# Emissions Rx™ - Thermal Oxidizer

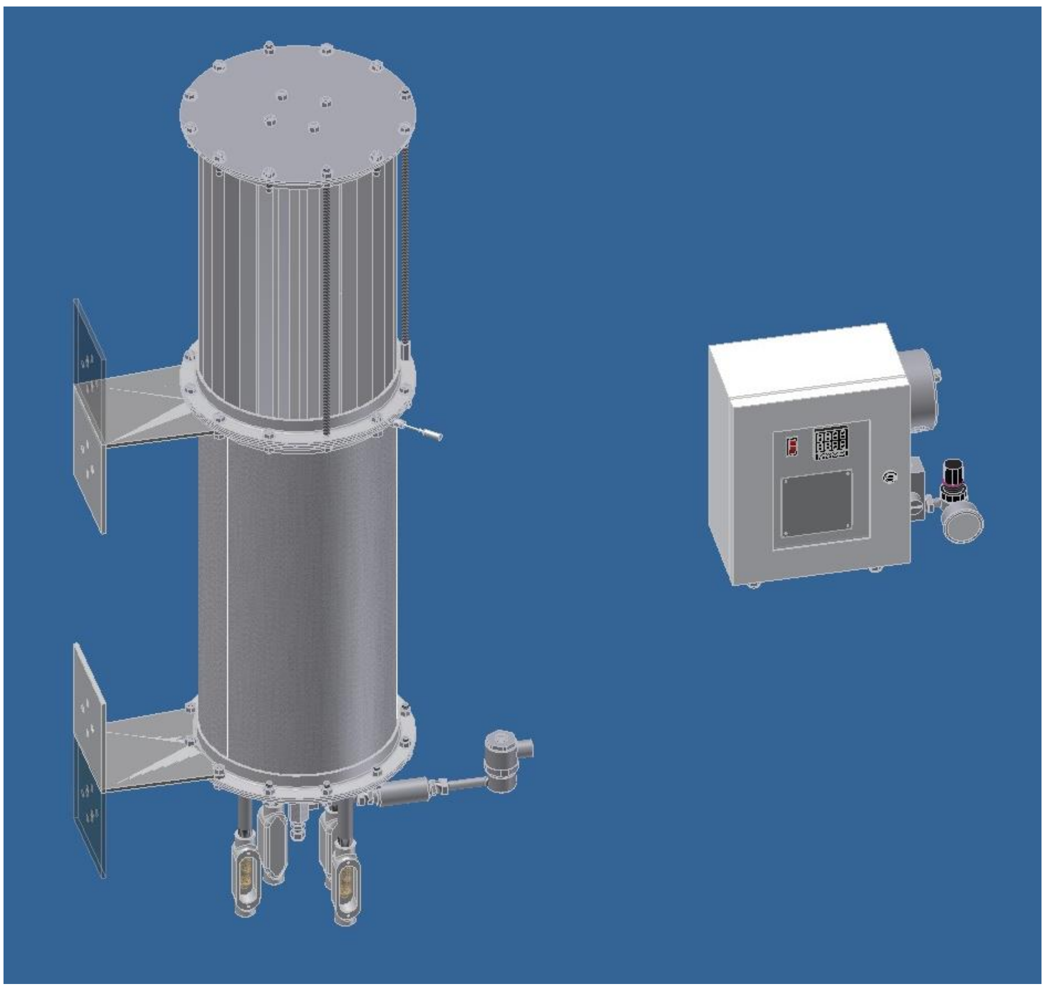
Emissions Rx™ - Thermal Oxidizer

## Operations & Maintenance Manual

Thermal Oxidizer Model :

Serial Number :

Job Name:



# Operators Manual

## Index

Job Name:

Customer:

Order No.:

## GENERAL

The installation of Emission Rx T.O. must be done according to the applicable local and national codes.

The person, or persons, performing the work must be familiar with, and operate within, these applicable codes.

Installation, modification or service of the equipment supplied by Emissions Rx, must only be carried out by qualified, licensed persons.

Emission Rx. will not be held responsible for any damages caused by unqualified persons, unsafe practices or unauthorized modifications to the received goods.

The pressure drop in the gas line should be kept to a minimum. Therefore, the gas supply line should be as short as possible.

A complete Emission Rx. Start-Up Report must be completed by the installer and a copy sent to Emission Rx. This is a warranty requirement!

It is the responsibility of the qualified installation person to determine the following from the local gas authority (company) prior to starting the burner:
The installation of Emissions Rx Thermal Oxidizers must be done according to the applicable local and national codes. The person, or persons, performing the work must be familiar with, and operate within, these applicable codes.
Installation, modification or service of the equipment supplied by Emissions Rx, must only be carried out by qualified, licensed persons.
Emissions Rx will not be held responsible for any damages caused by unqualified persons or unsafe practices.

The pressure drop in the Waste gas line should be kept to a minimum. Therefore, the Waste gas supply line should be as short as possible.
A complete Emissions Rx Start-Up Report must be completed by the installer and a copy sent to Emissions Rx. This is a warranty requirement!
It is the responsibility of the purchaser to determine the following prior to starting the Thermal Oxidizer:

- Type of Waste gas
- Higher Heating Value (BTU per cubic foot)
- Maximum $C0_2$ (Carbon Dioxide) content of flue Waste gas
- Incoming Waste gas pressure
- Whether, or not, the Waste gas meter is pressure and/or temperature compensated.

Acquire the correction factor in order to determine the correct Thermal Oxidizer input Chemical composition of special Waste gases (Digester, Sewage, Manufactured etc.)

## 1.1 WARNING

Read the following warnings and instructions before attempting startup of any Combustion Control device.
If you smell Waste gas: - Ventilate Room!
- Extinguish any open flame!
- Do NOT smoke!
- Do NOT tamper with or touch anything ELECTRICAL!
- Do NOT attempt to start the Thermal Oxidizer!
- Call the Waste gas supply company!

- The installation, Start Up, Operation and Servicing of an Emission Rx Thermal Oxidizer must be done according to the manufacturers' instructions and applicable local and national codes.
- Incorrect procedures can lead to the exposure of components of the fuel and combustion products which can cause serious bodily harm or death.
- The storage of flammable liquids in an open container near the Thermal Oxidizer application, or in the same room, can be dangerous and should be avoided.
- Before commencing any service work:
  1. Close off all fuel lines!
  2. Switch off and isolate electrical power to the equipment!

The use of Teflon tape as an oil and Waste gas pipe sealant can cause fuel valves to fail and create hazardous situations. If Teflon tape is used, ALL WARRANTIES ARE INVALID and Emissions Rx will not accept responsibility for any liability.

As a safety precaution, Emissions Rx has adopted the policy that all automated waste gas service piping must have 1 safety valve and a Back Flash Arrestor. Emissions Rx cannot accept responsibility for any installation which compromises this safety policy, even if local code states otherwise. NOT FOLLOWING THIS Emissions Rx POLICY WILL RENDER ANY WARRANTY VOID!

Any work performed on the Thermal Oxidizer, applicable interfaced equipment, or controls must be done by qualified and trained personnel familiar with the product and licensed to undertake such work. All work must be completed within the parameters of local and national codes.

Do not set up the flame on Emissions Rx Thermal Oxidizers without accurate flue Waste gas measuring instruments.
Correctly calibrated combustion instruments are the only reliable means to determine a safe operation of the Thermal Oxidizer.

All safety and control devices must be checked for correct operation and adjusted with the correct settings before operating the unit.

*This manual may be updated without notice. Consult your authorized distributer or Combustion Systems Co Inc. for the latest version.*

## 1.2 Checklist

In order to avoid damage to the equipment, check the following prior to starting the Thermal Oxidizer:

- Heat Exchanger is installed properly (if applicable)
- Limits and operating controls on the Thermal Oxidizer are mounted and wired correctly (if applicable)
- Type and range of all controls are correct for the application
- Oxidation chamber dimensions are adequate for the required waste gas disposal rate
- Oxidation chamber is unobstructed to allow for required flow rate
- Thermal Oxidizer/Heat Exchanger can be fired, at the required firing rate, long enough to take flue Waste gas readings
- Thermal Oxidizer/Controls are installed correctly (if applicable)
- Thermal Oxidizer is installed correctly
- No damage to the Thermal Oxidizer has resulted from transportation or installation
- The electrical supply is correct for the Thermal Oxidizer Elements and for the control voltage
- The field wiring to the Thermal Oxidizer and control panel (if applicable) is in accordance with the shop drawings provided
- All field wiring meets applicable local and national codes
- Sufficient combustion air is available for the Thermal Oxidizer to operate at the desired temperature and excess air.
- All equipment interfaced to the Thermal Oxidizer controls are correctly wired and are functioning properly
- Waste gas is identified prior to purchase and remains with range specified.
- The waste gas train is complete and complies to the applicable code
- No damage to the component parts of the waste gas train has resulted from transportation or installation (if applicable)

- The waste gas lines are the right size, have been installed correctly, are clear of dirt, have been purged and do not leak
- The incoming waste gas pressure is adequate for the installed waste gas train (if applicable) and required firing rate this per Instruction Manual!

## 1.3 – Site Conditions Data Sheet

Job Name: Date:
Customer Name:
Ship to Address
Customer P.O.
Customer Project File No. :
Quoted Model:
Site Elevation FASL __________ Feet
Waste Gas Pressure Min (inches W.C.): __________ Max (inches W.C.) _________
Waste Gas through put (Btu/hr): _________ HHV_________ LHV _________
Waste Gas Volume (ACFM) _______ (SCFM) ________ (LPM) _________
Waste Gas Temperature Degrees _________°F _________ °C

| Waste Gas Analysis by | Wt. % | Volume % |
|---|---|---|
| Carbon | _____ | _____ |
| Hydrogen | _____ | _____ |
| Nitrogen | _____ | _____ |
| Oxygen | _____ | _____ |
| Sulfur | _____ | _____ |
| Moisture | _____ | _____ |
| Ash | _____ | _____ |
| Other 1._____ | _____ | _____ |
| Other 2._____ | _____ | _____ |
| Other 3._____ | _____ | _____ |

Common Name: ________________________________________
Available Electrical Power Voltage: ____V/ _____PH/____Hz
Code Construction: [ ] None [ ] NFPA [ ] C1D2BCD [ ] Other
If Oher Specify ______________________________.

# 1.4 Unit Performance Data Sheet

1000 Btu/SCF Natural Gas Basis of Design (Maximum Btu/hr Input) ___________
Emission Rx Waste Gas Delivery requirements:

1. Waste Gas Connection Size: _______ NPT 316 SS
2. Waste Gas Static Pressure Required at ERx Connection: ________ (”W.C.)

Waste Gas Flash Protection:

1. [ ] N/A
2. [ ] Solenoid
3. [ ] Back Flash Arrestor
4. [ ] Solenoid & Back Flash Arrestor

Emission Rx Combustion Ari Requirements:

1. Combustion Air Required: _________ SCFM
2. Combustion Air Static Pressure: ________Inches W.C.

| Type of Combustion Air Delivery: | Type of CA Control |
|---|---|
| 1. [ ] Natural Draft | [ ] N/A |
| 2. [ ] Owner Supplied C.A. | [ ] On/Off |
| 3. [ ] ERx Supplied Forced Draft Fan | [ ] Modulated |

F.D. Motor Amperage: ______ Amps

Combustion Air Flash Protection:
[ ] N/A
[ ] Combustion Air - Flash Attenuator
[ ] Combustion Air Back Flash Arrestor
[ ] Combustion Air Flame Arrestor

T.O. Exhaust Flash Protection:
[ ] N/A
[ ] Exhaust Gas - Flash Attenuator
[ ] Exhaust Gas - Back Flash Arrestor
[ ] Exhaust Gas - Flame Arrestor

Control Voltage Standard: 120/1/60 Other [ ]:____V/ _____PH/____Hz
Control Circuit Amperage: ________Amps
Heating Element Voltage: Standard 120/1/60 [ ] Other [ ]:____V/ _____PH/____Hz

Heating Element Control:

1. Continuous [ ]
2. Intermittent [ ]
3. PID Set Point [ ]

# 1.5 Model Capacity

Unit Model is based on Unit Capacity in Btu/hr. input. Larger units available upon request.

**Design Air input to Waste Gas Ratio (based on) 100% concentration of Waste Gas HHV**

| Btu/CF | Gas | LPM | CFM | Btu/M | Btu's/hr. | CF/H | Max Air CFH |
|---|---|---|---|---|---|---|---|
| 1000 ★ | Methane | 1 | 0.035315 | 35.31472 | 2,118.88 | 2.12 | 31.78 |
| Liter Per CF | | 2 | 0.070629 | 70.62945 | 4,237.77 | 4.24 | 63.57 |
| 28.3168 | 1 | 3 | 0.105944 | 105.9442 | 6,356.65 | 6.36 | 95.35 |
| | | 4 | 0.141259 | 141.2589 | 8,475.53 | 8.48 | 127.13 |
| | | 4.7195 | 0.166668 | 166.6678 | 10,000.07 | 10.00 | 150.00 |
| | | 5 | 0.176574 | 176.5736 | 10,594.42 | 10.59 | 158.92 |
| | | 6 | 0.211888 | 211.8883 | 12,713.30 | 12.71 | 190.70 |
| | | 7 | 0.247203 | 247.2031 | 14,832.18 | 14.83 | 222.48 |
| | | 8 | 0.282518 | 282.5178 | 16,951.07 | 16.95 | 254.27 |
| | | 9 | 0.317833 | 317.8325 | 19,069.95 | 19.07 | 286.05 |
| | | 10 | 0.353147 | 353.1472 | 21,188.83 | 21.19 | 317.83 |
| | | 11 | 0.388462 | 388.462 | 23,307.72 | 23.31 | 349.62 |
| | | 12 | 0.423777 | 423.7767 | 25,426.60 | 25.43 | 381.40 |
| | | 13 | 0.459091 | 459.0914 | 27,545.49 | 27.55 | 413.18 |
| | | 14 | 0.494406 | 494.4061 | 29,664.37 | 29.66 | 444.97 |
| | | 15 | 0.529721 | 529.7209 | 31,783.25 | 31.78 | 476.75 |
| | | 16 | 0.565036 | 565.0356 | 33,902.14 | 33.90 | 508.53 |
| | | 17 | 0.60035 | 600.3503 | 36,021.02 | 36.02 | 540.32 |
| | | 18 | 0.635665 | 635.665 | 38,139.90 | 38.14 | 572.10 |
| | | 19 | 0.67098 | 670.9798 | 40,258.79 | 40.26 | 603.88 |
| | | 20 | 0.706294 | 706.2945 | 42,377.67 | 42.38 | 635.67 |
| | | 21 | 0.741609 | 741.6092 | 44,496.55 | 44.50 | 667.45 |
| | | 22 | 0.776924 | 776.9239 | 46,615.44 | 46.62 | 699.23 |
| | | 23 | 0.812239 | 812.2387 | 48,734.32 | 48.73 | 731.01 |
| | | 24 | 0.847553 | 847.5534 | 50,853.20 | 50.85 | 762.80 |
| | | 25 | 0.882868 | 882.8681 | 52,972.09 | 52.97 | 794.58 |
| | | 26 | 0.918183 | 918.1828 | 55,090.97 | 55.09 | 826.36 |
| | | 27 | 0.953498 | 953.4976 | 57,209.85 | 57.21 | 858.15 |
| | | 28 | 0.988812 | 988.8123 | 59,328.74 | 59.33 | 889.93 |
| | | 29 | 1.024127 | 1024.127 | 61,447.62 | 61.45 | 921.71 |
| | | 30 | 1.059442 | 1059.442 | 63,566.50 | 63.57 | 953.50 |
| | | 31 | 1.094756 | 1094.756 | 65,685.39 | 65.69 | 985.28 |
| | | 32 | 1.130071 | 1130.071 | 67,804.27 | 67.80 | 1017.06 |
| | | 33 | 1.165386 | 1165.386 | 69,923.16 | 69.92 | 1048.85 |
| | | 34 | 1.200701 | 1200.701 | 72,042.04 | 72.04 | 1080.63 |
| | | 35 | 1.236015 | 1236.015 | 74,160.92 | 74.16 | 1112.41 |
| | | 36 | 1.27133 | 1271.33 | 76,279.81 | 76.28 | 1144.20 |
| | | 37 | 1.306645 | 1306.645 | 78,398.69 | 78.40 | 1175.98 |
| | | 38 | 1.34196 | 1341.96 | 80,517.57 | 80.52 | 1207.76 |
| | | 39 | 1.377274 | 1377.274 | 82,636.46 | 82.64 | 1239.55 |
| | | 40 | 1.412589 | 1412.589 | 84,755.34 | 84.76 | 1271.33 |
| | | 41 | 1.447904 | 1447.904 | 86,874.22 | 86.87 | 1303.11 |
| | | 42 | 1.483218 | 1483.218 | 88,993.11 | 88.99 | 1334.90 |
| | | 43 | 1.518533 | 1518.533 | 91,111.99 | 91.11 | 1366.68 |
| | | 44 | 1.553848 | 1553.848 | 93,230.87 | 93.23 | 1398.46 |
| | | 45 | 1.589163 | 1589.163 | 95,349.76 | 95.35 | 1430.25 |
| | | 46 | 1.624477 | 1624.477 | 97,468.64 | 97.47 | 1462.03 |
| | | 47 | 1.659792 | 1659.792 | 99,587.52 | 99.59 | 1493.81 |
| | | 48 | 1.695107 | 1695.107 | 101,706.41 | 101.71 | 1525.60 |
| | | 49 | 1.730422 | 1730.422 | 103,825.29 | 103.83 | 1557.38 |
| | | 50 | 1.765736 | 1765.736 | 105,944.17 | 105.94 | 1589.16 |
| | | 51 | 1.801051 | 1801.051 | 108,063.06 | 108.06 | 1620.95 |
| | | 52 | 1.836366 | 1836.366 | 110,181.94 | 110.18 | 1652.73 |
| | | 53 | 1.87168 | 1871.68 | 112,300.82 | 112.30 | 1684.51 |
| | | 54 | 1.906995 | 1906.995 | 114,419.71 | 114.42 | 1716.30 |
| | | 55 | 1.94231 | 1942.31 | 116,538.59 | 116.54 | 1748.08 |
| | | 56 | 1.977625 | 1977.625 | 118,657.48 | 118.66 | 1779.86 |
| | | 57 | 2.012939 | 2012.939 | 120,776.36 | 120.78 | 1811.65 |
| | | 58 | 2.048254 | 2048.254 | 122,895.24 | 122.90 | 1843.43 |
| | | 59 | 2.083569 | 2083.569 | 125,014.13 | 125.01 | 1875.21 |
| | | 60 | 2.118883 | 2118.883 | 127,133.01 | 127.13 | 1907.00 |
| | | 61 | 2.154198 | 2154.198 | 129,251.89 | 129.25 | 1938.78 |
| | | 62 | 2.189513 | 2189.513 | 131,370.78 | 131.37 | 1970.56 |
| | | 63 | 2.224828 | 2224.828 | 133,489.66 | 133.49 | 2002.34 |
| | | 64 | 2.260142 | 2260.142 | 135,608.54 | 135.61 | 2034.13 |
| | | 65 | 2.295457 | 2295.457 | 137,727.43 | 137.73 | 2065.91 |
| | | 66 | 2.330772 | 2330.772 | 139,846.31 | 139.85 | 2097.69 |
| | | 67 | 2.366087 | 2366.087 | 141,965.19 | 141.97 | 2129.48 |
| | | 68 | 2.401401 | 2401.401 | 144,084.08 | 144.08 | 2161.26 |
| | | 69 | 2.436716 | 2436.716 | 146,202.96 | 146.20 | 2193.04 |
| | | 70 | 2.472031 | 2472.031 | 148,321.84 | 148.32 | 2224.83 |

