BROOKHAVEN NATIONAL LABORATORY

RHIC

MEMORANDUM

Date: January 11, 1999

To: M. Harrison

From: A.G. Prodell, Chairman-Cryogenic Safety Committee AGP

Subject: Analysis of the Oxygen Deficiency Hazard (ODH) in the RHIC Accelerator Tunnel with the Helium System at 50K.

The Cryogenic Safety Committee (CSC) has reviewed calculations made by S. Kane of RHIC ODHs in the six RHIC sextants under conditions where both the ODH detection and tunnel ventilation systems are non-operational. The analyses indicated that, with the helium system in the RHIC tunnel at a temperature of 50K, the lowest oxygen concentration in the tunnel in the event of a helium release would be 20.4% by volume and the RHIC ODH Category O would be maintained. This condition is in contrast to that when the helium system is at 4K and non-operation of the ODH detection and ventilation systems would create a RHIC ODH category in the tunnel greater than zero. The CSC therefore concurs that the RHIC ODH Category O is still applicable in the RHIC tunnel when the collider is cooled to and/or held at a temperature of 50K with the ODH detection and ventilation systems not operating.

AP/gc
cc: K. Brog
A. Etkin
S. Musolino
S. Ozaki
CSC Members and Secretary

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

RHIC

Date: December 21, 1998 SE3020

To: M. Harrison

From: Steven F. Kane

Subject: RHIC Accelerator Tunnel Oxygen Deficiency Hazard Analysis for 50K Operating Temperature

Enclosures:
(1) RHIC 1 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature
(2) RHIC 3 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature
(3) RHIC 5 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature
(4) RHIC 7 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature
(5) RHIC 9 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature
(6) RHIC 11 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature

At your request, I have conducted an analysis of the Oxygen Deficiency Hazard (ODH) in the RHIC Accelerator Tunnel when the cryogenic system is in operation. Your request was to determine the lowest temperature the machine could operate with the tunnel fans not operational, while maintaining a RHIC ODH Category 0. This memorandum and its attachments document this analysis.

During cooldown, the RHIC refrigerator has, very simplistically stated, two operating temperatures – 55K from Coldbox 3, and 4K from Coldbox 5. Current plans for cooldown will use these refrigerator output temperatures to cooldown the RHIC rings. The RHIC SAD and the RHIC Cryogenic System Failure Modes Effects Analysis (FMEA) both address the RHIC Tunnel ODH at 4K operating temperature, and find that the ODH detection and ventilation systems are necessary to maintain a RHIC ODH Category 0 classification. Thus, use of the 4K output from the RHIC refrigerator for RHIC ring cooldown, without the ODH detection and ventilation systems operational, would create a RHIC ODH Category within the RHIC tunnels greater than 0. This does not meet your criteria.

The Enclosed analyses are RHIC ODH calculations for each of the RHIC tunnels at a 50K operating temperature. These calculations use the same algorithms used for the original RHIC tunnel ODH analysis, but scale the helium release rates for the lower density at 50K. The densities used were 0.144 g/cc helium density at 4K, and 0.142×10^{-1} g/cc helium density at 50K.

The worst cases are represented by the analyses for the RHIC 3 O'Clock and 11 O'Clock tunnels. The enclosed analyses indicate the lowest oxygen concentration would be 20.4% by volume, and RHIC ODH Category 0. This is well above any current standards for ODH safety, including those for RHIC. Therefore, it is my conclusion and recommendation that the RHIC tunnel may be safely occupied without the ODH detection and ventilation systems operational, and with the RHIC rings cooled to a temperature no lower than 50K.

cc:
S. Ozaki
J. Sondericker
M. Iarocci
S. Musolino
A. Etkin
S. Hoey
L. Bower

RHIC 1 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature

This mathcad program calculates the ODH class when the ventilation fans are drawing from the confined volume at a rate greater than the spill rate, and upon completion of the spill. The methodology followed is described in the RHIC ODH standard. This particular file calculates the ODH classification for fan failure (or shut down) and a 50K operating temperature.

ENTER AREA CODE

Area in Question= AREACODE := 100 Code

ENTER DATA : R...,V,Q,P1...,N1....

DATA

Gas Spill Rate (R) [ft3/min]_____

Confined Volume (V) V := 310000 (CF)

Fan Vent Rate (Q) Q := 1 (CFM)

Note: failure rates below obtained from the ODH standard. If the variety of equipment numbers less then 6, enter "0" for N..... DATA

$density_4K := .144 \cdot \frac{gm}{mL}$ $density_50K := .142 \cdot 10^{-1} \cdot \frac{gm}{mL}$

$Scale_50K := \frac{density_50K}{density_4K}$

DATA

R := 126000	R14 := 0	(SCFM He)
R1 := 87000	R15 := 0	(SCFM He)
R2 := 48000	R16 := 0	(SCFM He)
R3 := 18000	R17 := 0	(SCFM He)
R4 := 12000	R18 := 0	(SCFM He)
R5 := 7800	R19 := 0	(SCFM He)
R6 := 2000	R20 := 0	(SCFM He)
R7 := 2000	R21 := 0	(SCFM He)
R8 := 2000	R22 := 0	(SCFM He)
R9 := 2000	R23 := 0	(SCFM He)
R10 := 2000	R24 := 0	(SCFM He)
R11 := 2000	R25 := 0	(SCFM He)
R12 := 2000	R26 := 0	(SCFM He)
R13 := 2000	R27 := 0	(SCFM He)

Equip. #1 failure rate (P1)	$P1 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #1 (N1)	N1 := 888	(ea.)
Equip. #2 failure rate (P2)	$P2 := 1 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #2 (N2)	N2 := 180	(ea.)
Equip. #3 failure rate (P3)	$P3 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #3 (N3)	N3 := 00	(ea.)
Equip. #4 failure rate (P4)	$P4 := 5 \cdot 10^{-8}$	(per hr.)
Quantity of Equip. #4 (N4)	N4 := 3	(ea.)
Equip. #5 failure rate (P5)	$P5 := 2.5 \cdot 10^{-5}$	(per hr.)
Quantity of Equip. #5 (N5)	N5 := 3	(ea.)(FANS)
Equip. #6 failure rate (P6)	$P6 := 5 \cdot 10^{-2}$	(per hr.)
Quantity of Equip. #6 (N6)	N6 := 1	(ea.)

Note: R - R5 above are time (t in min.) dependant spill rates as follows:

R:	$0 \le t \le .5$	
R1:	$.5 < t \le 1.0$	
R2:	$1.0 < t \le 1.5$	
R3:	$1.5 < t \le 2.0$	
R4:	$2.0 < t \le 2.5$	
R5:	$2.5 < t \le 3.0$	ETC.

$i := 0, 1 .. 28$

$t_i := \frac{i}{2}$

$R_i := R \cdot Scale_50K$ $R1_i := R1 \cdot Scale_50K$ $R2_i := R2 \cdot Scale_50K$ $R6_i := R6 \cdot Scale_50K$ $R7_i := R7 \cdot Scale_50K$ $R8_i := R8 \cdot Scale_50K$

$R12_i := R12 \cdot Scale_50K$ $R3_i := R3 \cdot Scale_50K$ $R4_i := R4 \cdot Scale_50K$ $R5_i := R5 \cdot Scale_50K$ $R9_i := R9 \cdot Scale_50K$

$R10_i := R10 \cdot Scale_50K$ $R11_i := R11 \cdot Scale_50K$ $R13_i := R13 \cdot Scale_50K$ $R14_i := R14 \cdot Scale_50K$ $R15_i := R15 \cdot Scale_50K$

$R16_i := R16 \cdot Scale_50K$ $R17_i := R17 \cdot Scale_50K$ $R18_i := R18 \cdot Scale_50K$ $R19_i := R19 \cdot Scale_50K$ $R20_i := R20 \cdot Scale_50K$

$R21_i := R21 \cdot Scale_50K$ $R22_i := R22 \cdot Scale_50K$ $R23_i := R23 \cdot Scale_50K$ $R24_i := R24 \cdot Scale_50K$ $R25_i := R25 \cdot Scale_50K$

$R26_i := R26 \cdot Scale_50K$ $R27_i := R27 \cdot Scale_50K$

$R_i := \text{if}(t_i \le 5.5, R_i, \text{if}(t_i \le 1.0, R1_i, \text{if}(t_i \le 1.5, R2_i, \text{if}(t_i \le 2.0, R3_i, \text{if}(t_i \le 2.5, R4_i, \text{if}(t_i \le 3.0, R5_i, \text{if}(t_i \le 3.5, R6_i, \text{if}(t_i \le 4.0, R7_i, \text{if}(t_i \le 4.5, R8_i, \text{if}$

