**APPENDIX 7**

AD/RHIC/RD-72
Revised

**RHIC PROJECT**

Brookhaven National Laboratory

# Calculation of Oxygen Deficiency Hazard Classes for RHIC

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## INTRODUCTION

The calculation of Oxygen Deficiency Hazard (ODH) Classifications was completed for the Magnet Enclosure Building which encloses equipment that may release cryogen or pressurized gas to the building internal volume[1]. Calculation of ODH Classifications was also completed for any other buildings enclosing equipment that may release cryogen or pressurized gas to the building internal volume[2]. This sudden release[3] could then expose personnel in that building to an oxygen deficient atmosphere.

The criteria, guidelines, and methods for the calculation of ODH classifications, are defined in the Rhic Project Document "Oxygen Deficiency Hazards (ODH)[4]." The classifications are quantified from "0" to "4", for no hazard to the most severe hazard respectively, by calculating the ODH fatality rate (per hour) as defined by:

$$\Phi = \Sigma N_i P_i F_i \qquad (1)$$

where $N_i$ = number of i-type components
$P_i$ = probability of the i-th component failure per hour
$F_i$ = fatality factor or $O_2$%.

The value of the ODH fatality rate is used to determine the ODH classification.

**Table I ODH Classes**

| ODH Class | Fatality Rate $\Phi$ (1/hr.) |
|---|---|
| Unclassified | $\Phi < 10^{-9}$ |
| 0 | $10^{-9} \leq \Phi < 10^{-7}$ |
| 1 | $10^{-7} \leq \Phi < 10^{-5}$ |
| 2 | $10^{-5} \leq \Phi < 10^{-3}$ |
| 3 | $10^{-3} \leq \Phi < 10^{-1}$ |
| 4 | $\Phi \geq 10^{-1}$ |

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## DISCUSSION

To prepare for a specific ODH calculation the following data and calculations are required:

1- The quantity of each different type of component, contained in the building volume, that could fail and cause a spill. $N_1$, $N_2$, $N_3$, etc.

2- The probability of the i-th component failure and human error rate estimates (per hour) shown in Reference 3 tables B-IV, B-V, B-VI, and B-VII. $P_1$, $P_2$, $P_3$, etc.

3- The building volume in $ft^3$ (V), from Reference 1 and calculations of building volumes from architectural drawings, Reference 2.

4- The fan ventilation rate in CFM (Q).

5- The spill rate in SCFM (R), from Reference 2 and/or manufacturer's data.

6- Spill time in minutes (t).

7- Atmospheric pressure in Torr (p)

8- The fatality factor (F) per hour as defined by:

$$F_i = 10^{(6.5-P02i/10)} \qquad (2)$$

where

$$P0_{2i} = cr_i * p/100 \qquad \text{Partial pressure } O_2 \text{ (mmHg)} \qquad (3)$$

and

$$cr_i = 0.21*[1-R/Q*(1-e^{(-Q*t/V)})]*100 \qquad O_2\% \text{ (volumetric) during release} \qquad (4)$$

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## CALCULATIONS

The building volumes requiring ODH classifications were numerous and calculations to arrive at the most optimum ventilation rates were repetitive. In addition a parametric study, with variable fan rates, was performed to assure the optimal number of fan(s) were selected for a given enclosure. For each building volume three sets of calculations were made as follows: 1- full fans, 2- one fan off, and 3- no fan. To expedite the calculations a Mathcad program was developed (see Appendix I). The equations from Reference 4 were utilized, in this program, to conduct the parametric study and calculate all ODH classifications.

## RESULTS

The results of the ODH calculations, for full fan operation, can be found in Appendix II.

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## REFERENCES


1. D.P. Brown, ", RHIC Project Technical Note AD/RHIC/RD-78, Nov. 1994.

2. RHIC Cryogenic System Safety Analysis Report, Introduction; Table 4, calculated from P.E. Architectural Drawings.

3. K.C. Wu, "Estimation of Helium Discharge Rates for RHIC ODH Calculations", RHIC Project Technical Note AD/RHIC/RD-79, Nov. 1994.

4. Oxygen Deficiency Hazards (ODH), RHIC Project Document.


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# APPENDIX 1

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, it also considers the initial spill rate greater than the ventilation rate. The methodology followed is described in the RHIC ODH standard.