| Btu/CF | Gas | LPM | CFM | Btu/M | Btu's/hr. | CF/H | Max Air CFH |
|---|---|---|---|---|---|---|---|
| 2500 | Propane | 1 | 0.035315 | 88.28681 | 5,297.21 | 2.12 | 79.46 |
| Liter Per CF | | 2 | 0.070629 | 176.5736 | 10,594.42 | 4.24 | 158.92 |
| 28.3168 | 1 | 3 | 0.105944 | 264.8604 | 15,891.63 | 6.36 | 238.37 |
| | | 4 | 0.141259 | 353.1472 | 21,188.83 | 8.48 | 317.83 |
| | | 4.7195 | 0.166668 | 416.6696 | 25,000.18 | 10.00 | 375.00 |
| | | 5 | 0.176574 | 441.4341 | 26,486.04 | 10.59 | 397.29 |
| | | 6 | 0.211888 | 529.7209 | 31,783.25 | 12.71 | 476.75 |
| | | 7 | 0.247203 | 618.0077 | 37,080.46 | 14.83 | 556.21 |
| | | 8 | 0.282518 | 706.2945 | 42,377.67 | 16.95 | 635.67 |
| | | 9 | 0.317833 | 794.5813 | 47,674.88 | 19.07 | 715.12 |
| | | 10 | 0.353147 | 882.8681 | 52,972.09 | 21.19 | 794.58 |
| | | 11 | 0.388462 | 971.1549 | 58,269.30 | 23.31 | 874.04 |
| | | 12 | 0.423777 | 1059.442 | 63,566.50 | 25.43 | 953.50 |
| | | 13 | 0.459091 | 1147.729 | 68,863.71 | 27.55 | 1032.96 |
| | | 14 | 0.494406 | 1236.015 | 74,160.92 | 29.66 | 1112.41 |
| | | 15 | 0.529721 | 1324.302 | 79,458.13 | 31.78 | 1191.87 |
| | | 16 | 0.565036 | 1412.589 | 84,755.34 | 33.90 | 1271.33 |
| | | 17 | 0.60035 | 1500.876 | 90,052.55 | 36.02 | 1350.79 |
| | | 18 | 0.635665 | 1589.163 | 95,349.76 | 38.14 | 1430.25 |
| | | 19 | 0.67098 | 1677.449 | 100,646.97 | 40.26 | 1509.70 |
| | | 20 | 0.706294 | 1765.736 | 105,944.17 | 42.38 | 1589.16 |
| | | 21 | 0.741609 | 1854.023 | 111,241.38 | 44.50 | 1668.62 |
| | | 22 | 0.776924 | 1942.31 | 116,538.59 | 46.62 | 1748.08 |
| | | 23 | 0.812239 | 2030.597 | 121,835.80 | 48.73 | 1827.54 |
| | | 24 | 0.847553 | 2118.883 | 127,133.01 | 50.85 | 1907.00 |
| | | 25 | 0.882868 | 2207.17 | 132,430.22 | 52.97 | 1986.45 |
| | | 26 | 0.918183 | 2295.457 | 137,727.43 | 55.09 | 2065.91 |
| | | 27 | 0.953498 | 2383.744 | 143,024.64 | 57.21 | 2145.37 |
| | | 28 | 0.988812 | 2472.031 | 148,321.84 | 59.33 | 2224.83 |

✚ Designed Air Flow delivered is based on Btu/hr. input, not Waste Gas Flow Rate.

| Btu/CF | Gas | LPM | CFM | Btu/M | Btu/H | CF/H | Max Air CFH ◆ |
|---|---|---|---|---|---|---|---|
| 0 | Nitrogen | 1 | 0.035315 | 0 | 0 | 2.12 | 31.78 |
| Liter Per CF | | 2 | 0.070629 | 0 | 0 | 4.24 | 63.57 |
| 28.3168 | 1 | 3 | 0.105944 | 0 | 0 | 6.36 | 95.35 |
| | | 4 | 0.141259 | 0 | 0 | 8.48 | 127.13 |
| | | 4.7195 | 0.166668 | 0 | 0 | 10.00 | 150.00 |
| | | 5 | 0.176574 | 0 | 0 | 10.59 | 158.92 |
| | | 6 | 0.211888 | 0 | 0 | 12.71 | 190.70 |
| | | 7 | 0.247203 | 0 | 0 | 14.83 | 222.48 |
| | | 8 | 0.282518 | 0 | 0 | 16.95 | 254.27 |
| | | 9 | 0.317833 | 0 | 0 | 19.07 | 286.05 |
| | | 10 | 0.353147 | 0 | 0 | 21.19 | 317.83 |
| | | 11 | 0.388462 | 0 | 0 | 23.31 | 349.62 |
| | | 12 | 0.423777 | 0 | 0 | 25.43 | 381.40 |
| | | 13 | 0.459091 | 0 | 0 | 27.55 | 413.18 |
| | | 14 | 0.494406 | 0 | 0 | 29.66 | 444.97 |
| | | 15 | 0.529721 | 0 | 0 | 31.78 | 476.75 |
| | | 16 | 0.565036 | 0 | 0 | 33.90 | 508.53 |
| | | 17 | 0.60035 | 0 | 0 | 36.02 | 540.32 |
| | | 18 | 0.635665 | 0 | 0 | 38.14 | 572.10 |
| | | 19 | 0.67098 | 0 | 0 | 40.26 | 603.88 |
| | | 20 | 0.706294 | 0 | 0 | 42.38 | 635.67 |
| | | 21 | 0.741609 | 0 | 0 | 44.50 | 667.45 |
| | | 22 | 0.776924 | 0 | 0 | 46.62 | 699.23 |
| | | 23 | 0.812239 | 0 | 0 | 48.73 | 731.01 |
| | | 24 | 0.847553 | 0 | 0 | 50.85 | 762.80 |
| | | 25 | 0.882868 | 0 | 0 | 52.97 | 794.58 |
| | | 26 | 0.918183 | 0 | 0 | 55.09 | 826.36 |
| | | 27 | 0.953498 | 0 | 0 | 57.21 | 858.15 |
| | | 28 | 0.988812 | 0 | 0 | 59.33 | 889.93 |
| | | 29 | 1.024127 | 0 | 0 | 61.45 | 921.71 |
| | | 30 | 1.059442 | 0 | 0 | 63.57 | 953.50 |
| | | 31 | 1.094756 | 0 | 0 | 65.69 | 985.28 |
| | | 32 | 1.130071 | 0 | 0 | 67.80 | 1017.06 |
| | | 33 | 1.165386 | 0 | 0 | 69.92 | 1048.85 |
| | | 34 | 1.200701 | 0 | 0 | 72.04 | 1080.63 |
| | | 35 | 1.236015 | 0 | 0 | 74.16 | 1112.41 |
| | | 36 | 1.27133 | 0 | 0 | 76.28 | 1144.20 |
| | | 37 | 1.306645 | 0 | 0 | 78.40 | 1175.98 |
| | | 38 | 1.34196 | 0 | 0 | 80.52 | 1207.76 |
| | | 39 | 1.377274 | 0 | 0 | 82.64 | 1239.55 |
| | | 40 | 1.412589 | 0 | 0 | 84.76 | 1271.33 |
| | | 41 | 1.447904 | 0 | 0 | 86.87 | 1303.11 |
| | | 42 | 1.483218 | 0 | 0 | 88.99 | 1334.90 |
| | | 43 | 1.518533 | 0 | 0 | 91.11 | 1366.68 |
| | | 44 | 1.553848 | 0 | 0 | 93.23 | 1398.46 |
| | | 45 | 1.589163 | 0 | 0 | 95.35 | 1430.25 |
| | | 46 | 1.624477 | 0 | 0 | 97.47 | 1462.03 |
| | | 47 | 1.659792 | 0 | 0 | 99.59 | 1493.81 |
| | | 48 | 1.695107 | 0 | 0 | 101.71 | 1525.60 |
| | | 49 | 1.730422 | 0 | 0 | 103.83 | 1557.38 |
| | | 50 | 1.765736 | 0 | 0 | 105.94 | 1589.16 |
| | | 51 | 1.801051 | 0 | 0 | 105.94 | 1620.95 |
| | | 52 | 1.836366 | 0 | 0 | 105.94 | 1652.73 |
| | | 53 | 1.87168 | 0 | 0 | 105.94 | 1684.51 |
| | | 54 | 1.906995 | 0 | 0 | 105.94 | 1716.30 |
| | | 55 | 1.94231 | 0 | 0 | 105.94 | 1748.08 |
| | | 56 | 1.977625 | 0 | 0 | 105.94 | 1779.86 |
| | | 57 | 2.012939 | 0 | 0 | 105.94 | 1811.65 |
| | | 58 | 2.048254 | 0 | 0 | 105.94 | 1843.43 |
| | | 59 | 2.083569 | 0 | 0 | 105.94 | 1875.21 |
| | | 60 | 2.118883 | 0 | 0 | 105.94 | 1907.00 |
| | | 61 | 2.154198 | 0 | 0 | 105.94 | 1938.78 |
| | | 62 | 2.189513 | 0 | 0 | 105.94 | 1970.56 |
| | | 63 | 2.224828 | 0 | 0 | 105.94 | 2002.34 |
| | | 64 | 2.260142 | 0 | 0 | 105.94 | 2034.13 |
| | | 65 | 2.295457 | 0 | 0 | 105.94 | 2065.91 |
| | | 66 | 2.330772 | 0 | 0 | 105.94 | 2097.69 |
| | | 67 | 2.366087 | 0 | 0 | 105.94 | 2129.48 |
| | | 68 | 2.401401 | 0 | 0 | 105.94 | 2161.26 |
| | | 69 | 2.436716 | 0 | 0 | 105.94 | 2193.04 |
| | | 70 | 2.472031 | 0 | 0 | 105.94 | 2224.83 |

★ Emissions Rx Design Capacity is based on Natural Gas - $CH_4$ - 1000 Btu/CF HHV

◆ If actual heat value drops to 0 as is the case of $N_2$ (Nitrogen has "0" Heating Value) the air flow will remain sufficient to support the design Waste Gas max Btu/hr. input analysis.

## 1.6 Model Nomenclature

**Select capacity and features below.**

***Emission Rx Model Number Matrix***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $ER_x$ | -1 | -2 | -3 | -4 | -5 | -6 | -7 | -8 - - - - - - - - - - |
| | $ER_x$ | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 1 | **Unit Capacity in Btu/hr. Input @100%Sat.** | | 5 | **Exhaust Protection** | |
| | **A** | 0-10K Btu/hr. | | **A** | None |
| | **B** | 10K-15K Btu/hr. | | **B** | Back Flash Preventer |
| | **C** | 15K-40K Btu/hr. | | **C** | N/A |
| | **D** | 40K-80K Btu/hr. | | **D** | N/A |
| | **E** | 80K-140K Btu/hr. | | **E** | N/A |
| | **F** | N/A | | **F** | N/A |
| 2 | **Combustion Air Delivery** | | 6 | **Electronics** | |
| | **A** | Natural Draft | | **A** | None |
| | **B** | Blower | | **B** | 1 PID Loop Indicating controller w/ T/C |
| | **C** | C1D2 Pump | | **C** | 2 PID Loop Indicating controller w/ T/C |
| | **D** | Owner Supplied | | **D** | 3 PID Loop Indicating controller w/ T/C |
| | **E** | N/A | | **E** | PLC 3 loop BMS/CCS Modulated Air |
| | **F** | N/A | | **F** | PLC & Cloud Storage |
| 3 | **Waste Gas Protection** | | 7 | **Unit Construction** | |
| | **A** | None | | **A** | None |
| | **B** | Flame Arrestor FA | | **B** | NFPA 85 |
| | **C** | Blocking Valve BV | | **C** | C1D2 |
| | **D** | Flame Arrestor (FA) & Blocking Valve BV | | **D** | N/A |
| | **E** | N/A | | **E** | N/A |
| | **F** | N/A | | **F** | N/A |
| 4 | **Combustion Air Protection** | | 8 | **Options** | |
| | **A** | None | | **A** | None |
| | **B** | Back Flash Preventer | | **B** | Rain Cap |
| | **C** | N/A | | **C** | Alarm Horn |
| | **D** | N/A | | **D** | Waste Gas Flow Meter |
| | **E** | N/A | | **E** | Panel Purge Kit |
| | **F** | N/A | | **F** | Continued Below |

| Options Continued: | |
|---|---|
| F | Direct Cloud Reporting Service |
| G | Recommended Spare Parts Kit for this unit |
| H | Exhaust Heat Exchanger/Flash Arrestor Weather Shield |
| I | Combustion Air Flash Arrestor Weather Shield |
| J | Spark Ignitor & Ignition Transformer |
| K | Safety Cage |
| L | $H_2S$ Kit |
| M | Specify |
| N | Specify |
| O | Specify |

# 2. Operation

Thermal Oxidization (T.O.) has long been the standard method of destroying waste gas streams such as VOC’s in large quantities. Traditionally T.O. devices have been installed in very passive environments which can tolerate extreme external temperatures such as, an open field, atop of structural towers in “non-hazardous environment”. Natural gas combustion has been the preferred method of generating the heat necessary to allow oxidation to take place in these large systems. Excess air, internal to the waste gas stream or mechanically injected by a separate supply device, provides the Oxygen for Oxidation. With the advent of new regulations and tightening of existing allowable limits regulation such as Title VI of US EPA, and specifically the new TRI regulations, smaller and smaller quantities of VOC’s emissions are being tolerated.

The waste gas stream, for this discussion relates to those compounds (natural or manmade) which are known as Toxic Release Inventory (TRI) gas or Volatile Organic Compounds (VOC’s), that require oxidization by US EPA or other Jurisdictional air quality authorities.

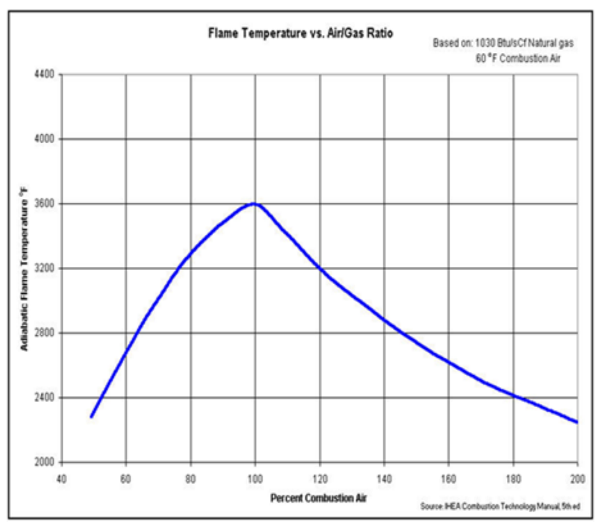
2.1 Theory **of Operation**:

TRI Gases or VOC’s consist of Hydrogen and Carbon molecules which by themselves or in combination with other elements form highly toxic substances or are environmentally egregious in their natural state such as Natural Gas, which is mostly Methane ($CH_4$). When Natural gas reacts with air in the process of combustion heat and light is released. In that process air, containing 20% Oxygen and 80% Nitrogen is mixed with Natural Gas (Fuel) in a ratio of 10 Cubic feet of air and 1 cubic foot of fuel. Theoretically, there is enough Oxygen ($O_2$) in 10 Cubic foot of air to completely unite with the Hydrogen and Carbon that contained in 1 Cubic foot of Natural Gas ($CH_4$). If all of the Oxygen ($O_2$) is completely united with all of the Carbon and Hydrogen then the reaction is as follows:

Air = $O_2 + 4N_2$ and Natural Gas = $CH_4$

$2O_2 + 8\,N_2 + CH_4 > CO_2 + 2H_2O + 8N_2$

In the process Products of Combustion (P.O.C) are elevated to 3600 $^oF$. This perfect mixture is said to be a Stoichiometric mixture.



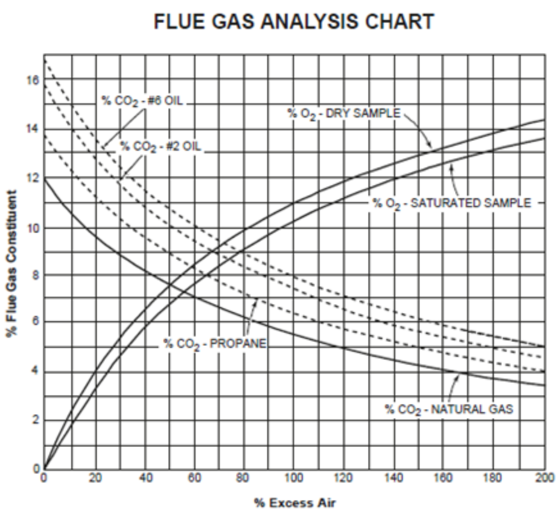

If perfect mixing of the fuel and air does take place it will result in forming Carbon dioxide ($CO_2$) and Water Vapor ($H_2O$) while releasing heat. Because the $N_2$ introduce with the air is inert, it may pass through the T.O. unchanged chemically but elevated in temperature.

