



A SELAS HEAT TECHNOLOGY BRAND

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Your Combustion System – How does it work?

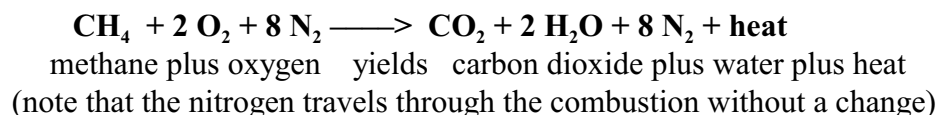
Thomas J. Clune - Ensign Ribbon Burners LLC

All fuels, whether natural gas, propane, butane, gasoline, or oil require a certain amount of oxygen (O₂) to burn. The oxygen can be supplied in its pure form, to develop an extremely hot flame at a high cost, or can be mixed with non-combustible gas (such as nitrogen, or N₂) at virtually no cost but at a lower heating potential. Since the air we breathe is composed of approximately 20% oxygen and 78% nitrogen, let us use air as our O₂ source.

Requirements of Combustion

Next let's consider how much air we need to burn a given amount of fuel.

The chemical formula for natural gas (or methane) is CH₄ (one carbon and four hydrogens). Without getting too technical, I can tell you that 1000 BTU's of any fuel requires 2 cubic feet of oxygen (or 10 cubic feet of air) for stoichiometric combustion, a fancy term for complete combustion of the mixture. When we mix 10 parts of air and 1 part of methane, we get the following formula:



This example assumes the air to be pure and the gas to be pure and everything to be easy. In reality the air has 2% other gases (not enough to really worry about), and the methane gas contains all manner of other stuff. In fact the exact composition of a gas supply is rarely consistent. Most of the time, in addition to methane, there will be traces of butane, ethane, propane, carbon dioxide, and nitrogen present in any given sample. Even so, unless we need to deal with a laboratory situation, a simple ratio of 10 cubic feet of air to 1000 BTUs of gas will almost always suffice. This rule holds true whether the gas is methane (which has about 1000 BTUs per cubic foot), propane (2500 BTUs per cubic foot), or butane (3200 BTUs per cubic foot). This means that to burn completely, 1 cubic foot of methane requires 10 cubic feet of air, 1 cubic foot of propane requires 25 cubic feet of air, and 1 cubic foot of butane requires 32 cubic feet of air.

Mixing Air and Gas

Now we must consider how to mix the air and gas.

1. We could just blow raw gas through a hole and let it mix and burn in the open. This is the simplest of burners and is known as an atmospheric burner. It produces a flame which is long and lazy. This is due to the inability of the air to mix with the gas fast enough via natural convection.
2. A better solution would be to employ an inspirator to utilize the pressure at which the

gas is delivered to induce air into the mixture. The BTU capacity of an inspirator can be precisely figured because, given the gas pressure, the orifice size, entry conditions, and type of gas, there is an Orifice Flow Formula that will calculate how many cubic feet of gas will pass through. This information is summarized in gas orifice tables for each size of orifice at various pressures.

Having the gas volume gives us the BTU capacity, but doesn't tell us how much air will be mixed with this gas. By convention, the energy of the gas stream can induce approximately 40% to 60% of the air needed, so for 1 cubic foot of methane we can get 4 to 6 cubic feet of air. The balance of air is provided from the atmosphere at the point of combustion. If we consider the pressure of the gas coming out of the orifice, and its volume, and add the air at atmospheric pressure, we can see that the mixture pressure developed is approximately 1/7th to 1/5th of the supply pressure (generalizing the result by ignoring the fine details). Of course, this result also depends upon the selection of inspirator which must follow the same rules as the orifice flow equations. A smoothly rounded entry point with gradually opened throat will produce the highest efficiency flow, and allow for the greatest air entrainment percentage. While an inspirator provides a better mixer than raw gas out of a hole, it is still somewhat inefficient. Due to its low cost, however, the inspirator is often the mixer of choice in terms of both initial expense and operating expense.