$D := READPRN(\text{"v100r.prn"})$ Reads data input file "vXXXX.prn"

$v0 := D^{<0>}$

$AREACODE := D_{28}$

Area in Question= $AREACODE = 100$

DATA

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

DATA

Gas Spill Rate (R) [f(t)]

Confined Volume (V) $V := D_0$ (CF)

Fan Vent Rate (Q) $Q := D_1$ (CFM)

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

| | | |
|---|---|---|
| $R := D_2$ | $R6 := D_8$ | (SCFM He) |
| $R1 := D_3$ | $R7 := D_9$ | (SCFM He) |
| $R2 := D_4$ | $R8 := D_{10}$ | (SCFM He) |
| $R3 := D_5$ | $R9 := D_{11}$ | (SCFM He) |
| $R4 := D_6$ | $R10 := D_{12}$ | (SCFM He) |
| $R5 := D_7$ | $R11 := D_{13}$ | (SCFM He) |
| | $R12 := D_{14}$ | (SCFM He) |
| | $R13 := D_{15}$ | (SCFM He) |

| | | |
|---|---|---|
| Equip. #1 failure rate (P1) | $P1 := D_{16}$ | (per hr.) |
| Quantity of Equip. #1 (N1) | $N1 := D_{17}$ | (ea.) |
| Equip. #2 failure rate (P2) | $P2 := D_{18}$ | (per hr.) |
| Quantity of Equip. #2 (N2) | $N2 := D_{19}$ | (ea.) |
| Equip. #3 failure rate (P3) | $P3 := D_{20}$ | (per hr.) |
| Quantity of Equip. #3 (N3) | $N3 := D_{21}$ | (ea.) |
| Equip. #4 failure rate (P4) | $P4 := D_{22}$ | (per hr.) |
| Quantity of Equip. #4 (N4) | $N4 := D_{23}$ | (ea.) |
| Equip. #5 failure rate (P5) | $P5 := D_{24}$ | (per hr.) |
| Quantity of Equip. #5 (N5) | $N5 := D_{25}$ | (ea.)(FANS) |
| Equip. #6 failure rate (P6) | $P6 := D_{26}$ | (per hr.) |
| Quantity of Equip. #6 (N6) | $N6 := D_{27}$ | (ea.) |

Note: R - R13 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. |

$i := 0, 1 .. 14$

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

$R_i := R \cdot 1$ $R1_i := R1 \cdot 1$ $R2_i := R2 \cdot 1$ $R6_i := R6 \cdot 1$ $R7_i := R7 \cdot 1$ $R8_i := R8 \cdot 1$ $R12_i := R12 \cdot 1$

$R3_i := R3 \cdot 1$ $R4_i := R4 \cdot 1$ $R5_i := R5 \cdot 1$ $R9_i := R9 \cdot 1$ $R10_i := R10 \cdot 1$ $R11_i := R11 \cdot 1$ $R13_i := R13 \cdot 1$

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

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

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

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

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

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

$$p_i := \frac{R_i + A_i}{2}$$

spill rate averaged over the incremented time period

$$cra_i := 21 \cdot \left(\left(e^{-p_i \cdot \frac{t_i}{V}}\right)\right)$$

eq. A- calculate O2 % by vol. during the spill period when the spill rate is greater than the ventilation rate. Note spill rate averaged within time increments. **Note in this case this equation is used.**

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

eq. B- calculate O2 % by vol. during the spill period when the spill rate is less than the ventilation rate. Note spill rate averaged within time increments. **Note in this case this equation is used.**

$$crc_i := 21 - \left(21 - crb_j\right) \cdot e^{-Q \cdot \frac{t_i}{V}}$$

eq. C- calculate O2 % by vol. after the spill period. Note crb48 is the O2 concentration at the beginning of the non-spill period. **Note in this case this equation is not used.**

$$Cr_i := \text{if}(t_i \le 1, cra_i, crb_i)$$

$$Cr_i := \text{if}(t_i \ge 1.0, crb_i, crb_i)$$

eqs. defines the use of eq A, B, or C. **Note in this case all calculations use equation "B"**

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

PP O2

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

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

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.