$A_i := \text{if}(t_i \le 5.5, R1_i, \text{if}(t_i \le 1.0, R2_i, \text{if}(t_i \le 1.5, R3_i, \text{if}(t_i \le 2.0, R4_i, \text{if}(t_i \le 2.5, R5_i, \text{if}(t_i \le 3.0, R6_i, \text{if}(t_i \le 3.5, R7_i, \text{if}(t_i \le 4.0, R8_i, \text{if}(t_i \le 4.5, R9_i, i$

$P11 := N1 \cdot P1 \quad P44 := N4 \cdot P4 \quad P22 := N2 \cdot P2 \quad P33 := N3 \cdot P3 \quad P55 := N5 \cdot P5 \quad P66 := N6 \cdot P6$

$$cr_i := 21 \cdot \left[1 - \frac{R_i + A_i}{2 \cdot Q} \cdot \left(1 - e^{-Q \frac{t_i}{V}} \right) \right]$$

eq. A- calculate O2 % by vol. during the spill period. Note spill rate averaged within time increments.

$$Cr_i := \text{if}(cr_i \ge 0, cr_i, 0)$$

eqs. displays O2 % by vol. and constrain to >0%

$$ce_i := 21 - (21 - Cr_{14}) \cdot e^{-Q \frac{t_i}{V}}$$

eq. B- calculate O2 % by vol. after the spill period. Note Cr14 is the beginning of the non-spill period

$$Cr_i := \text{if}(t_i \ge 7.5, ce_i, cr_i)$$

eq. defines the use of eq A or B

$$PO2_i := Cr_i \cdot \frac{760}{100}$$

PP O2

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

$$F_i := \text{if}(G_i \ge 1, 1, \text{if}(G_i \le 1 \cdot 10^{-7}, 0.0, \text{if}(G_i > 1 \cdot 10^{-7}, G_i, 1)))$$

$$\phi_i := P11 \cdot F_i + P22 \cdot F_i + P33 \cdot F_i + P44 \cdot F_i + P55 \cdot F_i + P66 \cdot F_i$$

Eq. at left calculates fatality factor and sets limits between 0 and 1. Nested "if" statement.

$$P_i := (P11 + P22 + P33 + P44 + P55 + P66) \cdot 1$$

ODH fatality Rate.

$$P_i := P_i \cdot 1 \cdot 10^6 \qquad F_i := F_i \cdot 1 \cdot 10^7$$

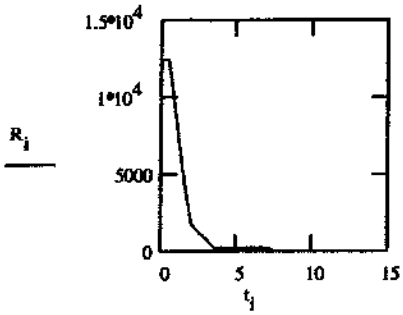
$$ODH_i := \text{if}(\phi_i \le 1 \cdot 10^{-7}, 0, \text{if}(\phi_i \le 1 \cdot 10^{-5}, 1, \text{if}(\phi_i \le 1 \cdot 10^{-3}, 2, \text{if}(\phi_i \le 1 \cdot 10^{-1}, 3, 4))))$$

The eq. above calculates the ODH class. Nested "if" statement.

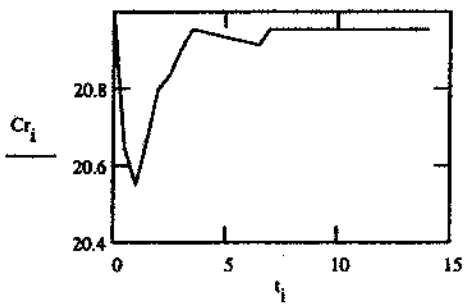
$$\phi_i := \phi_i \cdot 1 \cdot 10^7$$

Spill Rate (SCFM) R_i	T (min) t_i	O2 (%) Cr_i	PP (mmHg) $PO2_i$	Fatality Factor Fi (10E-7) F_i	Event Rate Pi (10E-6) (per hr.) P_i	ODH Fatality Rate phi (10E-7) (per hr.) ϕ_i	ODH Class ODH_i
12425	0	21	159.6	0	52919.15	0	0
12425	0.5	20.6	156.9	0	52919.15	0	0
8579.2	1	20.5	156.2	0	52919.15	0	0
4733.3	1.5	20.7	157.1	0	52919.15	0	0
1775	2	20.8	158.1	0	52919.15	0	0
1183.3	2.5	20.8	158.3	0	52919.15	0	0
769.2	3	20.9	158.9	0	52919.15	0	0
197.2	3.5	21	159.2	0	52919.15	0	0
197.2	4	20.9	159.2	0	52919.15	0	0
197.2	4.5	20.9	159.1	0	52919.15	0	0
197.2	5	20.9	159.1	0	52919.15	0	0
197.2	5.5	20.9	159	0	52919.15	0	0
197.2	6	20.9	159	0	52919.15	0	0
197.2	6.5	20.9	158.9	0	52919.15	0	0
197.2	7	21	159.2	0	52919.15	0	0
0	7.5	21	159.2	0	52919.15	0	0
0	8	21	159.2	0	52919.15	0	0
0	8.5	21	159.2	0	52919.15	0	0
0	9	21	159.2	0	52919.15	0	0
0	9.5	21	159.2	0	52919.15	0	0
0	10	21	159.2	0	52919.15	0	0
0	10.5	21	159.2	0	52919.15	0	0
0	11	21	159.2	0	52919.15	0	0
0	11.5	21	159.2	0	52919.15	0	0
0	12	21	159.2	0	52919.15	0	0
0	12.5	21	159.2	0	52919.15	0	0
0	13	21	159.2	0	52919.15	0	0
0	13.5	21	159.2	0	52919.15	0	0
0	14	21	159.2	0	52919.15	0	0

Spill rate (CFM) vs. Time (min.)



O2 (%) vs. Time (min.)



$ODHCLASS := if(ODH_2 < ODH_1, ODH_1, if(ODH_3 < ODH_2, ODH_2, if(ODH_4 < ODH_3, ODH_3, if(ODH_5 < ODH_4, ODH_4, if(ODH_6 < ODH_5$

The equation above selects the highest ODH class.

For: $AREACODE = 100$,the $ODHCLASS = 0$

RHIC 3 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature

This mathcad program calculates the ODH class when the ventilation fans are drawing from the confined volume at a rate greater than the spill rate, and upon completion of the spill. The methodology followed is described in the RHIC ODH standard. This particular file calculates the ODH classification for fan failure (or shut down) and a 50K operating temperature.

ENTER AREA CODE

Area in Question= AREACODE := 100 Code

ENTER DATA : R...,V,Q,P1...,N1....

DATA

Gas Spill Rate (R) [ft3/min]_____

Confined Volume (V) V := 300000 (CF)

Fan Vent Rate (Q) Q := 1 (CFM)

Note: failure rates below obtained from the ODH standard. If the variety of equipment numbers less then 6, enter "0" for N.....

DATA

$density_4K := .144 \cdot \frac{gm}{mL}$ $density_50K := .142 \cdot 10^{-1} \cdot \frac{gm}{mL}$

$Scale_50K := \frac{density_50K}{density_4K}$

DATA

R := 126000	R14 := 0	(SCFM He)
R1 := 87000	R15 := 0	(SCFM He)
R2 := 48000	R16 := 0	(SCFM He)
R3 := 18000	R17 := 0	(SCFM He)
R4 := 12000	R18 := 0	(SCFM He)
R5 := 7800	R19 := 0	(SCFM He)
R6 := 2000	R20 := 0	(SCFM He)
R7 := 2000	R21 := 0	(SCFM He)
R8 := 2000	R22 := 0	(SCFM He)
R9 := 2000	R23 := 0	(SCFM He)
R10 := 2000	R24 := 0	(SCFM He)
R11 := 2000	R25 := 0	(SCFM He)
R12 := 2000	R26 := 0	(SCFM He)
R13 := 2000	R27 := 0	(SCFM He)

Equip. #1 failure rate (P1)	$P1 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #1 (N1)	N1 := 888	(ea.)
Equip. #2 failure rate (P2)	$P2 := 1 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #2 (N2)	N2 := 180	(ea.)
Equip. #3 failure rate (P3)	$P3 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #3 (N3)	N3 := 00	(ea.)
Equip. #4 failure rate (P4)	$P4 := 5 \cdot 10^{-8}$	(per hr.)
Quantity of Equip. #4 (N4)	N4 := 3	(ea.)
Equip. #5 failure rate (P5)	$P5 := 2.5 \cdot 10^{-5}$	(per hr.)
Quantity of Equip. #5 (N5)	N5 := 3	(ea.)(FANS)
Equip. #6 failure rate (P6)	$P6 := 5 \cdot 10^{-2}$	(per hr.)
Quantity of Equip. #6 (N6)	N6 := 1	(ea.)