3. The third and most widely used simple combustion system works almost the same as an inspirator, except the air and gas have reversed their positions. Now the air is pressurized to provide the motive force to draw in the gas and, like the inspirator flow, can draw approximately 4 cubic feet of gas to 1 cubic foot of air. This proportion gives an extremely rich mixture. The gas must be therefore be restricted to limit it to the correct gas-air ratio. The gas is connected through a specialized pressure regulator called a Zero Gas Governor, which reduces the gas pressure to whatever the atmospheric pressure is at that time. Proper combustion requires 1 cubic foot of methane per 10 cubic feet of air, a 1:10 ratio. Since this mixer system can draw so much more gas than is needed, it is easily adjusted to either rich or lean as the process demands. Adjustment of the gas orifice will give this control. Once the air volume is fixed and the gas is adjusted for that air flow, the physics of mass flow take over. This means that adjustment of the air volume will directly correspond to the amount of gas dragged in. If we start with 10 cubic feet of air and 1 cubic foot of gas and we turn down to 1 cubic foot of air, the gas will automatically decrease to 0.1 cubic foot. Now we can control the firing rate using simple air volume flow controls like a butterfly valve or needle valve. This system is generally the one in use in bakery operations due to its simplicity, reliability, and flexibility of heating patterns (each burner can be individually adjusted for the heat input needed at that point of the cycle).

The final common type of combustion supply is a premix or mechanical system. This usually entails a blower with a gas feed, in which the room air is drawn in, and the gas is forced into the incoming air stream in such a way that the mechanical action of the rotating blower wheel thoroughly mixes the air and gas. This style mixer is generally used with large port area burners, but can be used with almost any burner provided the feed pipe is large enough. In other words, if the blower has a 2-inch diameter outlet, you will want to connect it to a 2-inch or larger burner feed. If the burner is smaller, then the air/gas mixture will back up in the blower and may create problems.

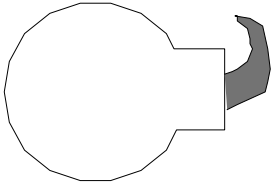
Flame Safety and Exhaust Requirements

The essence of flame safety systems is the requirement that the fuel mixture will be ignited without resulting in any part of the system reaching the LEL (Lower Explosive Level). This is the point below which the gas / air mixture will not support combustion (mixture is too lean). This is accomplished first by purging any enclosed combustion chambers for the period of time it takes to change the air 4 times. Next we use a flame safety that starts ignition prior to allowing gas entry. Under NFPA (National Fire Protection Association) rules, we have 10 seconds to attempt to light and prove a burner, after which the system must be shut down. In addition, if the flame signal is lost for any reason, the ignition must come back on instantly and if ignition is not proven in 4 seconds, again the gas is shut off.

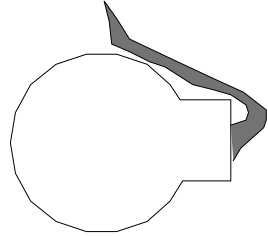
Gas Supply Valve Requirements

The NFPA requirements state that all burner must provide two automatic safety valves. These are usually wired in series with the air pressure switch, low gas pressure switch, high gas pressure switch, high temperature limiting switch, and purge completion switch. This valve would then shut down the entire system in case of any failures. Systems utilizing less than 150,000 BTUs require no additions to the valves. Between 150,000 and 400,000 BTUs both safety shutoff valves must have visual indication of valve position. Additionally, above 400,000 BTUs one valve must also have a proof of closure switch interlocked to the safety system. Factory Mutual (FM) and Industrial Risk Insurers (IRI) require their own additions, either switches to prove valve closure or vent valves between the main gas valves.

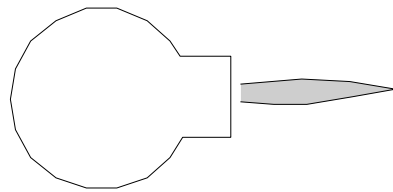
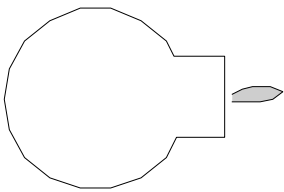
Low Fire



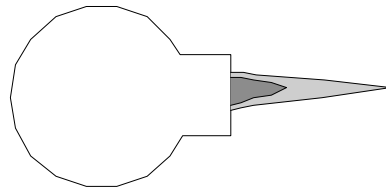
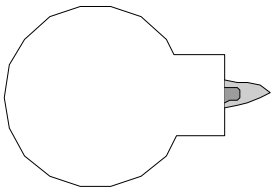
High Fire