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

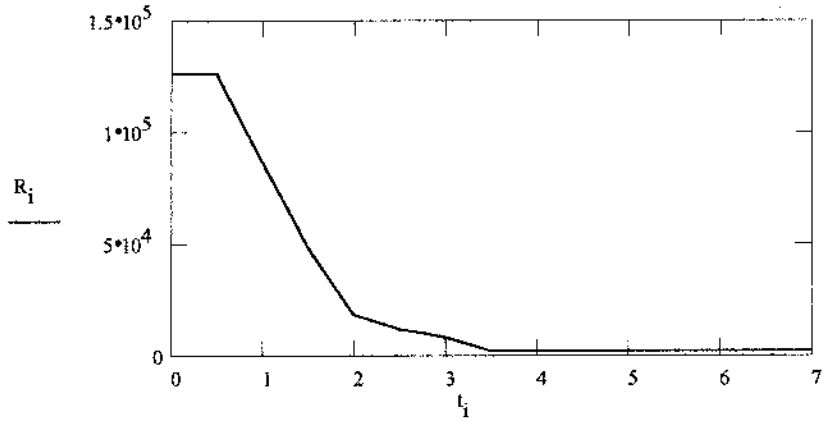
$$ODH_i := \text{if}\left(\phi_i \le 1 \cdot 10^{-7}, 0, \text{if}\left(\phi_i \le 1 \cdot 10^{-5}, 1, \text{if}\left(\phi_i \le 1 \cdot 10^{-3}, 2, \text{if}\left(\phi_i \le 1 \cdot 10^{-1}, 3, 4\right)\right)\right)\right)$$

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

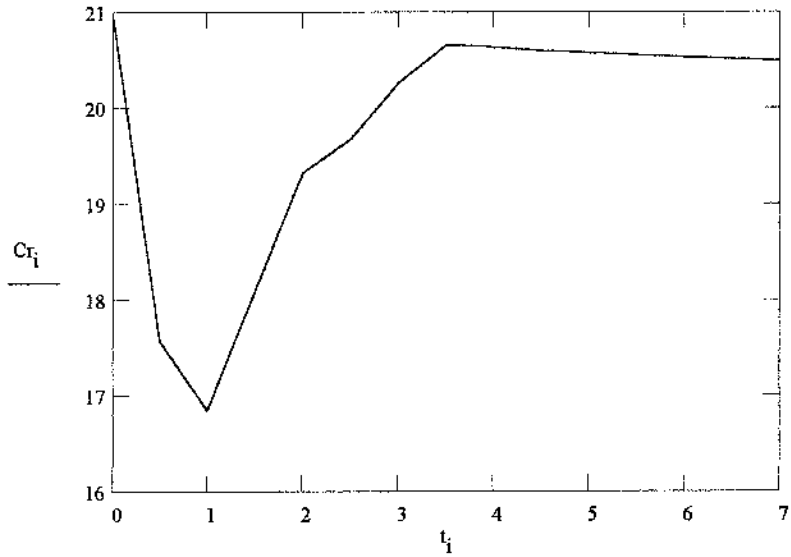
$$\phi_i := \phi_i \cdot 1 \cdot 10^7$$

| Spill Rate (SCFM) $R_i$ | T (min) $t_i$ | O2 (%) $Cr_i$ | PP (mmHg) $PO2_i$ | Fatality Factor Fi (10E-7) $F_i$ | i | Event Rate Pi (10E-6) (per hr.) $P_i$ | ODH Fatality Rate phi (10E-7) (per hr.) $\phi_i$ | ODH Class $ODH_i$ |
|---|---|---|---|---|---|---|---|---|
| 126000 | 0 | 21 | 159.6 | 0 | 0 | 7919.15 | 0 | 0 |
| 126000 | 0.5 | 17.6 | 133.5 | 1.422 | 1 | 7919.15 | 0.011 | 0 |
| 87000 | 1 | 16.8 | 128 | 5.007 | 2 | 7919.15 | 0.04 | 0 |
| 48000 | 1.5 | 18.1 | 137.5 | 0 | 3 | 7919.15 | 0 | 0 |
| 18000 | 2 | 19.3 | 146.8 | 0 | 4 | 7919.15 | 0 | 0 |
| 12000 | 2.5 | 19.7 | 149.5 | 0 | 5 | 7919.15 | 0 | 0 |
| 7800 | 3 | 20.2 | 153.9 | 0 | 6 | 7919.15 | 0 | 0 |
| 2000 | 3.5 | 20.7 | 157 | 0 | 7 | 7919.15 | 0 | 0 |
| 2000 | 4 | 20.6 | 156.7 | 0 | 8 | 7919.15 | 0 | 0 |
| 2000 | 4.5 | 20.6 | 156.5 | 0 | 9 | 7919.15 | 0 | 0 |
| 2000 | 5 | 20.6 | 156.3 | 0 | 10 | 7919.15 | 0 | 0 |
| 2000 | 5.5 | 20.5 | 156.1 | 0 | 11 | 7919.15 | 0 | 0 |
| 2000 | 6 | 20.5 | 155.9 | 0 | 12 | 7919.15 | 0 | 0 |
| 2000 | 6.5 | 20.5 | 155.8 | 0 | 13 | 7919.15 | 0 | 0 |
| 2000 | 7 | 20.5 | 155.7 | 0 | 14 | 7919.15 | 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 $ODHCLASS = 0$