If complete mixing doesn't occur then Carbon Monoxide (CO) is formed in various amounts as follows:

$2O_2 + 8\ N_2 + CH_4 \ > CO + CO_2 + 2H_2O + 8N_2 + O$

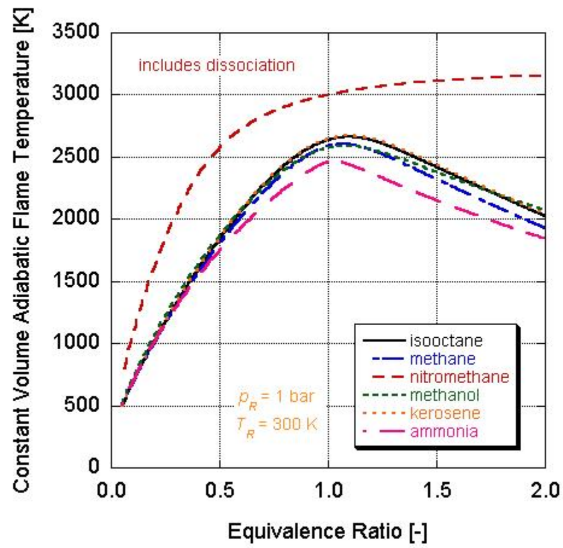
In order to ensure that more than enough Oxygen is available a minimum of 15% additional air molecules needs to be present during the process of combustion or 11.5 Cubic Feet of air per 1 Cubic foot of Natural Gas or:

$2.3\ O2 + 9.2\ N2 + CH4 \ > CO2 + 2H2O + 9.2N2 + 0.3\ O2$ = 15% excess air with (Products of combustion at 3200 $^{o}$F).




The higher the excess air is, the lower the exit gas temperature of Products of Combustion (POC) will be. This is true for all gases listed in standard Tables of Combustion Constants (in Appendix B). If a large amounts of air is present in a Fuel/Air mixture, lowering the (Hydrocarbons/Air) ratio to (< 0.4:10) such that the amount of natural gas in the mixture is less than 4% of the total, it is said to be too lean for auto ignition or below the Lower Explosion Limit (LEL). This means that such mixtures at ambient temperatures, when exposed to an Ignition source, will not react. On the other hand, if the mixture is too rich with fuel i.e. > 15% (1.5cf. fuel: 10 cf. air) it will not ignite because it is said to have exceeded the Upper Explosion Limit (UEL).

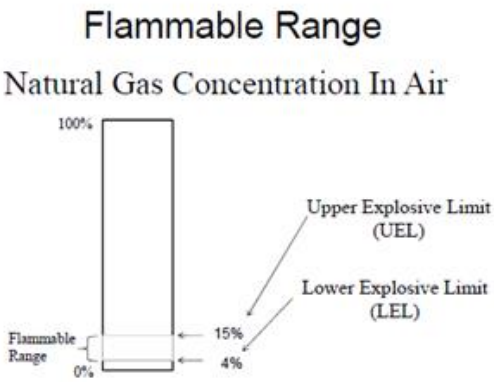
Complete conversion of hydrocarbons to $H_2O$

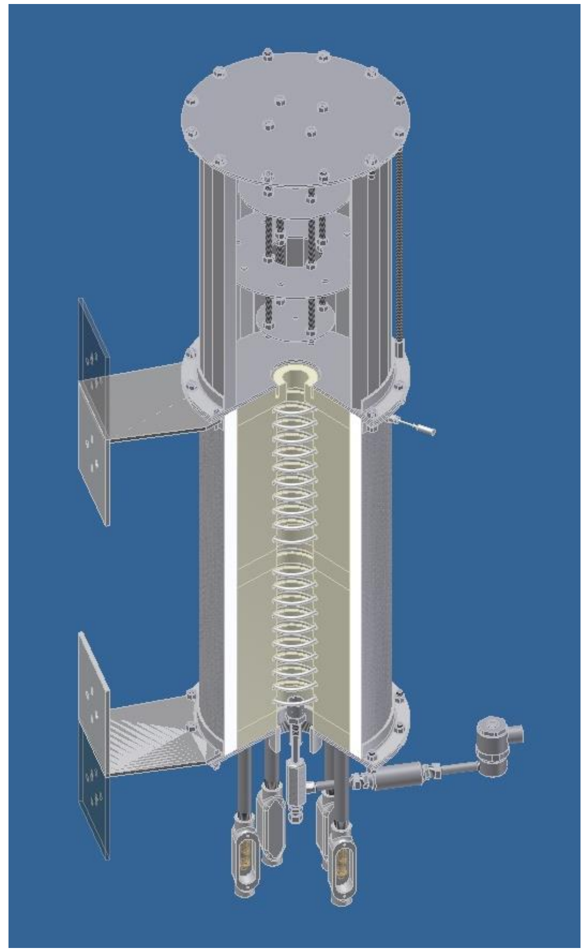



and $CO_2$ through Thermal Oxidation can only take place if a sufficient amount of Oxygen (normally from Air) is available in the presents a of heat source for a sufficient amount of time for the reaction to take place.

The normal state of operation of many T.O. systems is that of a waste gas stream is in the LEL range with an insufficient quantity of hydrocarbons to allow for self-sustained combustion. Without an external heat source to heat the contaminated waste stream, typically a Natural gas flame to provide the heat source as stated earlier.

**2.2 Successful Destruction of VOC's** Excess O2 and temperature are indicators as to quality of destruction.



Therefore depending on the waste gas to be destroyed the T.O. exit gas temperature is maintained between 1100 °F and 1800 °F and contains sufficient excess air to measure a minimum of 3% $O_2$ in the exit flue gas sample or 15% excess air in a chamber sized to provide for retention times of no less than 0.3 seconds on the low end to 2 seconds on gases containing Dioxins and Furans.

**<u>2.3 Emission Rx.™</u>** (Patent Pending) utilizes these principals on a smaller scale to meet existing and pending legislation for TRI gas regulations.

In its simplest form the Emission Rx.™ (Patent Pending) is an electrically heated thermal oxidizer designed to oxidize hydrocarbon waste gas streams. The Oxidization Chamber is preheated to 1500 °F by an electrical heating element, the waste gas is introduced in a vertical flow that must rise through the oxidation chamber and cross the heating elements. At the same time air is admitted at the unit's base and is mixed with the waste gas stream. Both the waste gas and the air are elevated to >1400 °F as they exit the oxidation chamber. Oxidation begins to occur at the point where heated fuel and air mixing begins. A secondary retention combustion section in series with the oxidation chamber provides sufficient retention time to allow the hydrocarbons in the waste gas to react with the oxygen in the air to complete the combustion process which converts Hydrogen to $H_2O$ (Water Vapor) and Carbon to Carbon Dioxide $CO_2$.

In practice the actual constituents being delivered to the Emissions Rx. T.O. unit are not known as they are often a mixture of several different sources and can vary from LEL to UEL within the waste gas stream or have no Hydrocarbons at all as in the case of a Nitrogen Purge. Because the waste gas stream may be an unknown analysis at any given time, its flow is limited such that, irrespective of the waste streams constituents, the Emission Rx. T.O. will to deliver sufficient air to maintain a minimum of 11.5:1 ratio of air to waste gas stream.

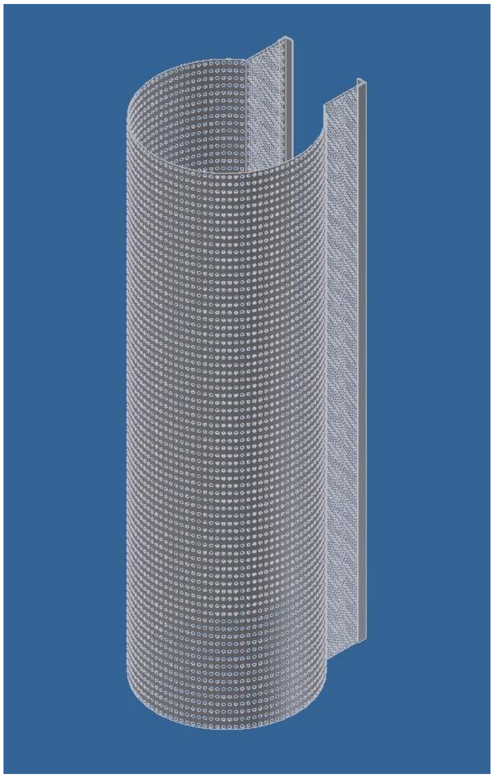
Therefor the ERx T.O. can insure that the unit will always have sufficient Oxygen to oxidize the hydrocarbons in the waste gas stream.

This is accomplished by the introduction a fixed amount of air and limiting the waste gas stream to a customer prescribed design value and worst-case basis. Known gas characteristics are stated in the data sheet and becomes the basis of design to include Specific Gravity and Higher Heating Value. The waste gas flow is controlled by a flow limiting orifice and static supply pressure based on a stated gas.

Heat in the T.O. cell is supplied by an electric heating element specifically design for this duty. Air may be supplied by simple induction from the bottom or by an air pump depending on the owner's requirements and destruction capacity. Oxidized Products of Combustion (POC), inert waste gas and associated heat is exhausted to atmosphere out the top.

The Emission Rx cell design allows for many iterations of this basic principal to include manually operated units which require minimal safety features in capacities of 10,000 Btu/hr or less, to units with capacities in excess of 80,000 Btu/hr installed in C1D2 area classification or constructed to NFPA 85, 75 and 68. These units may also be PLC based and contain contentious Emissions Monitoring which can both display or post compliance locally or to the owners DCS or directly to a cloud based data collection space supplied and monitored by Emissions Rx for maintenance and reporting purposes.

Options available with the Emission Rx unit.
Examples:
-Personnel Safety Cage
-$H_2S$ Kit



Optional safety cage shown above.

# 3.0 Installation

Your Emissions Rx Tri Gas Oxidizer comes assembled requiring only minor installation measures.

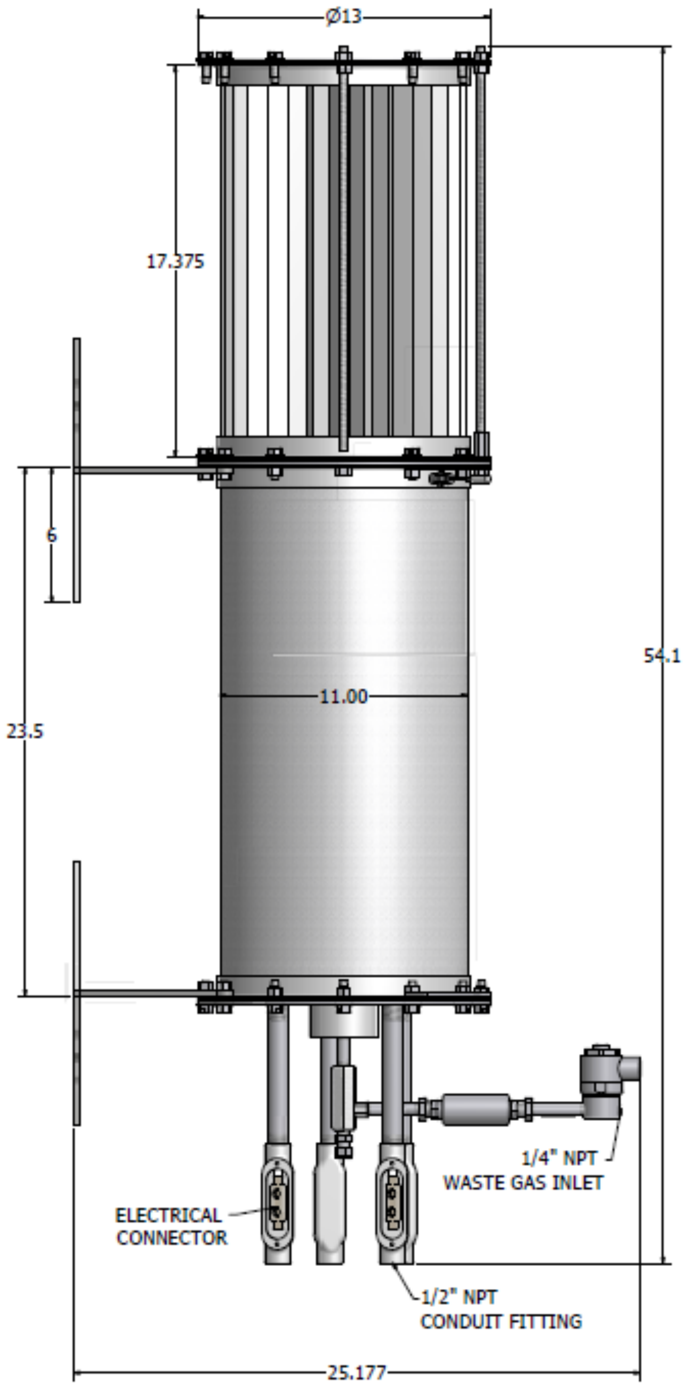
**3.1 Contents**:

1. The Emissions Rx Thermal Oxidizer Assembly
2. Exhaust Gas Heat Exchanger
3. A universal mounting bracket (Shipped Loose). These brackets can be installed in many different configurations to meet your specific needs. (See recommended mounting arrangements). Also included is the Mixing Nozzle and Venture assembly shipped loose for field assembly.
4. Single PID Temperature control system w/ (1) T/C and CID2 Purge Panel kit installed.
5. Multi Source TRI Gas Manifold assembly containing:
   a. TRI Gas Blocking Valve
   b. TRI Gas Flash Arrestor
   c. Optional pressure gages and flow meters.
   d. Optional ½ inch Stainless Steel piping manifold with NPT fittings and Isolation Ball Valves (Maximum 10 source taps)
6. Depending on the model you have selected, additional components may also include:
   a. CID2 Air Pump
   b. Pressure Regulator
   c. Personnel protection safety cage

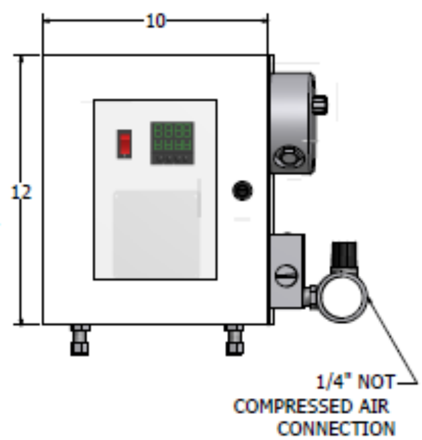
**3.2 Location:**

- Identify a location for the Emissions Rx™ Thermal Oxidizer that is compatible with local codes and restrictions. (C1D2 classification is certified on site).
- Proper Ventilation is required by code. The Oxidizer requires atmospheric air (NO concentrated oxygen) to operate and will emit $CO_2 + N_2 + H_2O$ + inerts in the sample at <300 $^oF$.
- Make-up air may be required if installed in a walk-in enclosure.
- If the Emission Rx™ is located where personnel may come in contact with the oxidizer shell, the unit must be ordered with a Personnel Protection Safety Cage.
- Capacity and pricing calculations based on 10ft maximum distance between control panel and Emissions Rx unit.
- If utilizing air pump purchased with unit, air pump must be placed within 10ft of the control panel and be plumbed with a minimum of 3/8 inch stainless steel tubing.
- If utilizing air pump supplied by others, there must be a minimum of 20 PSI and 4 CFM at the point of connection of the control panel.

- **3.4 Dimensions**




| Emissions Rx™ | |
|---|---|
| CAPACITY | 15K BTU/Hr |
| AMPERAGE | 16 A |
| VOLTAGE | 110 VAC |
| POWER CONSUMPTION | 1.76kW |
| AIR PRESSURE | 20 PSIG |
| AIR FLOW | 4 CFM |




| Shipping Data | |
|---|---|
| Length | |
| Width | |
| Height | |
| Weight | |
| Number of containers | |



*All measurements are in inches*

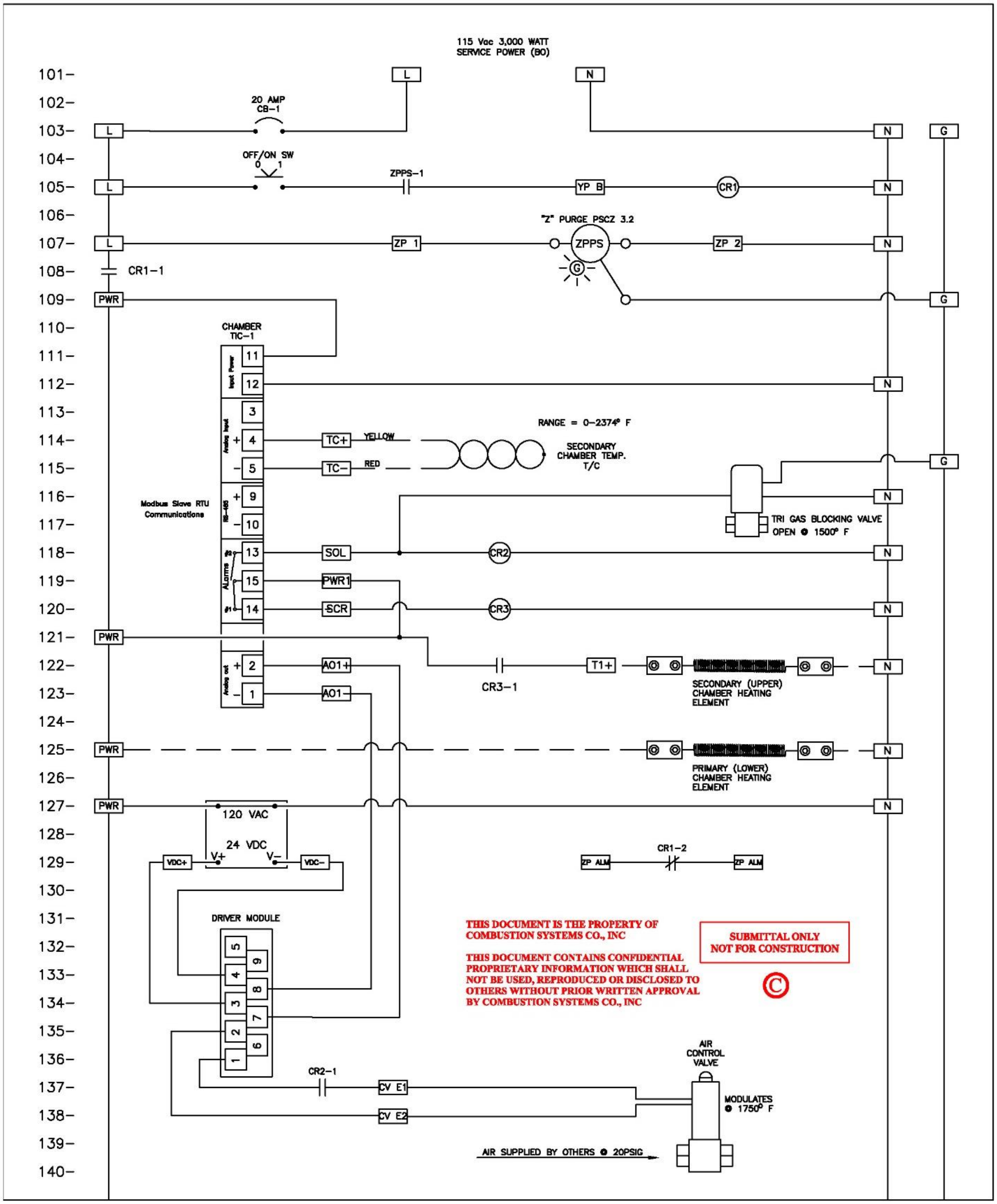
**3.5 By Others:**

The owner shall install an isolation valve upstream of Emissions Rx™ Tri gas point of connection. This valve shall be sized and constructed for the intended use.