Rich Flame - Lazy, Bright Flame



Lean Flame - Sharp, Lifts off burner



Normal Flame - Steady, well defined

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Flame Characteristics



Pipe Manifolding Calculator

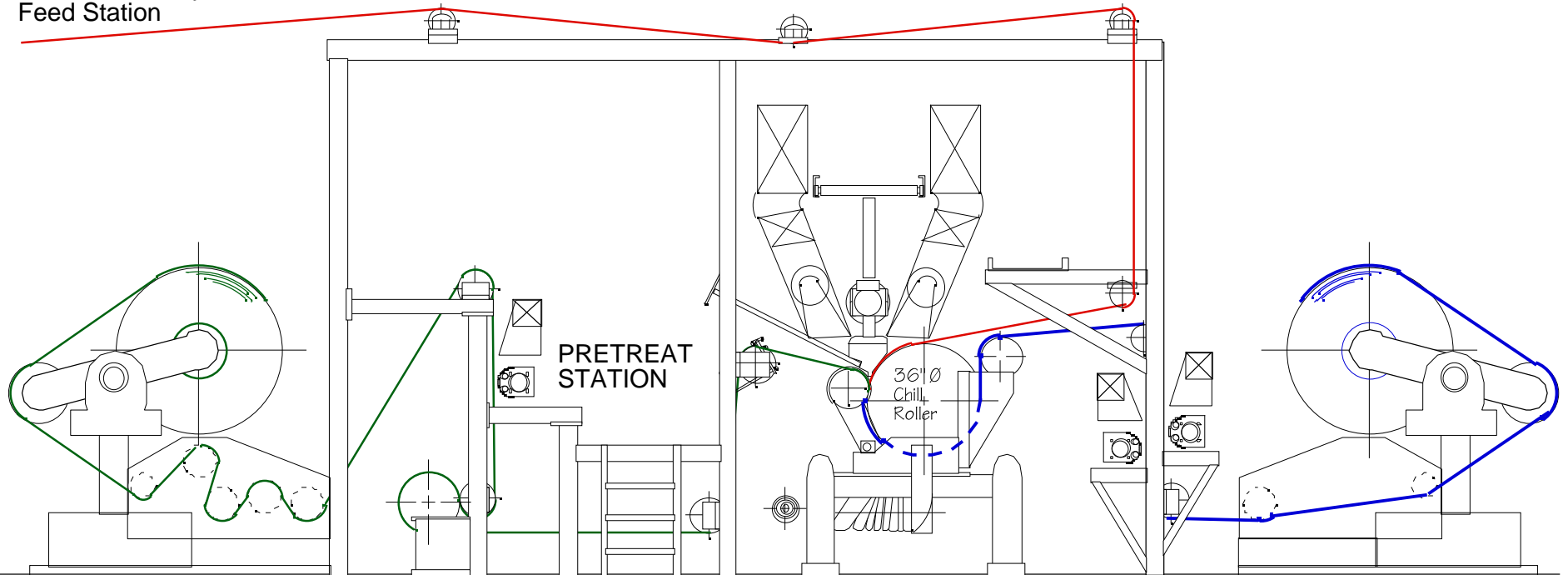
Pipe sizes in first column will allow for number of outlets shown in table when sized accordingly

Size	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8
1/8	1														
1/4	2.1	1													
3/8	4.5	2.1	1												
1/2	8	3.8	1.8	1											
3/4	16	8	3.6	2	1										
1	30	14	6.6	3.7	1.8	1									
1 1/4	60	28	13	7	3.6	2	1								
1 1/2	88	41	19	11	5.3	2.9	1.5	1							
2	164	77	36	20	10	5.5	2.7	1.9	1						
2 1/2	255	120	56	31	16	8	4.3	2.9	1.6	1					
3	439	206	97	54	27	15	7	5	2.7	1.7	1				
4	867	407	191	107	53	21	15	10	5.3	3.4	1.4	1			
5	1525	716	335	188	70	29	19	17	9	6	2.4	1.8	1		
6	2414	1133	531	297	93	51	40	28	15	9	3.8	2.8	1.6	1	
8	4795	2251	1054	590	147	80	58	55	29	19	7.6	5.5	3.1	2	1

National Taper Pipe Standard Pipe Dimensions
 Engagement

Pipe Size	No. of Threads	Hand Tight	Tight Joint	Advance per Turn	External Dia. In.	Internal Dia. S40	Internal Dia. S80
1/4	18	0.200	0.312	0.055	0.540	0.364	0.302
3/8	18	0.240	0.375	0.055	0.675	0.493	0.423
1/2	14	0.320	0.437	0.071	0.840	0.622	0.546
3/4	14	0.339	0.500	0.071	1.050	0.824	0.742
1	11-1/2	0.400	0.562	0.087	1.315	1.049	0.957
1 1/4	11-1/2	0.420	0.562	0.087	1.660	1.380	1.278
1 1/2	11-1/2	0.420	0.562	0.087	1.900	1.610	1.500
2	11-1/2	0.436	0.625	0.087	2.375	2.067	1.939
2 1/2	8	0.682	0.875	0.125	2.875	2.469	2.323