Note: R - R5 above are time (t in min.) dependant spill rates as follows:

R:	$0 \le t \le .5$	
R1:	$.5 < t \le 1.0$	
R2:	$1.0 < t \le 1.5$	
R3:	$1.5 < t \le 2.0$	
R4:	$2.0 < t \le 2.5$	
R5:	$2.5 < t \le 3.0$	ETC.

$i := 0, 1 .. 28$

$t_i := \frac{i}{2}$

$R_i := R \cdot Scale_50K$ $R1_i := R1 \cdot Scale_50K$ $R2_i := R2 \cdot Scale_50K$ $R6_i := R6 \cdot Scale_50K$ $R7_i := R7 \cdot Scale_50K$ $R8_i := R8 \cdot Scale_50K$

$R12_i := R12 \cdot Scale_50K$ $R3_i := R3 \cdot Scale_50K$ $R4_i := R4 \cdot Scale_50K$ $R5_i := R5 \cdot Scale_50K$ $R9_i := R9 \cdot Scale_50K$

$R10_i := R10 \cdot Scale_50K$ $R11_i := R11 \cdot Scale_50K$ $R13_i := R13 \cdot Scale_50K$ $R14_i := R14 \cdot Scale_50K$ $R15_i := R15 \cdot Scale_50K$

$R16_i := R16 \cdot Scale_50K$ $R17_i := R17 \cdot Scale_50K$ $R18_i := R18 \cdot Scale_50K$ $R19_i := R19 \cdot Scale_50K$ $R20_i := R20 \cdot Scale_50K$

$R21_i := R21 \cdot Scale_50K$ $R22_i := R22 \cdot Scale_50K$ $R23_i := R23 \cdot Scale_50K$ $R24_i := R24 \cdot Scale_50K$ $R25_i := R25 \cdot Scale_50K$

$R26_i := R26 \cdot Scale_50K$ $R27_i := R27 \cdot Scale_50K$

$R_i := \text{if}(t_i \le .5, R_i, \text{if}(t_i \le 1.0, R1_i, \text{if}(t_i \le 1.5, R2_i, \text{if}(t_i \le 2.0, R3_i, \text{if}(t_i \le 2.5, R4_i, \text{if}(t_i \le 3.0, R5_i, \text{if}(t_i \le 3.5, R6_i, \text{if}(t_i \le 4.0, R7_i, \text{if}(t_i \le 4.5, R8_i, \text{if}$

$A_i := \text{if}(t_i \le .5, R1_i, \text{if}(t_i \le 1.0, R2_i, \text{if}(t_i \le 1.5, R3_i, \text{if}(t_i \le 2.0, R4_i, \text{if}(t_i \le 2.5, R5_i, \text{if}(t_i \le 3.0, R6_i, \text{if}(t_i \le 3.5, R7_i, \text{if}(t_i \le 4.0, R8_i, \text{if}(t_i \le 4.5, R9_i, i$

$P11 := N1 \cdot P1 \quad P44 := N4 \cdot P4 \quad P22 := N2 \cdot P2 \quad P33 := N3 \cdot P3 \quad P55 := N5 \cdot P5 \quad P66 := N6 \cdot P6$

$$cr_i := 21 \cdot \left[1 - \frac{R_i + A_i}{2 \cdot Q} \cdot \left(1 - e^{-Q \frac{t_i}{V}}\right)\right]$$

eq. A- calculate O2 % by vol. during the spill period. Note spill rate averaged within time increments.

$$Cr_i := \text{if}(cr_i \ge 0, cr_i, 0)$$

eqs. displays O2 % by vol. and constrain to >0%

$$ce_i := 21 - (21 - Cr_{14}) \cdot e^{-Q \frac{t_i}{V}}$$

eq. B- calculate O2 % by vol. after the spill period. Note Cr14 is the beginning of the non-spill period

$$Cr_i := \text{if}(t_i \ge 7.5, ce_i, cr_i)$$

eq. defines the use of eq A or B

$$PO2_i := Cr_i \cdot \frac{760}{100}$$

PP O2

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

$$F_i := \text{if}(G_i \ge 1, 1, \text{if}(G_i \le 1 \cdot 10^{-7}, 0.0, \text{if}(G_i > 1 \cdot 10^{-7}, G_i, 1)))$$

Eq. at left calculates fatality factor and sets limits between 0 and 1. Nested "if" statement.

$$\phi_i := P11 \cdot F_i + P22 \cdot F_i + P33 \cdot F_i + P44 \cdot F_i + P55 \cdot F_i + P66 \cdot F_i$$

$$P_i := (P11 + P22 + P33 + P44 + P55 + P66) \cdot 1$$

ODH fatality Rate.

$$P_i := P_i \cdot 1 \cdot 10^6 \qquad F_i := F_i \cdot 1 \cdot 10^7$$

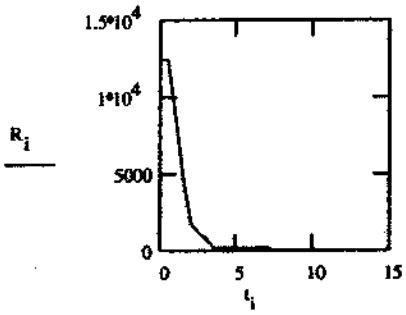
$$ODH_i := \text{if}(\phi_i \le 1 \cdot 10^{-7}, 0, \text{if}(\phi_i \le 1 \cdot 10^{-5}, 1, \text{if}(\phi_i \le 1 \cdot 10^{-3}, 2, \text{if}(\phi_i \le 1 \cdot 10^{-1}, 3, 4))))$$

The eq. above calculates the ODH class. Nested "if" statement.

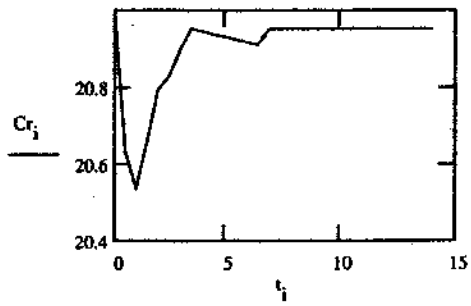
$$\phi_i := \phi_i \cdot 1 \cdot 10^7$$

Spill Rate (SCFM) R_i	T (min) t_i	O2 (%) Cr_i	PP (mmHg) $PO2_i$	Fatality Factor Fi (10E-7) F_i	Event Rate Pi (10E-6) (per hr.) P_i	ODH Fatality Rate phi (10E-7) (per hr.) ϕ_i	ODH Class ODH_i
12425	0	21	159.6	0	52919.15	0	0
12425	0.5	20.6	156.8	0	52919.15	0	0
8579.2	1	20.5	156.1	0	52919.15	0	0
4733.3	1.5	20.7	157	0	52919.15	0	0
1775	2	20.8	158	0	52919.15	0	0
1183.3	2.5	20.8	158.3	0	52919.15	0	0
769.2	3	20.9	158.8	0	52919.15	0	0
197.2	3.5	21	159.2	0	52919.15	0	0
197.2	4	20.9	159.2	0	52919.15	0	0
197.2	4.5	20.9	159.1	0	52919.15	0	0
197.2	5	20.9	159.1	0	52919.15	0	0
197.2	5.5	20.9	159	0	52919.15	0	0
197.2	6	20.9	159	0	52919.15	0	0
197.2	6.5	20.9	158.9	0	52919.15	0	0
197.2	7	21	159.2	0	52919.15	0	0
0	7.5	21	159.2	0	52919.15	0	0
0	8	21	159.2	0	52919.15	0	0
0	8.5	21	159.2	0	52919.15	0	0
0	9	21	159.2	0	52919.15	0	0
0	9.5	21	159.2	0	52919.15	0	0
0	10	21	159.2	0	52919.15	0	0
0	10.5	21	159.2	0	52919.15	0	0
0	11	21	159.2	0	52919.15	0	0
0	11.5	21	159.2	0	52919.15	0	0
0	12	21	159.2	0	52919.15	0	0
0	12.5	21	159.2	0	52919.15	0	0
0	13	21	159.2	0	52919.15	0	0
0	13.5	21	159.2	0	52919.15	0	0
0	14	21	159.2	0	52919.15	0	0

Spill rate (CFM) vs. Time (min.)



O2 (%) vs. Time (min.)



$$ODHCLASS := if(ODH_2 < ODH_1, ODH_1, if(ODH_3 < ODH_2, ODH_2, if(ODH_4 < ODH_3, ODH_3, if(ODH_5 < ODH_4, ODH_4, if(ODH_6 < ODH_5$$

The equation above selects the highest ODH class.

For: $AREACODE = 100$,the $ODHCLASS = 0$

RHIC 5 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature

This mathcad program calculates the ODH class when the ventilation fans are drawing from the confined volume at a rate greater than the spill rate, and upon completion of the spill. The methodology followed is described in the RHIC ODH standard. This particular file calculates the ODH classification for fan failure (or shut down) and a 50K operating temperature.

ENTER AREA CODE

Area in Question= AREACODE := 100 Code

ENTER DATA : R...,V,Q,P1...,N1....