$O := ODHCLASS$

$APPEND(\text{"output.dat"}) := O$ Writes output to file "output.dat"

## OXYGEN DEFICIENCY HAZARD CLASS FOR RHIC BUILDINGS DURING NORMAL OPERATIONS

| BLDG NO | BUILDING NAME | ODH CLASS |
|---|---|---|
| 1005H | Compressor Bldg. | 0 |
| 1005R | Cryogenic Bldg. | 1 |
| 1001 | RME-1:00 | 0 |
| 1003 | RME-3:00 | 0 |
| 1005 | RME-5:00 | 0 |
| 1007 | RME-7:00 | 0 |
| 1009 | RME-9:00 | 0 |
| 1011 | RME-11:00 | 0 |
| 1002B | 2:00 Service Bldg | 0 |
| 1004B | 4:00 Service Bldg | 0 |
| 1006B | 6:00 Service Bldg | 0 |
| 1008B | 8:00 Service Bldg | 0 |
| 1010A | 10:00 Service Bldg | 0 |
| 1012A | 12:00 Service Bldg | 0 |

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# 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 less 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 := 1100 Code

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

DATA

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

Confined Volume (V) V := 100000 (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 := 2000 | (SCFM He) |
| R1 := 87000 | R15 := 2000 | (SCFM He) |
| R2 := 48000 | R16 := 2000 | (SCFM He) |
| R3 := 28000 | R17 := 2000 | (SCFM He) |
| R4 := 18000 | R18 := 2000 | (SCFM He) |
| R5 := 7800 | R19 := 2000 | (SCFM He) |
| R6 := 6000 | R20 := 2000 | (SCFM He) |
| R7 := 4000 | R21 := 2000 | (SCFM He) |
| R8 := 2000 | R22 := 2000 | (SCFM He) |
| R9 := 2000 | R23 := 2000 | (SCFM He) |
| R10 := 2000 | R24 := 2000 | (SCFM He) |
| R11 := 2000 | R25 := 2000 | (SCFM He) |
| R12 := 2000 | R26 := 2000 | (SCFM He) |
| R13 := 2000 | R27 := 2000 | (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 - R28 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. |

$i := 0, 1 .. 50$

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

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

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

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

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

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

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

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

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

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

$$p_i := \frac{R_i + A_i}{2}$$

spill rate averaged over the incremented time period

$$cra_i := 21 \cdot \left(\left(e^{-p_i \cdot \frac{t_i}{V}}\right)\right)$$

eq. A- calculate O2 % by vol. during the spill period when the spill rate is greater than the ventilation rate. Note spill rate averaged within time increments.

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

eq. B- calculate O2 % by vol. during the spill period when the spill rate is less than the ventilation rate. Note spill rate averaged within time increments. **Note in this case this equation is not used.**

$$crc_i := 21 - \left(21 - crb_{48}\right) \cdot e^{-Q \cdot \frac{t_i}{V}}$$

eq. C- calculate O2 % by vol. after the spill period. Note crb48 is the O2 concentration at the beginning of the non-spill period. **Note in this case this equation is not used.**

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

$$Cr_i := \text{if}(t_i \ge 11.5, cra_i, cra_i)$$

eqs. defines the use of eq A, B, or C. **Note in this case all calculations use equation "A"**

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

**PP O2**

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

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

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

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.

