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Safety Analysis Report

**For the Use of Hazardous Production
Materials in Photovoltaic Applications
at the National Renewable Energy
Laboratory**

Volume II: Appendices

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APPENDIX A1 FAILURE RATE DATA

In the storage, handling, use and disposal of toxic gases, accidental releases may arise for any of the following reasons: design errors, construction errors, equipment failures, human errors, and process upsets. Marsh and McLennan Protection Consultants [1] have analyzed 100 major incidents (fire, explosion, and toxic release) in the hydrocarbon-chemical industry and classified the causes of these events into the following categories: mechanical equipment failure, process upsets, human error and arson or sabotage. Figure A1 shows their compiled statistics on these incidents. Failure of individual components in isolation may not result in the accidental release of a hazardous gas or liquid. Often a release may occur only after a series of components fail. These chains of events or failures are often identified using fault and event tree analyses. These techniques have not been used in this SAR because of the scoping nature of this document. To help identify the rough order of magnitude for events probabilities, sample system/component failure rate data compiled by EPA [2] are shown in Table A1-1. Table A1-2 gives representative data for operator or human error. Because these data are derived from industries other than the semiconductor or photovoltaic industry, they are presented as representative estimates only.

Figure A1

**APPENDIX TABLE A1-1
TYPICAL FAILURE RATES***

SYSTEM	PROCESS COMPONENTS	FAULTS/YEAR
Process System Components		
	Control valve	0.25 - 0.60
	Differential pressure transmitter	0.76 - 1.73
	Variable area flowmeter transmitter	0.68 - 1.01
	Thermocouple	0.088 - 0.52
	Pneumatic controller	0.29 - 0.38
Flow Control Components		
	Flowmeters	
	D/P cell and transmitter	0.76 - 1.73
	Magnetic	2.18
	Flow controller	0.29 - 0.38
	Control valve	0.25 - 0.60
	Flow switch	1.12
	Flow indicators	0.026
	Check valve (backflow prevention)	1.10×10^{-4}
	Control loop	1.73
Pressure Control Components		
	Pressure/Transducer/Transmitter	0.76 - 1.73
	Pressure indicator	0.026 - 1.41
	Pressure switch	0.34
	Control valve	0.25 - 0.60
	Pressure controller	0.29 - 0.38
	Pressure control loop	1.73
Temperature Control Components		
	Sensor With Thermowell	
	Thermocouple (TC)	0.52
	Resistance temperature detector	0.41
	Temperature transducer	0.88
	Temperature controller	0.29 - 0.38
	Control valve	0.25 - 0.60
	Control loop	1.73

Appendix A1

Quality Control Components	
Load Cell Weigh System	3.75
Level Detection System	
Differential pressure transducer	1.71
Float system	1.64
Capacitance system	0.22
Electrical Conductivity Probes	2.36
Flow totalizer	1.0
Mixing System Components	
Mechanical Agitator (agitator motor only)	
"Normal" Service	0.088
"Severe" Service	8.8
Induced Flow Pump System (pump and motor only)	
"Normal" Service	0.26
"Severe" Service	8.8
Static mixer	NA
Flow switch	1.12
Pressure switch	0.34
Tachometer	0.044
Composition System Components	
Composition Determination Equipment	
Density	NA
•indicator	NA
•transmitter	_NA
pH Meter	5.88
Viscosity Sensor	NA
•indicator	NA
•transmitter	NA
Chemical Species Analyzers	
Chromatograph	30.6
Infrared Analyzer	1.40
Oxygen Analyzer	2.5 - 5.65
Moisture Analyzer (gases)	8.0
Conductivity Sensor	14.2 - 16.7

Appendix A1

Vessel Components

Vessel shell	
Complete failure	3×10^{-6}
Rupture equivalent to 6 in. opening	7×10^{-6}
Flanged head joint	N/A
Flanged nozzle piping connections, flange leak or rupture	0.0026
Seam welds	N/A

Piping Components

Pipe wall, under 3 in. diameter rupture	8.8×10^{-6}
Pipe wall over 3 in. diameter rupture	8.8×10^{-7}
Flanged joint, leak or rupture	0.0026
Gasket leak	0.026
Welded joint, leak	2.63×10^{-5}
Valve casing	N/A
Valve stem seal	N/A
Manual valve	
Failure to operate	0.365
Failure to remain open (plug)	0.0365
Leak or rupture	8.8×10^{-5}
Solenoid valve - failure to operate	0.365
Automated valves	
Failure to operate	0.1095
Failure to remain open (plug)	0.0365
Leak or rupture	3.65×10^{-6}
Check valves	
Failure to open	0.0026
Reverse flow leak	1.10×10^{-4}
Rupture	8.8×10^{-5}

Process Machinery Components

Pumps	
Failure to start	0.365
Failure to run	0.011
Shaft seal, major leak	5×10^{-3}
Compressors	N/A

*adapted from [1]

**APPENDIX TABLE A1-2
HUMAN OPERATOR ERROR ESTIMATES**

Estimated Rates	Activity
10^{-4}	Selection of a key-operated switch rather than a non-key switch this value does not include the error of decision where the operator misinterprets situation and believes key switch is correct choice.
10^{-3}	Selection of a switch (or pair of switches) dissimilar in shape or location to the desired switch (or pair of switches), assuming no decision error. For example, operator actuates large-handled switch rather than small switch.
3×10^{-3}	General human error of commission, e.g., misreading label and, therefore selecting wrong switch.
10^{-2}	General human error of omission, where there is no display in the control room of the status of the item omitted, e.g., failure to return manually operated test valve to proper configuration after maintenance.
3×10^{-3}	Error of omission, where the items being omitted are embedded in a procedure rather than at the end as above.
3×10^{-2}	Simple arithmetic errors with self-checking but without repeating the calculation by redoing it on another piece of paper.
$1/x$	Given that an operator is reaching for an incorrect switch (or pair of switches), he selects a particular similar-appearing switch (or pair of switches), where x = the number of incorrect switches (or pair of switches) adjacent to the desired switch (or pair of switches). The $1/x$ applies up to 5 or 6 items. After that point the error rate would be lower because the operator would take more time to search. With up to 5 or 6 items he doesn't expect to be wrong and therefore is more likely to do less deliberate searching.
10^{-1}	Given that an operator is reaching for a wrong motor-operated valve (MOV) switch (or pair of switches), he fails to note from the indicator lamps that the MOV(s) is (are) already in the desired state and merely changes the status of the MOV(s) without recognizing he had selected the wrong switch(es).
10^{-1}	Monitor or inspector fails to recognize initial error by operator. Note: With continuing feedback of the error on the annunciator panel, this high error rate would not apply.
10^{-1}	Personnel on different work shift fail to check condition of hardware unless required by check list or written directive.
5×10^{-1}	Monitor fails to detect undesired position of valves, etc., during general walk-around inspections, assuming no check list is used.
0.2-0.3	General error rate, given very high stress levels where dangerous activities are occurring rapidly.

APPENDIX A2

ESTIMATING CONCENTRATIONS FROM GAS/VAPOR RELEASES IN GAS CABINETS & LABORATORIES

1. Estimation of Concentration Due to Gas or Vapor Release within an Enclosure (e.g., Gas Cabinet or Laboratory).

Assuming that a gas leaks into an enclosure at a constant rate and that the enclosure is ventilated by a constant volume air flow, a mass balance on the leaked compound can be expressed as [3]:

$$V (dC/dt) = Q_m - k Q_v C \quad (1)$$

where:

C: concentration of released material in the cabinet (lb/min)

V: volume of the cabinet (ft³)

Q_m: leak rate of material (lb/min)

Q_v: cabinet purge rate (cfm)

k: non-ideal mixing factor

The non-ideal mixing factor, k, accounts for less than perfect mixing conditions in the enclosure. k varies from 0.1 to 0.5 for most applications of ventilation on storage rooms and laboratories. In this analysis we use k=0.3 for laboratories. For the exhaust out of gas cabinets, we assume perfect mixing (i.e., k=1) due to the small volume and the high turbulence in the cabinet. Within the cabinet, however, a spatial variation of concentration is possible, and therefore a k in the range 0.5 to 1 is used.

1a. Steady State Continuous Leakage and Ventilation.

At steady state there is no accumulation and from equation (1) the resulting concentration is

$$C = \frac{Q_m}{kQ_v} \text{ [lb/min]} \quad (2a)$$

And conversion of concentration units from lb/min to ppm, assuming ideal gas behavior, results to

$$C = \frac{Q_m RT}{kQ_v PM} \times 10^6 \text{ [ppm]}, \quad (2b)$$

where

R is the ideal gas constant

T is the absolute gas temperature

P is the absolute pressure

M is the molecular weight of the gas or vapor.

1 b. Unsteady State: Case #1.

For unsteady state conditions, estimation of the concentration build-up as a function of time calls for the solution of the complete equation (1). This solution is

$$C = \frac{Q_m RT}{k Q_v P M} \times 10^6 \times (1 - e^{-k Q_v t / V}) \text{ [ppm]} \quad (3)$$

Equation (3) is used for calculations of contaminant leaked into quiescent air or into an enclosure with very poor ventilation.

1 c. Unsteady State: Case #2.

When leakage has been stopped, the term Q_m in equation (1) is zero, and the solution of (1) is an exponential decay

$$C = C_0 \times e^{-k Q_v t / V} \quad (4)$$

where C_0 is the initial concentration in the same units as C.

Equation (4) can be used to calculate how long it will take for a given concentration to dissipate when leakage has been stopped.

2. Concentration Build-up Due to Spill Evaporation.

The rate by which a volatile liquid evaporates is mainly a function of the partial pressure of the vapor, its saturation vapor pressure, and the temperature of the liquid. Assuming that the ideal gas law applies, an expression for the vaporization rate is [4]

$$Q_m = \frac{MKA (P_{sat} - P)}{RT_1} \text{ [lb/min]} \quad (5)$$

where:

- Q_m : evaporation rate [lb/min]
- M: molecular weight of the volatile substance
- A: area of the spill [ft²]
- K: vapor mass transfer coefficient for an area A [ft/s]
- P_{sat} : saturation vapor pressure [atm]
- P: partial pressure of the vapor [atm]
- T_1 : absolute temperature of the liquid [R]

The vaporization rate calculated from equation (5) can then be used as the leak rate in equations (2) or (3) to calculate the concentration build-up in a given enclosure.

The vapor mass transfer coefficient can be estimated using the relationship [5]

$$K = aD^{2/3} \quad (6)$$

where a is a constant and D is the vapor diffusivity in air.

Equation (6) can be used to estimate the vapor mass transfer coefficient from a known value of a reference compound (e.g., water). Then

$$\frac{K}{K_w} = \left(\frac{D}{D_w}\right)^{2/3} \quad (7)$$

and since the diffusivity of a vapor is proportional to the square root of its molecular weight [6]

$$\frac{K}{K_w} = \left(\frac{M}{M_w}\right)^{1/3} \quad (8)$$

3. Flow rates through flow restrictors.

Data from Hoeschst Celanese regarding flow rates through cylinder valves equipped with flow restrictors are given beginning on the following page.

4. Laboratory and enclosure ventilation rates

The table below summarizes the pre-SAR corrective action ventilation rates for each of the laboratories.

Laboratory Number	Laboratory Description	Equip Encl. (cfm)	GC #1 (cfm)	GC #2 (cfm)	GC #3 (cfm)	Total Vent. (cfm)	Lab Area (ft ²)	Lab Vol. (ft ³)	Vent/Lab Area	Air Exc/hour
103	MOCVD	200	250	150		2500	890	8010	2.8	19
190 - "HV"	high vac. sys.	990	125	115						
190 - "A"	a-Si PECVD	1529	526	260		6600	1020	9180	6.5	43
190 - "E"	Electrochromics	516	233	290	260					
222	MOCVD	400	270	321		2000	330	2970	4.8	32
285	Selenization	1000	400	400		1800	495	4455	3.6	24
368	MOCVD	236	80	130		2800	630	5670	4.4	30
369	a-Si hot wire	1047	441			2800	551	4959	5.1	34
458	MOCVD	685	246	259		1200	235	2115	5.1	34

Equip Encl. = Equipment enclosure

GC = Gas cabinet

Total Vent. = Total ventilation being exhausted from the laboratory (includes fume hoods)

Vent/Lab Area = Laboratory exhaust in cubic feet per minute (cfm) per laboratory area (ft²)

Air Exc/hour = Air exchanges per hour, based on laboratory volume and ventilation rate

APPENDIX TABLE A2-1 **ESTIMATES OF CONCENTRATIONS WITHIN ENCLOSURES,** **DUE TO SPILL VAPORIZATION**

Assumptions: 1) Total Content of TBA Bubbler Leaks Out
 2) Enclosure Purge Rate = 685 cfm

1. STEADY STATE

Variable	Mix A (ppm)	Mix B (ppm)
Spill Area (ft ²)	5	5
Vapor Pressure @ 1' (atm)	0.0184	0.0184
Mass transfer Coeff (1pm)	2	5
Evolution Rate (lb/min)	0.06257	0.156324
Mixing factor	0.5	1
Ventilation Rate (cfm)	685	685
Enclosure Volume (cf)	13.5	13.5
R (ft ³ atm/lb-mole R)	0.7302	0.7302
Mol. Weight	134	134
Pressure (atm)	1	1
Temperature (R)	540	540
Conc built-up (ppm)=	537	672

2. NON-STEADY STATE (with ventilation)

Time (min)	Mix A Conc. (ppm)	Mix B Conc. (ppm)
0.0832	472	662
0.1666	529	671
0.3333	537	672
1	537	672
2	537	672
5	537	672
10	537	672

APPENDIX TABLE A2-1
Continued

3. NON-STEADY STATE (ventilation failure)

Time (min)	Conc. (ppm) (Vent 0.0001 CFM)	Conc. (ppm) (Vent 1 CFM)
0.1666	2271	5642
0.5	6815	16725
1	13630	32843
1.5	20444	48374
2	27259	63340
2.5	34074	77763
3	40889	91661
4	54518	117959
4.5	61333	130396
5	68148	142380
6	81777	165057
7	95406	186115
8	109035	205670
9	122665	223828
10	136294	240690
15	204439	308571
30	408866	410151
60	817687	454598

APPENDIX TABLE A2-2 ESTIMATES OF CONCENTRATIONS WITHIN ENCLOSURES, DUE TO SPILL VAPORIZATION

Assumptions: 1) 1/10 of Total Content of TBA Bubbler Leaks Out
2) Enclosure Purge Rate = 685 cfm

1. STEADY STATE

Variable	Mix A (ppm)	Mix B (ppm)
Spill Area (ft ²)	3	3
Vapor Pressure @ T (atm)	0.0184	0.0184
Mass transfer Coeff (fpm)	2	5
Evolution Rate (lb/min)	0.003752	0.009379
Mixing factor	0.5	1
Ventilation Rate (cfm)	685	685
Enclosure volume (cf)	13.5	13.5
R (ft ³ atm/lb-mole R)	0.7302	0.7302
Mol. Weight	134	134
Pressure (atm)	1	1
Temperature (R)	540	540
Conc built-up (ppm)=	32	40

2. NON-STEADY STATE (with ventilation)

Time (min)	Mix A Conc. (ppm)	Mix B Conc. (ppm)
0.0166	11	23
0.0833	28	40
0.1666	32	40
1	32	40
2	32	40
5	32	40
10	32	40

APPENDIX TABLE A2-2

Continued

3. NON-STEADY STATE (ventilation failure)

Time (min)	Conc. (ppm) (Vent 0.0001 CFM)	Conc. (ppm) (Vent 1 CFM)
0.1666	136	339
0.5	409	1004
1	818	1971
1.5	1227	2902
2	1636	3800
2.5	2044	4666
3	2453	5500
4	3271	7078
4.5	3680	7824
5	4089	8543
6	4907	9903
7	5724	11167
8	6542	12340
9	7360	13430
10	8178	14441
15	12266	18514
30	24532	24609
60	49061	27276

APPENDIX TABLE A2-3 **ESTIMATES OF CONCENTRATIONS WITHIN GAS CABINETS**

Assumptions: 1) Cabinet Size: 38"W x 18"D x 72"H
 2) Purge Rate: 250 cfm
 3) Mixing Factor: 0.5 to 1

1. STEADY STATE

Variable	AsH ₃	AsH ₃	PH ₃	PH ₃	H ₂ Se	H ₂ Se
Mixing factor	0.5	1	0.5	1	0.5	1
Evolution Rate (slpm)	1.7	1.7	6.9	6.9	1.1	1.1
Evolution Rate (lb/min)	0.012	0.012	0.023	0.023	0.011	0.011
Ventilation Rate (cfm)	250	250	250	250	250	250
Cabinet volume (cft)	28.5	28.5	28.5	28.5	28.5	28.5
R (ft ³ atm/lb-mole R)	0.70302	0.70302	0.70302	0.70302	0.70302	0.70302
Mol. Weight	78	78	34	34	81	81
Pressure (atm)	1	1	1	1	1	1
Temperature (R)	540	540	540	540	540	540
Outlet Conc (ppm)	467	234	2054	1027	412	206

2. NON-STEADY STATE* WITH VENTILATION = 250 cfm (concentration values in ppm)

Mixing Factor	(0.5)	(1.0)	(0.5)	(1.0)	(0.5)	(1.0)
Time (min)	AsH ₃	AsH ₃	PH ₃	PH ₃	H ₂ Se	H ₂ Se
0.0166	33	32	144	139	29	28
0.0833	143	121	629	533	126	107
0.5	415	231	1825	1014	366	204
1	461	234	2029	1027	407	206
1.5	467	234	2052	1027	412	206
2	467	234	2054	1027	412	206
5	467	234	2054	1027	412	206
6	467	234	2054	1027	412	206
7	467	234	2054	1027	412	206
8	467	234	2054	1027	412	206
9	467	234	2054	1027	412	206
10	467	234	2054	1027	412	206

*Evolution rate and other release parameters are the same ones listed in the steady state case.

APPENDIX TABLE A2-3
Continued

3. NON-STEADY STATE* WITH VENTILATION FAILURE (values in ppm)

Ventilation (CFM)	(0.0001)	(1.0)	(0.0001)	(1.0)	(0.0001)	(1.0)
Time (min)	AsH ₃	AsH ₃	PH ₃	PH ₃	H ₂ Se	H ₂ Se
0.0166	34	34	150	150	30	30
0.0833	171	170	751	750	151	150
0.5	1025	1016	4505	4466	904	897
1	2049	2014	9011	8855	1809	1778
1.5	3074	2994	13516	13167	2713	2643
2	4099	3958	18022	17404	3618	3494
5	10246	9398	45054	41323	9045	8296
6	12296	11088	54065	48753	10854	9787
7	14345	12719	63076	55927	12663	11227
8	16394	14294	72086	62853	14471	12618
9	18443	15815	81097	69541	16280	13960
10	20493	17284	90108	75997	18089	15257
15	30739	23901	135161	105092	27134	21097
30	61477	38020	270318	167178	54267	33561
60	122951	51290	540622	225526	108531	45275

*Evolution rate and other release parameters are the same ones listed in the steady state case.

APPENDIX TABLE A2-4
ESTIMATES OF CONCENTRATIONS WITHIN LABORATORIES

1. STEADY STATE

Variable	Hydrogen	Arsine	Phosphine	H₂Se
Mixing factor	0.3	0.3	0.3	0.3
Evolution Rate (lb/min)	0.004 (20 slpm)	0.0036	0.0036	0.0036
Ventilation Rate (cfm)	1600	2800	2800	2800
Room volume (cf)	2970	5670	5670	5670
R (ft ³ atm/lb-mole R)	0.70302	0.70302	0.70302	0.70302
Mol. Weight	2	78	34	81
Pressure (atm)	1	1	1	1
Temperature (R)	540	540	540	540
Outlet Conc (ppm) =	1582	21	48	20

APPENDIX TABLE A2-5 ESTIMATES OF CONCENTRATIONS WITHIN GAS CABINETS

Assumptions: 1) Cabinet Size: 38"W x 18"D x 72"H
2) Purge Rate: 250 cfm
3) Mixing Factor: 0.5 to 1

1. STEADY STATE

Variable	H ₂ (0.5)	H ₂ (1.0)	H ₂ (1.0)
Mixing factor	0.5	1	1
Evolution Rate (lb/min)	4.5	4.5	1
Ventilation Rate (cfm)	250	250	250
Cabinet volume (cft)	28.5	28.5	28.5
R (cu. ft. atm/lb-mole R)	0.7302	0.7302	0.7302
Mol. Weight	2	2	2
Pressure (atm)	1	1	1
Temperature (R)	540	540	540
Outlet Conc (%w) =	saturated	saturated	78.86

2. NON-STEADY STATE WITH VENTILATION = 250 cfm (concentration values in ppm)

	H ₂	H ₂	H ₂
Ventilation (cfm)	0.5	1.0	1.0
Time (min)	Conc. (ppm)	Conc. (ppm)	Conc. (ppm)
0.0166	49.84	48.09	10.69
0.0833	saturated	saturated	40.88
1	saturated	saturated	78.85
2	saturated	saturated	78.86
5	saturated	saturated	78.86

3. NON-STEADY STATE WITH VENTILATION FAILURE (values in ppm)

	H ₂	H ₂	H ₂
Ventilation (cfm)	0.5	1.0	1.0
Time (min)	Conc. (ppm)	Conc. (ppm)	Conc. (ppm)
0.0166	51.67	51.66	11.48
0.0833	saturated	saturated	57.54
1	saturated	saturated	saturated
2	saturated	saturated	saturated
5	saturated	saturated	saturated

APPENDIX TABLE A2-6
ESTIMATES OF STACK CONCENTRATIONS

1. STEADY STATE

Variable	H₂Se	Arsine	Phosphine	Hydrogen
Mixing factor	1	1	1	1
Evolution Rate (lb/min)	0.0047	0.0047	0.0047	0.004
Ventilation Rate (cfm)	2000	2000	2000	2000
R (cu. ft. air/lb-mole R)	0.70302	0.70302	0.70302	0.70302
Mol. Weight	81	78	34	2
Pressure (atm)	1	1	1	1
Temperature (R)	600	600	600	600
Outlet Conc (ppm) =	11	11	26	380

APPENDIX TABLE A2-7 **ESTIMATES OF POTENTIAL HYDROGEN BUILD-UP IN** **LABORATORIES**

Comparisons with HYDROGEN Low Flammability Limit of 4.1%

ASSUMPTIONS: 1) Room Volume (Lab 222): 2970 cft
 2) Ventilation Rate: 2000 cfm
 3) Mixing factor: 0.3 to 1.0
 4) Release through 0.25" open valve:
 flow rate @ P=2,000 psi = 25,000 lpm = 4.9 lb/min

1. STEADY STATE

Variable	Hydrogen	Hydrogen	Hydrogen
Mixing Factor	0.3	0.7	1
Initial Leak Rate (lb/min)	4.9	4.9	4.9
Ventilation Rate (cfm)	2000	2000	2000
Room Volume (cft)	2970	2970	2970
R (cu. ft.atm/lb-mole R)	0.7302	0.7302	0.7302
Mol. Weight	2	2	2
Pressure (atm)	1	1	1
Temperature (R)	540	540	540
Outlet Conc (ppm) =	saturated	69.00	48.30

2. NON-STEADY STATE (Ventilation = 2500 cfm)

Time (min)	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen
0.0166	0.54	0.54	0.54
0.0833	2.69	2.66	2.63
0.1	3.22	3.18	3.15
0.2	6.38	6.21	6.09
0.5	15.47	14.49	13.81
1.0	29.45	25.94	23.67
2.0	53.52	42.12	35.74

3. NON-STEADY STATE (Ventilation Failure)

Ventilation Rate (cfm): 1 1 1

Time (min)	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen
0.0166	0.54	0.54	0.54
0.0833	2.71	2.71	2.71
0.1	3.25	3.25	3.25
0.2	6.51	6.51	6.51
0.5	16.26	16.26	16.26
1.0	32.53	32.52	32.52
2.0	65.05	65.04	65.03

APPENDIX TABLE A2-8

ESTIMATES OF POTENTIAL HYDROGEN BUILD-UP IN GAS CABINETS

Estimates of potential H₂ concentration built-up within gas cabinets.

Comparisons with HYDROGEN Low Flammability Limit of 4.1%

ASSUMPTIONS: 1) Gas Cabinet Volume (Lab 222): 28.5 cft

2) Ventilation Rate: 250 cfm

3) Mixing factor: 0.3 to 1.0

1. STEADY STATE

Variable	Hydrogen	Hydrogen	Hydrogen
Mixing Factor	0.3	0.7	1
Initial Leak Rate (lb/min)	4.9	4.9	4.9
Ventilation Rate (cfm)	2000	2000	2000
Room Volume (cft)	2970	2970	2970
R (cu. ft.atm/lb-mole R)	0.7302	0.7302	0.7302
Mol. Weight	2	2	2
Pressure (atm)	1	1	1
Temperature (R)	540	540	540
Outlet Conc (ppm) =	saturated	69.00	48.30

2. NON-STEADY STATE (Ventilation = 2500 cfm)

Time (min)	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen
0.0166	0.54	0.54	0.54
0.0833	2.69	2.66	2.63
0.1	3.22	3.18	3.15
0.2	6.38	6.21	6.09
0.5	15.47	14.49	13.81
1.0	29.45	25.94	23.67
2.0	53.52	42.12	35.74

3. NON-STEADY STATE (Ventilation Failure)

Ventilation Rate (cfm): 1 1 1

Time (min)	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen
0.0166	0.54	0.54	0.54
0.0833	2.71	2.71	2.71
0.1	3.25	3.25	3.25
0.2	6.51	6.51	6.51
0.5	16.26	16.26	16.26
1.0	32.53	32.52	32.52
2.0	65.05	65.04	65.03

APPENDIX TABLE A2-8 Continued

Estimates of potential H₂ concentration built-up within gas cabinets
 Comparisons with HYDROGEN Low Flammability Limit of 4.1%

ASSUMPTIONS: 1) Gas Cabinet Volume: 28.5 cft
 2) Ventilation Rate: 50 cfm
 3) Mixing factor: 0.3 to 1.0

1. STEADY STATE

Variable	Hydrogen	Hydrogen	Hydrogen
Mixing Factor	0.3	0.7	1
Initial Leak Rate (lb/min)	4.9	4.9	4.9
Ventilation Rate (cfm)	250	250	2500
Cabinet Volume (cft)	28.5	28.5	28.5
R (cu. ft.atm/lb-mole R)	0.7302	0.7302	0.7302
Mol. Weight	2	2	2
Pressure (atm)	1	1	1
Temperature (R)	540	540	540
Outlet Conc (ppm) =	saturated	saturated	saturated

1. NON-STEADY STATE (Ventilation = 2500 cfm)

Time (min)	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen
0.0166	55.06	53.50	52.36
0.0833	saturated	saturated	saturated
0.1	saturated	saturated	saturated
0.2	saturated	saturated	saturated

1. NON-STEADY STATE (Ventilation Failure)

Ventilation Rate (cfm): 1 1 1

Time (min)	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen	Conc (% vol) Hydrogen
0.0166	56.26	56.26	56.25
0.0833	saturated	saturated	saturated
0.1	saturated	saturated	saturated
0.2	saturated	saturated	saturated
0.5	saturated	saturated	saturated
1.0	saturated	saturated	saturated
2.0	saturated	saturated	saturated

Hoechst Celanese
Guardian Gas Protection System
Flow Rates of Common Semiconductor Gases
Through Orifices of Various Sizes

Orifices sizes:

- 0.15625 or 5/32 inch - Flow path through a CGA350 toxic gas valve
(no safety)
- 0.28125 or 9/32 inch - Flow path through a CGA350 silane gas valve
(with safety device)
- 0.006 inch - Flow-limiting device for toxic gas
- 0.010 inch - Flow-limiting device for silane

All flows expressed in standard liters/minute
(28.32 liters = 1 cubic foot)

1. PURE GASES

Gas	Orifice Size	Pressure (psig)			
		200	150	100	50
Arsine	0.006	1.594	1.196	0.797	0.399
	0.010	4.428	3.322	2.214	1.108
	0.15625	1081.188	810.891	540.594	270.297
Phosphine	0.006	7.157	4.828	2.414	0.603
	0.010	19.881	13.411	6.706	1.675
	0.15625	4853.651	3274.197	1637.098	403.936
Silane	0.006	16.021	11.682	4.968	3.415
	0.010	44.503	32.450	13.800	9.486
	0.28125	35202.150	25668.230	10915.390	7504.340
Hydrogen Selenide	0.006	0.978	0.782	0.587	0.391
	0.010	2.717	2.172	1.631	1.086
	0.15625	662.979	530.386	397.788	265.192
Germane	0.006	3.457	2.010	0.804	0.402
	0.010	9.603	5.583	2.233	1.117
	0.15625	2344.613	1363.147	545.259	283.535

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2. GAS MIXTURES

Note: Hydrogen has been selected as the matrix gas in the mixtures to present a true "worst case" model. Because it is the gas with the smallest molecule, hydrogen's flow rates are faster than any other gas. As an example, hydrogen will flow at approximately 3.7 times the rate of nitrogen, the next most common diluent gas in semiconductor applications.

Mixture	Orifice Size	Pressure (psig)		
		2000	1500	1000
1% AsH ₃ /H ₂	0.006	84.449	63.337	42.225
	0.010	234.581	175.936	117.292
	0.15625	57270.640	42952.980	23635.320
5% AsH ₃ /H ₂	0.006	58.380	43.785	29.190
	0.010	162.167	121.625	81.083
	0.15625	39591.140	29693.350	19795.570
10% AsH ₃ /H ₂	0.006	34.055	22.703	11.352
	0.010	94.597	63.064	31.533
	0.15625	23095.12	15396.75	7698.375
1% PH ₃ /H ₂	0.006	92.092	69.069	46.046
	0.010	255.811	191.858	127.906
	0.15625	62454.210	46840.660	31227.100
5% PH ₃ /H ₂	0.006	74.030	55.522	37.015
	0.010	205.639	154.228	102.819
	0.15625	50204.660	37653.490	25102.330
10% PH ₃ /H ₂	0.006	61.642	46.231	30.821
	0.010	171.228	128.419	85.614
	0.15625	41803.500	31352.620	20901.750
5% SiH ₄ /H ₂	0.006	75.011	56.259	37.506
	0.010	208.364	156.275	104.183
	0.28125	164820.100	123615.000	82410.050
10% SiH ₄ /H ₂	0.006	62.784	47.088	31.392
	0.010	174.400	130.800	87.200
	0.28125	137953.200	103464.900	68976.630
15% SiH ₄ /H ₂	0.006	55.081	41.311	27.541
	0.010	153.003	114.753	76.503
	0.28125	121028.200	90771.150	60514.100

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2. GAS MIXTURES (con't)

Mixture	Orifice Size	Pressure (psig)		
		2000	1500	1000
1% B ₂ H ₆ /H ₂	0.006	93.360	70.020	46.680
	0.010	259.333	194.500	129.667
	0.15625	63313.810	47485.360	31656.900

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Limiting the Potential for a Catastrophic Release of Toxic Semiconductor Process Gases

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The large scale release of a hazardous gas is the most compelling of all the worst case scenarios that must be addressed by the semiconductor safety professional. Recent events such as in Bhopal, India, and Berkeley Heights, NJ, have heightened public awareness of the potential for a hazardous gas catastrophe. These events have resulted in increased regulatory scrutiny of those industries that routinely employ vapor phase hazardous production materials. While the semiconductor industry has an exemplary record for the safe handling and storage of toxic and explosive gases, even higher safety standards will be required in the future. It is commonly believed that implementing a "fail safe" system for handling materials with permissible exposure levels on the order of 50 to 300 ppb is expensive not only in dollars, but in engineering effort and concessions in manufacturing throughput. However, by relying on a combination of hazard mitigation measures, and not strictly on engineering controls, it is possible to develop a common sense, inexpensive and non-disruptive program of safe gas handling.

Developing a Program for Hazard Reduction

The first step in developing a program to reduce the risk of toxic gas releases in a facility is to thoroughly investigate current practices through an internal audit. The audit should be structured to incorporate each of the following goals:

1. A reduction in cylinder gas inventory.
2. A reduction in the quantity of gas per cylinder where possible;

3. Calculation of the safest concentrations of process gas mixtures (in some cases, pure gases might be preferable);

4. Strict requirements for the use of passive flow limiters in all toxic gas cylinder valves.

5. Installation of high capacity toxic gas treatment systems.

6. Calculation of optimal flow limiting orifice sizes based on considerations of manufacturing throughput and toxic gas treatment capacity.

7. Verification and documentation of the program's conformity to applicable codes and regulations.

Reduce Cylinder Gas Inventories

The reduction of cylinder gas inventories is not a new concept. It is generally a measure that is taken to cut costs and increase efficiency. But when pushed to the lower limits which an effective safety scheme demands, inventory reduction itself can result in marginal cost increases.

Such items as same day delivery, dedication of cylinders to exclusive use, and storage of those dedicated gas inventories at the vendor's site are negotiable with the cylinder gas vendor on an individual basis, and will usually involve additional expenses. The monitoring of the contents of on-line cylinders on a regular basis might also result in some increase in internal costs.

Reduce Quantity of Gas Per Cylinder

The question of whether to reduce the quantity of gas per cylinder as a means of reducing risk has been argued among semiconductor companies for some time. The point at issue is that when reducing the quantity of gas per cylinder the potential volume of a spill is reduced. However, it demands more frequent cylinder changes - and the probability of a spill is highest during a cylinder change. Sophisticated risk assessment techniques must be considered in making this decision. The safest cylinder quantities will vary with the characteristics of the total cylinder inventory, a problem

that is most apparent when one compares the frequency of silane cylinder changes with the potential energy of a cylinder explosion at various silane levels.

With gas mixture concentrations, the goal should be the minimum possible dilution of the cylinder gas at one gas panel of the process tool. For example, it is better to inventory two cylinders of 5,000 ppm arsine in hydrogen, which might be introduced to the process at 100 sccm, than to store one cylinder of 1% arsine, which would be utilized at 50 sccm. Clearly, the mixture with the higher concentration presents a greater hazard should a gas leak occur. Therefore, each process gas mixture must be carefully reviewed because of the potential hazard.

When using arsine in equal quantities, either as pure material or at a concentration of 10% in hydrogen, the pure material presents far less potential for catastrophe than the mixture in an upset condition. Besides the greater quantity of arsine delivered through an orifice, as indicated in Table 1, the gas mixture also diffuses more quickly and will take longer to exhibit a lowering of delivery pressure due to adiabatic cooling. This example emphasizes the importance of thorough analysis in establishing a hierarchy of hazards among process gases.

TABLE I
Comparison of
Catastrophic Potential

0.010 Passive Flow Restrictor in Use		
1500 g Pure Arsine 10% Arsine/Hydrogen		
Cylinder Pressure	200 psig	1500 psig
Molecular Weight	77.086	9.509
Flow rate at full cylinder pressure	4.428 SLM	34.597 SLM
Arsine delivered at full cylinder pressure	4.428 SLM	3.45 SLM

Use Flow Limiting Orifices

The key element in any program of risk reduction in toxic and pyrophoric gas use is the unwavering requirement that passive flow limiters of the appropriate size be installed in every cylinder valve. In cooperation with Hewlett-Packard Co., Hoechst Celanese Corporation has calculated the

approximate flow rates of various semiconductor process gases through open gas cylinder valves - both with and without flow limiters installed (1). The calculations show that the use of a flow-limiting orifice in the cylinder valve is essential to the safe disposal of hazardous process gases under upset conditions. For example, the unrestricted initial flow rate of a 1% diborane/hydrogen mixture through a fully open cylinder valve at 2000 psig is 1,300 SLM. By installing a 10-mil orifice passive flow limiter in the valve outlet, the initial flow rate is reduced to 259.3 SLM, making it possible to treat a potential gas release.

Even at the reduced maximum flow rates obtained through the use of passive flow limiters, a substantial gas treatment capacity is necessary to guarantee that levels are kept below TLV values within the fab, and under 100 ppm levels at the stacks. If the capacity of the gas treatment system is high enough, larger orifices can be used in the passive flow limiters. This action eliminates some of the operational difficulties associated with flow limiters in the past (2) (3), e.g., a tendency of the orifices to clog with silane use and the need to drastically increase the number of purge cycles during cylinder changeovers.

A Guardian 8 high-volume thermal processor can be used as a benchmark gas treatment system to analyze the orifice size vs. treatment capacity relationship. Using the Guardian, it is possible to plumb not only several Epitaxial LPCVD reactor exhausts, but also gas cabinet vent and purge lines from the gas cylinders which supply the process reactors into a single gas processor. A number of these high-capacity thermal processors are currently being used in multiple inlet configurations in major semiconductor fabs.

TABLE II
Flow Capacities* —
Guardian 8

(A flow through Guardian = 1.358 cfm)

Arsine (AsH ₃)	—	58.83 SLM
Diborane (B ₂ H ₆)	—	99.33 SLM
Phosphine (PH ₃)	—	44.6 SLM
Silane (SiH ₄)	—	156.66 SLM
Hydrogen (H ₂)	—	829.9 SLM

*Based on Guardian exit temperature of 200° C

Using the rated capacities of the Guardian 8 for various process gases (Table 2), it is easy to calculate the approximate size to which the flow limiter's orifice can be enlarged without compromising the system's ability

to handle a high pressure gas release. Extrapolations can be made from the values on the table based on the rate of flows being directly proportional to the cylinder pressure and to the area of the orifice, and inversely proportional to the square root of the molecular weight of the referenced gas.

For example, a Guardian 8 can process 212.7 SLM of pure silane, and the flow through a 10 mil orifice at full cylinder pressure of 875 psig (5 Kg cylinder of silane) is 32.45 SLM. Using this information, the maximum conforming flow limiter size can be determined by the simple proportion:

$$\frac{\text{Flow Capacity of System}}{\text{Flow through 10-mil Orifice}} = \frac{\text{Area of Permissible Orifice}}{\text{Area of 10-mil Orifice}}$$

$$\frac{212.7 \text{ SLM}}{32.45 \text{ SLM}} = \frac{X}{0.000506 \text{ sq. cm.}}$$

$$0.0244 \text{ sq. cm.} = X \text{ (Area of Permissible Orifice)}$$

$$0.06 \text{ cm. or } .022 \text{ in.} = \text{Diameter of Permissible Orifice}$$

This ability to significantly enlarge the orifices of most of the flow limiters in the fab makes their use in all toxic gas cylinder valves a practical and safe operating procedure. As a result, the risk of clogging is eliminated and the extra purge cycle time is reduced to a minimum. (Purging can be further expedited by substituting helium for nitrogen as a purge gas. The helium will flow through an orifice about 2.5 times as fast as nitrogen.)

TABLE III
Maximum Diameter Flow
Restrictors for
Various Process Gases

Gas (Pressure)	SLM Flow at 0.010 in. Orifice	SLM G-8 Capacity	Permissible Flow Restrictor
2000 psig in H ₂ (2000 psig)	250	829.9	0.018"
Phosphine (PH ₃) (500 psig)	19.88	44.6	0.015"
Arsine (AsH ₃) (500 psig)	4.605	58.83	0.036"

Table 3 shows some typical enlarged flow restrictor sizes which were calculated with the above formula. This approach, using a restrictor plus gas treatment system, has been effectively demonstrated in at least one semiconductor company. It permits full compliance with Article 80's directive that treatment systems be sized to handle a worst case release as determined by the "maximum achievable flow from the valve," while minimizing the impact of a safety first approach upon manufacturing operations. This safety system enables a semiconductor company to become a responsible corporate and environmental citizen at a minimal cost in development and manufacturing time, and capital expense.

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2. J. D. Samoth, J. A. Proctor, "Gas Flow Restrictors for the Semiconductor Manufacturing Industry," a Report of the Preliminary Test Product Project EV-100-184, February 29, 1984, Matheson Gas Products, East Rutherford, NJ.

3. W. E. Quinn, D. Raiber, "Flow Restricting Devices Used with Semiconductor Process Gases," Solid State Technology, Vol. 29(7), pp 83-86, July 1986.

Prior to Semiconductor Safety Technology, Michael Hayes was marketing manager for Scientific Gas Products, and also managed the design and construction of the company's specialty gas plant in Fremont, California. As national sales manager at Synthatron Corp. (now Solkastronics Corp.), Hayes managed national accounts in the semiconductor and fiber optics industries. He has also held sales, marketing and laboratory management positions at Phoenix Research Corp., Precision Gas Products, and Liquid Carbonic Corp.

APPENDIX A3

PVPUFF: GAUSSIAN PUFF DISPERSION MODEL

This model estimates atmospheric concentrations downwind from an instantaneous "puff" release of a gas. The code used for this model was originally developed by William Petersen, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. It is described in the report, "Estimating Concentrations Downwind from an Instantaneous Puff Release" (EPA 600/3-82-078). In this model, dispersion is described by the Gaussian Puff equation, using the dispersion parameters presented in Meteorology and Atomic Energy.

The general formula for the model is

$$X(x,y,z=h) = \frac{2Q}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{x-ut}{\sigma_x}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

where X is the ground level concentration of the released compound (gm/m^3), Q is the released mass (gm), u is the wind velocity (m/s), x is the downwind distance, y is the crosswind distance, z is the elevation, and σ_x , σ_y , and σ_z the corresponding dispersion coefficients.

The model can be used for releases that are not really instantaneous if the duration of a release is shorter than the travel time of the "puff" to a receptor of interest. Assumptions inherent within the code include: 1) Steady state atmospheric conditions; 2) Neutrally buoyant non-reactive releases; and 3) No deposition. For most applications the residence time over any specific location will be less than 30 minutes. Therefore, appropriate critical concentration levels are the IDLH concentrations which refer to 30 min exposure of healthy adults.

PVPUFF has been developed for the Department of Energy - National Photovoltaic Program.

APPENDIX TABLE A3-1
PVPUFF H₂Se RUNS FOR STABLE AIR
FIVE MINUTE RECEPTOR SAMPLE

	Stable 5 min Sample
Wind Speed (m/sec)	1.0
Mixing Height (m)	500
Downwind Distance (km)	.1
Distance from PUFF Center (m)	.000
Receptor Height (m)	1.000
Concentration (g/m ³)	1.074E-6
Emission Strength (g)	226
Emission Height (m)	5.0
Initial Sigma R (m)	0.1
Initial Sigma Z (m)	0
Distance Out to Peak Concentration (km)	.909
Critical Concentration (g/m ³)	6.700E-03
Peak Concentration (g/m ³)	2.56E-03

APPENDIX TABLE A3-2
PVPUFF PH₃ RUNS FOR STABLE AIR
FIVE MINUTE RECEPTOR SAMPLE

	Stable 5 min Sample
Wind Speed (m/sec)	1.0
Mixing Height (m)	500
Downwind Distance (km)	.1
Distance from PUFF Center (m)	.000
Receptor Height (m)	1.000
Concentration (g/m ³)	1.074E-6
Emission Strength (g)	226
Emission Height (m)	5.0
Initial Sigma R (m)	0.1
Initial Sigma Z (m)	0
Distance Out to Peak Concentration (km)	.909
Critical Concentration (g/m ³)	2.67E-01
Peak Concentration (g/m ³)	2.56E-03

**APPENDIX TABLE A3-3
PVPUFF ASH₃ RUNS FOR STABLE AIR
FIVE MINUTE RECEPTOR SAMPLE**

	Stable 5 min Sample
Wind Speed (m/sec)	1.0
Mixing Height (m)	500
Downwind Distance (km)	.1
Distance from PUFF Center (m)	.000
Receptor Height (m)	1.000
Concentration (g/m ³)	4.3054E-6
Emission Strength (g)	906
Emission Height (m)	5.0
Initial Sigma R (m)	0.1
Initial Sigma Z (m)	0
Distance Out to Peak Concentration (km)	.909
Critical Concentration (g/m ³)	2.400E-02
Peak Concentration (g/m ³)	1.026E-02

**APPENDIX TABLE A3-4
PVPUFF AsH₃ RUNS FOR STABLE AIR
FIVE MINUTE RECEPTOR SAMPLE**

	Stable 5 min Sample	Stable 5 min Sample	Stable 5 min Sample
Wind Speed (m/sec)	1.0	1.0	1.0
Mixing Height (m)	500	500	500
Downwind Distance (km)	.100	.050	.100
Distance from PUFF Center (m)	.000	.000	.000
Receptor Height (m)	1.500	1.000	1.000
Concentration (g/m ³)	3.20E-05	1.130E-12	2.128E-06
Emission Strength (g)	454	454	454
Emission Height (m)	5.0	5.0	5.0
Initial Sigma R (m)	0.2	0.2	0.2
Initial Sigma Z (m)	0	0	0
Distance Out to Peak Concentration (km)	.909	.909	.909
Critical Concentration (g/m ³)	2.400E-02	2.400E-02	2.400E-02
Peak Concentration (g/m ³)	5.141E-03	5.151E-03	5.151E-03

APPENDIX TABLE A3-5
PVPUFF ASH₃ RUNS FOR NEUTRAL AIR
FIVE MINUTE RECEPTOR SAMPLE

	Neutral 5 min Sample	Neutral 5 min Sample	Neutral 5 min Sample
Wind Speed (m/sec)	5.0	5.0	5.0
Mixing Height (m)	500	500	500
Downwind Distance (km)	.050	.100	.100
Distance from PUFF Center (m)	.000	.000	.000
Receptor Height (m)	1.000	1.000	1.000
Concentration (g/m ³)	2.473E-03	2.620E-03	1.429E-03
Distance Out to Peak Concentration (km)	.082	.082	.082
Critical Concentration (g/m ³)	2.400E-02	2.400E-02	2.400E-02
Peak Concentration (g/m ³)	2.656E-03	2.656E-03	2.656E-03

**APPENDIX TABLE A3-6
PYPUFF ASH₃ RUNS FOR UNSTABLE AIR
FIVE MINUTE RECEPTOR SAMPLE**

	Unstable 5 min Sample	Unstable 5 min Sample	Unstable 5 min Sample
Wind Speed (m/sec)	10	10	10
Mixing Height (m)	100	100	100
Downwind Distance (km)	0.05	0.10	0.20
Distance from PUFF Center (m)	.000	.000	.000
Receptor Height (m)	1.000	1.000	1.000
Concentration (g/m ³)	8.777E-4	3.078E-4	1.016E-4
Distance Out to Peak Concentration (km)	0.012	0.012	0.012
Critical Concentration (g/m ³)	2.400E-02	2.400E-02	2.400E-02
Peak Concentration (g/m ³)	3.296E-03	3.296E-03	3.296E-03

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ARTICLE 80

HAZARDOUS MATERIALS

Division I

GENERAL PROVISIONS

Scope

Sec. 80.101. The purpose of this article is to provide requirements for the prevention, control and mitigation of dangerous conditions related to hazardous materials and to provide information needed by emergency response personnel. Hazardous materials are those chemicals or substances defined as such in Article 9. See Appendix VI-A for the classification of hazard categories and hazard evaluations.

The general provisions and requirements in Division I shall apply to all hazardous materials, including those materials regulated elsewhere in this code, except that when specific requirements are provided in other articles, those specific requirements shall apply. When a material has multiple hazards, all hazards shall be addressed.

The provisions of this article related to health hazards as defined in this article and classified in Division II of this article are waived when the chief or other official charged with the enforcement of this code has determined that such enforcement is preempted by other codes, statutes or ordinances. The details of any action granting any such waiver shall be recorded and entered in the files of the code enforcement agency.

The classification system referenced in Division II shall apply to all hazardous materials, including those materials regulated elsewhere in this code.

EXCEPTIONS: 1. The off-site transportation of hazardous materials when in conformance with the Department of Transportation (DOT) regulations.

2. The quantities of alcoholic beverages, medicines, foodstuffs and cosmetics, containing not more than 50 percent by volume of water-miscible liquids and with the remainder of the solutions not being flammable, in retail sales occupancies are unlimited when packaged in individual containers not exceeding 4 liters.

For existing buildings, see Section 1.103 (b).

Definitions:

Sec. 80.102. (a) General. For definitions of AIR-REACTIVE MATERIALS; CFR; CARCINOGEN; CHEMICAL; CHEMICAL NAME; COMMON RADIATION SOURCE MATERIALS; COMPRESSED GAS; CORROSIVE; DEFLAGRATION; DETACHED STORAGE; DETONATION; EXPLOSION; EXPLOSIVE; FISSILE MATERIALS; FLAMMABLE SOLID; HAZARDOUS MATERIALS; HIGHLY TOXIC MATERIALS; IRRITANT; ISOLATED STORAGE; MATERIAL SAFETY DATA SHEET; NTP OSHA; ORGANIC PEROXIDE; OXIDIZER; PEROXIDE-FORMING CHEMICAL; PRIMARY CONTAINMENT; PROPRIETARY INFORMATION; PYROPHORIC; SECONDARY CONTAINMENT; SEGREGATED STORAGE; SENSITIZER;

TARGET ORGAN EFFECTS; TOXIC; UNAUTHORIZED DISCHARGE; UNSTABLE; and WATER-REACTIVE MATERIALS, see Article 9.

(b) **Limited Application.** For the purpose of this article, certain terms and words are defined as follows:

BARRICADE is a structure that consists of a combination of walls, floor and roof that is designed to withstand the rapid release of energy in an explosion. Barricades may be fully confined, partially vented or fully vented.

CEILING LIMIT is the maximum concentration of an airborne contaminant to which one may be exposed. The ceiling limits utilized are to be those published in 29 CFR 1910.1000.

CONTAINER is any vessel of 60 U.S. gallons or less capacity used for transporting or storing hazardous materials.

CONTINUOUS GAS-DETECTION SYSTEM is a gas-detection system where the analytical instrument is maintained in continuous operation and sampling is performed without interruption. Analysis may be performed on a cyclical basis at intervals not to exceed 30 minutes.

CONTROL AREA is space within a building where the exempt amounts specified in Division III may be stored or the exempt amounts specified in Division IV may be dispensed, used or handled.

CYLINDER is a pressure vessel designed for pressures higher than 40 pounds per square inch absolute and having a circular cross section. It does not include a portable tank, multi-tank tank car tank, cargo tank or tank car.

EXCESS FLOW CONTROL is a fail-safe system designed to shut off flow due to a rupture in pressurized piping systems.

EXCESS FLOW VALVE is a valve inserted into a compressed gas cylinder, portable or stationary tank that is designed to positively shut off the flow of gas in the event that its predetermined flow is exceeded.

HEALTH HAZARD is a classification of a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed persons. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes or mucous membranes.

HIGHLY VOLATILE LIQUID is a liquid with a boiling point of less than 68°F.

IDLH (Immediately Dangerous to Life and Health) is a concentration of airborne contaminants, normally expressed in parts per million (ppm) or milligrams per cubic meter, which represents the maximum level from which one could escape within 30 minutes without any escape-impairing symptoms or irreversible health effects. This level is established by the National Institute of Occupational Safety and Health (NIOSH). If adequate data do not exist for precise establishment of IDLH data, an independent certified industrial hygienist, industrial toxicologist or appropriate regulatory agency shall make such determination.

PERMISSIBLE EXPOSURE LIMIT (PEL) is the maximum permitted eight-hour time-weighted average concentration of an airborne contaminant. The maximum permitted time-weighted average exposures to be utilized are those published in 29 CFR 1910.1000.

PHYSICAL HAZARD is a classification of a chemical for which there is scientifically valid evidence that it is a combustible liquid, compressed gas, cryogenic, explosive, flammable gas, flammable liquid, flammable solid, organic, peroxide, oxidizer, pyrophoric, unstable (reactive) or water-reactive material.

PORTABLE TANK is any packaging over 60 U.S. gallons capacity and designed primarily to be loaded into or on or temporarily attached to a transport vehicle or ship and equipped with skids, mounting or accessories to facilitate handling of the tank by mechanical means. It does not include any cylinder having less than a 1,000-pound water capacity, cargo tank, tank car tank or trailers carrying cylinders of over 1,000-pound water capacity.

REDUCED FLOW VALVE is a valve equipped with a restricted flow orifice and inserted into a compressed gas cylinder, portable or stationary tank that is designed to reduce the maximum flow from the valve under full flow conditions. The maximum flow rate from the valve is determined with the valve allowed to flow to atmosphere with no other piping or fittings attached.

SEPARATE GAS STORAGE ROOM is a separate enclosed area which is part of or attached to a building and is utilized for the storage or use of highly toxic compressed or liquefied gases.

STATIONARY TANK is packaging designed primarily for stationary installations not intended for loading, unloading or attachment to a transport vehicle as part of its normal operation in the process of use. It does not include cylinders having less than 1,000-pound water capacity.

STORAGE FACILITY is a building, portion of a building or exterior area used for the storage of hazardous materials in excess of exempt amounts specified in Division III.

USE (Material) is the placing in action or making available for service by opening or connecting anything utilized for confinement of material whether a solid, liquid or gas.

Permits

Sec. 80.103. (a) General. No person, firm or corporation shall store, dispense, use or handle hazardous material in excess of quantities specified in Section 4.108 unless and until a valid permit has been issued pursuant to this article.

A permit shall be obtained when a material is classified as having more than one hazard category if the quantity limits are exceeded in any category.

No person, firm or corporation shall install, repair, abandon, remove, place temporarily out of service, close or substantially modify a storage facility or other area regulated by this article until a permit has been issued. (See also Sections 80.107 and 80.108.)

EXCEPTIONS: 1. Routine maintenance.

2. For emergency repair work performed on an emergency basis, application for permit shall be made within two working days of commencement of work.

Permittee shall apply for approval to close any storage, use or handling facility at least 30 days prior to the termination of the storage, use or handling of hazardous materials. Such application shall include any change or alteration of the facility closure plan filed pursuant to Section 80.107 of this article. This 30-day period may be waived by the chief if there are special circumstances requiring such waiver.

(b) **Posting Permits.** Hazardous materials permits shall be posted in a conspicuous location on the premises or shall be kept on the premises designated therein. Permits shall at all times be subject to inspection by an officer of the fire or police department or other authorized persons.

(c) **Hazardous Materials Management Plan.** When required by the chief, each application for a permit pursuant to this article shall include a Hazardous Materials Management Plan (HMMP) in accordance with Appendix II-E.

(d) **Hazardous Materials Inventory Statement.** When required by the chief, each application for a permit pursuant to this article shall include a Hazardous Materials Inventory Statement (HMIS) in accordance with Appendix II-E.

General Requirements

Sec. 80.104 (a) General. The storage, dispensing, use and handling of hazardous materials shall be in compliance with the provisions of this article.

(b) **Release of Hazardous Materials.** Hazardous materials shall not be released into a sewer, storm drain, ditch, drainage canal, lake, river or tidal waterway, or upon the ground, sidewalk, street, highway or into the atmosphere.

EXCEPTIONS: 1. Materials intended for use in weed abatement, erosion control, soil amendment or similar applications, when applied in accordance with the manufacturer's instructions or nationally recognized practices.

2. Materials released in accordance with federal, state or local governing regulations or permits of the jurisdictional Air Quality Management Board with a National Pollutant Discharge Elimination System Permit, with waste discharge requirements established by the jurisdictional Water Quality Control Board or with local sewer pretreatment requirements for publicly owned treatment works.

(c) **Unauthorized Discharge.** 1. Accurate records shall be kept by the permittee of the unauthorized discharge of hazardous materials.

2. The chief shall be immediately notified when an unauthorized discharge becomes reportable under state, federal or local regulations.

3. Provisions shall be made for controlling and mitigating unauthorized discharges.

4. Whenever an unauthorized discharge due to primary container failure is discovered, the involved primary container shall be repaired or removed from service.

5. A person, firm or corporation responsible for an unauthorized discharge shall institute and complete all actions necessary to remedy the effects of such

unauthorized discharge, whether sudden or gradual, at no cost to the jurisdiction. When deemed necessary by the chief, cleanup may be initiated by the fire department or by an authorized individual or firm. Costs associated with such cleanup shall be borne by the owner, operator or other person responsible for the unauthorized discharge.

(d) **Material Safety Data Sheets.** Material Safety Data Sheets (MSDS) shall be readily available on the premises for hazardous materials regulated by this article.

(e) **Identification.** Visible hazard identification signs as specified in U.F.C. Standard No. 79-3 shall be placed at entrances to locations where hazardous materials are stored, dispensed, used or handled in quantities requiring a permit. The chief may waive this requirement in special cases when consistent with safety. Individual containers, cartons or packages shall be conspicuously marked or labeled in accordance with nationally recognized standards. See also Section 80.301 (d).

Construction Requirements

Sec. 80.105. Buildings or portions thereof in which hazardous materials are stored, handled or used shall be constructed in accordance with the Building Code.

Boundaries of a control area shall be formed by one or more of the following:

1. An occupancy separation with a minimum one-hour fire-resistive rating.
2. The exterior wall, roof or foundation of the building.

A maximum of four control areas shall be permitted within a building.

EXCEPTION: A maximum of two control areas shall be permitted in buildings or portions of buildings used for retail sales.

Personnel Training and Written Procedures

Sec. 80.106. Persons responsible for the operation of areas in which hazardous materials are stored, dispensed, handled or used shall be familiar with the chemical nature of the materials and the appropriate mitigating actions necessary in the event of fire, leak or spill.

Responsible persons shall be designated and trained to be liaison personnel for the fire department. These persons shall aid the fire department in preplanning emergency responses and identification of the locations where hazardous materials are located and shall have access to Material Safety Data Sheets and be knowledgeable in the site emergency response procedures.

Facility Closure Plan

Sec. 80.107. The permit holder or applicant shall submit a plan to the fire department to terminate storage, dispensing, handling or use of hazardous materials at least 30 days prior to facility closure. The plan shall demonstrate that hazardous materials which were stored, dispensed, handled or used in the facility have been transported, disposed of or reused in a manner that eliminates the need for further maintenance and any threat to public health and safety. Such plan shall be submitted in accordance with Section 80.103.

Out-of-service Facilities

Sec. 80.108. Facilities may be placed out of service in accordance with the following:

1. **Temporarily out-of-service facilities.** Facilities which are temporarily out of service shall continue to be permitted, monitored and inspected.

2. **Permanently out-of-service facilities.** Facilities for which a permit is not kept current or is not monitored and inspected on a regular basis shall be deemed to be permanently out of service and shall be closed in accordance with Section 80.107.

See also Section 80.103.

Division II CLASSIFICATION BY HAZARD

Scope

Sec. 80.201. For the purpose of this code, hazardous materials shall be divided into hazard categories. The categories include materials regulated under this article and materials regulated elsewhere in this code.

Hazard Categories

Sec. 80.202. (a) **Physical Hazards.** The materials listed in this section are classified as physical hazards. A material with a primary classification as a physical hazard may also present a health hazard.

1. Explosives and blasting agents, regulated elsewhere in this code.
2. Compressed gases, regulated under this article and elsewhere in this code.
3. Flammable and combustible liquids regulated elsewhere in this code.
4. Flammable solids.
5. Organic peroxides.
6. Oxidizers.
7. Pyrophoric materials.
8. Unstable (reactive) materials.
9. Water-reactive materials.
10. Cryogenic fluids, regulated under this article and elsewhere in this code.

(b) **Health Hazards.** The materials listed in this section are classified as health hazards. A material with a primary classification as a health hazard may also present a physical hazard.

1. Highly toxic or toxic materials, including highly toxic or toxic compressed gases.
2. Radioactive materials.
3. Corrosives.
4. Other health hazards.

Appendix

Sec. 80.203. Descriptions and examples of materials included in hazard categories are contained in Appendix VI-A.

Division III STORAGE REQUIREMENTS

General

Sec. 80.301. (a) **Scope.** This division applies to the storage of hazardous materials in containers, cylinders and tanks in excess of the exempt amounts specified in Sections 80.302 through 80.315.

EXCEPTIONS: 1. Hazardous materials regulated by other articles in this code unless specifically indicated in this division.

2. Indoor storage of liquid and solid oxidizers, organic peroxides, unstable (reactive) and water-reactive materials in quantities less than the exempt amounts shall be as specified in Sections 80.306, 80.307, 80.309 and 80.310.

(b) **Containers and Tanks.** 1. **Design and construction.** Containers and tanks shall be designed and constructed in accordance with nationally recognized standards. See Section 2.303 (b).

2. **Tanks out-of-service 90 days.** Any stationary tank not used for a period of 90 days shall be properly safeguarded or removed in a manner approved by the chief. Such tanks shall have the fill line, gauge opening and pump connection secured against tampering. Vent lines shall be properly maintained.

Tanks which are to be placed back in service shall be tested in a manner approved by the chief.

3. **Defective containers and tanks.** Defective containers and tanks shall be removed from service, repaired, or disposed of in an approved manner.

4. **Empty containers and tanks.** Empty containers and tanks previously used for the storage of hazardous materials shall be free from residual material and vapor as defined by D.O.T., R.C.R.A. or other regulating authority or maintained as specified for the storage of the hazardous material.

5. **Underground tanks.** Underground tanks used for the storage of hazardous materials shall be located and protected in accordance with Sections 79.601 and 79.603 of this code. Secondary containment shall be provided for all new installations of underground tanks.

6. **Aboveground tanks.** Aboveground stationary tanks used for the storage of hazardous materials shall be located and protected in accordance with the provisions for exterior storage of the particular material involved and shall be marked as required by Section 80.301 (d).

(c) **Piping, Valves and Fittings.** Piping, valves, fittings and related components appurtenant to or intended for the storage of hazardous materials shall be designed and fabricated from materials compatible with the material to be contained and shall be of adequate strength and durability to withstand the pressure, structural and seismic stress and exposure to which they may be subjected.

(d) **Signage.** In addition to the hazard identification signs required by Section 80.104 (e), stationary aboveground tanks shall be placarded with hazard identification signs as specified in U.F.C. Standard No. 79-3 for the specific material contained.

Signs prohibiting smoking shall be provided in storage areas and within 25 feet of outdoor storage areas.

Signs shall not be obscured or removed.

Signs shall be in English as a primary language or in symbols allowed by this code.

Signs shall be durable. The size, color and lettering shall be in conformance with nationally recognized standards.

(e) **Security.** The storage of hazardous materials shall be safeguarded with such protective facilities as public safety requires.

(f) **Ignition Sources.** Smoking shall not be permitted in any room where hazardous materials are stored nor within 25 feet of outdoor storage areas.

The use of open flames or high-temperature devices in a manner which creates a hazardous condition shall not be permitted.

EXCEPTION: Energy-consuming equipment listed for use with the hazardous material stored.