# 4.0 Electrical

Each unit has been tested in the factory for proper operation and is ready for installation per the attached instructions.  Power should not be applied to the system until the installation check is complete.

## 4.1 Wiring Diagram



## 4.1.1 Wiring Diagram Notes

1.) Power to the Pressurized Air Source is supplied and initiated (by the others).
2.) Unit Power is available when applied to L1 and L2.
3.) Control Power is present when ON/OFF Switch is in ON position however operation is inhibited until panel door is closed.
4.) When the panel pressure is sufficient to close the Purge Air Pressure switch ZPSS-1 the system will power up and start the heat-up sequence. (See Sequence Timeline).
5.) All Set point temperatures are permanently set and no adjustments are necessary.
6.) Initial warm-up. - The unit will reach 1500 F in about 4 hours as displayed on the digital indicator display.
7.) The Waste Gas Blocking Valve will open emitting gas in the Oxidation Chamber.
8.) Chamber temperature will be maintained at 1750 F once Gas is emitted into the Oxidizer Chamber.
9.) Should the Oxidization Chamber drop below 1500 F the Waste Gas Blocking Valve will close.

## 4.2 Power requirements:

Unless otherwise noted in the installation manual supplied with the unit, all units utilize 115 volt single phase power and must be have supply service protection, conduit and wiring properly sized for the location and power consumption of the system supplied.

- Each element will consume 1000 Watts (example unit in this packet utilizes 2 elements)
- Control panel will draw no more than 20FLA at 110 VAC.
- Oxidation air source, whether supplied with the order or by others, will require additional power and circuit protection not supported by the control panel.  (See the individual wiring diagram for details)

## 4.3 Electrical Connections:

Your Emissions Rx T.O. only requires termination to (4) lugs located inside the ½" LC supplied with the unit.  A 9/32" Hex head wrench is required to make the final connection.  The top lug has been tightened to the heating element but should be checked for tightness.   The lower lug is loose and ready to receive the field power connection.  ***Caution should be taken pulling field wire into the LC as the heating element lead is attached to a ceramic electrical isolation tube which is easily fractured.***

*¾" LC conduit containing field terminal for power wiring.*

## 4.4 Electrical Checks

After the unit has been mounted in accordance to **Section 3.0** and prior to landing supply wiring. Check all coil terminations (4) for continuity to the casing and frame. There should be no continuity from the elements to the casing or frame. If there is continuity, stop and contact your distributer. DO NOT apply power to the unit.

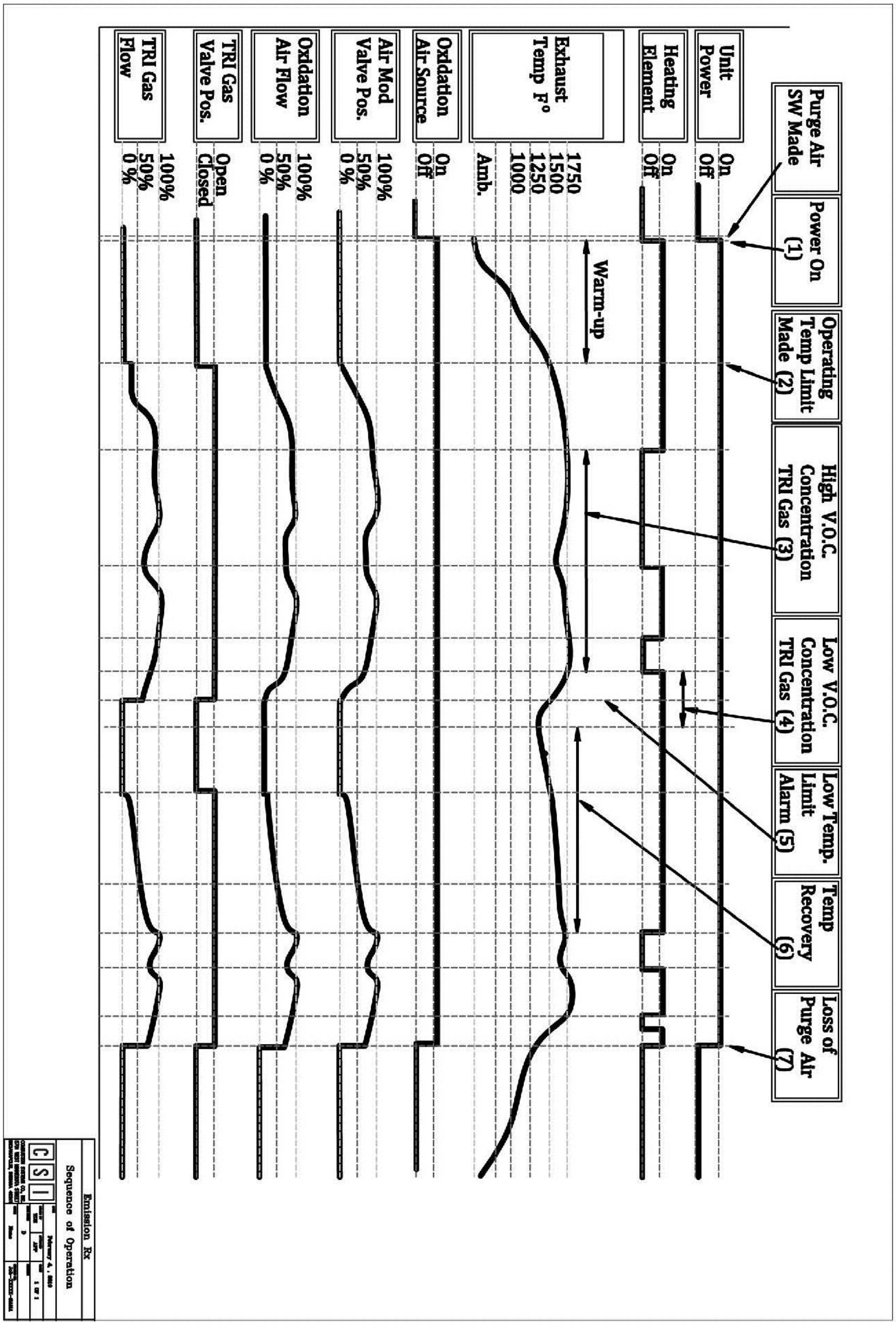
## 4.5 Electrical Gas Tight Connections:

Any junction or connection made to the control panel must be installed in conjunction with and area classifications where applicable.

High Temperature Silicone Caulk has been installed from the factory on heating element leads entering the field connecting LC conduit supplied with the unit. This serves to prevent gas from inside the cell from exiting the Cell.

# 5.0 Unit Operation

### 5.1 Emission Rx™ Event Reaction Chart

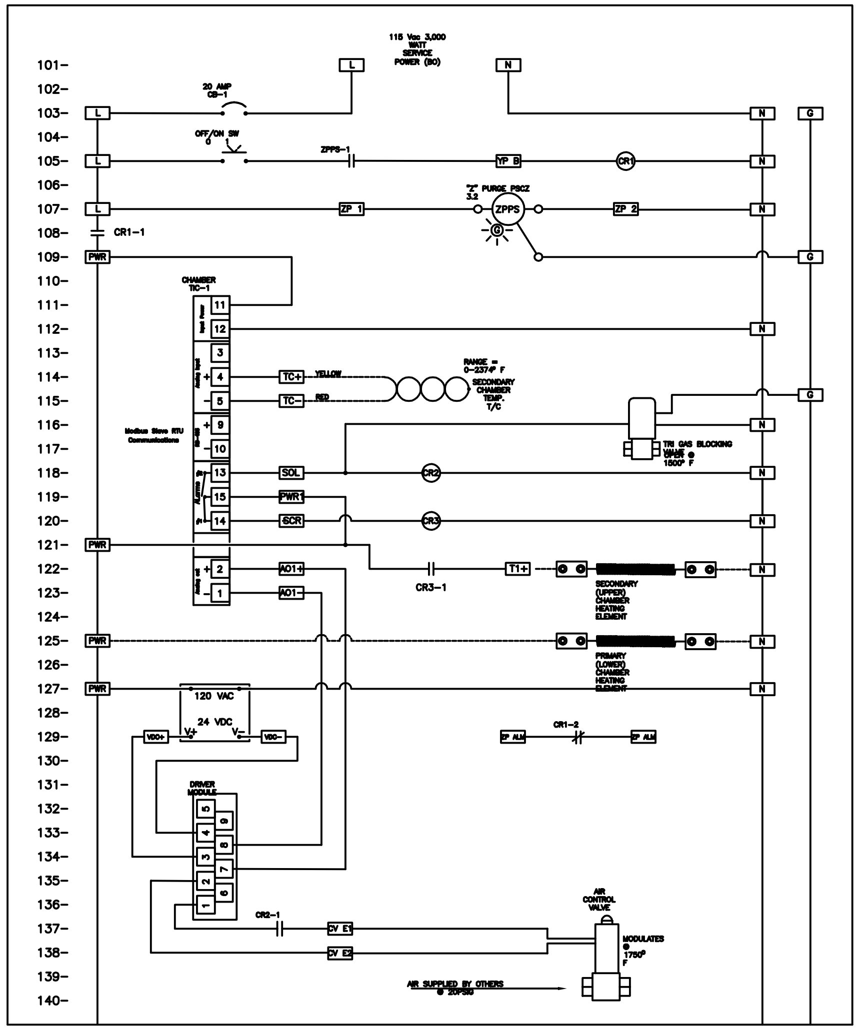



Emission Rx™ Event Reaction Chart

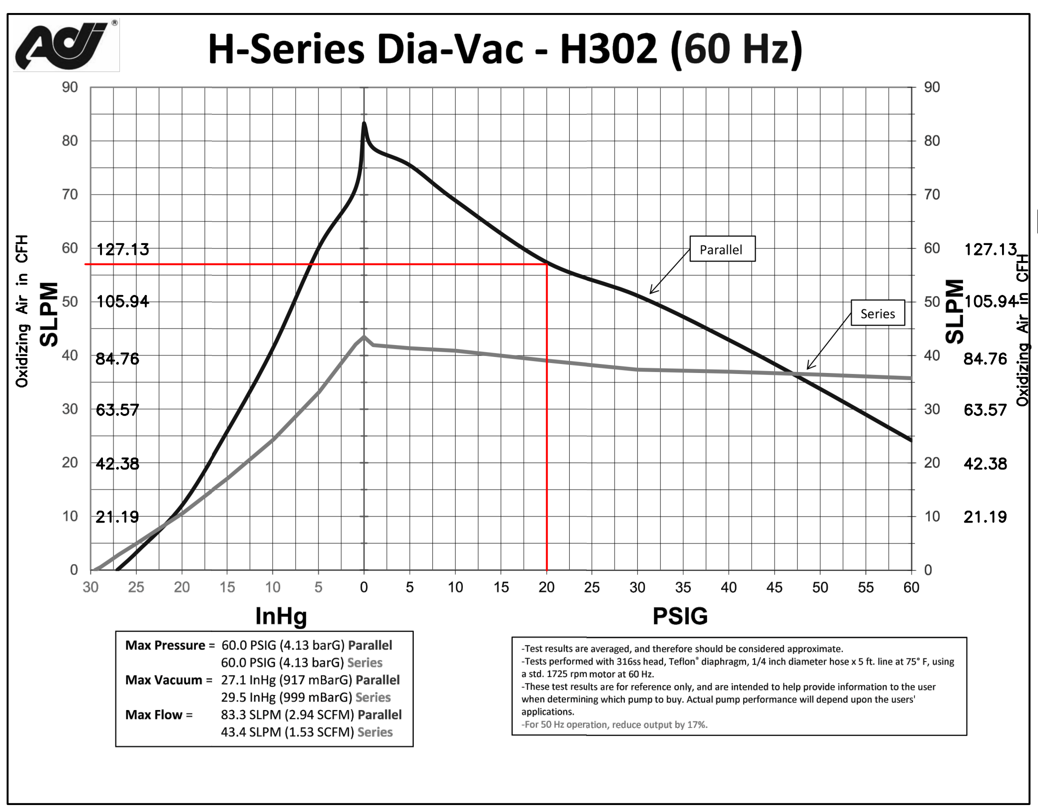
## 5.2 Emissions Rx™ Thermal Oxidizer

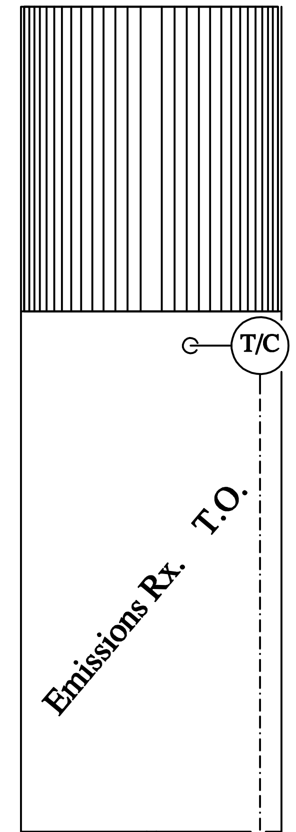
Model ERx -A-D-C-B-B-B-B-E contains an exhaust gas T/C and an Indicating Temperature Controller (ITC) which is designed to maintain a constant 1,750 $^{o}$F at the Exhaust of the ERx T.O. by cycling the heating element power which will reduce electrical usage and extend heating element life. Per the Electrical Section 4.0. Power and field wiring between the ERx Control Panel and the Oxidizer unit is by the owner. The Unit ON/OFF switch is located inside the control panel and must be switched to the ON position before closing the enclosure door.

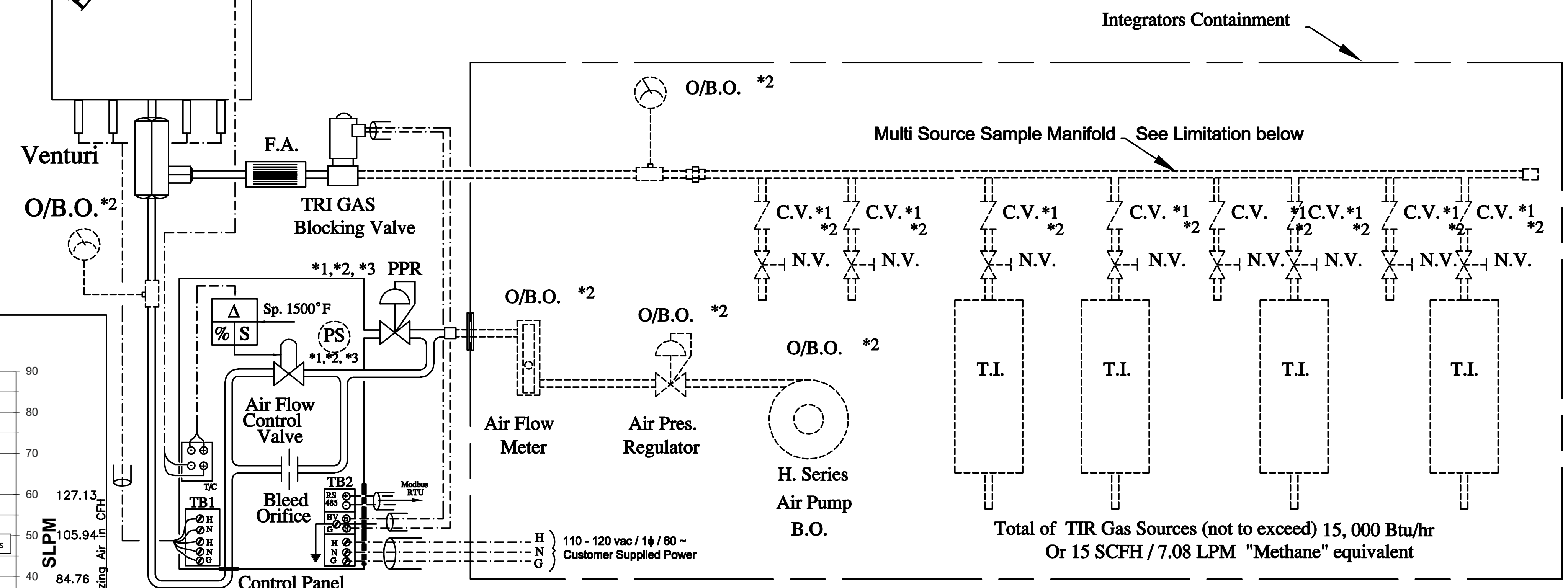
1. The unit will not actually apply power to the control circuitry nor Oxidizer cell until the enclosure is purged with fresh air delivered by the Combustion Air Source (e.g. : ADI pump).
   Once the Control Panel is pressurized, power is applied to the Temperature Indicating Controller (TIC) and the Cell will begin to heat per Column (1)- (2) in the above control sequence time line.
2. When the Cell temperature reaches its operating limit, the Oxidizing Air Valve (OAV) is released to modulate to maintain the set point temperature at 1,750 $^{o}$F and the TRI Gas Blocking Valve (TRI-GBV) is opened. As the OAV opens TRI gas is induced into the Cell through the Venturi.
3. High Volatile Organic Compound (VOC) concentration in the waste gas will drive temperature in the cell higher and the Heating Element will be turned off allowing Oxidation of TRI Gas to drive the thermal process.
4. If the TRI Waste Gas concentration of VOC's diminishes or is replaced with Inserts such as $N_2$ or $CO_2$ the Heating Element will again be energized to bring the Oxidization Chamber temperature back to set point.
5. If however Cell temperature drops below Oxidization temperature the heating element will be powered, the OAV will close, and the TRI-GBV will close if the heating element cannot recover or maintain Oxidation Temperature.
6. Once the Cell Temperature recovers the system will return to operation mode 2 above.
7. Loss of Purge Air for any reason will shut the Unit down by killing power to the control system completely and close a set of alarm contacts which can imitate an Optional Alarm Horn or Light or Both.