DATA

Gas Spill Rate (R) [ft3/min]_____

Confined Volume (V) V := 390000 (CF)

Fan Vent Rate (Q) Q := 1 (CFM)

Note: failure rates below obtained from the ODH standard. If the variety of equipment numbers less then 6, enter "0" for N..... DATA

$density_4K := .144 \cdot \frac{gm}{mL}$ $density_50K := .142 \cdot 10^{-1} \cdot \frac{gm}{mL}$

$Scale_50K := \frac{density_50K}{density_4K}$

DATA

R := 126000	R14 := 0	(SCFM He)
R1 := 87000	R15 := 0	(SCFM He)
R2 := 48000	R16 := 0	(SCFM He)
R3 := 18000	R17 := 0	(SCFM He)
R4 := 12000	R18 := 0	(SCFM He)
R5 := 7800	R19 := 0	(SCFM He)
R6 := 2000	R20 := 0	(SCFM He)
R7 := 2000	R21 := 0	(SCFM He)
R8 := 2000	R22 := 0	(SCFM He)
R9 := 2000	R23 := 0	(SCFM He)
R10 := 2000	R24 := 0	(SCFM He)
R11 := 2000	R25 := 0	(SCFM He)
R12 := 2000	R26 := 0	(SCFM He)
R13 := 2000	R27 := 0	(SCFM He)

Equip. #1 failure rate (P1)	$P1 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #1 (N1)	N1 := 888	(ea.)
Equip. #2 failure rate (P2)	$P2 := 1 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #2 (N2)	N2 := 180	(ea.)
Equip. #3 failure rate (P3)	$P3 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #3 (N3)	N3 := 00	(ea.)
Equip. #4 failure rate (P4)	$P4 := 5 \cdot 10^{-8}$	(per hr.)
Quantity of Equip. #4 (N4)	N4 := 3	(ea.)
Equip. #5 failure rate (P5)	$P5 := 2.5 \cdot 10^{-5}$	(per hr.)
Quantity of Equip. #5 (N5)	N5 := 3	(ea.)(FANS)
Equip. #6 failure rate (P6)	$P6 := 5 \cdot 10^{-2}$	(per hr.)
Quantity of Equip. #6 (N6)	N6 := 1	(ea.)

Note: R - R5 above are time (t in min.) dependant spill rates as follows:

R:	$0 \le t \le .5$	
R1:	$.5 < t \le 1.0$	
R2:	$1.0 < t \le 1.5$	
R3:	$1.5 < t \le 2.0$	
R4:	$2.0 < t \le 2.5$	
R5:	$2.5 < t \le 3.0$	ETC.

$i := 0, 1 .. 28$

$t_i := \frac{i}{2}$

$R_i := R \cdot Scale_50K$ $R1_i := R1 \cdot Scale_50K$ $R2_i := R2 \cdot Scale_50K$ $R6_i := R6 \cdot Scale_50K$ $R7_i := R7 \cdot Scale_50K$ $R8_i := R8 \cdot Scale_50K$

$R12_i := R12 \cdot Scale_50K$ $R3_i := R3 \cdot Scale_50K$ $R4_i := R4 \cdot Scale_50K$ $R5_i := R5 \cdot Scale_50K$ $R9_i := R9 \cdot Scale_50K$

$R10_i := R10 \cdot Scale_50K$ $R11_i := R11 \cdot Scale_50K$ $R13_i := R13 \cdot Scale_50K$ $R14_i := R14 \cdot Scale_50K$ $R15_i := R15 \cdot Scale_50K$

$R16_i := R16 \cdot Scale_50K$ $R17_i := R17 \cdot Scale_50K$ $R18_i := R18 \cdot Scale_50K$ $R19_i := R19 \cdot Scale_50K$ $R20_i := R20 \cdot Scale_50K$

$R21_i := R21 \cdot Scale_50K$ $R22_i := R22 \cdot Scale_50K$ $R23_i := R23 \cdot Scale_50K$ $R24_i := R24 \cdot Scale_50K$ $R25_i := R25 \cdot Scale_50K$

$R26_i := R26 \cdot Scale_50K$ $R27_i := R27 \cdot Scale_50K$

$R_i := \text{if}(t_i \le .5, R_i, \text{if}(t_i \le 1.0, R1_i, \text{if}(t_i \le 1.5, R2_i, \text{if}(t_i \le 2.0, R3_i, \text{if}(t_i \le 2.5, R4_i, \text{if}(t_i \le 3.0, R5_i, \text{if}(t_i \le 3.5, R6_i, \text{if}(t_i \le 4.0, R7_i, \text{if}(t_i \le 4.5, R8_i, \text{if}$

$A_i := \text{if}(t_i \le .5, R1_i, \text{if}(t_i \le 1.0, R2_i, \text{if}(t_i \le 1.5, R3_i, \text{if}(t_i \le 2.0, R4_i, \text{if}(t_i \le 2.5, R5_i, \text{if}(t_i \le 3.0, R6_i, \text{if}(t_i \le 3.5, R7_i, \text{if}(t_i \le 4.0, R8_i, \text{if}(t_i \le 4.5, R9_i, i$

$P11 := N1 \cdot P1 \quad P44 := N4 \cdot P4 \quad P22 := N2 \cdot P2 \quad P33 := N3 \cdot P3 \quad P55 := N5 \cdot P5 \quad P66 := N6 \cdot P6$

$$cr_i := 21 \cdot \left[1 - \frac{R_i + A_i}{2 \cdot Q} \cdot \left(1 - e^{-Q \cdot \frac{t_i}{V}}\right)\right]$$

eq. A- calculate O2 % by vol. during the spill period. Note spill rate averaged within time increments.

$$Cr_i := \text{if}(cr_i \ge 0, cr_i, 0)$$

eqs. displays O2 % by vol. and constrain to >0%

$$ce_i := 21 - (21 - Cr_{14}) \cdot e^{-Q \cdot \frac{t_i}{V}}$$

eq. B- calculate O2 % by vol. after the spill period. Note Cr14 is the beginning of the non-spill period

$$Cr_i := \text{if}(t_i \ge 7.5, ce_i, cr_i)$$

eq. defines the use of eq A or B

$$PO2_i := Cr_i \cdot \frac{760}{100}$$

PP O2

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

$$F_i := \text{if}(G_i \ge 1, 1, \text{if}(G_i \le 1 \cdot 10^{-7}, 0.0, \text{if}(G_i > 1 \cdot 10^{-7}, G_i, 1)))$$

Eq. at left calculates fatality factor and sets limits between 0 and 1. Nested "if" statement.

$$\phi_i := P11 \cdot F_i + P22 \cdot F_i + P33 \cdot F_i + P44 \cdot F_i + P55 \cdot F_i + P66 \cdot F_i$$

$$P_i := (P11 + P22 + P33 + P44 + P55 + P66) \cdot 1$$

ODH fatality Rate.

$$P_i := P_i \cdot 1 \cdot 10^6 \qquad F_i := F_i \cdot 1 \cdot 10^7$$

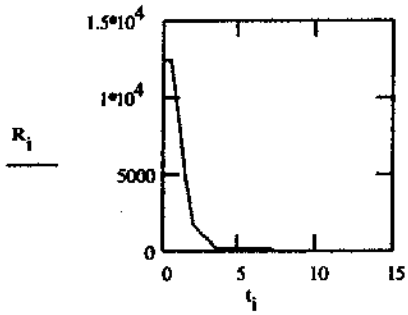
$$ODH_i := \text{if}(\phi_i \le 1 \cdot 10^{-7}, 0, \text{if}(\phi_i \le 1 \cdot 10^{-5}, 1, \text{if}(\phi_i \le 1 \cdot 10^{-3}, 2, \text{if}(\phi_i \le 1 \cdot 10^{-1}, 3, 4))))$$

The eq. above calculates the ODH class. Nested "if" statement.