(g) **Protection from Light.** Materials which are sensitive to light shall be stored in containers designed to protect them from such exposure.

(h) **Shock Padding.** Materials which are shock sensitive shall be padded, suspended or otherwise protected against accidental dislodgement and dislodgement during seismic activity. For seismic requirements and the seismic zone in which the material is located, see the Building Code.

(i) **Shelf Storage.** Shelves shall be of substantial construction and adequately braced. For seismic requirements and the seismic zone in which the material is located, see the Building Code.

Shelves shall be provided with a lip or guard when used for the storage of individual containers.

EXCEPTION: Storage in hazardous materials storage cabinets or laboratory furniture specifically designed for such use.

Shelf storage of hazardous materials shall be maintained in an orderly manner.

(j) **Maximum Quantity on Site.** The storage of hazardous materials shall conform to the provisions of the local zoning ordinance.

(k) **Storage Plan.** A storage plan shall be provided for all storage facilities. The plan shall indicate the intended storage arrangement, including the location and dimensions of aisles.

(l) **Spill Control, Drainage and Containment.** 1. **General.** Unless exempted or otherwise provided for in Sections 80.302 through 80.315, rooms, buildings or areas used for the storage of solid and liquid hazardous materials shall be provided with a means to control spillage and to contain or drain off spillage and fire protection water discharged in the storage area.

2. **Spill Control.** Floors shall be recessed a minimum of 4 inches or shall be provided with a liquid-tight raised sill to a minimum height of 4 inches so as to prevent the flow of liquid to adjoining areas. When liquid-tight sills are provided, they may be omitted at door openings with the installation of an open-grate trench which connects to the room drainage system.

3. **Drainage.** A. The room, building or area shall be provided with a drainage system to direct the flow of liquids to an approved location, or, when required in Sections 80.302 through 80.315, the room, building or area shall be designed to provide secondary containment for the hazardous materials and fire protection water.

B. A slope to drain not less than one percent shall be provided.

C. Drains from the area shall be sized to carry the automatic fire-extinguishing system design flow rate over the system design area.

D. Materials of construction for the drainage system shall be compatible with the stored materials.

E. Incompatible materials shall be separated from each other in drain systems. They may be combined when they have been rendered acceptable by an approved means for discharge into the public sewer.

F. Flow from the drainage system shall be directed to an approved location.

G. Drainage of spillage and fire protection water may be directed to a neutralizer or treatment system which complies with the following:

- (i) The system shall be designed to handle the maximum worst case spill from the single largest container plus the volume of fire protection water from the system over the minimum design area for a period of 20 minutes.
- (ii) The system shall be designed to overflow from the neutralizer or treatment system so that liquid leakage and fire protection water is directed to a safe location away from the building, valves, means of egress, adjoining property or fire department access roadway.

4. **Containment.** When required in Sections 80.302 through 80.315, drains shall be directed to a containment system or other location designed as secondary containment for the hazardous materials liquids and fire protection water, or the building, room or area shall be designed to provide secondary containment of hazardous material liquids and fire protection water through the use of recessed floors or liquid-tight raised sills.

EXCEPTION: The provisions of this subsection may be waived when the chief or other official charged with the enforcement of this code has determined that such enforcement is preempted by other codes, statutes or ordinances. See Section 80.101.

Secondary containment shall be designed to retain the spill from the largest single container plus the design flow rate of the automatic fire-extinguishing system for the area of the room or area in which the storage is located or the system design area, whichever is smaller. The containment capacity shall be capable of containing the flow for a period of 20 minutes.

Overflow from the secondary containment system shall be provided to direct liquid leakage and fire-protection water to a safe location away from the building, valves, means of egress, fire access roadway, adjoining property or storm drains.

If the storage area is open to rainfall, the secondary containment shall be designed to accommodate the volume of a 24-hour rainfall as determined by a 25-year storm. When curbs are used, provisions shall be made for draining accumulations of groundwater or rainwater.

When secondary containment is required, a monitoring method capable of detecting hazardous material leakage from the primary containment into the secondary containment shall be provided. Visual inspection of the primary containment is the preferred method; however, other means of monitoring may be approved by the chief. Where secondary containment may be subject to the intrusion of water, a monitoring method for such water shall be provided. Whenever monitoring devices are provided, they shall be connected to distinct visual and/or audible alarms.

(m) **Ventilation.** Unless exempted or otherwise provided for in Sections 80.302 through 80.315, indoor storage areas and storage buildings shall be provided with mechanical exhaust ventilation.

EXCEPTION: Where natural ventilation can be shown to be acceptable for the materials as stored.

Exhaust ventilation systems shall comply with the following:

1. Installation shall be in accordance with the provisions of the Mechanical Code.
2. Mechanical ventilation shall be at a rate of not less than 1 cubic foot per minute per square foot of floor area over the storage area.
3. Systems shall operate continuously. Alternate designs may be approved by the chief.
4. A manual shutoff control shall be provided outside the room adjacent to the access door into the room or in a location approved by the chief. The switch shall be of the break-glass type and shall be labeled "Ventilation System Emergency Shutoff."
5. Exhaust ventilation shall be arranged to consider the density of the potential fumes or vapors released. For fumes or vapors that are heavier than air, exhaust shall be taken from a point within 12 inches of the floor.
6. The location of both the exhaust and inlet air openings shall be arranged to provide air movement across all portions of the floor or room to prevent the accumulation of vapors.
7. Exhaust ventilation shall not be recirculated within the room or building if the materials stored are capable of emitting hazardous vapors.

(n) **Separation from Incompatible Hazardous Materials.** Storage in excess of the exempt amounts specified in Sections 80.302 through 80.315 shall either be:

1. Segregated from incompatible hazardous materials storage by a distance of not less than 20 feet, or

2. Isolated from incompatible hazardous materials storage by a noncombustible partition extending not less than 18 inches above and to the sides of the stored material, or
3. Stored in hazardous materials storage cabinets or gas cabinets. Materials which are incompatible shall not be stored within the same cabinet.

(c) **Hazardous Materials Storage Cabinets.** 1. **General.** When storage cabinets are used to comply with the provisions of this article, such cabinets shall be in accordance with this subsection.

EXCEPTION: Compressed gases shall be stored in cabinets designed in accordance with Section 80.303.

Cabinets shall be conspicuously labeled in red letters on contrasting background "Hazardous—Keep Fire Away."

2. **Construction.** Cabinets shall be constructed of metal. The interior of cabinets shall be treated, coated or constructed of materials that are nonreactive with the hazardous material stored. Such treatment, coating or construction shall include the entire interior of the cabinet. Cabinets shall either be listed as suitable for the intended storage or constructed in accordance with the following:

- A. Cabinets shall be of steel having a thickness of not less than 0.043 inch. The cabinet, including the door, shall be double walled with 1 1/2-inch airspace between the walls. Joints shall be riveted or welded and shall be tight fitting. Doors shall be well fitted, self-closing and equipped with a self-latching device.
- B. The bottoms of cabinets utilized for the storage of liquids shall be liquid tight to a minimum height of 2 inches.

(p) **Fire-extinguishing Systems.** Unless exempted or otherwise provided for in Sections 80.302 through 80.315, indoor storage areas and storage buildings shall be protected by an automatic sprinkler system. The design of the sprinkler system shall be not less than that required under U.B.C. Standard No. 38-1 for Ordinary Hazard Group 3 with a minimum design area of 3,000 square feet. Where the materials or storage arrangement require a higher level of sprinkler system protection in accordance with nationally recognized standards, the higher level of sprinkler system protection shall be provided.

EXCEPTION: Approved alternate automatic fire-extinguishing systems may be used.

(q) **Explosion Venting or Suppression.** Unless exempted or otherwise provided for in Sections 80.302 through 80.315, indoor storage areas and storage buildings shall be provided with explosion venting, equivalent protective devices, suppression systems or barricades. The design shall be by competent persons and recognize the nature of the stored material and its likely behavior in an explosion. Areas which are provided with explosion venting shall comply with the following:

1. Walls, ceilings and roofs exposing another occupancy or use shall be designed to resist a minimum internal pressure of 100 pounds per square foot.

2. Explosion venting shall be only in exterior walls, roofs or through specially designed shafts to the exterior of the building.

3. Venting shall be designed to prevent serious structural damage and the production of lethal projectiles.

4. The aggregate clear vent relief area shall be governed by the pressure resistance of the nonrelieving portions of the building.

5. Vents shall be designed to relieve at a maximum internal pressure of 20 pounds per square foot and shall consist of any one or any combination of the following:

- A. Walls of lightweight material.
- B. Lightly fastened hatch covers.
- C. Lightly fastened, outward-opening swinging doors in exterior walls.
- D. Lightly fastened walls or roofs.

6. Venting devices shall discharge directly to the open air or to an unoccupied space not less than 50 feet in width on the same lot.

7. Relieving devices shall be so located that the discharge end shall be not less than 10 feet vertically and 20 feet horizontally from window openings or exits in the same or adjoining buildings or structures.

8. Discharge shall be in the direction of least exposure and not into the interior of the building.

(r) **Electrical Wiring and Equipment.** Electrical wiring and equipment shall be installed in accordance with the Electrical Code.

(s) **Standby Power.** When mechanical ventilation, treatment systems, temperature control, alarm, detection or other electrically operated systems are required, such systems shall be connected to a secondary source of power to automatically supply electrical power in the event of loss of power from the primary source. See the Electrical Code.

(t) **Limit Controls.** Unless exempted or otherwise provided for in Sections 80.302 through 80.315, limit controls shall be provided as follows:

1. **Liquid-level limit control.** Atmospheric tanks with a capacity exceeding 500 gallons used for the storage of hazardous materials liquids shall be equipped with a liquid-level limit control to prevent overfilling of the tank.

EXCEPTION: Tanks monitored by a system which will limit net contents by weight.

2. **Temperature control.** Materials which must be stored at temperatures other than normal ambient temperatures to prevent a hazardous reaction shall be stored in an area provided with a means to maintain the temperature within a safe range. Redundant temperature control equipment which will operate upon failure of the primary temperature control system shall be provided. Alternate means to prevent a hazardous reaction may be provided.

3. **Pressure.** Stationary tanks used for the storage of hazardous materials liquids which may generate pressures exceeding the tank design limits due to exposure fires or internal reaction shall have some form of construction or device

that will relieve excessive internal pressure. Such relief devices shall vent to an approved location or to an exhaust scrubber or treatment system when specified in Sections 80.302 through 80.315.

(u) **Manual Alarm.** A local fire alarm manual pull station or approved emergency signal device shall be installed outside of each interior exit door of storage buildings, rooms or areas. Activation of the manual alarm shall sound a local alarm.

(v) **Supervision.** When manual alarm, emergency signal, detection or automatic fire-extinguishing systems are required in Sections 80.302 through 80.315, such systems shall be supervised by an approved central, proprietary or remote station service or shall initiate an audible and visual signal at a constantly attended on-site location.

(w) **Protection from Vehicles.** Guard posts or other means shall be provided to protect exterior storage tanks from vehicular damage. When guard posts are installed, the posts shall be:

1. Constructed of steel not less than 4 inches in diameter and concrete filled.
2. Spaced not more than 4 feet between posts on center.
3. Set not less than 3 feet deep in a concrete footing of not less than 15-inch diameter.
4. Set with the top of the posts not less than 3 feet above ground; and
5. Located not less than 5 feet from the tank.

(x) **Clearance from Combustibles.** The area surrounding an exterior storage area or tank shall be kept clear of combustible materials and vegetation for a minimum distance of 30 feet.

(y) **Fire Access Roadways and Water Supply.** Fire access roadways and approved water supplies shall be provided for exterior storage areas in accordance with the following:

1. **Fire access roadways.** Fire apparatus access roadways shall be provided to within 150 feet of all portions of an exterior storage area. Such access roadways shall comply with the provisions of Section 10.107.
2. **Water supply.** An approved water supply shall be provided. Fire hydrants or other approved means capable of supplying the required fire flow shall be provided to within 150 feet of all portions of an exterior storage area. The water supply and fire hydrants shall comply with the provisions of Section 10.301.

(z) **Noncombustible Floor.** Except for surfacing, floors of storage areas shall be of noncombustible construction.

(aa) **Professional Engineer.** The chief may require design submittals to bear the stamp of a professional engineer.

Explosives and Blasting Agents

Sec. 80.302. Storage of explosives and blasting agents shall be in accordance

with the provisions of Article 77. Storage of fireworks shall be in accordance with the provisions of Article 78.

Compressed Gases

Sec. 80.303. (a) **Indoor Storage.** 1. **General.** Indoor storage of compressed gases shall be in accordance with the provisions of Article 74. In addition, storage of highly toxic or toxic compressed gases shall be in accordance with the provisions of Sections 80.303 (a) and (c) and the general provisions specified in Section 80.301.

2. **Exempt amounts.** When the amount of highly toxic or toxic compressed gases stored in one control area exceeds that specified in Table No. 80.303-A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 7 Occupancy.

TABLE NO. 80.303-A
COMPRESSED GAS STORAGE
EXEMPT AMOUNTS^{1 2}

CONDITION	EXEMPT AMOUNTS (Cubic Feet at NTP)	
	Highly Toxic	Toxic
Unprotected by sprinklers, gas cabinets or separate rooms	0	0
Within gas cabinets in unsprinklered building	20	20
In sprinklered building, not in gas cabinets or separate rooms	0	0
In sprinklered building, within gas cabinets	40	40

¹No exempt amounts are permitted in Group R Occupancies or offices or retail sales portions of Group B Occupancies.

²Except for cylinders not exceeding 20 cubic feet stored within a gas storage cabinet or fumehood, no exempt amounts are permitted in Group A, E, I or M Occupancies or in classrooms of Group B Occupancies.

3. **Fire-extinguishing system.** In addition to the requirements of Section 80.301 (p), the following requirements shall apply:

- A. Gas cabinets or exhausted enclosures for the storage of cylinders shall be internally sprinklered.
- B. Alternate fire-extinguishing systems shall not be used for either storage areas, gas cabinets or exhausted enclosures.

4. **Explosion venting or suppression.** When highly toxic or toxic flammable gases are stored in rooms outside of gas cabinets or exhausted enclosures, the storage rooms shall be provided with explosion venting or suppression in accordance with the provisions of Section 80.301 (q).

5. **Spill control, drainage and containment.** Spill control, drainage and containment shall not be required for the storage of highly toxic or toxic compressed gases.

6. Exhaust ventilation. A. Ventilated area. Storage of cylinders shall be within ventilated gas cabinets, exhausted enclosures or within a ventilated separate gas storage room. Storage of portable and stationary tanks shall be within a separate ventilated room without other occupancy or use. If gas cabinets are provided, the room or area in which they are located shall have independent exhaust ventilation.

Exhaust systems for gas cabinets, exhausted enclosures and separate gas storage rooms shall be designed to handle the accidental release of gas. Such exhaust systems shall be capable of diluting, adsorbing, absorbing, neutralizing, burning or otherwise processing the entire contents of the largest single tank or cylinder of gas stored. Systems utilized for such processing shall be designed as a treatment system. If a total containment system is utilized, the system shall be designed to handle the maximum anticipated pressure of release to the system when it reaches equilibrium.

B. Gas cabinets. When gas cabinets are provided they shall be:

- Operated at negative pressure in relation to the surrounding area.
- Provided with self-closing limited access ports or noncombustible windows to give access to equipment controls. The average velocity of ventilation at the face of access ports or windows shall be not less than 200 feet per minute (fpm) with a minimum of 150 fpm at any point of the access port or window.
- Connected to a treatment system.
- Provided with self-closing doors.
- Constructed of not less than 12-gage steel.

C. Separate gas storage rooms. When separate gas storage rooms are provided they shall be designed to:

- Operate at a negative pressure in relation to the surrounding area.
- Direct the exhaust ventilation to a treatment system.

D. Treatment systems. (i) General. Treatment systems shall be utilized to process all exhaust ventilation to be discharged from gas cabinets, exhausted enclosures or separate storage rooms. Treatment systems shall be designed to reduce the maximum allowable discharge concentration of the gas to one-half IDLH at the point of discharge to the atmosphere as specified in items (iii) and (iv) below. When more than one gas is emitted to the treatment system, the treatment system shall be designed to handle the worst case release based on the release rate, the quantity and the IDLH for all the gases stored or used.

- Treatment system sizing. Treatment systems shall be sized to process the maximum worst case release of gas based on the maximum flow rate of release from the largest cylinder or tank utilized. The entire contents of tanks and cylinders shall be considered.
- Stationary tanks. Stationary tanks shall be labeled with the maximum rate of release for the gas contained based on any valves or fittings that are inserted directly into the tank. If multiple valves or fittings are provided,

the maximum flow rate of release for the valve or fitting with the highest flow rate shall be indicated. If liquefied gases are in contact with any valve or fitting, the liquid flow rate shall be utilized for purposes of computation. All flow rates indicated on the label shall be converted to cubic feet per minute of gas at normal temperature and pressure.

- Portable tanks and cylinders. For portable tanks and cylinders, the maximum flow rate of release shall be calculated based on assuming the total release from the cylinder or tank within the time specified in Table No. 80.303-B. When portable tanks or cylinders are equipped with approved excess flow or reduced flow valves, the worst case release will be determined by the maximum achievable flow from the valve as determined by the valve manufacturer or the gas supplier. Reduced flow and excess flow valves shall be permanently marked by the manufacturer to indicate the maximum design flow rate. Such markings shall indicate the flow rate for air under standard conditions.

TABLE NO. 80.303-B
RATE OF RELEASE FOR CYLINDERS AND PORTABLE TANKS

CONTAINER	NONLIQUEFIED (lb/min)	LIQUEFIED (lb/min)
Cylinders	5	30
Portable Tanks	40	240

7. Emergency power. Emergency power shall be provided in lieu of standby power for:

- Exhaust ventilation, including the power supply for treatment systems.
- Gas-detection systems.
- Emergency alarm systems.
- Temperature-control systems.

8. Limit controls. In addition to the limit controls required in Section 80.301 (t), excess flow control shall be provided for stationary tanks which are piped for filling or dispensing.

9. Gas detection. A continuous gas-detection system shall be provided to detect the presence of gas at or below the permissible exposure limit or ceiling limit. The detection system shall initiate a local alarm and transmit a signal to a constantly attended control station. The alarm shall be both visual and audible and shall be designed to provide warning both inside and outside of the storage area. The audible alarm shall be distinct from all other alarms.

EXCEPTIONS: 1. Signal transmission to a constantly attended control station need not be provided when not more than one cylinder is stored.

2. A continuous gas-detection system need not be provided for toxic gases when the physiological warning properties for the gas are at a level below the accepted permissible exposure limit for the gas.

The gas-detection system shall be capable of monitoring the room or area in which the gas is stored at or below the permissible exposure limit or ceiling limit and the discharge from the treatment system at or below one-half the IDLH limit.

10. **Smoke detection.** An approved supervised smoke-detection system shall be provided in rooms or areas where highly toxic compressed gases are stored indoors. Activation of the detection systems shall sound a local alarm.

11. **Storage conditions.** The number of cylinders contained in a single gas cabinet shall not exceed three.

EXCEPTION: Cabinets containing cylinders not exceeding 1 pound net contents each shall be limited to a maximum of 100 cylinders.

(b) **Exterior Storage.** 1. **General.** Exterior storage of highly toxic or toxic compressed gases shall be in accordance with the provisions of Sections 80.303 (b) and (c) and the general provisions specified in Section 80.301.

2. **Distance from storage to exposures.** In addition to the provisions of the Building Code, exterior storage of highly toxic or toxic compressed gases shall comply with the following:

A. **Distance limitation to exposures.** The exterior storage of highly toxic or toxic compressed gases shall not be within 75 feet of a building, property line, street, alley, public way or exit to a public way unless the storage is shielded by a structure having a minimum fire-resistive rating of two hours and which interrupts the line of sight between the storage and the exposure. The protective structure shall be at least 5 feet from any exposure. The protective structure shall have not more than two sides at approximately 90-degree directions, except that a third diagonal section may be used at the vertex.

B. **Openings in exposure buildings.** When the storage area is located closer than 75 feet to a building, openings into a building other than piping shall not be above the height of the top of the shielding structure or within 50 feet horizontally from the storage area whether or not shielded by a protective structure.

C. **Air intakes.** The storage area shall not be within 75 feet of air intakes.

3. **Canopies.** Portable tanks and cylinders stored outside of buildings shall be stored under a canopy of noncombustible construction. Such storage shall not be considered indoor storage.

An automatic fire-sprinkler system shall be provided for canopies provided for the storage of highly toxic or toxic compressed gases.

4. **Piping and controls.** In addition to the requirements of Section 80.301 (c), piping and controls on stationary tanks shall be in accordance with the following:

A. Pressure-relief devices shall be vented to a treatment system designed in accordance with the provisions of Section 80.303 (a) 6 D.

B. Where filling or dispensing connections are provided, they shall be provided with a means of local exhaust. Such exhaust shall be designed to capture fumes and vapors. The exhaust shall be directed to a treatment system designed in accordance with the provisions of Section 80.303 (a) 6 D.

C. Stationary tanks shall be provided with a means of excess flow control on all tank inlet or outlet connections.

EXCEPTIONS: 1. Inlet connections that are designed to preclude backflow.

2. Pressure-relief devices.

5. **Spill control, drainage and containment.** Spill control, drainage and containment shall not be required for the exterior storage of highly toxic or toxic compressed gases.

(c) **Special Provisions.** 1. **Seismic protection.** Stationary tanks and associated piping systems shall be seismically braced in accordance with the provisions of the Building Code.

2. **Security.** Storage areas shall be secured against unauthorized entry.

3. **Gas cabinets for leaking cylinders.** At least one gas cabinet or exhausted enclosure shall be provided for the handling of leaking cylinders. The cabinet or enclosure shall be located as follows:

A. Within or adjacent to exterior storage areas.

B. Within separate gas storage rooms used for cylinders.

The gas cabinet or exhausted enclosure shall be connected to a treatment system as specified in Section 80.303 (a) 6 D.

EXCEPTION: A cabinet or exhausted enclosure need not be provided for leaking cylinders if all cylinders are stored within gas cabinets or exhausted enclosures.

4. **Local exhaust for leaking portable tanks.** A means of local exhaust shall be provided to capture leaks from portable tanks. The local exhaust may consist of portable ducts or collection systems designed to be applied to the site of a leak in a valve or fitting on the tank. The local exhaust system shall be connected to a treatment system as specified in Section 80.303 (a) 6 D. The local exhaust system shall be provided:

A. Within or immediately adjacent to exterior storage areas.

B. Within separate gas storage rooms used for portable or stationary tanks.

5. **Breathing apparatus.** When highly toxic or toxic compressed gases are stored, a minimum of two self-contained breathing apparatus shall be provided. The breathing apparatus shall be suitable for use with the material stored and shall be located near the immediate area of storage in a location that provides safety to those expected to don the apparatus. A safe area is one which is not likely to be immediately affected by the release of hazardous material in the area of concern.

When self-contained breathing apparatus would be inadequate protection due to the nature of the gases present, other appropriate protective equipment shall be provided.

Flammable/Combustible Liquids

Sec. 80.304. Storage of flammable and combustible liquids shall be in accordance with the provisions of Article 79.

Flammable Solids

Sec. 80.305. (a) **Indoor Storage.** 1 **General.** Indoor storage of flammable solids shall be in accordance with the provisions of Section 80.305 (a) and the general provisions specified in Section 80.301. Storage of combustible fibers shall be in accordance with the provisions of Article 28.

2 **Exempt amounts.** When the amount of flammable solids stored in one control area exceeds that specified in Table No. 80.305-A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 3 Occupancy, or a Group H, Division 2 Occupancy when combustible dusts are stored in piles or within open containers.

**TABLE NO. 80.305-A
FLAMMABLE SOLIDS—EXEMPT AMOUNTS**

CONDITION	EXEMPT AMOUNTS (Pounds)
Unprotected by sprinklers or cabinet	125
Within cabinet in unsprinklered building	250
In sprinklered building, not in cabinet	250
In sprinklered building, within cabinet	500

3 **Spill control, drainage and containment.** Spill control, drainage and containment shall not be required for the storage of flammable solids.

4 **Explosion venting or suppression.** Rooms, buildings or equipment used for the storage of combustible dusts shall be provided with explosion venting or suppression in accordance with the provisions of Section 80.301 (q).

5 **Ventilation.** Mechanical exhaust ventilation shall not be required.

6 **Storage conditions.** Flammable solids stored in quantities greater than 1,000 cubic feet shall be separated into piles each not larger than 1,000 cubic feet. Aisle widths between piles shall be equal to not less than the height of the piles or 4 feet, whichever is greater.

Flammable solids shall not be stored in basements.

(b) **Exterior Storage.** 1 **General.** Exterior storage of flammable solids shall be in accordance with the provisions of Section 80.305 (b) and the general provisions specified in Section 80.301. Storage of combustible fibers shall be in accordance with the provisions of Article 28.

2 **Distance from storage to exposures.** Exterior storage of flammable solids shall not be within 20 feet of any building, property line, street, alley, public way, or exit to a public way. An unpierced two hour fire resistive wall extending not less than 30 inches above and to the sides of the storage area may be provided in lieu of such distance.

3 **Spill control, drainage and containment.** Spill control, drainage and containment shall not be required for exterior storage of flammable solids.

4 **Storage conditions.** Exterior storage of flammable solids shall be separated into piles not larger than 5,000 cubic feet each. Aisle widths between piles shall be not less than one-half the height of the piles or 10 feet, whichever is greater.

Liquid and Solid Oxidizers

Sec. 80.306. (a) **Indoor Storage.** 1 **General.** Indoor storage of liquid and solid oxidizers shall be in accordance with Section 80.306 (a) and the general provisions specified in Section 80.301.

2 **Exempt amounts.** When the amount of liquid and solid oxidizers stored in one control area exceeds that specified in Table No. 80.306-A, such storage shall be within a room or building conforming to the Building Code requirements for the following occupancies:

Oxidizer Class	Occupancy Group
Class 4	H 1
Class 3	H 2
Class 1 and Class 2	H 3

Storage in excess of the exempt amounts specified in Table No. 80.306-A shall comply with Items 3 through 14. Storage not exceeding the exempt amounts specified in Table No. 80.306-A shall comply with Items 12 and 13.

**TABLE NO. 80.306-A
LIQUID AND SOLID OXIDIZERS¹
EXEMPT AMOUNTS**

CONDITION	EXEMPT AMOUNT (Pounds)			
	CL 1	CL 2	CL 3	CL 4
Unprotected by sprinklers or cabinet	1,000	250	10	0
Within cabinet in unsprinklered building	2,000	500	20	0
In sprinklered building, not in cabinet	2,000	500	20	1
In sprinklered building, within cabinet	4,000	1,000	40	2

¹No exempt amounts of Class 3 and Class 4 oxidizers are permitted in Group R Occupancies or offices or retail sales portions of Group B Occupancies.

²No exempt amounts of Class 3 or 4 oxidizers are permitted in Group A, E, I or M Occupancies or in classrooms of Group B Occupancies unless storage is within a hazardous materials storage cabinet containing no other storage.

3 **Detached storage.** Storage of liquid and solid oxidizers in quantities in excess of those specified in Table No. 80.306-B shall either be in a detached building used for no other purpose or in an exterior storage area. Detached storage buildings shall be single-story buildings, without basement or crawl space and be of noncombustible construction.

**TABLE NO. 80.306-B—REQUIRED DETACHED STORAGE
OF OXIDIZERS**

CLASS	DETACHED STORAGE REQUIRED WHEN AMOUNT EXCEEDS (Tons)
1	No requirement
2	2,000
3	1,200
4	Exempt amount specified in Table No. 80.306-A

4 Distance from detached storage buildings to exposures. In addition to the provisions of the Building Code, detached storage buildings shall be located in accordance with Tables Nos. 80.306-C and 80.306-D.

TABLE NO. 80.306-C—CLASS 1, 2 OR 3 OXIDIZERS—SEPARATION OF DETACHED STORAGE FROM OTHER BUILDINGS, PROPERTY LINES, STREETS, ALLEYS, PUBLIC WAYS OR EXITS TO A PUBLIC WAY

CLASS	MINIMUM DISTANCE (Feet)
1	1
2	35
3	50

Detached storage of Class 1 liquid or solid oxidizers not required.

TABLE NO. 80.306-D—CLASS 4 OXIDIZERS—SEPARATION OF DETACHED STORAGE FROM OTHER BUILDINGS, PROPERTY LINES, STREETS, ALLEYS, PUBLIC WAYS OR EXITS TO A PUBLIC WAY

WEIGHT (Pounds)	MINIMUM DISTANCE (Feet)
Over 10 to 100	75
101 to 500	100
501 to 1,000	125
1,001 to 3,000	200
3,001 to 5,000	300
5,001 to 10,000	400
Over 10,000	As determined by the chief

5 Liquid-tight floor. In addition to the provisions of Section 80.301 (z), floors of storage areas shall be of liquid tight construction.

6 Insulated roof. Roofs of storage areas shall be of lightweight construction and suitably insulated.

7 Smoke and heat venting. Storage areas shall be provided with means to vent smoke and heat in a fire or other emergency in accordance with the provisions of the Building Code.

8 Explosion venting or suppression. Explosion venting or suppression shall not be required in storage areas for Class 1 and Class 2 oxidizers.

9 Containment. Secondary containment shall be provided in accordance with the provisions of Section 80.301 (j) 4.

10 Standby power. Standby power shall not be required for the storage of Class 1 and Class 2 oxidizers.

11 Detection. An approved supervised smoke-detection system shall be installed in all liquid and solid oxidizer storage areas. Activation of the detection systems shall sound a local alarm.

EXCEPTION: A smoke detection system need not be provided in detached storage buildings with an automatic fire-extinguishing system.

12 Storage conditions. The maximum quantities per building in detached storage buildings shall not exceed that specified in Tables Nos. 80.306-E through 80.306-H.

The storage arrangement for liquid and solid oxidizers shall be as specified in Tables Nos. 80.306-E through 80.306-H.

Class 2 oxidizers shall not be stored in basements except when storage is in stationary tanks. Class 3 and Class 4 oxidizers in excess of the exempt amounts specified in Table No. 80.306-A shall be stored on the ground floor only.

TABLE NO. 80.306-E—STORAGE OF CLASS 1 OXIDIZERS IN COMBUSTIBLE CONTAINERS¹

CONDITION	PILE LIMITS
Piles	No limit
Length (feet)	50
Width (feet)	20
Height (feet)	3
Distance to next pile (feet)	2
Distance to walls (feet)	No limit
Maximum quantity per building	No limit

¹Storage in noncombustible containers or in bulk in detached storage buildings is not limited as to quantity or arrangement.

TABLE NO. 80.306-F—STORAGE OF CLASS 2 OXIDIZERS IN COMBUSTIBLE CONTAINERS¹

CONDITION	SEGREGATED AS	CUT OFF	DETACHED
Piles			
Height (feet)	10	12	12
Distance to next pile (feet)	—	2	2
Distance to walls (feet)	2	2	2
Maximum quantity per pile (tons)	20	50	200
Maximum quantity per building (tons)	200	500	No limit

¹Storage in noncombustible containers is not limited as to quantity or arrangement except that piles shall be at least 2 feet from walls in nonsprinklered buildings and 4 feet from walls in sprinklered buildings; distance between piles shall be not less than the pile height.

Aisle width shall be not less than the pile height.

²Quantity limits shall be reduced by 50 percent in buildings or portions of buildings used for retail sales.

TABLE NO. 80.306-G—STORAGE OF CLASS 3 OXIDIZERS
IN CONTAINERS^{1, 2}

CONDITION	SEGREGATED	CUT OFF	DETACHED
Piles			
Height (feet)	8	10	10
Distance to next pile (feet)	3	3	3
Distance to walls (feet)	4	4	4
Maximum quantity per pile (tons)	20	30	150
Maximum quantity per building (tons)	100	300	No limit

¹Except in buildings used for retail sales, quantity limits per pile and per building may be doubled where Class 3 oxidizers are in noncombustible containers.

²Quantity limits per pile and per building shall be reduced by 50 percent in buildings or portions of buildings used for retail sales.

³Aisle width shall equal pile height.

TABLE NO. 80.306-H—STORAGE OF CLASS 4 OXIDIZERS
IN DRUMS, CONTAINERS, CASES

CONDITION	MAXIMUM FEET
Piles	
Length	10
Width	4
Height	8
Distance to next pile	8
Maximum quantity per building	No limit

13 **Separation.** In addition to the provisions of Section 80.301 (n), Class 3 and Class 4 oxidizers shall be separated from other hazardous materials by not less than one-hour fire-resistive construction or stored in hazardous materials storage cabinets.

Detached storage buildings for Class 4 oxidizers shall be located a minimum of 50 feet from all other hazardous materials storage.

14 **Contamination.** Oxidizers shall not be stored on or against combustible surfaces. During storage, care shall be taken to prevent contamination.

(b) **Exterior Storage.** 1 **General.** Exterior storage of liquid and solid oxidizers shall be in accordance with the provisions of Section 80.306 (b) and the general provisions specified in Section 80.301.

2 **Distance from storage to exposures.** Storage areas for oxidizers shall be located in accordance with Tables Nos. 80.306-C and 80.306-D.

3 **Storage conditions.** A **Maximum quantities.** The maximum quantities of Class 4 oxidizers shall be as specified in Table No. 80.306-D.

B **Storage Arrangement.** Storage arrangement shall be as specified in Tables Nos. 80.306-E through 80.306-H.

Organic Peroxides

Sec. 80.307. (a) Indoor Storage. 1. **General.** Indoor storage of organic peroxides shall be in accordance with the provisions of Section 80.307 (a) and the general provisions specified in Section 80.301.

EXCEPTION: Unclassified detonatable organic peroxides that are capable of detonation in their normal shipping containers under conditions of fire exposure shall be stored in accordance with the requirements of Article 77 for high explosives.

2. **Exempt amounts.** When the amount of organic peroxides stored in one control area exceeds that specified in Table No. 80.307-A, such storage shall be within a room or building conforming to the Building Code requirements for the following occupancies:

Organic Peroxide Class	Occupancy Group
Unclassified detonatable	H-1
I	H-2
II, III, IV	H-3
V ¹	B-2

¹Class V peroxides are not considered to be physical hazards.

Storage exceeding the exempt amounts specified in Table No. 80.307-A shall comply with Items 3 through 15. Storage not exceeding the exempt amounts specified in Table No. 80.307-A shall comply with Items 14 and 15.

TABLE NO. 80.307-A
ORGANIC PEROXIDE STORAGE EXEMPT AMOUNTS^{1, 2}

CONDITION	EXEMPT AMOUNT (Pounds)				
	UD	CL 1	CL 2	CL 3	CL 4
Unprotected by sprinklers or cabinet	0	5	50	125	500
Within cabinet in unsprinklered building	0	10	100	250	1,000
In sprinklered building, not in cabinet	1	10	100	250	1,000
In sprinklered building, within cabinet	2	20	200	500	2,000

UD—Unclassified detonatable

¹No exempt amounts of unclassified detonatable or Class I organic peroxides are permitted in Group R Occupancies or offices or retail sales portions of Group B Occupancies.

²No exempt amounts of unclassified detonatable or Class I organic peroxides are permitted in Group A, E, I or M Occupancies or in classrooms of Group B Occupancies unless storage is within a hazardous material storage cabinet containing no other storage.

3. **Detached storage.** Storage of organic peroxides in quantities exceeding those specified in Table No. 80.307-B shall be in a detached building used for no other purpose or in an exterior storage area. Detached storage buildings shall be single-story buildings, without basement or crawl space and of noncombustible construction.

TABLE NO. 80.307-B—REQUIRED DETACHED STORAGE OF ORGANIC PEROXIDES

CLASS	DETACHED STORAGE REQUIRED WHEN AMOUNT EXCEEDS (Tons)
UD ¹	See Article 77
I	Exempt amount specified in Table No. 80.307-A
II	25
III	50
IV and V	No requirement

¹Unclassified detonatable

4. **Distance from detached storage buildings to exposures.** In addition to the provisions of the Building Code, detached storage buildings shall be located in accordance with Tables Nos. 80.307-C and 80.307-D.

TABLE NO. 80.307-C—SEPARATION OF DETACHED STORAGE FROM OTHER BUILDINGS, PROPERTY LINES, STREETS, ALLEYS, PUBLIC WAYS OR EXITS TO A PUBLIC WAY

CLASS	MAXIMUM STORAGE QUANTITY (Pounds) AT MINIMUM SEPARATION		
	50 Feet	100 Feet	150 Feet
I	2,000	20,000	175,000
II	100,000	200,000	Unlimited
III	200,000	Unlimited	Unlimited
IV	Unlimited	Unlimited	Unlimited

TABLE NO. 80.307-D—SEPARATION BETWEEN INDIVIDUAL DETACHED STORAGE BUILDINGS OR AREAS

CLASS	MAXIMUM STORAGE QUANTITY (Pounds) AT MINIMUM SEPARATION		
	20 Feet	75 Feet	100 Feet
I	1,000	4,000	10,000
II, III, IV	2,000	20,000	175,000

¹When the amount of organic peroxide stored does not exceed the amount indicated in Table No. 80.307-C, minimum separation shall be 20 feet; when the amount of organic peroxide stored exceeds the amount indicated in Table No. 80.307-C, minimum separation shall be 50 feet.

5. **Liquid-tight floor.** In addition to the requirements of Section 80.301 (z), floors of storage areas shall be of liquid-tight construction.

6. **Insulated roof.** Roofs of detached storage buildings shall be of lightweight construction and suitably insulated.

7. **Smoke and heat venting.** Storage areas shall be provided with a means to vent smoke and heat in a fire or other emergency in accordance with the provisions of the Building Code.

8. **Explosion venting or suppression.** Explosion venting or suppression shall not be required for storage areas for Class II, Class III, Class IV and Class V organic peroxides.

9. **Containment.** Secondary containment shall be provided in accordance with the provisions of Section 80.301 (l) 4.

10. **Standby power.** Standby power shall not be required for the storage of Class III, IV or V organic peroxides.

11. **Electrical wiring and equipment.** In addition to the requirements of Section 80.301 (r) electrical wiring and equipment in storage areas for Class I or II organic peroxides shall comply with the requirements for Class I, Division 2 locations.

12. **Limit controls.** Liquid-level limit controls need not be provided for atmospheric tanks used for storage of Class II, III, IV or V organic peroxides.

13. **Detection.** An approved supervised smoke-detection system shall be provided in rooms or areas where Class I or II organic peroxides are stored, and where Class III or IV organic peroxides are stored in quantities exceeding the exempt amounts specified in Table No. 80.307-A. Activation of the detection system shall sound a local alarm.

EXCEPTION: A smoke-detection system need not be provided in detached storage buildings provided with an automatic fire-extinguishing system.

14. **Storage conditions.** A. **Maximum quantities.** Maximum quantity per building in a mixed-occupancy building shall not exceed the amounts specified in Table No. 80.307-B. Maximum quantity per building in a detached storage building shall not exceed the amounts specified in Tables Nos. 80.307-C and 80.307-D.

B. **Storage arrangement.** Storage arrangement for organic peroxides shall be as specified in Tables Nos. 80.307-E through 80.307-G and shall comply with the following:

- Containers and packages in storage areas shall be closed.
- Bulk storage shall not be in piles or bins.
- A minimum 2-foot clear space shall be maintained between storage and uninsulated metal walls.
- Fifty-five-gallon drums shall not be stored more than one container high.

TABLE NO. 80.307-E—STORAGE OF CLASS I ORGANIC PEROXIDES

CONDITION	LIMITS
Piles	
Width (feet)	6
Height (feet)	8
Distance to next pile (feet)	4 ¹
Distance to walls (feet)	4 ²
Maximum quantity per building	3

¹At least one main aisle with a minimum width of 8 feet shall divide the storage area.²Distance to noncombustible walls may be reduced to 2 feet.³See Tables Nos. 80.307-B and 80.307-C for maximum quantities.

TABLE NO. 80.307-F—STORAGE OF CLASS II AND CLASS III ORGANIC PEROXIDES

CONDITION	LIMITS
Piles	
Width (feet)	10
Height (feet)	8
Distance to next pile (feet)	4
Distance to walls (feet)	4 ¹
Maximum quantity per building	2

¹At least one main aisle with a minimum width of 8 feet shall divide the storage area.²Distance to noncombustible walls may be reduced to 2 feet.³See Tables Nos. 80.307-B, 80.307-C and 80.307-D for maximum quantities.

TABLE NO. 80.307-G—STORAGE OF CLASS IV ORGANIC PEROXIDES

CONDITION	LIMITS
Piles	
Width (feet)	16
Height (feet)	10
Distance to next pile (feet)	3 ¹
Distance to combustible walls (feet)	2
Maximum quantity per building	3

¹At least one main aisle with a minimum width of 8 feet shall divide the storage area.²Distance shall be not less than one-half the pile height.³See Tables Nos. 80.307-B and 80.307-C for maximum quantities.

C Location in building. The storage of Class I or II organic peroxides shall be on the ground floor only. Class III organic peroxides shall not be stored in basements.

15 Contamination. Organic peroxides shall be stored in their original shipping containers (DOT containers). During storage, care shall be taken to prevent contamination.

(b) Exterior Storage. 1 General. Exterior storage of organic peroxides shall be in accordance with Section 80.307 (b) and the general provisions specified in Section 80.301.

EXCEPTION: Unclassified detonatable organic peroxides that are capable of detonation in their normal shipping containers under fire conditions shall be stored in accordance with the requirements of Article 77 for high explosives.

2 Distance from storage to exposures. Storage areas for organic peroxides shall be located in accordance with Tables Nos. 80.307-C and 80.307-D.

3 Fire-extinguishing system. Automatic fire-sprinkler system protection shall be provided when required for weight or distance by Tables Nos. 80.307-C and 80.307-D.

4 Electrical wiring and equipment. In addition to the requirements of Section 80.301 (r), electrical wiring and equipment in exterior storage areas containing Class I, II or III organic peroxides shall comply with the requirements for Class I, Division 2 locations.

5 Limit controls. Liquid-level limit controls shall not be required for atmospheric tanks used for the storage of Class II, III, IV or V organic peroxides.

6 Storage conditions. A Maximum quantities. Maximum quantities of organic peroxides shall be as specified in Tables Nos. 80.307-C and 80.307-D.

B Storage arrangement. Storage arrangement shall be as specified in Tables Nos. 80.307-E, 80.307-F and 80.307-G.

7 Separation. In addition to the provisions of Section 80.301 (n), storage areas for organic peroxides exceeding the amounts specified in Table No. 80.307-B shall be located a minimum distance of 50 feet from other hazardous material storage.

Pyrophoric Materials

Sec. 80.308. (a) Indoor Storage. 1 General. Indoor storage of pyrophoric solids, liquids and gases shall be in accordance with the provisions of Section 80.308 (a) and the general provisions specified in Section 80.301.

2 Exempt amounts. When the amount of pyrophoric material stored in one control area exceeds that specified in Table No. 80.308-A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 2 Occupancy for gases and a Group H, Division 3 Occupancy for solids and liquids.

TABLE NO 80.308-A
PYROPHORIC MATERIALS EXEMPT AMOUNTS

CONDITION	EXEMPT AMOUNT	
	Solids and Liquids (Pounds)	Gases (Cubic Ft)
Unprotected by sprinklers or storage cabinets	0	0
Within storage cabinet in unsprinklered building	0	0
In sprinklered building, not in storage cabinet	4	50
In sprinklered building, in storage cabinet	8	100

*For pyrophoric liquids, a conversion of 10 pounds per gallon shall be used.

3 **Type of construction.** In addition to the requirements of the Building Code for Group H, Division 2 and 3 Occupancies, buildings used for the storage of pyrophoric materials shall be of noncombustible construction.

4 **Liquid-tight floor.** In addition to the provisions of Section 80 301 (z), floors of storage areas shall be of liquid tight construction.

5 **Containment.** Secondary containment shall be provided for storage rooms and buildings containing pyrophoric liquids in accordance with the provisions of Section 80 301 (l) 4.

6 **Electrical wiring and equipment.** In addition to the requirements of Section 80 301 (r), electrical wiring and equipment in storage areas for pyrophoric gases and liquids shall comply with the requirements for Class I, Division 2 locations.

7 **Storage conditions.** Palletized storage of pyrophoric liquids and solids shall be limited to a maximum size of 10 feet by 10 feet by 5 feet high. Individual containers shall not be stacked.

Aisles between storage piles shall be a minimum of 10 feet in width.

Tanks or containers inside buildings shall not be larger than 500 gallons.

8 **Separation.** In addition to the provisions of Section 80 301 (n), indoor storage of pyrophoric solids, liquids and gases shall be isolated from incompatible hazardous materials by one-hour fire resistive noncombustible walls with openings protected in accordance with Building Code Section 3305 (h).

EXCEPTION. Storage in approved hazardous materials storage cabinets built in accordance with the provisions of Section 80 301 (a).

(b) **Exterior Storage.** 1 **General.** Exterior storage of pyrophoric solids, liquids and gases shall be in accordance with Section 80 308 (b) and the general provisions specified in Section 80 301.

2 **Distance from storage to exposures.** The separation of pyrophoric solids, liquids and gases from buildings, property lines, streets, alleys, public ways or exits to a public way shall be twice the separation required by Article 79 for Class I B flammable liquids.

3 **Containment.** Secondary containment shall be provided for pyrophoric liquids in accordance with the provisions of Section 80 301 (l) 4.

4 **Storage conditions.** Quantities, arrangement and spacing for pyrophoric liquids and solids in tanks, portable tanks, and containers shall be in accordance with Article 79 for Class I B flammable liquids.

5 **Separation.** In addition to the provisions of Section 80 301 (n), separation of pyrophoric liquids and solids from other hazardous materials shall be in accordance with Article 79 for Class I B flammable liquids.

Unstable (Reactive) Materials

Sec. 80 309. (a) Indoor Storage. 1 **General.** Indoor storage of unstable (reactive) materials shall be in accordance with the provisions of Section 80 309 (a) and the general provisions specified in Section 80 301.

EXCEPTION. Detonatable unstable (reactive) materials shall be stored in accordance with Article 77.

2 **Exempt amounts.** When the amount of unstable (reactive) material stored in one control area exceeds that specified in Table No. 80 309 A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 1 Occupancy for detonatable Class 3 and Class 4 materials, Group H, Division 2 Occupancy for nondetonatable Class 3 materials, and Group H, Division 3 Occupancy for Class 2 and Class 1 materials.

Storage exceeding the exempt amounts specified in Table No. 80 309 A shall comply with Items 3 through 9 of this subsection. Storage not exceeding the exempt amounts specified in Table No. 80 309 A shall comply with Item 9.

TABLE NO 80 309-A
UNSTABLE (REACTIVE) MATERIALS EXEMPT AMOUNTS

CONDITION	EXEMPT AMOUNT							
	SOLIDS AND LIQUIDS (Pounds)				GASES (Cubic Feet)			
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4
Unprotected by sprinklers or storage cabinets	125	50	5	0	750	250	50	0
Within storage cabinet in unsprinklered building	250	100	10	0	1 500	500	100	0
In sprinklered building, not in storage cabinet	250	100	10	1	1 500	500	100	10
In sprinklered building, in storage cabinet	500	200	20	2	3 000	1 000	200	20

*For unstable (reactive) materials, a conversion of 10 pounds per gallon shall be used.

No exempt amounts of Class 3 or 4 materials are permitted in Group R Occupancies or offices or retail sales portions of Group B Occupancies.

No exempt amounts of Class 3 or 4 materials are permitted in Group A, E, I or M Occupancies or in classrooms of Group B Occupancies unless storage is within a hazardous materials storage cabinet containing no other storage.

3 **Type of construction.** In addition to the provisions of the Building Code, buildings or rooms used for the storage of Class 3 or 4 materials shall be of noncombustible construction.

4 **Detached storage.** Detached storage shall be provided when the amount of materials stored exceeds that specified in Table No. 80.309-B. Detached storage buildings shall be single-story buildings, without basement or crawl space.

TABLE NO. 80.309-B—REQUIRED DETACHED STORAGE OF UNSTABLE (REACTIVE) MATERIALS

CLASS	DETACHED STORAGE REQUIRED WHEN AMOUNT EXCEEDS	
	Solids and Liquids (Pounds)	Gases (Cubic Feet)
4	Exempt amount specified in Table No. 80.309-A	
3	2,000	2,000
2	50,000	10,000

5 **Liquid-tight floor.** In addition to the provisions of Section 80.301 (z), floors of storage areas for liquids and solids shall be of liquid-tight construction.

6 **Insulated roof.** Roofs of storage rooms and buildings shall be of lightweight construction and suitably insulated.

7 **Heat and smoke venting.** Storage areas shall be provided with a means to vent smoke and heat in a fire or other emergency in accordance with the provisions of the Building Code.

8 **Containment.** Secondary containment shall be provided in accordance with the provisions of Section 80.301 (l) 4.

9 **Storage conditions.** Unstable (reactive) materials stored in quantities greater than 500 cubic feet shall be separated into piles each not larger than 500 cubic feet. Aisle width shall be equal to not less than the height of the piles or 4 feet, whichever is greater.

EXCEPTION: Materials stored in tanks.

Unstable (reactive) materials shall not be stored in basements.

(b) **Exterior Storage.** 1 **General.** Exterior storage of unstable (reactive) materials shall be in accordance with the provisions of Section 80.309 (b) and the general provisions specified in Section 80.301.

2 **Distance from storage to exposures.** Exterior storage of unstable (reactive) materials shall not be permitted within 20 feet of any building, property line, street, alley, public way or exit to a public way. An unpierced two-hour fire-resistant wall extending not less than 30 inches above and to the sides of the storage may be provided in lieu of such distance.

EXCEPTION: Unstable (reactive) material which may deflagrate shall not be within 75 feet of any building, property line, street, alley, public way or exit to a public way.

3 **Containment.** Secondary containment shall be provided in accordance with the provisions of Section 80.301 (l) 4.

4 **Storage conditions.** Class 3 or 4 materials shall be limited to piles not greater than 100 cubic feet.

Class 1 or 2 materials shall be limited to piles not greater than 1,000 cubic feet.

Aisle widths between piles shall not be less than one-half the height of the pile or 10 feet, whichever is greater.

Water-reactive Materials

Sec. 80.310. (a) Indoor Storage. 1 **General.** Indoor storage of water-reactive materials shall be in accordance with the provisions of Section 80.310 (a) and the general provisions specified in Section 80.301.

2 **Exempt amounts.** When the amount of water-reactive material stored in one control area exceeds that specified in Table No. 80.310-A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 3 Occupancy.

Storage exceeding the exempt amounts specified in Table No. 80.310-A shall comply with Items 2 through 10. Storage not exceeding the exempt amounts specified in Table No. 80.310-A shall comply with Item 10.

**TABLE NO. 80.310-A
WATER-REACTIVES EXEMPT AMOUNTS¹**

CONDITION	Class 1	Class 2	Class 3	Class 4 ²
Unprotected by sprinklers or cabinet	125	50	5	—
Within cabinet in unsprinklered building	250	100	10	—
In sprinklered building, not in cabinet	NL	100	10	—
In sprinklered building, within cabinet	NL	200	20	—

NL—Not Limited.

¹For water-reactive materials, a conversion of 10 pounds per gallon shall be used.

²The U.F.C. Standard No. 79-3 classification system does not currently provide for Class 4 water-reactive materials.

3 **Type of construction.** In addition to the provisions of the Building Code, buildings or rooms used for the storage of water-reactive materials shall be of noncombustible construction.

4 **Detached storage.** Detached storage shall be provided when the amount stored exceeds 2,000 pounds of Class 3 or 50,000 pounds of Class 2 material. Detached storage buildings shall be single-story buildings without basement or crawl space.

5 **Liquid-tight floor.** In addition to the provisions of Section 80.301 (z), floors of storage areas shall be of liquid-tight construction.

6 **Waterproof room.** Rooms or areas used for the storage of water-reactive materials shall be constructed so as to resist the penetration of water through the

use of waterproof materials. Piping carrying water for other than approved automatic fire-sprinkler systems shall not be within such rooms or areas.

7. **Smoke and heat venting.** Storage areas shall be provided with a means to vent smoke and heat in a fire or other emergency in accordance with the provisions of the Building Code.

8. **Fire-extinguishing systems.** When Class 3 materials are stored in areas protected by an automatic fire-sprinkler system, the materials shall be stored in closed watertight containers.

9. **Containment.** Secondary containment shall be provided in accordance with the provisions of Section 80.301 (1) 4.

10. **Storage conditions.** Water-reactive materials stored in quantities greater than 500 cubic feet shall be separated into piles each not larger than 500 cubic feet. Aisle widths between piles shall be equal to not less than the height of the pile or 4 feet, whichever is greater.

EXCEPTION: Water-reactive materials stored in tanks.

Class 2 water-reactive materials shall not be stored in basements of buildings unless such materials are stored in closed watertight containers or tanks.

Class 3 water-reactive materials shall not be stored in basements.

(b) **Exterior Storage.** 1. **General.** Exterior storage of water-reactive materials shall be within tanks or closed watertight containers and shall be in accordance with the provisions of Section 80.310 (b) and the general provisions specified in Section 80.301.

2. **Distance from storage to exposures.** Exterior storage of water-reactive materials shall not be permitted within 20 feet of any building, property line, street, alley, public way or exit to a public way. An unpierced two-hour fire-resistive wall extending not less than 30 inches above and to the sides of the storage area may be provided in lieu of such distance.

EXCEPTION: Class 3 water-reactive materials shall not be permitted within 75 feet of any building, property line, street, alley, public way or exit to a public way.

3. **Containment.** Secondary containment shall be provided in accordance with the provisions of Section 80.301 (1) 4.

4. **Storage conditions.** Class 3 water-reactive materials shall be limited to piles not greater than 100 cubic feet.

Class 1 or 2 water-reactive materials shall be limited to piles not greater than 1,000 cubic feet.

Aisles widths between piles shall be not less than one-half the height of the pile or 10 feet, whichever is greater.

Cryogenic Fluids

Sec. 80.311. (a) **General.** Storage of cryogenic fluids shall be in accordance with the provisions of Article 75.

(b) **Indoor Storage.** Cryogenic fluids in individual cylinders, containers or tanks which exceed a water capacity of 1,000 pounds shall not be stored inside of buildings.

Highly Toxic Solids and Liquids

Sec. 80.312. (a) **Indoor Storage.** 1. **General.** Indoor storage of highly toxic solids and liquids shall be in accordance with the provisions specified in Subsections 80.312 (a) and (c) and Section 80.301.

2. **Exempt amounts.** When the amount of highly toxic solids or liquids stored in one control area exceeds that specified in Table No. 80.312-A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 7 Occupancy.

TABLE NO. 80.312-A
HIGHLY TOXIC SOLIDS AND LIQUIDS EXEMPT AMOUNTS¹

CONDITION	EXEMPT AMOUNT (Pounds)
Unprotected by sprinklers or cabinet	1
Within cabinet in unsprinklered building	2
In sprinklered building, not in cabinet	2
In sprinklered building, within cabinet	4

¹For highly toxic liquids, a conversion of 10 pounds per gallon shall be used.

3. **Type of construction.** In addition to the provisions of the Building Code, storage of highly toxic solids and liquids shall be in buildings or rooms of noncombustible construction or stored in hazardous material storage cabinets.

4. **Liquid-tight floors.** In addition to the provisions of Section 80.301 (2), floors of storage rooms shall be of liquid-tight construction.

5. **Explosion venting or suppression.** Explosion venting or suppression shall not be required for the indoor storage of highly toxic solids or liquids.

6. **Containment.** Secondary containment shall be provided in accordance with the provisions of Section 80.301 (1) 4.

7. **Exhaust scrubber.** Exhaust scrubbers or other systems for the processing of highly toxic liquid vapors shall be provided for storage areas where a spill or other accidental release of such liquids can be expected to release highly toxic vapors. Exhaust scrubbers and other processing systems shall be installed in accordance with the Mechanical Code. Emission control shall conform to the requirements of the local air quality authority.

8. **Separation.** In addition to the provisions of Section 80.301 (n), storage of highly toxic liquids and solids shall be isolated from other hazardous materials by one-hour fire-resistive construction or stored in approved hazardous material storage cabinets.

(b) **Exterior Storage.** 1. **General.** Exterior storage of highly toxic solids and liquids shall be in accordance with the provisions of Section 80.312 (b) and (c) and the general provisions specified in Section 80.301.

2. **Distance from storage to exposures.** Exterior storage of highly toxic solids and liquids shall not be permitted within 20 feet of any building, property line, street, alley, public way or exit to a public way. An unpierced two-hour fire-resistive wall extending not less than 30 inches above and to the sides of the storage area may be provided in lieu of such distance.

3. **Fire-extinguishing systems.** Exterior storage of highly toxic solids and liquids shall be in fire-resistive containers or shall comply with one of the following:

A. The storage area shall be protected by an automatic, open head, deluge fire-sprinkler system of the type and density specified in U.B.C. Standard No. 38-1, or

B. Storage shall be located under a canopy of noncombustible construction, with the canopied area protected by an automatic fire-sprinkler system of the type and density specified in U.B.C. Standard No. 38-1. Such storage shall not be considered indoor storage.

4. **Containment.** Secondary containment shall be provided in accordance with the provisions of Section 80.301 (1) 4.

5. **Storage conditions.** Exterior storage piles of highly toxic solids and liquids shall be separated into piles each not larger than 2,500 cubic feet. Aisle widths between piles shall be not less than one-half the height of the pile or 10 feet, whichever is greater.

The storage of highly toxic liquids which liberate highly toxic vapors in the event of a spill or other accidental discharge shall not be permitted outside of a building unless effective collection and treatment systems are provided. The treatment system shall comply with the provisions of the Mechanical Code.

(c) **Breathing Apparatus.** Where highly toxic solids or liquids are stored, a minimum of two self-contained breathing apparatus shall be provided. The breathing apparatus shall be suitable for use with the materials stored and shall be located near the immediate area of storage in a location that provides safety to those expected to don the apparatus. A safe area is one which is not likely to be immediately affected by the release of hazardous vapors in the area of concern.

EXCEPTION: Storage areas or buildings where storage is continually limited to materials which can be demonstrated to present no respiratory dangers.

Radioactive Materials

Sec. 80.313. (a) Indoor Storage. 1. **General.** Indoor storage of radioactive materials shall be in accordance with the provisions of Sections 80.313 (a) and (b) and the general provisions specified in Section 80.301.

2. **Exempt amounts.** When the amount of radioactive material stored in one control area exceeds that specified in Table No. 80.313-A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 7 Occupancy.

**TABLE NO. 80.313-A
RADIOACTIVE MATERIALS—EXEMPT AMOUNTS**

CONDITION	EXEMPT AMOUNT
Any storage condition	1. Less than the permit amount (See Section 4.101, No. 40.) 2. Licensed, sealed sources for instruments, calibration devices and equipment.

3. **Liquid-tight floor.** In addition to the provisions of Section 80.301 (z), floors of storage areas shall be of liquid-tight construction.

4. **Containment.** Secondary containment shall be provided in accordance with the provisions of Section 80.301 (1) 4.

5. **Detection.** Areas used for the storage of radioactive materials shall be provided with detection equipment suitable for determining surface level contamination at levels that would present a short term hazard condition. Such detection equipment shall be permitted to be maintained at a location other than the storage area but shall be on the premises.

6. **Storage conditions.** The maximum quantity and storage arrangement of radioactive materials to be stored in buildings or rooms designed for such purposes shall be in accordance with the requirements of the Nuclear Regulatory Commission and state or local requirements.

Storage of contaminated combustible materials shall be in tightly closed non-combustible containers containing no other waste. Special attention shall be given to prompt disposal of combustible wastes contaminated with oxidizing materials that are subject to spontaneous heating.

(b) **Exterior Storage.** 1. **General.** Exterior storage of radioactive materials shall be in accordance with the provisions of Sections 80.313 (b) and (c) and the general provisions specified in Section 80.301.

2. **Distance from storage to exposures.** Exterior storage shall not be within 20 feet of any property line, street, alley, public way or exit to a public way. An unpierced two-hour fire-resistive wall extending not less than 30 inches above and to the sides of the storage area may be provided in lieu of such distance.

Exterior storage shall not be within 20 feet of any building unless the building exterior walls are not less than one-hour fire-resistive construction. Storage is not permitted less than 10 feet from any building opening. Building openings less than 20 feet from exterior storage shall be protected by a fire assembly having a three-fourths-hour fire-resistive rating.

3. **Fire-extinguishing systems.** Exterior storage of radioactive materials shall be in fire-resistive containers or shall comply with one of the following:

A. The storage area shall be protected by an automatic, open head, deluge fire-sprinkler system of the type and density specified in U.B.C. Standard No. 38-1, or

B Storage shall be located under a canopy of noncombustible construction, with the canopied area protected by an approved automatic fire-extinguishing system. Such storage shall not be considered to be indoor storage.

4 Containment. Secondary containment shall be provided in accordance with the provisions of Section 80.301 (1) 4.

5 Storage conditions. Storage shall be arranged in accordance with Nuclear Regulatory Commission, state and local requirements.

(c) Breathing Apparatus. Where radioactive materials are stored, a minimum of two self-contained breathing apparatus shall be provided. The breathing apparatus shall be suitable for use with the material stored and shall be located near the immediate area of storage in a location that provides safety to those expected to don the apparatus. A safe area is one which is not likely to be immediately affected by the release of the hazardous material in the area of concern.

Corrosives

Sec. 80.314. (a) Indoor Storage. 1 General. Indoor storage of corrosive materials shall be in accordance with the provisions of Section 80.314 (a) and the general provisions specified in Section 80.301.

2 Exempt amounts. When the amount of corrosive materials stored in one control area exceeds that specified in Table No. 80.314-A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 7 Occupancy.

TABLE NO. 80.314-A
CORROSIVES EXEMPT AMOUNTS

CONDITION	EXEMPT AMOUNT		
	Solids (Pounds)	Liquids (Gallons)	Gases (Cubic Feet)
Unprotected by sprinklers or cabinet	5,000	500	650
Within cabinet in unsprinklered building	10,000	1,000	1,300
In sprinklered building, not in cabinet	10,000	1,000	1,300
In sprinklered building, within cabinet	20,000	2,000	2,600

3 Liquid-tight floor. In addition to the provisions of Section 80.301 (z), floors in storage areas for corrosive liquids shall be of liquid-tight construction.

4 Explosion venting or suppression. Explosion venting or suppression shall not be required for the indoor storage of corrosive materials.