*See wiring diagram for sequence of operations




Scenario#1 (4) Test units are delivering test samples with 0% (by v.) Combustibles 1.46LPM ea. for a total of 5.85 LPM.

1. Heating Elements are 1000 watts ea.
2. (2) Heating Elements = 6,824 Btu's/hr
3. 10% R&C Loss allows 6,141Btu's available
4. 6,141Btu's will elevate 18.2lbs./hr. of air to 1400°F
5. 18.2 lbs. =241.7 SCFH of Air or 114.54 LPM of combined air and sample, at a ratio of 14 CF of air to 1 CF of sample. This results in a sample feed rate of 7.43 LPM or 15.74CFH of inert's such as Nitrogen
6. If the sample is all inert's such as Nitrogen the unit capacity is 7.43 LPM.

Scenario#2 the (4) Test units are delivering test samples with 100% Combustibles (by v.) in the form of Natural gas at 1000 Btu/CF, at a rate of ~ 1.8575 LPM ea. or 15.74 CFH of Natural Gas total or 15,740 Btu/hr input.

7. 15.74 CFH of TRI Gas or 15,740 Btu's/hr. as Natural gas will require 226.5 SCFH of Air from the Oxidation Air Source and will produce 242.7 SCFH of CO2 H20, Oxygen and N2
8. If the sample is as stated above the units capacity can also be rated as 15,740 Btu's/hr

Scenario#3 the Cell is capable of combusting 17,000 Btu's /hr of Propane or Natural gas while maintaining 7% 02 and >20 PPM of CO @ > 1500°F and could require as many as (2) ADI Pumps to deliver sufficient air at max capcity.

9. A single ADI Pump per the attached is 57.5LPM @ the desired static or 121.84 CFH.
10. A single ADI Pump per the attached limits the units capacity to 55% of rating for both inert's and combustibles.
11. Purge air consumption will lower capacity as well, and needs to be deducted from these capacities.

## Explanation of Abreavations

| | |
|---|---|
| B.O. | By Others. |
| C.V. | CheckValve |
| F.A. | Flame Arrestor (Option) |
| N.V. | Needle Valve (Optional by Integrator) |
| O/B.O. | Option or by Others. |
| PS. | Pressure Switch (C1D2 Required) |
| Sp. | Set Point |
| T.B. | Terminal Board |
| T.I. | Test Instrument |
| V.B. | Vent Breather (Option) |

Symbols ;

- Electrical Wiring
- Conduit
- (TIP) PID Loop Temp. Indicating Controller

Notes:

*1 Require for C1D2 area classification
*2 Available upon request
*3 Purge Panel Regulator



SUBMITTAL ONLY
NOT FOR CONSTRUCTION

| REV | REVISION DESCRIPTION | BY | DATE |
|---|---|---|---|
| 4 | | | |
| 3 | | | |
| 2 | Corrected typo in Scenario #1 to 241.7 SCFH | TE | 09/03/19 |
| 1 | Added Modbus RTU 485 Terminals to Panel | TE | 07/19/19 |

Emissions Rx
Product Developement

# Multi Source Sample Manifold
Patent Pending ©

C S I
COMBUSTION SYSTEMS CO., INC.
5701 WEST MINNESOTA STREET
INDIANAPOLIS, INDIANA 46241

| | | |
|---|---|---|
| DATE April 11, 2019 | | |
| DRAWN BY TDE | APPROVED TDE | SHEET 2 |
| DWG NOTES D | | REVISION |
| SCALE None | | DRAWING NO. J-XXXX-XXX |

# 6.0 Maintenance

The Emissions Rx Thermal Oxidizer has been designed to minimize routine maintenance requirements and yet is fully repairable with original CSI supplied parts. Using components supplied by other than CSI will void all warrantee, safety and performance guarantee.

The following table recommends component inspection and intervals for various devices external to the control panel.

| Maintenance & PM Schedule | | | | | |
|---|---|---|---|---|---|
| Group | Item | Action | Test for: | Frequency | Range or method |
| External Piping & Components | Pipe Fittings | Tighten to Spec. | Leaks | Quarterly | Bubble Test |
| | Back Flow Flame Arrestor | Check for plugging | Flow at Static | Quarterly | Per Troubleshooting Guide |
| | Waste Gas Blocking Valve | Bench Test | Seal at Static | Annually | Per Troubleshooting Guide |
| | Mixing "T" Venturi | Remove & Inspect | Flow at Static | Annually | Per Troubleshooting Guide |
| | Nozzle | Remove & Inspect | | Annually | No Erosion or Corrosion |
| Cell | Exhaust Heat Exchanger | Remove & Inspect | Carbon build up on interior | 2000 hours of operation | Use 80 PSI Compressed Air to Puff from Outside to Inside |
| | Secondary Chamber Oxidizer Target Puck | Remove from Top & Inspect | Visible Deterioration | 4000 hours of operation | No Erosion or Corrosion |
| | Secondary Chamber | Remove Jacket & blanket - Inspect | Visible Deterioration | 4000 hours of operation | No Erosion or Corrosion |
| | Secondary Chamber Heating Element | Test in place | Test for open Circit & Tighten Field Connectors | 4000 hours of operation | Element Resistance >15 Ω & < ∞Ω |
| | Primary Chamber | Remove Jacket & blanket - Inspect | Visible Deterioration | 4000 hours of operation | No Erosion or Corrosion |
| | Primary Chamber Heating Element | Test in place | Test for open Circit & Tighten Field Connectors | 4000 hours of operation | Element Resistance >15 Ω & < ∞Ω |
| Control Panel | Z-Purge | Open Panel Door | Z-Purge Operation | Monthly | Loss of Power to Controls |
| | By-Pass Orifice | Remove and clean | Blockage | 2000 hours of operation | #74 Drill |
| No other Preventative maintainance required | Any other failures inside the control panel should be return to CSI for Repairs. | | | | |
| NOTES: Frequency of preventative maintenance is dependent on cleanliness of Compressed air (used for oxidation source) and Waste Gas Stream and is recommended based on commercial gas such as Natural Gas or Propane on the wetted components and Filtered Air. Actual Frequency may very with the waste gas and compressed air source. Frequency may change from application to application. Maintenance personnel should make note of results of PM analysis before shortening or lengthen the recommended frequency. | | | | | |

# 7.0 Troubleshooting Guide

Working on Electrical Equipment while powered implies a level of precaution which should be strictly observed and conducted by a qualified person. If after following this guide you cannot determine the probable cause of your problem contact your Emissions Rx Representative or call Combustion Systems Co., Inc. before attempting to disassemble the unit. Carless disassembly is potentially dangerous and can cause additional damage and cost to resolve.

Forced Draft Units -NFPA & C1D2

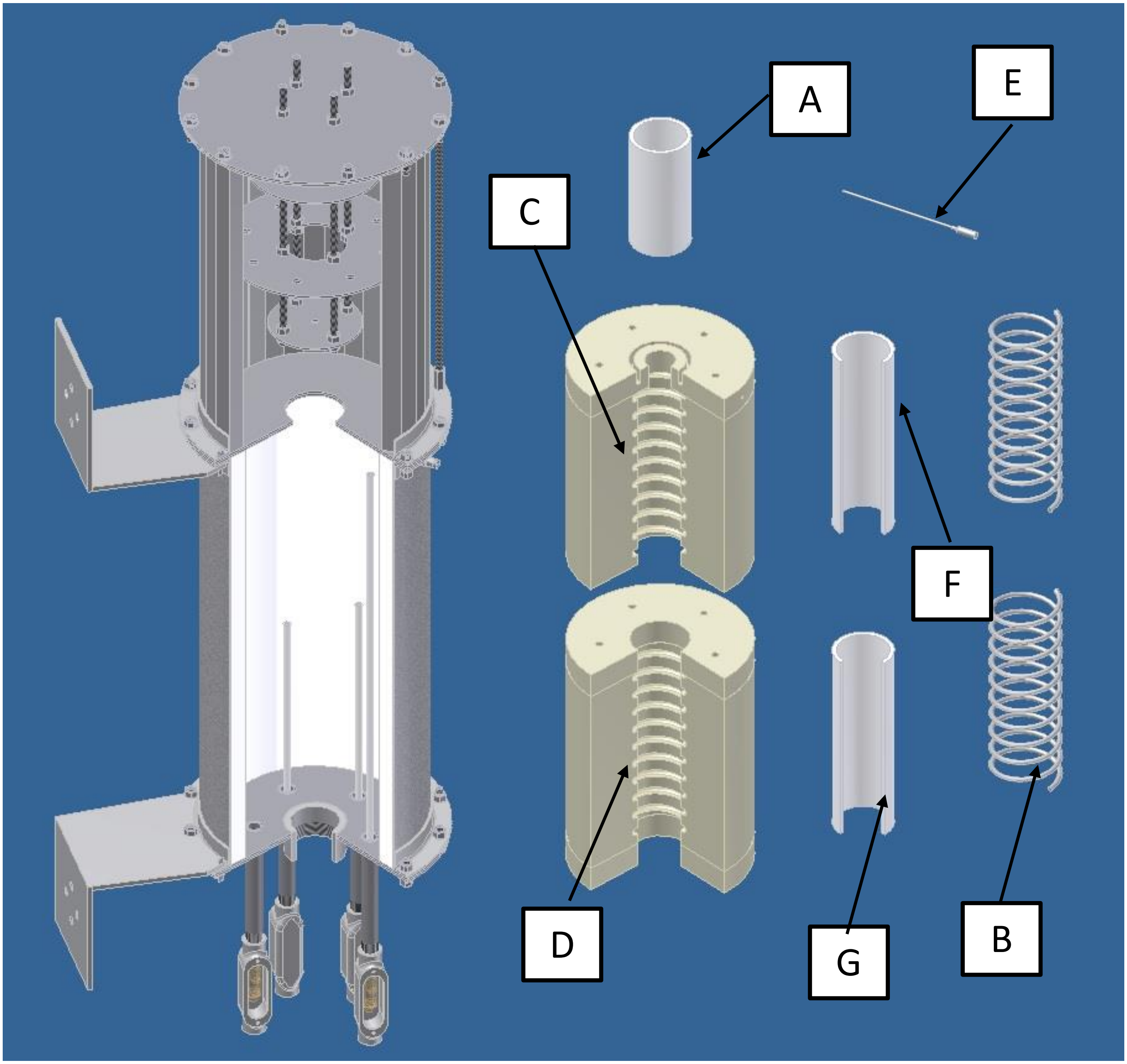
WARNING: Before troubleshooting, refer to sequence of operation timeline and general operating procedures for Emissions Rx™ Unit.

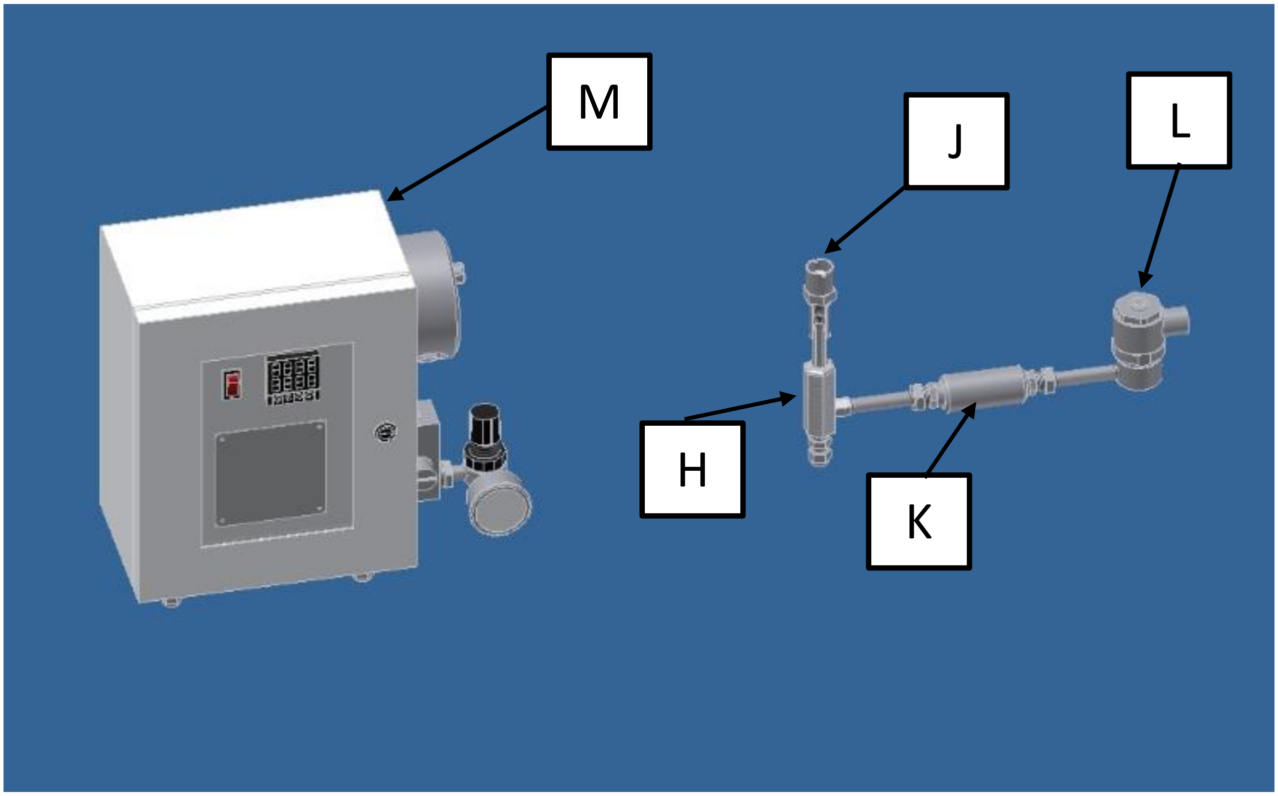
| Problem | Error # | Probable Cause | Check | Appropriate Range | Actions |
|---|---|---|---|---|---|
| Unit not reaching operating temperature | 1 | No Power to Control Panel | Is power turned on to panel? | 110VAC to 120 VAC | Apply Power to Unit |
| | | | Check if Fuses or Circuit Barker is Blown | | Reset circuit breaker/replace fuse |
| | | | Verify power to Z-purge Switch | | Check wiring |
| | | | Is Z-Purge green light on when panel is shut? | Green light is lit | Verify proper air supply, verify properly sealed panel, Replace Z-purge switch |
| | | | Is controller powered ? | Visible display | Check CR1 for proper operation, bench test controller |
| | | | Is TIC calling for heat? | 110 VAC to 120 VAC | Verify correct power at element connections |
| | 2 | Loose Heating Element Connection | Check for loose field connections at element leads | xxxx in-lbs | Tighten terminals to spec. |
| | 3 | No power to lower heating element | Check voltage across lower element field connection | 110VAC to 120 VAC | Check field wiring |
| | 4 | Open lower heating element | Check amperage draw of element | 7.9-8.9 amps | Replace lower heating element |
| | 5 | No power to upper heating element | Check for voltage across upper element field connections | 110VAC to 120 VAC | Bench test zero cross over relay and single loop controller, Replace thermocouple |
| | 6 | Open upper heating element | Check amperage draw of element | 7.9-8.9 amps | Replace upper heating element |
| | 7 | High oxidation air flow | Check air supply pressure at panel connection | 20 PSIG | Adjust pressure accordingly, verify bleed orifice installation |
| | 8 | Air modulation valve failed open | Check air pressure at mixing tee | Less than 20 oz static pressure | Replace modulation valve |
| No Sample flow within operating temperature range | 9 | Blocking Valve not opening | Check voltage on solenoid | 110VAC to 120 VAC | Bench test or replace controller, |
| | | | Bench test solenoid | 20 scfh @ 10"WC static pressure | Replace blocking valve |
| | 10 | Flame arrestor plugged | Bench test flame arrestor | 20 scfh @ 10"WC static pressure | Replace flame arrestor |
| | 11 | Failed thermocouple | Check controller for Temp reading | Type K thermocouple range | Replace thermocouple |
| | 12 | No airflow at mixing tee | Check air leaks in piping | N/A | Return to manufacturer for repair |
| Carbon Collecting Eshaust Heat Exchanger | 13 | Waste gas out of Specification | Analyze Waste and compare to Specification. | See Specification at purchase. | Notify the factory |
| | 14 | Waste Stream pressure to high | Check Waste Stream pressure | (3-4) " W.C. | Reduce pressure and Flow |
| | 15 | Low Combustion Air Flow from Blower | Check unit for blockage | 20 PSIG at panel connection | Check for Proper Operation |

