{\text{min}} \\
&\sim 500\ kW
\end{aligned} \tag{10}$$

$$\begin{aligned}
Heat\ Load &\sim 0.05\ \frac{W}{cm^2} \times Area \\
&\sim 0.05 \times 9.3 \times 10^6\ W \\
&\sim 465\ kW
\end{aligned} \tag{11}$$

8). Number of Dipoles and Quadrupoles Q4 to Q4

The number of dipole D and quadrupole Q from Q4 to Q4 is obtained from the following break down:

Q4 to Q8	----->	2 D + 5 Q
Q9 to Q9	----->	24 D + 25 Q
Q8 to Q4	----->	2 D + 5 Q
Total	----->	28 D + 35 Q

9). Iron Weight Q4 to Q4

The weight is assumed to be 3860 kg for a dipole and 1275 kg for a quadrupole. Thus the total iron weight from Q4 to Q4 equals

$$\begin{aligned} \textit{Iron Weight } (Q4 - Q4) &\sim 28 \times 3860 + 35 \times 1275 \\ &\sim 152700 \; kg \end{aligned} \tag{12}$$

10). Magnetic Stored (Quench) Energy Q4 to Q4

The magnetic stored energies are 350 kj for a dipole and 20 kj for a quadrupole. Total magnetic stored energy from Q4 to Q4 equals

$$\begin{aligned} \textit{Magnetic (Quench) Energy} &\sim 28 \times 350 + 35 \times 20 \; kj \\ &\sim 10500 \; kj \end{aligned} \tag{13}$$

11). Valve Boxes

All twelve valve boxes are horizontal cylinders with dish heads. The diameter, overall length, approximated volume and surface area for these valve boxes are given below.

Valve Box	Diameter	Length	Volume	Surface Area
O'clock	ft	ft	L	cm^2
6	8	16.5	20,000	4.8×10^5
2, 4(yellow), 8 & 12	5	26.5	14,700	4.2×10^5
4(blue) & 10	5	29.5	16,000	4.6×10^5

If we use the same heat flux of 0.05 W per cm^2 as for the RHIC dipole, the total heat input to the valve boxes would be approximately 24 kW.

12). Triplet Magnet

The vacuum tank for the D0 and Q1, Q2 & Q3 Triplet is approximately 48 inches in diameter and 18.5 meters long. The volume is about 21,600 L for the vacuum tank, 2,000 L for the magnets and 740 L for various pipes and heat shield. The net volume at the vacuum space is approximately 19,000 L. The surface area of the vacuum tank is about 7.1×10^5 cm^2. If we use the same heat flux of 0.05 W per cm^2 as for a RHIC dipole, the heat input to the valve box would be approximately 36 kW. The weight is 2045 kg for D0, 1410 kg for Q1, 3360 kg for Q2 and 3045 kg for Q3. The vacuum tank is shared by magnets from both rings. The total weight for the magnet is approximately 20,000 kg.

13). DX Magnet

The vacuum tank for the DX is approximately 36 inches in diameter and 15.2 meters long. The volume is about 3,035 L for the vacuum tank and 1,350 L for the magnets. The net volume for the vacuum space is approximately 1,685 L. The surface area of the vacuum tank is about 1.3×10^5 cm^2. If we use the same heat flux of 0.05 W per cm^2 as for the RHIC dipole, the heat input to the valve box would be approximately 6.7 kW. The weight of DX is approximately 7,730 kg.

Appendix B: Results for helium release rate calculation

Calculation for vacuum tank relief (including magnet iron mass),
Please enter remarks
Estimation of helium releasing rate for ODH study in RHIC tunnel
Enter initial pressure, pi-atm
5
Enter initial temperature, ti-K
4.2
Enter liquid helium volume - L
5653
Enter vacuum tank volume - L
97000
Enter mass of iron - kg
152700
Enter venting pressure pvent-atm
1.2
Enter heating rate qheat-kW
500