5 Containment. Secondary containment shall be provided for the storage of corrosive liquids in accordance with the requirements of Section 80.301 (1) 4.

(b) Exterior Storage. 1 General. Exterior storage of corrosive materials shall be in accordance with the provisions of Section 80.314 (b) and the general provisions specified in Section 80.301.

2 Distance from storage to exposures. Exterior storage of corrosive liquids shall not be permitted within 20 feet of any building, property line, street, alley, public way or exit to a public way. An unpierced two-hour fire-resistive wall extending not less than 30 inches above and to the side of the storage area may be provided in lieu of such distance.

3 Containment. Secondary containment shall be provided for the storage of corrosive liquids in accordance with the requirements of Section 80.301 (1) 4.

Other Health Hazard Solids, Liquids and Gases

Sec. 80.315. (a) Indoor Storage. 1 General. Indoor storage of other health hazard solids, liquids and gases shall be in accordance with the provisions of Sections 80.315 (a) and (c) and the general provisions specified in Section 80.301.

2 Exempt amounts. When the amount of other health hazard solids, liquids and gases exceeds that specified in Table No. 80.315-A, such storage shall be within a room or building conforming to the Building Code requirements for a Group H, Division 7 Occupancy.

TABLE NO. 80.315-A
HEALTH HAZARD SOLIDS, LIQUIDS AND GASES
EXEMPT AMOUNTS

CONDITION	EXEMPT AMOUNT		
	Solids (Pounds)	Liquids (Gallons)	Gases (Cubic Feet)
Unprotected by sprinklers or cabinet	5,000	500	650
Within cabinet in unsprinklered building	10,000	1,000	1,300
In sprinklered building, not in cabinet	10,000	1,000	1,300
In sprinklered building, within cabinet	20,000	2,000	2,600

3 Liquid-tight floor. In addition to the provisions of Section 80.301 (z), floors in storage areas for other health hazard liquids shall be of liquid-tight construction.

4 Explosion venting or suppression. Explosion venting or suppression systems shall not be required for the inside storage of other health hazard solids, liquids and gases.

5 Containment. Secondary containment shall be provided for liquids in accordance with the provisions of Section 80.301 (1) 4.

(b) Exterior Storage. 1 General. Exterior storage of other health hazard solids, liquids and gases shall be in accordance with the provisions of Sections 80.315 (b) and (c) and the general provisions specified in Section 80.301.

2 Distance from storage to exposures. Exterior storage of other health hazard solids, liquids and gases shall not be permitted within 20 feet of any building.

property line, street, alley, public way or exit to a public way. An unpierced two-hour fire-resistive wall extending not less than 30 inches above and to the sides of the storage area may be provided in lieu of such distance.

3 **Containment.** Secondary containment for liquids shall be provided in accordance with the provisions of Section 80.301 (1) 4.

4 **Storage conditions.** Exterior storage of other health hazard solids and liquids shall be separated into piles not larger than 2,500 cubic feet. Aisle widths between piles shall be not less than one half the height of the piles or 10 feet, whichever is greater.

(c) **Breathing Apparatus.** Where other health hazard solids, liquids and gases are stored, a minimum of two self-contained breathing apparatus shall be provided. The breathing apparatus shall be suitable for use with the material stored and shall be located near the immediate area of storage in a location that provides safety to those expected to don the apparatus. A safe area is one which is not likely to be immediately affected by the release of hazardous material in the area of concern.

EXCEPTION: Storage areas or buildings where storage is continually limited to materials which can be demonstrated to present no respiratory dangers.

Division IV

DISPENSING, USE AND HANDLING

General

Sec. 80.401. (a) **Scope.** This division applies to the dispensing, use and handling of hazardous materials in excess of the exempt amounts specified in Tables Nos. 80.402-A and 80.402-B.

EXCEPTION: Hazardous materials regulated by other articles in this code.

(b) **Containers, Cylinders and Tanks.** 1 **General.** Containers, cylinders and tanks utilized for the dispensing, handling or use of hazardous materials shall comply with the provisions of Section 80.401 (b).

2 **Design and construction.** Containers, cylinders and tanks shall be designed and constructed in accordance with nationally recognized standards. See Section 2.303 (b).

3 **Tanks out of service 90 days.** Any stationary tank not used for a period of 90 days shall be properly safeguarded or removed in manner approved by the chief. Such tanks shall have the fill line, gage opening and gump connection secured against tampering. Vent lines shall be properly maintained.

4 **Defective containers, cylinders and tanks.** Defective containers, cylinders and tanks shall be removed from service, repaired or disposed of in an approved manner.

5 **Empty containers, cylinders and tanks.** Empty containers, cylinders and tanks previously containing hazardous materials shall be free from residual

material and vapor or stored as specified for the storage of the hazardous material in Division III.

6 **Underground tanks.** Underground tanks containing hazardous materials shall be located and protected in accordance with Sections 79.601 and 79.603 of this code. Secondary containment shall be provided for all new underground tanks.

7 **Aboveground tanks.** Aboveground tanks containing hazardous materials shall be located and protected in accordance with the provisions for exterior storage of the particular materials as specified in Division III. Such tanks shall be marked as required by Section 80.401 (n).

(c) **Piping, Valves and Fittings.** 1 **General.** Piping (including tubing), valves and fittings conveying hazardous materials shall be installed in accordance with approved standards and shall comply with the provisions of Section 80.401 (c).

2 **Design and Construction.** Piping, valves, fittings and related components used for hazardous materials shall comply with the following:

- A Piping, valves, fittings and related components shall be designed and fabricated from materials compatible with the material to be contained and shall be of adequate strength and durability to withstand the pressure, structural and seismic stress and exposure to which they may be subjected.
- B Piping and tubing shall be identified in accordance with nationally recognized standards to indicate the material conveyed.
- C Emergency shutoff valves shall be identified and the location shall be clearly visible and indicated by means of a sign.
- D Backflow-prevention or check valves shall be provided when the backflow of hazardous materials may create a hazardous condition or cause the unauthorized discharge of hazardous materials.

3 **Supply piping.** Supply piping and tubing for gases and liquids having a health hazard ranking of 3 or 4 in accordance with U.F.C. Standard No. 79-3 shall also comply with the following:

- A Piping and tubing utilized for the transmission of highly toxic or toxic material shall have welded or brazed connections throughout unless an exhausted enclosure is provided if the material is a gas, or the piping is provided with a receptor for containment if the material is a liquid.

EXCEPTION: Nonmetallic piping with approved connections.

- B Piping and tubing shall not be located within exit corridors, within any portion of an exit required to be enclosed in fire resistive construction or above areas not classified as Group H Occupancies.

EXCEPTION: Such piping and tubing may be installed within the space defined by the walls of exit corridors and floor or roof above or in concealed space above other occupancies when installed in accordance with the provisions of Building Code Section 911 (f) 2.

- C Where gases or liquids are carried in pressurized piping above 15 psig, excess flow control shall be provided. Where the piping originates from within a hazardous material storage room or area, the excess flow control

shall be located within the storage room or area. Where the piping originates from a bulk source, the excess flow control shall be located as close to the bulk source as practical.

D. Readily accessible manual or automatic remotely activated fail-safe emergency shutoff valves shall be installed on supply piping and tubing at the following locations:

- (i) At the point of use.
- (ii) At the tank, cylinder or bulk source.

(d) **Equipment.** Equipment, machinery and processes utilized for dispensing, use or handling of hazardous materials shall be suitable for the intended use. Such equipment, machinery and processes shall be maintained in an operable condition and shall be replaced, repaired or removed from service when found to be defective.

(e) **Separation from Storage of Hazardous Materials.** Dispensing, use and handling of hazardous materials having a reactivity hazard ranking of 3 or 4 in accordance with U.F.C. Standard No. 79-3 shall be separated from the storage of incompatible materials when the quantity in storage exceeds the exempt amounts specified in Sections 80.302 through 80.315. The separation shall be provided by one of the following:

1. Segregated from incompatible hazardous materials storage by a distance of not less than 20 feet, or
2. Isolated from incompatible hazardous materials storage by a noncombustible partition extending not less than 18 inches above and to the front and sides of the stored material, or
3. Storage of hazardous materials in hazardous materials storage cabinets in accordance with the provisions of Section 80.301 (c), or
4. Storage of compressed gases in gas cabinets or exhausted enclosures in accordance with the provisions of Section 80.303 (a) 6 B.

(f) **Noncombustible Floor.** Except for surfacing, floors of areas where liquid or solid hazardous materials are dispensed or used in open systems shall be of noncombustible, liquid-tight construction.

(g) **Spill Control, Drainage and Containment.** When required by other provisions of this division, spill control, drainage and containment shall be provided in accordance with the provisions of Section 80.301 (l).

(h) **Ignition Source Control.** Smoking shall not be permitted in any room or area where hazardous materials are dispensed or used in open systems or within 25 feet of outdoor dispensing areas.

Open-flame and other heat-producing equipment shall be located a safe distance from areas where temperature-sensitive materials, flammable materials and compressed gases are dispensed, used or handled.

(i) **Static Accumulation.** When processes or conditions exist where a flammable mixture may be ignited by static electricity, means shall be provided to prevent the accumulation of a static charge.

(j) **Electrical Equipment and Wiring.** Electrical equipment and wiring in dispensing and use areas shall be installed in accordance with the provisions of the Electrical Code.

(k) **Limit Controls.** Limit controls shall be provided in accordance with the following:

1. **Liquid level.** Open tanks in which hazardous materials are used shall be equipped with a liquid level limit control or other means to prevent overfilling of the tank.

2. **Temperature.** Process tanks and equipment which involve temperature control of the material shall be provided with limit controls to maintain the temperature within a safe range.

3. **Pressure.** Stationary tanks or equipment containing materials which may generate pressures exceeding the tank or equipment design limits due to exposure fires or internal reaction shall be equipped with pressure-limiting or relief devices. Relief devices for stationary tanks or equipment for highly toxic or corrosive materials shall vent to an exhaust scrubber or treatment system for processing of vapors or gases. Relief devices for flammable or explosive vapors or gases shall vent to an approved location.

(l) **Standby power.** When mechanical ventilation, treatment systems, temperature control, manual alarm, detection or other electrically operated systems are required by other provisions of this division, such systems shall be connected to a standby source of power to automatically supply electrical power in the event of loss of power from the primary source. (See the Electrical Code.)

EXCEPTION: When highly toxic compressed gases or highly toxic, highly volatile liquids are used or dispensed, emergency power shall be provided in lieu of standby power on all required systems. (See the Electrical Code.)

(m) **Supervision.** Manual alarm, detection, and automatic fire-extinguishing systems required by other provisions of this division shall be supervised by an approved central, proprietary or remote station service or shall initiate an audible and visual signal at a constantly attended on-site location.

(n) **Signage.** In addition to the hazard identification signs required by Section 80.104 (e), additional hazard identification and warning signs shall be provided as follows:

1. Signs prohibiting smoking shall be provided in dispensing and open-use areas and within 25 feet of outdoor dispensing or open-use areas.

2. Stationary containers and tanks shall be placarded with hazard identification signs as specified in U.F.C. Standard No. 79-3 for the specific material contained.

(o) **Security.** Dispensing, use and handling areas shall be secured against unauthorized entry.

(p) **Seismic Protection.** Machinery and equipment utilizing hazardous materials shall be seismically anchored in accordance with the provisions of the Building Code.

(q) **Lighting.** Adequate lighting by natural or artificial means shall be provided. Artificial lighting shall be in accordance with the recommendations of the

Illuminating Engineering Society Handbook or other nationally recognized standards.

(r) **Fire-extinguishing Systems.** Indoor rooms or areas in which hazardous materials are dispensed or used shall be protected by an automatic fire-extinguishing system. Sprinkler system design shall be not less than that required under U.B.C. Standard No. 38-1 for Ordinary Hazard, Group 3, with a minimum design area of 3,000 square feet. Where the materials or storage arrangement require a higher level of sprinkler system protection in accordance with nationally recognized standards, the higher level of sprinkler system protection shall be provided.

EXCEPTION: Approved alternate automatic fire-extinguishing systems may be used.

Dispensing and Use

Sec. 80.402. (a) Exempt Amounts. When the amount of hazardous materials dispensed or used in one control area exceeds that specified in Tables Nos. 80.402-A or 80.402-B, such dispensing or use shall either be located in a room or area constructed in accordance with the provisions of the Building Code or located in an exterior dispensing, use or handling area located in accordance with the provisions of Sections 80.301 through 80.315.

(b) **Indoor Dispensing and Use.** 1. **General.** Indoor dispensing and use of hazardous materials shall be in accordance with the provisions of this subsection and the general provisions specified in Section 80.401.

2. **Open systems.** Dispensing and use of hazardous materials in open containers or systems shall comply with the following:

- A. **Dispensing.** When liquids having a hazard ranking of 3 or 4 in accordance with U.F.C. Standard No. 79-3 are dispensed from tanks or drums, dispensing shall be only by approved pumps taking suction from the top.
- B. **Ventilation.** When gases, liquids or solids having a hazard ranking of 3 or 4 in accordance with U.F.C. Standard No. 79-3 are dispensed or used, mechanical exhaust ventilation shall be provided to capture fumes, mists or vapors at the point of generation.

EXCEPTION: Gases, liquids or solids which can be demonstrated not to create harmful fumes, mists or vapors.

- C. **Fire-extinguishing system.** In addition to the provisions of Section 80.401 (r), laboratory fume hoods and spray booths where flammable materials are dispensed or used shall be protected by an automatic fire-extinguishing system.
- D. **Explosion venting or suppression.** Explosion venting or suppression shall be provided in accordance with the provisions of Section 80.301 (q) when an explosive environment can occur because of the characteristics or nature of the hazardous materials dispensed or used, or as a result of the dispensing or use process.

E. **Spill control, drainage and containment.** Rooms or areas where hazardous material liquids are dispensed into containers exceeding 1-gallon capacity or used in open containers or systems exceeding 5-gallon capacity shall be provided with a means to control spills. Secondary containment shall be provided in accordance with the provisions of Section 80.301 (1) when the capacity of an individual container exceeds 55 gallons or the aggregate of multiple containers exceeds 100 gallons.

3. **Closed systems.** Use of hazardous materials in closed containers or systems shall comply with the following:

- A. **Use.** Systems shall be suitable for the use intended and shall be designed by persons competent in such design. Where nationally recognized good practices or standards have been established for the processes employed, they shall be followed in the design. Controls shall be designed to prevent materials from entering or leaving process or reaction systems at other than the intended time, rate or path. Whenever automatic controls are provided, they shall be designed to be fail safe.
- B. **Ventilation.** If closed systems are designed to be opened as part of normal operations, ventilation shall be provided in accordance with the provisions of Section 80.402 (b) 2 B.
- C. **Fire-extinguishing system.** In addition to the provisions of Section 80.401 (r), laboratory fume hoods and spray booths where flammable materials are used shall be protected by an automatic fire-extinguishing system.
- D. **Explosion venting or suppression.** Explosion venting or suppression shall be provided in accordance with the provisions of Section 80.301 (q) when an explosive environment can occur because of the hazardous materials dispensed or used, or as a result of the dispensing or use process.

EXCEPTION: When process vessels are designed to fully contain the worst case explosion anticipated within the vessel under process conditions considering the most likely failure.

- E. **Spill control, drainage and containment.** Rooms or areas where hazardous material liquids are used in individual tanks or containers exceeding 55 gallons shall be provided with a means to control spills. Secondary containment shall be provided in accordance with the provisions of Section 80.301 (1) if the aggregate of multiple tanks or containers exceeds 1,000 gallons.
- F. **Special requirements for highly toxic and toxic compressed gases.**

- (i) **Ventilated area.** Compressed gas cylinders in use shall be within ventilated gas cabinets, laboratory fume hoods, exhausted enclosures or separate gas storage rooms. When portable or stationary tanks are employed in use or dispensing, they shall be within a ventilated separate gas storage room or placed within an exhausted enclosure.

Exhaust systems for gas cabinets, fume hoods, exhausted enclosures or separate gas storage rooms shall be designed to handle the accidental release of gas. Such exhaust systems shall be capable of diluting, adsorbing, absorbing, neutralizing, burning or otherwise processing the entire

contents of the largest single tank or cylinder of gas in use. Systems for such processing shall be designed as a treatment system.

- (ii) **Gas cabinets or exhausted enclosures.** When gas cabinets or exhausted enclosures are provided, they shall be in accordance with the provisions of Section 80 303 (a) 6 B. Gas cabinets and exhausted enclosures shall be internally sprinklered.
- (iii) **Separate gas storage rooms.** When separate gas storage rooms are provided, they shall be in accordance with the provisions of Section 80 303 (a) 6 C.
- (iv) **Treatment systems.** When treatment systems are provided, they shall be in accordance with the provisions of Section 80 303 (a) 6 D.
- (v) **Gas detection.** Gas detection shall be provided in accordance with the provisions of Section 80 303 (a) 9. Activation of the monitoring system shall automatically close the shutoff valve on highly toxic or toxic gas supply lines related to the system being monitored.
- (vi) **Smoke detection.** Smoke detection shall be provided in accordance with the provisions of Section 80 303 (a) 10.
- (vii) **Storage conditions.** The number of cylinders contained in a single gas cabinet shall not exceed three.
- (viii) **Process equipment.** Effluent from process equipment containing highly toxic or toxic gases which may be discharged to the atmosphere shall be processed through an exhaust scrubber or other processing system. Such systems shall comply with the provisions of the Mechanical Code for product-conveying ventilation systems.

(c) **Exterior Dispensing and Use.** 1 **General.** Exterior dispensing or use of hazardous materials in either closed or open containers or systems shall be in accordance with the provisions of this subsection and the general provisions specified in Section 80 401.

2 **Dispensing.** When liquids having a hazard ranking of 3 or 4 in accordance with U.F.C. Standard No. 79 3 are dispensed from tanks or drums, dispensing shall be only by approved pumps taking suction from the top.

3 **Fire-extinguishing system.** Flammable hazardous materials dispensing or use areas located within 50 feet of either a storage area or building, and vehicle loading racks where flammable hazardous materials are dispensed shall be protected by an approved fire-extinguishing system.

4 **Spill control, drainage and containment.** A **Open systems.** Exterior areas where hazardous materials liquids are dispensed into containers exceeding 1 gallon capacity or used in open containers or systems exceeding 5 gallon capacity shall be provided a means to control spills. Secondary containment shall be provided when the capacity of an individual container exceeds 55 gallons or the aggregate capacity of multiple containers exceeds 100 gallons.

B **Closed systems.** Exterior areas where hazardous materials liquids are used in individual tanks or containers exceeding 55 gallons shall be provided with a means to control spills. Secondary containment shall be provided if the aggregate of multiple tanks or containers exceeds 1,000 gallons.

5 **Clearance from combustibles.** The area surrounding an exterior dispensing or use area shall be kept clear of combustible materials and vegetation for a minimum distance of 30 feet.

6 **Fire access roadways and water supply.** Fire access roadways and approved water supplies shall be provided for exterior dispensing or use areas in accordance with the following:

A **Fire access roadways.** Fire apparatus access roadways shall be provided to within 150 feet of all portions of an exterior dispensing or use area. Such access roadways shall comply with the provisions of Section 10 107.

B **Water supply.** An approved water supply shall be provided. Fire hydrants or other approved means capable of supplying the required fire flow shall be provided to within 150 feet of all portions of an exterior dispensing or use area. The water supply and fire hydrants shall comply with the provisions of Section 10 301.

7 **Protection from vehicles.** Guard posts or other means shall be provided to protect exterior dispensing or use areas from vehicular damage. When guard posts are installed, the posts shall be in accordance with the provisions of Section 80 301 (w).

8 **Special requirements for highly toxic or toxic compressed gases.** A **Gas cabinets or local exhaust.** When cylinders or portable containers are used out-of-doors, gas cabinets or a locally exhausted enclosure shall be provided. When gas cabinets are provided, the installation shall be in accordance with the provisions of Section 80 303 (a) 6 B. The required treatment system shall be designed in accordance with the provisions of Section 80 303 (a) 6 D.

B **Exhaust systems.** Exhaust systems for gas cabinets or locally exhausted enclosures shall be designed to handle the accidental release of gas. Such exhaust systems shall be capable of diluting, adsorbing, absorbing, neutralizing, burning or otherwise processing the entire contents of the largest single tank or cylinder of gas in use. Systems for such processing shall be designed as treatment systems in accordance with the provisions of Section 80 303 (a) 6 D.

C **Gas detection.** Gas detection shall be provided in gas cabinets and exhausted enclosures in accordance with the provisions of Section 80 303 (a) 9. Activation of the monitoring system shall automatically close the shutoff valve on highly toxic or toxic gas supply lines related to the system being monitored.

D **Fire-extinguishing system.** Gas cabinets and exhausted enclosures shall be internally sprinklered.

Handling

Sec. 80.403. (a) Scope. The handling of hazardous materials shall comply with the provisions of Section 80.403 and the general provisions specified in Section 80.401.

(b) Containers, Cylinders, Tanks and Drums. All containers, cylinders, tanks, drums or other means for the transport of hazardous materials shall be of an approved type.

Liquids in containers exceeding 5 gallons shall be transported on a cart.

When more than two containers of hazardous materials having a hazard ranking of 3 or 4 in accordance with U.F.C. Standard No. 79-3 are transported within an exit corridor or exit enclosure, they shall be on an approved cart in conformance with the provisions of Section 80.403 (c).

Hazardous materials gas cylinders in transit shall have their protective cylinder caps in place. Cylinders of highly toxic or toxic compressed gases shall have their valves capped or plugged with an approved closure device.

(c) Carts and Trucks. Carts and trucks used to transport hazardous materials rated 3 or 4 in accordance with U.F.C. Standard No. 79-3 inside buildings within any part of an exit corridor or exit enclosure shall comply with the following:

EXCEPTIONS: 1. Two hazardous materials liquid containers may be hand carried in acceptable safety carriers.

2. Single drums not exceeding 55 gallons may be transported by suitable drum trucks.

3. Cylinders of compressed gases may be transported by acceptable gas cylinder hand trucks. Cylinders not exceeding 25 pounds may be hand carried.

4. Solid hazardous materials not exceeding 100 pounds may be transported by acceptable hand trucks. A single container not exceeding 50 pounds may be hand carried.

1. Carts and trucks used to transport hazardous materials shall be designed to provide a stable base for the commodities to be transported and shall have a means of restraining containers against accidental dislodgement. Compressed gas cylinders placed on carts and trucks shall be individually restrained.

2. Carts and trucks shall be provided with a device which will enable the operator to safely control movement by providing stops or speed-reduction devices.

3. Construction materials for hazardous materials carts or trucks shall be compatible with the material transported. The cart or truck shall be of substantial construction.

4. Carts and trucks transporting liquids shall be capable of containing a spill from the largest single container transported.

5. Carts and trucks used to transport materials shall not obstruct or be left unattended within any part of an exit.

6. Incompatible materials shall not be transported on the same cart or truck.

(d) Emergency Alarm. When hazardous materials rated 3 or 4 in accordance with U.F.C. Standard No. 79-3 are transported through exit corridors or exit enclosures, there shall be an emergency telephone system, a local manual alarm station or an approved signaling device at not more than 150-foot intervals and at each exit doorway throughout the transport route. The signal shall be relayed to an approved central, proprietary or remote station service or constantly attended on-site location and shall also initiate a local audible alarm.

(Tables on following pages.)

TABLE NO. 80.402-A—EXEMPT AMOUNTS OF HAZARDOUS MATERIALS PRESENTING A PHYSICAL HAZARD
MAXIMUM QUANTITIES PER CONTROL AREA

Values within parentheses are in cubic feet (Cu. Ft.) or pounds (Lbs.)

MATERIAL	CLASS	CLOSED SYSTEMS			OPEN SYSTEMS		
		Solid Lbs. (Cu. Ft.)	Liquid Gallons (Lbs.)	Gas Cubic Feet	Solid Lbs. (Cu. Ft.)	Liquid Gallons (Lbs.)	Gas Cubic Feet
1.1 Combustible liquid ¹	II	N.A.	120 ¹	N.A.	N.A.	30 ¹	N.A.
	III-A	N.A.	330 ¹	N.A.	N.A.	80 ¹	N.A.
	III-B	N.A.	13,200 ¹	N.A.	N.A.	3,300 ¹	N.A.
1.2 Combustible dust lbs./1000 cu. ft.		1 ¹	N.A.	N.A.	1 ¹	N.A.	N.A.
1.3 Cryogenic, flammable or oxidizing		N.A.	45 ¹	N.A.	N.A.	10 ¹	N.A.
2.1 Explosives		1/4 ¹	(1/4) ¹	N.A.	1/4 ¹	(1/4) ¹	N.A.
3.1 Flammable solid		25 ¹	N.A.	N.A.	25 ¹	N.A.	N.A.
3.2 Flammable gas (gaseous)		N.A.	N.A.	750 ¹	N.A.	N.A.	N.A.
(liquefied)		N.A.	15 ¹	N.A.	N.A.	N.A.	N.A.
3.3 Flammable liquid ¹	I-A	N.A.	30 ¹	N.A.	N.A.	10 ¹	N.A.
	I-B	N.A.	60 ¹	N.A.	N.A.	15 ¹	N.A.
	I-C	N.A.	90 ¹	N.A.	N.A.	20 ¹	N.A.
Combination I-A, I-B, I-C		N.A.	120 ¹	N.A.	N.A.	30 ¹	N.A.
4.1 Organic peroxide	U.D.	1/4 ¹	(1/4) ¹	N.A.	1/4 ¹	(1/4) ¹	N.A.
	I	1 ¹	(1) ¹	N.A.	1 ¹	(1) ¹	N.A.
	II	50 ¹	(50) ¹	N.A.	10 ¹	(10) ¹	N.A.
	III	125 ¹	(125) ¹	N.A.	25 ¹	(25) ¹	N.A.
	IV	500 ¹	(500) ¹	N.A.	100 ¹	(100) ¹	N.A.
	V	N.L.	N.L.	N.A.	N.L.	N.L.	N.A.

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4.2 Oxidizer	4	1/4 ¹	(1/4) ¹	N.A.	1/4 ¹	(1/4) ¹	N.A.
	3	2 ¹	(2) ¹	N.A.	2 ¹	(2) ¹	N.A.
	2	250 ¹	(250) ¹	N.A.	50 ¹	(50) ¹	N.A.
	1	1,000 ¹	(1,000) ¹	N.A.	200 ¹	(200) ¹	N.A.
4.3 Oxidizer—Gas (gaseous)		N.A.	N.A.	1,500 ¹	N.A.	N.A.	N.A.
(liquefied)		N.A.	15 ¹	N.A.	N.A.	N.A.	N.A.
5.1 Pyrophoric		1 ¹	(1) ¹	10 ¹	N.A.	N.A.	N.A.
6.1 Unstable (reactive)	4	1/4 ¹	(1/4) ¹	2 ¹	1/4 ¹	(1/4) ¹	N.A.
	3	1 ¹	(1) ¹	10 ¹	1 ¹	(1) ¹	N.A.
	2	50 ¹	(50) ¹	250 ¹	10 ¹	(10) ¹	N.A.
	1	125 ¹	(125) ¹	750 ¹	25 ¹	(25) ¹	N.A.
7.1 Water (reactive)	3	5 ¹	(5) ¹	N.A.	1 ¹	(1) ¹	N.A.
	2	50 ¹	(50) ¹	N.A.	10 ¹	(10) ¹	N.A.
	1	125 ¹	(125) ¹	N.A.	25 ¹	(25) ¹	N.A.

N.A. = Not applicable

N.L. = Not limited

U.D. = Unclassified detonatable

¹The amount may be doubled in sprinklered buildings. When Footnote 2 also applies, the increase for both footnotes may be applied.

²The quantities permitted in a sprinklered building are not limited.

³A dust-explosion potential is considered to exist if one pound or more of combustible dust per 1,000 cubic feet of volume is normally in suspension or could be put into suspension in all or a portion of an enclosure, including dust inside pieces of equipment. This also includes combustible dust which accumulates on horizontal surfaces inside buildings or equipment and which could be put into suspension by an accident, sudden force or small explosion.

⁴Permitted in sprinklered buildings only. No amount is allowed in unsprinklered buildings.

⁵The amount may be doubled when dispensed or used in closed containers or systems. When Footnote 1 also applies, the increase for both footnotes may be applied.

⁶Containing not more than the exempt amounts of Class I-A, I-B or I-C flammable liquids.

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**TABLE NO. 80.402-B—EXEMPT AMOUNTS OF HAZARDOUS MATERIALS PRESENTING A HEALTH HAZARD
MAXIMUM QUANTITIES PER CONTROL AREA**

MATERIAL	MAXIMUM QUANTITIES PER CONTROL AREA					
	Closed Systems			Open Systems		
	Solid Lbs. ¹	Liquid Gal (Lbs.) ¹	Gas Cu. Ft. ¹	Solid Lbs. ¹	Liquid Gal (Lbs.) ¹	Gas Cu. Ft.
Carcinogen	As regulated by federal or state OSHA guidelines					
Corrosive	5000	500 ²	650 ²	1000	100 ²	0
Highly Toxic	1	(1)	20 ⁴	1/4	(1/4)	0
Irritant	5000	500	650 ²	1000	100	0
Radioactive ³	Amounts Requiring a Permit—See Sec. 4.101					
Sensitizer	5000	500	650 ²	1000	100	0
Other Health Hazards	5000	500	650 ²	1000	100	0

¹The amount may be doubled in sprinklered buildings. When Footnote 2 also applies, the increase for both footnotes may be applied.

²The amount may be doubled when dispersed or used in closed containers or systems. When Footnote 1 also applies, the increase for both footnotes may be applied.

³Containers shall be provided and shall be arranged so that spillage discharge cannot overflow and mix materials which are not compatible.

⁴Permitted only when stored in approved exhausted gas cabinets or exhausted enclosures. See Section 80.303 (a) 6 B.

⁵Licensed, sealed sources in instruments, calibration devices and equipment.

ARTICLE 81 HIGH-PILED COMBUSTIBLE STORAGE

Scope

Sec. 81.101. This article shall apply to the storage of high-piled combustible material and high-rack storage systems. Factors such as method and height of stock piling, combustibility of materials, fuel load and rate of heat release, areas and size of piles, aisles, automatic fire-extinguishing systems, smoke-removal systems, fire protection and fire separations are considered in setting forth the provisions of this article. In the absence of specific provisions in the article, U.F.C. Standard No. 81-1 or No. 81-2 shall apply.

Definitions

Sec. 81.102. For definitions of COMMODITY, DESIGNATED HIGH-PILED COMBUSTIBLE STORAGE AREA, HIGH-PILED COMBUSTIBLE STORAGE AND HIGH-RACK STORAGE SYSTEMS, see Article 9.

Permits

Sec. 81.103. For permits to use buildings for high-piled combustible storage, see Section 4.108.

Classification of Contents

Sec. 81.104. Commodity classifications shall be as defined and in accordance with the following:

Class 1 commodity is a commodity which is essentially noncombustible products on wooden or nonexpanded polyethylene solid deck pallets, in ordinary corrugated cartons with or without single-thickness dividers, or in ordinary paper wrappings with or without pallets. Examples of Class 1 commodities include, but are not limited to, the following:

- Appliances, electrical
- Beer or wine up to 20 percent alcohol
- Cement in bags
- Ceramics
- Dairy products in nonwax-coated containers
- Dry insecticides
- Foods in noncombustible containers
- Frozen foods
- Fresh fruits and vegetables in nonplastic trays or containers
- Glass
- Glycol in metal cans
- Gypsum board
- Inert materials, bagged
- Insulation, noncombustible
- Metal products

Protection Against Static Electricity and Lightning

Sec. 50.112. (a) All equipment such as tanks, machinery and piping, where an ignitable mixture may be present, shall be bonded and connected to a ground. The bond or ground or both shall be physically applied or shall be inherently present by the nature of installation. This electrically conductive path shall have a resistance of not more than one million ohms.

(b) Electrically isolated sections of metallic piping or equipment shall be bonded to the other portions of the system or grounded.

(c) Tank vehicles loaded or unloaded through open connections shall be grounded and bonded to the receiving system.

(d) When a flammable mixture is transferred from one portable container to another, a bond shall be provided between the two containers.

(e) Steel framing of buildings shall be grounded with resistance of not more than five ohms.

Fire Protection

Sec. 50.113. (a) An approved fire alarm system shall be provided.

(b) All plant fire protection facilities shall be adequately maintained, periodically inspected and tested.

Maintenance

Sec. 50.114. (a) The cleaning of tanks or vessels which have contained flammable or combustible liquids shall be done only under the supervision of persons who understand the fire and explosion potential.

(b) When necessary to make repairs involving "hot work," the work shall be authorized by the responsible individual in charge before the work is started.

(c) When necessary to enter a tank, pit, manhole or other confined spaces, such entry shall be authorized by the responsible individual in charge.

(d) Power-operated industrial trucks shall be of a type approved for the location.

(e) Open flames and direct-fired heating devices shall be prohibited in areas where flammable vapor-air mixtures may exist.

(f) Smoking shall be prohibited except in designated areas.

(g) Empty containers previously used for flammable or combustible liquids shall be removed to a well-detached, outside location and, if not cleaned on the premises, removed from the plant as soon as practical.

(h) Storage in containers outside of buildings shall conform to Article 79.

(i) Adequate aisles shall be maintained for the unobstructed movement of personnel and fire-protection equipment.

ARTICLE 51

SEMICONDUCTOR FABRICATION FACILITIES USING HAZARDOUS PRODUCTION MATERIALS

Scope

Sec. 51.101. This article shall apply to buildings in which hazardous production materials are used in excess of quantities shown in Table No. 9-A of the Building Code and which are classified as Group H, Division 6 Occupancies.

The storage, handling and use of hazardous production materials shall comply with the provisions of this article as well as other applicable provisions of this code. All required devices and systems shall be maintained in an operable condition.

Definitions

Sec. 51.102. For the purpose of this article, certain terms are defined as follows:

EMERGENCY ALARM SYSTEM is a system intended to provide the indication and warning of abnormal conditions and summon appropriate aid.

EMERGENCY CONTROL STATION is an approved location on the premises of a Group H, Division 6 Occupancy where signals from emergency equipment are received and which is continually staffed by trained personnel.

FABRICATION AREA (Fab Area) is an area within a Group H, Division 6 Occupancy in which there are processes involving hazardous production materials and may include ancillary rooms or areas such as dressing rooms and offices that are directly related to the fab area processes.

HAZARDOUS PRODUCTION MATERIAL (HPM) is a solid, liquid or gas that has a degree-of-hazard rating in health, flammability or reactivity of Class 3 or 4 as ranked by U.F.C. Standard No. 79-3 and which is used directly in research, laboratory or production processes which have as their end product materials which are not hazardous.

HPM FLAMMABLE LIQUID is an HPM liquid that is defined as being either flammable or combustible under the definitions listed in Article 9.

HPM STORAGE ROOM is a room used for the storage or dispensing of hazardous production material (HPM) and which is classified as a Group H, Division 1, 2, 3 or 7 Occupancy.

INSIDE HPM STORAGE ROOM is a room totally enclosed within a building and having no exterior walls.

SERVICE CORRIDOR is a fully enclosed passage used for transporting hazardous production materials and purposes other than required exiting.

USE (Material) is the placing in action or making available for service by opening or connecting any container utilized for confinement of material whether a solid, liquid or gas.

WORK STATION is a defined space or an independent principal piece of equipment using hazardous production materials within a fabrication area where a specific function, a laboratory procedure or a research activity occurs. Approved cabinets serving the work station shall be defined as a part of the work station. The station may contain ventilation equipment, fire protection devices, sensors for gas and other hazards, electrical devices and other processing and scientific equipment.

Permits

Sec. 51.103. For a permit for the storage, handling and use of hazardous production materials, see Section 4.108.

Sprinkler System Alarm

Sec. 51.104. Sprinkler systems shall be supervised as provided in Chapter 38 of the Building Code with alarm signaling sent to the emergency control station.

Fabrication Area

Sec. 51.105. (a) **General.** Fabrication areas shall comply with the requirements of the Building Code for a Group H Division 6 Occupancy.

(b) **Location.** The occupied levels of fab areas shall not be located below the first story.

(c) **Maximum Quantities of HPM.** The average density of HPM within a single fabrication area shall not exceed the density as specified in Table No 51.105-B. Nothing in this provision shall limit any single fabrication area from having a total quantity of HPM to an amount less than that specified in Table No 51.105-A.

TABLE NO. 51.105-A
PERMITTED QUANTITIES OF HPM IN A SINGLE FABRICATION AREA

MATERIAL	MAXIMUM QUANTITY
Flammable liquids	
Class I-A	90 gal
Class I-B	180 gal
Class I-C	270 gal
Combination flammable liquids	360 gal
Combustible liquids	
Class II	360 gal
Class III-A	750 gal
Flammable gases	9,000 cu ft at one atmosphere of pressure at 70°F
Liquefied flammable gases	180 gal
Flammable solids	1,500 lbs
Corrosive liquids	165 gal
Oxidizing material—gases	18,000 cu ft
Oxidizing material—liquids	150 gal
Oxidizing material—solids	1,500 lbs
Organic peroxides	30 lbs
Highly toxic material and poisonous gas	Included in the aggregate for flammables as noted above

TABLE NO. 51.105-B
PERMITTED QUANTITIES OF HPM IN A SINGLE GROUP H, DIVISION 6 OCCUPANCY—DENSITY BASIS¹

STATE	UNITS	FLAMMABLE	OXIDIZER	CORROSIVE
Solid	lb/sq ft	0.001	0.003	0.003
Liquid	gal/sq ft	0.04 ²	0.03	0.08
Gas	c f/sq ft	1.250	1.250	3.000

¹HPM within piping shall not be included in the calculated quantities.

²The maximum permitted quantities of flammable, toxic gases shall not exceed the quantity specified by Table No. 51.105-A.

³The maximum permitted quantities of flammable and combustible liquids shall not exceed the following quantities:

Class (I-A) + (I-B) + (I-C) (Combination flammable liquids)	= 025
however, Class I-A shall not exceed	= 0025
Class II	= 01
Class III-A	= 02

(d) **Ventilation Requirements.** 1 **General.** Exhaust ventilation shall be provided to produce not less than 1 cubic foot per minute per square foot, floor area, and shall comply with Section 79.804, Item No. 3.

2 **Separating systems.** The return air system of one fab area shall not connect to another system within the building.

3 **Ventilation controls.** There shall be a manual control switch for the supply or recirculation air systems; or both, located outside the fab area. Additional manual control switch locations may be required by the chief.

(e) **Special Provisions.** 1 **Excess flow control.** Where HPM supply gas is carried in pressurized piping, a fail-safe system shall shut off flow due to a rupture in the piping. Where the piping originates from within the HPM storage room, this excess flow valve shall be located within the HPM storage room. Where the piping originates from outside the building, the valve shall be located outside the building as close to the bulk source as practical.

2 **Piping and tubing installation.** Piping and tubing shall be installed in accordance with approved standards. Supply piping of hazardous production materials having a health hazard ranking of 3 or 4 shall have welded connections throughout unless an exhausted enclosure is provided.

EXCEPTION. Material which is incompatible with ferrous piping may be installed in nonmetallic piping with approved connections.

3 **Gas-detection system.** When hazardous production material gas is used or dispensed and the physiological warning properties for the gas are at a higher level than the accepted permissible exposure limit for the gas, a continuous gas monitoring system shall be provided to detect the presence of a short term hazard condition. When dispensing occurs and flammable gases or vapors may be present in quantities in excess of 20 percent of the lower explosive limit, a continuous gas-monitoring system shall be provided. The monitoring system shall be connected to the emergency control station.

Work Station Within the Fabrication Area

Sec. 51.106. (a) Construction. Work stations within fabrication areas shall be constructed of materials compatible with the materials used at the station. The portion of the work station that serves as a cabinet for hazardous gases and flammable liquids shall be noncombustible and, if of metal, shall be not less than 0.0478-inch (18 gage) steel. Hazardous gases and liquid containers within the work station shall be protected from seismic forces in an approved manner.

(b) Maximum Quantities of HPM. The HPM materials in use in a work station shall not exceed:

Flammables and Toxics Combined	gases	3 cylinders
	liquids	15 gallons
	solids	5 pounds
Corrosives	gases	3 cylinders
	liquids	25 gallons ¹
	solids	20 pounds
Oxidizers	gases	3 cylinders
	liquids	12 gallons ¹
	solids	20 pounds

¹An equal amount of nonflammable HPM liquid in reservoirs of filtering systems of connected materials in use shall be permitted.

(c) Exhaust Ventilation. 1. **Design criteria.** There shall be a ventilation system to capture and exhaust fumes and vapors at the work station.

2. **Duct systems.** A. **Materials.** Materials for ducts shall comply with the Mechanical Code.

B. **Reactivities.** Two or more operations shall not be connected to the same exhaust system when either one or the combination of the substances removed may constitute a fire, explosion or chemical reaction hazard within the duct system.

C. **Penetrations.** Exhaust duct systems penetrating occupancy separations shall be contained in a shaft of equivalent fire-resistive construction. Ducts shall not penetrate area separation walls. Fire dampers shall not be installed in exhaust ducts.

D. **Sprinkler requirement.** All exhaust ducts shall be internally sprinklered when all of the following conditions apply:

1. When the largest cross-sectional diameter is equal to or greater than 10 inches.
2. The ducts are within the building.
3. The ducts are conveying gases or vapors in a flammable range.

Combustible nonmetallic ducts whose largest cross-sectional diameter is equal to or greater than 10 inches shall be internally sprinklered.

EXCEPTIONS: 1 Ducts listed for nonsprinklered applications

2 Ducts not more than 12 feet in length installed below ceiling level.

3. **Ventilation power and controls— emergency power.** The exhaust ventilation system shall have an emergency source of power. The emergency power shall be designed and installed in accordance with the Electrical Code.

The emergency power may operate the exhaust system at not less than half fan speed when it is demonstrated that the level of exhaust will maintain a safe atmosphere.

(d) Fire-protection Requirements. Sprinkler coverage of the horizontal surface at any work station shall not be obstructed. There shall be a sprinkler installed within the exhaust duct connection of work stations of combustible construction. The sprinkler shall be located not more than 4 feet from the point of duct connection to the work station. The sprinkler and connecting piping to the duct shall be coated with approved materials to prevent corrosion, when necessary. The sprinkler shall be accessible for periodic inspection. The design of the sprinkler system in the area shall take into consideration the spray pattern and the effect on the equipment.

EXCEPTIONS: 1 Approved alternate fire-extinguishing systems may be used. Activation of such systems shall deactivate the related processing equipment.

2. Process equipment which operates at temperatures exceeding 500°C. and which is provided with automatic shutdown capabilities for HPM.

3. Exhaust ducts 10 inches or less in diameter from flammable gas storage cabinets that are part of the work station.

(e) Electrical Requirements. Electrical equipment and devices within 5 feet of work stations in which flammable liquids or gases are used shall comply with the requirements of the Electrical Code for Class 1, Division 2 hazardous locations. Work stations shall not be energized without adequate exhaust ventilation.

EXCEPTION: The requirements for Class 1, Division 2 locations shall not apply when the air removal from the work station or dilution will provide nonflammable atmospheres on a continuous basis.

(f) Special Provisions. 1. **Chemical drainage and containment.** Each work station utilizing hazardous production material liquids shall have:

- A. Drainage piping systems connected to a compatible system for disposition of said liquids.
- B. The work surface provided with slope or other means for directing any spilled materials to the containment or drainage system.
- C. An approved means of containing or directing any spilled or leaked liquids to the drainage system.

2. **Identification.** All systems utilized in hazardous materials supply and drainage shall be identified. Labels shall be affixed so as to be conspicuously visible at all times.

3. **Shutoff valves.** Readily accessible shutoff valves for HPM supply piping shall be provided at the work station and as provided in Section 51.108 (d), Item No. 1.

4. **Protection of containers from damage.** All hazardous material containers located in or connected to a work station shall be protected from damage and shall not project from the work station.

5. **Work station clearances.** Work stations involving hazardous material shall be provided with horizontal servicing clearances of not less than 3 feet for electrical equipment, gas cylinder connections and similar hazardous conditions. These clearances apply only to normal operational procedures and not to repair or maintenance-related work.

Storage and Dispensing of Hazardous Production Materials Within Fabrication Areas

Sec. 51.107. (a) **General.** The storage of HPM liquids, gases and solids shall be within fully enclosed storage cabinets or within a work station. See Section 79.201 (g) 4.

Separate cabinets shall be provided for each class of hazardous material. Flammables, acids, bases, oxidizers, toxics and other incompatible materials shall not be stored within the same cabinet. Inert materials may be intermingled with other materials.

(b) **Cabinet Construction.** Storage cabinets shall be of approved construction and if metal shall be of not less than 0.0478-inch (18 gage) steel. Doors to cabinets shall be self-closing and latching.

Electrical equipment and devices within cabinets used for the storage of hazardous gases or liquids shall be in accordance with the requirements of the Electrical Code.

(c) **Special Requirements for HPM Gases.** 1. **General.** In addition to other requirements of this section, cabinets used for the containment of HPM gases shall comply with this subsection. Storage cabinets containing HPM gases shall be internally sprinklered.

EXCEPTION: Sprinklers shall not be required in gas cabinets that are located within an HPM storage room other than those used to contain pyrophoric gases.

Self-closing limited-access ports shall be installed on gas cabinets to give access to equipment controls.

2. **Gas detection.** Storage cabinets for hazardous gases shall be provided with a continuous gas-monitoring system in accordance with Section 51.105 (e) 3 whether dispensing occurs or not. Activation of the monitoring system shall automatically shut the valves on all HPM gas lines from the cabinets and initiate an alarm to the emergency control system.

3. **Ventilation.** Storage cabinets shall be ventilated. When the cabinet contains toxic gases, the average velocity of ventilation at the face of access ports shall be not less than 200 feet per minute (fpm) with a minimum of 150 fpm at any point of the access port.

Gas storage cabinets shall be operated at a negative pressure in relation to the surrounding area. The storage cabinet ventilation system shall comply with Section 51.106 (c) 2 and 3 and may be connected to a work station ventilation system.

4. **Excess flow control.** Excess flow control valves shall be installed when required by Section 51.105 (e) 1.

Handling of Hazardous Production Materials Within Exit Corridors

Sec. 51.108. (a) **New Buildings.** In new buildings, hazardous production materials shall not be permitted within an exit corridor.

(b) **In Existing Buildings.** When there are alterations or modifications to existing fabrication areas, the chief may permit the transportation of hazardous production materials in exit corridors that comply with Chapter 9 of the Building Code, subject to all of the following subsections.

1. **Containers.** All containers, tanks, drums or other means of transporting the materials shall be an approved type.

Liquids in quantities not exceeding 5 gallons may be transported in individual original containers of that size. When more than two such containers are transported within a corridor, they shall be in an approved cart. Glass containers shall not be used except where contamination is a factor. Glass containers shall not exceed 1 gallon in size.

2. **Carts and trucks.** Transporting carts and trucks of an approved design that complies with Subsection (c) of this section shall be used for transportation of HPM.

EXCEPTIONS: 1. Two HPM liquid containers each not exceeding 5 gallons may be hand carried in acceptable safety carriers. Single drums not exceeding 55 gallons may be transported by suitable drum trucks.

2. Cylinders of HPM gases may be transported by acceptable gas cylinder hand trucks. Cylinders not exceeding 25 pounds may be hand carried.

3. Solid HPM not exceeding 100 pounds may be transported by acceptable hand trucks. A single container not exceeding 50 pounds may be hand carried.

HPM gas cylinders in transit shall have their valves capped or plugged with an approved closure device in addition to having their protective cylinder caps in place. Cylinders placed on carts and trucks shall be individually restrained.

HPM shall not be dispensed in exit corridors nor shall carts or trucks be stored unattended while they are within exit corridors.

3. **HPM Pass-throughs in Exit Corridors.** When pass-throughs are provided, self-closing doors having a fire protection rating of not less than one hour shall be installed between the pass-through and the existing exit corridor. The pass-through shall be fully enclosed with wall protection as required for the exit corridor. Pass-throughs shall be sprinklered.

4. **Emergency alarm.** There shall be an emergency telephone system or a local alarm manual pull station or an approved signaling device at not more than 150-foot intervals or fraction thereof and at each exit stair doorway. The signal shall be relayed to the emergency control station and a local signaling device shall be provided.

5. **Sprinklers.** Sprinkler protection shall be designed in accordance with U.B.C. Standard No. 38-1 as designed for ordinary hazard Group 3. When the design area of the sprinkler system consists of one row of sprinklers in the corridor, the maximum number of sprinklers that need be calculated is 13.

(c) **Cart and Truck Design.** 1. **General.** Carts and trucks shall be designed to

provide a stable base for the commodities to be transported and shall have a means of restraining containers against accidental dislodgement. Carts and trucks shall be provided with a device which will enable the operator to safely control movement by providing stops or speed reduction devices. Power carts and trucks shall be approved for Class I, Division 1 or Class I, Division 2 hazardous locations. Internal combustion engines shall not be used.

2. **Liquid transporters.** Construction materials for HPM carts or trucks utilized for HPM flammable or combustible liquids shall be not less than 0.0478-inch (18 gage) steel or approved materials having a Class I flame-spread rating.

EXCEPTION: Materials utilized for casters, gaskets, trim and drains.

HPM liquid carts and trucks shall be designed so that the contents to be transported will be fully enclosed. They shall be capable of containing a spill from the largest single container transported with a maximum individual container size of 5 gallons.

3. **Size.** Neither the length nor width of a cart shall exceed 48 inches nor one-half the width of existing exit corridors, whichever is more restrictive. The capacity of carts and trucks used for transportation of HPM shall not exceed: liquids—55 gallons, gases—7 cylinders (up to 400 pounds each), solids—500 pounds.

4. **Identification.** Carts and trucks shall bear a marking indicating the contents therein. Noncompatible materials shall not be transported on the same cart or truck.

(d) **Piping.** When the hazardous production material is transported in piping placed within the space defined by the walls of the exit corridor and the floor or roof above the exit corridor, all the following requirements shall apply:

1. **Shutoff valves.** Readily accessible manual or automatic remotely activated fail-safe emergency shutoff valves shall be provided as follows:

A. At the entry of the piping system into the exit corridor.

B. At the branch piping connection into the fab area. The valves shall be identified and the location shall be clearly visible.

2. **Excess flow control.** Excess flow control shall be provided as set forth in Section 51.105 (e) 1.

3. **Gas detection.** Gas detectors shall be installed as set forth in Section 51.105 (e) 3.

4. **Electrical.** Electrical wiring and equipment located in the piping space shall be approved for Class I, Division 2 hazardous locations.

Handling of Hazardous Production Materials Within Service Corridors

Sec. 51.109. (a) **Transportation Criteria.** A service corridor shall be provided when necessary to transport HPM to and from an HPM storage room, or from the outside of the building, to the perimeter wall of the fabrication area. It shall not be used as a required exit corridor. Service corridors used for the transport of HPM shall meet the following requirements:

1. All containers shall comply with Section 51.109 (b) 1.

2. The minimum clear width of the service corridor shall be 5 feet.

EXCEPTION: When carts or trucks are used, the minimum width shall be 33 inches wider than the widest cart or truck.

3. The maximum quantities of HPM that may be transported in a service corridor at one time may be two times that set forth in Section 51.108 (c).

4. There shall be a local manual alarm station or other approved signal device in the service corridor. See Section 51.108 (b) 3.

Additional alarm devices may be required by the inspection authority.

5. Sprinklers shall be installed in accordance with Section 51.108 (b) 4.

(b) **Prohibited Procedures.** HPM shall not be dispensed in a service corridor.

(c) **Construction Requirements.** See Building Code.

(d) **Exits.** See Building Code.

(e) **Piping.** See Section 51.105 (e).

Storage of Hazardous Production Materials

Sec. 51.110. (a) **Outside Storage.** 1. **General.** General storage of hazardous production materials outside the building shall comply with the separation, construction and fire safety requirements of the Building Code and this code.

2. **Shutoffs in piping from outside storage.** All HPM gaseous supply piping from the outside storage shall be provided with excess flow control in accordance with Section 51.105 (e) 1.

A manual emergency shutoff valve located outside the building shall be installed on each HPM supply pipe from outside storage. The valve shall be identified, readily accessible, and its location clearly visible.

3. **Special provisions.** Outside storage of HPM shall be safeguarded from public access. See Section 80.103.

(b) **Storage of Hazardous Production Materials Within Buildings.** 1. **Construction.** Storage of HPM in excess of the quantities in Table No. 9-A or 9-B of the Building Code shall be in a room complying with the requirements of the Building Code for an inside liquid room or in an HPM storage room. Such HPM storage room shall not exceed 6000 square feet in area and shall be separated from all other areas by not less than a two-hour occupancy separation when the area exceeds 300 square feet. The occupancy separation shall be not less than one-hour fire-resistive construction when the area does not exceed 300 square feet. Except for approved combustible surfacing, floors of storage rooms shall be noncombustible with liquid-tight construction. See Section 911 (c) of the Building Code. When HPM storage rooms are used for dispensing of Class I or II flammable hazardous production material liquids or gases, the area of the HPM storage room shall not exceed 1000 square feet.

2. **Location within building.** The HPM storage room shall be located on the outer perimeter of the building and its exterior wall shall be a minimum of 30 feet from the property line. Explosion venting shall be provided when an explosive environment can occur.

3. **Separation requirements within storage rooms.** Flammables, corrosives, oxidizers, water-reactives, solids and liquids within a storage room shall be separated from each other in accordance with Table No. 51.110-A.

When Table No. 51.110-A permits a noncombustible partition between classes of HPM, the classes may be in the same room.

Water-reactive HPM shall be in separate rooms from flammable or combustible liquids. The separation may be nonfire-rated.

Toxics shall be separated as set forth in Table No. 51.110-A with an occupancy separation having a fire-resistive rating of not less than one hour.

HPM gas shall be separated from HPM liquids and solids by at least a one-hour fire-resistive occupancy separation. See Table No. 51.110-A for classes of gases required to be separated.

4. **Determining quantities in HPM storage room.** The quantity of hazardous production material within each HPM storage room shall not exceed the amounts permitted by this code. For HPM oxidizers, see Tables Nos. 51.110-B through 51.110-E. Highly toxic liquids shall be counted as flammable liquids. Corrosive liquids shall be counted as Class 3 flammable liquids. Highly toxic solids shall be counted as flammable solids.

The quantities of hazardous production material gases shall not exceed the following:

Oxidizers	20,000 cubic feet
Corrosives	30,000 cubic feet
Flammables	15,000 cubic feet
Toxics	Toxic gas quantities shall be counted as flammable gases

5. **Ventilation requirements.** Ventilation shall be provided in accordance with Section 51.105 (d) 1.

6. **Emergency alarm.** A local fire alarm manual pull station or approved signal device shall be installed outside of each interior exit door with a signal relayed to the emergency control station and a local alarm provided.

7. **Special provisions. A. Drainage.** All HPM storage rooms for hazardous production material liquids shall have drainage facilities that comply with the requirements of Section 79.804, Item No. 7, of this code. Hazardous production material flammable liquid drains shall be separated from other hazardous production material liquid drains. Other hazardous production material liquids in drains that are not compatible shall be separated from each other, provided that they may be combined when they have been rendered acceptable for discharge by an approved means into the public sewers.

B. **Sills.** Liquid HPM storage rooms and subdivisions therein shall have liquid-tight wall-to-floor intersections and noncombustible sills at least 4 inches in height at all door openings.

An open-grated noncombustible trench on the inside of the room, extending at least 1 foot past the edge of the door opening, may be used in lieu of a sill. The trench shall connect to an approved drain in accordance with Subsection A above.

C. **Gas detection.** Gas detection systems shall be provided as set forth in Section 51.105 (c) 3.

8. **Electrical requirements.** Electrical wiring and equipment located in HPM storage rooms shall be approved for Class I, Division 1 hazardous locations, in addition to any other requirements of the Electrical Code.

EXCEPTION: When separate storage rooms are used, the storage rooms without flammable liquids or gases need not be approved for Class I, Division 1 hazardous locations.

9. **Special hazards.** Energy-consuming equipment shall comply with Section 908 of the Building Code and Subsection 8 above.

TABLE NO. 51.110-A
MATERIAL SEPARATION¹

	MINIMUM SEPARATION FROM						
	TOXICS	ACIDS	BASES	FLAMMABLES	OXIDIZERS	WATER-REACTIVE	PYROPHORIC
Toxics		1 hr.	1 hr.	1 hr.	1 hr.	1 hr.	1 hr.
Acids	1 hr.		S	S ²	S	S	S ²
Bases	1 hr.	S		S	S	S	S
Flammables	1 hr.	S ²	S		S	*	S
Oxidizers	1 hr.	S	S	S		S	S ²
Water-reactive	1 hr.	S	S	*	S		S
Pyrophoric	1 hr.	S ²	S	S	S ²	S	

¹For separation of hazardous production material gases from hazardous production liquids and solids, see Section 51.110 (b) 3.

²Separation by not less than 20 feet may be used as alternative to noncombustible partition.

Notes:

S = Noncombustible partition. The partition shall extend not less than 18 inches above and to front and rear of stored material.

1 hr. = One-hour noncombustible fire-resistive occupancy separation, except when approved gas cabinets are used.

* = Not allowed; a separate storage room is required.

TABLE NO. 51.110-B
STORAGE OF CLASS 1 OXIDIZERS IN COMBUSTIBLE CONTAINERS¹

COMBUSTIBLE CONTAINERS ²	INSIDE ROOM OR HPM STORAGE ROOM
Piles	No limit
Length (feet)	50
Width (feet)	20
Height (feet)	3
Distance to next pile (feet)	2
Distance to walls (feet)	No limit
Quantity limit per building (tons)	No limit

¹Class 1 oxidizers are materials whose primary hazard is that they may increase the burning rate of combustible material with which they come in contact.

²Class 1 oxidizers in storage in noncombustible containers or in bulk in noncombustible buildings are not limited as to quantity or size of piles.

TABLE NO. 51.110-C
STORAGE OF CLASS 2 OXIDIZERS IN CONTAINERS¹

	INSIDE STORAGE ROOM	HPM STORAGE ROOM
Building limit (tons)	200	2,000
Pile limit (tons)	20	100
Height limit (feet)	10	12
Distance to next pile (feet)	Footnote 2	Footnote 2
Distance to incompatible storage (feet)	12	—
Distance to wall (feet)	2	2

¹Class 2 oxidizers are materials that can cause spontaneous ignition when in contact with combustible materials.

²Aisle width to equal pile height.

TABLE NO. 51.110-D
STORAGE OF CLASS 3 OXIDIZERS IN CONTAINERS¹

	WIDE STORAGE ROOM	HPM STORAGE ROOM
Building limit (tons)	100	1,200
Pile limit (tons)	20	60
Height limit (feet)	8	10
Distance to next pile (feet)	Footnote 2	Footnote 2
Distance to incompatible storage (feet)	10	Not applicable
Distance to wall (feet)	4	4

¹Class 3 oxidizers are materials that can undergo vigorous self-sustained decomposition when catalyzed or exposed to heat.

²Aisle width to equal pile height

TABLE NO. 51.110-E
STORAGE OF CLASS 4 OXIDIZERS IN DRUMS, CONTAINERS AND CASES¹

Piles	10
Length (feet)	4
Width (feet)	8
Height (feet)	8
Distance to next pile (feet)	No limit
Quantity limit per building (tons)	No limit

¹Class 4 oxidizers are materials that can undergo an explosive reaction when catalyzed or exposed to heat, shock or friction.

Emergency Plan

Sec. 51.111. (a) Plans and Diagrams. Plans and diagrams shall be maintained in approved locations indicating the approximate plan for each area, the amount and type of HPM stored, handled and used, locations of shutoff valves for HPM supply piping, emergency telephone locations and locations of exits.

(b) Plan Updating. Plans and diagrams shall be maintained up-to-date and the fire department shall be informed of all major changes.

(c) Emergency Response Team. Responsible persons shall be designated the on-site emergency response team and trained to be liaison personnel for the fire department. These persons shall aid the fire department in preplanning emergency responses, identifying locations where HPM is stored, handled and used, and be familiar with the chemical nature of such material. An adequate number of personnel for each work shift shall be designated.

(d) Emergency Drills. Emergency drills of the on-site emergency response team shall be conducted on a regular basis but not less than once every three months. Records of drills conducted shall be maintained.

EMERGENCY RESPONSE PROCEDURES TO THE MDA TOXIC GAS ALARM

(05/20/88)

Revised 11/89

This document represents a complete guideline for the appropriate emergency response to a toxic gas alarm. The introduction outlines the overall duties and responsibilities of all personnel who may respond to a toxic gas alarm. The remainder of the document is a step-by-step explanation of the response procedures for different release levels. These release levels include a catastrophic release, a high level release, a low level release, and a less than low level release. Also included is an after hours response (5:00 p.m. — 8:00 a.m.) and some guidelines for other uses of the toxic gas monitors (e.g., changing gas cylinders).

If a problem arises with a particular piece of equipment, it is the responsibility of the researcher in charge of that equipment to ensure the safety of self and of fellow personnel. Therefore, this document has been prepared as an A-Z approach to assist the researcher from the time an alarm is sounded in the laboratory to the time the event is declared safe. Other personnel who may be involved in these procedures need to be familiar with this document as well. This includes personnel from Safety and Health, Facilities, Security, Fire Marshalls, and Building Landlords.

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I) INTRODUCTION

I.A) GENERAL REMARKS. These procedures address the appropriate emergency response to the four types of toxic gas release. The four types of releases are: (1) a catastrophic release, possibly endangering building occupants other than the researchers involved; (2) a high level release, possibly endangering the researchers in the immediate area or laboratory involved; (3) a low level release, which may or may not be sufficient to cause a health risk to the researchers after prolonged exposure; and (4) a less than low level release which is not large enough to set off the MDA toxic gas monitor, but it is large enough to be detected. The response to each of these conditions is provided in separate, individual sections below. At the beginning of each response section is a definition of what characterizes each type of release, Section IX provides a summary of these definitions.

Since each of the steps are described in detail, it makes this seem like a rather long document. It would take too long to have to read these procedures in the event of an actual emergency. Therefore, it is imperative that these procedures be reviewed frequently, so they can be carried out in an expedient manner. For a quick overview of these procedures refer to the attached flow chart, (Section VIII). This flow chart should be posted in a prominent location in all laboratories when the procedure applies.