# 8.0 Replacement Parts

**Emissions Rx™ Replacement Parts:**

Model ERx -B-B-D-A-B-E-B-B & C shown below





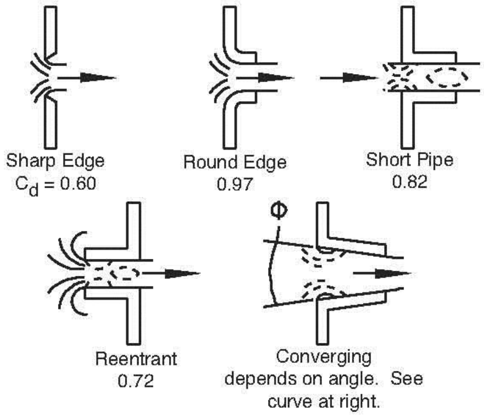

| Tag | Item | Part # | Qty. |
|---|---|---|---|
| A | Exhaust Liner | CSI-1101 | 1 |
| B | Heating Element | CSI-1201 | 2 |
| C | Retention Chamber | CSI-1301 | 1 |
| D | Oxidation Chamber | CSI-1302 | 1 |
| E | Thermocouple | CSI-1401 | 1 |
| F | Retention Chamber $H_2S$ Liner | CSI-1102 | 1 |
| G | Oxidation Chamber $H_2S$ Liner | CSI-1103 | 1 |
| H | Mixing Venturi | CSI-2101 | 1 |
| J | Oxidation Nozle | CSI-2102 | 1 |
| K | Flame Arrestor | CSI-2103 | 1 |
| L | TRI Waste Gas Blocking Valve | CSI-2104 | 1 |
| M | Control Panel | CSI-3100 | 1 |

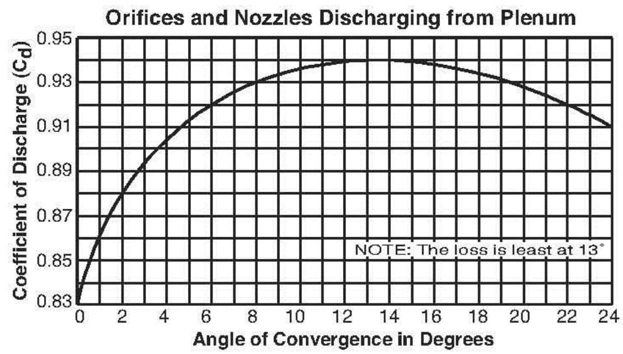
***The above parts list is a partial list of major components. Each unit is shipped with a complete parts list specific to your unit.***

# Appendix

# CHAPTER 1 – ORIFICES & FLOWS

## COEFFICIENTS OF DISCHARGE FOR VARIOUS TYPES OF ORIFICES




## ORIFICE FLOW FORMULAS

The flow of air or gas through an orifice can be determined by the formula

$$Q = 1658.5 \text{ x } A \text{ x } C_d \sqrt{\frac{h}{g}}$$

where Q = flow, cfh
A = area of the orifice, sq. in. (see Pages 57 & 58)
$C_d$ = discharge coefficient of the orifice (see above)
h = pressure drop across the orifice," w.c.
g = specific gravity of the gas, based on standard air at 1.0 (see Pages 19, 20, & 22 thru 24.)

### 1. Sizing Orifice Plates

To calculate the size of an orifice plate, this equation can be rearranged as follows:

$$A = \frac{Q}{1658.5 \text{ x } C_d} \text{ x } \sqrt{\frac{g}{h}}$$

### 2. Effect of Changes in Operating Conditions on Flow through an Orifice – General Relationship

$$\frac{Q_2}{Q_1} = \frac{A_2}{A_1} \text{ x } \frac{C_{d2}}{C_{d1}} \text{ x } \sqrt{\frac{h_2}{h_1}} \text{ x } \sqrt{\frac{g_1}{g_2}}$$

If any of the factors in this relationship remain constant from Condition 1 to Condition 2, they can be dropped out of the equation, yielding these simplified relationships. Each of them assumes only one factor has been changed.

#### 2a. Flow Change vs. Orifice Area Change

$$\frac{Q_2}{Q_1} = \frac{A_2}{A_1}$$

#### 2b. Flow Change vs. Pressure Drop Change

$$\frac{Q_2}{Q_1} = \sqrt{\frac{h_2}{h_1}}$$

This is the so-called "square root law."

#### 2c. Flow Change vs. Specific Gravity Change

$$\frac{Q_2}{Q_1} = \sqrt{\frac{g_1}{g_2}}$$

### 3. Effect of Changes in Operating Conditions on Pressure Drop Across an Orifice–General Relationship:

$$\frac{h_2}{h_1} = \left(\frac{Q_2}{Q_1}\right)^2 \text{ x } \left(\frac{A_1}{A_2}\right)^2 \text{ x} \left(\frac{C_{d1}}{C_{d2}}\right)^2 \text{ x } \frac{g_2}{g_1}$$

Again, if any of the factors in this equation are unchanged from Condition 1 to Condtion 2, they can be dropped out to form simplified relationships:

#### 3a. Pressure Drop Change vs. Flow Change

$$\frac{h_2}{h_1} = \left(\frac{Q_2}{Q_1}\right)^2$$

This is the square root law, stated another way.

#### 3b. Pressure Drop Change vs. Orifice Area Change

$$\frac{h_2}{h_1} = \left(\frac{A_1}{A_2}\right)^2$$

#### 3c. Pressure Drop Change vs. Specific Gravity Change

$$\frac{h_2}{h_1} = \frac{g_2}{g_1}$$

This relationship may not apply where specific gravity has been changed by a change in gas temperature. See Page 25.

### 4. Effect of Changes in Gas Temperature on Flow and Pressure Drop through an Orifice

Raising a gas's temperature has two effects - it increases the volume and decreases the specific gravity, both in proportion to the ratio of the absolute temperatures. If we are concerned with changes in flows (cfh), these relationships must be used (assuming constant mass flow).

#### 4a. Flow Change vs. Temperature Change

$$\frac{Q_2}{Q_1} = \sqrt{\frac{T_{ABS2}}{T_{ABS1}}}$$ with $T_{ABS}$ = absolute temp.*

*See page 68 for calculation of the absolute temperature.

#### 4b. Pressure Drop Change vs. Temperature Change

$$\frac{h_2}{h_1} = \frac{T_{ABS2}}{T_{ABS1}}$$

# ORIFICE CAPACITY TABLES
# LOW PRESSURE GAS

Flows in these tables are based on an orifice pressure drop of 1″ w.c. and a coefficient of discharge ($C_d$) of 1.0.

**To determine flow through an orifice of a known diameter:**

1. Locate the orifice diameter in the left-hand column of the table.
2. Read across to the column corresponding to the gas being measured. This is the uncorrected flow.
3. Multiply this flow by the coefficient of discharge of the orifice. (see page 4)
4. Correct this flow to the pressure drop actually measured, using the square root law (equation 2b, page 4).

**Example:** What is the flow of natural gas through a 7/32" diameter sharp edge orifice at 6″ w.c. pressure drop?

From the table, uncorrected natural gas flow through a 7/32" orifice is 80.7 cfh at 1″ w.c.

$C_d$ for a sharp edge orifice is 0.60 (page 1.1), so corrected flow is 80.7 x 0.60 = 48.4 cfh at 1" w.c. pressure drop.

Per equation 2b, page 4,

$$\frac{Q_2}{Q_1} = \sqrt{\frac{h_2}{h_1}} \text{ or } Q_2 = Q_1 \text{ x} \sqrt{\frac{h_2}{h_1}}$$

Substituting the numbers for this case:

$$Q_2 = 48.4 \text{ x} \sqrt{\frac{6'' \text{ w.c.}}{1'' \text{ w.c.}}} = 119 \text{ cfh}$$

**To determine the orifice size to handle a known flow at a specified pressure drop, reverse the process:**

1. Correct the known flow to a pressure drop of 1″ w.c., using the square root law.
2. Divide the flow by the orifice coefficient.
3. In the orifice table, locate the column for the gas under consideration. In this column, locate the flow closest to the corrected value found in step 2.
4. Read to the left to find the corrected orifice size.

Example: Size a gas jet for a mixer. Entrance to the jet ori-fice converges at a 15° included angle. Gas is propane. Required flow is 120 cfh at 30″ w.c. pressure drop.

Per equation 2b, page 4,

$$\frac{Q_2}{Q_1} = \sqrt{\frac{h_2}{h_1}}, \text{ or } Q_2 = Q_1 \text{ x} \sqrt{\frac{h_2}{h_1}}$$

Substituting the numbers for this case:

$$Q_2 = 120 \text{ x} \sqrt{\frac{1}{30}} = 22 \text{ cfh}$$

From page 1.1, Cd for a 15° convergent nozzle is 0.94, so corrected flow is

22 ÷ 0.94 = 23.4 cfh.

Locate 23.4 cfh in the propane column of the orifice table and then read to the left to find a #26 drill size orifice.

## CAPACITY, CFH @ 1″ W.C. PRESSURE DROP AND COEFFICIENT OF DISCHARGE OF 1.0

| Drill Size | Dia. In. | Area | Natural Gas 0.60 Sp. Gr. | Air 1.0 Sp. Gr. | Propane/ Air 1.29 Sp. Gr. | Propane 1.5 Sp. Gr. | Butane 2.0 Sp. Gr. |
|---|---|---|---|---|---|---|---|
| 80 | .0135 | .000143 | .308 | .239 | .210 | .195 | .169 |
| 79 | .0145 | .000165 | .355 | .275 | .242 | .225 | .195 |
| 1/64 | .0156 | .00019 | .409 | .317 | .279 | .259 | .224 |
| 78 | .016 | .00020 | .431 | .334 | .294 | .272 | .236 |
| 77 | .018 | .00025 | .538 | .417 | .367 | .340 | .295 |
| 76 | .020 | .00031 | .668 | .517 | .455 | .422 | .366 |
| 75 | .021 | .00035 | .754 | .584 | .514 | .477 | .413 |
| 74 | .0225 | .00040 | .861 | .668 | .587 | .545 | .472 |
| 73 | .024 | .00045 | .969 | .751 | .661 | .613 | .531 |
| 72 | .025 | .00049 | 1.06 | .817 | .720 | .667 | .578 |
| 71 | .026 | .00053 | 1.14 | .884 | .778 | .722 | .625 |
| 70 | .028 | .00062 | 1.33 | 1.03 | .910 | .844 | .731 |
| 69 | .0292 | .00067 | 1.44 | 1.12 | .984 | .912 | .790 |
| 68 | .030 | .00075 | 1.61 | 1.25 | 1.10 | 1.02 | .885 |
| 1/32 | .0312 | .00076 | 1.64 | 1.27 | 1.12 | 1.04 | .896 |
| 67 | .032 | .00080 | 1.72 | 1.33 | 1.17 | 1.09 | .944 |
| 66 | .033 | .00086 | 1.85 | 1.43 | 1.26 | 1.17 | 1.01 |
| 65 | .035 | .00092 | 2.07 | 1.60 | 1.41 | 1.31 | 1.13 |
| 64 | .036 | .00102 | 2.20 | 1.70 | 1.50 | 1.39 | 1.20 |
| 63 | .037 | .00108 | 2.33 | 1.80 | 1.59 | 1.47 | 1.27 |
| 62 | .038 | .00113 | 2.43 | 1.88 | 1.66 | 1.54 | 1.33 |
| 61 | .039 | .00119 | 2.56 | 1.98 | 1.75 | 1.62 | 1.40 |
| 60 | .040 | .00126 | 2.71 | 2.10 | 1.85 | 1.72 | 1.49 |
| 59 | .041 | .00132 | 2.84 | 2.20 | 1.94 | 1.8 | 1.56 |
| 58 | .042 | .00138 | 2.97 | 2.30 | 2.03 | 1.88 | 1.63 |

## CAPACITY, CFH @ 1″ W.C. PRESSURE DROP AND COEFFICIENT OF DISCHARGE OF 1.0

| Drill Size | Dia. In. | Area | Natural Gas 0.60 Sp. Gr. | Air 1.0 Sp. Gr. | Propane/ Air 1.29 Sp. Gr. | Propane 1.5 Sp. Gr. | Butane 2.0 Sp. Gr. |
|---|---|---|---|---|---|---|---|
| 57 | .043 | .00145 | 3.12 | 2.42 | 2.13 | 1.97 | 1.71 |
| 56 | .0465 | .00170 | 3.66 | 2.84 | 2.5 | 2.32 | 2.01 |
| 3/64 | .0469 | .00173 | 3.73 | 2.89 | 2.54 | 2.36 | 2.04 |
| 55 | .0520 | .00210 | 4.52 | 3.50 | 3.08 | 2.86 | 2.48 |
| 54 | .0550 | .0023 | 4.95 | 3.84 | 3.38 | 3.13 | 2.71 |
| 53 | .0595 | .0028 | 6.03 | 4.67 | 4.11 | 3.81 | 3.30 |
| 1/16 | .0625 | .0031 | 6.68 | 5.17 | 4.55 | 4.22 | 3.66 |
| 52 | .0635 | .0032 | 6.89 | 5.34 | 4.7 | 4.36 | 3.77 |
| 51 | .0670 | .0035 | 7.54 | 5.84 | 5.14 | 4.77 | 4.13 |
| 50 | .070 | .0038 | 8.18 | 6.34 | 5.58 | 5.18 | 4.48 |
| 49 | .073 | .0042 | 9.04 | 7.01 | 6.17 | 5.72 | 4.95 |
| 48 | .076 | .0043 | 9.26 | 7.17 | 6.31 | 5.86 | 5.07 |
| 5/64 | .0781 | .0048 | 10.3 | 8.01 | 7.05 | 6.54 | 5.66 |
| 47 | .0785 | .0049 | 10.5 | 8.17 | 7.2 | 6.67 | 5.78 |
| 46 | .081 | .0051 | 11. | 8.51 | 7.49 | 6.95 | 6.02 |
| 45 | .082 | .0053 | 11.4 | 8.84 | 7.78 | 7.22 | 6.25 |
| 44 | .086 | .0058 | 12.5 | 9.67 | 8.52 | 7.9 | 6.84 |
| 43 | .089 | .0062 | 13.4 | 10.3 | 9.11 | 8.44 | 7.31 |
| 42 | .0935 | .00687 | 14.8 | 11.4 | 10. | 9.36 | 8.1 |
| 3/32 | .0937 | .0069 | 14.9 | 11.5 | 10.1 | 9.40 | 8.14 |
| 41 | .096 | .0072 | 15.5 | 12. | 10.6 | 9.81 | 8.49 |
| 40 | .098 | .0075 | 16.2 | 12.5 | 11. | 10.2 | 8.85 |
| 39 | .0995 | .0078 | 16.8 | 13. | 11.5 | 10.6 | 9.2 |
| 38 | .1015 | .0081 | 17.4 | 13.5 | 11.9 | 11.0 | 9.55 |
| 37 | .104 | .0085 | 18.3 | 14.2 | 12.5 | 11.6 | 10. |
| 36 | .1065 | .0090 | 19.4 | 15. | 13.2 | 12.3 | 10.6 |
| 7/64 | .1093 | .0094 | 20.2 | 15.7 | 13.8 | 12.8 | 11.1 |
| 35 | .110 | .0095 | 20.5 | 15.8 | 14. | 12.9 | 11.2 |
| 34 | .111 | .0097 | 20.9 | 16.2 | 14.2 | 13.2 | 11.4 |
| 33 | .113 | .0100 | 21.5 | 16.7 | 14.7 | 13.6 | 11.8 |
| 32 | .116 | .0106 | 22.8 | 17.7 | 15.6 | 14.4 | 12.5 |
| 31 | .120 | .0113 | 24.3 | 18.8 | 16.6 | 15.4 | 13.3 |
| 1/8 | .125 | .0123 | 26.4 | 20.4 | 18. | 16.7 | 14.5 |
| 30 | .1285 | .0130 | 27.9 | 21.6 | 19. | 17.6 | 15.3 |
| 29 | .136 | .0145 | 31.1 | 24.1 | 21.2 | 19.7 | 17. |
| 28 | .1405 | .0155 | 33.3 | 25.8 | 22.7 | 21. | 18.2 |
| 9/64 | .1406 | .0156 | 33.5 | 25.9 | 22.8 | 21.2 | 18.3 |
| 27 | .144 | .0163 | 35. | 27.1 | 23.9 | 22.1 | 19.2 |
| 26 | .147 | .0174 | 37.3 | 28.9 | 25.5 | 23.6 | 20.4 |
| 25 | .1495 | .0175 | 37.5 | 29.1 | 25.6 | 23.7 | 20.6 |
| 24 | .152 | .0181 | 38.8 | 30.1 | 26.5 | 24.6 | 21.3 |
| 23 | .154 | .0186 | 39.9 | 30.9 | 27.2 | 25.2 | 21.9 |
| 5/32 | .1562 | .0192 | 41.2 | 31.9 | 28.1 | 26.1 | 22.6 |
| 22 | .157 | .0193 | 41.4 | 32.1 | 28.2 | 26.2 | 22.7 |
| 21 | .159 | .0198 | 42.5 | 32.9 | 29. | 26.9 | 23.3 |
| 20 | .161 | .0203 | 43.6 | 33.7 | 29.7 | 27.5 | 23.9 |
| 19 | .166 | .0216 | 46.3 | 35.9 | 31.6 | 29.3 | 25.4 |
| 18 | .1695 | .0226 | 48.5 | 37.6 | 33.1 | 30.7 | 26.6 |
| 11/64 | .1719 | .0232 | 49.8 | 38.6 | 33.9 | 31.5 | 27.3 |
| 17 | .175 | .0235 | 50.4 | 39.1 | 34.4 | 31.9 | 27.6 |
| 16 | .177 | .0246 | 52.8 | 40.9 | 36. | 33.4 | 28.9 |
| 15 | .180 | .0254 | 54.5 | 42.2 | 37.2 | 34.5 | 29.9 |
| 14 | .182 | .0260 | 55.8 | 43.2 | 38. | 35.3 | 30.6 |
| 13 | .185 | .0269 | 57.7 | 44.7 | 39.4 | 36.5 | 31.6 |
| 3/16 | .1875 | .0276 | 59.2 | 45.9 | 40.4 | 37.5 | 32.4 |