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

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

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

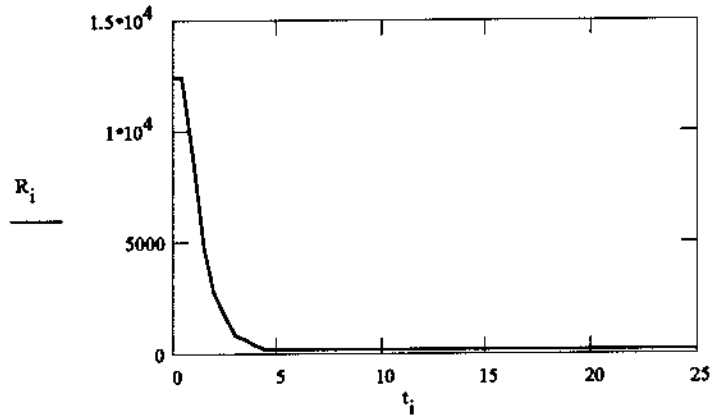
$$\phi_i := \phi_i \cdot 1 \cdot 10^7$$

| $G_i$ |
|---|
| $3.5 \cdot 10^{-10}$ |
| $2.3 \cdot 10^{-9}$ |
| $3.7 \cdot 10^{-9}$ |
| $2.6 \cdot 10^{-9}$ |
| $1.8 \cdot 10^{-9}$ |
| $1.1 \cdot 10^{-9}$ |
| $7.3 \cdot 10^{-10}$ |