I.B) TRAINING. The review of this document and/or the flow chart does not constitute the fundamental training requirements of all users of toxic gases. All users must have minimum training in the use of Fire Extinguishers, MDA operation, and in the Emergency Response Procedures to the MDA Toxic Gas Alarm. Additional training in First Aid, CPR, compressed gas safety, and electrical safety are recommended. Training in Emergency Response Procedures to the MDA Toxic Gas Monitor should occur annually. SCBAs will be required to be worn when changing toxic gas cylinders with annual SCBA training required.

Nonusers who are involved with responding to the MDA room in the case of an alarm should have training in MDA operation, and the Emergency Response to the MDA Toxic Gas Monitor. These nonusers would include personnel from Safety and Health and the Facilities branches. The annual simulated emergency exercises should be made available to personnel from these areas; as well as personnel from the shipping and receiving staff.

Shipping and Receiving personnel are involved with the transportation of toxic gases, but are never expected to respond to the MDA room. Because of their potential exposure, Shipping and Receiving personnel should receive training in compressed gas safety, Hazard Communication, and an emergency response to a toxic gas release (a condensed version of the Emergency Response to the MDA Toxic Gas Monitor).

The building Fire Marshall, Landlord, and Fire Marshall Assistants should have training in the Emergency Response to the MDA Toxic Gas Alarm in order to be aware of the conditions which warrant the activation of the building fire alarm system.

Security personnel become a valuable link in the response to an MDA alarm which occurs after hours (5:00 p.m. - 8:00 a.m.). Since they will be notifying appropriate personnel of the occurrence, and may be asked to relay information, security personnel should receive training in the use of the Emergency Notification phone list, how to read the MDA remote printer from Building 17, and how to remotely evacuate Building 16. See Subsections I.F and VI for more details.

I.C) RESEARCH STAFF RESPONSIBILITIES. These procedures are prepared for those members of the research staff who are users of toxic gases. They are intended to be a guide as to the appropriate action from the time of an alarm in the laboratory, through the resolution of the problem. If a problem arises with a particular piece of equipment, it is the responsibility of the researcher in charge of that equipment to ensure the safety of self and of fellow personnel.

The researcher who is responsible for the equipment or area where a problem has occurred may ask for assistance in rectifying the problem, but the actual decision as to the severity of the release and what action to take is up to that individual. During normal business hours it is up to the researcher to determine the severity of the release. The building Landlord and/or personnel from Safety and Health can override the researcher's decision if they deem it necessary. In the case of an after hours alarm the Facilities or Safety and Health personnel will determine the severity of the release and call upon the researcher for necessary corrective action.

It is up to the individual users of toxic gases to comply with Institutional standards and practices. These practices include the following:

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- o Never operate a system using toxic gases before 8:00 am or after 5:00 pm. (Back-up personnel are not available to respond.) This is to be strictly followed. Compliance with this requirement is absolutely mandatory.
- o Never leave a system using toxic gases running (with toxic gases flowing) unattended. (If you need to leave the laboratory even for a moment, find someone, who is adequately trained, to watch the system in your absence.)
- o Properly label and know where your MDA monitoring points are in your laboratory.
- o Know what the high and low alarm level set points are for your laboratory and for which gases they represent (see Section XII).
- o Know where the nearest fire alarm (pull station) is in relation to your laboratory.
- o Know where the fire extinguishers are in and near your laboratory.
- o Know where nearest SCBA units are in relation to your laboratory.
- o Know what is the quickest way to shut down your system(s), particularly toxic gas flows as close to the source as possible.
- o Know the fire evacuation route.
- o If possible, turn off each toxic gas cylinder, at the cylinder valve, after each run. No toxic gas cylinders should be open outside of normal working hours.
- o Always check for the green MDA light in the laboratory before starting a run. If the light is out it indicates that the MDA unit monitoring that laboratory is not operating (or lamp is burned out).
- o Whenever running, all equipment enclosure doors and openings should be closed so that proper ventilation is achieved.
- o If a fire alarm sounds, shut down your system before evacuating.
- o If you make a change in the type(s) of gases you use, notify the Facilities Branch and the ES&H Section in writing so that the MDA monitors can be set correctly.

I.D) FACILITIES RESPONSIBILITIES. Whenever there is a toxic gas alarm a buzzer will activate at the Security Desk. Additionally, after calling x1234 the Facilities personnel will be notified of the alarm. The appropriate personnel will respond to the MDA room. When they arrive they have the primary responsibility for the operation of the MDA units. They will not make the decisions as to what action to take, but they can provide valuable assistance in determining the severity of the release, interpreting the printout,

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detecting a false alarm, and operating the unit. After an alarm they will reset the MDA unit and preserve the printout. In the case of an after hours alarm, they may be one of the first to respond and will therefore make a judgement as to the severity of the release, but they will not implement any corrective action. If necessary, they may implement building evacuation.

Facilities personnel are responsible for the day-to-day upkeep, maintenance, and calibration of the MDA units. This includes the replacing of chemcassettes® and printer tape. After proper notification from the research staff, facilities has the sole responsibility for programming the set points into the units. The set points on for each lab will be 1 X Threshold Limit Value (TLV) for the low level alarm and 5 X TLV for the high level alarm. Some gases (e.g., phosphine) may saturate the chemical reaction on the chemcassette® before this high level is achieved. In this case the high level set point will be the saturation level (see Section XII). If more than one gas is used in a laboratory, the set points will be determined by the lowest levels on the correlation scale for different gas reactions with the chemcassette® (see Section XIII). The Facilities personnel will notify all users of an MDA unit before they shut down that unit for any repairs or maintenance.

There is some information which is invaluable when determining the severity of a release. The Facilities personnel will ensure that this information is readily available in the MDA room. Each MDA monitoring point should be clearly labeled so as to identify the location of that point, the set point levels, and the type of gas for which it is set. In addition to the above information, the flow chart of response procedures (Section VIII), the chart defining the release levels (Section IX), and MDA Alarm Checklists (Section X) should all be easily accessible.

1.E) SAFETY AND HEALTH RESPONSIBILITIES. When there is a toxic gas alarm, a buzzer will be activated in the Safety and Health area. Additionally, after calling x1234, the Safety and Health personnel will be notified of the alarm. The appropriate personnel will respond to the MDA room. When they arrive, they have the secondary responsibility for the operation of the MDA units behind the Facilities personnel. They will not make the decisions as to what actions should be taken, but they can provide valuable assistance in determining the severity of the release, interpreting the printout and providing input on the type of corrective action. Safety and Health personnel will ensure that only authorized personnel will be allowed in the MDA room. In the case of an after hours

alarm, they may be one of the first to respond and will therefore make a judgement as to the severity of the release, but they will not implement any corrective action. If it is necessary, they may implement building evacuation.

1.F) SECURITY RESPONSIBILITIES. In the event of an after hours alarm (5:00 p.m. - 8:00 a.m.), it is very likely that the only person aware of the alarm will be one of the security guards. Section VI specifically outlines the after hours response and should be referred to for specific actions. The Security personnel are not expected to respond in any way other than to provide information to the appropriate personnel. Guards are never expected to make decisions concerning the severity of the release or to take any corrective actions. They may, however, be called upon to evacuate the building if the situation is thought to be catastrophic.

1.G) MDA ROOM PROCEDURES. Once people start responding to the MDA room, the first properly trained person responding should enable the printer(s). If more than one person is present, there is a set priority of who operates the MDA units. A representative from Facilities has priority over everyone else, followed by a representative from Safety and Health, and finally the researcher responsible for the area of the release (or someone appointed by that person). Except in the case of a catastrophic release, the researcher is the primary person responsible for making decisions concerning the severity of the release and the appropriate action. Personnel from Safety and Health and/or the building Landlord can override the researcher's decision. In the case of an after hours alarm personnel from Safety and Health or Facilities may determine the severity of the release on behalf of the researcher. This is done either by telephone or from the remote printer in Building 17.

Because the alarm can be easily heard by a large number of people, there is a potential for many people to respond to the MDA room. In all cases, only the researcher responsible for the area of the release, one person chosen as an assistant, personnel from Safety and Health, personnel from Facilities, and the building Landlord are allowed access to the MDA room. All other personnel should stay out!

If the researcher responsible for the area of the release does not respond to the MDA room within two minutes of when the first person arrived, someone will have to respond on the researcher's behalf. This substitute response priority is as follows: a representative from Safety and Health first, followed by a research staff member who is

familiar with the release area (see the backup notification list in Section VI), and finally a representative from Facilities. The first thing to do when responding for the absent researcher is to pick up one of the MDA Alarm Checklists and proceed as outlined on the checklist.

II) CATASTROPHIC RELEASE

A gas release is determined to be catastrophic if it has the potential of immediate endangerment to personnel; especially personnel other than those researchers directly involved with the release. It is possible that the situation can be deemed a catastrophic leak immediately and the appropriate actions can be taken. An example of this might be if a valve was broken off a cylinder, which could cause a large release in a short period of time. Another example might be if a line, which contained a pure toxic gas such as arsine, were to rupture outside of a vented enclosure. If a researcher were present at the time of such an occurrence, it should be immediately identified as a catastrophic release and acted on accordingly.

However, it may be that when responding to a high or low level alarm, the situation is determined to be catastrophic based upon the readings from the MDA toxic gas monitor. The criteria for making this determination are as follows. (See also Section IX.)

- o Two or more points in the same laboratory registering a high level.
- o Any point registering a high level plus the ambient registering a concentration above the low level.
- o The ambient registering a high level.
- o A single point with three successive readings above the high level which are of the same concentration or increasing.
- o Successive readings which are increasing, or otherwise indicating that they will soon reach a catastrophic level.

If the release is determined to be catastrophic the following procedure is to be followed.

II.A) ENSURE SYSTEM IS OFF — EVACUATE LAB. The first response is to make sure all operational systems using toxic gases are shut down as all personnel in the laboratory are evacuating. In most laboratories this can be done by pushing the red panic button, near the exit(s), on the way out. It is necessary to ensure that all systems are shut down in order to stop gas flows as close to the source (cylinder) as possible. Personnel which are not going to help respond to the situation should evacuate to the fire evacuation assembly area.

II.B) PULL FIRE ALARM. The next step is to pull the fire alarm. This is done to evacuate the building so that no one is endangered. The closest fire alarm to you, at the time when the release is determined to be catastrophic, should be pulled. This minimizes the time it takes to evacuate the building.

II.C) REPORT TO FIRE MARSHALL. Because the fire alarm summons the Lakewood Fire Department and activates the building fire Marshall and Assistants, it is necessary to report to the building fire marshal (in the lobby of 16/2) in order to inform that person that it is not a fire, but rather a toxic gas emergency. This is necessary so that the fire teams can respond accordingly.

II.D) CALL x1234 FROM ANOTHER BUILDING. In addition to notifying the building fire marshal it is also necessary to notify the Security Desk as to the status of the situation. You should state who you are, where the alarm occurred, that the building has been evacuated by pulling the fire alarm, and answer any questions the person on the other end asks you. Remember, when calling this number, always allow the other person to hang up first! You should evacuate the building before making this call, so that you are not endangering yourself.

II.E) REMAIN AVAILABLE FOR FURTHER ASSISTANCE. Once the above steps are carried out, you may or may not be needed to provide further assistance. Since the emergency occurred in your area you may be able to provide valuable information or services in order to correct the situation. (NOTE: It is up to the researcher who is responsible for the area where the leak occurred to make the decision as to the severity of the release. In all the other procedures the decisions for the type of corrective action taken is left up to that researcher. In the case where the building is evacuated there will be many different people involved in the decision making process. It will be up to the building Landlord whether the researcher involved is needed for further assistance.)

II.F) **COMPLETE UOR.** Anytime there has been a catastrophic gas release it is mandatory to complete an Unusual Occurrence Report (UOR). Copies of this form can be obtained from Safety and Health. In this case, it may be necessary to fill out other forms as well. Safety and Health will distribute these forms to the appropriate personnel.

II) HIGH LEVEL RELEASE

A high level alarm is a release which is sufficiently large to set off the high level alarm on the MDA toxic gas monitor. The set point for this alarm is either 5 X TLV (Threshold Limit Value) or the saturation level of the chemcassette®, whichever is lower.

NOTE: There is a difference between the terms "high level alarm" and "high level release." A high level alarm is when there is a reading on one or more points which exceeds the high level set point and sounds the alarm in the appropriate laboratory. This alarm is the loud bell. Also, there is a light box outside of each entrance to areas using toxic gases which have red lights that flash as a warning not to enter that area.

Just because the high level alarm is activated does not necessarily mean there has been a high level release. The high level alarm could be a false alarm. It is only after responding to the MDA room and monitoring the situation that a "high level alarm" can be determined to be a "high level release." A high level release is characterized as below. (See also Section IX.)

- o Any single point with three successive readings which are decreasing in concentration, but still above the high level.
- o Any point registering a high level plus the ambient registering above zero, but below the low level.
- o The ambient registering a low level concentration.
- o Successive low level readings which are increasing, indicating that they will soon reach the high level.

Usually, you will be aware of a high level release because the high level alarm bell will sound. It is necessary to respond to the MDA unit in order to accurately determine the severity of the release. When a high level alarm is heard, one should proceed as follows:

III.A) CATASTROPHIC. The first question to ask yourself and other personnel in the area of the alarm is, "Is there a known catastrophic release?" This is not a question to be debated, but rather an affirmative answer to this question should be quickly relayed to all personnel in the area so they can evacuate as quickly as possible.

- 1) **YES**, if there is a known catastrophic release, proceed according to Section II above.
- 2) **NO**, if the answer to the question is not immediately known, proceed as quickly as possible with the following steps.

III.B) ENSURE SYSTEM IS OFF — EVACUATE LAB. Before leaving the laboratory, make sure all systems using toxic gases are shut down and all personnel in the laboratory are evacuated. It is necessary to ensure that all systems are shut down because if the leak is associated with the equipment, all gas flows should be stopped as close to the source (cylinder) as possible. Personnel which are not going to help respond to the situation should evacuate to safe location.

III.C) GO TO MDA ROOM. Just because the high level alarm sounded in your area, does not necessarily mean that there has been a high level release. It is necessary to respond to the MDA unit monitoring your area in order to determine the severity of the alarm situation. Upon entering the MDA room pick up one of the MDA Alarm Checklists, which is a shortened version of the following procedures and will help you quickly implement the correct sequence of actions.

III.D) SILENCE ALARM. Because there is an alarm at the entrance to the MDA room, it will be very difficult to communicate with the Security Desk (x1234). The alarm can be silenced by turning off the switch to the bell, next to MDA unit No. 1. This only silences the alarm outside of the MDA room.

III.E) CALL x1234. Before taking any further action it is necessary to contact the Security Desk and inform them that there has been a toxic gas alarm. You should state

who you are, where the alarm occurred, that it is a high level alarm, and answer all the questions the person on the other end asks you. Remember, when calling this number, always allow the other person to hang up first! This way they are getting all the information they need. If more than one person is present, the researcher can ask another person to make this call, therefore enabling the researcher to respond to the MDA unit as fast as possible.

III.F) EVACUATE? The next step is to read the printout from the appropriate MDA unit and evaluate the information available at that time.

- 1) **YES** If any of the criteria determining a catastrophic leak are met (Sections II and IX), proceed with the building evacuation procedures as outlined in Section II.
- 2) **NO** If the severity of the release cannot be determined at this time, it is necessary to continue with this procedure. If the severity of the release can be determined at this time, jump to SubSection III.I in case of a high level release or Subsection IV.G in case of a low level release.

III.G) ENABLE PRINTER/DISABLE EXTRA POINTS. If the severity of the release cannot be determined upon first inspection of the printout, it is necessary to monitor the situation in order to make an informed decision. This is done by first enabling the MDA printer (Section XI) and then disabling all the extra points on the monitor. Usually points in laboratories other than where the leak occurred are not kept on. This will allow for shorter times between sampling the problem area. The ES&H Section will notify the other users of that monitor that there has been an alarm and their points are being shut down. If they are to keep running, they need to use their portable monitors.

III.H) EVACUATE? The next step is to read the printout from the MDA unit and evaluate the information which is being printed out.

- 1) **YES** If any of the criteria determining a catastrophic leak are met (Sections II and IX), proceed with the building evacuation procedures as outlined in Section II.

- 2) NO If the severity of the release cannot be determined at this time, it is necessary to continue with this procedure. If the severity of the release can be determined at this time, jump to SubSection III.I in case of a high level release or Subsection IV.G in case of a low level release.

III.I) 1-MONITOR MDA/Z-SCBA, FIX LEAK. If the leak is determined to be a high level release, then it is a sufficiently large release to warrant taking special precautions before returning to the laboratory to effect repairs. One person should be put in charge of monitoring the MDA printout (while the printer is enabled and the extra points are disabled). This person can then relay information to those personnel responding to the laboratory via the telephone. When returning to the area of the release it is absolutely necessary that there are two people and that they both wear self contained breathing apparatus (SCBA). The person with primary responsibility for the source of the leak should be effecting repairs. If needed the second person can listen, over the phone, to the person in the MDA room as to the status of the readings. The primary purpose of the second person is to ensure the safety of both people responding. The use of a hand held monitor or moving around an MDA monitoring point will greatly aid in pinpointing the source of the release.

III.J) DETERMINE WHEN SAFE. After the source of the leak(s) has been fixed and the all leaks have been stopped, it is necessary to determine when the levels are safe enough to reopen the lab. There should be five consecutive readings below the TLV before it is even considered to be safe. Another check with a portable detector in a thorough inspection of the area should also be done. When it is determined to be safe the red, flashing lights outside of the laboratory entrances can be reset.

III.K) FACILITIES WILL RESET MDA. Since the MDA has been changed from the normal operating conditions, it needs to be reset. This will be performed by a representative from the Facilities Branch and should never be done by the research staff. In addition to resetting the MDA they will also recalibrate the optics, check the tape, and preserve the printout. The research staff should never remove any of the printout at any time.

III.L) COMPLETE MDA ALARM FORM. The MDA Alarm Checklist, mentioned in Subsection III.C, should be completed by the research staff responsible for the affected area. This is done by receiving the appropriate signatures on the bottom of the form and signing and dating it yourself. A representative from Safety and Health will collect the

form. Copies will be distributed to the building Landlord and the appropriate line management personnel. This is a mandatory step for all toxic gas alarms, whether real or false, and cannot be skipped.

III.M) COMPLETE UOR. Any time there has been a high level gas release it is mandatory to complete an Unusual Occurrence Report (UOR). Copies of this form can be obtained from Safety and Health.

IV) LOW LEVEL RELEASE

A low level release is a concentration of gas which is at or above the TLV for a specific gas, but below the point of immediate health risk (see high level setpoint in Section III and set point table Section XII). A low level release will set off the low level alarm from the MDA. This alarm is different from the high level alarm in that it is a sonalert (buzzer), not a bell, and does not activate the flashing red lights outside of the laboratory.

NOTE: There is a difference between the term "low level alarm" and "low level release." A low level alarm only means that the MDA has picked up a concentration of gas over the low setpoint, but not over the high setpoint. A low level release is characterized as below. (See also Section IX.)

- o Any point with three successive readings which are above the low level, but below the high level and do not indicate they will increase above the high level.
- o The ambient reading a concentration greater than zero, but below the low level.

It is likely that a low level release will first be communicated by the sounding of the low level alarm (buzzer). If the low level alarm is heard, you should proceed as follows.

NOTE: If at any time the conditions change so as to sound the high level alarm, you should respond according to those procedures listed for the high level alarm (Section III).

IV.A) EVACUATE ALL EXTRA PERSONNEL. Since the low level alarm is set at the TLV the level of gas detected is well below the point of being immediately dangerous to life and health (IDLH). Therefore, it is not necessary to evacuate the laboratory completely. However, all "extra" personnel should evacuate to a safe location. "Extra" personnel would include all personnel that will not be actively providing assistance in the

corrective procedures. Always have two people present with a portable toxic gas monitor when responding to a toxic gas alarm. If no one is in the laboratory to assist you, find someone via telephone before effecting any repairs.

IV.B) CALL X1234. It is still necessary to contact the Security Desk and inform them that there has been a toxic gas alarm in your area. You should state who you are, where the alarm occurred, that it is a low level alarm, and answer all the questions the person on the other end asks you. Remember, when calling this number, always allow the other person to hang up first! This way they are getting all the information they need. Since the level has not reached the high level, you can make this call from the laboratory.

IV.C CALL X1266. This is the extension for the MDA room. It is not necessary to personally respond to the MDA in the case of a low level alarm. Because x1234 was called and a buzzer goes off at the Facilities reception desk and in the Safety and Health area, personnel from these Branches will automatically be responding to the MDA room. Once someone answers at this number, they can provide you with the information you need to make the following decisions. It may be necessary to let the phone ring many times before it is answered.

IV.D) IN AMBIENT ? The first thing you should find out, from the person answering the phone in the MDA room, is if there is a low level concentration in the ambient. The person can give you this information immediately, without enabling the printer or disabling any extra points, provided the unit has cycled through all the points at least once. If two minutes have elapsed since the alarm time, it has completed at least one cycle.

(NOTE: If there were a high level in the ambient you would need to consider the situation catastrophic and implement the building evacuation procedures. However, the high level alarm would have sounded and you should shut down and evacuate the area, not be in the laboratory talking on the phone. You would be operating under a different set of procedures; Section II.)

- 1) **YES** If there is a low level gas concentration in the ambient the situation is declared to be a high level release and you should proceed according to Section III starting with Subsection B.

- 2) NO If there is no gas concentration in the ambient, or if the concentration is less than the low level, then proceed as follows.

IV.E) INCREASING?. The person responding the the MDA room should now enable the printer and disable all extra monitoring points. (The person from xl234 will notify the other users that their points will be disabled.) Now by monitoring the MDA printout the person can relay to you information whether or not the release is increasing.

- 1) YES If the concentrations are increasing and it looks like a high level alarm will be reached, it is necessary to proceed as if the high level alarm sounded, under Subsection III.B.

- 2) NO If the situation remains to be a low level release proceed as follows.

IV.F) FIND LEAKS AND REPAIR. Remember, there should be two people present at this time. One person can maintain a telephone contact with the MDA room, while the person responsible for the leak safely implements the corrective action. The first step before repairing anything is to confirm the source of the leak. This process can be assisted by the use of a hand held detector or by moving an MDA point around. Once the leak is found it should safely be corrected. If repairs include dismantling any components, the use of SCBA should be employed. Consider not only your own safety, but also the safety of those around you.

IV.G) DETERMINE WHEN SAFE. After the source of the leak has been fixed and all leaks have been stopped, it is necessary to determine when the levels are safe enough to reopen the lab. There should be five consecutive readings below the TLV before it is even considered to be safe. A check with a portable detector in a thorough inspection of the area should also be conducted.

IV.H) FACILITIES RESETS MDA. Since the MDA has been changed from the normal operating conditions it needs to be reset. This will be performed by a representative from the Facilities Branch and should never be done by the research staff. In addition to resetting the MDA they will also recalibrate the optics, check the tape, and preserve the printout. The research staff should never remove any of the printout at any time.

IV.I) COMPLETE MDA ALARM FORM. Obtain a copy of the MDA Alarm Checklist, mentioned in Subsection III.C. It should be completed in cooperation with the person responding to the MDA on your behalf. A representative from Safety and Health will collect the form. Copies will be distributed to the building Landlord and the appropriate line management personnel. This is a mandatory step for all toxic gas alarms, whether real or false, and cannot be skipped.

IV.J) COMPLETE UOR. It may or may not be necessary to complete an Unusual Occurrence Report (UOR). Safety and Health will determine when it is necessary to complete an UOR and distribute the form.

V) LESS THAN LOW LEVEL RELEASE

The MDA toxic gas monitors are constantly monitoring the points connected to them. If there is a gas concentration detected which is below the low level alarm point, it will show up on the time weighted average. The time weighted average is printed out every eight hours, around the clock, and is reviewed daily by a member of the Facilities Branch. If there has been a small release, which did not alarm, it would be picked up on these daily inspections. Any non-zero time weighted average for a point will be reported to the appropriate researcher, Branch Manager, and Safety and Health by Facilities.

While this is not an emergency situation, the presence of a non-zero time weighted average could be indicative of a leak developing that could lead to a worse situation. Because of this possibility, the source of the leak should be found and repaired as soon as possible.

VI) AFTER HOURS RESPONSE

The after hours (5:00 p.m. — 8:00 a.m.) response is taken from the Emergency Preparedness Plan (EPP) as referenced on page 17. There are two key elements to this response. The first is that a person is contacted who has been adequately trained as to determine the severity of the alarm. The second key element is that a laboratory representative is contacted to effect any necessary corrective action.

It is important that someone who is capable of interpreting the MDA readout (in 17/1) is contacted so that the appropriate actions are implemented. This way, if the release

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develops into a catastrophic situation, evacuation of the building can be implemented as soon as possible. A false alarm can also be identified. Personnel who are trained in making this determination include laboratory personnel working with toxic gases, Safety and Health personnel, and personnel from Facilities. However, either Safety and Health or Facilities personnel will determine whether a laboratory representative needs to be contacted. This determination is made either from the remote printer in 17/1 or from information relayed by the guard over the telephone from the guard station in 17/1. If it is possible to communicate the relevant information over the telephone, the determination of release severity can be made much more quickly than waiting for someone to respond in person.

It is not reasonable to expect either Safety and Health or Facilities personnel to effect repairs on the equipment in the laboratories if the situation warrants such action. The research personnel are much more familiar with the equipment used in handling toxic gases and are therefore much better suited to respond to the laboratory.

It is entirely possible that the personnel from a particular laboratory are not available at the time of an alarm. Because of this, it is necessary to possess a backup notification list. This phone list at the Security Desk (page 21), is broken up into two groups. There are four laboratories containing similar type equipment in each group. If the operator cannot notify any of the people from a particular laboratory, personnel from the other laboratories in that group will be contacted until someone is able to respond. This will require that the research personnel become somewhat familiar with the equipment in the other laboratories who are within their notification group.

In Subsection I.C it is pointed out that all toxic gas cylinders are to be shut off at the cylinder valve after each run. It is also stated that no one is to run toxic gases after hours. Provided that these procedures are properly followed, the chance of a catastrophic release occurring after hours is very remote and most responses to an MDA alarm will require minimal action.

EMERGENCY NOTIFICATION

First -----> Guard Desk, X1234
Observer

-----> Facilities
(see on-call list)

----> Env., Safety & Health ----->
W. Griffing, 526-9452, Pager #230-5079
D. Stewart, 239-8427
R. Robbins, 279-1813

Branch Personnel - Bldg. 16
See Lab Emergency Contact List
for lab with alarm

----> Security, J. Howard
425-0342, Pager #230-8825

Notification below dashed
line only for gas release

and at discretion of
Env., Safety & Health

----> Director/Deputy -----> DOE/SAO
Directors* P. Kearns*

----> Area Landlord* ----> External Affairs
(for affected area) S. Morgan-Smith
233-3321

*Consult Directors
Emergency Phone Card
for home phone numbers.

----> Division Director*
(for affected area)

FOLLOW-UP Branch Office
NOTIFICATION (for alarm area)
(NEXT DAY)

----> Directors' Office -----> DOE/SAO, X1378
X7111

----> Env., Safety & Health --> Area Landlord
X7194 (for affected area)

----> Security, X7004-----> Reception/Guard Desk, X1234

----> Division Office
(for affected area)

Area Landlords

15 - Thresher, X1897
16 - Stone, X1370
17 - Sample, X1318
FTLB - Wyman, X1753
FETA - Jones, X1004
WETC - Thresher, X1897
or 966-7164

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Someone from Safety and Health or Facilities will determine whether a research staff member is needed.

The list of responding personnel from the eight laboratories containing toxic gases is arranged in two groups. If you cannot contact a person from the laboratory with the alarm, try contacting someone from a lab in the same group before trying to contact someone from outside that group.

GROUP ONE

LAB 124

Ted Ciszek	674-3424
Rick Schwerdfeger	279-9202
Satyen Deb	443-7847

LAB 222

Brent Nelson	232-6864
Yuegin Xu	278-4571
Simon Tsuo	985-5125
Satyen Deb	443-7847

LAB 216

Rommel Noufi	431-5196
John Tuttle	939-8955
Jim Dolan	922-9649
Satyen Deb	443-7847

LAB 369

Hary Mahan	989-0686
Brent Nelson	232-6864
Simon Tsuo	985-5125
Satyen Deb	443-7847

GROUP TWO

LAB 103

Kris Bertness	494-9656
Elvira Beck	279-5137
Jerry Olson	989-3827
Satyen Deb	443-7847

LAB 222

Brad Thacker	526-2553
John Turner	978-1904
David Szymd	494-3534
Art Nozik	449-0784

LAB 368

Alan Kibbler	494-9025
Jerry Olson	989-3827
Sarah Kurtz	278-2704
Satyen Deb	443-7847

LAB 458

Mark Wanlass	277-1823
Tim Gessert	1-838-0162
Tim Coutts	278-8208
Larry Kazmerski	987-8585

VII) OTHER USES OF THE TOXIC GAS MONITOR

There are situations where the MDA toxic gas monitor could be used in order to have a real time check on the conditions in a laboratory. Examples of this would include the changing of a gas cylinder, dismantling of used equipment, or the first run with a new or modified system, etc. In all these cases it is required that there be two people present in the laboratory and one monitoring the MDA unit. In the case of changing a cylinder or taking apart equipment, SCBA must be worn by the two people in the laboratory. Both Environment, Safety and Health and Facilities should be informed of the operation prior to any work. A representative from the Facilities branch should reset the MDA unit.

IX) DEFINITIONS OF RELEASE LEVELS

Catastrophic Release	High Level Release	Low Level Release
Two or more points readings $\geq$ HL		
Enclosure $\geq$ HL + ambient $\geq$ LL	Enclosure $\geq$ HL + ambient $<$ LL	
Ambient $\geq$ HL	LL $\leq$ Ambient $<$ HL	0 $<$ ambient $<$ LL
3 steady or increasing readings $\geq$ HL	3 decreasing readings $\geq$ HL	LL $\leq$ 3 readings $<$ HL
Readings which are approaching any of the above conditions	Readings which are approaching any of the above conditions	Readings which are approaching any of the above conditions
LL = Low Level Alarm Set Point (1 x TLV) HL = High Level Alarm Set Point (5 x TLV)		

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X) MDA Alarm Checklist

Fill out all of this form. Check off each step as it is completed and only if that step is completed.

- ☐ Silence Alarm.
- ☐ Call x1234.
- ☐ Review printout and determine severity of release. (If catastrophic implement building evacuation procedures.)
- ☐ Enable printer and disable extra points.
- ☐ Review printout and determine severity of release. (If catastrophic implement building evacuation procedures.)
- ☐ One person monitor MDA.
- ☐ Two qualified persons respond to repair leak. Wear SCBA if needed.
- ☐ Determine when safe.

-
- Time of alarm ____:____ am / pm, date of alarm _____.
 - Point number of alarm ____ on MDA unit number ____.
 - This point is monitoring the following location:
 - Provide a brief description of the cause of the alarm and corrective action required:

I have completed the steps as checked off above and have declared the situation resolved. To the best of my knowledge the problem area is safe. I have stappled a copy of the MDA printout from this alarm condition to this form. (Copy may be obtained from 17/1 remote printer.)

Researcher

Date

Obtain the following signatures.

I have assisted in responding to this alarm. _____

Facilities Representative

I have assisted in responding to this alarm. _____

Safety and Health Representative

I am aware of this alarm. _____

Building Landlord

XI) MDA Printer Enable (Disable) Procedures

Required Action	Resulting Readout on MDA
Press together - SET & ESC buttons until the machine stops sampling	SELECT MODE - * ESC FOR LIST
Turn the dial to 3	*
Press the SET button	MODE: PROGRAM OPTIONS (followed by) SELECT OPTION MODE - *
Press the SET button	PRINTOUT - DISABLED (enabled)
Pressing the SET button again allows you to toggle between printer enable and disable	PRINTOUT - ENABLED (disabled)
Press the ESC button for at least 2 seconds	SELECT MODE - * ESC FOR LIST
Turn the dial to 6	*
Press the SET button	MODE: ANALYSIS (followed by) SELECT ANALYSIS MODE - *
Turn the dial to 1	SELECT ANALYSIS MODE - *
Press the SET button	INITIALIZING SEQUENCING MODE (followed by) SEQUENTIAL: POINT # GAS
The printer is now enabled (disabled).	SEQUENTIAL: POINT # GAS

Make sure alarm enable switches (on outside of unit) are on.

Make sure appropriate sample line enable switches (on inside of unit) are on.

XII) TLV, IDLH AND SET POINT TABLE

GAS	TLV(LL) (ppm)	IDLH (ppm)	max. set (ppm)	HL (ppm)	HL/TLV (ratio)	LL/IDLH (ratio)	HL/IDLH (ratio)
arsine	0.05	6.00	1.00	0.25	5.00	0.008	0.042
diborane	0.10	40.00	0.50	0.50	5.00	0.003	0.013
disilane	0.50	N/A	N/A	2.50	5.00	N/A	N/A
germane	0.20	N/A	2.00	0.60	3.00	N/A	N/A
H ₂ Se	0.05	2.00	0.50	0.25	5.00	0.025	0.125
phosphine	0.30	200.00	1.00	1.00	3.33	0.002	0.005
silane	5.00	N/A	25.00	25.00	5.00	N/A	N/A
stibine	0.10	N/A	1.00	0.50	5.00	N/A	N/A

TLV = Threshold Limit Value ("Allowable" 40 hr/wk exposure.)

IDLH = Immediately Dangerous to Life and Health ($\frac{1}{2}$ hour to evacuate without irreversible physiological damage).

LL = Low Level alarm set point.

HL = High Level alarm set point.

max. set = Highest allowable set point on MDA monitor (sequential mode).

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**SOLAR ENERGY RESEARCH INSTITUTE
LABORATORY CHEMICAL HYGIENE PLAN**

May 13, 1991

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Industrial Hygienist
SERI ES&H Section**

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10.0 APPENDIX

- 10.1 OSHA Standard 29 CFR 1910.1450
- 10.2 Carcinogen List
- 10.3 Chemical Compatibility
- 10.4 SERI Lab Specific Chemical Hygiene Plan Worksheet

SERI
LABORATORY CHEMICAL HYGIENE PLAN

Section 1.0 - PURPOSE

The purpose of the SERI Laboratory Chemical Hygiene Plan (LCHP) is to provide SERI management and staff with the guidance and information needed to fulfill the requirements of the OSHA Laboratory Standard, 29 CFR 1910.1450, Occupational Exposures to Hazardous Chemicals in Laboratories.

SERI laboratory workers are generally involved in research activities that use small amounts of a variety of potentially hazardous chemicals for short periods of time. Few laboratory chemicals are without acute or chronic hazards and many of these chemicals, such as reaction products, may be of unknown toxicity. If the hazard properties of the chemicals are not identified and properly controlled during use, you may be needlessly overexposed to these materials which can cause lung impairments, liver damage, cancer, or may even result in death or serious injury due to a fire or explosion.

Achieving a safe laboratory environment requires the same kind of attention and effort that is required for achieving research project goals. Experience has shown that the lab can be a safe workplace if all lab workers are knowledgeable and informed about the hazards in the lab and routinely use the proper work practices to safely control the hazards. This procedure will outline the general precautions required for the safe use, storage and disposal of chemicals in the research laboratory.

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Section 2.0 - SCOPE

The OSHA Lab Standard requires SERI to have a written Chemical Hygiene Plan (CHP) which describes SERI's policies concerning the protection of workers from hazardous materials in the laboratory. This procedure applies to all SERI employees, visiting scientists, and contractors that use, generate, store, or dispose of small quantities of hazardous chemicals within the definition of "laboratory scale" and "laboratory use". This document serves as SERI's CHP.

Exceptions: Those operations, including laboratories, which do not fit the definition of laboratory use or scale must meet the requirements outlined in SERI's Chemical Hazard Communication Procedure (Haz Comm). Examples of operations that must comply with the Haz Comm Program are operations using large quantities of hazardous chemicals such as pilot plants or maintenance activities.

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Section 3.0 - DEFINITIONS

Action Level: a concentration designated in 29 CFR 1910 for a specific substance, calculated as an eight hour time-weighted-average, which initiates certain required activities such as exposure monitoring and medical surveillance.

Carcinogen: see "select carcinogen"

Chemical Hygiene Officer: designated employee who is qualified to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan.

Chemical Hygiene Plan (CHP): the procedures, equipment, personal protective equipment (PPE), and work practices that are capable of protecting employees from health hazards presented by chemicals in the laboratory as required in the OSHA Laboratory Standard. This document serves as SERI's CHP.

Designated Area: an area which may be used for work with "select carcinogens", reproductive toxins, or substances that have a high degree of acute or chronic toxicity. It may be the entire lab, an area of the lab or a device such as a lab hood.

Extremely Hazardous Chemical (Substance): a chemical substance which is extremely hazardous because it has been identified as a select carcinogen, reproductive health hazard, a chemical of moderate/high chronic toxicity, and/or a chemical of high acute toxicity. This term is specific to the requirements of the OSHA Lab Standard.

Hazardous Chemicals: a chemical substance (or material) for which there is statistically significant evidence, based on at least one study conducted in accordance with established scientific procedures, that this chemical is a physical hazard or a health hazard that can cause illness or injury if used the wrong way.

Health Hazard: a chemical substance for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific procedures that acute or chronic health effects may occur in exposed employees. This includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins (liver toxins), nephrotoxins (kidney toxins), neurotoxins, agents which act on the hematopoietic systems (blood forming system), and agents

which damage the lungs, skin, eyes or mucous membranes.

Laboratory: a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

Laboratory Use of Hazardous Chemicals: handling or using chemicals in which all of the following conditions are met: (i) Chemical manipulations are carried out on a "laboratory scale"; (ii) Multiple chemical procedures are used; (iii) The procedures involved are not part of a production process, nor in any way simulate a production process; (iv) "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

Laboratory Scale: work with substances in which the containers used for reactions, transfers, and other handling of substances are designated to be easily and safely manipulated by one person.

LC50: the concentration in air that causes the death of 50% of the test animals. Test animals and test conditions should be specified.

LD50: the quantity of material that when ingested, injected or applied to the skin as a single dose will cause the death of 50% of the test animals. Test conditions should be specified.

Material Safety Data Sheet (MSDS): written information concerning a hazardous chemical that contains the chemical identity of the material, physical and chemical properties, physical and health hazards, protective safety measures and emergency procedures.

Mutagen: a chemical causing a heritable change in the gene structure.

PEL: the Permissible Exposure Levels (PELs) are exposure levels identified by OSHA to which nearly all workers can be exposed day after day without adverse effects. OSHA PELs have the force of law.

Physical Hazard: a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water reactive.

Reproductive Hazard: chemicals which affect the reproductive capabilities including chromosomal damage (mutations) and

effects on the fetus (teratogenesis).

Select Carcinogen: any substance which meets one of the following criteria (see Appendix 10.2):

- * it is regulated by OSHA as a carcinogen
- * it is listed under the category "Known To Be Carcinogens" in the Annual Report on Carcinogens published by the National Toxicological Program (NTP).
- * it is listed in Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer (IARC).
- * it is listed in either Group 2A or 2B by IARC or under the category "reasonably anticipated to be carcinogens" under NTP.

Teratogen: a chemical that produces a malformation of the embryo.

TLV: Threshold Limit Value (TLV) is a term used by the American Conference of Governmental Industrial Hygienists (ACGIH) to express the recommended airborne concentration of a chemical to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. The TLVs are recommendations and should be used as guidelines for good practices. ACGIH TLVs are recommended exposure limits that may or may not be adopted by OSHA as PELs.

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Section 4.0 - RESPONSIBILITIES

- 4.1 SERI Director is responsible for
Supporting and ensuring enforcement of SERI's LCHP.
- 4.2 Operation Managers are responsible for
 - 4.2.1 Ensuring that the requirements of SERI's LCHP are understood and implemented by all laboratory managers.
 - 4.2.2 Ensuring that the Laboratory Specific CHP Worksheets are developed for each laboratory. (Appendix 10.4)
 - 4.2.3 Demonstrating, by active participation, a high level of importance for the LCHP.
- 4.3 Line managers and supervisors are responsible for
 - 4.3.1 Ensuring that laboratory staff know and follow the laboratory safety requirements, that protective equipment is available and in proper working order, and that appropriate training has been provided.
 - 4.3.2 Ensuring that the Laboratory Specific CHP Worksheets are developed and updated as necessary for each laboratory and laboratory staff are instructed as to its contents.
 - 4.3.3 Providing regular self inspections to ensure the requirements of SERI's LCHP are met.
 - 4.3.4 Completing a semi-annual inventory of chemicals in each lab and arranging for the removal of excess chemicals and ensuring existing chemicals are properly labeled and stored. Providing a copy of the chemical inventory to the ES&H Section.
 - 4.3.5 Ensuring that the facilities and training for the safe use of any material being ordered are adequate.

- 4.3.6 Ensuring that MSDSs for all hazardous chemicals in supervised work areas are accessible, either in hard copy or via a MSDS database, within two hours of a request by an employee.

Laboratory operations are not required to develop MSDSs for chemicals synthesized for use in the laboratory.

- 4.3.7 Ensuring lab workers know emergency procedures in case of fire, explosion, or hazardous chemical spills.

4.3 Laboratory Staff are responsible for

- 4.3.1 Understanding the hazard severity of all hazardous materials prior to purchasing, handling, using or disposing of hazardous chemicals.
- 4.3.2 Planning and conducting each operation to ensure the proper work practices, personal protective equipment and facilities are adequate for the safe use, storage and disposal of hazardous chemicals as outlined in this procedure.
- 4.3.3 Ensuring that all hazardous chemicals are properly labeled.
- 4.3.4 Submitting copies of Material Safety Data Sheets (MSDS) to the ES&H Section that are supplied directly to the employee.
- 4.3.5 Immediately notifying the SERI emergency operator (X1234) of emergency situations involving hazardous chemicals.

4.4 Chemical Hygiene Officer is responsible for

- 4.4.1 Working with laboratory staff and other employees to develop and implement appropriate chemical safety practices.
- 4.4.2 Monitoring the procurement and use of chemicals used in the lab.
- 4.4.3 Knowing the current legal requirements concerning regulated substances.

4.4.4 Ensuring a ventilation performance surveillance program for all local exhaust ventilation systems is completed at least annually.

4.4.5 Auditing the performance of SERI's LCHP.

4.5 Facilities Branch is responsible for

4.5.1 Ensuring all eyewash stations and emergency safety showers are maintained for emergency use and are inspected quarterly.

4.5.2 Developing, conducting, and documenting a scheduled (at least annually) preventative maintenance program for new and existing building ventilation systems and all local exhaust ventilation systems which include fume hoods, canopy hoods, laminar flow hoods and biological hoods.

4.6 Procurement Office is responsible for

4.6.1 Requesting a MSDS from the supplier for all hazardous chemical purchases.

4.6.2 Forwarding all MSDSs received to the ES&H Section for inclusion into the MSDS library.

4.6.3 Providing the ES&H Section with a copy of all purchase requests for hazardous chemicals and working with the ES&H Section to screen hazardous chemical purchases.

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Section 5.0 - PROCEDURES FOR WORKING WITH LABORATORY CHEMICALS

It is not possible to list all safety requirements for all types of hazards that may be found in a laboratory. This section establishes some of the more common rules and requirements for the safe handling, use, and storing of laboratory chemicals that have been documented to be useful in minimizing lab accidents.

5.1 GOOD LABORATORY PRACTICES

5.1.1 General Principles

1. Do not underestimate the potential risks involved in handling, using, storing and disposing of chemicals. Exposures should be minimized even for substances with no known significant hazards. One should assume that any mixture will be more toxic than its most toxic component and that all substances of unknown toxicity are toxic. Avoid all skin contact and inhalation of laboratory chemicals.
2. Minimize all chemical exposure by determining and understanding the hazards of chemicals and by knowing and using proper work practices, engineering controls (i.e. ventilation), administrative controls (i.e. SOPs), and personal protective equipment. Know the location of the emergency equipment in your area.
3. Observe the Permissible Exposure Limits (PELs) and Threshold Limit Values (TLVs). The PELs of OSHA and the TLVs of the American Conference of Governmental Industrial Hygienists must not be exceeded.
4. Recognize and try to control the following factors which have historically resulted in laboratory incidents causing deaths, injuries, illnesses and property losses:
 - * Incorrect handling and storage of hazardous chemicals
 - * Improper use of flammable and explosive materials
 - * Incorrect use of strong acids and alkalis
 - * Careless use and handling of glassware
 - * Lack of proper housekeeping
 - * Improper use or bad repair of electrical equipment
 - * Failure to properly dress or to use protective equipment
 - * Inadequate fire prevention procedures

- * Inadequate first-aid and emergency procedures
- * Incorrect use or careless handling of radioactive and biological materials

5.1.2 Hazard Identification

Proper hazard identification is critical to controlling lab hazards before they result in injuries or illnesses. The following hazard identification processes are utilized at SERI:

1. Laboratories must be inspected monthly by management and staff to identify and correct deficiencies in the implementation of the LCHP. Both the inspection and corrective actions must be properly documented.
2. As required in SERI's ES&H Policy and Procedure Manual, laboratory management must ensure the following applicable safety documents are completed when warranted:
 - * Safety Analysis Review (SAR)
 - * Safe Operating Procedure (SOP)
 - * Unusual Occurrence Report (UOR)
 - * Individual Accident/Incident Report
3. As outlined in greater detail in Section 5.2 - Special Procedures for Extremely Hazardous Substances, prior management approval and a completed SOP is required for work with these substances.

5.1.3 Basic Safe Work Practices

The following safe work practices apply to all laboratory operations and should be used as general guidelines.

1. Prior to any new operation, seek information and assistance about possible hazards and controls required for the work area. Ensure that all laboratory activities are reviewed for safety and health problems and prepare and follow the Safe Operating Procedures (SOP) for your work area. (see ES&H Policy & Procedures for SOPs)
2. Conduct regular self-inspections of your work area and correct all safety problems as they are identified. Do not wait for a scheduled safety inspection! Most safety problems can be identified on a daily basis by lab personnel.
3. Observe caution when working alone. Anyone wanting to work alone outside of normal work hours (8:00 a.m. to 5:00 p.m.) must obtain their supervisors's written permission if the work is hazardous. No use of "acutely

toxic gases" outside of normal working hours is allowed.
(see ES&H Policy & Procedures)

4. Properly label all hazardous materials with (at least) the names(s) of the primary hazardous ingredients, an appropriate warning statement of the physical and health hazards of the material, and an expiration date for age sensitive materials.
5. Post warning signs for hazardous operations (i.e. laser operation, biological or radiation hazards) and to indicate designated work areas with extremely hazardous materials.
6. Ensure a current Emergency Notification Card is posted on the entrance door for each laboratory.
7. Inspect laboratory glassware before using and do not use damaged glassware. Use a thick cloth and/or gloves when fitting glass tubing into corks. When possible, flame polish the ends of tubing.
8. Discourage unattended potentially hazardous operations. If an operation is left unattended, the operation should be posted with a sign to indicate an operation is in progress (i.e. "Experiment in Progress") which includes the name of the responsible employee and a date.
9. If safe to do so, promptly cleanup all spills using proper protective equipment and disposal procedures. If the cleanup cannot be done safely by laboratory personnel, activate the Emergency Notification System by dialing X1234 and allow properly trained emergency response personnel to cleanup the spill. (see Sec. 6.5)
10. Special precautions are required for handling extremely hazardous chemicals. Only use perchloric acid in a specially designed ventilation hood to avoid possible explosions from accumulated dried perchloric acid. Whenever possible, substitute salts or acids without perchlorate ions.
11. When possible, purchase chemicals in non-breakable containers.
12. Use local exhaust ventilation systems such as a laboratory ventilation hood or glove box for operations which might result in the release of toxic or flammable materials.
13. When chemicals are hand carried in breakable containers, they should be placed in an outside container or acid-

carrying bucket to protect against breakage and spillage.

14. Safety shielding should be used for any operation having the potential for explosion.
15. Ensure that proper personal protective equipment is worn by all persons, including visitors, as required based on the activities conducted in the lab.

5.1.4 Procurement and Distribution of Chemicals

The achievement of safe handling, use, and disposal of hazardous chemicals begins with the person who purchase the chemical. The following actions should be followed:

1. Lab employees and supervisors purchasing hazardous chemicals (stock and special order) must be familiar and understand the proper handling, storage and disposal requirements and ensure that adequate safety facilities (i.e. storage, ventilation) are available before ordering.
2. Order the smallest quantity that is required for the immediate task. Excess chemicals that are not used represent a potential hazard when stored in the lab and can be very expensive to dispose of as a hazardous waste.
3. Substitute a less hazardous material when possible.
5. The Procurement Office will send copies of all potentially hazardous chemical purchase orders to the ES&H Section. The ES&H Section will work with the Procurement Office to screen hazardous substance Purchase Orders for ES&H implications and contact the Requestor if questions arise.

5.1.5 Chemical Handling

5.1.5.1 General Guidelines

1. Keep all chemical containers closed when not in immediate use. This will minimize the vapors emitted and reduce the potential for spills.
2. When chemicals are hand carried in breakable containers, they should be placed in an outside container or acid-carrying bucket to protect against breakage and spillage.
3. Keep open flames and spark producing equipment away from flammable liquids and vapors.

4. Do not handle and/or open chemical containers that appear to be bulging, leaking or suspect. Get safety assistance.
6. Do not attempt to lift glass dewars by the neck since the inner vessel of a double walled dewar is supported by the neck and the chance for container failure is increased. Use handles on container if available.

5.1.5.2 Acids and Bases

1. Transfer acids and bases under local exhaust ventilation. Do not pour from a carboy; always siphon.
2. Never pour water into concentrated acids or onto solid caustics.
3. Use proper personal protective equipment and clothing.

5.1.5.3 Explosives/Reactive Including Organic Peroxides

1. Some chemical compounds can be explosive or highly reactive. In general, compounds containing the following functional groups tend to be sensitive to heat and shock: acetylide, diazo, halamide, nitroso, ozonide, azides, and peroxide. Compounds containing nitro groups may be explosive or highly reactive. Perchlorates, chlorates, nitrates, bromates, chlorites, and iodates, whether organic or inorganic, should be treated with respect, especially at higher temperatures. *The handling of potentially explosive compounds demands attention to minute details.* The following are some general precautions to be taken:
 - * Various Federal and State regulations exist for the transportation, storage, and use of explosives. Explosive material may not be brought into the lab without prior approval from the lab supervisor and an approved SOP.
 - * The unusual nature of work involving these substances requires special safety procedures that must be thoroughly understood and followed by all persons involved.
 - * Quantities must be kept to a minimum and the substances removed and properly disposed of from the lab when no longer needed.
 - * Proper handling precautions must be specified such as required personal protective equipment (faceshield, heavy gloves, etc.) protective devices (shields,

barriers, etc.), and proper handling procedures. These must be detailed in the SOP.

2. Organic peroxides are a special class of compounds and can be the most hazardous substances normally handled in the lab since they can act as low-power explosives. They are hazardous because of their extreme sensitivity to shock, sparks, or other forms of ignition. Some general precautions for handling peroxides include the following:

- * All peroxide forming chemicals should be identified when received and labeled with a separate label. Stock labels are available and must include the date received, date opened, and date due for testing or disposal.
- * Metal spatulas or other metal implements should not be used in contact with peroxides, since contamination by metals can lead to explosive decompositions.
- * All sources of heat or ignition should be eliminated before working with peroxides.
- * Avoid solutions of peroxides in volatile solvents under conditions where the solvent may be evaporated and increase peroxide concentration.
- * Work with dilute solutions of peroxides in inert solvents, such as aliphatic hydrocarbons to reduce their sensitivity to shock and heat.

5.1.5.4 Alkali Metals

1. Examples of alkali metals are sodium or potassium. Assume that flammable hydrogen is present when you open containers of alkali metals.
2. Locate the process as to avoid contact between alkali metals and water.
3. To handle spills or drips, install catch trays.
4. Have available special fire extinguishing agents such as "Metal X" as needed.
5. Handle solid alkali only with tongs or with impermeable gloves.
6. Evaluate and develop proper handling requirements before using alkali metals.

5.1.5.5 Cryogenic Fluids

1. At a minimum, heavy gloves and faceshield should be worn when handling cryogenic fluids. Avoid wearing watches or jewelry.
2. Always perform operations, such as charging a warm container with liquid nitrogen, slowly to minimize boiling and splashing.
3. Open valves carefully. A sudden release of pressure can result in explosive expansion which can cause severe injury to any persons directly in its path.
4. Do not hit liquid oxygen containers since liquid oxygen is shock sensitive.
5. Confinement and storage of cryogenic fluids at low temperatures followed by the loss of insulating capacity can result in extremely high pressure build-up in vacuum-jacketed lines or vessels. Ice formation in the neck of small dewars, or cryogenic fluid trapped between valves, can also result in high pressure build-up.

5.1.5.6 Flammable and Combustible Liquids

1. Employees should know the location and proper use of the fire extinguisher and the fire alarm for their workplace.
2. Keep open flames and spark producing equipment away from flammable liquids and vapors. Enforce the "No Smoking" rule.
3. Make certain that all static electricity sources are grounded and/or bonded.
4. Make certain that electrical equipment for potential flammable/explosive atmospheres is in compliance with the National Electric Code No. 70.
5. Only use flammable liquids in the minimum quantities needed for immediate use.
6. Only UL listed explosion-proof laboratory refrigerators should be used for storage of volatile flammable and combustible liquids.
7. As a general rule, store flammable liquids in approved flammable liquid storage cabinets or containers.

5.1.5.7 Radioactive Materials

Hazardous chemicals that may be radioactive must be handled under the authorization of an approved SOP and in compliance with SERI's Radiation Safety Procedure.

5.1.5.8 Allergens/Sensitizing Agents

Use gloves and other skin protection as required to avoid skin contact. Handle these materials under local exhaust ventilation whenever possible. If an employee becomes sensitized, it may be necessary to eliminate all contact by the employee with the material in question.

5.1.6 Chemical Storage

Every chemical should have a definite storage place and should be returned to that location after every use. The following section provides general guidance for proper chemical storage.

5.1.6.1 Stockrooms

1. Chemicals should be segregated in a well-identified area with local exhaust ventilation, clear aisle space and adequate shelf space. Chemicals which are extremely hazardous should be stored in unbreakable secondary containers.
2. Stored chemicals should be examined periodically (at least annually) for replacement, deterioration, and container integrity.
3. Stockrooms/storerrooms should not be used as preparation or repackaging areas. They should be accessible during normal working hours, and should be controlled by one person.
4. Many chemicals are incompatible and reactive. Chemicals must be properly segregated and stored according to their hazard class to prevent fires, explosions, or uncontrolled chemical reactions.

5.1.6.2 General Laboratory Storage Considerations

1. A chemical inventory must be completed at least semi-annually and an inventory record maintained. Periodically dispose of or return unneeded items by contacting the ES&H Section. Many chemicals can be redistributed if they are turned into the ES&H Section and are in good condition for use by others.

2. The number and quantity of chemicals stored in the lab must be kept to a minimum.
3. Store chemicals in storage cabinets as opposed to bench tops or hoods. Shelves should have retaining lips if open shelf storage is required.
4. All chemicals must be properly labeled with the chemical name and hazard warning(s).
5. Store chemicals in well stoppered, labeled containers. Extremely hazardous substances should be stored in a second, unbreakable container.
6. Store strong oxidizers and flammable substances separately from each other. Store flammable solvents in an approved flammable storage cabinet with self-closing doors.
7. Incompatible chemicals must not be stored together. A list of incompatible chemicals can be found in Appendix 10.3 This list is not comprehensive but provides general guidance with common examples.
8. Storage areas for extremely hazardous substances (including select carcinogens) should have a sign posted warning of the hazard, have controlled access, and be stored in adequately ventilated storage areas in unbreakable, chemically resistant secondary containers.

S.1.6.3 Acids and Bases

1. Acids and bases are highly reactive and corrosive compounds. They should be stored in ventilated areas away from water.
2. Keep acids and bases in corrosion resistant trays of sufficient volume to hold at least the loss of the entire contents.
3. Do not keep acids and bases in the same tray. Store strong oxidizing acids and organic acids in separate spill trays.
4. Store acids and bases below eye level and away from heat and light.

5.1.6.4 Explosives/Reactive Including Organic Peroxides

1. This class of chemicals must be routinely and closely managed and kept to a minimum. The lab chemical inventory should be maintained so that the number and quantity of these substances can be properly managed.
2. Ethers, dioxane, tetrahydrofuran (peroxide forming chemicals) and other chemicals that are age sensitive must be labeled with the date received, date opened, and date due for testing, discard or disposal which generally should not be longer than six months.
3. Peroxides must be managed so that the manufacturer's shelf life requirements are not exceeded. A general rule is that peroxide-forming chemicals should not be stored longer than six months.
4. Organic peroxides should be stored at reduced temperatures in an explosion-proof refrigerator in accordance with the manufacture's instructions.

5.1.6.5 Alkali Metals

1. The hazards of alkali metals arise from their high degree of reactivity with numerous materials. Alkali metals must not be stored with incompatible chemicals such as water, acids, alcohols, or oxidizing material.
2. Keep storage facilities dry and protect from water sources such as sprinklers, steam, etc.
3. Provide adequate ventilation, either natural or mechanical, to assure safe dissipation of hydrogen that may be generated.

5.1.6.6 Cryogenic Fluids

1. Storage containers should be able to withstand the weights and pressures that will be encountered.
2. Adequately vent the container to permit the escape of evaporated gas.
3. Confinement and storage of cryogenic fluids at low temperatures and pressures followed by the loss of insulating capacity can result in extremely high pressure build-up in vacuum-jacketed lines or vessels. Ice formation in the neck of small dewars, or cryogenic fluid trapped between valves, can also result in high pressure build-up.

4. Store with adequately sized and properly located relief valves, rupture disks and vents.
5. Ensure that only properly trained and authorized personnel have access to cryogenic fluid storage areas.

5.1.6.7 Flammable and Combustible Liquids

1. The maximum amount of flammable and combustible liquids stored in open areas in individual laboratories or rooms should be maintained at one day's working level only.
2. When not in use, flammable and combustible liquids must be stored in approved flammable liquid storage containers or cabinets. At a minimum, this must be done at the end of the work day.
3. Large quantities of flammable and combustible liquids should be stored in approved and designated storage areas.
4. Do not store flammable and combustible liquids near any oxidizer.
5. Provide adequate ventilation to prevent accumulation and ignition of flammable vapors.
6. Store in a location away from ignition sources.

5.1.7 Proper Hygiene and Housekeeping

1. Laboratory refrigerators, ice chests, cold rooms, etc. must not be used for food storage and must be labeled as such. Separate equipment must be dedicated for food storage and prominently labeled as such.
2. Eating, drinking, food preparation, and applying cosmetics is prohibited in the laboratory. Wash hands before conducting these activities and after using or handling hazardous chemicals.
3. Wash areas of exposed skin well before leaving the laboratory. Touching, tasting, smelling chemicals as a means of identifying their composition should not be performed. Avoid inhaling gases and vapors. In case of skin contact, promptly flush the affected area with water and remove any contaminated clothing.
4. Mouth pipetting is prohibited.

5. Confine long hair (including beards) and loose clothing around moving machinery and open flames.
6. Work areas must be orderly , free of obstructions and clean. Cleanup must be completed at the end of any operation or at the end of the shift.
7. Keep aisle free of obstructions and keep work areas orderly. All unnecessary items should be removed from the lab and all necessary items should be properly stored.
8. Access to exits, emergency equipment, controls, etc. must be kept clear. Emergency evacuation routes must have a minimum 44 inches clearance and should be posted.

5.1.8 Proper Use of Laboratory Safety Equipment

1. Lab ventilation hoods: see Section 6.3.
2. Vacuum pumps used with hazardous materials must be vented into a local exhaust ventilation system such as a lab hood.
3. Use care with Dewar flasks and other evacuated glass apparatus. This equipment should be shielded or wrapped in case of implosion during use.
4. Lab equipment must be operated in an electrically safe manner including:
 - * Complying with the SERI Electrical LOCKOUT & TAGOUT Procedure.
 - * If electrical conditions exist which are not understood by the person performing the work, the worker must consult their supervisor or the ES&H Section regarding safe work methods.
 - * All electrical outlets and equipment must be grounded.
 - * Electrical cords and connections must be kept out of water. Ground fault circuit interrupters are required for installations near water.
 - * All electrical connections must be encased or shielded to prevent accidental contact to live electrical components.
 - * Motor-driven electrical equipment used in a lab where volatile flammable vapors may be present must be equipped with a nonsparking induction motor.
 - * Extension cords should not be used in place of permanent hard wiring.
 - * There should be no potential sources of electrical sparks on the inside of a laboratory refrigerator which is used to store flammable/combustible liquids.

5. Autoclave sterilizers must be safely operated as follows:

- * Never place clean and contaminated material in the same autoclave. Old media, alkali, or other liquid may boil over and contaminate the clean material.
- * Do not autoclave plastic material unless it is capable of withstanding the temperatures.
- * Never autoclave flammable liquids.
- * Ensure the pressure vessel and the pressure relief device is properly vented into a local exhaust ventilation system.
- * Make sure the autoclave is equipped with pressure release controls for opening, or explosion protection and remote controls for high pressure autoclaving.
- * Loosen all stoppered or sealed containers before autoclaving.
- * Keep face away from door when opening a hot autoclave.
- * Never reach inside, unless wearing protective gloves, until the steam is completely exhausted and the apparatus is cool.

6. Centrifuges must be equipped with:

- * Adequate shielding - double walls provide greater protection.
- * An interlock disconnect switch which shuts off the rotor if the top is opened.
- * Positive locking for the head.
- * Electrical grounding.
- * Suction cups or wheel brakes to prevent "walking".
 - Never try to stop a moving centrifuge by hand.
 - Apply the brakes or let it run down by itself.

7. Chromatography equipment should be equipped with adequate ventilation to remove any vapors, etc. from work area.

8. Environmental chambers, either as cold or warm rooms, have the inherent property of being a closed air-circulation system in a contained room that can result in entrapment or buildup of toxic vapors/gases inside the rooms. Environmental chambers should:

- * Be equipped so an employee cannot get trapped inside (i.e. use magnetic door latch).
- * Be equipped so that a person can signal for help in case of an emergency (i.e. alarm, telephone).
- * Be considered as a "Confined Space" as outlined in SERI's Confined Space Procedure if air quality or escape provisions present a significant hazard.
- * Be equipped with monitoring devices and alarms if potentially explosive, toxic or oxygen deficient atmospheres may be present.