## CAPACITY, CFH @ 1″ W.C. PRESSURE DROP AND COEFFICIENT OF DISCHARGE OF 1.0

| Drill Size | Dia. In. | Area | Natural Gas 0.60 Sp. Gr. | Air 1.0 Sp. Gr. | Propane/ Air 1.29 Sp. Gr. | Propane 1.5 Sp. Gr. | Butane 2.0 Sp. Gr. |
|---|---|---|---|---|---|---|---|
| 12 | .189 | .02805 | 60.2 | 46.6 | 41. | 38.1 | 33. |
| 11 | .191 | .02865 | 61.5 | 47.6 | 41.9 | 38.9 | 33.7 |
| 10 | .1935 | .0294 | 63.1 | 48.9 | 43. | 39.9 | 34.6 |
| 9 | .196 | .0302 | 64.8 | 50.2 | 44.2 | 41. | 35.5 |
| 8 | .199 | .0311 | 66.7 | 51.7 | 45.5 | 42.2 | 36.5 |
| 7 | .201 | .0316 | 67.8 | 52.5 | 46.2 | 42.9 | 37.1 |
| 13/64 | .2031 | .0324 | 69.5 | 53.8 | 47.4 | 44. | 38.1 |
| 6 | .204 | .0327 | 70.2 | 54.3 | 47.8 | 44.4 | 38.4 |
| 5 | .2055 | .0332 | 71.2 | 55.2 | 48.6 | 45.1 | 39. |
| 4 | .209 | .0343 | 73.6 | 57.0 | 50.2 | 46.5 | 40.3 |
| 3 | .213 | .0356 | 76.4 | 59.2 | 52.1 | 48.3 | 41.8 |
| 7/32 | .2187 | .0376 | 80.7 | 62.5 | 55. | 51. | 44.2 |
| 2 | .221 | .0384 | 82.4 | 63.8 | 56.2 | 52.1 | 45.1 |
| 1 | .228 | .0409 | 87.8 | 68. | 59.8 | 55.5 | 48.1 |
| A | .234 | .0430 | 92.3 | 71.5 | 62.9 | 58.4 | 50.5 |
| 15/64 | .2343 | .0431 | 92.5 | 71.6 | 63.1 | 58.5 | 50.7 |
| B | .238 | .0444 | 95.3 | 73.8 | 65. | 60.3 | 52.2 |
| C | .242 | .0460 | 98.7 | 76.5 | 67.3 | 62.4 | 54.1 |
| D | .246 | .0475 | 102. | 78.9 | 69.5 | 64.5 | 55.8 |
| 1/4 | .250 | .0491 | 105. | 81.6 | 71.8 | 66.6 | 57.7 |
| F | .257 | .0519 | 111. | 86.3 | 75.9 | 70.4 | 61. |
| G | .261 | .0535 | 115. | 88.9 | 78.3 | 72.6 | 62.9 |
| 17/64 | .2656 | .0554 | 119. | 92.1 | 81.1 | 75.2 | 65.1 |
| H | .266 | .0556 | 119.3 | 92.4 | 81.4 | 75.4 | 65.3 |
| I | .272 | .0580 | 124. | 96.4 | 84.9 | 78.7 | 68.2 |
| J | .277 | .0601 | 129. | 99.9 | 87.9 | 81.6 | 70.6 |
| K | .281 | .0620 | 133. | 103. | 90.7 | 84.1 | 72.9 |
| 9/32 | .2812 | .0621 | 133.2 | 103.2 | 90.9 | 84.3 | 73. |
| L | .290 | .0660 | 142. | 110. | 96.6 | 89.6 | 77.6 |
| M | .295 | .0683 | 147. | 113. | 99.9 | 92.7 | 80.3 |
| 19/64 | .2968 | .0692 | 148. | 115. | 101. | 93.9 | 81.3 |
| N | .302 | .0716 | 154. | 119. | 105. | 97.2 | 84.1 |
| 5/16 | .3125 | .0767 | 165. | 127. | 112. | 104. | 90.1 |
| O | .316 | .0784 | 168. | 130. | 115. | 106. | 92.1 |
| P | .323 | .0820 | 176. | 136. | 120. | 111. | 96.4 |
| 21/64 | .3281 | .0846 | 182. | 141. | 124. | 115. | 99.4 |
| Q | .332 | .0866 | 186. | 144. | 127. | 118. | 102. |
| R | .339 | .0901 | 193. | 150. | 132. | 122. | 106. |
| 11/32 | .3437 | .0928 | 199. | 154. | 136. | 126. | 109. |
| S | .348 | .0950 | 204. | 158. | 139. | 129. | 112. |
| T | .358 | .1005 | 216. | 167. | 147. | 136. | 118. |
| 23/64 | .3593 | .1014 | 218. | 169. | 148. | 138. | 119. |
| U | .368 | .1063 | 228. | 177. | 156. | 144. | 125. |
| 3/8 | .375 | .1104 | 237. | 184. | 162. | 150. | 130. |
| V | .377 | .1116 | 239. | 185. | 163. | 151. | 131. |
| W | .386 | .1170 | 251. | 194. | 171. | 159. | 137. |
| 25/64 | .3906 | .1198 | 257. | 199. | 175. | 163. | 141. |
| X | .397 | .1236 | 265. | 205. | 181. | 168. | 145. |
| Y | .404 | .1278 | 274. | 212. | 187. | 173. | 150. |
| 13/32 | .4062 | .1296 | 278. | 215. | 190. | 176. | 152. |
| Z | .413 | .1340 | 288. | 223. | 196. | 182. | 157. |
| 27/64 | .4219 | .1398 | 300. | 232. | 205. | 190. | 164. |
| 7/16 | .4375 | .1503 | 322. | 250. | 220. | 204. | 177. |
| 29/64 | .4531 | .1613 | 346. | 268. | 236. | 219. | 190. |
| 15/32 | .4687 | .1726 | 370. | 287. | 253. | 234. | 203. |

## CAPACITY, CFH @ 1″ W.C. PRESSURE DROP AND COEFFICIENT OF DISCHARGE OF 1.0

| Drill Size | Dia. In. | Area | Natural Gas 0.60 Sp. Gr. | Air 1.0 Sp. Gr. | Propane/ Air 1.29 Sp. Gr. | Propane 1.5 Sp. Gr. | Butane 2.0 Sp. Gr. |
|---|---|---|---|---|---|---|---|
| 31/64 | .4843 | .1843 | 395. | 306. | 270. | 250. | 217. |
| 1/2 | .50 | .1963 | 421. | 326. | 287. | 266. | 231. |
| 33/64 | .5156 | .2088 | 448. | 347. | 306. | 283. | 245. |
| 17/32 | .5312 | .2217 | 476. | 368. | 324. | 301. | 261. |
| 35/64 | .5468 | .2349 | 504. | 390. | 344. | 319. | 276. |
| 9/16 | .5625 | .2485 | 533. | 413. | 364. | 337. | 292. |
| 37/64 | .5781 | .2625 | 563. | 436. | 384. | 356. | 308. |
| 19/32 | .5937 | .2769 | 594. | 460. | 405. | 376. | 325. |
| 39/64 | .6093 | .2916 | 626. | 485. | 427. | 396. | 343. |
| 5/8 | .625 | .3068 | 658. | 510. | 449. | 416. | 361. |
| 41/64 | .6406 | .3223 | 691. | 536. | 472. | 437. | 379. |
| 21/32 | .6562 | .3382 | 725. | 562. | 495. | 459. | 397. |
| 43/64 | .6718 | .3545 | 760. | 589. | 519. | 481. | 417. |
| 11/16 | .6875 | .3712 | 796. | 617. | 543. | 504. | 436. |
| 45/64 | .7031 | .3883 | 833. | 645. | 568. | 527. | 456. |
| 23/32 | .7187 | .4057 | 870. | 674. | 594. | 551. | 477. |
| 47/64 | .7343 | .4236 | 909. | 704. | 620. | 575. | 498. |
| 3/4 | .750 | .44179 | 948. | 734. | 646. | 599. | 519. |
| 49/64 | .7656 | .46040 | 988. | 765. | 674. | 625. | 541. |
| 25/32 | .7813 | .47937 | 1029. | 796. | 701. | 651. | 563. |
| 51/64 | .7969 | .49873 | 1070. | 829. | 730. | 677. | 586. |
| 13/16 | .8125 | .51849 | 1112. | 862. | 759. | 704. | 609. |
| 53/64 | .8281 | .53862 | 1156. | 895. | 788. | 731. | 633. |
| 27/32 | .8438 | .55914 | 1200. | 929. | 818. | 759. | 657. |
| 55/64 | .8594 | .5800 | 1244. | 964. | 849. | 787. | 682. |
| 7/8 | .8750 | .60132 | 1290. | 999. | 880. | 816. | 707. |
| 29/32 | .9062 | .64504 | 1384. | 1072. | 944. | 875. | 758. |
| 15/16 | .9375 | .69029 | 1481. | 1147. | 1010. | 937. | 811. |
| 31/32 | .9688 | .73708 | 1581. | 1225. | 1079. | 1000. | 866. |
| 1 | 1.0 | .7854 | 1685. | 1305. | 1149. | 1066. | 923. |
| 1-1/16 | 1.063 | .88664 | 1902. | 1474. | 1297. | 1203. | 1042. |
| 1-1/8 | 1.125 | .99402 | 2133. | 1652. | 1455. | 1349. | 1168. |
| 1-3/16 | 1.188 | 1.1075 | 2376. | 1841. | 1621. | 1503. | 1302. |
| 1-1/4 | 1.250 | 1.2272 | 2633. | 2040. | 1796. | 1665. | 1442. |
| 1-5/16 | 1.313 | 1.3530 | 2903. | 2249. | 1980. | 1836. | 1590. |
| 1-3/8 | 1.375 | 1.4849 | 3186. | 2468. | 2173. | 2015. | 1745. |
| 1-1/2 | 1.5 | 1.7671 | 3791. | 2937. | 2586. | 2398. | 2077. |
| 1-9/16 | 1.563 | 1.9174 | 4114. | 3187. | 2806. | 2602. | 2253. |
| 1-5/8 | 1.625 | 2.0739 | 4450. | 3447. | 3035. | 2814. | 2437. |
| 1-11/16 | 1.688 | 2.2365 | 4799. | 3717. | 3273. | 3035. | 2628. |
| 1-3/4 | 1.75 | 2.4053 | 5161. | 3998. | 3520. | 3264. | 2827. |
| 1-13/16 | 1.813 | 2.5802 | 5536. | 4288. | 3776. | 3501. | 3032. |
| 1-7/8 | 1.875 | 2.7612 | 5924. | 4589. | 4040. | 3747. | 3245. |
| 1-15/16 | 1.938 | 2.9498 | 6329. | 4903. | 4316. | 4003. | 3467. |
| 2 | 2.0 | 3.1416 | 6741. | 5221. | 4597. | 4263. | 3692. |
| 2-1/8 | 2.125 | 3.5466 | 7610. | 5894. | 5190. | 4813. | 4168. |
| 2-1/4 | 2.250 | 3.9761 | 8531. | 6608. | 5818. | 5396. | 4673. |
| 2-3/8 | 2.375 | 4.4301 | 9505. | 7363. | 6483. | 6012. | 5206. |
| 2-1/2 | 2.50 | 4.9087 | 10532. | 8158. | 7183. | 6661. | 5769. |
| 2-5/8 | 2.625 | 5.4119 | 11612. | 8995. | 7919. | 7344. | 6360. |
| 2-3/4 | 2.75 | 5.9396 | 12744. | 9872. | 8691. | 8060. | 6980. |
| 2-7/8 | 2.875 | 6.4918 | 13929. | 10789. | 9499. | 8809. | 7629. |

## Table 1 – Combustion Constants – Reference 1

| No. | Substance | Formula | Molecular Weight[a] | Density[b] lb per ft³ | Specific Volume[b] ft³ per lb | Specific Gravity[b] (air=1) | Heat of Combustion[c] Btu per ft³ Gross[d] | Btu per ft³ Net[e] | Btu per lb Gross[d] | Btu per lb Net[e] | ft³ per ft³ of Combustible – Required for Combustion $O_2$ | $N_{2a}$ | Air | Flue Products $CO_2$ | $H_2O$ | $N_{2a}$ | lb per lb of Combustible – Required for Combustion $O_2$ | $N_{2a}$ | Air | Flue Gas Products $CO_2$ | $H_2O$ | $N_{2a}$ | Theor air lb/ 10,000 Btu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Carbon | C | 12.0110 | — | — | — | — | — | 14,093 | 14,093 | 1.0 | 3.773 | 4.773 | 1.0 | — | 3.773 | 2.664 | 8.846 | 11.510 | 3.664 | — | 8.846 | 8.167 |
| 2 | Hydrogen | $H_2$ | 2.0159 | 0.0053 | 188.245 | 0.0696 | 324.2 | 273.9 | 61,029 | 51,558 | 0.5 | 1.887 | 2.387 | — | 1.0 | 1.887 | 7.936 | 26.353 | 34.290 | — | 8.937 | 26.353 | 5.619 |
| 3 | Oxygen | $O_2$ | 31.9988 | 0.0844 | 11.850 | 1.1053 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 4 | Nitrogen | $N_2$ | 28.0134 | 0.0738 | 13.543 | 0.9671 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 4 | Nitrogen (atm.)[f] | $N_{2a}$ | 28.1580 | 0.0742 | 13.474 | 0.9720 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 5 | Carbon monoxide | CO | 28.0104 | 0.0738 | 13.542 | 0.9672 | 320.6 | 320.6 | 4342 | 4342 | 0.5 | 1.887 | 2.387 | 1.0 | — | 1.887 | 0.571 | 1.897 | 2.468 | 1.571 | — | 1.897 | 5.684 |
| 6 | Carbon dioxide | $CO_2$ | 44.0098 | 0.1166 | 8.574 | 1.5277 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | **Parafin series $C_nH_{2n+2}$** | | | | | | | | | | | | | | | | | | | | | | |
| 7 | Methane | $CH_4$ | 16.0428 | 0.0424 | 23.608 | 0.5548 | 1012 | 911 | 23,891 | 21,511 | 2.0 | 7.547 | 9.547 | 1.0 | 2.0 | 7.547 | 3.989 | 13.246 | 17.235 | 2.743 | 2.246 | 13.246 | 7.214 |
| 8 | Ethane | $C_2H_6$ | 30.0697 | 0.0799 | 12.514 | 1.0466 | 1785 | 1634 | 22,334 | 20,429 | 3.5 | 13.206 | 16.706 | 2.0 | 3.0 | 13.206 | 3.724 | 12.367 | 16.092 | 2.927 | 1.797 | 12.367 | 7.205 |
| 9 | Propane | $C_3H_8$ | 44.0966 | 0.1183 | 8.456 | 1.5489 | 2561 | 2359 | 21,653 | 19,921 | 5.0 | 18.866 | 23.866 | 3.0 | 4.0 | 18.866 | 3.628 | 12.047 | 15.676 | 2.994 | 1.634 | 12.047 | 7.239 |
| 10 | n-Butane | $C_4H_{10}$ | 58.1235 | 0.1585 | 6.310 | 2.0758 | 3376 | 3124 | 21,299 | 19,657 | 6.5 | 24.526 | 31.026 | 4.0 | 5.0 | 24.526 | 3.578 | 11.882 | 15.460 | 3.029 | 1.550 | 11.882 | 7.259 |
| 11 | Isobutane | $C_4H_{10}$ | 58.1235 | 0.1580 | 6.328 | 2.0699 | 3355 | 3104 | 21,231 | 19,589 | 6.5 | 24.526 | 31.026 | 4.0 | 5.0 | 24.526 | 3.578 | 11.882 | 15.460 | 3.029 | 1.550 | 11.882 | 7.282 |
| 12 | n-Pentane | $C_5H_{12}$ | 72.1504 | 0.2019 | 4.952 | 2.6450 | 4258 | 3956 | 21,085 | 19,498 | 8.0 | 30.186 | 38.186 | 5.0 | 6.0 | 30.186 | 3.548 | 11.781 | 15.329 | 3.050 | 1.498 | 11.781 | 7.270 |
| 13 | Isopentane | $C_5H_{12}$ | 72.1504 | 0.2001 | 4.999 | 2.6202 | 4210 | 3908 | 21,043 | 19,455 | 8.0 | 30.186 | 38.186 | 5.0 | 6.0 | 30.186 | 3.548 | 11.781 | 15.329 | 3.050 | 1.498 | 11.781 | 7.284 |
| 14 | Neopentane | $C_5H_{12}$ | 72.1504 | 0.1984[g] | 5.040[g] | 2.5989[g] | 4159[g] | 3857 | 20,958[g] | 19,370 | 8.0 | 30.186 | 38.186 | 5.0 | 6.0 | 30.186 | 3.548 | 11.781 | 15.329 | 3.050 | 1.498 | 11.781 | 7.314 |
| 15 | n-Hexane | $C_6H_{14}$ | 86.1773 | 0.2508 | 3.987 | 3.2849 | 5252 | 4900 | 20,943 | 19,392 | 9.5 | 35.846 | 45.346 | 6.0 | 7.0 | 35.846 | 3.527 | 11.713 | 15.240 | 3.064 | 1.463 | 11.713 | 7.277 |
| | **Olefin series $C_nH_{2n}$** | | | | | | | | | | | | | | | | | | | | | | |
| 16 | Ethylene | $C_2H_4$ | 28.0538 | 0.0744 | 13.447 | 0.9740 | 1609 | 1509 | 21,643 | 20,282 | 3.0 | 11.320 | 14.320 | 2.0 | 2.0 | 11.320 | 3.422 | 11.362 | 14.784 | 3.138 | 1.284 | 11.362 | 6.831 |
| 17 | Propylene | $C_3H_6$ | 42.0807 | 0.1127 | 8.874 | 1.4760 | 2371 | 2220 | 21,039 | 19,678 | 4.5 | 16.980 | 21.480 | 3.0 | 3.0 | 16.980 | 3.422 | 11.362 | 14.784 | 3.138 | 1.284 | 11.362 | 7.027 |
| 18 | n-Butene (Butylene) | $C_4H_8$ | 56.1076 | 0.1524[g] | 6.560[g] | 1.9966[g] | 3175[g] | 2974 | 20,831[g] | 19,470 | 6.0 | 22.640 | 28.640 | 4.0 | 4.0 | 22.640 | 3.422 | 11.362 | 14.784 | 3.138 | 1.284 | 11.362 | 7.097 |
| 19 | Isobutene | $C_4H_8$ | 56.1076 | 0.1524[g] | 6.561[g] | 1.9964[g] | 3156[g] | 2955 | 20,704[g] | 19,343 | 6.0 | 22.640 | 28.640 | 4.0 | 4.0 | 22.640 | 3.422 | 11.362 | 14.784 | 3.138 | 1.284 | 11.362 | 7.141 |
| 20 | n-Pentene | $C_5H_{10}$ | 70.1345 | 0.1947[h] | 5.135[h] | 2.5508[h] | 4032[g] | 3781 | 20,704[g] | 19,343 | 7.5 | 28.300 | 35.800 | 5.0 | 5.0 | 28.300 | 3.422 | 11.362 | 14.784 | 3.138 | 1.284 | 11.362 | 7.140 |
| | **Aromatic series $C_nH_{2n-6}$** | | | | | | | | | | | | | | | | | | | | | | |
| 21 | Benzene | $C_6H_6$ | 78.1137 | 0.2213 | 4.518 | 2.8989 | 4024 | 3873 | 18,179 | 17,446 | 7.5 | 28.300 | 35.800 | 6.0 | 3.0 | 28.300 | 3.072 | 10.201 | 13.274 | 3.380 | 0.692 | 10.201 | 7.302 |
| 22 | Toluene | $C_7H_8$ | 92.1406 | 0.2750[h] | 3.637[h] | 3.6016[h] | 5068[g] | 4867 | 18,430[g] | 17,602 | 9.0 | 33.959 | 42.959 | 7.0 | 4.0 | 33.959 | 3.125 | 10.378 | 13.504 | 3.343 | 0.782 | 10.378 | 7.327 |
| 23 | Xylene | $C_8H_{10}$ | 106.1675 | 0.3480[h] | 2.874[h] | 4.5576[h] | 6480[g] | 6228 | 18,622[g] | 17,723 | 10.5 | 39.619 | 50.119 | 8.0 | 5.0 | 39.619 | 3.164 | 10.508 | 13.673 | 3.316 | 0.848 | 10.508 | 7.342 |
| | **Miscellaneous** | | | | | | | | | | | | | | | | | | | | | | |
| 24 | Acetylene | $C_2H_2$ | 26.0379 | 0.0691 | 14.480 | 0.9046 | 1484 | 1433 | 21,482 | 20,749 | 2.5 | 9.433 | 11.933 | 2.0 | 1.0 | 9.433 | 3.072 | 10.201 | 13.274 | 3.380 | 0.692 | 10.201 | 6.179 |
| 25 | Naphthalene | $C_{10}H_8$ | 128.1736 | 0.3384[h] | 2.955[h] | 4.4323[h] | 5866 | 5665 | 17,335 | 16,739 | 12.0 | 45.279 | 57.279 | 10.0 | 4.0 | 45.279 | 2.995 | 9.947 | 12.943 | 3.434 | 0.562 | 9.947 | 7.467 |
| 26 | Methyl alcohol | $CH_3OH$ | 32.0422 | 0.0846[h] | 11.820[h] | 1.1081[h] | 868[g] | 768 | 10,265[g] | 9073 | 1.5 | 5.660 | 7.160 | 1.0 | 2.0 | 5.660 | 1.498 | 4.974 | 6.472 | 1.373 | 1.124 | 4.974 | 6.305 |
| 27 | Ethyl alcohol | $C_2H_5OH$ | 46.0691 | 0.1216[h] | 8.224[h] | 1.5927[h] | 1602[g] | 1451 | 13,172[g] | 11,929 | 3.0 | 11.320 | 14.320 | 2.0 | 3.0 | 11.320 | 2.084 | 6.919 | 9.003 | 1.911 | 1.173 | 6.919 | 6.835 |
| 28 | Ammonia | $NH_3$ | 17.0306 | 0.0454[g] | 22.008[g] | 0.5951[g] | 440[g] | 364 | 9680[g] | 7998 | 0.75 | 2.830 | 3.580 | — | 1.5 | 3.330 | 1.409 | 4.679 | 6.088 | — | 1.587 | 5.502 | 6.290 |
| 29 | Sulfur | S | 32.0660 | — | — | — | — | — | 3980 | 3980 | 1.0 | 3.773 | 4.773 | $SO_2$ 1.0 | — | 3.773 | 1.000 | 3.320 | 4.310 | $SO_2$ 1.998 | — | 3.320 | 10.829 |
| 30 | Hydrogen sulfide | $H_2S$ | 34.0819 | 0.0907 | 11.030 | 1.1875 | 643 | 593 | 7094 | 6534 | 1.5 | 5.660 | 7.160 | $SO_2$ 1.0 | 1.0 | 5.660 | 1.410 | 4.682 | 6.093 | $SO_2$ 1.880 | 0.529 | 4.682 | 8.576 |
| 31 | Sulfur dioxide | $SO_2$ | 64.0648 | 0.1722[g] | 5.806[g] | 2.2558[g] | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 32 | Water vapor | $H_2O$ | 18.0153 | 0.0503 | 19.863 | 0.6594 | 50.312 | 0.0 | 1059.8 | 0.0 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 33 | Air[f] | — | 28.9625 | 0.0763 | 13.098 | 1.0000 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |