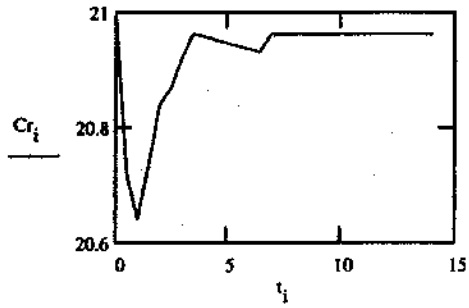
$$\phi_i := \phi_i \cdot 1 \cdot 10^7$$

Spill Rate (SCFM) R_i	T (min) t_i	O2 (%) Cr_i	PP (mmHg) $PO2_i$	Fatality Factor Fi (10E-7) F_i	Event Rate Pi (10E-6) (per hr.) P_i	ODH Fatality Rate phi (10E-7) (per hr.) ϕ_i	ODH Class ODH_i
12425	0	21	159.6	0	52919.15	0	0
12425	0.5	20.7	157.5	0	52919.15	0	0
8579.2	1	20.6	156.9	0	52919.15	0	0
4733.3	1.5	20.7	157.6	0	52919.15	0	0
1775	2	20.8	158.4	0	52919.15	0	0
1183.3	2.5	20.9	158.6	0	52919.15	0	0
769.2	3	20.9	159	0	52919.15	0	0
197.2	3.5	21	159.3	0	52919.15	0	0
197.2	4	21	159.3	0	52919.15	0	0
197.2	4.5	21	159.2	0	52919.15	0	0
197.2	5	20.9	159.2	0	52919.15	0	0
197.2	5.5	20.9	159.2	0	52919.15	0	0
197.2	6	20.9	159.1	0	52919.15	0	0
197.2	6.5	20.9	159.1	0	52919.15	0	0
197.2	7	21	159.3	0	52919.15	0	0
0	7.5	21	159.3	0	52919.15	0	0
0	8	21	159.3	0	52919.15	0	0
0	8.5	21	159.3	0	52919.15	0	0
0	9	21	159.3	0	52919.15	0	0
0	9.5	21	159.3	0	52919.15	0	0
0	10	21	159.3	0	52919.15	0	0
0.	10.5	21	159.3	0	52919.15	0	0
0	11	21	159.3	0	52919.15	0	0
0	11.5	21	159.3	0	52919.15	0	0
0	12	21	159.3	0	52919.15	0	0
0	12.5	21	159.3	0	52919.15	0	0
0	13	21	159.3	0	52919.15	0	0
0	13.5	21	159.3	0	52919.15	0	0
0	14	21	159.3	0	52919.15	0	0

Spill rate (CFM) vs. Time (min.)



O2 (%) vs. Time (min.)



$ODHCLASS := if(ODH_2 < ODH_1, ODH_1, if(ODH_3 < ODH_2, ODH_2, if(ODH_4 < ODH_3, ODH_3, if(ODH_5 < ODH_4, ODH_4, if(ODH_6 < ODH_5$

The equation above selects the highest ODH class.

For: AREACODE = 100 ,the ODHCLASS = 0

RHIC 7 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature

This mathcad program calculates the ODH class when the ventilation fans are drawing from the confined volume at a rate greater than the spill rate, and upon completion of the spill. The methodology followed is described in the RHIC ODH standard. This particular file calculates the ODH classification for fan failure (or shut down) and a 50K operating temperature.

ENTER AREA CODE

Area in Question= AREACODE := 100 Code

ENTER DATA : R...,V,Q,P1...,N1....

DATA

Gas Spill Rate (R) [ft3/min]_____

Confined Volume (V) V := 400000 (CF)

Fan Vent Rate (Q) Q := 1 (CFM)

Note: failure rates below obtained from the ODH standard. If the variety of equipment numbers less then 6, enter "0" for N..... DATA

$density_4K := .144 \cdot \frac{gm}{mL}$ $density_50K := .142 \cdot 10^{-1} \cdot \frac{gm}{mL}$

$Scale_50K := \frac{density_50K}{density_4K}$

DATA

R := 126000	R14 := 0	(SCFM He)
R1 := 87000	R15 := 0	(SCFM He)
R2 := 48000	R16 := 0	(SCFM He)
R3 := 18000	R17 := 0	(SCFM He)
R4 := 12000	R18 := 0	(SCFM He)
R5 := 7800	R19 := 0	(SCFM He)
R6 := 2000	R20 := 0	(SCFM He)
R7 := 2000	R21 := 0	(SCFM He)
R8 := 2000	R22 := 0	(SCFM He)
R9 := 2000	R23 := 0	(SCFM He)
R10 := 2000	R24 := 0	(SCFM He)
R11 := 2000	R25 := 0	(SCFM He)
R12 := 2000	R26 := 0	(SCFM He)
R13 := 2000	R27 := 0	(SCFM He)

Equip. #1 failure rate (P1)	$P1 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #1 (N1)	N1 := 888	(ea.)
Equip. #2 failure rate (P2)	$P2 := 1 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #2 (N2)	N2 := 180	(ea.)
Equip. #3 failure rate (P3)	$P3 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #3 (N3)	N3 := 00	(ea.)
Equip. #4 failure rate (P4)	$P4 := 5 \cdot 10^{-8}$	(per hr.)
Quantity of Equip. #4 (N4)	N4 := 3	(ea.)
Equip. #5 failure rate (P5)	$P5 := 2.5 \cdot 10^{-5}$	(per hr.)
Quantity of Equip. #5 (N5)	N5 := 3	(ea.)(FANS)
Equip. #6 failure rate (P6)	$P6 := 5 \cdot 10^{-2}$	(per hr.)
Quantity of Equip. #6 (N6)	N6 := 1	(ea.)

Note: R - R5 above are time (t in min.) dependant spill rates as follows:

R:	$0 \le t \le .5$	
R1:	$.5 < t \le 1.0$	
R2:	$1.0 < t \le 1.5$	
R3:	$1.5 < t \le 2.0$	
R4:	$2.0 < t \le 2.5$	
R5:	$2.5 < t \le 3.0$	ETC.

$i := 0, 1 .. 28$

$t_i := \frac{i}{2}$

$R_i := R \cdot Scale_50K$ $R1_i := R1 \cdot Scale_50K$ $R2_i := R2 \cdot Scale_50K$ $R6_i := R6 \cdot Scale_50K$ $R7_i := R7 \cdot Scale_50K$ $R8_i := R8 \cdot Scale_50K$

$R12_i := R12 \cdot Scale_50K$ $R3_i := R3 \cdot Scale_50K$ $R4_i := R4 \cdot Scale_50K$ $R5_i := R5 \cdot Scale_50K$ $R9_i := R9 \cdot Scale_50K$

$R10_i := R10 \cdot Scale_50K$ $R11_i := R11 \cdot Scale_50K$ $R13_i := R13 \cdot Scale_50K$ $R14_i := R14 \cdot Scale_50K$ $R15_i := R15 \cdot Scale_50K$

$R16_i := R16 \cdot Scale_50K$ $R17_i := R17 \cdot Scale_50K$ $R18_i := R18 \cdot Scale_50K$ $R19_i := R19 \cdot Scale_50K$ $R20_i := R20 \cdot Scale_50K$

$R21_i := R21 \cdot Scale_50K$ $R22_i := R22 \cdot Scale_50K$ $R23_i := R23 \cdot Scale_50K$ $R24_i := R24 \cdot Scale_50K$ $R25_i := R25 \cdot Scale_50K$

$R26_i := R26 \cdot Scale_50K$ $R27_i := R27 \cdot Scale_50K$

$R_i := \text{if}(t_i \le .5, R_i, \text{if}(t_i \le 1.0, R1_i, \text{if}(t_i \le 1.5, R2_i, \text{if}(t_i \le 2.0, R3_i, \text{if}(t_i \le 2.5, R4_i, \text{if}(t_i \le 3.0, R5_i, \text{if}(t_i \le 3.5, R6_i, \text{if}(t_i \le 4.0, R7_i, \text{if}(t_i \le 4.5, R8_i, \text{if}$

$A_i := \text{if}(t_i \le .5, R1_i, \text{if}(t_i \le 1.0, R2_i, \text{if}(t_i \le 1.5, R3_i, \text{if}(t_i \le 2.0, R4_i, \text{if}(t_i \le 2.5, R5_i, \text{if}(t_i \le 3.0, R6_i, \text{if}(t_i \le 3.5, R7_i, \text{if}(t_i \le 4.0, R8_i, \text{if}(t_i \le 4.5, R9_i, i$

$P11 := N1 \cdot P1 \quad P44 := N4 \cdot P4 \quad P22 := N2 \cdot P2 \quad P33 := N3 \cdot P3 \quad P55 := N5 \cdot P5 \quad P66 := N6 \cdot P6$

$$cr_i := 21 \cdot \left[1 - \frac{R_i + A_i}{2 \cdot Q} \cdot \left(1 - e^{-Q \frac{t_i}{V}}\right)\right]$$

eq. A- calculate O2 % by vol. during the spill period. Note spill rate averaged within time increments.

$$Cr_i := \text{if}(cr_i \ge 0, cr_i, 0)$$

eqs. displays O2 % by vol. and constrain to >0%

$$ce_i := 21 - (21 - Cr_{14}) \cdot e^{-Q \frac{t_i}{V}}$$

eq. B- calculate O2 % by vol. after the spill period. Note Cr14 is the beginning of the non-spill period

$$Cr_i := \text{if}(t_i \ge 7.5, ce_i, cr_i)$$

eq. defines the use of eq A or B

$$PO2_i := Cr_i \frac{760}{100}$$

PP O2

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

$$F_i := \text{if}(G_i \ge 1, 1, \text{if}(G_i \le 1 \cdot 10^{-7}, 0.0, \text{if}(G_i > 1 \cdot 10^{-7}, G_i, 1)))$$