9. Refrigerators should be:

- * Electrically grounded.
- * Approved for storing flammable liquids.
- * Properly labeled as to the status of the storage.
- * Do not store chemicals, film, or other non-food items in refrigerators used for food storage.

10. Cryogenic apparatus:

- * Ensure adequate ventilation is available so that a routine or accidental release of the entire contents does not cause an oxygen deficient atmosphere.
- * Provide oxygen monitoring devices and alarms as needed.
- * A "Confined Space" permit may be needed if an oxygen deficient atmosphere could develop due to a catastrophic release of the contents.

5.2 SPECIAL PROCEDURES FOR EXTREMELY HAZARDOUS SUBSTANCES

SERI has made special provisions for its employees who work with extremely hazardous substances. This section describes additional special controls that are required for those activities that use or handle significant quantities of extremely hazardous chemicals that may pose a carcinogenic, reproductive (teratogenic, mutagenic) hazard or are highly toxic. The adoption of these controls to a specific activity must be based on the judgement of the employee and/or supervisor responsible for safety of chemical operations under his/her control.

5.2.1 Types of Substances Covered Under This Section

- 5.2.1.1 Select Carcinogens (see definition): Appendix 10.2 lists carcinogens covered under this section.
- 5.2.1.2 Substances of Moderate, Chronic or High Acute Toxicity: Examples of substances with these degrees of toxicity include diisopropylfluorophosphate, hydrofluoric acid, and hydrogen cyanide.
- 5.2.1.3 Substances of High Chronic Toxicity: Examples of substances with high chronic toxicity include dimethylmercury, nickel carbonyl, benz-o-pyrene, and N-nitrosodiethylamine, as well as a number of potent human carcinogens.

5.2.1.4 Reproductive Health Hazards: Examples of these substances are teratogens such as organomercurial compounds (e.g. methyl mercury), lead compounds, formamide and male reproductive hazards such as dibromochloropropane. The MSDS may be the best source of information for identifying these materials. Additional information is provided below.

5.2.2 General Requirements

1. Safe Operating Procedures (SOP): SOPs are required for working with these substances and must identify the hazards involved and outline the routine and special controls as required in this section. Lab supervisors and employees working with these substances must be familiar and follow these specific procedures.
2. Designated Areas: Work involving these compounds must be done in "designated areas". The purpose of the designated area is to restrict all activities involving these substances to a specific area. The designated area can be an entire lab, a section of the lab, or a hood. All handling and use of these substances should occur only in the designated area and should include the following:
 - * The designated area should have specific identified boundaries with a sign indicating the designated area and the types of substances being handled;
 - * Only authorized personnel are allowed to enter and work in the designated area;
 - * Special controls for minimizing exposure;
 - * Special storage provisions may need to be specified such as storage of containers in a limited access area in appropriately labeled and unbreakable, chemically resistant secondary containers;
 - * Employees should receive special training by their lab supervisor concerning the hazards and proper safe work practice requirements in the designated area;
 - * Consideration should be given to the need for special personal hygiene facilities; i.e. sinks with wash stations;
 - * Special requirements for containment devices, non-contamination/decontamination, exiting and recordkeeping requirements (see discussion below).

3. Containment Devices: Work which involves the potential for release of vapors, dusts, fumes, or gases from the special substances being handled should be used in containment devices such as hoods and glove boxes when practical to minimize employee exposure.
- * Special considerations must be made to ensure other equipment or operations are not contaminated with these extremely hazardous substances.
 - * Glove boxes should be periodically inspected to ensure that the equipment is in good shape and that unintentional releases of substances cannot occur from tears, gaps, etc.
 - * Negative pressure glove boxes should have a minimum ventilation of 2 volume changes/hour and a negative pressure of 0.5 inches of water. A manometer can be installed to indicate if adequate negative pressure is present.
 - * "Designated Area" containment devices should be evaluated to determine if an inline high efficiency particulate air (HEPA) filter or scrubber is required to remove highly toxic substances from the air stream before being exhausted from the building.
4. Non-contamination/Decontamination Procedures: Special non-contamination and decontamination procedures must be specified when working with a extremely hazardous substance and must include, but not be limited to the following:
- * Protect vacuum pumps and other equipment against contamination by scrubbers, traps, or HEPA filters and vent them into an approved LEV system.
 - * When practical, working surfaces should be protected from contamination by using chemically resistant trays that can be easily decontaminated or use dry, absorbent, plastic-backed paper that can be disposed after use.
 - * Clean up of dry substances should be performed using wet techniques or a vacuum cleaner with a HEPA filter.
 - * All equipment (i.e. glassware) removed from the designated area must be thoroughly decontaminated before it is removed from the designated area.
 - * All materials used for cleaning and decontaminating equipment and surfaces must be collected and disposed as a regulated waste. This includes contaminated protective clothing.
 - * The designated area must be decontaminated before normal work is resumed there.
 - * Cleanup and removal activities should be performed

with adequate personal protective equipment including skin protection (gloves, lab coat) and respiratory protection if exposure to air contaminants is possible.

5. Exiting: On leaving a designated area, remove any protective equipment such as a lab coat and thoroughly wash your hands, forearms and face as necessary.
6. Records: Keep accurate lab records of the amounts of these substances stored (chemical inventory) and used, the dates of use, and names of users. A laboratory notebook should be used to record user information and must be readily available for each lab and retained indefinitely.

5.2.3 Reproductive Health Hazards

Reproductive health hazards can affect both males and females. Teratogens are substances which adversely effect the fetus carried within the exposed mother during her pregnancy. Exposure to these compounds during pregnancy can lead to spontaneous abortions, birth defects, and health problems for the child and mother which may not be evident until after delivery. The period of greatest susceptibility to teratogens is during the first 8 to 12 weeks of pregnancy. During this time a woman may not realize she is pregnant. Therefore, women of child-bearing age need to avoid skin contact with ALL chemicals. The women should also follow the additional procedures described below whenever they work with teratogens:

1. Consultation with supervisors, the SERI Occupational Health Nurse and Chemical Hygiene Officer is extremely important.
2. All work with teratogens and other reproductive hazards must be in a designated work area whenever it is warranted.
3. Teratogens that need special controls must be stored in a ventilated area, in an unbreakable secondary container with the container clearly marked indicating a reproductive hazard.
4. All engineering controls, personal protective equipment and administrative controls must be used to protect women and men from embryotoxins. Supervisors will be notified of all accidental releases of embryotoxins and of all personal contaminations involving these compounds. Physicians should be consulted when necessary.

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Section 6.0 - CONTROL MEASURES FOR REDUCING POTENTIAL HAZARDS

Control measures are extremely important components in reducing potential exposures to employees. This section describes the types of controls that can be used to reduce employee exposure to hazardous chemicals, and how to determine when they are needed.

6.1 Types of Controls Available

Employee exposures to potential hazards can be controlled through the following basic methods:

- * Use of engineering controls
- * Administrative controls and following proper work practices
- * Proper use of personal protective equipment
- * Proper use of emergency safety equipment and procedures

6.1.1 Engineering Controls

The use of engineering controls involves permanent changes to the operation to reduce or remove the hazard from the laboratory. This is the best method for controlling the hazard and should be used whenever feasible. Examples of these methods include the following:

1. Performing the operation in a lab hood to capture and remove any hazardous releases from the operation.
2. The use of snorkels and other local exhaust ventilation devices to capture and remove any hazardous substance at the point of release. Exhaust from gas chromatograph, vacuum pump exhaust or other lab equipment can be vented to the exhaust ducting to avoid releasing the substance into the lab work area.
3. Enclosing a noisy operation to reduce the noise exposure of exposed employees.

6.1.2 Correct Work Practices

The purpose of the use of proper work practices is to design and implement the procedures and techniques that result in minimizing employee exposure to the hazardous substances. SOPs are used at SERI to develop and outline the proper work practices to minimize employee exposure. Examples of proper work practices include the following:

1. Allowing an experiment to cool down or to dissipate any residual vapors before opening it to the lab environment.
2. Using the correct tools (i.e. spark proof) and equipment to minimize the potential for spills, releases or fires.
3. Developing procedures for the correct sequence in mixing chemicals to minimize releases of vapors; e.g. adding powders to water rather than water to powders.
4. Using secondary spill trays or absorbent paper to minimize lab area contamination.
5. If possible, substituting a less toxic substance for a more toxic substance such as:
 - * Using toluene or xylene in place of benzene
 - * Using an aqueous soap solution to clean flasks in place of volatile organic solvents.

6.1.3 Emergency Safety Equipment

The following emergency safety equipment should be readily available to lab occupants when needed. The equipment should be located in readily accessible locations and must not be blocked by equipment or stored items. The equipment must be inspected on a predetermined interval.

1. Eye wash stations should be readily accessible if corrosive materials or other eye hazards exists which can cause eye damage. A label or sign should be posted near the eye wash to indicate its location if not obvious. Testing and inspection should be performed at least quarterly.
2. Drench type safety showers must be present if materials which can cause skin burns, or other serious skin problems are handled and splashes over the major portions of the body can occur. A label or sign should be posted to indicate its location if not obvious. Testing and inspection should be performed at least quarterly.
3. Fire extinguisher and chemicals spill kits should be available as needed.

6.2 DECIDING WHEN CONTROLS ARE NEEDED

The need for controls to reduce employee exposure during a specific operation should be based upon a determination of the potential for exposure during the operation. The ES&H Section should be consulted to assist you in determining if additional controls are required. In general, the criteria to consider are:

- * Length of employee exposure (full shift vs. short-term)
- * Magnitude of hazard based on the types of substances being handled or used.
- * Effectiveness of controls present to reduce employee exposure.
- * Number of employees involved.
- * Quantities of hazardous chemicals used.

Two types of Employee Exposure Determinations are described below:

- * Employee Exposure Monitoring
- * Employee Concerns/Symptoms

6.2.1 Employee Exposure Monitoring

Deciding When Monitoring Is Required

Exposure monitoring to measure the amount of employee exposure during a specific operation provides the best indication of whether controls are needed or if exposures are within acceptable limits (e.g. PELs, TLVs). In general, employee exposure monitoring is an important part of SERI's ES&H Program and the ES&H Section should be consulted to ensure proper monitoring is conducted. However, employee exposure monitoring is required by OSHA for only a limited number of substances. These are listed below. In addition, employee exposure monitoring may be required to ensure compliance with the PELs or TLVs (see following section).

OSHA regulations require that employee exposure monitoring be performed for the following substances if the exposures can exceed the action level for the substance.

- * benzene
- * asbestos
- * dibromochloropropane
- * inorganic arsenic
- * inorganic lead
- * vinyl chloride (monomer)
- * acrylonitrile
- * formaldehyde
- * ethylene oxide

Interpreting Monitoring Results

SERI uses two sets of exposure limits for comparison to accepted exposure criteria as follows:

- * The OSHA Permissible Exposure Limit (PEL) for any substance regulated by OSHA. These are legal limits that must be met for any lab operation.
- * The Threshold Limit Values (TLV) as listed by the American Conference of Governmental Hygienist.

Many substances have both a PEL and a TLV. In some cases these two limits are different for the same substance. In these cases, it is SERI's policy to use the lower of the two limits to evaluate exposure results. Remember, it is good practice to minimize all unnecessary chemical exposure even if the results are below the PEL or TLV.

6.2.2 Employee Concerns/Symptoms

A second criteria for determining if additional controls or exposure monitoring is required is for responding to employee concerns and/or symptoms. Employees are usually the most familiar with the real operating conditions and can provide useful information of those situations that may produce adverse effects. If a number of employees have identified similar effects or symptoms it may indicate the need for additional monitoring or the installations of controls. In some cases, controls may be straight forward (i.e. install lab hood) and it may not be desirable to wait for monitoring. The decision to install controls in response to employee concerns is a valid approach. Employees that have concerns/symptoms due to a potential hazardous material exposure should immediately contact their supervisor and the ES&H Section to investigate the concern so that the need for corrective action can be evaluated and taken.

6.3 Lab Ventilation

Local exhaust ventilation such as lab hoods, glove boxes, and snorkels must be used to protect lab personnel from potentially hazardous exposures from gases, vapors, particulates and other materials released from lab operations. Additional detailed requirements can be found in SERI's Local Exhaust Ventilation Program procedure. The following general practices should be followed when using laboratory hoods:

1. Lab hoods approved for use with hazardous materials must meet the following criteria:
 - * The average flowrate at the face of the hood should be at least 100 fpm.

- * The flowrate should not be less than 80 fpm at any point on the face of the hood.
 - * Lab hood flowrates should be monitored at least annually and after any repair/modifications that may alter the flowrates.
 - * Each lab hood should be labeled to indicate the minimum use requirements the hood is approved for, the date of the last test, and the next due date.
 - * A calibrated and operational airflow sensing device with a visual and audible low-flow alarm should be present with an airflow indicator ribbon.
 - * Emergency power requirements must be determined and followed.
2. The following practices must be followed when using lab hoods:
- * Chemicals or lab equipment must not be stored inside laboratory hoods since it may impede airflow;
 - * Confirm adequate ventilation performance before use;
 - * Operate the lab hood at the proper sash height. The hood performance label or sash stops will indicate the proper position and is based upon the proper average face velocity of the hood. Lowering the sash during use provides additional face/eye and inhalation hazard protection. Close the sash when the hood is not to be used or at least at the end of the shift;
 - * Work as far into the hood as possible;
 - * Use only the equipment necessary for the experiment in the hood. Avoid positioning equipment so that it blocks the air flow. Use equipment with legs to facilitate air flow under the equipment;
 - * Keep your head out of the hood during experiments;
 - * Leave the hood on when not in use unless specific instructions are given otherwise;
 - * Hoods and the fan control box must be tagged out of service when the ventilation fan is turned off.
3. Glove boxes should be periodically inspected to ensure the equipment is in good shape and the unintentional release of substances cannot occur from tears, gaps, etc. in the equipment.

Negative pressure glove boxes should have a minimum ventilation of 2 volume changes/hour and a negative pressure of 0.5 inches of water. A manometer can be installed to indicate if adequate negative pressure is present.

6.4 Personal Protective Equipment (PPE)

This method should be the last option considered for controlling exposures since it requires employees to cooperate in using the equipment correctly, that they understand the limitations of the equipment and that the equipment is readily available for use. Protection such as goggles, faceshield, gloves, apron, and lab coats should be in addition to other controls as described above. Respiratory protection must be obtained and used as described in SERI's Respiratory Protection procedure.

1. As a general rule, all personnel, including visitors and subcontractors, must wear eye protection when inside the defined lab working area and whenever an eye hazard may exist such as when chemicals are being handled. Avoid the use of contact lens. Contact lens may not be worn when personnel are potentially exposed to or handling chemicals. Prescription safety glasses must be worn instead.
2. Use face shields and/or goggles when there is a danger of splashing chemicals or flying particles. This is particularly important with corrosive materials, e.g. acids and bases. Use goggles when using glass apparatus for combustion, high temperature and high/low pressure operations and salt baths. Use properly selected eyewear when working around UV, IR, and laser radiation.
3. Gloves must be worn whenever it is necessary to handle corrosive/toxic chemicals, rough or sharp edged objects, and very hot or cold materials. The proper glove must be selected based on the material/chemical being handled, the particular hazard involved, the suitability for the operation being conducted, and replaced periodically. No one glove can protect against all chemicals! Glove materials are eventually permeated by chemicals. Before removal, gloves should be washed. Inspect gloves before each use by filling with air, tying off, and examining for leaks. A table showing resistance to chemicals of common glove materials is posted at the FTLB stockroom.
4. Respiratory protection is required if other controls are not feasible or adequate to reduce personal exposures to acceptable levels. Contact the ES&H Section for assistance in selecting the correct respirator. All respirator users must have a current SERI Respirator Certification Card (see written SERI Respiratory Protection Program procedure).

5. Lab coats or other protective equipment should be worn by all personnel working with chemicals. Special protective equipment such as rubber aprons, rubber boots, gloves should be worn when handling corrosive or other hazardous chemicals, e.g. hydrogen fluoride. Contaminated clothing should never be taken home and must be disposed as a potential hazardous waste.
6. All lab personnel must wear closed shoes compatible for the hazards in the lab.

6.5 Hazardous Material Spill

General experience has shown that accidental releases or spills of hazardous materials is a common enough occurrence in laboratories and that preplanning for procedures that will minimize exposure of personnel and property are necessary. SERI has established an Emergency Preparedness Plan which includes an Emergency Notification System and an Emergency Response Plan. All emergencies are to be reported by dialing X1234 which will implement the Emergency Notification and Response Plan. The following is a general response procedure to be followed in the event of a hazardous material spill:

1. Immediately evaluate the hazard severity of the spill by determining the following factors:
 - * Identify the hazard properties of the material spilled (flammable, corrosive, reactive, radioactive, etc.)
 - * Physical characteristics (solid, volatile liquid, etc.)
 - * Quantity of spill
 - * Adequacy of existing facilities to safely control spill (i.e. ventilation, drainage to sewer, potential exposure to lab/building occupants)
2. Implement the SERI Emergency Notification System by dialing X1234 if you are unsure about the hazard severity and for all spills that cannot be immediately controlled safely. Report all mercury spills and other spills of extremely hazardous materials and evacuate the area and affected personnel. If the safety of other building occupants is in question, pull the fire alarm to evacuate the building and follow the proper building evacuation procedure.

3. Minor spills that can be cleaned up safely should immediately be cleaned up by personnel within the area ONLY IF IT CAN BE DONE SAFELY!
 - * Take care of injured or contaminated personnel
 - * Notify persons in the immediate area of the spill
 - * Evacuate all nonessential personnel from the area and secure the area
 - * Immediately stop the source of discharge, ONLY IF SAFE TO DO SO! This may involve:
 - Avoid breathing vapors and all skin/eye contact - use proper PPE (i.e. respirator, gloves, etc.)
 - If the spill material is flammable, turn off ignition and heat sources
 - Leave on ventilation if safe to do so
 - Stop the release by righting an overturned or punctured container, shutoff pumps, close a valve, etc.
4. Contain the release to a small area and cleanup using available spill control kits.
5. Follow SERI's hazardous waste disposal requirements.

SERI
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Section 7.0 - INFORMATION AND TRAINING

7.1 OSHA Lab Standard Training Requirements

The OSHA Lab Standard is very similar to the OSHA Hazard Communication Standard and requires the employer to provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work areas. Such information is to be provided at the time of the initial assignments involving new exposure situations.

Employees are to be informed of:

- * The contents of the standard.
- * The location and availability of SERI's Chemical Hygiene Plan.
- * The PELs for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard.
- * Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory.
- * The location and availability of known reference material on the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including Material Safety Data Sheets.

Employee training should include:

- * Methods and observations that may be used to detect the presence or release of a hazardous chemical.
- * The physical and health hazards of chemicals in the work area.
- * The measures employees can take to protect themselves from these hazards.
- * The applicable details of the Chemical Hygiene Plan.

7.2 Employee Training

1. All new employees must receive Hazard Communication Awareness Training as part of the initial SERI employee orientation program. The training

requirement of the OSHA Lab Standard are to be integrated into this program.

2. Laboratory supervisors will ensure that the laboratory staff are provided with the information and training related to the chemical and physical hazards in their work area.

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Section 8.0 - MEDICAL SURVEILLANCE

SERI has a well established Medical Surveillance Program which consists of pre-placement and at least annual physical exams. A Medical Clinic is located in Building 16/4 and is staffed by a full time Occupational Health Nurse and a part time Occupational Health Physician. This section describes the criteria for deciding when you may need additional medical surveillance based on the type of work you do.

8.1 Identifying Operations That Need Medical Surveillance

Medical surveillance may be useful in a number of different operations and should be considered on a case by case basis. However, there are three categories in which employees must be provided the opportunity to receive medical surveillance and is generally done in conjunction with employee workplace exposure monitoring:

- * When required by OSHA regulations
- * When employees develop symptoms which appear to be associated with their exposures
- * When employees are involved in responding to a spill, leak, explosion or other release in hazardous exposures to chemicals.

8.2 OSHA Regulations Requiring Medical Surveillance

OSHA Regulated Substances: Employees involved in handling, working with, or using any of the OSHA regulated carcinogens listed below in concentrations at or above the percentage amount shown must be included in SERI's Medical Surveillance Program. There are only two exceptions:

- * Operations which only handle the carcinogens in closed, sealed containers that are not opened, i.e. there is no potential exposure.
- * Operations which only handle the carcinogen in concentrations below those listed below.

CHEMICAL NAME	PERCENT
2-Acetylaminofluorene	1.0
4-Aminodiphenyl	0.1
Benzidine and its salts	0.1

3,3'-Dichlorobenzidine	1.0
4-Dimethylaminoazobenzene	1.0
alpha-Naphthylamine	1.0
beta-Naphthylamine	0.1
4-Nitrobiphenyl	0.1
N-Nitrosodimethylamine	1.0
beta-Propiolactone	1.0
bis-Chloromethyl ether	0.1
Methyl chloromethyl ether	0.1
Ethyleneimine	1.0

Complete OSHA Health Regulations: The substances below have complete OSHA regulations and labs which handle, work with, or use these substances in a manner which results in employee exposures above the action level for the substance must implement a medical surveillance program as described in the regulations. The action level is a trigger level which is different for each substance and is specified in the OSHA regulation for each substance. As discussed in Section 6.2, employee exposure monitoring is generally required to measure the employees' exposure levels and to determine whether these levels exceed the action level and if medical surveillance may be required.

- * benzene
- * asbestos
- * dibromochloropropane (DBCP)
- * inorganic arsenic
- * inorganic lead
- * vinyl chloride (monomer)
- * acrylonitrile
- * formaldehyde
- * ethylene oxide
- * 4,4 - Methylene bis,(2 chloroaniline)

8.3 Medical Surveillance Programs in Response To Employee Complaints

Employees that develop symptoms which appear to be related to exposures associated with lab operations must report them to their supervisor immediately and seek medical assistance from the SERI Medical Clinic. If an emergency occurs, implement the Emergency Notification process by dialing X1234 and

request medical help. It is very important that employees inform their supervisor of adverse health effects so that this information can be used to correct the problem so that other employees are not affected as well.

8.4 Medical Surveillance for Employees Responding to Releases

Employees who are involved in responding to spills, explosions, or other releases may need to be included in SERI's Medical Surveillance Program. Medical surveillance is normally not needed in the following circumstances:

- * Employees responding to the release used the correct personal protective equipment and were trained in the correct procedures for responding to the release. Employees did not experience any symptoms or adverse health effects following the response.
- * The release involved small quantities of materials which were isolated from the main work area of the lab (i.e. in a hood). Only the employees with proper equipment and training were involved in responding to the incident.

Medical Surveillance may be needed if the employees were exposed to hazardous chemicals without proper protection for an extended period of time (i.e. > 15 minutes).

8.5 Medical Consultation and Medical Exams

As part of SERI's Medical Surveillance Program, employees are given an opportunity to receive medical examinations under the direct supervision of a licensed physician at no cost to the employee and without loss of pay.

8.5.1 Information Provided to the Physician

When consultation and medical exams are required for employees who work with hazardous chemicals, the employee will provide to SERI's Occupational Health Nurse and the physician the following information:

1. The identity of the hazardous chemical(s) to which the employee may have been exposed;
2. A description of the conditions under which the employee may have been exposed;
3. The signs and symptoms of exposure that the employee is experiencing.

8.5.2 Physicians Written Opinion

For examinations or consultation required under the OSHA Lab Standard, SERI's Occupational Health Nurse will require a written opinion (excluding specific findings of diagnoses unrelated to occupational exposures) from the examining physician which must include the following:

1. Any recommendations for further medical follow-up;
2. The results of the medical examinations and any associated tests;
3. Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous chemical found in the workplace; and
4. A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

NREL Response to the "Fluer Report"

Within the following document, all text in normal type (like this) is directly from "An Audit of Toxic Gas Use and Handling at Facilities Occupied by the Solar Energy Research Institute, Golden, Colorado, April 22, 1991" by Larry Fluer of Fluer, Inc. Carbondale, Colorado. *All text in italics (like this) is the NREL response to each of Fluer's recommendations.* These comments and responses are associated directly with the SAR written for the "Use of Hazardous Production Materials in Photovoltaic Applications at the National Renewable Energy Laboratory." All references to an SAR are made to the above document, except where noted.

5.0 RECOMMENDATIONS

The following list of recommendations has been prepared in order to assist SERI in bringing the facility into reasonable compliance with requirements of the code and good practice.

- 5.1 If occupancy of this building is to be continued, reasonable compliance with the provisions for Group H, Division 6 Occupancies must be achieved.

It may be possible to meet the requirements of UBC Section 503 by creating H-6 Occupancies which are limited to the laboratories considered in the review. UBC Sections 105 and 106 can be used as the means to establish a legal basis for occupancy, however, detailed thought must be given as to how equivalency may be established. In order to accomplish this task compliance with all requirements must be literally met or an equivalent provided.

A meeting to discuss these issues with the jurisdiction with a tentative solution in mind should be considered.

NREL: All operations which would trigger Group H, Division 6 (H-6) Occupancy (those using concentrated silane) have been deemed to be too high of a risk to continue operations within Building 16. Therefore, those operations will be moved off-site and be the subject of a separate SAR. All operations which have been chosen to remain in Building 16 will be modified to conform with Group B, Division 2 (B-2) Occupancy requirements. Therefore, this recommendation becomes moot. Reasonable compliance with the provisions of H-6 Occupancies has not been a goal of this SAR.

- 5.2 After a plan for occupancy has been developed, permits for hazardous materials must be requested.

NREL: H-6 Occupancy permits are not required since we are not trying to achieve reasonable compliance with the H-6 Codes. However, there are two areas of concern with respect to the B-2 occupancy requirements and the proposed operations covered in this SAR. They deal with providing a "legal equivalency" to gas cabinet scrubbers in the event of a catastrophic release and maintaining an internal, NREL, limit on pyrophoric liquids of two pounds in use (exempt quantity is one pound). These issues are specifically addressed in Sections 5.4.6.15. and 5.4.2. of the SAR, respectively.

After the SAR is approved, a copy will be provided to the Lakewood-Bancroft Fire District in order to help secure the necessary B-2 Occupancy permits by providing these "legal equivalencies".

- 5.3 The feasibility of retrofitting the building with sprinklers or partial sprinklers (labs only) should be investigated should such systems become part of the alternative solution.

NREL: *As a result of the Tiger Team Class II Finding, Building 16 will be equipped with automatic fire sprinklers. This greatly assists in meeting the letter of the UFC with regard to the use of pyrophoric materials (exempt amount is zero in a non-sprinkled building).*

- 5.4 Ventilation in the laboratories should be increased or all flammables placed under a zone of local exhaust.

NREL: *See Section 5.4.6.12. of the SAR.*

- 5.5 Exits from all laboratories should be brought into conformance with the codes. Such requirements are viewed as retrospective.

NREL: *The main issue with this recommendation has to do with Laboratory 222, where room 218 is used as an intervening, or exiting room. Fluer's comment here is that "As Group H Occupancies, they are required to have two independent exits and one must go to an exit corridor or the exterior. . ." Since we are not treating these as Group H Occupancies, this recommendation becomes moot.*

- 5.6 Isolate exhaust ducts from non H-6 areas as required.

NREL: *This is a requirement placed upon exhaust ducts when crossing from one Occupancy to another. Since we are not attempting to provide reasonable compliance with the provisions of H-6 Occupancies (the entire building is viewed as B-2), this recommendation becomes moot.*

- 5.7 Upgrade exit doors to meet requirements of UBC Section 3305(h)1.

NREL: *This requirement was specifically brought up in reference to the gaps present around some of the laboratory doors (see Fluer Report, Section 4.1.1.7, page 15). UBC Section 3305(h)1 states: "When corridor walls are required to be of one-hour fire-resistive construction by Section 3305(g), every door opening shall be protected by a tight-fitting smoke- and draft-control assembly . . ." Section 3305(g) refers to walls of corridors serving a Group R (Hotels and Apartment Houses), Division 1 or Group I (Nurseries, Nursing Homes, Mental Hospitals, etc.) Occupancies. Therefore, it is our interpretation that the requirement has been misapplied to these operations. Personnel from the Facilities Branch have confirmed that there does not exist a problem with the gaps around the exit doors. The doors do have the appropriate fire ratings.*

- 5.8 Establish a piping and tubing labeling practice and conspicuously label piping and tubing which transports HPM with the name of the materials transported to include a direction of flow arrow. Also see ANSI A13.1-1981.

NREL: *This recommendation remains outstanding. The NREL Safety Council will be working in conjunction with the Toxic Gas Safety Panel to establish such a labeling practice. Note that the lack of consistent signage throughout the Institute was a Tiger Team Finding, and that this becomes a subset of this issue.*

- 5.9 Isolate cylinders of toxic gases at the FTLB to the building exterior.

NREL: *See Sections 5.5.3.18. of the SAR.*

- 5.10 Revise the shipping manifest to meet 49 CFR requirements.

NREL: See Section 4.3.6. and 5.5.4.1. of the SAR.

- 5.11 Reorganize the remote gas storage building to separate gases as required by code. See UFC Table 51.110-A.

NREL: See Section 5.4.9.8. of the SAR.

- 5.12 Secure all cylinders in storage or use in an upright position.

NREL: See Section 5.4.9.9. of the SAR.

- 5.13 Provide a means for handling a leaking cylinder. Cylinder containment devices or treatment systems must be considered.

NREL: It is assumed that is recommendation is made in reference to the remote gas storage building. If this is the case, see Section 5.4.9.20. of the SAR.

- 5.14 Provide a gas detection system for the remote storage building.

NREL: UFC Section 80.303.(a).9 (see page 22 of Fluer's report) is a requirement for continuous gas detection on interior storage facilities. It does not apply to exterior storage facilities (UFC Section 80.303.(b)), which we consider this bunker to be. Therefore, this is a misdirected code requirement for this facility. See also Section 5.4.9.12. of the SAR.

- 5.15 Provide two self contained breathing apparatus at the remote storage building.

NREL: See Section 5.4.9.16. of the SAR.

- 5.16 Revise the SERI gas handling policy to address hazardous gases or limit the scope to compressed gases as defined. This report does not consider the metal alkyls as compressed gases.

NREL: This SAR necessarily supersedes the "SERI Standards for the Safe Handling, Use, and Monitoring of Toxic Gases." It has been expanded to cover all hazardous gases and explicitly covers the subject of "metal alkyls" in Sections 5.4.2. and 5.4.3.

- 5.17 Remove high pressure silane from Building 16 to a suitable exterior location. Alternatively, reduce the maximum concentration of silane to a level not to exceed 2%.

NREL: This recommendation has been followed. Section 5.4.1.30. specifically limits the concentration of silane to 1% in Building 16. All operations using silane beyond this concentration are in the process of being moved to 6800 Joyce Street, in Arvada, CO.

- 5.18 Mandate the use of proper cylinder closure devices on all process gases. Dust plug closures that are specifically designed for the CGA 350 style valve (two piece) must be used on all CGA 350 style valves. Other closure devices should be suited to the type of cylinder valve furnished.

NREL: See Section 5.5.6.6. of the SAR.

- 5.19 Provide emergency exhaust on treatment systems to handle emergency release scenarios mandated by the code. The use of reduced flow orifices will be mandatory. Mishap leakage in gas cabinets must be considered.

***NREL:** See Section 5.4.6.15. of the SAR.*

- 5.20 Reformat the SERI Gas Handling Policy to simplify requirements. The addition of several graphics to be utilized with the checklist will help users visualize requirements.

***NREL:** This SAR necessarily supersedes the "SERI Standards for the Safe Handling, Use, and Monitoring of Toxic Gases." It has been expanded to cover all hazardous gases, uses a variety of graphics, and has been broken down into more specific sub-requirements.*

- 5.21 Reformat the check list to be user friendly and establish a system to enforce the use of the policy. The toxic gas safety panel should be involved.

***NREL:** This is being done as part of the Operational Readiness Review (ORR) criteria or guidance. This guidance is currently under development and was not available at the time of printing. All systems will have to pass an ORR before being allowed to resume operations.*

- 5.22 Clarify the MDA policy to define which fire marshal (building or jurisdiction) is to be notified in event of emergency.

***NREL:** The next printing of this document will have the above change.*

- 5.23 Revise the monograph of relative responses for the MDA to include germane and other gases where relative response is to be compared.

***NREL:** The next printing of this document will have the above change.*

- 5.24 Placement of gas sensors in the work area and equipment should consider flow and air patterns in the enclosures, ducts and areas in which they are placed.

***NREL:** See Section 5.6.1.6. of the SAR.*

- 5.25 Manual shut off of ventilation systems (supply) are required to be provided for areas designated as H-6. The shut offs are to be located external to the laboratory. Placement at the required emergency control station (605) is desirable.

***NREL:** This is a requirement placed upon exhaust ducts when crossing from one Occupancy to another. Since we are not attempting to provide reasonable compliance with the provisions of H-6 Occupancies (the entire building is viewed as B-2), this recommendation becomes moot.*

- 5.26 Provide excess flow control valves for all HPM gas delivery systems.

***NREL:** See Section 5.4.1.6. of the SAR.*

- 5.27 When piping and tubing is installed, approved standards should be utilized. Existing tubing with poor welds should be retrofit and welds with severe undercutting replaced. SEMI standards for welding should be utilized.

***NREL:** See Section 5.4.1.23. of the SAR.*

- 5.28 Leak testing of piping systems should be performed in accordance with SEMI standards. Both inboard and outboard leak checks are required. Most existing systems likely have never been outboard leak checked with a sensitive leak test.

NREL: See Section 5.4.1.24. of the SAR.

- 5.29 Provide flammable gas detection in all areas utilizing hydrogen. The gas detectors installed in hydrogen purifiers are not deemed to be adequate under existing circumstances.

NREL: See Section 5.6.2. of the SAR.

- 5.30 Limit gas cylinders in gas cabinets to three maximum. All cylinders are to be compatible, e.g., pyrophorics separated from flammables, separated from toxics, separated from corrosives, etc.

NREL: See Sections 5.4.6.7.10. and 5.4.6.7.11. of the SAR, respectively.

- 5.31 Contain all exhaust ducts which penetrate required occupancy separations in shafts of equivalent fire resistive construction.

NREL: This is a requirement placed upon exhaust ducts when crossing from one Occupancy to another. Since we are not attempting to provide reasonable compliance with the provisions of H-6 Occupancies (the entire building is viewed as B-2), this recommendation becomes moot.

- 5.32 Provide adequate dilution ventilation in all areas where flammables and unclassified electrical are present. Air flows and patterns are to be considered. Remove all unclassified electrical fittings from internal of gas cabinets.

NREL: See Sections 5.4.6.16., 5.4.6.12., 5.4.6.4. and 5.4.6.7.12. of the SAR, respectively.

- 5.33 Provide three foot workstation clearances in front of all locations where operators are to utilize HPM as part of normal equipment operations or service functions.

NREL: This requirement cannot be strictly met in all cases. Wherever possible, a three foot clearance will be provided. Those instances where it is not possible, still have adequate clearance for comfortable operations.

- 5.34 Develop uniform labeling policy to identify all panic button shut offs to emergency response personnel.

NREL: This recommendation remains outstanding. The NREL Safety Council will be working in conjunction with the Toxic Gas Safety Panel to establish such a labeling practice. Note that the lack of consistent signage throughout the Institute was a Tiger Team Finding, and that this becomes a subset of this issue.

- 5.35 Arrange emergency shut offs to shut off the supply of all HPM at the source. Activation of shut offs must be arranged to positively shut off the flow of HPM and bring systems to a safe state.

NREL: See Sections 5.4.1.7., 5.4.1.25., and 5.4.7. of the SAR.

- 5.36 Provide operational self closing and self latching doors on all gas cabinets.

NREL: See Sections 5.4.6.7.7. and 5.4.6.7.3. of the SAR, respectively.

- 5.37 Provide automatic shut down for all gas cylinders (at cylinders) for toxic gases sensed. Shut offs are required to be provided in gas cabinets as close as practicable to cylinder valves.

NREL: See Sections 5.4.1.7., 5.4.1.25., and 5.4.7.1.1. of the SAR.

- 5.38 Establish a gas cabinet and hood monitoring program to routinely test face velocities at access openings. Tag and date all hoods and cabinets with date of last check and date of next check due.

NREL: See NREL ES&H Policies and Procedures for hood and cabinet testing.

- 5.39 Isolate purge gas supplies to serve only a single gas. Cross connections on the high pressure source cylinders are to be eliminated.

NREL: See Section 5.4.1.11. of the SAR.

- 5.40 Provide pressure relief valves on all reactor or other systems which can be ruptured by overpressure, or alternatively provide redundant pressure regulation with secondary regulators plumbed in series and downstream of the primary control regulator.

NREL: See Section 5.4.1.4. of the SAR.

- 5.41 Provide reduced flow orifices on all HPM gas cylinders if required to meet requirements for treatment systems.

NREL: See Sections 5.4.6.15., 5.5.3.4., and 5.5.3.5. of the SAR.

- 5.42 Establish a cylinder size limitation policy based on capacity of treatment systems.

NREL: See Sections 5.4.6.15., 5.5.3.4., and 5.5.3.5. of the SAR.

- 5.43 Relocate caustic scrubbers handling pyrophorics to unoccupied spaces or guarantee adequate inert gas flows under all operating and upset conditions preclude gas ignition.

NREL: The comments of page 54 of the Fluor report are in reference to wet scrubbers (caustic soda) used to specifically treat silane and phosphine. None of the operations for proposed restart in Building 16 that use phosphine are proposing restart using wet scrubbers. Additionally, all systems using concentrated silane (a fire and/or explosion hazard) are being moved off-site and are outside the scope of this SAR.

- 5.44 Eliminate active flame sources in environmental hoods where hydrogen and other flammables are contained in pressurized systems.

NREL: See Section 5.4.5.8. of the SAR.

- 5.45 Provide suitable effluent abatement systems to eliminate the problem created in the generation of arsenic oxides. Commercially available systems should be considered, including those of Emcore, Aixtron, Innovative Engineering or others. Standardization should be considered.

NREL: See Sections 5.4.5.1., 5.4.5.2., and 5.5.6.1.6. of the SAR. Note that because each system is unique in both process and the source materials, standardization may not be possible.

- 5.46 Provide detailed procedures for safe oxidation of the FCA carbon drums as well as safe disposal procedures for spent drums.

***NREL:** See Section 5.4.5.9. and 5.4.5.7. of the SAR, respectively.*

- 5.47 Prohibit the use of gas cabinets as a catch all for unused materials, hazardous waste, etc.

***NREL:** See Section 5.4.6.7.17. of the SAR.*

- 5.48 Eliminate toxic gas installations that are not designed for operation from a standing position. Installations which require operators to crouch or kneel to change cylinders or operate controls are not to be utilized.

***NREL:** See Section 5.4.6.7.18. of the SAR.*

- 5.49 Provide gas cabinets for all HPM gases installed in laboratories including hydrogen cylinders or cylinders of inert gases connected to toxic gas systems.

***NREL:** See Sections 5.4.6.12. and 5.4.1.12. of the SAR, respectively.*

- 5.50 Plumb gas system purge vents to treatment systems which meet requirements of the code. Purge systems capable of releasing high volumes of toxic gases if improperly operated are to be eliminated.

***NREL:** See Section 5.4.1.8. of the SAR.*

- 5.51 Upgrade the hydrogen-oxygen torch system in Lab 368 to comply with standards or remove it from the facility.

***NREL:** Completed.*

- 5.52 Mark the exterior of the remote storage building with required placards per UFCS 79-3 (NFPA 704).

***NREL:** See Sections 5.4.9.8. and 5.4.9.18.3. of the SAR.*

- 5.53 Provide storage plan (and post) at exterior storage building.

***NREL:** See Section 5.4.9.19. of the SAR.*

- 5.54 Verify the suitability of temperature control baths utilizing Class I flammables.

***NREL:** Confirmed that everything is acceptable.*

- 5.55 Enforce requirements of the training program.

***NREL:** A new training coordinator for the Laboratory has been hired. Also see Section 5.5.5. of the SAR.*

Hazards Presented by Natural Phenomena

An analysis of the hazards presented by natural phenomena was performed by a fire protection consultant hired by NREL to conduct a fire hazard and life safety analysis of Building 16. The following analysis is taken directly from Mr. Cliff Harvey's Report (pages 72-75).

Earthquake

The last time an earthquake was experienced in this area was in 1966, when a small tremor was felt. It did not do any damage to speak of. It was widely speculated that the reason it occurred at all was due to a deep well which had been drilled at the Rocky Mountain Arsenal to dispose of hazardous materials, but this was never proven.

Large, damaging earthquakes are not usual to this area, as it is away from any of the known fault lines. This is not to say, however, that a damaging earthquake cannot occur in this area.

Sprinkler System

The sprinkler system in Building 16 consists of a full set of piping on the fourth floor only, along with a larger pipe feeding that system. Although there is always some room for expansion and minor movement in the piping, a major, damaging earthquake at this site would probably fracture enough piping to put the system out of service and cause some water damage. The fracture(s) would most likely take place in the area where the main supply comes into the building, causing some flooding on the main level, and in and around the hazardous waste storage room. Unless the earthquake were of high magnitude, the main branch piping would probably make it through with little damage.

Smoke Detection

This system's wiring is installed in metal conduit, and thus might get stretched or broken in a major earthquake. Any minor quake would also set this system off, but would not damage it unless there were physical damage to the building itself.

Fire Alarm

This system's wiring is also installed in metal conduit, and thus might also get stretched or broken in a major earthquake. Any minor quake would also set this system off, but would not damage it unless there were physical damage to the building itself.

Standpipes

The standpipe system in Building 16 consists of a full set of piping throughout the building. Although there is always some room for expansion and minor movement in the piping, a major, damaging earthquake at this site would probably fracture enough piping to put the system out of service. Because it is a dry system, no water damage would result from this breakage. If the earthquake were of high magnitude, the main branch piping would probably not make it through without some damage.

Special Hazards

The special hazard systems found in several of the instrumentation labs would probably not be affected by a minor earthquake, and probably not by a larger quake either, unless structural damage were sustained in a specific lab. The worst case would be for a system to have its piping severed, and discharge. As an agent inside the system is a finite amount and not especially toxic, no catastrophic damage would result.

SERI Operations

A major earthquake in the area of Building 16 would, at least for the short term, stop the operations in the building. It would be unthinkable to restart processes and experiments using toxic liquids and gases without first doing exhaustive testing on all of the machinery involved, making certain it did not sustain any damage whatsoever. Even after a minor quake, it would be prudent to accomplish this sort of testing, if for none other than "political" reasons.

Flooding

The Denver metro area experiences spot flooding in the springtime of the year from both mountain runoff and heavy thunderstorms passing through the area. It is not unheard of to have heavy rains (1" to 2") in a period of 30 minutes during these times, and when that rain is coupled with hail, the damage can be substantial to the area involved. However, Building 16 is, to some extent, built up higher than the surrounding grade, and a major flood of medium term duration would have to occur for water to flood the building. Even under those highly unlikely conditions, the first level would be able to take a foot or more of standing water without causing any long term problems.

Sprinkler System

Flooding should have no effect on the integrity of the sprinkler system in Building 16.

Smoke Detection

Flooding should have no effect on the smoke detection system in Building 16. If there were a general power failure to the building, however, the smoke detection system might be rendered out of service. The length of this outage could be determined by the location (relative to the water levels) of the emergency generator, and whether that system is powered by the emergency generator when it is operational.

Fire Alarms

Flooding should have no effect on the fire alarm system in Building 16. If there were a general power failure to the building, however, the fire alarm system might be rendered out of service. The length of this outage could be determined by the location (relative to the water levels) of the emergency generator, and whether the alarm system is powered by the emergency generator when it is operational.

Standpipes

Flooding should have no effect on the integrity of the standpipe system in Building 16.

Special Hazards

Flooding should have no effect on the integrity of the special hazard systems in Building 16.

SERI Operations

Flooding should have little effect on the integrity of the operations in Building 16. It would, however, cause a great deal of disruption to the day-to-day operations, and would probably cause several, or all, of the projects to be postponed during the flooding itself. It is important to note, however, that this level of flooding at this location is highly unlikely.

Tornados

The Denver metro area has begun to experience extremely heavy and dramatic weather in the spring and summer of the year. It is not unheard of to have heavy rains (1" to 2") in a period of 30 minutes during these times, and it is not unusual to have one or more tornados touch down way to the east of Building 16, either in or east of Denver or one of the surrounding communities. Eastern Colorado experiences several, devastating tornados each season. It is less likely that a tornado would touch down as close to the foothills as is Building 16, but not impossible. Even if a tornado were to touch down in the Office Park, unless direct damage occurred to Building 16 itself, the outcome of such a touch down would not be devastating. Certainly the alarm systems would activate, and perhaps a special hazard system would activate due to the movement, but unless the tornado actually hit the building, the damage would be limited to some disruption only.

Sprinkler System

A tornado passing through the area should have no actual effect on the integrity of the sprinkler system in Building 16. If, however, a tornado were to actually touch down, hit, and damaged the building, the system would most certainly be rendered useless, with the piping severed and a great deal of water damage resulting.

Smoke Detection

A tornado passing through the area should have no actual effect on the integrity of the smoke detection system in Building 16. If, however, a tornado were to actually touch down, hit, and damaged the building, the system would most certainly be rendered useless.

Fire Alarms

A tornado passing through the area should have no actual effect on the integrity of the standpipe system in Building 16. If, however, a tornado were to actually touch down, hit, and damaged the building, the system would be rendered useless.

Standpipes

A tornado passing through the area should have no actual effect on the integrity of the standpipe system in Building 16. If, however, a tornado were to actually touch down, hit, and damaged the building, the system would most certainly be rendered useless, with some or all of the piping being broken.

Special Hazards

A tornado passing through the area should have no actual effect on the integrity of the special hazard systems in Building 16. If, however, a tornado were to actually touch down, hit, and damaged the building, the systems in the affected areas would be rendered completely out of service.

SERI Operations

A tornado which passes through the area should have little effect on the integrity of the operations in Building 16. It would, however, cause a great deal of commotion, and day-to-day operations would be affected for a short period while people gathered their wits about them. If, however, a tornado were to actually touch down, hit, and damaged the building, the projects in the affected areas would be rendered completely out of service. Further, under this most extreme example, there is a real chance that toxic gases and liquids would be released into the atmosphere. Given the windy conditions that would also accompany this event, the actual problem would be mitigated because the agents would be quickly dispersed. It is important to note, however, that an event of this magnitude is highly unlikely.

Impact to Nearby Structures and Population

Given the measures already taken at Building 16, and those measures recommended in the last portion of this report being implemented, the impact to nearby structures and the population of those structures would be minimal to nonexistent. If there were a minimal impact, it would be from smoke damage from the original fire. Unless "everything" were to go wrong, damage would be limited to the structure of origin, and more probably the floor or room of origin.

ARVADA FIRE PROTECTION DISTRICT

PRE372 ** BUSINESS DISPATCH DISPLAY PRINT ** TIME 14.

OWNER- SOCIETY BANK & TRUST LOCATION- 2249 GLASSTONH SOLAR INC
 (419) 259-5910 6800 JOYCE ST
 CONTACT-NEIL HEGHE PHONE 425-6610
 940-9300
 SCOTT BROWN FIRST- 8 FID. AERIAL CUL.
 421-5661 SECOND- FB R7 6/10
 THIRD- 3 7 4/5
 POLICE- ARV
 BLD. USE-INDUSTRIAL BLDG.
 BLD. MAT.- 18 STORIES- 1 BFL

BEST WAY IN - INDIANA ST N TO 68 AV. W TO JOYCE ST, NORTH 08/14/9.
 "COTTONWOOD WEST INDUSTRIAL PARK"
 * FIRE ALARM = UNITED SECURITY 778-7000

SPECIAL NOTES- SPRINKLED BLDG,
 CODE LABS EAST END OF BUILDING 425-0308

HYDRANT. ADDRESS	LOCATION	DIST.	PHONE NO
6800 JOYCE ST APPROX. NE CORNER	ARV 279-3766 431-3066		
6820 JOYCE ST APPROX. MID-BLOCK E SIDE	ARV 279-3766 431-3066		
14959 68 AV APPROX. MID-BLOCK N SIDE	ARV 279-3766 431-3066		
6870 JOYCE ST APPROX. MID-BLOCK E SIDE	ARV 279-3766 431-3066		

LOCATION OF:

KNOX BOX-	NORTH WALL BY FDC	8/L ACCESS-	NORTH, SOUTH, EAST W
ELEC. SHUTOFF-	ELEC ROOM BY VALVE R	ROOF ACCESS-	
GAS SHUTOFF-	NORTH WALL	ATTIC ACCESS-	
ELEVATORS-		BASE. ACCESS-	
ELEC. OVERRIDE-	NO	EXPOSURE HALL	
STAIRWAYS-		POWER LINES-	UNDERGROUND
F.A. PANEL-	NO WALL DOOR KNOX BX	SPRING. VALVE-SPRINKER RM NORTH ST	
F.D. CONNECTION-	NORTH WALL	SPRING. TEST- NE 1 ST WALL	
STAND PIPE-	OCCUPANT HOSE		

HANDICAP:
 FLR DESCRIPTION
 ** NONE **

HAZARD:
 FLR DESCRIPTION
 ** NONE **

YR OF:
 CONSTRUCTION-STEEL
 EXT. WALLS- STEEL SIDING

ROOF- INS OVER METAL
 FLOORING-CONCRETE

SOLAR ENERGY RESEARCH INSTITUTE ES&H OFFICE QUALITY ASSURANCE PLAN

Approved by: _____ date: _____
William Griffing
ES&H Office Manager

Section 1.0 - INTRODUCTION

Section 1.1 - Purpose

Monitoring is routinely conducted to measure the individual performance of various environment, safety and health programs at SERI such as groundwater monitoring, employee exposure monitoring to potential chemical hazards, and medical monitoring. The monitoring data must be accurate and valid so that a proper evaluation can be made to assess the potential effects of SERI activities on the employees' health and the environment. Monitoring that cannot be reliably conducted is seldom worth the time and expense to complete the monitoring.

The SERI ES&H Section is committed to adopting and carrying out the standards of excellence embodied in the SERI Quality Assurance Manual and the requirements of this procedure. A quality assurance program provides maximum benefits when it covers all aspects of monitoring from the collection and analysis of field samples to report generation and recordkeeping. This procedure will outline the major elements that are required to provide an effective environment, safety and health quality assurance program.

Section 1.2 - Definitions

Quality Assurance: The auditing procedure used to evaluate all known policies and procedures that affect the quality of environment, safety and health monitoring programs.

Quality Control: The operational procedure used to ensure that the samples collected and the analytical results of the monitoring programs are of known and acceptable precision and accuracy.

Section 1.3 - Quality Assurance Program Elements

- * Quality assurance responsibilities
- * Sources of Error
- * Sampling considerations
- * Equipment calibration and maintenance
- * Analytical methods
- * Laboratory analysis considerations
- * Data validation and interpretation
- * Reporting and recordkeeping

Section 2.0 - RESPONSIBILITIES

Section 2.1 - ES&H Section Employees Responsibilities

All ES&H Section employees that are assigned monitoring responsibilities by the ES&H Section Manager

will ensure the applicable requirements of this quality assurance procedure and the SERI Quality Assurance Manual are incorporated into all ES&H monitoring programs.

Section 2.2 - ES&H Section Manager Responsibilities

The ES&H Section Manager is responsible for selecting and assigning personnel that are qualified and properly trained to conduct ES&H monitoring programs in compliance with this procedure.

Section 3.0 - SOURCES OF ERROR

An essential element in a quality assurance program is the detection of error and its elimination and control. Once the sources of error are identified for a particular monitoring activity, the elimination or control of the error then can be corrected. The following table, Table 3.1, outlines the most common errors that may be encountered and can be used as a checklist to verify proper error identification and correction (should not be considered all-inclusive):

TABLE 3.1: SOURCES OF POTENTIAL ERROR

ELEMENT	SOURCES OF ERROR
Sampling	Improper sampling equipment selected Improper equipment/pump calibration Variation in pump flow rate Improper sampling procedure/media selection Improper sampling media preparation Selection of improper flow rate Improper sample volume (high or low) Failure to submit field blanks with samples Insufficient interference information Improper sample handling
Shipping/Storage of samples	Bulk samples shipped with samples to be analyzed Improper sample preservation (oxygen, light effects) Temperature limitations exceeded Excessive shipment interval Cross contamination during storage Excessive storage interval resulting in degradation Damage to sample in shipping and storage
Analytical instruments	Improper instrument parameter used Improper instrument calibration
Data interpretation	Improper calculations Improper evaluation of reported results Ignoring unacceptable quality control results
Report generation	Illegible field notes Inadequate auditing procedures Lack of pertinent quality control comments concerning problems during sampling and analysis Failure to follow chain-of-custody procedures

Section 4.0 - SAMPLING PROCEDURES

Section 4.1 - Introduction

To assure the scientific reliability of the data generated, quality control elements must include the field sampling procedure from the conception of the sampling strategy to the delivery of samples to the lab. Sample result validity is aided by adhering to proper calibration, sampling, handling, identification and chain-of-custody procedures. These elements provide the framework upon which the validity of field measurements and analytical results depend. All sampling procedures must be documented carefully and approved with the following steps developed to aid in this process:

1. Develop field sampling strategy
2. Complete pre-sampling equipment calibration
3. Prepare sampling media
4. Develop sample identification system
5. Collect area/personal/bulk samples
6. Complete post-sampling equipment calibration
7. Complete calculations and sample data sheets
8. Submit samples and blanks to the lab using approved chain-of-custody documentation

Section 4.2 - Trip Blanks and Field Blanks

Validation of sample collection methods by means of blanks must be performed in the field to aid in sample integrity. A Trip Blank is taken to the field with the sampling devices, but is not opened to the environment. As such, it provides an indication of whether the sample collection media (plates, filters, etc.) are initially contaminated. A Field Blank is also taken to the field, and it is exposed to the environment. It is placed in the sampling device, just as are the real sample collection media, but the device is not activated. It serves to indicate whether the sampling procedures cause contamination. If the Trip Blanks or the Field Blanks results are positive, the sample set results are suspect and must be evaluated with respect to their validity.

Section 4.3 - Sample Identification

Each sample collected that requires laboratory analysis must be properly identified and assigned a unique identification number (i.e. filter, water sample, collection device, etc.).

Section 4.4 - Sampling Data Sheets

The sampling data sheet must provide a complete, traceable record that will withstand the potential scrutiny of a court of law. This sheet should represent the compilation of employee/area sampling information along with the analytical results from the laboratory. In addition, a Chain-Of-Custody Record must be obtained and retained with all of the laboratory analytical reports.

All pertinent facts about each collected sample should be recorded on the sampling sheet and should include the following items depending on the type of sample collected:

- * Date, start/finish time, temperature, pressure and relative humidity, wind direction and speed; the time of the measurement of the atmospheric parameters must be stated (i.e. at the beginning or end of the monitoring or do they represent a mean or average of the parameters during the monitoring survey)
- * Location, department, shift, process description
- * Sample identification number and location
- * Name, job classification and employee number
- * Task description
- * Personal protective equipment worn
- * Worker's comments/area description concerning exposure/results potential
- * Sample media (manufacturer, lot number, etc.)
- * Sample type, collection rate, and duration of sample
- * Sample pump type and number
- * Substance monitored
- * Sample preservation used (if any)
- * Analysis required and possible interferences
- * Sampler's name and observations

Section 4.5 - Sampling Procedures

When possible, procedures should be selected and used that are recognized as the accepted method to use with respect to the type of samples collected. The sampling procedure selected must be documented and adhered to as the sampling is conducted. The following are examples of accepted sampling procedure protocol for different monitoring parameters:

SAMPLING PARAMETER	REFERENCED SAMPLE PROCEDURE
Environmental	EPA contract lab protocol
Industrial hygiene	NIOSH/OSHA sampling and analytical methods
Medical	American Assoc. of Occ. Health Nurses

Section 5.0: EQUIPMENT CALIBRATION AND MAINTENANCE**Section 5.1 - Sampling Equipment Calibration**

In order for a quality assurance program to have credibility, sampling equipment accuracy must be traceable at all levels of performance by conducting and documenting calibration results. The accuracy of the environment, safety or health monitoring results can be no greater than the accuracy of the instruments or equipment with which the samples are taken or analyzed.

All sampling equipment must be calibrated on a scheduled, periodic basis as required by the manufacturer. A record of calibration must be documented and maintained before and after each monitoring survey. In addition, each sampling instrument should have its own maintenance log and should contain the following information:

- * Instrument name, manufacturer, model number and serial number
- * Date of purchase
- * Location
- * Method of calibration
- * Calibration schedule
- * Calibration results including Certificates of Calibrations if performed by an outside vendor
- * Date of last, present and next calibration
- * Date and description maintenance procedure(s) were performed
- * Identification of person performing calibration or maintenance (including outside personnel)
- * Telephone number of service personnel

Whenever possible, calibration standards should be traceable to primary standards or to the NBS. The interval between instrument calibrations should be guided by the manufacturers instructions.

Section 6.0: LABORATORY ANALYSIS AND QA PROCEDURES**Section 6.1 - Introduction**

Environmental, industrial hygiene and medical monitoring consists of both sampling and laboratory analysis of the samples collected. The proper selection of the analytical procedure and the selection of an accredited laboratory is a crucial element in SERI's Quality Assurance Program. As with the sampling considerations, the accuracy of the monitoring results can not be greater than the accuracy of the analytical procedure selected and the quality assurance program of the laboratory conducting the analysis.

Section 6.2 - Laboratory Certifications

Once the sample analyte has been selected, a laboratory must be selected that has the necessary accreditation(s) or certification(s) and a quality assurance program to analyze the samples accurately. The accreditation(s) indicate that the laboratory has demonstrated the necessary proficiency and is professionally recognized to analyze the samples. The following information are the suggested accreditations that should be considered when selecting a laboratory:

Monitoring Parameter	Suggested Accreditation
Environmental	EPA Contract Lab Program (CLP)
Industrial hygiene	AIHA accreditation
Medical	College of American Pathologists

Section 6.3 - Laboratory Quality Assurance Program

In addition to ensuring the lab selected has the necessary accreditations to conduct the analysis, the lab selected must also be able to demonstrate and provide details of their laboratory QA/QC procedures. A specific QA/QC plan may need to be requested when developing routine monitoring programs such as groundwater monitoring. The specific QA/QC plan should specify proper quality control by laboratory personnel for collecting and analyzing the samples collected at SERI. Generally, a written QA Plan from the laboratory should include a project organization, responsibilities, sampling procedures, analytical procedures, QA procedures to verify the accuracy of the results and the required reports to document the QA procedures have been established and followed throughout the sampling process. Exhibit #1 is an example of a Quality Assurance Program by Metpath Laboratories that is currently used for analyzing SERI's medical monitoring samples.

Section 7.0 - DATA VALIDATION AND INTERPRETATION

Section 7.1 - Introduction

Data validation and interpretation refer to the process of evaluating the results after the samples have been analyzed. Data validation is an attempt to prevent the use of incorrect data. The process serves as a final screen before the analytical results are used in making conclusions or decisions concerning the monitoring results. It is important that the data validation be performed as soon as possible after receiving the results to facilitate timely corrective action.

Section 7.2 - Data Review Process

The following sampling and analytical data should be reviewed for accuracy to ensure the validity of the information before using the results:

- * Verify that the proper sampling media and the recommended sampling method have been used.
- * Verify that the sampling method was capable of quantifying the results at the level of the reported analytical result, and that the results were not affected by interferences.

- * Evaluate the calculations for accuracy. The data should be displayed in an orderly fashion with enough information to explain the calculations. Data and results that cannot be verified should be rejected.
- * Review the potential sources of error identified in Table 3.1 and validate that these errors have not occurred.

Section 7.3 - Rejection of Results

The following quality control parameters should be evaluated and the results should be rejected if they cannot be verified:

- * Breakthrough has occurred because the quantity of the sample reported exceeds the capacity of the sampling device.
- * Questionable results have been reported on the blank samples submitted to the lab.
- * An improper sampling device and procedure has been used.
- * Potential sources of error identified in Table 3.1 have occurred and the results cannot be accurately validated because of these errors.

Section 8.0 - REPORTING AND RECORDKEEPING
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The final report and records of the sampling and analytical results must be readily available and complete or the information presented will be of little value. When preparing the final report, it is very important that all supporting information is presented so that the author and the reader can evaluate the results and draw conclusions about the quantity or exposures that the samples represent. The final report and the archived data are major pathways back to supporting and validating the conclusions drawn from the data.

MATERIAL SAFETY DATA SHEET*Do Not Duplicate This Form. Request an Original*

Manufacturer's Name
PHOENIX RESEARCH CORPORATION

24 Hour Emergency Telephone No
(819) 466-0645

Address: 8075 ALVARADO ROAD, LA MESA, CALIFORNIA 92042
Telephone No (819) 462-8860

SECTION I - PRODUCT IDENTIFICATION

Chemical Name ARSINE
Formula AsH_3
CAS Registry Number 7784-42-1
Chemical Family covalent hydride
UN Number: 2188

Synonyms: arsenic hydride
arsenic trihydride
arsenuretted hydrogen
arsenous hydride
hydrogen arsenide

SECTION II - HAZARDOUS INGREDIENTS

Ingredient	Per cent	TLV-TWA (ACGIH) (OSHA-PEL)
ARSINE	100%	005 ppm

SECTION III - PHYSICAL DATA

Boiling point	-80.46°F (-62.48°C)
Freezing point	-178°F (-117°C)
Vapor pressure (psig @ 70 °F)	213 psig
Vapor density (air = 1)	2.69
Solubility in water @ 70°F	15 ml /100 ml water
Per cent volatile by volume (%)	100%
Appearance	colorless gas
Odor ¹	garlic-like

¹Odor is not a reliable indication of dangerous concentrations

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Flash point less than 70°F
 Lower explosive limit 4.6%
 Upper explosive limit approx. 64%
 Extinguishing media water, dry chemical, carbon dioxide

SPECIAL FIRE FIGHTING PROCEDURES:

- Wear self-contained breathing apparatus.
- Let burn, unless leak can be stopped immediately.
- Apply water from as far a distance as possible.
- Use water spray or fog in flooding quantities to keep cylinder(s) cool.
- Solid streams of water may be ineffective.
- For massive fire, use unmanned hose holder or monitor nozzles. If this is impossible, withdraw from area and let fire burn.
- If cylinders are NOT LEAKING but are endangered by fire, make every effort to extinguish the fire around them or move the cylinders away from the fire.