All gas volumes corrected to 60F and 14.696 psi dry.

a 1987 Atomic Weights: C=12.011, H=1.00794, O=15.9994, N=14.0067, S=32.066.

b Densities calculated from ideal values and compressibility factor given in ASTM D3588-98. Some of the materials cannot exist as gases at 60F and 14.696 psi, in which case the values are theoretical ones. Under the actual concentrations in which these materials are present, their partial pressure is low enough to keep them as gases.

c For gases saturated with water at 60F and 14.696 psi, 1.74% of the Btu value must be deducted. Reference 2.

d Reference 2, ASTM 3588-98.

e Correction from gross to net heating value determined by deducting the HV shown for water vapor times the moles of $H_2$.

f Reference 3, Jones, F.E.

g Gas Processors Suppliers Association (GPSA) Data Book, Fig 23-2, Physical Constants, 1987.

h Either the density or the compressibility factor has been assumed.

# Combustibles

| Material | LEL (%/Vol) | UEL (%/Vol) | TLV/TWA (ppm) | IDLH (ppm) | Density (Air = 1.0) |
|---|---|---|---|---|---|
| Acetone | 2.5 | 12.8 | 750 | 2,500 | 2.0 |
| Acetylene | 2.5 | 100.0 | -A- | -A- | .9 |
| Ammonia | 15.0 | 28.0 | 25 | 300 | 0.6 |
| Benzene | 1.2 | 7.8 | 1.0 | 500 | 2.6 |
| Butane | 1.6 | 8.4 | 800 | -U- | 2.0 |
| n-Butyl Acetate | 1.7 | 7.6 | 150 | 1,700 | 4.0 |
| Diborane | 0.8 | 88.0 | 0.1 | 15 | 1.0 |
| Ethane | 3.0 | 12.5 | -A- | -A- | 1.0 |
| Ethanol | 3.3 | 19.0 | 1,000 | -U- | 1.6 |
| Ethyl Acetate | 2.0 | 11.5 | 400 | 2,000 | 3.0 |
| Ethyl Ether | 1.9 | 36.0 | 400 | 1,900 | 2.6 |
| Ethylene Oxide | 3.0 | 100.0 | 1 | -C- | 1.5 |
| Gasoline (100 Octane) | 1.4 | 7.6 | 300 | -U- | 3-4.0 |
| Heptane | 1.05 | 6.7 | 400 | 750 | 3.5 |
| Hexane | 1.1 | 7.5 | 50 | 1,100 | 3.0 |
| Hydrogen | 4.0 | 75.0 | -A- | -A- | 0.1 |
| Isopropyl Alcohol | 2.0 | 12.0 | 400 | 2,000 | 2.1 |
| Methane | 5.0 | 15.0 | -A- | -A- | 0.6 |
| Methanol | 6.0 | 36.0 | 200 | 6,000 | 1.1 |
| Methyl Ethyl Ketone | 1.4 | 11.4 | 200 | 3,000 | 2.5 |
| Pentane | 1.5 | 7.8 | 600 | 15,000 | 2.5 |
| Propane | 2.1 | 9.5 | 1,000 | 2,100 | 1.6 |
| Propylene Oxide | 2.3 | 36.0 | 20 | 400 | 2.0 |
| Styrene | 0.9 | 6.8 | 50 | 700 | 3.6 |
| Toluene | 1.1 | 7.1 | 50 | 500 | 3.1 |
| Turpentine | 0.8 | ? | 100 | 800 | 4.7 |
| Vinyl Acetate | 2.6 | 13.4 | 10 | -U- | 3.0 |
| Vinyl Chloride | 3.6 | 33.0 | 1.0 | -C- | 2.2 |
| Xylene | 0.9 | 6.7 | 100 | 900 | 3.7 |

| | |
|---|---|
| LEL | Lower Explosive Limit |
| UEL | Upper Explosive Limit |
| PPM | Parts Per Million |
| TLV/TWA | Threshold Limit Value/Time Weighted Average |
| IDLH | Immediately Dangerous to Life or Health |
| Density | < 1.0 = lighter than air |
| | > 1.0 = heavier than air |
| A | Asphyxiant |
| C | Carcinogen |
| U | Data Not Available |

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# Toxics

| Material | TLV/TWA (ppm) | IDLH | LEL (ppm) | LEL (%/Vol) | Density (Air=1) |
|---|---|---|---|---|---|
| Acetone | 750 | 2,500 | 25,000 | 2.5 | 2.0 |
| Ammonia | 25 | 300 | 160,000 | 16.0 | 0.6 |
| Benzene | 1.0 | -C- | 12,000 | 1.2 | 2.6 |
| Butane | 800 | -U- | 16,000 | 1.6 | 2.0 |
| n-Butyl Acetate | 150 | 1,700 | 17,000 | 1.7 | 4.0 |
| Carbon Dioxide | 5,000 | 40,000 | N/C | N/C | 1.5 |
| Carbon Monoxide | 25 | 1,200 | 125,000 | 12.5 | 1.0 |
| Chlorine | 0.5 | 10 | N/C | N/C | 2.5 |
| Ethylene Oxide | 1 | -C- | 30,000 | 3.0 | 1.5 |
| Ethyl Ether | 400 | 19,000 | 19,000 | 1.9 | 2.6 |
| Gasoline | 300 | -U- | 14,000 | 1.4 | 3-4.0 |
| Heptane | 400 | 750 | 10,500 | 1.05 | 3.5 |
| Hexane | 50 | 1,100 | 11,000 | 1.0 | 3.0 |
| Hydrogen Cyanide | 10 | 50 | 56,000 | 5.6 | 0.9 |
| Hydrogen Sulfide | 10 | 100 | 40,000 | 4.0 | 1.2 |
| Isopropyl Alcohol | 400 | 2,000 | 20,000 | 2.0 | 2.1 |
| Methyl Acetate | 200 | 3,100 | 31,000 | 3.1 | 2.6 |
| Methanol | 200 | 6,000 | 60,000 | 6.0 | 1.1 |
| Methyl Chloride | 50 | 2,000 | 81,000 | 8.1 | 1.8 |
| Methyl Ethyl Ketone | 200 | 3,000 | 14,000 | 1.4 | 2.5 |
| Methyl Methacrylate | 100 | 1,000 | 17,000 | 1.7 | 3.5 |
| Nitric Oxide | 25 | 100 | N/C | N/C | 1.0 |
| Nitrogen Dioxide | 3 | 20 | N/C | N/C | 1.6 |
| Pentane | 600 | 15,000 | 15,000 | 1.5 | 2.5 |
| n-Propyl Acetate | 200 | 1,700 | 17,000 | 1.7 | 3.5 |
| Styrene | 50 | 700 | 9,000 | .9 | 3.6 |
| Sulfur Dioxide | 2 | 100 | N/C | N/C | 2.2 |
| 1,1,1-Trichloroethane | 350 | 700 | 75,000 | 7.5 | 4.6 |
| Toluene | 50 | 500 | 11,000 | 1.1 | 3.2 |
| Trichloroethylene | 50 | 1,000 | 80,000 | 8.0 | 4.5 |
| Turpentine | 100 | 800 | 8,000 | 0.8 | 4.7 |
| Vinyl Chloride | 1.0 | -C- | 36,000 | 3.6 | 2.2 |
| Xylene | 100 | 900 | 9,000 | .9 | 3.7 |

| | | | |
|---|---|---|---|
| LEL | Lower Explosive Limit | UEL | Upper Explosive Limit |
| PPM | Parts Per Million | TLV/TWA | Threshold Limit Value/Time Weighted Average |
| IDLH | Immediately Dangerous to Life or Health | Density | < 1.0 = lighter than air<br>> 1.0 = heavier than air |
| C | Carcinogen | N/C | Not Combustible |

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## Specific Gravity Correction Factors

| Gas Meter is Calibrated With | Gas Being Used: Hydrogen | Helium | Methane | Ammonia | Neon | Acetylene | Nitrogen/Carbon Monoxide | Ethylene | Air | Ethane | Oxygen | Hydrogen Sulfide | Argone | Nitrous / Carbon Dioxide | Propane | Butane | Sulfur Dioxide |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydrogen | 1 | 0.70 | 0.35 | 0.34 | 0.32 | 0.28 | 0.27 | 0.27 | 0.26 | 0.26 | 0.25 | 0.24 | 0.22 | 0.21 | 0.21 | 0.18 | 0.18 |
| Helium | 1.41 | 1 | 0.50 | 0.48 | 0.45 | 0.38 | 0.38 | 0.38 | 0.37 | 0.36 | 0.35 | 0.34 | 0.32 | 0.30 | 0.30 | 0.26 | 0.25 |
| Methane | 2.82 | 2 | 1 | 0.97 | 0.89 | 0.78 | 0.76 | 0.75 | 0.74 | 0.73 | 0.71 | 0.68 | 0.63 | 0.60 | 0.59 | 0.52 | 0.49 |
| Ammonia | 2.92 | 2.06 | 1.03 | 1 | 0.92 | 0.81 | 0.78 | 0.78 | 0.77 | 0.75 | 0.73 | 0.70 | 0.66 | 0.62 | 0.62 | 0.54 | 0.51 |
| Neon | 3.17 | 2.25 | 1.12 | 1.08 | 1 | 0.88 | 0.85 | 0.84 | 0.83 | 0.82 | 0.80 | 0.76 | 0.71 | 0.67 | 0.67 | 0.58 | 0.55 |
| Acetylene | 3.62 | 2.56 | 1.28 | 1.24 | 1.14 | 1 | 0.97 | 0.96 | 0.95 | 0.93 | 0.91 | 0.87 | 0.81 | 0.77 | 0.76 | 0.66 | 0.63 |
| Nitrogen /Carbon Monoxide | 3.74 | 2.64 | 1.32 | 1.28 | 1.18 | 1.03 | 1 | 1 | 0.98 | 0.96 | 0.94 | 0.90 | 0.84 | 0.80 | 0.79 | 0.68 | 0.65 |
| Ethylene | 3.74 | 2.66 | 1.33 | 1.26 | 1.18 | 1.03 | 1 | 1 | 1.01 | 0.96 | 0.94 | 0.90 | 0.84 | 0.80 | 0.79 | 0.69 | 0.66 |
| Air | 3.61 | 2.69 | 1.35 | 1.30 | 1.20 | 1.04 | 1.02 | 1.01 | 1 | 0.98 | 0.95 | 0.92 | 0.85 | 0.81 | 0.80 | 0.70 | 0.66 |
| Ethane | 3.90 | 2.76 | 1.38 | 1.33 | 1.23 | 1.08 | 1.04 | 1.04 | 1.02 | 1 | 0.98 | 0.94 | 0.88 | 0.83 | 0.82 | 0.71 | 0.68 |
| Oxygen | 4 | 2.82 | 1.41 | 1.36 | 1.26 | 1.10 | 1.06 | 1.06 | 1.05 | 1.02 | 1 | 0.95 | 0.90 | 0.85 | 0.84 | 0.73 | 0.70 |
| Hydrogen Sulfide | 4.15 | 2.94 | 1.47 | 1.42 | 1.31 | 1.15 | 1.11 | 1.11 | 1.09 | 1.06 | 1.04 | 1 | 0.93 | 0.88 | 0.88 | 0.76 | 0.72 |
| Argon | 4.45 | 3.15 | 1.58 | 1.52 | 1.40 | 1.23 | 1.19 | 1.18 | 1.17 | 1.14 | 1.12 | 1.07 | 1 | 0.94 | 0.94 | 0.82 | 0.78 |
| Nitrous Oxide / Carbon Dioxide | 4.70 | 3.33 | 1.67 | 1.61 | 1.48 | 1.30 | 1.26 | 1.25 | 1.24 | 1.21 | 1.18 | 1.13 | 1.06 | 1 | 0.99 | 0.88 | 0.82 |
| Propane | 4.76 | 3.36 | 1.68 | 1.63 | 1.50 | 1.31 | 1.27 | 1.26 | 1.25 | 1.22 | 1.19 | 1.15 | 1.07 | 1.01 | 1 | 0.87 | 0.83 |
| Butane | 5.46 | 3.66 | 1.93 | 1.67 | 1.72 | 1.51 | 1.46 | 1.45 | 1.43 | 1.40 | 1.37 | 1.32 | 1.22 | 1.16 | 1.15 | 1 | 0.95 |
| Sulfur Dioxide | 5.72 | 4.05 | 2.03 | 1.96 | 1.81 | 1.58 | 1.53 | 1.52 | 1.50 | 1.47 | 1.43 | 1.38 | 1.28 | 1.22 | 1.20 | 1.05 | 1 |