Eq. at left calculates fatality factor and sets limits between 0 and 1. Nested "if" statement.

$$\phi_i := P11 \cdot F_i + P22 \cdot F_i + P33 \cdot F_i + P44 \cdot F_i + P55 \cdot F_i + P66 \cdot F_i$$

$$P_i := (P11 + P22 + P33 + P44 + P55 + P66) \cdot 1$$

ODH fatality Rate.

$$P_i := P_i \cdot 1 \cdot 10^6 \qquad F_i := F_i \cdot 1 \cdot 10^7$$

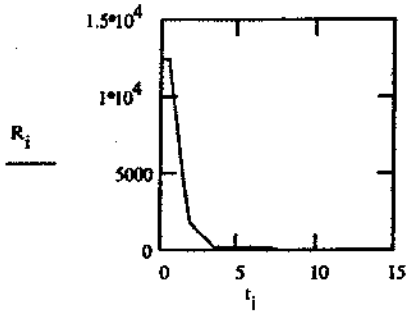
$$ODH_i := \text{if}(\phi_i \le 1 \cdot 10^{-7}, 0, \text{if}(\phi_i \le 1 \cdot 10^{-5}, 1, \text{if}(\phi_i \le 1 \cdot 10^{-3}, 2, \text{if}(\phi_i \le 1 \cdot 10^{-1}, 3, 4))))$$

The eq. above calculates the ODH class. Nested "if" statement.

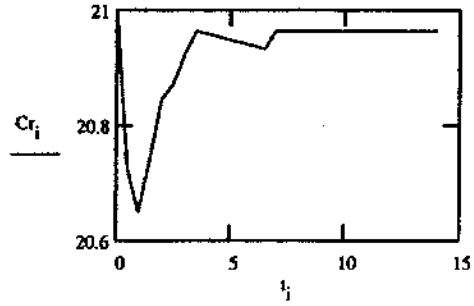
$$\phi_i := \phi_i \cdot 1 \cdot 10^7$$

Spill Rate (SCFM) R_i	T (min) t_i	O2 (%) Cr_i	PP (mmHg) $PO2_i$	Fatality Factor Fi (10E-7) F_i	Event Rate Pi (10E-6) (per hr.) P_i	ODH Fatality Rate phi (10E-7) (per hr.) ϕ_i	ODH Class ODH_i
12425	0	21	159.6	0	52919.15	0	0
12425	0.5	20.7	157.5	0	52919.15	0	0
8579.2	1	20.7	156.9	0	52919.15	0	0
4733.3	1.5	20.7	157.7	0	52919.15	0	0
1775	2	20.8	158.4	0	52919.15	0	0
1183.3	2.5	20.9	158.6	0	52919.15	0	0
769.2	3	20.9	159	0	52919.15	0	0
197.2	3.5	21	159.3	0	52919.15	0	0
197.2	4	21	159.3	0	52919.15	0	0
197.2	4.5	21	159.2	0	52919.15	0	0
197.2	5	20.9	159.2	0	52919.15	0	0
197.2	5.5	20.9	159.2	0	52919.15	0	0
197.2	6	20.9	159.1	0	52919.15	0	0
197.2	6.5	20.9	159.1	0	52919.15	0	0
197.2	7	21	159.3	0	52919.15	0	0
0	7.5	21	159.3	0	52919.15	0	0
0	8	21	159.3	0	52919.15	0	0
0	8.5	21	159.3	0	52919.15	0	0
0	9	21	159.3	0	52919.15	0	0
0	9.5	21	159.3	0	52919.15	0	0
0	10	21	159.3	0	52919.15	0	0
0	10.5	21	159.3	0	52919.15	0	0
0	11	21	159.3	0	52919.15	0	0
0	11.5	21	159.3	0	52919.15	0	0
0	12	21	159.3	0	52919.15	0	0
0	12.5	21	159.3	0	52919.15	0	0
0	13	21	159.3	0	52919.15	0	0
0	13.5	21	159.3	0	52919.15	0	0
0	14	21	159.3	0	52919.15	0	0

Spill rate (CFM) vs. Time (min.)



O2 (%) vs. Time (min.)



$$ODHCLASS := if(ODH_2 < ODH_1, ODH_1, if(ODH_3 < ODH_2, ODH_2, if(ODH_4 < ODH_3, ODH_3, if(ODH_5 < ODH_4, ODH_4, if(ODH_6 < ODH_5$$

The equation above selects the highest ODH class.

For: $AREACODE = 100$,the $ODHCLASS = 0$

RHIC 9 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature

This mathcad program calculates the ODH class when the ventilation fans are drawing from the confined volume at a rate greater than the spill rate, and upon completion of the spill. The methodology followed is described in the RHIC ODH standard. This particular file calculates the ODH classification for fan failure (or shut down) and a 50K operating temperature.

ENTER AREA CODE

Area in Question= AREACODE := 100 Code

ENTER DATA : R...,V,Q,P1...,N1....

DATA

Gas Spill Rate (R) [ft3/min]_____

Confined Volume (V) V := 320000 (CF)

Fan Vent Rate (Q) Q := 1 (CFM)

Note: failure rates below obtained from the ODH standard. If the variety of equipment numbers less then 6, enter "0" for N..... DATA

$density_4K := .144 \cdot \frac{gm}{mL}$ $density_50K := .142 \cdot 10^{-1} \cdot \frac{gm}{mL}$

$Scale_50K := \frac{density_50K}{density_4K}$

DATA

R := 126000	R14 := 0	(SCFM He)
R1 := 87000	R15 := 0	(SCFM He)
R2 := 48000	R16 := 0	(SCFM He)
R3 := 18000	R17 := 0	(SCFM He)
R4 := 12000	R18 := 0	(SCFM He)
R5 := 7800	R19 := 0	(SCFM He)
R6 := 2000	R20 := 0	(SCFM He)
R7 := 2000	R21 := 0	(SCFM He)
R8 := 2000	R22 := 0	(SCFM He)
R9 := 2000	R23 := 0	(SCFM He)
R10 := 2000	R24 := 0	(SCFM He)
R11 := 2000	R25 := 0	(SCFM He)
R12 := 2000	R26 := 0	(SCFM He)
R13 := 2000	R27 := 0	(SCFM He)

Equip. #1 failure rate (P1)	$P1 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #1 (N1)	N1 := 888	(ea.)
Equip. #2 failure rate (P2)	$P2 := 1 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #2 (N2)	N2 := 180	(ea.)
Equip. #3 failure rate (P3)	$P3 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #3 (N3)	N3 := 00	(ea.)
Equip. #4 failure rate (P4)	$P4 := 5 \cdot 10^{-8}$	(per hr.)
Quantity of Equip. #4 (N4)	N4 := 3	(ea.)
Equip. #5 failure rate (P5)	$P5 := 2.5 \cdot 10^{-5}$	(per hr.)
Quantity of Equip. #5 (N5)	N5 := 3	(ea.)(FANS)
Equip. #6 failure rate (P6)	$P6 := 5 \cdot 10^{-2}$	(per hr.)
Quantity of Equip. #6 (N6)	N6 := 1	(ea.)

Note: R - R5 above are time (t in min.) dependant spill rates as follows:

R:	$0 \le t \le .5$	
R1:	$.5 < t \le 1.0$	
R2:	$1.0 < t \le 1.5$	
R3:	$1.5 < t \le 2.0$	
R4:	$2.0 < t \le 2.5$	
R5:	$2.5 < t \le 3.0$	ETC.

$i := 0, 1 .. 28$

$t_i := \frac{i}{2}$

$R_i := R \cdot Scale_50K$ $R1_i := R1 \cdot Scale_50K$ $R2_i := R2 \cdot Scale_50K$ $R6_i := R6 \cdot Scale_50K$ $R7_i := R7 \cdot Scale_50K$ $R8_i := R8 \cdot Scale_50K$

$R12_i := R12 \cdot Scale_50K$ $R3_i := R3 \cdot Scale_50K$ $R4_i := R4 \cdot Scale_50K$ $R5_i := R5 \cdot Scale_50K$ $R9_i := R9 \cdot Scale_50K$

$R10_i := R10 \cdot Scale_50K$ $R11_i := R11 \cdot Scale_50K$ $R13_i := R13 \cdot Scale_50K$ $R14_i := R14 \cdot Scale_50K$ $R15_i := R15 \cdot Scale_50K$

$R16_i := R16 \cdot Scale_50K$ $R17_i := R17 \cdot Scale_50K$ $R18_i := R18 \cdot Scale_50K$ $R19_i := R19 \cdot Scale_50K$ $R20_i := R20 \cdot Scale_50K$

$R21_i := R21 \cdot Scale_50K$ $R22_i := R22 \cdot Scale_50K$ $R23_i := R23 \cdot Scale_50K$ $R24_i := R24 \cdot Scale_50K$ $R25_i := R25 \cdot Scale_50K$