UNUSUAL FIRE AND EXPLOSION HAZARD DATA:

Because the cylinders are not equipped with safety devices, they are liable to rupture when involved in a fire or when subjected to prolonged intense heat. Evacuate the area if the fire cannot be brought under immediate control to protect persons from cylinder fragments and toxic fumes should a rupture occur.

SECTION V - HEALTH HAZARD DATA

Threshold limit value - TWA 0.05 ppm

EFFECTS OF OVEREXPOSURE:

INHALATION - The predominance of any combination of symptoms is related to the total dose inhaled and the concentration of the gas inhaled.

When high concentrations of arsine gas are inhaled in large acute exposures, the gas may damage vital organs (such as heart, liver, kidney) directly, causing death before hemolysis (destruction) of red blood cells occurs.

Arsine causes a rapid hemolysis of red blood cells and can also cause renal (kidney) failure, which is uniformly fatal without proper treatment.

Acute, moderate to severe arsine poisoning is characterized by migratory abdominal cramps and tenderness, nausea, vomiting, tingling of extremities, and painless hemoglobinuria (hemoglobin in the urine—a person poisoned by arsine may complain of "blood in my urine").

Chronic arsine poisoning has been described in both man and experimental animals. A decrease in hemoglobin values and erythrocyte (red blood cell) numbers resulting in anemia has been reported. Individuals who have existing reduced renal function, may have that condition aggravated by acute severe exposure to arsine.

The International Agency for Research on Cancer (IARC) has reported that, "There is sufficient evidence that inorganic arsenic compounds are skin and lung carcinogens in humans." IARC Monograph: Some metals and metallic compounds, 23:39-141 (1980). Part 1910.1016 of Title 29 of the Code of Federal Regulations exempts arsine from the inorganic arsenic standard.

WARNING!!! Symptoms may be delayed up to 36 hours.

EMERGENCY AND FIRST AID PROCEDURES:

IF INHALED - Remove affected person from contaminated area.

Get immediate medical attention for persons exposed to arsine, even if no symptoms from exposure are evident.

Symptoms may be delayed up to 36 hours.

Keep under medical observation.

If not breathing, start resuscitation immediately with supplemental oxygen.

If breathing is difficult, give oxygen.

Keep victim quiet and maintain normal body temperature.

Those persons known to have been exposed to high concentrations of arsine should be hospitalized immediately.

SECTION V - HEALTH HAZARD DATA (Continued)

NOTES TO PHYSICIAN

TREATMENT¹

The treatment of choice for acute and severe arsine poisoning is exchange transfusion and, if renal failure develops, hemodialysis. McKinstry and Hickey² suggested the use of massive exchange transfusion to remove arsenic-hemoglobin complexes and erythrocyte debris as well as to restore red-cell mass. Theoretical support for this therapeutic approach is provided by the observation that a large percentage of the fixed arsenic in the blood of arsine-poisoned animals exists in a nondialyzable form.³ Teitelbaum and Klier⁴ noted that hemolysis continues for up to four days in patients not selected for exchange transfusion. They argued that exchange transfusion not only lowers serum potassium, creatinine and urea levels but also removes poisoned erythrocytes, large amounts of circulating oxidation products of arsine, and plasma hemoglobin.

The prognosis in arsine poisoning depends largely on the degree of damage inflicted on the kidneys. Alkaline diuretics to minimize precipitation of hemoglobin in the renal tubules may be of some value. At the first sign of oliguria, fluid and dietary restrictions, ion-exchange resins, and other measures to treat renal failure must be instituted. Before the introduction of dialysis, arsine-induced anuria was uniformly fatal. The usefulness of hemodialysis has since been demonstrated in numerous reports.⁵⁻⁷ Because of prolonged anemia in arsine poisoning, hemodialysis is preferable to peritoneal dialysis.⁴

Early enthusiasm about the benefits of dimercaprol (BAL) therapy had been tempered by the observation that it affords no protection against red-cell destruction.⁸⁻¹⁰ It has been speculated that dimercaprol may exert a protective effect against the long-term consequences of arsine poisoning. However, the therapeutic efficacy of this agent has not yet been firmly established.

Griffon, et al,¹¹ concluded that nothing is gained in the therapeutic use of BAL in the treatment of arsine poisoning and should even be avoided in order to not superimpose one poisoning on top of another.

As a rough rule-of-thumb guide, Pinto¹² suggested a replacement transfusion be done if the plasma hemoglobin reaches 15 grams % or higher. Pinto further stated that if no transfusion is done, kidney function should be very closely supervised. Any evidence of renal failure as shown by a significant increase in BUN or creatinine levels should be accepted as an indication for replacement transfusion. McKinstry and Hicks² stated that cases should be carefully selected because those receiving less than lethal dosages will recover without apparent sequelae.

1. Paragraphs 1, 2 and 3 are from Fowler B A, Wessberg J B. N Eng J Med 291:1171-1174, 1974.

2. McKinstry W J, Hickey J M. Arsine Poisoning. Arch Indust Health 10:32-41, 1957.

3. Graham A F, Crawford T B B, Mannan G F. The action of arsine on blood: observations on the nature of the fixed arsenic. Biochem J 40:255-259, 1946.

4. Teitelbaum D T, Klier L C. Arsine poisoning: report of five cases in the petroleum industry and a discussion of the indications for exchange transfusion and hemodialysis. Arch Environ Health 19:133-143, 1968.

5. Leach F. Erfolgreiche Behandlung einer akuten schweren Arsenvergiftung. Med Klin 58:92-93, 1961.

6. Mushinski R C, Phares C L. Arsine-induced anuria: a correlative clinicopathological study with electron microscope observations. Ann Intern Med 68:583-589, 1968.

7. Udell P R, Khan H A, Emme J E, et al. Renal damage from industrial arsine poisoning. Br J Indust Med 27:372-377, 1970.

8. Pinto S S, Feinglass S J, Johns D R, et al. Arsine poisoning: a study of thirteen cases. Arch Indust Hyg 1:437-451, 1950.

9. Macaulay D B, Starnley D A. Arsine poisoning. Br J Indust Med 13:217-221, 1956.

10. Kessler C J, Abels J C, Rhoads C P. Arsine poisoning: mode of action and treatment. J Pharmacol Exp Ther 88:99-106, 1946.

11. Griffon H, Darobert L. Claimed Disadvantages of using BAL for the treatment of arsine poisoning. Ann Med Leg Criminal Police Sci Med Soc Toxicol 25:182-184, 1946.

12. Pinto S S. J Occ Med 18:633-635, 1976.

SECTION VI - REACTIVITY DATA

Stability

stable

Conditions to avoid

sources of ignition
temperatures above 125°F

Incompatibility (materials to avoid)

oxidizing agents

Hazardous decomposition products

arsenic, hydrogen

Hazardous combustion products

arsenic oxides

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Evacuate area and keep personnel upwind.

Only persons equipped with self-contained breathing apparatus should be allowed in the contaminated area.

Air packs should always be used in pairs by two people working together.

If arsine gas is escaping through an open valve, personnel wearing self-contained breathing apparatus may close the cylinder valve and install valve-outlet cap leak-tight if without risk.

It is difficult to stop compressed gas leaks except where gas escapes through an open valve. A leaking cylinder should be moved to an open isolated place or to a forced ventilation hood that is connected to a gas disposal system.

WASTE DISPOSAL METHOD

Wear self contained breathing apparatus.

Arsine can be disposed of by slowly introducing the gas into a gas disposal system containing adequate quantities of sodium hypochlorite or potassium permanganate solution.

SECTION VIII - SPECIAL PROTECTION INFORMATION

Respiratory protection	self-contained breathing apparatus
Ventilation	provide sufficient mechanical (general) and local exhaust to maintain exposure below TLV.
Eye protection	safety glasses
Foot protection	steel-toed safety shoes

SECTION IX - SPECIAL PRECAUTIONS**PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:**

DANGER: Poisonous flammable liquefied gas under pressure
 May be fatal if inhaled
 May damage vital organs such as heart, liver, kidney and central nervous system
 May form explosive mixtures with air
 Cancer hazard, overexposure may create cancer risk
 Chronic exposure may create anemia
 Do not breathe gas.

Store in exhaust hoods or rooms with adequate ventilation, or in secure, covered outdoor area with cylinders off the ground.

Do not store with oxidizing agents or combustible materials.

Keep away from sources of ignition and radiant heat.

Avoid temperatures above 125°F.

Use equipment rated for cylinder pressure.

Observe precautions described in "Safe Handling of Compressed Gases in Containers," pamphlet P-1, Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

Have self-contained breathing apparatus AND oxygen resuscitators readily available, and personnel properly trained in their use.

Have physician and hospital prepared to treat arsine intoxication.

OTHER PRECAUTIONS:

Valve outlet caps or plugs must be installed leak-tight before moving or shipping cylinders.

Valve handwheel safety tie must be installed before shipping cylinders.

Cylinders, including those containing ANY residual arsine, must be shipped as "full" in accordance with Federal regulations.

A copy of these regulations titled "Hazardous Materials Regulations of the Department of Transportation Including Specifications for Shipping Containers" is published by the Bureau of Explosives, Association of American Railroads, 1920 L Street, Washington, D.C. 20036.

The information presented herein was prepared from sources and experience deemed reliable and accurate. We believe that the information contained herein is current as of the date of this Material Safety Data Sheet. "As with all information prepared for emergency response involving hazardous materials, the printed word cannot substitute for the informed judgment of those responsible on the scene. Only they can accurately assess the scope of damage to equipment, hazardous material lost, and the potential for further harm in the immediate post-accident environment. It is vital to understand that each occurrence is different, and each must be handled as the unique situation which it represents."

Since the use of this information and these opinions and the conditions of use of the product are not within the control of Phoenix Research Corporation, it is the user's obligation to determine the conditions of safe use of the product.

Material Safety Data Sheet

From Genium's Reference Collection
Genium Publishing Corporation
1145 Catalyn Street
Schenectady, NY 12303-1836 USA
(518) 377-8855

No. 225 ^{APPENDIX M1.2}
HYDROGEN SELENIDE
Issued: April 1988

SECTION 1. MATERIAL IDENTIFICATION

25

Material Name: HYDROGEN SELENIDE

Description (Origin/Uses): Produced by the action of acids on inorganic selenides; also by reaction of selenium with organic matter and by the direct combination of the elements. Used in doping gas mixtures for the preparation of semiconductors.

(Other Designations: Selenium Hydride; H_2Se ; NIOSH RTECS No. MX1050000; CAS No. 7783-07-5

Manufacturers: Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

HMIS	Not Found
H 3	
F 3	R 1
R 3	I 4
PPD*	S -
*See sect. 8	K 1

SECTION 2. INGREDIENTS AND HAZARDS

Hydrogen Selenide, CAS No. 7783-07-5

%

EXPOSURE LIMITS

ca 100

IDLH* Level: 2 ppm

OSHA PEL

8-Hr TWA: 0.05 ppm, 0.2 mg/m³

ACGIH TLV, 1987-88

TLV-TWA: 0.05 ppm, 0.2 mg/m³ (as Se)

Toxicity Data**

Human, Inhalation, TC_{50} : 0.2 ppm

Guinea Pig, Inhalation, LC_{50} : 280 mg/m³ (10 Min)

*Immediately dangerous to life and health

**See NIOSH, RTECS, for additional data.

SECTION 3. PHYSICAL DATA

Boiling Point: -42.7°F (-41.5°C)

Vapor Pressure: 9120 Torr at 88°F (31°C)

Vapor Density (Air = 1): 2.8

Melting Point: -87°F (-66°C)

Molecular Weight: 81 Grams/Mole

Specific Gravity ($H_2O = 1$): 2.12

Appearance and Odor: A colorless gas; disagreeable odor resembling decaying horseradish. Caution: Odor is not a reliable warning signal because hydrogen selenide causes olfactory fatigue.

SECTION 4. FIRE AND EXPLOSION DATA

LOWER

UPPER

Flash Point and Method

Autoignition Temperature

Flammability Limits in Air

% by Volume

Extinguishing Media: *Hydrogen selenide is a very flammable and reactive gas that presents serious fire and explosion hazards. Try to shut off the flow of gas. If a hydrogen selenide spill or leak is involved in a fire but has not yet ignited, use a water spray to disperse the gas, to protect the personnel attempting to stop the leak, and to cool fire-exposed containers.

Unusual Fire or Explosion Hazards: Hydrogen selenide is denser than air (see sect. 3), and it collects in low-lying enclosed areas such as sumps, wells, and underground piping systems. Eliminate possible sources of ignition in such areas and monitor them for toxic concentrations of this gas.

Special Fire-fighting Procedures: Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode.

SECTION 5. REACTIVITY DATA

Hydrogen selenide is stable in closed, pressurized containers at room temperature under normal storage and handling conditions. It does not undergo hazardous polymerization.

Chemical Incompatibilities: This material is incompatible with strong oxidizers, nitric acid, hydrogen peroxide, halogenated hydrocarbons, and water.

Conditions to Avoid: Avoid direct contact with materials that are chemically incompatible to prevent dangerous or violent reactions. Avoid exposure to possible sources of ignition such as open flame, lighted tobacco products, uninsulated heating elements, and sparks.

Hazardous Products of Decomposition: When heated to decomposition, hydrogen selenide readily emits highly toxic selenium oxide fumes.

SECTION 6. HEALTH HAZARD INFORMATION

Hydrogen selenide is not listed as a carcinogen by the NTP, IARC, or OSHA.

Summary of Risks: This material is reportedly one of the most toxic and irritating selenium compounds. Intolerable eye and nose irritation occurs in humans at concentrations as low as 1.5 ppm (5 mg/m³). There are no reports that it has ever caused a death or an illness that lasted more than ten days in a human because hydrogen selenide is never used in quantity and it is rendered to the less toxic red selenium by oxidation on the mucous membranes of the respiratory system (see *Gossium* ref. 89, p. 317). This gas has poor warning properties, so exposures where its odor has been detected are described as potentially dangerous. Delayed pulmonary edema up to 48 hours after exposure has been reported. **Medical Conditions Aggravated by Long-Term Exposure:** None reported.

Target Organs: Respiratory system and eyes. **Primary Entry:** Inhalation. **Acute Effects:** Irritation of eyes and upper respiratory tract (URT), dizziness, odor of garlic on breath, fatigue, nausea, vomiting, and diarrhea. **Chronic Effects:** None reported.

FIRST AID

Eyes: Immediately flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes.

Skin: Immediately wash the affected area.

Inhalation: Remove exposed person to fresh air; restore and/or support his or her breathing as needed. Oxygen should be administered by trained medical personnel if it is available.

Ingestion: This type of exposure to hydrogen selenide is unlikely because it is a gas.

Treat any exposure to hydrogen selenide as an emergency! GET MEDICAL HELP (IN PLANT, PARAMEDIC, COMMUNITY) FOR ALL EXPOSURES. Seek prompt medical assistance for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel, evacuate all nonessential personnel, provide maximum possible ventilation, and eliminate all sources of ignition immediately. Cleanup personnel must wear protection against contact with and inhalation of vapor (see sect. 8). Try to shut off the flow of hydrogen selenide gas. Use a water spray to protect personnel who are attempting to stop the leak. **Waste**

Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations OSHA Designations

Air Contaminant (29 CFR 1910.1000 Subpart Z)

FPA Designations (40 CFR 302.4) Selenium Compounds*

RCRA Hazardous Waste

CERCLA Hazardous Substance

*A specific RCRA identification number and a CERCLA reportable quantity value are not available for hydrogen selenide, however, it is clear from this section that the RCRA and CERCLA laws both apply to this gas because it is a selenium compound.

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Follow the eye- and face protection guidelines of

29 CFR 1910.133. **Respirator:** Use a NIOSH-approved respirator per the *NIOSH Pocket Guide to Chemical Hazards* for the maximum-use concentrations and/or the exposure limits cited in section 2. Follow the respirator guidelines in 29 CFR 1910.134. For

emergency or nonroutine use (e.g., cleaning reactor vessels or storage tanks), wear an SCBA with a full facepiece operated in the pressure demand or positive-pressure mode. **Warning:** Air-purifying respirators will not protect workers in oxygen-deficient atmospheres.

Other Equipment: Wear impervious gloves; boots; aprons, and clean, impervious, body-covering clothing to prevent any possibility of skin contact. **Ventilation:** Install and operate general and local maximum, explosion-proof ventilation systems powerful enough to

maintain airborne levels of hydrogen selenide below the OSHA PEL standard cited in section 2. **Safety Stations:** Make eyewash

stations, washing facilities, and safety showers available to areas of use and handling. **Contaminated Equipment:** Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them. Do not wear contact lenses in any work area.

Comments: Practice good personal hygiene, always wash thoroughly after using this material. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do not eat, drink, or smoke in any work area. Do not inhale this gas!

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store hydrogen selenide in a cool, dry, well-ventilated area away from oxidizing agents, sources of ignition, any flammable or explosive materials, cylinders containing oxygen, or incompatible chemicals (see sect. 5). Outside or detached storage is recommended; shade cylinders containing hydrogen selenide from direct sunlight and protect them from snow and ice.

Special Handling/Storage: Hydrogen selenide is shipped and stored as a pressurized gas in cylinders or tank cars. Protect these containers against physical damage and regularly inspect them for cracks, leaks, or faulty valves. Do not drag or slide cylinders, move them in a carefully supervised manner with a suitable hand truck. **Engineering Controls:** Hydrogen selenide should be used in closed engineering systems because of its significant health and physical hazards (see sects. 4, 5, and 6). All engineering systems (production, transportation, etc.) must be of maximum explosion proof design (nonsparking, electrically grounded and bonded, etc.).

Comments: Keep the valve protection cap in place until immediately before using hydrogen selenide. Insert a check valve or trap into the transfer line to prevent a dangerous backflow into the original container. Use a pressure-reducing regulator when connecting a storage container to a lower-pressure piping system. A trained chemist or safety specialist familiar with the physical and chemical properties of this material should be present during all work operations.

Transportation Data (49 CFR 172.101-2)

DOT Shipping Name: Hydrogen Selenide

DOT Label: Flammable Gas and Poison

References: 1, 2, 12, 73, 84-94, 100, 103

DOT Hazard Class: Flammable Gas

DOT ID No.: UN2202

IMO Label: Poison Gas and Flammable Gas

IMO Class: 2.3

Judgments as to the suitability of information here for purchaser's purposes are necessarily purchaser's responsibility. Therefore, although reasonable care has been taken in the preparation of such information, Gossium Publishing Corp. extends no warranties, makes no representations and assumes no responsibility as to the accuracy or suitability of such information for application to purchaser's intended purposes or for consequences of its use.

Prepared by PJ Igoe, BS

Industrial Hygiene Review DJ Wilson, CHL

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Material Safety Data Sheet

from Genium's Reference Collection
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No. 63

PHOSPHINE

(Revision A)

Issued: May 1980

Revised: November 1988

SECTION 1. MATERIAL IDENTIFICATION

27

Material Name: PHOSPHINE**Description (Origin/Uses):** Used as a fumigant, as a doping agent for electronic components, and in chemical synthesis.**Other Designations:** Phosphuretted Hydrogen; Hydrogen Phosphide; Phosphorus Trihydride; PH₃;**CAS No.** 7803-51-2**Manufacturers:** Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

NFPA

HMIS

H 3

R 2

F 4

I 4

R 1

S -

PPG*

K 4

*See sect. 8

SECTION 2. INGREDIENTS AND HAZARDS

%

EXPOSURE LIMITS

Phosphine, CAS No. 7803-51-2

Ca 100

OSHA PELs8-Hr TWA: 0.3 ppm, 0.4 mg/m³15-Min STEL: 1 ppm, 1 mg/m³**ACGIH TLVs, 1988-89**TLV-TWA: 0.3 ppm, 0.4 mg/m³TLV-STEL: 1 ppm, 1 mg/m³**Toxicity Data***Rat, Inhalation, LC₅₀: 11 ppm (4 Hrs)Human, Inhalation, LC₅₀: 1000 ppm

*See NIOSH, RTECS (SY7525000), for additional data.

SECTION 3. PHYSICAL DATA**Boiling Point:** -121°F (-85°C)**Molecular Weight:** 34 Grams/Mole**Melting Point:** -209°F (-134°C)**Vapor Density (Air = 1):** 1.529**Appearance and Odor:** A colorless gas; disagreeable odor of garlic or decaying fish. The odor of decaying fish is detectable at 2 ppm, but the TLV is 3 ppm, which does not provide sufficient warning of a dangerous concentration.**SECTION 4. FIRE AND EXPLOSION DATA****Flash Point*****Autoignition Temperature:** 100°F (38°C)**LEL*****UEL***

Extinguishing Media: *Use carbon dioxide, dry chemical, or water spray or fog to fight a phosphine fire if it is absolutely necessary to extinguish it. It may be best to let the phosphine burn itself out. From a safe distance use a water spray to cool fire-exposed cylinders of phosphine. If it is safe to do so, remove containers from the fire area and/or stop the flow of gas. Use a water spray to protect personnel attempting this shutoff. If the gas leak is successfully stopped, let the released gas continue to burn itself out. **Unusual Fire or Explosion Hazards:** Phosphine is an extremely flammable gas; when it is contaminated it becomes pyrophoric (it burns spontaneously in air without the aid of any source of ignition). Do not extinguish phosphine fires without first shutting off the leaking gas, because the still-escaping phosphine gas can reignite explosively without warning. It may be best to let phosphine fires burn themselves out, because the products of combustion (phosphoric acid and water) are less hazardous or toxic than the original phosphine gas. **Dangers:** Intact phosphine cylinders can rupture violently when heated; try to remove them from the fire area if it is safe to do so. **Special Fire-fighting Procedures:** Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode.

SECTION 5. REACTIVITY DATA

Stability/Polymerization: Phosphine is stable in closed, pressurized containers during routine operations at room temperature. It can be dangerously reactive with other materials under certain conditions. **Hazardous polymerization** cannot occur. **Chemical Incompatibilities:** Phosphine is a dangerously reactive gas; hazardous reactions can occur when it is exposed to oxygen, halogens (bromine and chlorine), nitric acid, chlorine monoxide, silver nitrate, mercuric nitrate, nitrogen trichloride, aluminum alloys, copper, potassium and ammonia, nitrous oxide, nitrous acid, zinc oxide, and chlorine monoxide. Dry phosphine is spontaneously flammable in cold air. **Conditions to Avoid:** Avoid all exposure to sources of ignition and to incompatible chemicals. Follow your supplier's instructions on safe-handling procedures carefully. **Hazardous Products of Decomposition:** Phosphoric acid and water are produced during phosphine fires.

SECTION 6. HEALTH HAZARD INFORMATION**Carcinogenicity:** Phosphine is not listed as a carcinogen by the NTP, IARC, or OSHA.

Summary of Risks: Inhalation of phosphine gas at levels of 400 to 600 ppm (parts per million) for 30 minutes can be fatal. Phosphine is irritating to the eyes, nose, and respiratory system; it also acts as a central nervous system (CNS) depressant. Kidney injuries can cause albuminuria and hematuria. **Medical Conditions Aggravated by Long-Term Exposure:** None reported. **Target Organs:** Skin, eyes, respiratory system, kidneys, and CNS. **Primary Entry:** Inhalation, skin contact. **Acute Effects:** Symptoms of inhalation exposure to phosphine include coughing, shortness of breath, wheezing, increased bronchial secretions, pulmonary edema, weakness, fatigue, drowsiness, loss of consciousness, by coma, staggering gait, abdominal pain, thirst, nausea, vomiting, diarrhea, and possibly death. **Exposure Limits:**

SECTION 6. HEALTH HAZARD INFORMATION, cont.

severe and medical attention is unavailable. **Chronic Effects:** Chronic effects of exposure to phosphine are associated with disturbances of sight, speech, and motor functions; skeletal injuries are possible. These effects can be attributed to chronic phosphorus poisoning. **FIRST AID:** **Eyes:** Immediately flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes. **Inhalation:** Rescuers should have appropriate respiratory protection; an SCBA is recommended. Remove the exposed person to fresh air, restore and/or support his or her breathing as needed. Have qualified medical personnel administer oxygen as required. Keep the exposed person warm and at rest until medical help is available. The onset of symptoms usually takes place within the first few hours of inhalation. **Get medical help** (in plant, paramedic, community) for all exposures. Seek prompt medical assistance for further treatment, observation, and support after first aid. **Note to Physicians:** Observe the person exposed to phosphine through inhalation for at least 24 hours for the delayed onset of possible fatal pulmonary edema (lungs filled with fluid). Maintain fluid balance; diuretics may be helpful. Steroids can be used on a short term basis (2 to 4 days) to decrease the inflammatory response of the lungs. Treat CNS effects symptomatically. Phosphine induced seizures respond well to phenytoin (Dilantin).

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel, evacuate unnecessary personnel upwind, eliminate all sources of ignition immediately, and provide adequate ventilation. Cleanup personnel need protection against inhalation of phosphine gas (see sect. 6). As part of emergency-response planning, obtain detailed recommendations from your supplier regarding disposal of waste phosphine. For easier disposal, phosphine can be oxidized to phosphate by mixing it with excess calcium or sodium hypochlorite. Return defective cylinders to your supplier properly tagged and labeled with valve-protection caps in place, outlet seals secured, and valves tightly closed. **Waste Disposal:** Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations.

OSHA Designations

Listed as an Air Contaminant (29 CFR 1910.1000 Subpart Z)

EPA Designations (40 CFR 302.4)

RCRA Hazardous Waste, No. P096

CERCLA Hazardous Substance, Reportable Quantity: 100 lbs (45.4 kg), per the Resource Conservation and Recovery Act (RCRA), § 3001

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Follow OSHA eye- and face protection regulations (29 CFR 1910.133). **Respirator:** Use a NIOSH-approved respirator per Genium reference 88 for the maximum-use concentrations and/or the exposure limits cited in section 2. Follow OSHA respirator regulations (29 CFR 1910.134). For emergency or nonroutine operations (leaks or cleaning reactor vessels and storage tanks), wear an SCBA. **Warning:** Air-purifying respirators will not protect workers in oxygen-deficient atmospheres. **Other:** Wear impervious neoprene gloves, boots, aprons, and gauntlets, etc., to prevent any contact with phosphine. **Ventilation:** Install and operate general and local maximum, explosion-proof ventilation systems powerful enough to maintain airborne levels of phosphine below the OSHA PEL standard cited in section 2. Local exhaust ventilation is preferred because it prevents dispersion of the contaminant into the general work area by eliminating it at its source. Consult the latest edition of Genium reference 103 for detailed recommendations. Phosphine should be used only in closed engineering systems (fume hoods or pipelines). **Safety Stations:** Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work areas. **Contaminated Equipment:** Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them. Do not wear contact lenses in any work area. Remove contaminated clothing and launder it before wearing it again; clean this material from your shoes and equipment. **Other:** An automatic monitoring system for phosphine gas in the work atmosphere may be appropriate. **Comments:** Practice good personal hygiene; always wash thoroughly after using this material and before eating, drinking, smoking, using the toilet, or applying cosmetics. Keep it off your clothing and equipment. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do not eat, drink, or smoke in any work area. Do not inhale phosphine gas. Keep anyone with a history of blood, heart, or lung disease from working with phosphine until a physician monitors his or her status.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store phosphine in closed, pressurized cylinders in a cool, dry, well-ventilated area away from sources of ignition, strong oxidizers, and incompatible chemicals (see sect. 5). Protect containers from physical damage. **Special Handling/Storage:** Aluminum, light alloys, and copper are not recommended for use as storage materials. Iron and steel are recommended; commercial products that appear to be suitable for storage facilities include Teflon, Kel-F, Viton, and nylon. **Engineering Controls:** Make sure all engineering systems (production, transportation) are of maximum explosion-proof design. Ground and bond all containers and pipelines, etc., used in shipping, transferring, reacting, production, and sampling operations to prevent static sparks. Install and use pressure-reducing regulators when connecting a cylinder of phosphine to lower pressure (< 150 psig) piping or systems. **Other Precautions:** Store phosphine cylinders upright, secure them tightly to prevent them from falling, and segregate full and empty cylinders. Proper rotation of stock is essential to prevent significant degradation of the phosphine over time. Use a first in, first out inventory system to alleviate storage problems.

Transportation Data (49 CFR 172.101-2)

DOT Shipping Name: Phosphine

DOT Hazard Class: Poison A

ID No. UN2199

DOT Label: Poison Gas, Flammable Gas

DOT Packaging Requirements: 49 CFR 173.328

IMO Shipping Name: Phosphine

IMO Hazard Class: 2.3

IMO Label: Poison Gas, Flammable Gas

References 1, 26, 38, 84, 94, 100, 116, 117, 120, 122

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Prepared by: PJ Igwe, BS

Industrial Hygiene Review: DJ Wilson, CHH

Medical Review: MJ Hardies, MD

Specialty Gas Material Safety Data Sheet

#1441

EMERGENCY PHONE (800) 523-9374 IN PENNSYLVANIA (800) 322-9082	PRODUCT NAME TUNGSTEN HEXAFLUORIDE	CAS NO: 7783-82-6
AIR PRODUCTS AND CHEMICALS, INC. ALLENTOWN, PA 18195 (215) 481-8287	TRADE NAME AND SYNONYMS Tungsten Hexafluoride	
	CHEMICAL NAME AND SYNONYMS Tungsten Hexafluoride	
ISSUE DATE April 1978 REVISION DATE June 1985, Feb. 1987	FORMULA WF_6	CHEMICAL FAMILY Inorganic Fluoride

HEALTH HAZARD DATA

TIME WEIGHTED AVERAGE EXPOSURE LIMIT

OSHA and ACGIH: none established. APCI recommends compliance with the OSHA PEL and the ACGIH TWA of 3 ppm for hydrogen fluoride, which may form when tungsten hexafluoride is hydrolyzed.

SYMPTOMS OF EXPOSURE

Corrosive and extremely irritating to the upper and lower respiratory tracts, skin, and eyes. Tungsten hexafluoride hydrolyzes to form hydrofluoric acid; therefore, skin burns and mucous membrane irritation are similar to those caused by hexafluoride. Symptoms include tearing of the eyes, coughing, difficult breathing, and abnormal fluids formation in the nose, mouth and throat. Inhalation of tungsten hexafluoride may cause pneumonitis (deep lung inflammation) and pulmonary edema (abnormal fluid buildup in the lungs) which could be fatal. Symptoms of hydrofluoric acid burns are severe pain, redness, possible swelling and tissue destruction.

TOXICOLOGICAL PROPERTIES

Tungsten hexafluoride is irritating and corrosive to all living tissues. Toxic level exposure to skin tissue causes hydrofluoric acid burns and skin lesions resulting in tissue destruction and eventual scarring. Burn activity continues while any residual active fluorides remain. Chemical pneumonitis and pulmonary edema result from exposure to the lower respiratory tract and deep lung. Residual pulmonary malfunction might also occur. Burns of the eye result in lesions and possible loss of vision. Extended low level systemic absorption of fluorides may cause fluorosis, an abnormal calcium accumulation in the bone structure.

Tungsten hexafluoride is not listed in the IARC, NTP or OSHA Subpart Z as a carcinogen or a potential carcinogen.

RECOMMENDED FIRST AID TREATMENT

IMMEDIATE MEDICAL ATTENTION IS REQUIRED IN ALL CASES OF OVEREXPOSURE TO TUNGSTEN HEXAFLUORIDE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH APPROPRIATE PROTECTIVE EQUIPMENT (SELF-CONTAINED BREATHING APPARATUS, ETC.) TO PREVENT UNNECESSARY EXPOSURE.

Inhalation: Move exposed personnel to an uncontaminated area. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Keep victim warm and quiet. Assure that mucus or vomited material does not obstruct the airway by use of positional drainage. Delayed pulmonary edema may occur. Keep patient under medical observation for at least 24 hours.

Eye Contact: PERSONS WITH POTENTIAL EXPOSURE TO TUNGSTEN HEXAFLUORIDE SHOULD NOT WEAR CONTACT LENSES. Flush contaminated eyes with large quantities of water. Hold eyelids open with fingers to assure complete flushing. Continue for minimum of 30 minutes.

Skin Contact: Flush affected area with large quantities of water. Remove affected clothing as rapidly as possible. Skin burns may be treated with a calcium diacetate gel or slurry in water or glycerine. This compound binds the active fluorides in an insoluble form and limits burn extension and relieves pain. Skin burns may also be treated by immersion of burn area in a solution of 0.2% iced aqueous Hyamine 1622.* If immersion is not practical, towels soaked with Hyamine 1622 solution may be applied to burn area.

*Hyamine 1622 is a trade name for Benzethonium Chloride. Merck Index monograph 1078, a quaternary ammonium compound sold by Rohm and Haas Company, PA.

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES

Tungsten hexafluoride reacts violently with water to produce hydrofluoric acid and tungsten oxyfluorides

PHYSICAL DATA

BOILING POINT 62.5°F (16.9°C)	LIQUID DENSITY AT BOILING POINT 217.9 lb/ft ³ (3490 kg/m ³)
VAPOR PRESSURE @ 70°F (21.1°C) 17.3 psia (119.3 kPa)	GAS DENSITY AT 70°F, 1 atm 0.800 lb/ft ³ (12.8 kg/m ³)
SOLUBILITY IN WATER Hydrolyzes violently	FREEZING POINT 35.62°F (2.0°C)
APPEARANCE AND ODOR Liquid is light yellow; vapor is colorless and odorless. Specific Gravity (Air = 1) 10.674	

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) N/A	AUTO IGNITION TEMPERATURE N/A	FLAMMABLE LIMITS % BY VOLUME LEL N/A UEL N/A	
EXTINGUISHING MEDIA Nonflammable			ELECTRICAL CLASSIFICATION Nonhazardous
SPECIAL FIRE FIGHTING PROCEDURES If possible without risk, cool cylinders that have been exposed to flames or intense heat with water spray until well after fire is out. If possible without risk, remove cylinders from fire area.			
UNUSUAL FIRE AND EXPLOSION HAZARDS Cylinders exposed to fire may begin to vent product.			

REACTIVITY DATA

STABILITY Unstable		CONDITIONS TO AVOID None
Stable	X	
INCOMPATIBILITY (Materials to avoid) Water as vapor or liquid		
HAZARDOUS DECOMPOSITION PRODUCTS Hydrofluoric acid and tungsten oxyfluorides when hydrolyzed		
HAZARDOUS POLYMERIZATION May Occur		CONDITIONS TO AVOID None
Will Not Occur	X	

SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Evaluate all personnel from affected area. Use appropriate protective equipment. If leak is in user's equipment, be certain to purge piping with an inert gas prior to attempting repairs. If leak is in container or container valve, call the "800" emergency phone number listed herein. WF ₆ is much heavier than air; it will collect in low areas. Insure affected area is properly ventilated.
WASTE DISPOSAL METHOD All Federal, State, and Local regulations regarding health and pollution should be followed in waste disposal. Contact Air Products for specific recommendations. Do not dispose of unused quantities. Return the properly labeled shipping container to Air Products for disposal with valve(s) tightly closed, outlet seal(s) secured and properly labeled. For emergency disposal assistance, call the "800" emergency number listed herein.

SPECIAL PROTECTION INFORMATION

APPENDIX ML.4

RESPIRATORY PROTECTION (Specify type) Positive pressure air line with mask or self-contained breathing apparatus should be available for emergency use.

VENTILATION

Use hood with forced ventilation and/or local exhaust to prevent accumulation above the ceiling limit for hydrogen fluoride. Insure good ventilation at floor level.

PROTECTIVE GLOVES

Neoprene

EYE PROTECTION

Safety goggles or glasses, face shield

OTHER PROTECTIVE EQUIPMENT

Safety shoes, safety shower, eyewash "fountain", chemical resistant overgarments

SPECIAL PRECAUTIONS***SPECIAL LABELING INFORMATION**

DOT Shipping Name: Tungsten Hexafluoride, DOT Shipping Label: Corrosive; DOT Hazard Class: Corrosive Material, DOT ID No. UN 2196

SPECIAL HANDLING RECOMMENDATIONS

Use only in well-ventilated areas. Valve protection caps must remain in place unless cylinder is secured with valve outlet piped to use point. Do not drag, slide or roll cylinders. Use a suitable hand truck for cylinder movement. Cylinders may only be heated in a thermostatically controlled bath - NOT TO EXCEED 130°F (54°C). Use a check valve or trap in the discharge line to prevent hazardous backflow into the cylinder.

For additional recommendations consult the Air Products Specialty Gas Catalog Safety and Technical Information Section or Compressed Gas Association Pamphlet P-1.

SPECIAL STORAGE RECOMMENDATIONS

Protect cylinder from physical damage. Store in cool, dry, well-ventilated area away from heavily traveled areas and emergency exits. Do not allow temperature where cylinders are stored to exceed 125°F (51.7°C). Cylinders should be stored upright and firmly secured to prevent falling or being knocked over. Full and empty cylinders should be segregated. Use a "first in - first out" inventory system to prevent full cylinders being stored for excessive periods of time. Isolate tungsten hexafluoride from flammable materials.

For additional recommendations consult the Air Products Specialty Gas Catalog Safety and Technical Information Section or Compressed Gas Association Pamphlet P-1.

SPECIAL PACKAGING RECOMMENDATIONS

Most metals form a passive fluoride film that protects the metal from further corrosion. MONEL® and nickel are preferred for higher temperature applications. TEFLON® is the preferred gasket material.

OTHER RECOMMENDATIONS OR PRECAUTIONS

Keep equipment scrupulously dry. Many of the metal fluorides are water soluble; therefore, the passive film corrosion protection may be destroyed if wetted with water. Compressed gas cylinders should not be refilled except by qualified producers of compressed gases. Shipment of a compressed gas cylinder which has not been filled by the owner or with his (written) consent is a violation of Federal Law (49CFR).

EPDMALT ESSENTIALLY SIMILAR TO OSHA FORM 20 FORM 4040 (7-77)		ADDRESS: Penwalt Corporation Ozark-Mahoning Company 5101 West 21st Street Tulsa, OK 74107	
PRODUCT IDENTIFICATION	Penwalt Product Name Molybdenum Hexafluoride, MoF₆		Penwalt Case No. 48717
	Chemical Name and Molecular Formula Molybdenum Hexafluoride, MoF₆		Emergency Phone Number(s) (918) 585-2661
	Synonyms		CAS No.(s) 7783-77-9 Chemical Family Inorganic Fluorides
HAZARDOUS INGREDIENTS	MATERIALS OR COMPONENTS	%	HAZARD DATA (TLV, LD50, LC50, etc.)
	Molybdenum Hexafluoride (Fluorides as F)		ACGIH adopted TLV for 1984-85 for fluorides as F: 2.5 mg/m ³
PHYSICAL PROPERTIES	Boiling Point/Range 35 °C °F	Melting Point 17.4 °C °F	Freezing Point 17.4 °C °F
	Molecular Weight (Calculated) 210		
	Density (g/cm ³) 2.544		Vapor Pressure (mm Hg) 760 @ 35 °C °F
	Vapor Density (Air=1) Hydrolyzes		Evaporation Rate 100 %
FIRE & EXPLOSION DATA	Flash Point None °C °F		Autoignition Temperature N/A °C °F
	Extinguishing Media ☐ Water-spray ☐ Water-fog ☐ Water-stream ☐ CO ₂ ☐ Dry Chemical ☐ Alcohol foam ☐ Foam ☐ Earth or sand		
	In case of fire, use dry chemical, water or carbon dioxide. May react, perhaps violently with water, therefore copious quantities of water must be used.		
	Special Fire Fighting Procedures ☐ Do not enter building ☐ Do not use water ☐ Allow fire to burn ☐ Other (specify)		
	Unusual Fire & Explosion Hazards ☐ Dust explosion hazard ☐ Sensitive to shock ☐ Contamination ☐ Temperature ☐ Other (specify)		
	Stability ☒ Stable ☐ Unstable		Conditions Contributing to Instability ☐ Thermal decomposition ☐ Photo degradation ☐ Polymerization
	Incompatibility - Avoid contact with ☐ Strong acids ☐ Strong alkalis ☐ Strong oxidizers ☒ Other (specify):		Readily hydrolyzed by moisture and produces bluish colored intermediate oxyfluorides or hydrous trioxides.
	Hazardous Decomposition Products - Thermal and Other (HAP) Reacts with skin or water to produce heat and HF, a toxic vapor or liquid which causes burns.		
	Conditions to Avoid ☐ Heat ☐ Open flames ☐ Sparks ☐ Ignition point		Molybdenum Hexafluoride has oxidizing properties and should be handled and stored as such.
	SPILL OR LEAK	Steps to be taken if material is released or spilled ☒ Flush with water ☐ Absorb with sand or inert material ☒ Neutralize ☐ Sweep or scoop up and remove ☐ Keep upwind ☐ Evacuate enclosed spaces ☐ Prevent spread or spill	
Other (specify): In case of leak, keep upwind, evacuate enclosed spaces until gas has dispersed. (Flush area with water)			
Waste Disposal Method Consult federal, state or local authorities for proper disposal procedures			

Before using product, read and follow directions and precautions on product label and bulletins.

TOXICITY	Oral (acute)	Very corrosive, toxic liquid may cause death immediately.					
	Dermal (acute)	highly corrosive					
	Eye	highly corrosive	Inhalation	corrosive, toxic			
	Chronic	Fluorosis, kidney or liver damage can occur with prolonged exposure to fumes.					
Other	Inhalation may cause irritation to respiratory tract, skin congestion, fluorosis, and severe burns to skin.						
HEALTH AND INFORMATION Effects of Exposure	PERMISSIBLE EXPOSURE LIMIT	2.5	OSHA 19	TWA	Other:		
	ACGIH 1984-85	TLV mg/m ³			(Fluorides as F)		
	IRRITATION	☒ Skin	☒ Eye	☒ Severe	☐ Moderate	☐ Mild (transient)	
	CORROSIVITY	☒ Skin	☒ Eye	☐ Reversible	☒ Irreversible	☒ May cause blindness	
	SENSITIZATION	☐ Skin	☐ Respiratory	☐ Allergen	☐ Narcotic effect	☐ Cyanosis	☐ Asphyxiant
	LUNG EFFECTS (Specify):	Chemical pneumonitis, pulmonary edema or death					
	OTHER (Specify):						
	INGESTION	☐ Induce vomiting	☒ Do not induce vomiting	☒ Get medical attention	☒ Other (specify):	Immediately give large quantities of water or milk or milk of magnesia. Repeat frequently and call a physician. Drench area with copious amounts of water (particularly under nails) until whiteness disappears. Apply magnesia paste.	
	DERMAL	☒ Flush with soap and water	☒ Get medical attention	☐ Other (specify):			
	EYE CONTACT	☒ Flush with plenty of water for at least 15 minutes	☒ Get medical attention	☒ Other (specify):	Can cause immediate blindness.		
INHALATION	☒ Remove to fresh air	☒ If not breathing, give artificial respiration	☒ Give oxygen	☒ Get medical attention	☐ Other (specify):		
SPECIAL PROTECTION INFORMATION	VENTILATION REQUIREMENTS - Always maintain exposure below permissible exposure limits						
	☐ Consult an industrial hygienist or environmental health specialist	☐ Local exhaust	☒ Use with adequate ventilation	☐ Check for air contaminants and oxygen deficiency			
	☐ Other (specify):						
	EYE	☒ Face shield	HAND (GLOVE TYPE)		☐ Butyl rubber	☐ Polyvinyl alcohol	☐ Other (specify):
SPECIAL CAUTIONS	☒ Safety glasses	☒ Goggles	☒ Polyvinyl chloride	☒ Neoprene	☐ Natural rubber	☐ Polyethylene	
	RESPIRATOR TYPE - Use only NIOSH / MESA approved equipment						
	☐ Self-contained	☐ Supplied air	☐ Can or cartridge gas or vapor	☐ Filter - dust, fume, mist	☒ Other (specify):		
	OTHER PROTECTIVE EQUIPMENT						
SPECIAL CAUTIONS	PRECAUTIONARY LABELING						
	☐ Wash thoroughly after handling	☒ Do not get in eyes, on skin or clothing	☒ Do not breathe dust, vapor, mist, gas	☒ Keep container closed	☐ Keep away from heat, sparks, and open flames	☐ Store in tightly closed containers	
	☐ Do not store near combustibles	☒ Keep from contact with clothing and other combustible materials	☒ Empty container may contain hazardous residues	☐ Use explosion proof equipment	☐ Other (specify):		
	Other handling and storage conditions						
Molybdenum Hexafluoride must be handled carefully in scrupulously dry vacuum line or in dry system free of oxygen.							
Prepared by	Date	Address			Phone		
Dayal T. Mehrotra	11-27-85	1870 South Boulder, Tulsa, OK 74119			(918) 585-2661		

EASE

The above information is accurate to the best of our knowledge. However, since data, safety standards and government regulations are subject to change and the nature of handling and use of materials are beyond our control, Pennwalt MAKES NO WARRANTY, EITHER EXPRESS OR

MATERIAL SAFETY DATA SHEET

(Essentially similar to U.S. Department of Labor Form OSHA-20)
An explanation of the terms used herein may be found in OSHA
publication 2255, available from OSHA regional or area offices.
Do Not Duplicate This Form. Request an Original.

I. PRODUCT IDENTIFICATION

PRODUCT Silicon Tetrafluoride (High Pressure Gas)

CHEMICAL NAME	Silicon Tetrafluoride	SYNONYMS	Tetrafluorosilane
FORMULA	SiF ₄	CHEMICAL FAMILY	Silanes
		MOLECULAR WEIGHT	104.08

TRADE NAME ---

II. HAZARDOUS INGREDIENTS

For mixtures of this product request the respective component Material Safety Data Sheets
See Section IX.

MATERIAL	Wt (%)	1982 ACGIH TLV-TWA (Units)
Silicon Tetrafluoride	100	Not established

III. PHYSICAL DATA

BOILING POINT, 760 mm Hg	-65°C (-85°F)	FREEZING POINT	-95.1°C (-139.2°F)
SPECIFIC GRAVITY (H ₂ O = 1)	Gas	VAPOR PRESSURE AT 20°C	Gas
VAPOR DENSITY (air = 1)	3.57	SOLUBILITY IN WATER, % by wt.	Reacts
PERCENT VOLATILES BY VOLUME	100	EVAPORATION RATE (Butyl Acetate = 1)	N/A

APPEARANCE AND ODOR Colorless, suffocating odor.

EMERGENCY PHONE NUMBER

IN CASE OF EMERGENCIES involving this material, further information is available at all times at 304 - 744 3487
For routine information contact your local supplier.

Union Carbide Corporation requests the users of this product to study this Material Safety Data Sheet (MSDS) and become aware of product hazards and safety information. To promote safe use of this product a user should (1) notify its employees, agents and contractors of the information on this MSDS and any product hazards and safety information, (2) furnish this same information to each of its customers for the product, and (3) request such customers to notify their employees and customers for the product of the same product hazards and safety information.

UNION CARBIDE CORPORATION ☐ LINDE DIVISION
Old Ridgebury Road, Danbury, CT 06817

PRODUCT Silicon Tetrafluoride (High Pressure Gas)

IV. HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE TLV TWA 0.1 ppm (0.4 mg/m³) (ACGIH 1982)

EFFECTS OF OVEREXPOSURE AND EMERGENCY AND FIRST AID PROCEDURES

Vapor and liquid are corrosive and a severe irritant to eyes, skin and mucous membranes. Skin contact can cause severe chemical and thermal burns, exposure to high concentrations causes pulmonary edema, lung damage and may be fatal.

FIRST AID FOR INHALATION - Remove to fresh air and administer 100% oxygen immediately. If breathing is difficult, give oxygen. If not breathing give artificial respiration, preferably with simultaneous administration of oxygen. Rescuer should avoid breathing any exhaled air from victim. Call a physician.

FIRST AID FOR CONTACT

EYES - Remove contact lenses if present. Immediately flush with water for 15 to 30 minutes, eyelids should be spread apart to ensure contact with all accessible areas. Consult a physician, preferably an eye specialist.

SKIN - Flush affected areas immediately with large quantities of running water, while removing contaminated clothing and shoes. Follow by applying iced alcoholic or aqueous 0.2% Zephiran Chloride or Hyamine 1622 solution. If not available, continue washing in cool water for 2 to 4 hours. Upon severe exposure shock symptoms such as rapid pulse, sweating and collapse may appear. In such cases keep the victim warm and at rest. Call a physician. Discard contaminated clothing and shoes.

NOTE TO PHYSICIAN - Severe burns due to concentrated fluoride or prolonged exposures may require calcium gluconate 10% infiltration in and around damaged tissue, including subungual areas if involved.

PRODUCT: Silicon Tetrafluoride (High Pressure Gas)

V. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (test method)	N/A	AUTOIGNITION TEMPERATURE	N/A
FLAMMABLE LIMITS IN AIR, % by volume	LOWER N/A	UPPER	N/A

EXTINGUISHING MEDIA

Silicon Tetrafluoride cannot catch fire. Use media appropriate for surrounding fire. Reacts with water.
Note incompatibilities in Section VI.

SPECIAL FIRE FIGHTING PROCEDURES

Evacuate all personnel from danger area. Do not approach area without self-contained breathing apparatus and protective clothing. Immediately cool containers with water spray from maximum distance until cool, then move containers away from fire if without risk. If containers are leaking reduce vapors with water spray or fog.

DANGER: Suckback into cylinder may cause explosion (see Section IX). Shut off leak if without risk. Move containers away from fire area if without risk.

UNUSUAL FIRE AND EXPLOSION HAZARDS

Non-flammable, toxic, corrosive gas. Container may rupture due to heat of fire. Vapors are extremely irritating. Contact may cause burns to skin and eyes (see Section IV). No part of a container should be subjected to a temperature higher than 52°C (approximately 125°F).

VI. REACTIVITY DATA

STABILITY		CONDITIONS TO AVOID See Section IX.
UNSTABLE	STABLE	
	X	

INCOMPATIBILITY (materials to avoid) Water, trimethylamine

HAZARDOUS DECOMPOSITION PRODUCTS

Fluorine, Silicon

HAZARDOUS POLYMERIZATION		CONDITIONS TO AVOID
May Occur	Will not Occur	
	X	

None currently known

VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

Immediately evacuate all personnel from danger area.

DANGER: Corrosive, toxic gas. Use self-contained breathing apparatus and protective clothing where needed. Reduce vapors with fog or fine water spray.

DANGER: Suckback into cylinder may cause explosion (see Section IX). Shut off leak if without risk. Ventilate area of leak or move leaking container to well-ventilated area. Prevent runoff from contaminating surrounding environment. Corrosive, toxic vapors may spread from spill. Before entering area, especially confined areas, check atmosphere with appropriate device.

WASTE DISPOSAL METHOD

Recover any product, residue, disposable container or liner in an environmentally acceptable manner, in full compliance with Federal, State and local regulations.

PRODUCT: Silicon Tetrafluoride (High Pressure Gas)

L-4652-A

APPENDIX ML.6

VIII. SPECIAL PROTECTION INFORMATION

LABORATORY PROTECTION (specify type)

Self-contained breathing apparatus where needed.

VENTILATION	LOCAL EXHAUST Corrosion resistant system is acceptable.
	MECHANICAL (general) Inadequate
	SPECIAL Corrosion resistant forced draft fume hood preferred.
	OTHER

PROTECTIVE GLOVES

Neoprene

EYE PROTECTION

Safety glasses.

OTHER PROTECTIVE EQUIPMENT

Metatarsal shoes for cylinder handling. Protective clothing where needed.

IX. SPECIAL PRECAUTIONS

DANGER: Toxic, corrosive, high pressure gas.

Do not breathe gas. Do not get liquid or vapors in eyes, on skin or on clothing (see Section IV). Safety showers and eyewash fountains should be immediately available. Use piping and equipment adequately designed to withstand pressures to be countered. Store and use with adequate ventilation at all times. Use only in a closed system constructed of corrosion resistant materials.

Close valve when not in use and when empty.

NOTE: Suckback into cylinder may cause explosion. Always use a vacuum break or other protective apparatus in any line or piping from the cylinder to prevent suckback.

MIXTURES: When two or more gases, or liquefied gases are mixed, their hazardous properties may combine to create additional unexpected hazards. Obtain and evaluate the safety information for each component before you produce the mixture. Consult an Industrial Hygienist, or other trained person when you make your safety evaluation of the end product. Remember, gases and liquids have properties which can cause serious injury or death.

OTHER HANDLING AND STORAGE CONDITIONS

Forms fluosilicic acid in presence of moisture.

The opinions expressed herein are those of qualified experts within Union Carbide Corporation. We believe that the information contained herein is current as of the date of this Material Safety Data Sheet. Since the use of this information and these opinions and the conditions of use of the product are not within the control of Union Carbide Corporation, it is user's obligation to determine the conditions of safe use of the product.

UNION CARBIDE CORPORATION
LINDE DIVISION

GENERAL OFFICES: DANBURY, CT
OFFICES IN PRINCIPAL CITIES

MATERIAL SAFETY DATA

MSDS NO. 4206-04
CAS NO. 4262-43-5
DATE: 04/05/89

PRODUCT IDENTIFICATION	TRADE NAME:	CYPURE® Tertiarybutylarsine CVD Source				
	SYNONYMS:	TBA				
	CHEMICAL FAMILY:	Mono alkylarsine				
	MOLECULAR FORMULA:	C4H11As				
	MOLECULAR WGT.:	134				
WARNING	DANGER! EXTREMELY FLAMMABLE CATCHES FIRE IF EXPOSED TO AIR MAY BE FATAL IF INHALED					
CHRONIC HAZARD WARNINGS	CANCER HAZARD. COMBUSTION PRODUCTS MAY CAUSE CANCER.					
OSHA REGULATED COMPONENTS	COMPONENT	CAS. NO.	%	TWA/CEILING	REFERENCE	
	Tertiarybutylarsine	004262-43-5	99	0.5 mg/M3 0.2 mg/M3	OSHA ACGIH	
NFPA HAZARD RATING	Fire 3 Health 3 Special 1 Reactivity	FIRE: Liquids and solids that can be ignited under almost all ambient temperature conditions. HEALTH: Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given. REACTIVITY: Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.				
HEALTH HAZARD INFORMATION	EFFECTS OF OVEREXPOSURE:	The toxicological properties of this material have not been fully investigated. This material is pyrophoric and therefore contact with skin or eyes may produce thermal burns. The acute 4 hour vapor inhalation LC50 in rats is 70 ppm. Rats exposed to vapor concentrations of 50 to 500 ppm exhibited signs of ocular irritation and decreased activity during the exposure. There was no evidence of hemolysis induced by inhalation of this material.				
	FIRST AID:	In case of skin contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Obtain medical attention. Wash clothing before reuse. Destroy or thoroughly clean shoes before reuse. In case of eye contact, immediately irrigate with plenty of water for 15 minutes. Obtain medical attention without delay. If vapor of this material is inhaled, remove from exposure. Administer				

EMERGENCY PHONE: 201/835-3100

AMERICAN CYANAMID COMPANY, 1 CYANAMID PLAZA, WAYNE, NEW JERSEY 07090

oxygen if there is difficulty in breathing. Give artificial respiration if person is not breathing, and continue until normal breathing is established. Obtain medical attention without delay.

**EXPOSURE
CONTROL METHODS**

A closed system process must be used. Food, beverages, tobacco products should not be carried, stored or consumed where this chemical is in use. Before eating, drinking or smoking wash face and hands with soap and water. Store street clothing separately from work clothing and protective equipment. Work clothing and shoes must not be taken home. Wear the following as necessary to prevent skin contact: impervious gloves, full impervious protective suit with air supply. Provide eyewash fountain and safety shower in close proximity to points of potential exposure. Where concentrations are below the PEL, no respiratory protection is required. For spills or leaks, such protection may be necessary. Where exposures exceed PEL use respirator approved by NIOSH for the material and level of exposure. See "GUIDE TO INDUSTRIAL RESPIRATORY PROTECTION" (NIOSH). A full facepiece respirator will provide eye and face protection.

FIRE AND EXPLOSION HAZARD INFORMATION	FLASH POINT:	Pyrophoric
	FLAMMABLE LIMITS (% BY VOL):	Not Available
	AUTOIGNITION TEMP:	<130 F (<54.5 C)
	DECOMPOSITION TEMP:	Not Available
	FIRE FIGHTING:	<p>Immediate action should be taken to confine the fire. The most effective fire extinguishing agent is dry chemical powder pressurized with nitrogen. Sand, absorbent clay or CO2 may be used. Caution - Re-ignition may occur. If fire cannot be controlled with extinguishing agent, keep a safe distance, protect adjacent property and allow the product to burn until consumed.</p> <p>Human exposure must be prevented and nonessential personnel evacuated from the immediate area. Breathing vapors from this material or its combustion products must be avoided by using respiratory equipment. NIOSH approved air-supplied full face respirator should be used.</p>
REACTIVITY DATA	STABILITY	Unstable
	CONDITIONS TO AVOID:	This material is stable when stored under an anaerobic atmosphere and away from heat and light. It is pyrophoric and will typically ignite if brought in contact with combustible material or large surface areas in the ambient.
	POLYMERIZATION CONDITIONS TO AVOID:	Will Not Occur None known
	INCOMPATIBLE MATERIALS	Oxidizing agents, strong acids, and air.
PHYSICAL PROPERTIES	HAZARDOUS DECOMPOSITION PRODUCTS	Thermal decomposition or combustion may produce carbon monoxide and/or carbon dioxide and arsenic oxides
	APPEARANCE AND ODOR	Colorless oil with a very unpleasant odor suggesting rotten onions. Limits of olfactory detection are unknown
	BOILING POINT	156 F (69 C)
	MELTING POINT	30 F (-1 C)
	VAPOR PRESSURE	$\log P_{\text{mmHg}} = 7.243 - 1509/T(K)$
	SPECIFIC GRAVITY	1.0
	VAPOR DENSITY	Not Available
	% VOLATILE (BY VOL)	100
	OCTANOL/H2O PARTITION COEF	Not Applicable
	pH	Not Applicable
	SATURATION IN AIR (BY VOL)	Not Available
	EVAPORATION RATE	Not Available
	SOLUBILITY IN WATER	Slightly soluble

SPILL OR LEAK PROCEDURES	STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:	Block off source of spill, extinguish any fire with appropriate extinguishing agent - See Fire Fighting Section. Caution: Re-ignition may occur. If fire cannot be controlled with extinguishing agent, keep a safe distance, protect adjacent property and allow product to burn until consumed. Remove sources of ignition. Do not contact spill with paper, cloth or vermiculite as spontaneous ignition will occur. Cover spill with an inert absorbent clay (such as cat litter or similar material) and place in a sealable container sized such that free air volume is minimized. Seal under inert gas. If absorbent clay is used, dispose of as arsenic containing waste in a sealed container. Wipe area with ethanol soaked rags or cloths then wash area with detergent. Dispose of all rags or cloths as arsenic containing waste. Do not dispose of rags or cloths in same container with arsenic containing clay.
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WASTE DISPOSAL	Disposal must be made in accordance with applicable governmental regulations.
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SPECIAL PRECAUTIONS	HANDLING AND STORAGE/OTHER:	It is essential to store, handle and use tertiarybutylarsine under an anaerobic atmosphere of nitrogen, helium, hydrogen, or argon. Avoid contact with oxidizing agents, strong acids, chlorocarbons, and bromocarbons. Store and use tertiarybutylarsine at or below room temperature. Do not expose to temperatures in excess of 50 C (122 F). Inhalation must be strictly avoided. Areas containing this material should have fire-safe practices and electrical equipment in accordance with Electrical and Fire Protection codes (NFPA-30) governing Class 1 Flammable Liquids. NOTE: This material has been determined to be a D.O.T. "Poison - Inhalation hazard".
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D.O.T. SHIPPING INFORMATION	PROPER SHIPPING NAME:	PYROPHORIC LIQUID, N.O.S.	
	HAZARD CLASS	FLAMMABLE	LIQUID
	UN/NA:	UN2845	
	D.O.T. HAZARDOUS SUBSTANCES:	(Reportable Quantity of Product) NONE	
	D.O.T. LABEL REQUIRED:	Flammable Liquid Poison	

TSCA INFORMATION	This product is manufactured in compliance with all provisions of the Toxic Substances Control Act, 15 U.S.C.
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ENVIRONMENTAL INFORMATION	The following components are defined as toxic chemicals subject to reporting requirements of Section 313 of Title III and of 40 CFR 372 or subject to other EPA regulations.
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COMPONENT	CAS. NO.	%	SARA TITLE III			RCRA	TSCA 12B
			TPQ (lbs.)	RQ (lbs.)	§313		
Tertiarybutylarsine	004262-43-5	99	NONE	NONE	YES	D004	NO

PRODUCT CLASSIFICATION UNDER SECTION 311 OF SARA				
ACUTE (M)	CHRONIC (M)	FIRE (M)	REACTIVE (M)	PRESSURE (N)

Marvin A. Friedman, Ph.D., Director of Toxicology and Product Safety

This information is given without any warranty or representation. We do not assume any legal responsibility for same nor do we give permission, inducement, or recommendation to practice any patented invention without a license. It is offered solely for your consideration, investigation and verification. Before using any product read its label.

CLIPURE[®]

CLIPURE[®]

MATERIAL SAFETY DATA

MSDS NO. 3956-04
CAS NO. 002501-94-2
DATE: 01/16/89

PRODUCT IDENTIFICATION	TRADE NAME:	CYPURE® Tertiarybutylphosphine CVD Source			
	SYNONYMS:	TBP			
	CHEMICAL FAMILY:	Mono Alkylphosphine			
	MOLECULAR FORMULA:	C4H11P			
	MOLECULAR WGT.:	90			
WARNING	DANGER! EXTREMELY FLAMMABLE CATCHES FIRE IF EXPOSED TO AIR HARMFUL IF INHALED				
OSHA REGULATED COMPONENTS	COMPONENT	CAS. NO.	%	TWA/CEILING	REFERENCE
	Tertiarybutylphosphine	002501-94-2	99.99	not established	
NFPA HAZARD RATING	Fire 3	FIRE: Liquids and solids that can be ignited under almost all ambient temperature conditions. HEALTH: Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given. REACTIVITY: Materials which in themselves are normally stable, but which can become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.			
	Health 3 1 Reactivity Special				
HEALTH HAZARD INFORMATION	EFFECTS OF OVEREXPOSURE:	This material is pyrophoric and therefore contact with skin or eyes may produce thermal burns. Acute inhalation exposure of rats to vapor of this material produced no deaths after exposure to 510 ppm for 4 hours or 1144 ppm for 3 hours. Animals exposed to 1144 ppm vapor exhibited ocular irritation during exposure.			
	FIRST AID:	In case of skin contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Obtain medical attention. Wash clothing before reuse. Destroy or thoroughly clean shoes before reuse. In case of eye contact, immediately irrigate with plenty of water for 15 minutes. Obtain medical attention without delay. If vapor of this material is inhaled, remove from exposure. Administer oxygen if there is difficulty in breathing. Give artificial respiration if person is not breathing and continue until normal breathing is established. Obtain medical attention without delay.			