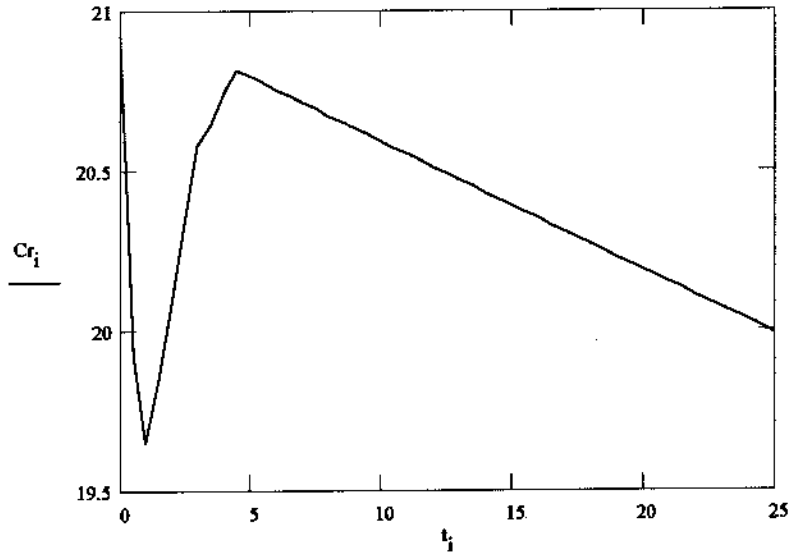
| Spill Rate (SCFM) $R_i$ | T (min) $t_i$ | O2 (%) $Cr_i$ | PP (mmHg) $PO2_i$ | Fatality Factor Fi (10E-7) $F_i$ | i | Event Rate Pi (10E-6) (per hr.) $P_i$ | ODH Fatality Rate phi (10E-7) (per hr.) $\phi_i$ | ODH Class $ODH_i$ | |
|---|---|---|---|---|---|---|---|---|---|
| 12425 | 0 | 21 | 159.6 | 0 | 0 | 52919.15 | 0 | 0 | $6.5\cdot10^{-10}$ |
| 12425 | 0.5 | 19.9 | 151.4 | 0 | 1 | 52919.15 | 0 | 0 | $5.3\cdot10^{-10}$ |
| 8579.2 | 1 | 19.6 | 149.3 | 0 | 2 | 52919.15 | 0 | 0 | $4.8\cdot10^{-10}$ |
| 4733.3 | 1.5 | 19.9 | 150.9 | 0 | 3 | 52919.15 | 0 | 0 | $5\cdot10^{-10}$ |
| 2761.1 | 2 | 20.1 | 152.5 | 0 | 4 | 52919.15 | 0 | 0 | $5.2\cdot10^{-10}$ |
| 1775 | 2.5 | 20.3 | 154.6 | 0 | 5 | 52919.15 | 0 | 0 | $5.3\cdot10^{-10}$ |
| 769.2 | 3 | 20.6 | 156.4 | 0 | 6 | 52919.15 | 0 | 0 | $5.5\cdot10^{-10}$ |
| 591.7 | 3.5 | 20.6 | 156.9 | 0 | 7 | 52919.15 | 0 | 0 | $5.7\cdot10^{-10}$ |
| 394.4 | 4 | 20.8 | 157.7 | 0 | 8 | 52919.15 | 0 | 0 | $5.9\cdot10^{-10}$ |
| 197.2 | 4.5 | 20.8 | 158.2 | 0 | 9 | 52919.15 | 0 | 0 | $6.2\cdot10^{-10}$ |
| 197.2 | 5 | 20.8 | 158 | 0 | 10 | 52919.15 | 0 | 0 | $6.4\cdot10^{-10}$ |
| 197.2 | 5.5 | 20.8 | 157.9 | 0 | 11 | 52919.15 | 0 | 0 | $6.6\cdot10^{-10}$ |
| 197.2 | 6 | 20.8 | 157.7 | 0 | 12 | 52919.15 | 0 | 0 | $6.9\cdot10^{-10}$ |
| 197.2 | 6.5 | 20.7 | 157.6 | 0 | 13 | 52919.15 | 0 | 0 | $7.1\cdot10^{-10}$ |
| 197.2 | 7 | 20.7 | 157.4 | 0 | 14 | 52919.15 | 0 | 0 | $7.4\cdot10^{-10}$ |
| 197.2 | 7.5 | 20.7 | 157.3 | 0 | 15 | 52919.15 | 0 | 0 | $7.6\cdot10^{-10}$ |
| 197.2 | 8 | 20.7 | 157.1 | 0 | 16 | 52919.15 | 0 | 0 | $7.9\cdot10^{-10}$ |
| 197.2 | 8.5 | 20.7 | 156.9 | 0 | 17 | 52919.15 | 0 | 0 | $8.2\cdot10^{-10}$ |
| 197.2 | 9 | 20.6 | 156.8 | 0 | 18 | 52919.15 | 0 | 0 | $8.5\cdot10^{-10}$ |
| 197.2 | 9.5 | 20.6 | 156.6 | 0 | 19 | 52919.15 | 0 | 0 | $8.8\cdot10^{-10}$ |
| 197.2 | 10 | 20.6 | 156.5 | 0 | 20 | 52919.15 | 0 | 0 | $9.1\cdot10^{-10}$ |
| 197.2 | 10.5 | 20.6 | 156.3 | 0 | 21 | 52919.15 | 0 | 0 | $9.4\cdot10^{-10}$ |
| 197.2 | 11 | 20.5 | 156.2 | 0 | 22 | 52919.15 | 0 | 0 | $9.8\cdot10^{-10}$ |
| 197.2 | 11.5 | 20.5 | 156 | 0 | 23 | 52919.15 | 0 | 0 | $1\cdot10^{-9}$ |
| 197.2 | 12 | 20.5 | 155.9 | 0 | 24 | 52919.15 | 0 | 0 | $1\cdot10^{-9}$ |
| 197.2 | 12.5 | 20.5 | 155.7 | 0 | 25 | 52919.15 | 0 | 0 | $1.1\cdot10^{-9}$ |
| 197.2 | 13 | 20.5 | 155.6 | 0 | 26 | 52919.15 | 0 | 0 | $1.1\cdot10^{-9}$ |
| 197.2 | 13.5 | 20.4 | 155.4 | 0 | 27 | 52919.15 | 0 | 0 | $1.2\cdot10^{-9}$ |
| 197.2 | 14 | 20.4 | 155.3 | 0 | 28 | 52919.15 | 0 | 0 | $1.2\cdot10^{-9}$ |
| 197.2 | 14.5 | 20.4 | 155.1 | 0 | 29 | 52919.15 | 0 | 0 | $1.2\cdot10^{-9}$ |
| 197.2 | 15 | 20.4 | 154.9 | 0 | 30 | 52919.15 | 0 | 0 | $1.3\cdot10^{-9}$ |
| 197.2 | 15.5 | 20.4 | 154.8 | 0 | 31 | 52919.15 | 0 | 0 | $1.3\cdot10^{-9}$ |
| 197.2 | 16 | 20.3 | 154.6 | 0 | 32 | 52919.15 | 0 | 0 | $1.4\cdot10^{-9}$ |
| 197.2 | 16.5 | 20.3 | 154.5 | 0 | 33 | 52919.15 | 0 | 0 | $1.4\cdot10^{-9}$ |
| 197.2 | 17 | 20.3 | 154.3 | 0 | 34 | 52919.15 | 0 | 0 | $1.5\cdot10^{-9}$ |
| 197.2 | 17.5 | 20.3 | 154.2 | 0 | 35 | 52919.15 | 0 | 0 | $1.5\cdot10^{-9}$ |
| 197.2 | 18 | 20.3 | 154 | 0 | 36 | 52919.15 | 0 | 0 | $1.6\cdot10^{-9}$ |
| 197.2 | 18.5 | 20.2 | 153.9 | 0 | 37 | 52919.15 | 0 | 0 | $1.7\cdot10^{-9}$ |
| 197.2 | 19 | 20.2 | 153.7 | 0 | 38 | 52919.15 | 0 | 0 | $1.7\cdot10^{-9}$ |
| 197.2 | 19.5 | 20.2 | 153.6 | 0 | 39 | 52919.15 | 0 | 0 | $1.8\cdot10^{-9}$ |
| 197.2 | 20 | 20.2 | 153.4 | 0 | 40 | 52919.15 | 0 | 0 | $1.8\cdot10^{-9}$ |
| 197.2 | 20.5 | 20.2 | 153.3 | 0 | 41 | 52919.15 | 0 | 0 | $1.9\cdot10^{-9}$ |
| 197.2 | 21 | 20.1 | 153.1 | 0 | 42 | 52919.15 | 0 | 0 | $2\cdot10^{-9}$ |
| 197.2 | 21.5 | 20.1 | 153 | 0 | 43 | 52919.15 | 0 | 0 | |
| 197.2 | 22 | 20.1 | 152.8 | 0 | 44 | 52919.15 | 0 | 0 | |
| 197.2 | 22.5 | 20.1 | 152.7 | 0 | 45 | 52919.15 | 0 | 0 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 197.2 | 22.5 | 20.1 | 152.7 | 0 | 45 | 52919.15 | 0 | 0 | $2\cdot10^{-9}$ |
| 197.2 | 23 | 20.1 | 152.5 | 0 | 46 | 52919.15 | 0 | 0 | |
| 197.2 | 23.5 | 20 | 152.4 | 0 | 47 | 52919.15 | 0 | 0 | |
| 197.2 | 24 | 20 | 152.2 | 0 | 48 | 52919.15 | 0 | 0 | |
| 197.2 | 24.5 | 20 | 152.1 | 0 | 49 | 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 = 1100 ,the ODHCLASS = 0