$R26_i := R26 \cdot Scale_50K$ $R27_i := R27 \cdot Scale_50K$

$R_i := if(t_i \le .5, R_i, if(t_i \le 1.0, R1_i, if(t_i \le 1.5, R2_i, if(t_i \le 2.0, R3_i, if(t_i \le 2.5, R4_i, if(t_i \le 3.0, R5_i, if(t_i \le 3.5, R6_i, if(t_i \le 4.0, R7_i, if(t_i \le 4.5, R8_i, if$

$A_i := if(t_i \le .5, R1_i, if(t_i \le 1.0, R2_i, if(t_i \le 1.5, R3_i, if(t_i \le 2.0, R4_i, if(t_i \le 2.5, R5_i, if(t_i \le 3.0, R6_i, if(t_i \le 3.5, R7_i, if(t_i \le 4.0, R8_i, if(t_i \le 4.5, R9_i, i$

$P11 := N1 \cdot P1 \quad P44 := N4 \cdot P4 \quad P22 := N2 \cdot P2 \quad P33 := N3 \cdot P3 \quad P55 := N5 \cdot P5 \quad P66 := N6 \cdot P6$

$$cr_i := 21 \cdot \left[1 - \frac{R_i + A_i}{2 \cdot Q} \cdot \left(1 - e^{-Q \cdot \frac{t_i}{V}} \right) \right]$$

eq. A- calculate O2 % by vol. during the spill period. Note spill rate averaged within time increments.

$Cr_i := if(cr_i \ge 0, cr_i, 0)$

eqs. displays O2 % by vol. and constrain to >0%

$$ce_i := 21 - (21 - Cr_{14}) \cdot e^{-Q \cdot \frac{t_i}{V}}$$

eq. B- calculate O2 % by vol. after the spill period. Note Cr14 is the beginning of the non-spill period

$Cr_i := if(t_i \ge 7.5, ce_i, cr_i)$

eq. defines the use of eq A or B

$$PO2_i := Cr_i \cdot \frac{760}{100}$$

PP O2

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

$F_i := if(G_i \ge 1, 1, if(G_i \le 1 \cdot 10^{-7}, 0.0, if(G_i > 1 \cdot 10^{-7}, G_i, 1)))$

$\phi_i := P11 \cdot F_i + P22 \cdot F_i + P33 \cdot F_i + P44 \cdot F_i + P55 \cdot F_i + P66 \cdot F_i$

Eq. at left calculates fatality factor and sets limits between 0 and 1. Nested "if" statement.

$P_i := (P11 + P22 + P33 + P44 + P55 + P66) \cdot 1$

ODH fatality Rate.

$P_i := P_i \cdot 1 \cdot 10^6 \qquad F_i := F_i \cdot 1 \cdot 10^7$

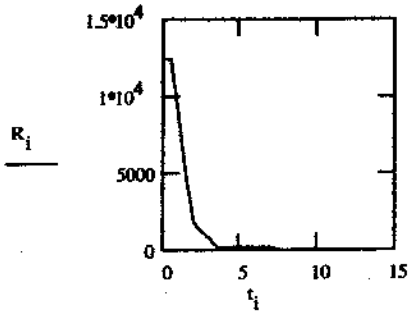
$ODH_i := if(\phi_i \le 1 \cdot 10^{-7}, 0, if(\phi_i \le 1 \cdot 10^{-5}, 1, if(\phi_i \le 1 \cdot 10^{-3}, 2, if(\phi_i \le 1 \cdot 10^{-1}, 3, 4))))$

The eq. above calculates the ODH class. Nested "if" statement.

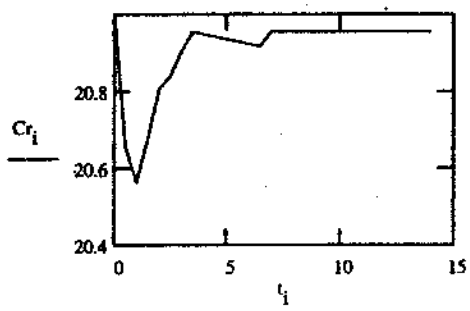
$\phi_i := \phi_i \cdot 1 \cdot 10^7$

Spill Rate (SCFM) R_i	T (min) t_i	O2 (%) Cr_i	PP (mmHg) $PO2_i$	Fatality Factor Fi (10E-7) F_i	Event Rate Pi (10E-6) (per hr.) P_i	ODH Fatality Rate phi (10E-7) (per hr.) ϕ_i	ODH Class ODH_i
12425	0	21	159.6	0	52919.15	0	0
12425	0.5	20.7	157	0	52919.15	0	0
8579.2	1	20.6	156.3	0	52919.15	0	0
4733.3	1.5	20.7	157.2	0	52919.15	0	0
1775	2	20.8	158.1	0	52919.15	0	0
1183.3	2.5	20.8	158.4	0	52919.15	0	0
769.2	3	20.9	158.9	0	52919.15	0	0
197.2	3.5	21	159.3	0	52919.15	0	0
197.2	4	20.9	159.2	0	52919.15	0	0
197.2	4.5	20.9	159.2	0	52919.15	0	0
197.2	5	20.9	159.1	0	52919.15	0	0
197.2	5.5	20.9	159.1	0	52919.15	0	0
197.2	6	20.9	159	0	52919.15	0	0
197.2	6.5	20.9	159	0	52919.15	0	0
197.2	7	21	159.3	0	52919.15	0	0
0	7.5	21	159.3	0	52919.15	0	0
0	8	21	159.3	0	52919.15	0	0
0	8.5	21	159.3	0	52919.15	0	0
0	9	21	159.3	0	52919.15	0	0
0	9.5	21	159.3	0	52919.15	0	0
0	10	21	159.3	0	52919.15	0	0
0	10.5	21	159.3	0	52919.15	0	0
0	11	21	159.3	0	52919.15	0	0
0	11.5	21	159.3	0	52919.15	0	0
0	12	21	159.3	0	52919.15	0	0
0	12.5	21	159.3	0	52919.15	0	0
0	13	21	159.3	0	52919.15	0	0
0	13.5	21	159.3	0	52919.15	0	0
0	14	21	159.3	0	52919.15	0	0

Spill rate (CFM) vs. Time (min.)



O2 (%) vs. Time (min.)



$ODHCLASS := if(ODH_2 < ODH_1, ODH_1, if(ODH_3 < ODH_2, ODH_2, if(ODH_4 < ODH_3, ODH_3, if(ODH_5 < ODH_4, ODH_4, if(ODH_6 < ODH_5$

The equation above selects the highest ODH class.

For: AREACODE = 100 ,the ODHCLASS = 0

RHIC 11 O'Clock Tunnel Oxygen Deficiency Hazard Classification for 50K Operating Temperature

This mathcad program calculates the ODH class when the ventilation fans are drawing from the confined volume at a rate greater than the spill rate, and upon completion of the spill. The methodology followed is described in the RHIC ODH standard. This particular file calculates the ODH classification for fan failure (or shut down) and a 50K operating temperature.

ENTER AREA CODE

Area in Question= AREACODE := 100 Code

ENTER DATA : R...,V,Q,P1...,N1....

DATA

Gas Spill Rate (R) [ft3/min]_____

Confined Volume (V) V := 300000 (CF)

Fan Vent Rate (Q) Q := 1 (CFM)

Note: failure rates below obtained from the ODH standard. If the variety of equipment numbers less then 6, enter "0" for N..... DATA

$density_4K := .144 \cdot \frac{gm}{mL}$ $density_50K := .142 \cdot 10^{-1} \cdot \frac{gm}{mL}$

$Scale_50K := \frac{density_50K}{density_4K}$

DATA

R := 126000	R14 := 0	(SCFM He)
R1 := 87000	R15 := 0	(SCFM He)
R2 := 48000	R16 := 0	(SCFM He)
R3 := 18000	R17 := 0	(SCFM He)
R4 := 12000	R18 := 0	(SCFM He)
R5 := 7800	R19 := 0	(SCFM He)
R6 := 2000	R20 := 0	(SCFM He)
R7 := 2000	R21 := 0	(SCFM He)
R8 := 2000	R22 := 0	(SCFM He)
R9 := 2000	R23 := 0	(SCFM He)
R10 := 2000	R24 := 0	(SCFM He)
R11 := 2000	R25 := 0	(SCFM He)
R12 := 2000	R26 := 0	(SCFM He)
R13 := 2000	R27 := 0	(SCFM He)

Equip. #1 failure rate (P1)	$P1 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #1 (N1)	N1 := 888	(ea.)
Equip. #2 failure rate (P2)	$P2 := 1 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #2 (N2)	N2 := 180	(ea.)
Equip. #3 failure rate (P3)	$P3 := 3 \cdot 10^{-6}$	(per hr.)
Quantity of Equip. #3 (N3)	N3 := 00	(ea.)
Equip. #4 failure rate (P4)	$P4 := 5 \cdot 10^{-8}$	(per hr.)
Quantity of Equip. #4 (N4)	N4 := 3	(ea.)
Equip. #5 failure rate (P5)	$P5 := 2.5 \cdot 10^{-5}$	(per hr.)
Quantity of Equip. #5 (N5)	N5 := 3	(ea.)(FANS)
Equip. #6 failure rate (P6)	$P6 := 5 \cdot 10^{-2}$	(per hr.)
Quantity of Equip. #6 (N6)	N6 := 1	(ea.)