EMERGENCY PHONE: 201/835-3100

AMERICAN CYANAMID COMPANY, 1 CYANAMID PLAZA, WAYNE, NEW JERSEY 07470

**EXPOSURE
CONTROL METHODS**

A closed system process must be used. Food, beverages, tobacco products should not be carried, stored or consumed where this chemical is in use. Before eating, drinking or smoking wash face and hands with soap and water. Store street clothing separately from work clothing and protective equipment. Work clothing and shoes must not be taken home. Wear the following as necessary to prevent skin contact; impervious gloves, full impervious protective suit with air supply. Provide eyewash fountain and safety shower in close proximity to points of potential exposure.

Where engineering controls are effective, respiratory protection is generally not required except during operations where exposures may occur. Use a NIOSH approved respirator recommended by an industrial hygienist after an evaluation of the operation. A full facepiece respirator will provide eye and face protection.

FIRE AND
EXPLOSION
HARD
INFORMATION

FLASH POINT:	Pyrophoric
FLAMMABLE LIMITS (% BY VOL):	Not Available
AUTOIGNITION TEMP:	<130 F(<54.5 C)
DECOMPOSITION TEMP:	>300F(>149C)
FIRE FIGHTING:	Immediate action should be taken to confine the fire. The most effective fire extinguishing agent is dry chemical powder pressurized with nitrogen or absorbant clay. Caution - reignition may occur. If fire cannot be controlled with extinguishing agent, keep a safe distance, protect adjacent property and allow the product to burn until consumed. Human exposure should be prevented and nonessential personnel evacuated from the immediate area. Breathing vapors from this material or its combustion products should be avoided by using proper respiratory equipment. NIOSH approved positive pressure self contained breathing apparatus or air line respirator with full face respirator should be used.

REACTIVITY DATA

STABILITY:	Stable
CONDITIONS TO AVOID:	This material is stable when stored under an anaerobic atmosphere and away from heat and light.
POLYMERIZATION:	Will Not Occur
CONDITIONS TO AVOID:	None known
INCOMPATIBLE MATERIALS:	Oxidizing agents, chlorocarbons, bromocarbons
HAZARDOUS DECOMPOSITION PRODUCTS:	Combustion may produce carbon monoxide and/or carbon dioxide, phosphine oxides, phosphinic or phosphonic acid and P ₂ O ₅ . The products formed by the thermal decomposition of TBP in an anaerobic atmosphere are elemental phosphorus, isobutane, isobutylene, and phosphine.

PHYSICAL
PROPERTIES

APPEARANCE AND ODOR:	Clear, colorless, volatile liquid; stench
BOILING POINT:	133 F(56.1 C)
MELTING POINT:	39 F(4 C)
VAPOR PRESSURE:	$\ln P(\text{mm}) = 17.47 - (3544/T(K))$
VAPOR DENSITY:	Not Available
% VOLATILE (BY VOL):	100
OCTANOL/H ₂ O PARTITION COEF.:	Not Available
pH:	Not Applicable
SATURATION IN AIR (BY VOL):	Not Available
EVAPORATION RATE:	Not Available
SOLUBILITY IN WATER:	Insoluble in water, miscible with most organic solvents.

APPENDIX ML.8

**SPILL OR LEAK
PROCEDURES****STEPS TO BE TAKEN IN
CASE MATERIAL IS
RELEASED OR SPILLED:**

Block off source of spill, extinguish fire with appropriate extinguishing agent - See Section IV. Caution - Re-ignition may occur. If fire cannot be controlled with extinguishing agents, keep a safe distance, protect adjacent property and allow product to burn until consumed. Remove sources of ignition. Do not contact spill with paper, cloth or vermiculite as spontaneous ignition will occur.
Cover spill with an inert absorbant clay (such as cat litter or similar material) and place in a sealable container sized such that free air volume is minimized. Seal under inert gas.

WASTE DISPOSAL

Disposal must be made in accordance with applicable governmental regulations.

**SPECIAL
PRECAUTIONS****HANDLING AND
STORAGE/OTHER:**

Store under inert atmosphere-nitrogen or carbon dioxide. Avoid contact with oxidizing agents, chlorocarbons, and bromocarbons. This material has an over-powering, noxious odor. Inhalation should be strictly avoided.
Areas containing this material should be fire-safe practices and electrical equipment in accordance with Electrical and Fire Protection codes (NFPA-30) governing Class I Flammable Liquids.

**D.O.T. SHIPPING
INFORMATION****PROPER SHIPPING
NAME:**

PYROPHORIC LIQUID, N.O.S.

HAZARD CLASS:

FLAMMABLE LIQUID

UN/NA:

UN2845

**D.O.T. HAZARDOUS
SUBSTANCES:**(Reportable Quantity of Product)
NONE**D.O.T. LABEL REQUIRED:** Flammable Liquid**TSCA
INFORMATION**

This product is manufactured in compliance with all provisions of the Toxic Substances Control Act, 15 U.S.C.

**ENVIRONMENTAL
INFORMATION**

The following components are defined as toxic chemicals subject to reporting requirements of Section 313 of Title III and of 40 CFR 372 or subject to other EPA regulations.

SARA TITLE III							
COMPONENT	CAS. NO.	%	TPQ (lbs.)	RQ (lbs.)	S313	RCRA	TSCA 12B
This product does not contain any components regulated under these sections of the EPA							

PRODUCT CLASSIFICATION UNDER SECTION 311 OF SARA

ACUTE (Y) CHRONIC (N) FIRE (Y) REACTIVE (Y) PRESSURE (N)

Marvin A. Friedman, Ph.D., Director of Toxicology and Product Safety

This information is given without any warranty or representation. We do not assume any legal responsibility for same, nor do we give permission, inducement, or recommendation to practice any patented invention without a license. It is offered solely for your consideration, investigation and verification. Before using any product read its label.

TRIMETHYLGALLIUM
(TMG Semiconductor Grade)

APPENDIX ML.9
**Material Safety
Data Sheet**

This Material Safety Data Sheet (MSDS) meets the requirements of the federal OSHA Hazard Communication Standard (29 CFR 1910.1200).

This product should not be used until personnel handling it have been thoroughly trained. Contact Texas Alkyls, Inc., c/o Akzo Chemicals Inc., Chicago, IL. Additional information on safety and handling of organometallics is available in a brochure entitled, "Organometallics from Texas Alkyls, Inc."

New Issue 7/89
Supersedes 5/89
MSDS No. 90452/TR1550

EMERGENCY TELEPHONE NUMBERS

Transportation Emergencies:

USA-CHEMTREC: 1-800-424-9300
CANADA-CANUTEC: 613-996-6666

All Other Emergencies Call:
312-906-7054

I. PRODUCT IDENTIFICATION/COMPOSITION

COMPOSITION:

Trimethylgallium (approx. 100%), CAS
Registry Number: 1445-79-0.

CHEMICAL FORMULA: $(CH_3)_3Ga$

FORMULA WEIGHT: 144.82

II. PHYSICAL/CHEMICAL PROPERTIES

The following represent all available, applicable physical hazard data on this product.

PHYSICAL STATE/APPEARANCE:

Clear, colorless liquid.

MELTING POINT: 3.2°F (-16°C)

BOILING POINT:

132.4°F (55.8°C) @ 760 mm Hg

VAPOR PRESSURE:

64 mm Hg @ 32°F (0°C)

DENSITY:

1.151 g/ml @ 59°F (15°C)

FLASH POINT:

Pyrophoric - ignites spontaneously in air.

EXCLUSIVE
SALES AGENT
Akzo Chemicals Inc.
Akzo Chemicals Plaza
11100 W. Higgins Road, Suite 1100
Chicago, Illinois 60634
Phone: (312) 906-7000
Telex: 254 254 254

Akzo Chemicals bv
Stationstraat 4B
P.O. Box 247
3300 AA Amsterdam
The Netherlands
phone: (020) 5166 40 41
telex: 5057 AKZOC NL

Akzo Ltda
Divisão Química
Rua Dr. Eduardo de Souza
Araújo 154 20 Andar
Edifício Itaim Center
04564 São Paulo, S.P. Brasil
phone: (011) 544 4100
telex: 5057 AKZOC NL

Akzo Chemicals Pte Ltd
910 Thomson Road, #15-02
SIF Complex
Singapore 1179
phone: (65) 254 1535
telex: (65) 254 2476

TRIMETHYLGALLIUM
(TMG Semiconductor Grade)

III. CHEMICAL REACTIVITY

Reacts violently with water, air and compounds containing active hydrogen, such as alcohols and acids. Reaction with water and air liberates flammable methane gas or methyl alcohol. Ignites spontaneously on contact with air.

Compounds containing oxygen or organic halide may react vigorously upon contact with the product. Partial oxidation or hydrolysis products are possible.

IV. STABILITY

The product is stable when stored under an inert atmosphere and away from heat. Dry nitrogen is a suitable inert gas.

V. FIRE HAZARD

This material is pyrophoric and spontaneously flammable in air. Decomposition under fire conditions will give off materials which may cause respiratory discomfort. Do not use welding or cutting torch on or near any container of this material, even empty, because an explosion could occur. Do not store near heat or open flame. The product is considered pyrophoric by the paper char test used to gauge pyrophoricity for transportation purposes (1).

Combustion products of TMG are gallium oxide, carbon dioxide and water.

VI. FIRE CONTROL TECHNIQUES

Protecting against fire by strict adherence to safe operating procedures and proper equipment design is the best way to minimize the possibility of fire

damage. Immediate action should be taken to confine the fire. All lines and equipment which could contribute to the fire should be shut off. THE MOST EFFECTIVE FIRE EXTINGUISHING AGENT IS DRY CHEMICAL POWDER PRESSURIZED WITH NITROGEN. Dry sand or vermiculite may also be used. CAUTION: REIGNITION MAY OCCUR. If the fire cannot be controlled with extinguishing agents, keep a safe distance, protect adjacent property and allow to burn until consumed.

DO NOT USE WATER, FOAM, CARBON TETRACHLORIDE OR CHLOROBROMOMETHANE extinguishing agents as product either reacts violently or liberates toxic fumes on contact with these agents.

A standard aluminized firefighting suit is recommended for fighting metal alkyl fires.

Human exposure must be prevented and nonessential personnel evacuated from the immediate area. Breathing vapors from metal alkyl fires should be avoided by using proper respiratory equipment. NIOSH approved, full-face breathing apparatus should be used.

VII. HUMAN HEALTH

The principal routes of exposure are skin and eye contact. Because of the low volatility and highly reactive nature of this compound in air, ingestion and inhalation of this compound are highly unlikely.

This product will react with moisture on the skin and in the eye to produce severe thermal and chemical burns. Ingestion of this product will result in severe chemical and thermal burns of the mouth, esophagus, stomach and any

TRIMETHYLGALLIUM
(TMG Semiconductor Grade)

procedures, consideration should be given to the need for cleaning of equipment and piping systems to render them nonhazardous before maintenance and repair activities are performed. Waste resulting from these procedures should be handled in accordance with SECTION XIII: DISPOSAL OF MATERIAL.

ENGINEERING CONTROLS:

In those cases where engineering controls are indicated by the use conditions, the following traditional exposure control techniques may be used to effectively minimize employee exposure: local exhaust ventilation, enclosed system design, process isolation and remote control, in combination with appropriate use of personal protective equipment.

INGESTION:

All food must be kept in a separate area away from the storage/use location. Eating, drinking, smoking and carrying of tobacco products must be prevented in areas where there is a potential for exposure to this material. Before eating, drinking or smoking, hands and face must be thoroughly washed.

SKIN CONTACT:

Skin contact must be prevented through the use of fire-retardant clothing. During sampling, disconnecting lines or opening connections, additional protective outerwear including full-face shield, impervious gloves, aluminized Nomex[®] coat, a hard hat and chemical safety glasses should also be worn.

Safety showers, with quick opening valves which stay open, should be

readily available in all areas where this material is handled or stored. Water should be supplied through insulated and heat-traced lines to prevent freeze-ups in cold weather.

* Registered trademark of E. I. du Pont de Nemours & Company.

EYE CONTACT:

Eye contact must be prevented through the use of chemical safety glasses, goggles or a face shield selected with regard for use condition exposure potential.

Eye wash fountains, or other means of washing the eyes with a gentle flow of tap water, should be readily available in all areas where this material is handled or stored. Water should be supplied through insulated and heat-traced lines to prevent freeze-ups in cold weather.

INHALATION:

This material is normally handled under closed process conditions. In an emergency situation where adequate ventilation is not available, inhalation must be prevented through the use of NIOSH-approved, organic vapor respirators to reduce potential for exposure. Where exposure potential necessitates a higher level of protection, use a positive-pressure, air-supplied respirator.

Either half-face respirators in combination with chemical goggles or full-face respirators may be required in certain use conditions to prevent eye contact or irritation.

TRIMETHYLGALLIUM
(TMG Semiconductor Grade)

procedures, consideration should be given to the need for cleaning of equipment and piping systems to render them nonhazardous before maintenance and repair activities are performed. Waste resulting from these procedures should be handled in accordance with SECTION XIII: DISPOSAL OF MATERIAL.

ENGINEERING CONTROLS:

In those cases where engineering controls are indicated by the use conditions, the following traditional exposure control techniques may be used to effectively minimize employee exposure: local exhaust ventilation, enclosed system design, process isolation and remote control, in combination with appropriate use of personal protective equipment.

INGESTION:

All food must be kept in a separate area away from the storage/use location. Eating, drinking, smoking and carrying of tobacco products must be prevented in areas where there is a potential for exposure to this material. Before eating, drinking or smoking, hands and face must be thoroughly washed.

SKIN CONTACT:

Skin contact must be prevented through the use of fire-retardant clothing. During sampling, disconnecting lines or opening connections, additional protective outerwear including full-face shield, impervious gloves, aluminized Nomex® coat, a hard hat and chemical safety glasses should also be worn.

Safety showers, with quick opening valves which stay open, should be

readily available in all areas where this material is handled or stored. Water should be supplied through insulated and heat-traced lines to prevent freeze-ups in cold weather.

* Registered trademark of E. I. du Pont de Nemours & Company.

EYE CONTACT:

Eye contact must be prevented through the use of chemical safety glasses, goggles or a face shield selected with regard for use condition exposure potential.

Eye wash fountains, or other means of washing the eyes with a gentle flow of tap water, should be readily available in all areas where this material is handled or stored. Water should be supplied through insulated and heat-traced lines to prevent freeze-ups in cold weather.

INHALATION:

This material is normally handled under closed process conditions. In an emergency situation where adequate ventilation is not available, inhalation must be prevented through the use of NIOSH-approved, organic vapor respirators to reduce potential for exposure. Where exposure potential necessitates a higher level of protection, use a positive-pressure, air-supplied respirator.

Either half-face respirators in combination with chemical goggles or full-face respirators may be required in certain use conditions to prevent eye contact or irritation.

TRIMETHYLGALLIUM
(TMG Semiconductor Grade)

EXPOSURE LIMITS:

No exposure limits have been established for this material.

X. SPILL HANDLING

Gear appropriate for firefighting should be worn while working with spilled material. Block off source of spill. Spilled material will likely give off smoke and fumes and may ignite spontaneously. See SECTION VI: FIRE CONTROL TECHNIQUES. After fire is extinguished or has been allowed to burn out, wash spill away with copious quantities of water. CAUTION: WATER MAY CAUSE IGNITION TO OCCUR.

XI. CORROSIVITY TO MATERIALS OF CONSTRUCTION

Under inert conditions the product is not corrosive to metals commonly used in construction. Some plastics and elastomers may be attacked. Contact Texas Alkyls, Inc., c/o Akzo Chemicals Inc., Chicago, Illinois, for specific recommendations regarding suitable materials of construction for use with this product.

XII. STORAGE REQUIREMENTS

Store under an inert atmosphere. Containers should be stored in a cool, dry, well-ventilated area away from flammable materials and sources of heat or flame. Exercise due caution to prevent damage to or leakage from the container.

Because this material is pyrophoric, storage should meet the requirements of 29 CFR 1910.106, Flammable and Combustible Liquid.

XIII. DISPOSAL OF MATERIAL

Combustion of the material by controlled feed of air and product is a suitable disposal procedure. The products from complete combustion are carbon dioxide, gallium oxide and water.

Alternately, disposal can be achieved by diluting the product with hydrocarbon (heptane, etc.) to less than 5 weight percent metal alkyl concentration and treating the hydrocarbon solution with water under a nitrogen atmosphere in a vented and agitated container. Allow for the generation of heat and flammable hydrocarbons when treating with water. The products from hydrolysis are methane and gallium oxide (hydrated). Conduct water treatment in the absence of oxygen to avoid possible ignition of flammable material.

XIV. DISPOSAL OF CONTAINER

Dispose of empty containers according to any applicable regulations. NOTE: State and local regulations may be more stringent than federal.

XV. PREPARATION INFORMATION

Prepared by: Product Stewardship, Akzo Chemicals Inc., Chicago, Illinois, 312-906-7500.

REFERENCES CITED:

- (1) W. L. Mudry, D. C. Burleson, D. H. Malpass and S. C. Watson, J. Fire and Flammability, 6, 478, 1975.
- (2) American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values and Biological Exposure Indices for 1988-89, ACGIH: Cincinnati, OH, 1988.

Product Data**TRIMETHYLGALLIUM—Semiconductor Grade (TMG)****General Information**

Formula:	$(\text{CH}_3)_3\text{Ga}$
Formula Weight:	114.82
CAS Number:	1445-79-0
Appearance:	Clear, colorless liquid.
Safety and Handling:	This product <i>must</i> be handled in an inert atmosphere and kept away from excessive heat. Please reference the Material Safety Data Sheet for further information on the safe storage, use and handling of this product. This information should be thoroughly reviewed prior to the acceptance of this product.

Shipping Containers:	Shipments are made in stainless steel cylinders equipped with bellows valves and a dip tube. See the multiple-part data sheet "Shipping Containers for Semiconductor Grade Metalorganics." Air and parcel post shipment of pyrophoric materials is prohibited. Shipment of non-pyrophoric solutions by these modes is not recommended.
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Cylinder size, cc	75	150	300	600	1000
Product weight, g	50	100	200	500	750

Metallic Purity	99.9999 wt. % (min) gallium
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Properties

Melting Point:	-15.8°C
Boiling Point:	55.8°C
Vapor Pressure:	64.5 mm Hg @ 0°C 226.5 mm Hg @ 25°C
Density:	1.151 g/mL @ 15°C
Stability to Air:	Ignites on exposure (pyrophoric).
Stability to Water:	Reacts violently.
Storage Stability:	Stable when stored under a dry, inert atmosphere and away from heat.
Solubility/Reactivity:	Completely miscible, without reaction, with aromatic and saturated aliphatic and alicyclic hydrocarbons. Forms complexes with Lewis bases.

EXCLUSIVE
SALE AGENT
Akzo Chemicals Inc.
500 S. Riverside Plaza
Chicago, Illinois 60606 USA
phone (312) 467-5000
telex 250100 AKZO

Akzo Chemicals Inc.
c/o Mr. Richard H. Pearce
1070 Mohr Lane #15
Concord, CA 94510 USA
phone and telex
(510) 270-0395

Akzo Chemicals bv
Stationstraat 4B
P.O. Box 247
3800 AE Amersfoort
The Netherlands
phone (045) 465 50 11
telex 0177000 26 68

Akzo Chemicals Pte Ltd
510 Thomson Road, #15 07
SLE Complex
Singapore 1129
phone (65) 258 1333
telex (65) 258 2676

TRIMETHYLALUMINUM
(TMAL Semiconductor Grade)

This Material Safety Data Sheet (MSDS) meets the requirements of the federal OSHA Hazard Communication Standard (29 CFR 1910.1200).

This product should not be used until personnel handling it have been thoroughly trained. Contact Texas Alkyls, Inc., c/o Akzo Chemicals Inc., Chicago, IL. Additional information on safety and handling of organometallics is available in a brochure entitled, "Organometallics from Texas Alkyls, Inc."

New Issue 7/89
Supersedes 5/89
MSDS No. 90240/TR1549

EMERGENCY TELEPHONE NUMBERS

Transportation Emergencies:

USA-CLIENTREC: 1-800-424-9300
CANADA-CANUTEC: 613-996-6666

All Other Emergencies Call:
312-906-7054

I. PRODUCT IDENTIFICATION/COMPOSITION

COMPOSITION:

Trimethylaluminum (approx. 100%), CAS Registry Number: 75-24-1.

CHEMICAL FORMULA: $(CH_3)_3Al$

CHEMICAL FORMULA WEIGHT: 72.09

II. PHYSICAL/CHEMICAL PROPERTIES

The following represent all available, applicable physical hazard data on this product.

PHYSICAL STATE/APPEARANCE:

Clear, colorless liquid.

MELTING POINT: 59.5°F (15.3°C)

BOILING POINT:

260.8°F (127.1°C) @ 760 mm Hg

VAPOR PRESSURE:

9 mm Hg @ 68°F (20°C)

DENSITY:

0.748 g/ml @ 77°F (25°C)

FLASH POINT:

Pyrophoric - ignites spontaneously in air.

**EXCLUSIVE
U.S. AGENT**

Akzo Chemicals Inc.
100 River Street, 19th Fl.
Chicago, Illinois 60601, USA
phone (312) 906-7054
telex 258 2426

Akzo Chemicals bv
Stationstraat 48
P.O. Box 247
5800 AE Amsterdam
The Netherlands
phone (020) 51 51 51
telex 258 2426

Akzo Ltda
Divisão Química
Rua Dr. Eduardo de Souza
Aranha, 153-20 Andar
Edifício Norm Center
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phone (011) 501-5151
telex (011) 258 2426

Akzo Chemicals Pte Ltd
510 Thomson Road, #15 02
SIF Complex
Singapore 1129
phone (65) 258-1355
telex (65) 258 2426

**TRIMETHYLALUMINUM
(TMAL Semiconductor Grade)**

III. CHEMICAL REACTIVITY

Reacts violently with water, air and compounds containing active hydrogen, such as alcohols and acids. Reaction with water and air liberates flammable methane gas or methyl alcohol. Ignites spontaneously on contact with air.

Compounds containing oxygen or organic halide may react vigorously upon contact with the product. Partial oxidation or hydrolysis products are possible.

IV. STABILITY

The product is stable when stored under an inert atmosphere and away from heat. Dry nitrogen is a suitable inert gas.

V. FIRE HAZARD

This material is pyrophoric and spontaneously flammable in air. Decomposition under fire conditions will give off materials which may cause respiratory discomfort. Do not use welding or cutting torch on or near any container of this material, even empty, because an explosion could occur. Do not store near heat or open flame. The product is considered pyrophoric by the paper char test used to gauge pyrophoricity for transportation purposes (1).

Combustion products of TMAL are aluminum oxide, carbon dioxide and water.

VI. FIRE CONTROL TECHNIQUES

Protecting against fire by strict adherence to safe operating procedures and proper equipment design is the best way to minimize the possibility of fire

damage. Immediate action should be taken to confine the fire. All lines and equipment which could contribute to the fire should be shut off. **THE MOST EFFECTIVE FIRE EXTINGUISHING AGENT IS DRY CHEMICAL POWDER PRESSURIZED WITH NITROGEN.** Dry sand or vermiculite may also be used. **CAUTION: REIGNITION MAY OCCUR.** If the fire cannot be controlled with extinguishing agents, keep a safe distance, protect adjacent property and allow to burn until consumed.

DO NOT USE WATER, FOAM, CARBON TETRACHLORIDE OR CHLOROBROMOMETHANE extinguishing agents as product either reacts violently or liberates toxic fumes on contact with these agents.

A standard aluminized firefighting suit is recommended for fighting metal alkyl fires.

Human exposure must be prevented and nonessential personnel evacuated from the immediate area. Breathing vapors from metal alkyl fires should be avoided by using proper respiratory equipment. NIOSH approved, full-face breathing apparatus should be used.

VII. HUMAN HEALTH

The principal routes of exposure are skin and eye contact. Because of the low volatility and highly reactive nature of this compound in air, ingestion and inhalation of this compound are highly unlikely. Produces cataracts in rats. Also can be mutagenic and tetratogenic.

This product will react with moisture on the skin and in the eye to produce severe thermal and chemical burns.

TRIMETHYLALUMINUM (TMAL Semiconductor Grade)

Ingestion of this product will result in severe chemical and thermal burns of the mouth, esophagus, stomach and any other part of the gastrointestinal tract that comes in contact with the product. In the presence of air, the compound may combust violently to form materials which may cause respiratory discomfort.

There are no data available which address the effects of long-term exposure or any medical conditions that are generally recognized as being aggravated by exposure to this product.

VIII. FIRST AID

CALL A POISON CENTER OR A PHYSICIAN IMMEDIATELY.

If contact with this material occurs, immediately start the recommended procedures below. Simultaneously contact a Poison Center, a physician or the nearest hospital. Inform the person contacted of the type and extent of exposure, describe the victim's symptoms and follow the advice given.

INGESTION:

Because of the reactive nature of this compound in air, ingestion is highly unlikely. If swallowed, immediately give several glasses of water, but do not induce vomiting. This material is corrosive. If vomiting does occur, give fluids again. Have a physician determine if condition of patient will permit induction of vomiting or evacuation of stomach. Do not give anything by mouth to an unconscious or convulsing person.

SKIN CONTACT:

Immediately remove all contaminated clothing and shoes. Under a safety

shower, flush all affected areas thoroughly with large amounts of running water for at least 15 minutes. Do not attempt to neutralize with chemical agents. Get medical attention immediately. Discard contaminated clothing and shoes.

EYE CONTACT:

Immediately flush the eyes with large quantities of running water for a minimum of 15 minutes. Hold the eyelids apart during the flushing to ensure rinsing of the entire surface of the eye and lids with water. Do not attempt to neutralize with chemical agents. Obtain medical attention immediately. Oils or ointments should not be used at this time. Continue the flushing for an additional 15 minutes if a physician is not immediately available.

INHALATION:

Exposure to combustion products may cause respiratory symptoms. If inhaled, remove to fresh air. If not breathing, clear victim's airway and start mouth-to-mouth, artificial respiration which may be supplemented by the use of a bagmask respirator or manually triggered oxygen supply capable of delivering one liter per second or more. If victim is breathing, supplemental oxygen may be given from a demand-type or continuous-flow inhaler, preferably with a physician's advice. Get medical attention immediately.

IX. INDUSTRIAL HYGIENE

The recommendations described in this section are provided as general guidance for minimizing exposure when handling this product. Because use

TRIMETHYLALUMINUM (TMAL Semiconductor Grade)

conditions will vary depending upon customer applications, specific safe handling procedures should be developed by a person knowledgeable of the intended use conditions and equipment. During the development of safe handling procedures, consideration should be given to the need for cleaning of equipment and piping systems to render them nonhazardous before maintenance and repair activities are performed. Waste resulting from these procedures should be handled in accordance with SECTION XIII: DISPOSAL OF MATERIAL.

ENGINEERING CONTROLS:

In those cases where engineering controls are indicated by the use conditions, the following traditional exposure control techniques may be used to effectively minimize employee exposure: local exhaust ventilation, enclosed system design, process isolation and remote control, in combination with appropriate use of personal protective equipment.

INGESTION:

All food must be kept in a separate area away from the storage/use location. Eating, drinking, smoking and carrying of tobacco products must be prevented in areas where there is a potential for exposure to this material. Before eating, drinking or smoking, hands and face must be thoroughly washed.

SKIN CONTACT:

Skin contact must be prevented through the use of fire-retardant clothing. During sampling, disconnecting lines or opening connections, additional protective outerwear including full-face shield, impervious gloves,

aluminized Nomex* coat, a hard hat and chemical safety glasses should also be worn.

Safety showers, with quick opening valves which stay open, should be readily available in all areas where this material is handled or stored. Water should be supplied through insulated and heat-traced lines to prevent freeze-ups in cold weather.

* Registered trademark of E. I. du Pont de Nemours & Company.

EYE CONTACT:

Eye contact must be prevented through the use of chemical safety glasses, goggles or a face shield selected with regard for use condition exposure potential.

Eye wash fountains, or other means of washing the eyes with a gentle flow of tap water, should be readily available in all areas where this material is handled or stored. Water should be supplied through insulated and heat-traced lines to prevent freeze-ups in cold weather.

INHALATION:

Inhalation of mists or vapors results in immediate irritation of the upper respiratory tract. Exposure to combustion products may cause symptoms including "metal fume fever" (throat irritation, headache, fever, chills, nausea, vomiting, muscular aches and pains, shortness of breath and weakness).

This material is normally handled under closed process conditions. In an emergency situation where adequate ventilation is not available,

TRIMETHYLALUMINUM (TMAL Semiconductor Grade)

inhalation must be prevented through the use of NIOSH-approved, organic vapor respirators to reduce potential for exposure. Where exposure potential necessitates a higher level of protection, use a positive-pressure, air-supplied respirator.

Either half-face respirators in combination with chemical goggles or full-face respirators may be required in certain use conditions to prevent eye contact or irritation.

EXPOSURE LIMITS:

The following exposure limit applies for aluminum alkyl compounds (not otherwise classified). The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended a Threshold Limit Value (TLV) of 2 mg/m³ (as aluminum) (2).

X. SPILL HANDLING

Gear appropriate for firefighting should be worn while working with spilled material. Block off source of spill. Spilled material will likely give off smoke and fumes and may ignite spontaneously. See SECTION VI: FIRE CONTROL TECHNIQUES. After fire is extinguished or has been allowed to burn out, wash spill away with copious quantities of water. CAUTION: WATER MAY CAUSE IGNITION TO OCCUR.

XI. CORROSIVITY TO MATERIALS OF CONSTRUCTION

Under inert conditions the product is not corrosive to metals commonly used in construction. Some plastics and elastomers may be attacked. Contact Texas Alkyls, Inc., c/o Akzo Chemicals Inc., Chicago, Illinois, for specific recommendations regarding suitable

materials of construction for use with this product.

XII. STORAGE REQUIREMENTS

Store under an inert atmosphere. Containers should be stored in a cool, dry, well-ventilated area away from flammable materials and sources of heat or flame. Exercise due caution to prevent damage to or leakage from the container.

Because this material is considered pyrophoric, storage should meet the requirements of 29 CFR 1910.106, Flammable and Combustible Liquids.

XIII. DISPOSAL OF MATERIAL

Combustion of the material by controlled feed of air and product is a suitable disposal procedure. The products from complete combustion are carbon dioxide, aluminum oxide and water.

Alternately, disposal can be achieved by diluting the product with hydrocarbon (heptane, etc.) to less than 5 weight percent methyl alkyl concentration and treating the hydrocarbon solution with water under a nitrogen atmosphere in a vented and agitated container. Allow for the generation of heat and flammable hydrocarbons when treating with water. The products from hydrolysis are methane and aluminum oxide (hydrated). Conduct water treatment in the absence of oxygen to avoid possible ignition of flammable material.

XIV. DISPOSAL OF CONTAINER

Dispose of empty containers according to any applicable regulations. NOTE: State and local regulations may be more stringent than federal.

TRIMETHYLALUMINUM
(TMAL Semiconductor Grade)

XV. PREPARATION INFORMATION

Prepared by: Product Stewardship, Akzo
Chemicals Inc., Chicago, Illinois,
312-906-7500.

REFERENCES CITED:

(1) W. L. Mudry, D. C. Burleson, D. B.
Malpass and S. C. Watson, J. Fire and
Flammability, 6, 478, 1975.

(2) American Conference of
Governmental Industrial Hygienists
(ACGIH), Threshold Limit Values and
Biological Exposure Indices for
1988-89, ACGIH: Cincinnati, OH, 1988.

Texas Alkyls, Inc. brochure: "Aluminium
Alkyls...Specifications, Properties and
Procedures." (1971)

ALKYLS

DIETHYLZINC (DEZ Semiconductor Grade)

APPENDIX M1.11 Material Safety Data Sheet

This Material Safety Data Sheet (MSDS) meets the requirements of the federal OSHA Hazard Communication Standard (29 CFR 1910.1200).

This product should not be used until personnel handling it have been thoroughly trained. Contact Texas Alkyls, Inc., c/o Akzo Chemicals Inc., Chicago, IL. Additional information on safety and handling of organometallics is available in a brochure entitled, "Organometallics from Texas Alkyls, Inc."

New Issue 7/89
Supersedes 5/89
MSDS No. 90025/DIE278

EMERGENCY TELEPHONE NUMBERS

Transportation Emergencies:

USA-CHEMTREC: 1-800-424-9300
CANADA-CANUTEC: 613-996-6666

All Other Emergencies Call:
312-906-7054

This product is subject to SARA Section 313 annual toxic chemical release reporting.

I. PRODUCT IDENTIFICATION/COMPOSITION

COMPOSITION:

Diethylzinc (approx. 100%), CAS
Registry Number: 557-20-0.

CHEMICAL FORMULA: $(C_2H_5)_2Zn$

FORMULA WEIGHT: 123.50

II. PHYSICAL/CHEMICAL PROPERTIES

The following represent all available, applicable physical hazard data on this product.

PHYSICAL STATE/APPEARANCE:

Clear, colorless liquid.

MELTING POINT: -22°F (-30°C)

BOILING POINT:

243.7°F (117.6°C) @ 760 mm Hg

VAPOR PRESSURE:

16 mm Hg @ 77°F (25°C)

DENSITY:

1.201 g/ml @ 77°F (25°C)

FLASH POINT:

Pyrophoric - ignites spontaneously in air.

TECHNICAL AGENT
Akzo Chemicals Inc.
P.O. Box 1000, Plaza
Chicago, IL 60601-1000, USA
Tel: 312-906-7054

Akzo Chemicals by
Netherlands 68
P.O. Box 247
4000 AE Amsterdam
The Netherlands
Tel: 020-611 11 11
Telex: 5135 EX NL

Akzo Ltda
Divisão Química
Rua Dr. Eduardo de Souza
Arantina 15-520 Andar
Edição Itam Center
Itaú S.A. Rua Prata S.D. Brasil
Phone: (011) 543-5060
Telex: 5135 EX NL

Akzo Chemicals Pte Ltd
510 Thomson Road #15 02
S.E. Complex
Singapore 1129
phone: (06) 258-1555
telex: 5135 EX NL

DIETHYLZINC
(DEZ Semiconductor Grade)

SOLUBILITY IN WATER:

Reacts violently.

III. CHEMICAL REACTIVITY

Reacts violently with water, air and compounds containing active hydrogen, such as alcohols and acids. Reaction with water and air liberates flammable ethane gas or ethyl alcohol. Ignites spontaneously on contact with air.

Compounds containing oxygen or organic halide may react vigorously upon contact with the product. Partial oxidation or hydrolysis products are possible.

IV. STABILITY

The product is stable when stored under an inert atmosphere and away from heat. Dry nitrogen is a suitable inert gas. It may undergo decomposition above 120°C and can violently decompose above 150°C.

V. FIRE HAZARD

This material is pyrophoric and spontaneously flammable in air. Decomposition under fire conditions will give off materials which may cause respiratory discomfort. Do not use welding or cutting torch on or near any container of this material, even empty, because an explosion could occur. Do not store near heat or open flame. The product is considered pyrophoric by the paper char test used to gauge pyrophoricity for transportation purposes (1). Runoff to sewer may create fire or explosion hazard.

Combustion products of DEZ are zinc oxide, carbon dioxide and water.

VI. FIRE CONTROL TECHNIQUES

Protecting against fire by strict adherence to safe operating procedures and proper equipment design is the best way to minimize the possibility of fire damage. Immediate action should be taken to confine the fire. All lines and equipment which could contribute to the fire should be shut off. THE MOST EFFECTIVE FIRE EXTINGUISHING AGENT IS DRY CHEMICAL POWDER PRESSURIZED WITH NITROGEN. Dry sand or vermiculite may also be used. CAUTION: REIGNITION MAY OCCUR. If the fire cannot be controlled with extinguishing agents, keep a safe distance, protect adjacent property and allow to burn until consumed.

DO NOT USE WATER, FOAM, CARBON TETRACHLORIDE OR CHLOROBROMOMETHANE extinguishing agents as product either reacts violently or liberates toxic fumes on contact with these agents.

A standard aluminized firefighting suit is recommended for fighting metal alkyl fires.

Human exposure must be prevented and nonessential personnel evacuated from the immediate area. Breathing vapors from metal alkyl fires should be avoided by using proper respiratory equipment. NIOSH approved, full-face breathing apparatus should be used.

VII. HUMAN HEALTH

The principal routes of exposure are skin and eye contact. Because of the low volatility and highly reactive nature of this compound in air, ingestion and inhalation of this compound are highly unlikely.

DIETHYLZINC
(DEZ Semiconductor Grade)

This product will react with moisture on the skin and in the eye to produce severe thermal and chemical burns. Ingestion of this product will result in severe chemical and thermal burns of the mouth, esophagus, stomach and another part of the gastrointestinal tract that comes in contact with the product. In the presence of air, the compound may combust violently to form materials which may cause respiratory discomfort.

There are no data available which address the effects of long-term exposure or any medical conditions that are generally recognized as being aggravated by exposure to this product.

Other symptoms, including chills, fatigue, headache, vomiting and leukocytosis may be delayed 4-12 hours. Tolerance to zinc fume fever may develop, but is lost quickly. Chronic exposure - latent liver dysfunction and peptic ulcer indicative of gastrointestinal tract damage - have been reported from repeated exposure to zinc oxide.

VIII. FIRST AID

CALL A POISON CENTER OR A PHYSICIAN IMMEDIATELY.

If contact with this material occurs, immediately start the recommended procedures below. Simultaneously contact a Poison Center, a physician or the nearest hospital. Inform the person contacted of the type and extent of exposure, describe the victim's symptoms and follow the advice given.

INGESTION:

Because of the reactive nature of this compound in air, ingestion is highly unlikely. If swallowed, immediately give several glasses of water, but do not induce vomiting. This material is

corrosive. If vomiting does occur, give fluids again. Have a physician determine if condition of patient will permit induction of vomiting or evacuation of stomach. Do not give anything by mouth to an unconscious or convulsing person.

SKIN CONTACT:

Immediately remove all contaminated clothing and shoes. Under a safety shower, flush all affected areas thoroughly with large amounts of running water for at least 15 minutes. Do not attempt to neutralize with chemical agents. Get medical attention immediately. Discard contaminated clothing and shoes.

EYE CONTACT:

Immediately flush the eyes with large quantities of running water for a minimum of 15 minutes. Hold the eyelids apart during the flushing to ensure rinsing of the entire surface of the eye and lids with water. Do not attempt to neutralize with chemical agents. Obtain medical attention immediately. Oils or ointments should not be used at this time. Continue the flushing for an additional 15 minutes if a physician is not immediately available.

INHALATION:

Exposure to combustion products may cause respiratory symptoms, which include dry throat, chest pain, dyspnea, dry cough, metallic taste and rales. If inhaled, remove to fresh air. If not breathing, clear victim's airway and start mouth-to-mouth, artificial respiration which may be supplemented by the use of a bagmask respirator or manually triggered oxygen supply capable of delivering one

DIETHYLZINC
(DEZ Semiconductor Grade)

liter per second or more. If victim is breathing, supplemental oxygen may be given from a demand-type or continuous-flow inhaler, preferably with a physician's advice. Get medical attention immediately.

IX. INDUSTRIAL HYGIENE

The recommendations described in this section are provided as general guidance for minimizing exposure when handling this product. Because use conditions will vary depending upon customer applications, specific safe handling procedures should be developed by a person knowledgeable of the intended use conditions and equipment. During the development of safe handling procedures, consideration should be given to the need for cleaning of equipment and piping systems to render them nonhazardous before maintenance and repair activities are performed. Waste resulting from these procedures should be handled in accordance with SECTION XIII: DISPOSAL OF MATERIAL.

ENGINEERING CONTROLS:

In those cases where engineering controls are indicated by the use conditions, the following traditional exposure control techniques may be used to effectively minimize employee exposure: local exhaust ventilation, enclosed system design, process isolation and remote control, in combination with appropriate use of personal protective equipment.

INGESTION:

All food must be kept in a separate area away from the storage/use location. Eating, drinking, smoking and carrying of tobacco products must be prevented in areas where there is a potential for exposure to this material. Before eating, drinking or

smoking, hands and face must be thoroughly washed.

SKIN CONTACT:

Skin contact must be prevented through the use of fire-retardant clothing. During sampling, disconnecting lines or opening connections, additional protective outerwear including full-face shield, impervious gloves, aluminized Nomex* coat, a hard hat and chemical safety glasses should also be worn.

Safety showers, with quick opening valve* which stay open, should be readily available in all areas where this material is handled or stored. Water should be supplied through insulated and heat-traced lines to prevent freeze-ups in cold weather.

* Registered trademark of E. I. du Pont de Nemours & Company.

EYE CONTACT:

Eye contact must be prevented through the use of chemical safety glasses, goggles or a face shield selected with regard for use condition exposure potential.

Eye wash fountains, or other means of washing the eyes with a gentle flow of tap water, should be readily available in all areas where this material is handled or stored. Water should be supplied through insulated and heat-traced lines to prevent freeze-ups in cold weather.

INHALATION:

This material is normally handled under closed process conditions. In an emergency situation where adequate ventilation is not available, inhalation must be prevented through the use of NIOSH-approved, organic

DIETHYLZINC
(DEZ Semiconductor Grade)

vapor respirators to reduce potential for exposure. Where exposure potential necessitates a higher level of protection, use a positive-pressure, air-supplied respirator.

Either half-face respirators in combination with chemical goggles or full-face respirators may be required in certain use conditions to prevent eye contact or irritation.

EXPOSURE LIMITS:

No exposure limits have been established for this material.

X. SPILL HANDLING

Gear appropriate for firefighting should be worn while working with spilled material. Block off source of spill. Spilled material will likely give off smoke and fumes and may ignite spontaneously. See SECTION VI: FIRE CONTROL TECHNIQUES. After fire is extinguished or has been allowed to burn out, wash spill away with copious quantities of water. CAUTION: WATER MAY CAUSE IGNITION TO OCCUR.

For occupational spills, shut off ignition sources. Do not touch spilled material. Stop leak if you can do it without risk. Do not get water on spilled material or inside the container. For small dry spills, with clean shovel place material into clean, dry container and cover; move containers from spill area. For small liquid spills, take up with sand or other absorbent material and place into containers for later disposal. For larger spills, dike spill for later disposal. Cover powder spills with plastic sheet or tarp to minimize spreading. Keep unnecessary people away. Isolate hazard area and deny entry.

XI. CORROSIVITY TO MATERIALS OF CONSTRUCTION

Under inert conditions the product is not corrosive to metals commonly used in construction. Some plastics and elastomers may be attacked. Contact Texas Alkyls, Inc., c/o Akzo Chemicals Inc., Chicago, Illinois, for specific recommendations regarding suitable materials of construction for use with this product.

XII. STORAGE REQUIREMENTS

Store under an inert atmosphere. Containers should be stored in a cool, dry, well-ventilated area away from flammable materials and sources of heat or flame. Exercise due caution to prevent damage to or leakage from the container.

Because this material is considered pyrophoric, storage should meet the requirements of 29 CFR 1910.106, Flammable and Combustible Liquids. Also, guidelines specified in NFPA 77-1983 recommended practice on static electricity should be followed.

XIII. DISPOSAL OF MATERIAL

Combustion of the material by controlled feed of air and product is a suitable disposal procedure. The products from complete combustion are carbon dioxide, zinc oxide and water.

Alternately, disposal can be achieved by diluting the product with hydrocarbon (heptane, etc.) to less than 5 weight percent metal alkyl concentration and treating the hydrocarbon solution with water under a nitrogen atmosphere in a vented and agitated container. Allow for the generation of heat and flammable hydrocarbons when treating with water.

DIETHYLZINC
(DEZ Semiconductor Grade)

The products from hydrolysis are ethane and zinc oxide (hydrated). Conduct water treatment in the absence of oxygen to avoid possible ignition of flammable material.

XIV. DISPOSAL OF CONTAINER

Dispose of empty containers according to any applicable regulations. NOTE: State and local regulations may be more stringent than federal.

XV. PREPARATION INFORMATION

Prepared by: Product Stewardship, Akzo Chemicals Inc., Chicago, Illinois, 312-906-7500.

REFERENCES CITED:

(1) W. L. Mudry, D. C. Burleson, D. B. Malpass and S. C. Watson, J. Fire and Flammability, 6, 478, 1975.

Material Safety Data Sheet

TMI
QUICK IDENTIFIER (In Pict Common Name)

APPENDIX M1.12

Manufacturer's Name	Stauffer Chemical Company	Emergency Telephone No.	CHEMTREC, (800) 424-9300
Address	Westport, CT 06881	Other Information Call	(203) 222-3122
Signature of Person Responsible for Preparation	R. H. Pearce	Date Prepared	2/10/86

SECTION 1 - IDENTITY

Common Name (used on label) (Trade Name & Synonyms)	TMI	Cas No.	3385-78-2
Chemical Name	Trimethylindium	Chemical Family	Organometallic compound
Formula	(CH ₃) ₃ In		

SECTION 2 - HAZARDOUS INGREDIENTS

Principal Hazardous Component(s) (chemical & common names)	%	Threshold Limit Value (ceiling)
Trimethylindium	99.999	N/A

SECTION 3 - PHYSICAL & CHEMICAL CHARACTERISTICS (Fire & Explosion Data)

Boiling Point	dec. >130°C	Specific Gravity (H ₂ O=1)	1.568	Vapor Pressure (mm Hg)	5mm (25°C)
Percent Volatile by Volume (%)	100%	Vapor Density (Air = 1)	N/A	Evaporation Rate (_____ = 1)	N/A
Solubility in Water	Reacts violently	Reactivity in Water	Reacts violently		
Appearance and Odor	Colorless crystals, or white powder				

Flash Point	N/A	Flammable Limits in Air % by Volume	N/A	Lower	Upper	Extinguisher Media	Dry chemical	Auto-ignition Temperature	Pyrophoric
Special Fire Fighting Procedures	Dry chemical extinguisher recommended								
	Do not use water								

Unusual Fire and Explosion Hazards
Pyrophoric solid

SECTION 4 - PHYSICAL HAZARDSStability ☐ Unstable ☒ Stable ☒ Conditions to Avoid

Avoid contact with air or water

Immunizability
Materials to Avoid

Water, air

Hazardous

Decomposition Products Burns in air producing indium oxides

Hazardous May Occur ☐ Lead/LossesPolymerization Will Not Occur ☒ to Avoid**SECTION 5 - HEALTH HAZARDS**Threshold
Limit Value

N/A

Signs and
Symptoms of Exposure 1 Acute
Overexposure2 Chronic
OverexposureMedical Conditions Generally
Aggravated by ExposureChemical Listed as Carcinogen
or Potential CarcinogenNational Toxicology
Program Yes ☐
No ☐IARC
Monographs Yes ☐
No ☐OSHA Yes ☐
No ☐OSHA Permissible
Exposure LimitACGIH Threshold
Limit ValueOther Exposure
Limit UsedEmergency and
First Aid Procedures

1 Inhalation

2 Eyes

3 Skin

4 Ingestion

SECTION 6 - SPECIAL PROTECTION INFORMATION

Respiratory Protection

(Specify Type) Wear fire proof clothing and face shield

Ventilation

Local
ExhaustMechanical
(General)

Special

Other

Protective
Gloves

Loose fitting vinyl

Eye
Protection

Safety glasses/face shield

Other Protective

Clothing or Equipment NOMEX lab coat advised for product transfers

SECTION 7 - SPECIAL PRECAUTIONS AND SPILL/LEAK PROCEDURESPrecautions to be Taken
in Handling and StorageMaterial should only be handled under an inert atmosphere of
argon or nitrogen.

Other

Precautions

Steps to be Taken in Case

Material is Released or Spilled Material will ignite. Confine the fire with dry powder.

Waste Disposal
Methods

Material can be burned under controlled conditions.

Consult local, federal or state regulations.

IMPORTANT

Do not leave any blank space. If required information is unavailable, unknown, or does not apply, so indicate.

J. C. SCHUMACHER COMPANY

MATERIAL SAFETY DATA SHEET

APPENDIX M1.13

No. 125.01

Rev. Date 04/89

I. MATERIAL IDENTIFICATION

CHEMICAL NAME:	Diethylsilane	CA# 542-91-6	
SYNONYMS:	LTO-410	CHEMICAL FAMILY:	Organosilanes
FORMULA:	C_2H_6Si	MOLECULAR WEIGHT:	88.2
TRADE NAME AND SYNONYMS:	LTO-410		

II. PHYSICAL DATA

BOILING POINT, 760 mm. Hg	58°C	FREEZING POINT	-134°C
SPECIFIC GRAVITY ($M_{20}=1$)	0.6843 @ 20°C	VAPOR PRESSURE AT 20°C	207 torr
VAPOR DENSITY ($a/r=1$)	>1	SOLUBILITY IN WATER, % by wt.	Insoluble
PERCENT VOLATILES BY VOLUME	100	EVAPORATION RATE (1)	
APPEARANCE AND ODOR	Colorless liquid		

III. HAZARDOUS INGREDIENTS

MATERIAL	%	TLV (Units)
Diethylsilane	98+	

IV. FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (test method)	-20°C closed cup	AUTOIGNITION TEMPERATURE	218 ± 3°C (Satchkin method)
FLAMMABLE LIMITS IN AIR, % by volume	LOWER	1.1 ± 0.1%	UPPER >10.0%

EXTINGUISHING MEDIA	Carbon Dioxide, Dry Chemical, Foam
SPECIAL FIRE FIGHTING PROCEDURES	Fire Fighters should wear approved self contained breathing apparatus and protective clothing, gloves and boots.
UNUSUAL FIRE AND EXPLOSION HAZARDS	Combustion products may contain toxic gases or irritating aerosols. Highly flammable. Vapor concentrations of 10% or greater in air can be explosive upon ignition

EMERGENCY PHONE NUMBERS

8:00 AM to 5:00 PM PST Monday Thru Friday, Call (619) 931-9555
Hours Other Than 8:00 AM to 5:00 PM PST, Monday Thru Friday, Call (619) 439-2645

No responsibility is assumed only for the fact that all studies reported here and all opinions are those of qualified experts.

1468 Palomar Oaks Way / Carlsbad, CA 92009 / (619) 931-9555 / TWX (910) 322-1382

V. HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE	Not established
EFFECTS OF OVEREXPOSURE	
FIRST AID	<p>Remove from exposure</p> <p>Eyes: Flush with water for at least 15 minutes</p> <p>Skin: Flush with water. Seek medical attention.</p> <p>Inhalation: Remove to fresh air, seek medical attention if there are signs of breathing difficulty.</p>

VI. REACTIVITY DATA

STABILITY		CONDITIONS TO AVOID	
UNSTABLE	STABLE		
	X		
INCOMPATIBILITY (materials to avoid)		mineral acids, oxidizers, caustics	
HAZARDOUS DECOMPOSITION PRODUCTS		SiO ₂ , CO ₂ , ethylene, hydrogen gas	
HAZARDOUS POLYMERIZATION		CONDITIONS TO AVOID	
May Occur	Will Not Occur		
	X		

VII. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED	Clear area of personnel. Eliminate ignition sources and cover spill with absorbent (such as vermiculite). Dispose of as a flammable liquid.
WASTE DISPOSAL METHOD	Review local regulations for appropriate disposal procedures.

VIII. SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (specify type)		organic vapor type	
VENTILATION	LOCAL EXHAUST	fume hood	SPECIAL
	MECHANICAL (general)	required	OTHER
PROTECTIVE GLOVES		rubber/plastic	EYE PROTECTION required
OTHER PROTECTIVE EQUIPMENT		eye protection, safety shower and eye wash	

IX. SPECIAL PRECAUTIONS AND COMMENTS

HANDLING AND STORING	Do not store near food or beverages. Store in cool location.
OTHER	

Material Safety Data Sheet

From Genium's Reference Collection
Genium Publishing Corporation
1145 Catalyn Street
Schenectady, NY 12303-1836 USA
(518) 377-8855

APPENDIX M1.15

No. 65
HYDROGEN, GAS
(Revision A)

Issued: May 1980
Revised: April 1986

SECTION 1. MATERIAL IDENTIFICATION

21

MATERIAL NAME: HYDROGEN, GAS
DESCRIPTION: Supplied as a compressed (2000 psig) gas in cylinders.
OTHER DESIGNATIONS: H₂; CAS #1333-74-0
MANUFACTURER/SUPPLIER: Available from several suppliers, including:
Airco Industrial Gases of the BOC Group, Inc., 575 Mountain Ave., Murray Hill, NJ 07974;
Telephone: (201) 464-8100

Union Carbide Corp., Linde Division, 37 Old Ridgebury Rd., Danbury, CT 06817;
Telephone: (203) 794-5300

HMIS

H: 0	R 2
F: 4	I 1
R: 0	S -
PPE*	K 4

*See Sect. 8

SECTION 2. INGREDIENTS AND HAZARDS

%

HAZARD DATA

Hydrogen, Gas, CAS #1333-74-0

>99.9

Simple Asphyxiant*

* The TLV for a simple asphyxiant gas (ACGIH, 1985-86). ACGIH does not recommend a TLV for certain asphyxiants because the limiting factor is the air-oxygen content. Oxygen concentrations should not go below 18% by volume.

SECTION 3. PHYSICAL DATA

Boiling Point, 760 mm Hg ... -423.2°F (-252.7°C)
Melting Point ... -434.5°F (-259.2°C)
Specific Gravity (Air = 1) ... 0.069
Solubility in Water @ 60°F, 1 atm, vol/vol H₂O ... 0.019

Viscosity, @ 15°C, atm, cps ... 0.0087
Critical Temperature ... -399.8°F (-239.9°C)
Critical Pressure, atm ... 12.8
Molecular Weight ... 2.02

Appearance and odor: Colorless, tasteless, odorless gas.

SECTION 4. FIRE AND EXPLOSION DATA

LOWER UPPER

Flash Point and Method

Autoignition Temp.

Flammability Limits in Air

NA (Gaseous Mat'l)

1075°F (580°C)

% by Volume

4

75

EXTINGUISHING MEDIA: Small fires can be extinguished with carbon dioxide, dry chemical, or halogenated gas. However, do not extinguish a hydrogen fire until surroundings have been cooled and the hydrogen (flow) has been controlled or shut off in order to eliminate the danger of reignition and/or possible explosion. **UNUSUAL FIRE/EXPLOSION HAZARDS:** Hydrogen is extremely flammable. It forms explosive mixtures with air. In case of a pipeline fire, when possible, gradually reduce the H₂ flow to a small jet. Do not stop the flow completely before an inert gas or steam system has been activated to control flashback. Fires at cylinders or storage tanks should be allowed to burn until nearly empty before they are closed off, keeping the containers and surroundings as cool as possible by using water spray.

SECTION 5. REACTIVITY DATA

Hydrogen is extremely flammable. It forms explosive mixtures with air, oxygen, and oxidizing agents. It is a stable material in closed containers at room temperature. It does not polymerize. It will react vigorously or explosively with many oxidizing agents. A mixture of flammable hydrogen gas and air is stable in the absence of catalysts until an ignition source is supplied. (An electric spark with the energy of as little as 0.017 mJ can be sufficient.) A mixture of hydrogen gas with air can burn with a very hot nonluminous flame that is difficult to see, or it can explode. Hydrogen/chlorine mixtures in the dark are stable, but they will explode if exposed to light. Fluorine reacts with hydrogen at -418°F (-250°C) when impurities are present in the mixture. A hydrogen/oxygen mixture with a platinum catalyst will explode. Lithium metal will burn in a hydrogen atmosphere to form the hydride. Hydrogen can interact with some metals (i.e., hardened steels) to cause embrittlement.

SECTION 6. HEALTH HAZARD INFORMATION

Hydrogen is not listed as a carcinogen by the NTP, IARC, or OSHA.

It is nontoxic. It can act as a simple asphyxiant by displacing the oxygen in the air. Symptoms of exposure depend on the degree and duration of oxygen deficiency. Persons exposed to an oxygen-deficient atmosphere can become cyanotic and experience diminished mental alertness, impaired muscular coordination, and breathing impairment, followed by collapse and even death if exposure is prolonged at low oxygen levels.

PRIMARY ENTRY: Inhalation.

ACUTE EFFECTS: Simple asphyxiation by displacement of oxygen.

FIRST AID: (CAUTION! Would-be rescuers must be concerned for their own safety in oxygen-deficient atmospheres and use approved breathing apparatus.)

EYE CONTACT: Get medical help.*

SKIN CONTACT: Get medical help.*

INHALATION: Remove victim to fresh air. Quickly proceed to restore and/or support his breathing as required (mouth-to-mouth resuscitation should probably be used initially). Have a trained person administer oxygen if it is available. Get medical help.*

INGESTION: Get medical help.*

* **GET MEDICAL ASSISTANCE** = In plant, paramedic, community. Get medical help for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Establish emergency procedures and training. Evacuate the area. Notify safety personnel of leaks. Keep upwind of leaks. Provide optimum explosion-proof ventilation. Shut off the source of the hydrogen leak, if possible. A vapor-explosion hazard exists in confined areas and sewers. Remove combustibles and sources of heat if you can do so without risk. Small leaks can be detected by bubbles that form when a suspected leak area has been painted with soapy water. Note: Because hydrogen ignites readily and burns with a nearly invisible flame in daylight, leaks must be approached in a manner to protect against a jet flame. Ventilate area sufficiently before permitting personnel to reenter it. Remove a leaking cylinder to an isolated area outdoors or place it into a hood with good forced ventilation. Allow gas to be discharged at a slow rate. Tag the defective cylinder to indicate the defect, then close the valve and return it to the supplier.

SECTION 8. SPECIAL PROTECTION INFORMATION

RESPIRATOR: Provide air-supplied or self-contained breathing equipment for emergency or nonroutine situations where the hydrogen level is excessive.

VENTILATION: Provide adequate general and local exhaust ventilation (explosion proof) to prevent the workplace atmosphere from becoming deficient or from approaching the LEL (lower explosive limit) for hydrogen.

OTHER PRECAUTIONS: Safety shoes, insulated gloves, and safety glasses are recommended when handling hydrogen cylinders. Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them.

SPECIAL CONSIDERATIONS: Hydrogen gas will rise and accumulate in high places. Confined areas need special attention to prevent buildup of hydrogen gas concentrations.

COMMENTS: Those involved in handling and using hydrogen should be trained in its safe use.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Store hydrogen cylinders in a clean, cool, dry, well-ventilated, low fire-risk area away from combustible materials, oxidizing agents, and sources of heat or ignition. Use explosion-proof motors, lights, and fixtures in work area. Follow the general safety procedures for handling a compressed flammable gas in cylinders, including keeping it separate from oxygen cylinders, never exposing any part of the cylinder to a temperature that exceeds 125° F (51.6°C), and grounding cylinders and hydrogen handling equipment to prevent a buildup of static charge. Use nonsparking tools. Vessels and piping systems should be designed to the DOT, ASME, and ANSI pressure piping codes. Piping systems and vessels from hydrogen service should be made inert by suitable purging procedures.

DOT Classification: Flammable Gas

Label: Flammable Gas

UN1049

Data Source(s) Code: 1, 12, 17, 18, 25, 51, 63, 82 CH

Judgement as to the suitability of information herein for purchaser's purposes are necessarily purchaser's responsibility. Therefore, although reasonable care has been taken in the preparation of such information, Cesium Publishing Corp. makes no warranties, makes no representations and assumes no responsibility as to the accuracy or suitability of such information for application to purchaser's intended purposes or for consequences of its use.

Approvals *J. O. Acemore, 1/87.*

Indust. Hygiene/Safety *JW 12-86*

Medical Review *[Signature]*

Genium Publishing Corporation

 1145 Catalyn Street
 Schenectady, NY 12303-1836 USA
 (518) 377-8854

 Sheet No. 440
 Methane

Issued: 7/80

Revision: A, 8/89

Section 1. Material Identification

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Methane Description: Widely distributed in nature, methane comprises 0.00022% by volume of the earth's atmosphere. American natural gas is mostly methane (85%). At temperatures greater than 2012 °F (1100 °C), pure carbon combines with pure hydrogen to form methane. Above 2732 °F (1500 °C), the amount of methane produced increases with temperature. Obtained from sodium acetate and sodium hydroxide or from aluminum carbide and water. Commercially prepared from natural gas or by fermentation of cellulose and sewage sludge. Constituent of illuminating and cooking gas. Used in the manufacture of hydrogen, hydrogen cyanide, ammonia, acetylene, formaldehyde, and many other organics.

Other Designations: Fire damp; marsh gas; methyl hydride; CH₄; CAS No. 0074-82-8.

Manufacturers: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide* (Genium ref. 73) for a suppliers list.

 R 1
 I -
 S -
 K 4

NFPA

HMIS

H 1

F 4

R 0

PG 0

* Sec 1

Section 2. Ingredients and Occupational Exposure Limits

Methane, ca 100%*

OSHA PEL

None established

ACGIH TLV, 1988-89

None established

NIOSH REL

None established

Toxicity Data†

Not listed

* Check with your supplier to determine the exact composition of the purchased methane. Possible contaminants are ethane (C₂H₆), propane (C₃H₈), butane (C₄H₁₀), higher molecular weight alkanes, carbon dioxide (CO₂), nitrogen (N₂), and oxygen (O₂).

† Monitor NIOSH, RTECS (PA1490000), for future toxicity data.

Section 3. Physical Data

Boiling Point: -259 °F (-161.6 °C)

Water Solubility: Slight*

Vapor Density (Air = 1): 0.544 at 32 °F (0 °C)

Melting Point: -296.5 °F (-182.5 °C)

Molecular Weight: 16 g/mol

Appearance and Odor: A colorless, odorless, tasteless, extremely flammable gas. Commercial methane's trace amounts of a suitable mercaptan compound give it natural gas's familiar rotten egg smell.