Constant density heating process

p	t	rho	M	u	Mu	hmag	dtime	time
atm	K	g/cc	kg	j/g	kj	kj	sec	sec
5.00	4.20	.141	799.0	7.45	5951.8	124.9	.00	.0
.59	4.20	.008	799.0	25.95	20731.1	124.9	29.56	29.6
.66	4.54	.008	799.0	27.05	21608.1	146.6	1.80	31.4
.72	4.89	.008	799.0	28.13	22478.2	170.6	1.79	33.1
.78	5.23	.008	799.0	29.22	23343.3	196.9	1.78	34.9
.84	5.57	.008	799.0	30.30	24205.1	225.6	1.78	36.7
.90	5.92	.008	799.0	31.37	25064.3	256.5	1.78	38.5
.96	6.27	.008	799.0	32.47	25943.5	286.2	1.82	40.3
1.02	6.61	.008	799.0	33.54	26799.5	318.3	1.78	42.1
1.08	6.96	.008	799.0	34.61	27654.7	354.8	1.78	43.9
1.14	7.30	.008	799.0	35.68	28509.4	395.9	1.79	45.7
1.20	7.65	.008	799.0	36.78	29384.7	442.5	1.84	47.5

Constant pressure venting process

t1	rho1	h1	tx	q-he	q-mag	q-tot	heatl	mdot	He)r	Area	dtime	time
K	g/cc	j/g	K	kj	kj	kj	j/g	g/s	Kg	in**2	sec	sec
7.7	.008	51.5	8.7	4194.	153.	4346.	41.	12329.	107.3	48.5	8.7	9.
8.7	.007	57.2	9.7	3597.	179.	3777.	47.	10624.	187.6	44.2	7.6	16.
9.7	.006	62.7	10.7	3160.	208.	3368.	53.	9304.	250.3	40.6	6.7	23.
10.7	.006	68.1	11.7	2827.	240.	3067.	60.	8240.	300.8	37.6	6.1	29.
11.7	.005	73.5	12.7	2562.	276.	2838.	67.	7351.	342.5	35.0	5.7	35.
12.7	.005	78.9	13.7	2345.	317.	2663.	75.	6590.	377.6	32.6	5.3	40.
13.7	.004	84.3	14.7	2163.	363.	2527.	84.	5927.	407.6	30.4	5.1	45.
14.7	.004	89.6	15.7	2009.	412.	2421.	92.	5346.	433.5	28.3	4.8	50.
15.7	.004	94.9	16.7	1876.	465.	2341.	102.	4828.	456.1	26.4	4.7	55.
16.7	.004	100.2	18.7	3422.	1179.	4601.	119.	4090.	493.7	23.6	9.2	64.
18.7	.003	110.7	20.7	3055.	1461.	4516.	145.	3327.	523.7	20.2	9.0	73.
20.7	.003	121.3	22.7	2761.	1788.	4549.	177.	2704.	548.3	17.2	9.1	82.
22.7	.003	131.8	24.7	2519.	2208.	4728.	224.	2170.	568.9	14.4	9.5	91.
24.7	.002	142.2	26.7	2317.	2709.	5026.	266.	1730.	586.3	11.9	10.1	102.
26.7	.002	152.7	28.7	2146.	3316.	5462.	349.	1367.	601.2	9.8	10.9	112.
28.7	.002	163.2	30.7	1998.	4030.	6029.	424.	1075.	614.1	8.0	12.1	125.
30.7	.002	173.6	32.7	1870.	4852.	6722.	505.	845.	625.5	6.5	13.4	138.
32.7	.002	184.1	34.7	1757.	5789.	7546.	694.	665.	635.5	5.2	15.1	153.
34.7	.002	194.5	36.7	1658.	6840.	8498.	919.	526.	644.5	4.3	17.0	170.
36.7	.002	204.9	38.7	1569.	8006.	9575.	1182.	418.	652.5	3.5	19.2	189.
38.7	.002	215.3	40.7	1489.	9319.	10808.	1448.	334.	659.7	2.8	21.6	211.
40.7	.001	225.8	42.7	1417.	10785.	12201.	1742.	268.	666.2	2.3	24.4	235.
42.7	.001	236.2	44.7	1351.	12323.	13675.	2191.	217.	672.2	1.9	27.3	263.