Note: R - R5 above are time (t in min.) dependant spill rates as follows:

R:	$0 \le t \le .5$	
R1:	$.5 < t \le 1.0$	
R2:	$1.0 < t \le 1.5$	
R3:	$1.5 < t \le 2.0$	
R4:	$2.0 < t \le 2.5$	
R5:	$2.5 < t \le 3.0$	ETC.

$i := 0, 1 .. 28$

$t_i := \frac{i}{2}$

$R_i := R \cdot Scale_50K$ $R1_i := R1 \cdot Scale_50K$ $R2_i := R2 \cdot Scale_50K$ $R6_i := R6 \cdot Scale_50K$ $R7_i := R7 \cdot Scale_50K$ $R8_i := R8 \cdot Scale_50K$

$R12_i := R12 \cdot Scale_50K$ $R3_i := R3 \cdot Scale_50K$ $R4_i := R4 \cdot Scale_50K$ $R5_i := R5 \cdot Scale_50K$ $R9_i := R9 \cdot Scale_50K$

$R10_i := R10 \cdot Scale_50K$ $R11_i := R11 \cdot Scale_50K$ $R13_i := R13 \cdot Scale_50K$ $R14_i := R14 \cdot Scale_50K$ $R15_i := R15 \cdot Scale_50K$

$R16_i := R16 \cdot Scale_50K$ $R17_i := R17 \cdot Scale_50K$ $R18_i := R18 \cdot Scale_50K$ $R19_i := R19 \cdot Scale_50K$ $R20_i := R20 \cdot Scale_50K$

$R21_i := R21 \cdot Scale_50K$ $R22_i := R22 \cdot Scale_50K$ $R23_i := R23 \cdot Scale_50K$ $R24_i := R24 \cdot Scale_50K$ $R25_i := R25 \cdot Scale_50K$

$R26_i := R26 \cdot Scale_50K$ $R27_i := R27 \cdot Scale_50K$

$R_i := if(t_i \le .5, R_i, if(t_i \le 1.0, R1_i, if(t_i \le 1.5, R2_i, if(t_i \le 2.0, R3_i, if(t_i \le 2.5, R4_i, if(t_i \le 3.0, R5_i, if(t_i \le 3.5, R6_i, if(t_i \le 4.0, R7_i, if(t_i \le 4.5, R8_i, if$

$A_i := if(t_i \le .5, R1_i, if(t_i \le 1.0, R2_i, if(t_i \le 1.5, R3_i, if(t_i \le 2.0, R4_i, if(t_i \le 2.5, R5_i, if(t_i \le 3.0, R6_i, if(t_i \le 3.5, R7_i, if(t_i \le 4.0, R8_i, if(t_i \le 4.5, R9_i, i$

$P11 := N1 \cdot P1 \quad P44 := N4 \cdot P4 \quad P22 := N2 \cdot P2 \quad P33 := N3 \cdot P3 \quad P55 := N5 \cdot P5 \quad P66 := N6 \cdot P6$

$$cr_i := 21 \cdot \left[1 - \frac{R_i + A_i}{2 \cdot Q} \cdot \left(1 - e^{-Q \frac{t_i}{V}}\right)\right]$$

eq. A- calculate O2 % by vol. during the spill period. Note spill rate averaged within time increments.

$Cr_i := if(cr_i \ge 0, cr_i, 0)$

eqs. displays O2 % by vol. and constrain to >0%

$$ce_i := 21 - \left(21 - Cr_{14}\right) \cdot e^{-Q \cdot \frac{t_i}{V}}$$

eq. B- calculate O2 % by vol. after the spill period. Note Cr14 is the beginning of the non-spill period

$Cr_i := if(t_i \ge 7.5, ce_i, cr_i)$

eq. defines the use of eq A or B

$$PO2_i := Cr_i \cdot \frac{760}{100}$$

PP O2

$$G_i := 10^{\left(6.5 - \frac{PO2_i}{10}\right)}$$

$F_i := if(G_i \ge 1, 1, if(G_i \le 1 \cdot 10^{-7}, 0.0, if(G_i > 1 \cdot 10^{-7}, G_i, 1)))$

$\phi_i := P11 \cdot F_i + P22 \cdot F_i + P33 \cdot F_i + P44 \cdot F_i + P55 \cdot F_i + P66 \cdot F_i$

Eq. at left calculates fatality factor and sets limits between 0 and 1. Nested "if" statement.

$P_i := (P11 + P22 + P33 + P44 + P55 + P66) \cdot 1$

ODH fatality Rate.

$P_i := P_i \cdot 1 \cdot 10^6 \qquad F_i := F_i \cdot 1 \cdot 10^7$

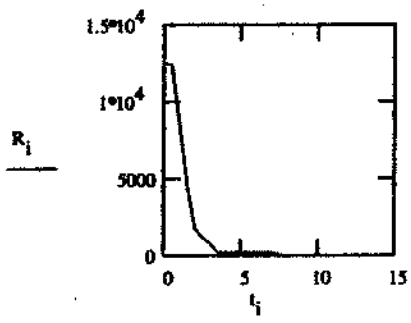
$ODH_i := if(\phi_i \le 1 \cdot 10^{-7}, 0, if(\phi_i \le 1 \cdot 10^{-5}, 1, if(\phi_i \le 1 \cdot 10^{-3}, 2, if(\phi_i \le 1 \cdot 10^{-1}, 3, 4))))$

The eq. above calculates the ODH class. Nested "if" statement.

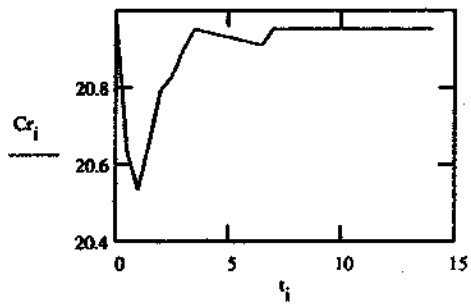
$\phi_i := \phi_i \cdot 1 \cdot 10^7$

Spill Rate (SCFM) R_i	T (min) t_i	O2 (%) Cr_i	PP (mmHg) $PO2_i$	Fatality Factor Fi (10E-7) F_i	Event Rate Pi (10E-6) (per hr.) P_i	ODH Fatality Rate phi (10E-7) (per hr.) ϕ_i	ODH Class ODH_i
12425	0	21	159.6	0	52919.15	0	0
12425	0.5	20.6	156.8	0	52919.15	0	0
8579.2	1	20.5	156.1	0	52919.15	0	0
4733.3	1.5	20.7	157	0	52919.15	0	0
1775	2	20.8	158	0	52919.15	0	0
1183.3	2.5	20.8	158.3	0	52919.15	0	0
769.2	3	20.9	158.8	0	52919.15	0	0
197.2	3.5	21	159.2	0	52919.15	0	0
197.2	4	20.9	159.2	0	52919.15	0	0
197.2	4.5	20.9	159.1	0	52919.15	0	0
197.2	5	20.9	159.1	0	52919.15	0	0
197.2	5.5	20.9	159	0	52919.15	0	0
197.2	6	20.9	159	0	52919.15	0	0
197.2	6.5	20.9	158.9	0	52919.15	0	0
197.2	7	21	159.2	0	52919.15	0	0
0	7.5	21	159.2	0	52919.15	0	0
0	8	21	159.2	0	52919.15	0	0
0	8.5	21	159.2	0	52919.15	0	0
0	9	21	159.2	0	52919.15	0	0
0	9.5	21	159.2	0	52919.15	0	0
0	10	21	159.2	0	52919.15	0	0
0	10.5	21	159.2	0	52919.15	0	0
0	11	21	159.2	0	52919.15	0	0
0	11.5	21	159.2	0	52919.15	0	0
0	12	21	159.2	0	52919.15	0	0
0	12.5	21	159.2	0	52919.15	0	0
0	13	21	159.2	0	52919.15	0	0
0	13.5	21	159.2	0	52919.15	0	0
0	14	21	159.2	0	52919.15	0	0

Spill rate (CFM) vs. Time (min.)



O2 (%) vs. Time (min.)



$$ODHCLASS := if(ODH_2 < ODH_1, ODH_1, if(ODH_3 < ODH_2, ODH_2, if(ODH_4 < ODH_3, ODH_3, if(ODH_5 < ODH_4, ODH_4, if(ODH_6 < ODH_5$$

The equation above selects the highest ODH class.

For: $AREACODE = 100$,the $ODHCLASS = 0$