*Soluble in alcohol and ether

Section 4. Fire and Explosion Data

Flash Point: -213 °F (-136.11 °C)

Autoignition Temperature: 999 °F (537 °C)

LEL: 5% v/v*

UEL: 15% v/v*

Extinguishing Media: Methane's extreme flammability, extensive explosibility range, and very low flash point represent dangerous fire and explosion risks. *Treat any fire situation involving rapidly escaping and burning methane gas as an emergency.* Extinguish methane fires by shutting off the source of the gas. Use water sprays to cool fire-exposed containers and to protect the personnel attempting to seal the source of the escaping gas.

Unusual Fire or Explosion Hazards: Methane gas is very flammable with an extensive explosibility range. The best fire fighting technique may be simply to let the burning gas escape from the pressurized cylinder, tank car, or pipelines. Never extinguish the burning gas without first locating and sealing its source. Otherwise, the still leaking gas could explosively re-ignite without warning and cause more damage than if it burned itself out.

Special Fire-fighting Procedures: Wear a self contained breathing apparatus (SCBA) with a full facepiece operated in the pressure demand or positive pressure mode.

* The lowest methane-air explosions occur when 1 volume of methane is mixed with 10 volumes of air (or 2 volumes of oxygen). Warning: Air with more than 14% by volume methane burns explosively. Methane burns with a pale, fairly luminous, not always easily detected flame.

Section 5. Reactivity Data

Stability/Polymers: Methane is stable at room temperature in closed, pressurized containers during routine operations. Hazardous polymerization cannot occur.

Chemical Incompatibilities: Genium reference R4 reports that methane can react violently with bromine pentafluoride, chlorine, chlorine dioxide, nitrogen trifluoride, liquid oxygen, and oxygen difluoride.

Conditions to Avoid: Never expose methane to ignition sources such as open flame, lighted cigarettes or pipes, uninsulated heating elements, or electrical or mechanical sparks. Prevent any accidental or uncontrollably rapid release of methane gas from high pressure cylinders, tank cars, or pipelines.

Hazardous Products of Decomposition: Thermal oxidative degradation of methane can produce carbon dioxide and toxic carbon monoxide (CO).

Section 6. Health Hazard Data

Carcinogenicity: Neither the NTP, IARC, nor OSHA lists methane as a carcinogen. **Summary of Risks:** As a simple asphyxiant, methane does not cause significant physiological responses, but it can displace the minimum required atmospheric oxygen level. Significant displacement results in an oxygen-deficient atmosphere with no adequate warning properties. Asphyxiation can occur especially in confined, poorly ventilated, undisturbed spaces infrequently entered by workers. Frostbite (cryogenic damage) can result from contact with liquid methane at extremely low temperatures. **Medical Conditions Aggravated by Long-Term Exposure:** None reported. **Target Organs:** None reported. **Primary Entry:** Inhalation. **Acute Effects:** The initial symptoms of simple asphyxiant gases effects are rapid respiration and air hunger, diminished mental alertness, and impaired muscular coordination. Continuing lack of oxygen causes faulty judgement, depression of all sensations, rapid fatigue, emotional instability, nausea, vomiting, prostration, unconsciousness, and finally, convulsions, coma, and death. **Chronic Effects:** None reported. **FIRST AID**

Skin (Liquid methane): Promptly flush the affected area with lots of tepid/fukewarm water to reduce freezing of tissues. Never apply direct heat to frostbitten areas. Loosely apply dry, bulky dressings to protect the area from further injury. Get treatment from qualified medical personnel. **Inhalation:** Rescuers must consider their own safety when entering confined, poorly ventilated, oxygen-deficient areas. Self-contained breathing equipment must be readily available. Rescuers must use nonsparking tools and equipment; e.g., floodlights lowered into any incident area must be electrically grounded and bonded, non-sparking, and sparkproof. After first aid, get appropriate in-plant, paramedic, or community medical attention and support for inhalation exposures in oxygen-deficient atmospheres. Seek prompt medical assistance for further observation and treatment.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Design and practice a methane spill control and countermeasure plan (SCCP). When a leak occurs, notify safety personnel, eliminate heat and ignition sources, evacuate unnecessary personnel, provide maximum explosion-proof ventilation, and implement the SCCP. Use only nonsparking tools and equipment. Locate and seal the source of the leaking gas. Use water sprays to protect the personnel attempting this shut-off. Large methane releases can result in spectacular explosions. If attempts to shut off the leaking gas are unsuccessful, evacuate the likely explosion area. **Disposal:** Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations. Remove leaking or defective cylinders to a safe, outside, posted discharge location. Let the methane gas discharge at a moderate rate. When it is empty, return the cylinder to the supplier after it is properly tagged, labelled, or stenciled MT (empty) or defective.

OSHA Designations

Air Contaminant (29 CFR 1910.1000, Subpart Z) Not listed

EPA Designations

RCRA Hazardous Waste (40 CFR 261.33). Not listed

CERCLA Hazardous Substance (40 CFR 302.4). Not listed

SARA Extremely Hazardous Substance (40 CFR 355). Not listed

SARA Toxic Chemical (40 CFR 372.65). Not listed

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). **Gloves:** To prevent skin contact, workers handling liquid methane should wear appropriate insulating gloves, safety glasses, and splash aprons, as required by the particular work conditions. **Respirators:** Wear a NIOSH approved respirator if necessary. Follow OSHA respirator regulations (29 CFR 1910.134). For emergency or nonroutine operations (spills or cleaning reactor vessels and storage tanks), wear an SCBA. **Warning:** Air purifying respirators do not protect workers in oxygen-deficient atmospheres, use self-contained breathing equipment there. **Ventilation:** Provide general and local explosion proof ventilation systems to maintain airborne concentrations below the 5% v/v LEL (Sec. 4). Local exhaust ventilation is preferred since it prevents methane dispersion into the work area by eliminating it at its source (Consun ref. 103). Give special attention to proper ventilation of enclosed areas. **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, washing facilities, fire extinguishers, and oxygen bottles for emergency first-aid. **Contaminated Equipment:** Never wear contact lenses in the work area. Soft lenses may absorb, and all lenses concentrate, irritants. Launder contaminated clothing before wearing. Remove this material from your shoes and equipment. **Other:** If appropriate, consider installing automatic sensing equipment that warns workers of oxygen-deficient atmospheres or of potentially explosive air-gas mixtures. All engineering systems in any methane gas storage, handling, or processing area must be explosion proof so they have no spark potential or hot spots. Pressurized systems must use only approved valves, manifolds, flanges, and flame arrestors. **Comments:** Methane gas presents dangerous fire, explosion, and reactivity risks. Regularly inspect and service all the piping systems which transport methane gas in production and storage areas. Before use, thoroughly test methane lines with nitrogen gas for leaking, especially in enclosed areas.

Section 9. Special Precautions and Comments

Storage Requirements: Store methane in closed, pressurized cylinders, tank cars, pipelines, or other containers in a cool, dry, well ventilated fireproof area away from heat and ignition sources and incompatible chemicals (Sec. 5). Protect these containers from physical damage and heat. Shield them from direct sunlight. **Special Handling/Storage:** Electrically ground and bond all containers, tanks, cylinders, tank cars and pipelines used in methane shipping, receiving, or transferring operations. Never smoke in any work area where the possibility of exposure to methane gas (fire hazard) exists. Recommended storage containers include steel.

Transportation Data (49 CFR 172.101-2)

DOT Shipping Name: Methane

IMO Shipping Name: Methane, compressed

DOT Hazard Class: Flammable gas

IMO Hazard Class: 2.1

DOT ID No.: UN1971

IMO Label: Flammable gas

DOT Label: Flammable gas

DOT Packaging Requirements: 49 CFR 173.302

DOT Packaging Exceptions: 49 CFR 173.306

MSDS Collection References: 1 6 7 84 94 109 116 117 119 120 122

Prepared by: PJ Iggoe, BS, Industrial Hygiene Review; DJ Wilson, CHH, Medical Review; MJ Hardies, MD

ROUTE 811 NORTH, PLUMSTEADVILLE, PA 15949 (215) 755-8861

Electronics Group

7647010

2330 HAMILTON BOULEVARD, P.O. BOX 648, SOUTH PLAINFIELD, N.J. 07080 (201) 754-7700

REGIONAL PHONE NUMBERS

PA (215) 766-8881 CA (714) 887-2571 MI (313) 589-2950 TX (713) 624-4427
NJ (201) 794-7700 CA (415) 631-0162 CO (303) 442-7100 MA (617) 267-8100

MATERIAL SAFETY DATA SHEET

SECTION 1 - MATERIAL IDENTIFICATION

CHEMICAL NAME: Hydrogen chloride	SUPPLIER: Scott Specialty Gases
CHEMICAL FORMULA: HCl	ADDRESS: Route 611 Plumsteadville, PA 18949
CHEMICAL FAMILY: Acid gas, halogen	In Case of Emergency, Contact your Regional Plant Manager
DATE PREPARED: 10/16/89	OTHER DESIGNATIONS: Hydrochloric acid, CAS# 7647-01-0

SECTION II - HAZARDOUS INGREDIENTS

COMPONENT	CONCENTRATION	EXPOSURE LIMITS (PPM)		
		ACGIH TLV	OSHA PEL	OTHER
Hydrogen chloride	100%	5.0 (ceiling)	5.0 (ceiling)	

SECTION III - PHYSICAL DATA

BOILING POINT (°C): -84.8	SPECIFIC GRAVITY (H ₂ O = 1) @ 20°C: 1.19
VAPOR PRESSURE @ 20°C: 42.71	PERCENT, VOLATILE BY VOLUME (%): 100
VAPOR DENSITY (AIR = 1) @ 25°C 1 atm: 1.268	EVAPORATION RATE (_____ = 1): N/A
SOLUBILITY IN WATER: Complete	APPEARANCE AND ODOR: Clear, colorless or yellow, fuming liquid with pungent odor

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT AND METHOD	FLAMMABLE LIMITS	LEL	UEL
N/A	N/A		

EXTINGUISHING MEDIA: Use what is suitable for surrounding fire.

SPECIAL FIRE FIGHTING PROCEDURES: Wear self-contained breathing apparatus and full protective clothing. Remove cylinders or cool with water spray to prevent release of HCl by safety devices of cylinders.

UNUSUAL FIRE AND EXPLOSION HAZARDS: May emit hydrogen gas upon contact with metal. Contact with water causes formation of dense hydrochloric acid fumes.

[illegible]

SECTION V - REACTIVITY DATA

STABILITY: Stable under normal storage conditions

INCOMPATIBILITY (MATERIALS TO AVOID): Corrosive to many metals when moisture is present releasing flammable hydrogen gas. Galvanized pipe, brass, copper, bronze, alkaline materials, cyanides, and sulfites. Reacts exothermically with many organics. Also reacts with fluorine, calcium carbide, rubidium carbide, and lithium silicide.

HAZARDOUS DECOMPOSITION PRODUCTS: HCl, hydrogen, chlorine gases

HAZARDOUS POLYMERIZATION: Will not occur

SECTION VI - HEALTH HAZARD DATA

ROUTES OF ENTRY: Inhalation, skin

EFFECTS OF OVER EXPOSURE (ACUTE): Inhalation of vapors may cause pulmonary edema, circulatory collapse, damage to upper respiratory tract, collapse, coughing, difficulty breathing, and choking. It is severely irritating and corrosive to the eyes, mucous membranes, and upper respiratory tract. Liquid contact may cause severe burns to the skin and eyes. **(CHRONIC):** None known **(MEDICAL CONDITIONS AGGRAVATED BY OVEREXPOSURE):** None

CARCINOGENICITY - NTP? NO **IARC MONOGRAPHS?** NO **OSHA REGULATED?** NO

EMERGENCY AND FIRST AID: Inhalation - Immediately remove victim to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen. Skin/Eye contact - Immediately flush with copious amounts of water for at least 15 minutes while removing contaminated clothing. Contact a physician.

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN: Evacuate and ventilate area. Small leaks can be detected with concentrated NH_4OH giving off white fumes. Stop leakage if possible. If not, remove to safety outdoors area. Neutralize spill with soda ash or lime. Place waste into a clean, dry container for disposal.

WASTE DISPOSAL METHOD: Return cylinders to supplier for proper disposal with any valve outlet plugs or caps secured and valve protection cap in place. Can be neutralized with sodium hydroxide or other suitable alkali. Neutral salt solution can usually be flushed to sewer with high dilution. Follow all federal, state, and local regulations.

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (SPECIFY TYPE): Use a self-contained breathing apparatus in case of emergency or non-routine use.

VENTILATION: Recommend use of exhaust hood.

OTHER PROTECTIVE EQUIPMENT: Protective gloves recommended, safety glasses/goggles, safety shower eyewash station.

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: Store in well ventilated areas only. Keep valve protection cap on cylinders when not in use and secure cylinder when using to protect from falling. Use suitable hand truck to move cylinders. Store in cool ($< 125^\circ\text{F}$) and dry area.

OTHER PRECAUTIONS: Protect containers from physical damage. Do not deface cylinders or labels. Move cylinder with adequate hand truck. Cylinders should be refilled by qualified producers of compressed gases. Shipment of a compressed gas cylinder which has not been filled by the owner or with his written consent is a violation of federal law (49 CFR). In case of emergency, contact supplier for special instructions.

11071102.0,15-V(01)V10204(01)V110(01)IX(01)

Material Safety Data Sheet

From Genium's Reference Collection
Genium Publishing Corporation
1145 Catalin Street
Schenectady, NY 12303-1836 USA
(518) 377-8855

APPENDIX ML.18

No. 62
OXYGEN
(Revision A)

Issued: April 1980
Revised: April 1986

SECTION 1. MATERIAL IDENTIFICATION

21

MATERIAL NAME: OXYGEN

DESCRIPTION: Compressed gas (2100 psig) supplied in cylinders or cold liquid supplied in Dewar containers.

OTHER DESIGNATIONS: O₂; CAS #7782-44-7, ,

MANUFACTURER/SUPPLIER: Available from several suppliers, including:
Airco Industrial Gases of the BOC Group, Inc., 575 Mountain Avenue,
Murray Hill, NJ 07974, Telephone: (201) 464-8100

Union Carbide Corporation, Linde Div., 39 Old Ridgebury Road,
Danbury, CT 06817, Telephone: (203) 794-5300

HMIS

H: 3

F: 0

R: 0 (Liq.)

PPE*

*See Sect. 8

(Liquid)

R 1

I .

S 2 (Liquid)

K .

SECTION 2. INGREDIENTS AND HAZARDS

%

HAZARD DATA

Oxygen, CAS #7782-44-7

>99.5

No TLV Established.*

* The minimum oxygen content in workplace air is 18 % by volume (ACGIH 1985-86).

Note: Ambient air contains 21% O₂ by volume.

SECTION 3. PHYSICAL DATA

Boiling Point, 760 mm Hg ... -297.4°F (-183°C)

Vapor Pressure @ -199°C, mm Hg ... ca 100

Vapor Density (Air = 1) ... 1.1

Solubility in Water, cm³/100g, @ 25°C ... 3.16

Expansion Ratio, Liquid to Gas @ 70°F ... 1:860

Specific Gravity @ -183°C ... 1.14

Freezing Point ... -361.1°F (-218.4°C)

Viscosity, cpa, @ 25°C ... 0.0206

Critical Temperature ... -245°F (-118.38°C)

Critical Pressure, Atm ... 50.14

Molecular Weight ... 32.00

Appearance and odor: Colorless gas, bluish liquid, or blue solid with hexagonal crystals. Odorless and tasteless.

SECTION 4. FIRE AND EXPLOSION DATA

LOWER

UPPER

Flash Point and Method

Autoignition Temp.

Flammability Limits in Air

Not Found

Not Found

Not Found

Not Found

Not Found

EXTINGUISHING MEDIA: Stop flow if you can do so without risk. Use media that are appropriate to the surrounding fire. Immediately cool fire-exposed container, standing at a safe distance and using a water spray. If feasible, remove oxygen containers from fire area. Containers may explode in the heat of fire. Though not flammable itself, oxygen vigorously supports combustion. Materials that do not burn in air may burn in oxygen-enriched air. Materials can become spontaneously flammable at high oxygen levels. Oxygen released in a fire situation greatly increases fire and explosion hazards. (Oxygen cylinders are equipped with safety devices to release O₂ at excessive temperature or pressure.) Liquid oxygen can explode on contact with flammables. Do not direct water spray into liquid oxygen.

SECTION 5. REACTIVITY DATA

Oxygen is stable when kept isolated as a compressed gas in cylinders or as a cold liquid in vented, insulated containers. Stainless steel, aluminum, copper, and its alloys are useful materials for oxygen or liquid oxygen service. This material is an oxidizing agent that vigorously accelerates combustion. Oxygen will undergo highly exothermic reactions or explosions with many materials. The greater the concentration of O₂ in contact with a fuel or reducing agent, the greater the violence of the reaction. Air contains 21% oxygen; reactivity with environmental materials is substantially increased at above 23% oxygen by volume.

Oxygen reacts explosively with phosphine, hydrazine, hydrogen sulfide, ethers, alcohols, hydrocarbons, etc. Liquid oxygen mixed with powdered metals can be detonated. Red-hot steel burns in an oxygen atmosphere. This material is incompatible with oils, grease, lubricants, and flammable materials.

SECTION 6. HEALTH HAZARD INFORMATION

Oxygen is not listed as a carcinogen by the IARC, NTP, or OSHA.

SUMMARY OF RISKS: Adults can satisfactorily breathe pure oxygen for extended periods at 0.33 atm, or at 1 atm for several days at less than 5 hours a day. However, irritation to mucous membranes may occur when 100% oxygen is inhaled continuously for several hours. Chest pains and cough can result from breathing O_2 at 1 atm for 8 to 24 hours or 2 atm for 2 to 3 hours or from an atmosphere of 60% oxygen for several days. A variety of central nervous system effects can occur from breathing oxygen at partial pressures greater than 2 atm, including dizziness, impaired coordination, visual and hearing disturbances, and seizures. Contact with liquid oxygen can cause severe frostbite/freeze burns. Prolonged breathing of very cold atmospheres can produce lung damage. Prolonged exposure to cold areas can result in hypothermia.

PRIMARY ENTRY: Inhalation

FIRST AID: EYE AND SKIN CONTACT: Contact with liquid oxygen: Remove victim from the source of contact. Flush affected areas with lots of tepid water. (Do not apply direct heat to affected area!) Do not rub frozen area. Loosely apply dry, sterile, bulky dressings to protect area from infection/injury. Get medical help.* **INHALATION:** Get medical help for overexposure.* **INGESTION:** Get medical help.* **HYPOTHERMIA:** Remove victim to a warm (not hot) area. Remove contaminated clothing, if possible. Wrap him in blankets. Slowly restore his body temperature. Get medical help.*

* GET MEDICAL ASSISTANCE = In plant, paramedic, community. Get medical help for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Notify safety personnel of significant leaks or spills. Evacuate all personnel from the danger area. Provide optimum exhaust ventilation. Shut off the source of the oxygen leak if you can do so without risk. Remove sources of heat, ignition and, if feasible, separate combustibles from the leak. Small leaks in an oxygen system in an enclosed, unventilated area can build up a hazardous oxygen level.

To increase the rate of controlled evaporation of spilled liquid oxygen (when desired), spray the spill with large amounts of water. (This may generate a fog and reduce visibility.)

DISPOSAL: Remove waste containers or leaking cylinders to an open outdoor area away from combustibles and allow the oxygen to discharge at a moderate rate. Tag a leaking cylinder to indicate a defect, close the valve, and return the cylinder to its supplier.

SECTION 8. SPECIAL PROTECTION INFORMATION

Where oxygen may be released, provide adequate ventilation to prevent excessive oxygen enrichment of the workplace atmosphere (holding at <23% O_2 by volume is recommended for fire safety). Personnel who have been exposed to high concentrations of oxygen should stay in a well-ventilated or open area for 15 minutes before going into a confined space or near an ignition source.

Workers handling liquid oxygen should wear safety glasses; clean, approved insulated gloves; and other approved protective clothing as required to prevent skin contact. (Gloves and protective clothing must be of material that is resistant to ignition on contact with liquid oxygen; leather gloves and safety shoes have been recommended.) Safety shoes and safety glasses are recommended when handling cylinders of compressed gas. Clothing that has been overexposed or contaminated with oxygen should be removed and considered unsafe (highly flammable) to wear for at least 30 minutes. If oxygen-enriched clothing catches fire, extinguish the flame under a safety shower; a fire blanket may not be effective in this situation. Use a continuous water spray to soak the clothing of a rescuer who must operate in an oxygen-enriched fire area.

Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Store oxygen containers in a clean, cool, dry, well-ventilated, low fire-risk area, away from combustible materials and acetylene cylinders or other flammable gases or gas mixtures. Protect containers against physical damage. Follow general safety procedures for handling compressed-gas cylinders. Never expose any part of a cylinder to temperature above 125°F (51.5°C). Ground equipment to eliminate buildup of static charge. Make sure that containers of liquid oxygen are properly vented to prevent pressure buildup and that suitable materials are used to contact liquid oxygen and high-purity oxygen. Some materials are unsuitable for service at low temperatures because they become brittle and can be easily shattered by impact. Many materials are unsuitable for oxygen service; do not use oil or grease to lubricate the valves on oxygen cylinders.

DOT Classification: Nonflammable Gas

UN1072 (Compressed Gas); UN1073 (Cryogenic Liquid)

Data Source(s) Code: 1, 2, 4-12, 17, 24, 25, 51, 63, 82, 84, CK

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Approvals *J. O. Anderson* 1/87.

Indust. Hygiene/Safety *JW* 12-86

Medical Review *Dee*

RECEIVED JUL 1 1978

Specialty Gas Material Safety Data Sheet

AIR PRODUCTS AND CHEMICALS, INC. BOX 538 ALLENTOWN, PA 18105 (215) 481-8267	PRODUCT NAME	SILANE*
	EMERGENCY PHONE	(800) 523-8374; IN PENNSYLVANIA (800) 322-9082
	*THIS MSDS DOES NOT REFLECT THE HIGH DILUTION IN HELIUM.	
	TRADE NAME AND SYNONYMS	Silane
	CHEMICAL NAME AND SYNONYMS	Silane, Silicon Tetrahydride, Silicane
ISSUE DATE AND REVISIONS	1 July 1978	FORMULA SiH_4
		CHEMICAL FAMILY Silicon Hydride

HEALTH HAZARD DATA

TIME WEIGHTED AVERAGE EXPOSURE LIMIT	0.5 ppm
SYMPTOMS OF EXPOSURE	
The symptoms of exposure to silane are not well-defined.	
TOXICOLOGICAL PROPERTIES	
Inhalation mouse	LCLo:9600 ppm/4 hours
<p>The major hazard associated with silane exposure is its spontaneous flammability in air with the production of silicon dioxide and hydrogen. Acute inhalation studies with rodents have shown an LD50 at concentrations of silane approaching one percent. The cause of death in these experiments was not defined and their relevance to human exposure at low levels is not established. Rodent exposures at 1000 ppm over periods approximating one hour produced no lethality.</p>	
RECOMMENDED FIRST AID TREATMENT	
RESCUE PERSONNEL SHOULD AVOID UNNECESSARY EXPOSURE.	
<p>Low concentrations of silane may accumulate without pyrophoric ignition. Hazard of fire or explosion may result from static electrical discharge or other ignition sources.</p>	
<p>Manifestations attributable to silane exposure should be treated on the basis of sound clinical judgement.</p>	

Information contained in this material safety data sheet is offered without charge for use by technically qualified personnel at their discretion and risk. All statements, technical information and recommendations contained herein are based on tests and data which we believe to be reliable, but the accuracy or completeness thereof is not guaranteed and no warranty of any kind is made with respect thereto. This information is not intended as a license to operate under or a recommendation to practice or infringe any patent of this Company or others covering any process, composition of matter or use.

The Company shall have no control of the use of the product described herein. The Company assumes no liability for loss or

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES

Silane is spontaneously combustible on contact with air. Silane reacts with most free halogens or heavy metal hydrides. Silane is slowly decomposed by water.

PHYSICAL DATA

BOILING POINT -169.4°F (-111.9°C)	LIQUID DENSITY AT -301°F (-185°C) 43 lb/ft ³ (680 kg/m ³)
VAPOR PRESSURE at 70°F (21.1°C) Above the critical pressure	GAS DENSITY AT 70°F, 1 atm 0.0826 lb/ft ³ (1.32 kg/m ³)
SOLUBILITY IN WATER Reacts slowly	FREEZING POINT -300.5°F (-184.7°C)
APPEARANCE AND ODOR Colorless gas with a repulsive odor	

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used) N/A	AUTO IGNITION TEMPERATURE Pyrophoric	FLAMMABLE LIMITS % BY VOLUME LEL UEL	N/A
EXTINGUISHING MEDIA None		ELECTRICAL CLASSIFICATION Not specified	
SPECIAL FIRE FIGHTING PROCEDURES Shut off the source of silane and allow the fire to burn itself out.			
UNUSUAL FIRE AND EXPLOSION HAZARDS Silane is spontaneously flammable on contact with air or oxidizing agents, and burns with a relatively low temperature flame.			

REACTIVITY DATA

STABILITY Unstable		CONDITIONS TO AVOID
Stable	X	
INCOMPATIBILITY (Materials to avoid) Air, halogens, oxidizing agents		
HAZARDOUS DECOMPOSITION PRODUCTS Silicon and hydrogen at 572°F (300°C)		
HAZARDOUS POLYMERIZATION May Occur		CONDITIONS TO AVOID
WM Not Occur	X	

SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Most silane leaks will be indicated by a flame. In many cases, silica will form at the point of the leak and seal itself, with no destruction of equipment. If the leak is in the piping, turn off the silane source, evacuate the area and allow the residual silane to burn itself out. Do not attempt to neutralize silane.
WASTE DISPOSAL METHOD Do not attempt to dispose of waste or surplus silane. Return all unused quantities to Air Products and Chemicals, Inc. for proper disposal.

SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type) Positive pressure self-contained breathing apparatus should be available for emergency use.		
VENTILATION	LOCAL EXHAUST Vent with carrier gas directly to outdoors, not through hoods	SPECIAL
	MECHANICAL (Gen)	OTHER
PROTECTIVE GLOVES Leather		
EYE PROTECTION Safety goggles or glasses		
OTHER PROTECTIVE EQUIPMENT Safety shoes		

SPECIAL PRECAUTIONS*

SPECIAL LABELING INFORMATION
D.O.T. Red Label "Flammable Gas" N.D.S.
SPECIAL HANDLING RECOMMENDATIONS Use only in a well-ventilated area. Never drop cylinders or allow them to strike each other violently. Avoid dragging or sliding cylinders, even for short distances. They should be moved by a suitable hand truck. Keep the valve protection cap in place until cylinder is secured and ready for use. Always insert a trap or check-valve in the line to prevent hazardous back-flow into the cylinder. Piping and equipment should be thoroughly pressure checked and be leak tight. Evacuate systems and purge with inert gas before introducing silane. Before disconnecting any system that has had silane in it, thoroughly purge the system with an inert gas. Do not purge through a vacuum pump. All fittings should be of the welded type or SWAGELOK® style to minimize the likelihood of leaks. Use diaphragm packless valves with (Continued on last page)
SPECIAL STORAGE RECOMMENDATIONS Protect against physical damage. Store cylinders in a cool, dry, well-ventilated area of noncombustible construction. Protect cylinders from excessive temperature rise by storing away from sources of heat. No part of a cylinder should be subjected to a temperature above 125°F (52°C). Store cylinders in an upright position and firmly secured. Segregate full and empty cylinders. Silane should be stored and used at positive pressures in well-ventilated areas. Positive pressures insure against the possibility of air being sucked into contact with silane. Isolate from oxygen, halogens and combustible or other oxidizing materials. (Continued on last page)
SPECIAL PACKAGING RECOMMENDATIONS Silane is noncorrosive to most metals. Piping and tubing can be of iron, brass, steel, stainless, or aluminum but must be designed to withstand the pressures to be encountered.
OTHER RECOMMENDATIONS OR PRECAUTIONS Do not condense silane (-166°F, -110°C or less). Extremely reactive gas. Ignites spontaneously in air. Keep away from heat, flames and sparks. Subject to decomposition upon heating. Close valve when not in use.

SPECIAL PRECAUTIONS

SPECIAL HANDLING RECOMMENDATIONS (Continued)

resilient seats such as TEFLON®. Remove the back plates from rotameters and pressure gauge covers where gases may collect on leakage. Pressure regulators should have metal diaphragms to allow complete evacuation and prevent air diffusion leakage.

For additional handling recommendations consult the Air Products Specialty Gas Catalog Safety and Technical Information Section or Compressed Gas Association Pamphlet P-1.

SPECIAL STORAGE RECOMMENDATIONS (Continued)

For additional storage recommendations consult the Air Products Specialty Gas Catalog Safety and Technical Information Section or Compressed Gas Association Pamphlet P-1.

DESCRIPTION: BASED ON 'NORMAL' 2" & 3" DIAMETER VER-1 CYLINDER
 (REFERENCE DRAWING: 5A-124.05). CHANGE CONSISTS OF REMOVING
 THE 1/2" CAJON VCD ASSEMBLY FROM TOP PLATE AND CENTERING THE
 OPENINGS FOR INLET AND OUTLET TUBES IN TOP PLATE. ALL
 OTHER DIMENSIONS WILL REMAIN UNCHANGED.

SIDE VIEW

SGMO CONTAINER DIMENSIONS

CYLINDER DESIGNATION	CYLINDER VOL.(ml)	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)
VER-150	150	51	100	140	83	13
VER-300	300	51	203	140	83	13
VER-600	600	76	127	140	83	13
VER-1000	1000	76	235	140	83	13

LKYLs
 P.O. BOX 500
 DEER PARK, TEXAS 77536

SEMICONDUCTOR GRADE
 METALORGANIC STAINLESS
 STEEL CONTAINER
 VERTICAL STYLE
 SERIES MODIFICATION: VER-1-A

PROJECT NO.

DRAWING NO.

5A-124.15

SHT 1 OF 1

DRAWN BY JKP

CHECKED *[Signature]*APPROVED *[Signature]*

DATE 3/87

Directions for Use

The following items are required to install the bubbler:

- A key to remove safety plugs from inlet/outlet ports
- New washers for VCR compatible connections (please find these enclosed in the shipping container)
- Torque wrench
- Vise

Please Note:

The Cyanamid CVD Source Bubbler has three ports:

- 1/2" filling port on the corner of the block (NOT TO BE OPENED BY USERS—see Figure 1)
- 1/4" VCR compatible female inlet port which leads to a dip-tube (controlled by the *blue* knob)
- 1/4" VCR compatible female outlet port (controlled by the *red* knob)

Figure 1

Figure 2 Closed Position

Figure 3 Open Position

- The outlet valve and port are both marked with the word "out." Similarly, the inlet valve and port are both marked with the word "in." All ports are protected by safety plugs that are opened by a key.
- The valves, controlled by the blue and red knobs, are 1/4 turn packless diaphragm valves. The small bump on the top of each knob is the "closed/open" indicator. **Important**— See Figures 2 and 3 for proper closed and open positions.

Opening and Attaching the Bubbler:

1. Verify that both the inlet valve (blue knob) and the outlet valve (red knob) are in the closed position and that the taped closures have not been disturbed. If either valve is open or the tape has been disturbed, **Do not remove the safety plugs**. Close the valve and immediately call American Cyanamid Company at (201) 831-3334 for assistance. After hours, call the Cyanamid emergency phone number (201) 835-3100 for assistance.
2. Firmly secure the bubbler in a vise clamping the rectangular block, making sure that the vise jaws do not interfere with the plugs.
3. Attach the key to the port plug and use a torque wrench to apply sufficient counterclockwise torque (approx. 20 ft. lb.) to loosen the plug. Remove the plug and discard the washer. (Save plugs for returning bubbler-- see Directions for Return of Used Bubblers.)
4. Repeat step 3 on the remaining plug.
5. Insert **new washers** (included with bubbler) and attach 1/4" VCR compatible male connections from your reactor system to the inlet and outlet ports with no more than 20 ft. lb. clockwise torque.
6. It is important to install the bubbler in a perfectly upright position to achieve proper bubble distribution.
7. After the reactor lines leading to and from the bubbler have been evacuated and purged, the bubbler is ready for use.
8. Open the valves by turning the valve knobs 1/4 turn so that the indicator bumps point parallel to the connector lines (see Figures 2 and 3). Operate the valves with your hands only. Over-torquing may cause valve damage. Remember that the blue valve is for the inlet and the red valve is for the outlet.

	Cyanamid Part Number			
	2670203	2670204	2670205	2670208*
A	1.5"	2.0"	2.0"	4.0"
B	7.0"	5.8"	8.5"	17.5"
C	2.0"	2.0"	2.0"	"
D	1.2"	1.2"	1.2"	"
E	2.2"	2.2"	2.2"	"
Approximate Working Volume	150cc	200cc	350cc	2500cc

*This bubbler is manufactured to the same high standards but specifications are slightly different as a result of its size. Details available upon request.

SECONDARY CONTAINMENT FOR GAS CYLINDERS

MODEL 5501 SMALL CYLINDER UNIT

FEATURES

- Capable of holding all small size cylinders from 17 liters down to 7X cylinders used for ion implantation
- Quick opening and closing flange
- Hard truck mounted for easy portability
- Built-in purging system
- Pending D.O.T. approval for truck transportation when containing a leaking cylinder

The Model 5501 small cylinder emergency response containment vessel provides the capability for every facility that uses hazardous gases to contain a leaking cylinder within minutes of discovery. With a 5501 on premises, you no longer have to wait for an outside emergency response team to control a potentially hazardous situation: your employees can easily control the situation (usually in less time than it takes to mobilize an E.R. team).

For complete information, request a copy of Data Sheet DS 121.

ENGINEERING DATA

#9900 DOE [232 Dept - 55 - 1111]

Weight	Approx. 250 pounds
Height	53 inches
Width	25 inches
Depth	26 inches
Construction	Carbon steel, welded ASME Section 8 Division 1 Specification
Working Pressure	1480 psig
Operating Temperature	-20°F to 130°F

For complete information request a copy of Data Sheet DS121.

TO ORDER CALL 800-521-3981

MODEL 5502 LARGE CYLINDER UNIT

FEATURES

- Capable of holding cylinders size 49 liters and smaller
- Quick easy opening hinged door mechanism
- Built-in normally on braking system
- Built-in purging system
- Sized for easy maneuverability through most building situations
- Pending D.O.T. approval for truck transportation when containing a leaking cylinder

The Model 5502 is similar to the 5501 but able to contain large size cylinders up to 50 liters. A 5502 is a necessity for all facilities using large size cylinders of hazardous gases.

ENGINEERING DATA

<i>*3c K</i>	
Pressure Rating	1200 psig at 260°F
Operating temperature	-20°F to 130°F
Internal Dimensions	12" I.D.x66" Long
Overall Length	72"
Overall Width	25"
Overall Height	42"
Construction	Carbon steel, welded ASME section 8, Division 1, Specification (304 Stainless steel option available)
Weight	Approximately 700 pounds

For complete information request copy of Data Sheet DS 121.

Pneumatically Operated Cylinder Valve
Manufactured to Superior Standards

SUPERIOR VALVE COMPANY
Division of
AMCAST INDUSTRIAL COMPANY

TR No. 90-03

Pneumatically Operated Cylinder Valve
For hazardous gas applications

Superior Valve Company developed this patented product to meet the published standards with no exemptions. Because of the applications of hazardous gas, this rugged valve has been constructed to surpass the strictest of safety tests. A valve unequalled in performance, strength and safety.

RICHARD P. PALADINO (201) 882-7900

solkatronic Chemicals Inc.

30 TWO BRIDGES ROAD
FAIRFIELD, N.J. 07004-1530

FAX (201) 882-7967
TLX 219702

**Pneumatically Operated Cylinder Valve
Manufactured to Superior Standards**

SUPERIOR VALVE COMPANY
Division of
AMCAST INDUSTRIAL CORPORATION

The Superior Standards

To produce products that consistently exceed customer requirements. Superior products are tested and continuously improved to provide maximum safety during any type of critical application.

The Superior Valve Company is committed to establishing, meeting and exceeding written standards to provide maximum safety and security to end users of hazardous gases.

Features

Manufactured with maximum safety considerations

- Light weight, high strength aluminum actuator
- Shock resistant--Leak proof after D.O.T. 49 CFR impact test, and recommended CGA 10 time tip over test
- Permanently locked, tamper proof and maintenance free actuator
- Locked, vibration and shock resistant actuator valve connection
- Fail safe, loss of pneumatic pressure closes valve
- Isolated internal bonnet allows actual shock, impact and inertial forces to bypass the diaphragm seal, and transmit directly to the cylinder

Easy to install, transport and use

- Fits under standard cylinder cap
- Locking mechanism to secure valve in closed position during transportation, handling and storage of cylinders
- Multiple pneumatic connection locations to ensure connection can be located toward the front of gas cabinet
- Caution/ instruction label affixed to actuator cap
- 100% individually tested before shipment for operating functions and leakage

RICHARD P. PALADINO

(201) 882-7900

solkatronic Chemicals Inc.

30 TWO BRIDGES ROAD
FARFIELD, N.J. 07004-1530

FAX (201) 882-7967
TLX 219702

Pneumatically Operated Cylinder Valve
Manufactured to Superior Standards

SUPERIOR VALVE COMPANY
A Division of
AMCAST INDUSTRIAL CORPORATION

Drop Test Results

TEST CONDITION #1

Cylinder pressure at 2000 psig; diaphragm seal torqued to 100 ft/lbs

Procedure

D.O.T. 49 CFR cylinder tip over test; impact on steel plate 6" off concrete floor with transport cap in place

Results

Leak tight at 2000 psig; at least 95 ft/lbs remaining on diaphragm seal*; transport cap severely dented

TEST CONDITION #2

Used same valve and cylinder at 2000 psig from test #1

Procedure

Cylinder tip over test without transport cap; cylinder shoulder impacting on concrete floor; test performed twice

Results

Leak tight at 2000 psig; at least 95 ft/lbs remaining on diaphragm seal*

TEST CONDITION #3

Used same valve and cylinder; 300 psig air in cylinder from test #2

Procedure

Same as test #2; test performed 8 times

Results

Leak tight at 2000 psig including cylinder connection; 85 ft/lbs remaining on diaphragm seal; valve functional

* Did not re-torque before next test.

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**Pneumatically Operated Cylinder Valve
Manufactured to Superior Standards**

SUPERIOR VALVE COMPANY

Division of
AMCAST INDUSTRIAL CORPORATION

D.O.T. Standards

RICHARD P. PALADINO

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30 TWO BRIDGES ROAD
FAIRFIELD, N.J. 07004-1530

FAX (201) 882-7967
TLX 218702

The Superior pneumatically operated cylinder valve meets D.O.T. regulations without taking any exemptions. This patented design insures the end user of the safest combination of features.

Important D.O.T. safety requirements in 49 CFR regulation:

- Cylinder valve to be of the packless type [sec. 173.327a]
- Non perforated diaphragms [sec. 173.327a]
- Manual operation override for locking valve shut [sec. 173.327a]
- Pressure relief devices per CGA S-1.1 [sec. 173.34d]
- Impact test [sec. 173.327a(2)]

Sectional View

- Begins to open at 50 psig.
- Full flow at 90 psig.
- Designed to close against 2500 psig gas pressure.
- Performed normally for 53,000 cycles in an on-going test.
- Diaphragm life cycle test of 9000 - 12,000 cycles.
- All 316L material in flow path to prevent particulate shedding.
- 25% glass filled Kel-F lower seat material for longer life.
- Platinum clad safety disc to preclude corrosion.
- D.L.S.S. outlets available.

U.S. Patent No. 4776562
Japan Application No. SHO 63-189530
Other Patents Pending

APPENDIX M5
PURAFIL® Drum Filter

• **Effective Protection**

Effectively removes toxic or noxious odors from industrial plants, and wastewater treatment processing areas

• **Media Selection**

Custom selection of medias manufactured by Purafil, Inc. for targeting specific odor or contaminant gases

• **Corrosion Resistant Housing**

Constructed of high density plastic to resist deterioration by exposure to acid and alkaline environments

• **Economical Solution**

Designed to be an effective, economical solution with simple installation

• **Local Service**

Our international network of trained Purafil representatives are available to provide local assistance.

PURAFIL®
First...in clean air

ES-1500 FUME SCRUBBER

Vector Technology's Hydro-dynamic Fume Scrubbers define the state of the art in effective, economical control of gaseous pollutants and gas-borne particulates. Superior construction (which meets or exceeds all Title 20 secondary-containment requirements) and resourceful design give Vector Scrubbers a clear-cut edge in

satisfying the most critical demands of effluent processing throughout a wide range of industrial environments.

Vector open-loop ES-series Scrubbers remove water-soluble pollutants in the exhaust of epitaxial reactors and similar processing equipment. All Vector Scrubbers are available with the Smart

Scrubber™ option, which, on the ES Series automatically synchronizes Scrubber operation to the process activity. Thereby reducing power and water.

Beside their outstanding performance — controlling pollutants with certified efficiency surpassing 99.999%* — the ES-1500 may be "tuned" to specific process equipment for optimum yields. This tuning is accomplished with Vector's adjustable negative draw venturi valve system. It not only affords optimal matching of scrubbers to particular processes and pipe run lengths, but also allows thorough evacuation of exhaust manifolds. Vector's unique entry system makes it possible to achieve negative pressure between .15" and 3" of water column at the source. This feature is also an advantage in obtaining higher deposition rates in the reaction chamber, through increased flow.

Vector Scrubbers are of PVC and polypropylene construction, with fused — not welded — seams, which creates bonds stronger than the neighboring plastic itself. All units are 100% gas tight. No external containment devices are required.

The modular design of Vector Scrubbers allows units to be configured to enhance a variety of systems, both inside and outside the semiconductor industry. We at Vector recommend that you call to review in detail your facility's gasses usage, flow rates, and other relevant factors, so we can suggest how an appropriate Vector Scrubber system can be tailored to your applications.

0.5 lbs. ¹⁴ 2.4 ft³
7 lbs. =

*Vector's claim of 99.999% efficiency isn't idle marketing hype. Vector Technology will be happy to supply interested customers with documentation: a copy of a test report by an independent EPA-certified laboratory showing that Vector equipment actually performs at the stated level. The exhaust of a properly installed Vector Scrubber is safe to release into the atmosphere without any further conditioning.

1080 Olin Street
Suite 105A
Santa Clara, California 95054
TEL: 408-727-1966
FAX: 408-496-1121

ES-1500 PRODUCT SPECIFICATIONS

The following specifications list is provided for reference purposes and for calculating the requirements for future additions

Total Gas Flow	600 CFM
Process Gas Flow	1500 LPM
Number of Chambers	1
Vent Scrubber	NO
Drain Diameter	2"
Water Usage	5 GPM
CL Tank Capacity	—
Nitrogen Usage	50 SCFH
Emergency City Water	60 PSI
Emergency Inlet	Two 1 1/2 "
Exhaust	6 "
Footprint	24 " x 48 "
Height	63 1/2 "
Height, W/Fume Cap	70 1/4 "
Height, CL Modul	—
Power	208-230* s/p**
Weight, Scrubber Dry	520 lbs
Weight, Scrubber Wet	735 lbs
Weight, CL Unit Dry	—
Weight, CL Unit Wet	—

APPENDIX M6

Particulate laden gas streams enter the Vector ES-Series Fume Scrubber through a patented, nitrogen fed Controlled Moisture Interface. This special system inhibits any reaction between silicon effluent and water vapor — preventing the formation of inlet-clogging silicate buildup, thus eliminating the non-uniform depositions associated with high exhaust back pressure.

Once in the ES-1500 chamber, the effluent is subjected to a shower of water adjustable from 140 to 280 gallons per minute — though the ES-1500 water consumption is just 2.3 gallons per minute. Recirculation of the water through special packed bed media accomplishes the intense scrubbing with minimal water use. This design permits the ES-1500 to occupy only eight square feet of floor space and stand little more than five feet high. Without the packed-bed media, a 70 foot scrubbing tower would be required to achieve comparable results.

The ES-1500 also features exceptionally safe operation. Its self-cleaning inner chamber inhibits the buildup of hazardous ionic silicon halides, and a continual nitrogen purge sweeps the Scrubber to eliminate pockets of hydrogen and oxygen. These functions also translate into dramatic operational savings. Cleaning is rarely necessary.

The ES-Series Scrubbers are available in three models: ES-350, ES-350/3 and ES-1500. Consult the 'Specifications' sheet for the capacities and sizes of each model.

NOTES:

- Vector Scrubbers are available in 200V or 220/230V systems in either 60 Hz or 50 Hz.
- The ES-1500 and CL-1500 Scrubbers have two independent electrical systems requiring two separate hookups.
- Vector Technical Group Inc. reserves the right to change specifications without prior notice.
- By nature of their construction, all Vector Scrubbers meet Title 20 standards for double containment.

Represented by

WESTATE
PRODUCTS, INC.

8180 E. Butcherus Dr. Suite 7
Scottsdale, Arizona 85260
(602) 998-0508 Fax (602) 998-0553

ATM

ATM VENT GAS SCRUBBER/SCRAM™ SYSTEM DESCRIPTION

- **THE SCRAM SYSTEM:** Epigrade® S-417 Resin, Scrubber Cabinet & Containment and Interconnects.
- **APPLICATIONS:** Series 100 & 200 within Fabs/Gas use areas. Series 300--- Cylinder storage areas.
- **UTILITY:** Helps Meet Safety and Environmental Regulations of Federal, State and Local Agencies (TGMO).

**Passive, Dry Chemical Scrubbing Offers
Significant Safety, Facilities, Operating,
and Environmental Advantages.**

ATM

SCRAM SYSTEM BENEFITS

- Meets the requirements and intent of the Toxic Gas Model Ordinance (TGMO).
- One high efficiency (S-417), Epigrade® scavenger resin provides cost-effective emission control.
- Systems work when needed---designed to operate in a passive, unattended mode. Minimum facilitation requirements.
- Toxics are concentrated and contained for disposal.
- Systems are flexible allowing both vent gas scrubbing and emergency containment and treatment.

ATM

Arsine Scrubber Capacity

VGS/HyperScram™ Scrubber System Series 100

VGS/HyperScram™ Scrubber Cabinet Series 100

SCRAM™ Scrubber Cabinet Series 300

ATM

EMERGENCY TREATMENT of TOXIC GASES

"SCRAMS"

- Scrams are used for the controlled release of a faulty tank of high pressure toxic gas ("Leaker") into an emergency trapping device.
 - Toxic gases are chemically changed into a non-volatile solid suitable for transportation and disposal
- In field trials, a one gallon Scram canister treated almost 4 lbs. of arsine at 30 liters per minute!

ATM Scram units are used in:

- Fabs/Gas Cabinets as vent gas scrubbers and for controlled release/treatment of toxic gases.
- Cylinder storage bunkers/pads for "leakers"

ATM

**DEFINING THE FUTURE
IN
SEMICONDUCTOR SAFETY
AND
GAS MANAGEMENT SYSTEMS**

Advanced Technology Materials, Inc.
New Milford, CT
(203) 355-2681

APPENDIX M8

BURN BOX - PLUS SCHEMATIC DESIGN FOR EFFLUENT TREATMENT IN OMVPE/MOCVD SYSTEMS AT NREL

Prior to the 1989-90 rebuild of the OMVPE system in Lab 103 and again this summer several commercial toxic gas treatment systems were evaluated, and none were found that offered an ideal combination of simplicity of operation, low and stable back pressure, and minimum waste generation. All commercial scrubbers are designed to meet the requirements of a large variety of operations, not just III-V epitaxy, and most assume the process chamber is separated from the scrubber by a vacuum pump. Scrubbers based on absorption-neutralization with dry material produce large pressure drops and/or fluctuations which will adversely affect the growth process by changing the pressure in the growth vessel. Some of these models also generate a large amount of spent absorber material to be disposed of as toxic waste. Commercial burn boxes require several gas flows to function, sometimes large amounts of extra hydrogen, and consequently a complex set of interlocks. They also do not come with satisfactory systems for removing arsenic oxide particles from the ventilation exhaust. Through this research into what is commercially available and what other OMVPE users have done, it became clear that the best scrubber would be one built here at NREL to meet the needs of NREL's smaller, atmospheric pressure systems.

The basic principle of the burn box is that toxic gases are converted to their less toxic oxides by burning. The fuel for this burning is the hydrogen process gas. NREL researchers have been using flames to remove toxic gases from the effluent for several years now. There has never been a case of incomplete combustion, which is known from monitoring the treated exhaust with an MDA monitoring port.

More recently arsenic oxide has been classified as a carcinogen, and therefore in the last reactor rebuild a filter system was installed on the ductwork of the OMVPE reactor in Lab 103 to remove oxide particles from the exhaust stream. Previously these particles were allowed to deposit on the ductwork or be exhausted through the ventilation fans, this procedure having been approved by the Safety and Security Office (SSO) because of the low quantities of materials involved. Deposits did flake off from time to time, and these larger particles could fall back into the reactor hood. In the last few months wipe tests for arsenic have indicated a small level of arsenic contamination in some labs, although detectors for airborne arsenic- the only form for which there are established limits- found no detectable arsenic. Wipe samples on the HEPA side of the filter enclosure from Lab 103 also showed a small level of arsenic contamination, which we think may be due to a leak around the HEPA seal. Foam tape was used; a seamless polymer/rubber gasket will be used in the new design. The gasket which comes attached to the HEPA is on the wrong side since HEPA filters are normally used to purify air going into a clean volume, not out of a dirty volume.

Attached are schematic drawings of the proposed design for burn boxes to be used on the OMVPE systems in Labs 103 and 368. This design was reviewed and approved by the Toxic Gas Safety Panel and representatives of the Safety and Security Office and Facilities on October 15, 1991.

The system addresses two concerns brought up by Larry Fluor in his report. First, the flame has been relocated to a separately vented enclosure. Second, the flame has been located where deposits of combustion products will not fall back into work spaces.

The basic safety features of the burn box design are as follows:

- (1) Flame is isolated from the main reactor enclosure so as to not be an ignition source for hydrogen leaks there.
- (2) To guard against ignition of a hydrogen-air mixture above the lower flammability limit (LFL) of 4% hydrogen in air, the following precautions are taken:
 - (a) Hydrogen flow through the growth system and hence into the burn box is interlocked to the hydrogen monitor in the box. The setpoint is 20% of the LFL.
 - (b) Hydrogen flow is interlocked to a ventilation detector which measures whether or not the ductwork is at negative pressure relative to the room.
 - (c) No continuous ignition sources are present in the burn box. The sparkers must be manually operated to generate a spark. Operators are trained to not light the flames if the ventilation is not functioning.

With minimum ventilation air flow of 50 cfm and normal reactor hydrogen flows (6 slpm max), the hydrogen mixture is less than 0.8%, so hydrogen can be flowing to allow the flame to be lit when all systems are operating normally.

- (3) Flow of toxic gases through the reactor is interlocked to the thermocouple in the flame, so toxic gas flow will stop if the flame should go out for any reason.
- (4) As in previous designs, an MDA port will be located downstream of the burn box, and this port is interlocked to the toxic gas supply to shut down in case of a high level alarm. This control is a back-up to the flame sensor.
- (5) Air inlets are near the bottom to promote flushing of the flame area. Inlets are on the side of the box and covered with deflector shields or neighboring equipment to direct any outrushing gas away from personnel in case of a fire.
- (6) Disposable lightweight baffles and trays are used to collect deposits which must be cleaned up on an occasional basis (once every two to three years).
- (7) The system will generate one contaminated prefilter every two to three months and one contaminated HEPA filter every two to three years as hazardous waste. Changing procedures developed for the system in Lab 103 demonstrated that changing the filters can be done without generation of detectable amounts of airborne arsenic, although personal protective gear is required as an extra precaution.

Fig. 1: BURN BOX DESIGN (10 December 1991)

Fig. 2: DETAILS of FLAME AREA (10 December 1991)

Transportation: Never transport a cylinder, even an empty one, in anything but an approved cart or hand truck. Only authorized personnel in authorized vehicles can transport a gas cylinder in a vehicle.

IV.B. Hazardous Gas Cylinder Changing Procedures

The format for this section is that of a check list. When a hazardous gas cylinder is changed it is necessary that two qualified employees be present; each wearing Self Contained Breathing Apparatus (SCBA). One will actually perform the steps on the check list and one will check each step off as they are performed. This check list should be photocopied if spare check lists are not available.

This check list is written in general terminology so that it applies to all the hazardous gas lines on the system. References to specific valve numbers are omitted. See section II.C.B. for a specific description of each component.

Only personnel familiar with the system, trained in the Emergency Response Procedures to the MDA Toxic Gas Alarm, and certified in the use of SCBA are allowed to be involved with the changing of a hazardous gas cylinder.

___ Ensure that the MDA run light is illuminated.

___ Turn off gas cylinder.

___ Set up as to make a run: evacuate chamber, set nitrogen flows.

After the chamber and the scrubber are adequately purged:

___ Establish a flow through the chamber to evacuate the line.

___ Be sure all valves are opened that would be open during a run.

After the line is evacuated (vacuum shown on regulator gauge):

___ ___ ___ ___ ___ Close 3-way gas delivery valve (leave safety shut off valve open).

- ___ ___ ___ ___ ___ Open argon valve on cross purge assembly.
- ___ ___ ___ ___ ___ After argon has filled the line, close the argon valve on cross purge assembly.
- ___ ___ ___ ___ ___ Open delivery valve and evacuate the line through the chamber.
- ___ Repeat above four steps at least five times.

- ___ Close 3-way gas delivery valve (leave safety shut off valve open).
- ___ Close roughing valve on chamber.
- ___ Close 1/4 turn diaphragm valve on the outlet of the regulator.
- ___ Close diaphragm valve on outlet of cross purge (to regulator).
- ___ Open cross purge evacuation valve to roots blower.

- ___ After the cross purge evacuation line is evacuated:
- ___ Open argon valve on cross purge, pressurizing cross purge.
- ___ Close argon valve on cross purge assembly.
- ___ Open evacuation valve on cross purge assembly.
- ___ When line is drained (watch TC gauge), close evacuation valve.
- ___ Repeat above four steps at least five times.

- ___ Open argon valve on cross purge, to supply positive pressure.
- ___ Double check that the cylinder valve, cross purge outlet valve, and cross purge evacuation valves are all closed.

- ___ Don self contained breathing apparatus (SCBA).

- ___ Remove old cylinder. Note: argon will flow out of CGA fitting.
- ___ Put on protective cylinder outlet cap.
- ___ Put on cylinder valve cap.

- ___ Remove cylinder valve cap and outlet cap from new cylinder. NOTE: There exists a possibility that there has been a leakage of gas through the cylinder valve resulting in a build up of pressure behind the outlet cap. Therefore, the cylinder should be facing away and under ventilation when removing this cap.
- ___ Install new cylinder.
- ___ Remove SCBA.
- ___ Close argon valve on cross purge assembly.
- ___ Open evacuation valve on cross purge assembly.
- ___ Open argon valve, allow enough time to fill the cross purge.
- ___ Repeat the above four steps at least five times.
- ___ Close argon valve.
- ___ When line is drained (watch TC gauge), close evacuation valve.
- ___ Close cross purge evacuation valve to roots blower.
- ___ Use the RGA to leak test the line.
- ___ Make sure regulator delivery pressure adjusting screw is fully turned counter-clockwise (the zero delivery pressure setting).
- ___ Open the cylinder valve slowly.
- ___ Slowly open the cross purge outlet valve (to regulator).
- ___ Slowly turn the regulator delivery pressure adjusting screw clockwise to the desired delivery pressure.
- ___ Slowly open the diaphragm valve on the regulator outlet.
- ___ Open the roughing valve to the chamber.
- ___ Open the 3-way gas delivery valve to establish a flow to the chamber.
- ___ Monitor the flow for a few minutes to be sure everything is OK.
- ___ Shut down the line (gas delivery and safety shut off valves).
- ___ Purge out the chamber.

TRAINING LOG

For
Yueqin Xu

Yueqin is authorized to fully operate† the Single Chamber ("S") System ; as well as, monitor* both the modified Photo-CVD ("A") and the Two Chamber ("T") Systems. Additionally, Yueqin is authorized to assist in the changing of toxic gas cylinders on these systems.

As such, Yueqin is required to receive the following training. (All of these systems are located in laboratory 16/190.)

TYPE OF TRAINING REQUIRED	Frequency Required	Date Received	Date Received	Date Received	Date Received	Date Received	Date Received	Date Received
Fire Extinguisher	once / year	9 / 88	5/20/91					
SCBA	once / year	12 / 89	10/20/90					
Toxic Gas (MDA) Monitors	once / year	10 / 89	4/25/90					
Compressed Gas Safety	one time only	9 / 87	7/3/91					
Chemical Hazard Communication	one time only	4 / 89	6/4/91					
Electrical Safety	one time only		5/22/91					
Spill Control	one time only		5/29/91					
Waste Minimization/Disposal	one time only	3 / 87						
CPR (optional)	once / year	2 / 89	3/20/91					
First Aid (optional)	once / 3 yrs	4 / 90	3/20/91					

† Fully Operate means performing any or all of the steps necessary to make a film or solar cell. The operator is also responsible for any emergency action or decisions that need to be made because of the operation of a deposition system.

* Monitor means watching the system for a short period of time, while the operator is away. Monitoring would include emergency shut down, if needed, but corrective action would be taken by the operator.

TOXIC GAS INVENTORY

for
Single Chamber Amorphous Silicon Deposition System
in
Laboratory 16/190

Description of Toxic Gas/Hazardous Material	Type of Container	Qty. in Container	Cylinder Number	SERI Number	P.O. Number	Date Received	Date Removed	Person Responsible
100% Silane (SiH_4)	Cylinder	5 Kg	00897	2235	C-5-23115-1	6/20/85		Simon
1% Diborane (B_2H_6) in Silane	Cylinder	500 gram	926958	3762	N-7-3398-1	8/20/87		Simon
3% Phosphine (PH_3) in Silane	Cylinder	500 gram	FF6123	2789	R-7-3099-1	2-15-87		Simon
100% Methane (CH_4)	Cylinder	500 gram			R-7-32784-1	5/27-87		Simon
100% Germane (GeH_4)	Cylinder	200 gram	FF30724	N/A	W-43513-1	5/26/89		Simon
100% Hydrogen (H_2)	Cylinder	500 gram	C1256	N/A	R-7-33330-1	7/17/87		Simon
25% PH_3 in SiH_4	"	533 "	FF346672		B-6-47152-1	2/26/90		Y. Xu
1% Trimethylboron $\text{B}(\text{CH}_3)_3$	Cylinder	5 g + 200 g			W-0-4573-1	10/5/89		Simon
100% Silane (silly)	Cylinder	500 g			W-9-4507-1	8/20/89		Simon

Simon
Simon
Simon

Simon

46

47

48

44

43

APPENDIX S3

PREVENTATIVE MAINTENANCE LOG

For the Single Chamber Amorphous Silicon Deposition System, in laboratory 16/190.

(Note that actual records of the maintenance performed is kept in the blue Technical Record Books on the book shelf on the south wall.)

TYPE OF PREVTATIVE MAINTENANCE REQUIRED	Frequency Required	Date Performed	Date Performed	Date Performed	Date Performed	Date Performed	Date Performed	Date Performed
Check Pressure on Oil Filters	before each run	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Change Oil Filters	when P > 45 psi	11/2/89	11/13/90					
Check Oil in All Pumps	once / week	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Change Oil in Mechanical Pumps	twice / year	11/20/89	11/13/90					
Change Oil in Roots Blower	twice / year	11/20/89	11/13/90					
Change Oil in Turbo Pump	twice / year	10/10/89	12/05/90					
Calibrate Mass Flow Controllers	twice / year	12/10/89						
"Sweep" Out Inlet to Scrubber	before each run	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Check pH of Scrubber Solution	once / week	12/8/89 to 12/11/89	N/A	N/A	N/A	N/A	N/A	N/A
Add NaOH + H ₂ O to Scrubber	when pH ≤ 12	12/11/89						
Change Scrubber Solution	when saturated	4/4/90						
Clean Scrubber Tower and Jets	at solution chang	6/1/90						
Check Scrubber Sol. Interlock	twice / year		12/24/90					
Check Scrubber Press. Interlock	twice / year		12/24/90					
Check Nitrogen Flow Interlock	twice / year							
Check Ch. Overpressure Interlock	twice / year							
Check Exhaust Fan Interlock	twice / year							
Check System MDA Interlock	twice / year							
Check MDA Alarms in Lab	twice / year							

APPENDIX 2

APPENDIX 54

SAFETY INTERLOCK/ALARM INSPECTION LOG

For System "S" Located in Laboratory 16/190

(A copy of the circuit diagram, with explanations, is included in the SOP for each system, as well as the laboratory SOP.)

NAME OF INTERLOCK/ALARM	RESULT OF ACTUATION	Date of Test /Signature	Date of Test /Signature	Date of Test /Signature	Date of Test /Signature	Date of Test /Signature	Date of Test /Signature
"S" Exhaust Ventilation	Complete System Shut Down	1/24/91					
"S" Scrubber Inlet Over Pressure	Complete System Shut Down	1/24/91	1/24/91				
"S" Scrubber Solution Flow	Complete System Shut Down	1/24/91	1/24/91				
"S" MDA High Level Alarm	Complete System Shut Down	1/24/91	1/26/91				
Chamber Over Pressure	Complete System Shut Down						
Foreline Over Pressure	Complete System Shut Down						
Out of Valve/Pneu. Nitrogen	Control Panel Alarm Only						
Out of Ar	Control Panel Alarm Only						
Out of Pump/Purge Nitrogen	Complete System Shut Down						

4. "S" SCRUBBER OFF Complete System Shut Down 1/24/91
- The top four Interlock/Alarms are on a circuit external to the control panel. This circuit controls the AC power supplied to the system control panel. Audio and visual alarms are activated separate from the system control panel, at the appropriate locations, upon activation of these alarms.
 - The remainder of the Interlock/Alarms are a part of the system control panel circuitry. The audio and visual alarms are located on the control panel.
 - Complete System Shut Down means all flows of toxic gases are stopped, both at the cylinder and from either the bypass line(s) and/or the process.
 - Control Panel Alarm Only means that the flow of toxic gases are not automatically stopped, but both an audio and a visual alarm is activated.

END

**DATE
FILMED
11 / 5 / 92**