| $t_i$ | $cra_i$ | $crb_i$ | $crc_i$ |
|---|---|---|---|
| 0 | 21 | 21 | 20 |
| 0.5 | 19.9 | 19.9 | 20 |
| 1 | 19.6 | 19.6 | 20 |
| 1.5 | 19.9 | 19.8 | 20 |
| 2 | 20.1 | 20 | 20 |
| 2.5 | 20.3 | 20.3 | 20 |
| 3 | 20.6 | 20.6 | 20 |
| 3.5 | 20.6 | 20.6 | 20 |
| 4 | 20.8 | 20.8 | 20 |
| 4.5 | 20.8 | 20.8 | 20 |
| 5 | 20.8 | 20.8 | 20 |
| 5.5 | 20.8 | 20.8 | 20 |
| 6 | 20.8 | 20.8 | 20 |
| 6.5 | 20.7 | 20.7 | 20 |
| 7 | 20.7 | 20.7 | 20 |
| 7.5 | 20.7 | 20.7 | 20 |
| 8 | 20.7 | 20.7 | 20 |
| 8.5 | 20.7 | 20.6 | 20 |
| 9 | 20.6 | 20.6 | 20 |
| 9.5 | 20.6 | 20.6 | 20 |
| 10 | 20.6 | 20.6 | 20 |
| 10.5 | 20.6 | 20.6 | 20 |
| 11 | 20.5 | 20.5 | 20 |
| 11.5 | 20.5 | 20.5 | 20 |
| 12 | 20.5 | 20.5 | 20 |
| 12.5 | 20.5 | 20.5 | 20 |
| 13 | 20.5 | 20.5 | 20 |
| 13.5 | 20.4 | 20.4 | 20 |
| 14 | 20.4 | 20.4 | 20 |
| 14.5 | 20.4 | 20.4 | 20 |
| 15 | 20.4 | 20.4 | 20 |