From Secondary
Feed Station



UNWIND
STATION

PRE TREATMENT
STATION

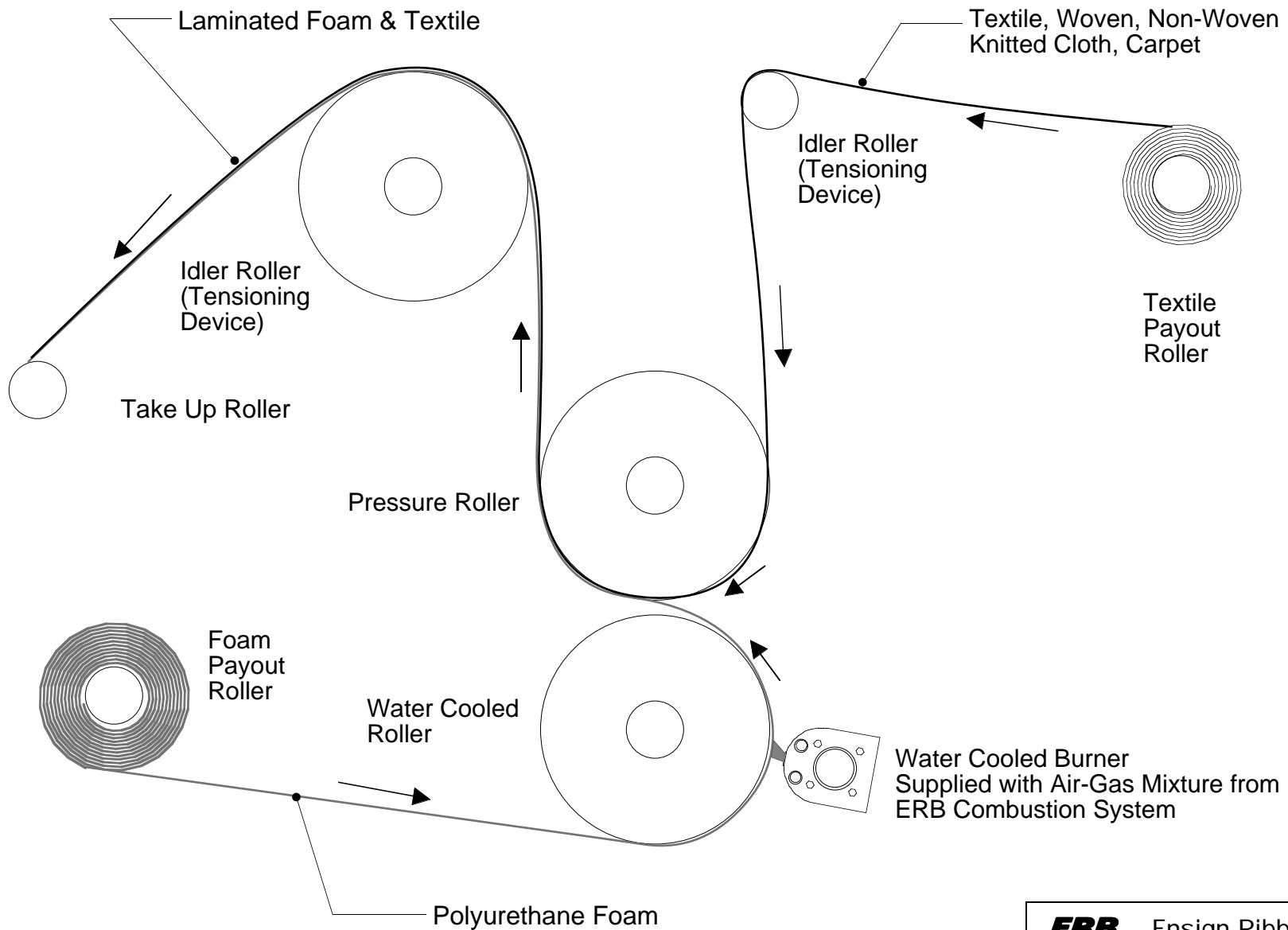
EXTRUSION
COATING

POST-TREATMENT
STATIONS

REWIND
STATION

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Flame Treating Coating Line



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Foam Laminating

BURNER ADJUSTMENTS

Total Flame Capacity

On each air/gas mixer is an air control valve, which can be rotated to provide control of the flame. Fully opened, clockwise rotation provides full air to the burner. Likewise, counter clockwise rotation will provide minimal air, and therefor a lower flame size.

Air/Gas Mixture

Above the air butterfly valve and to the side of the mixer body, there is a gas cock. A cap covers the gas proportioning screw. By removing the cap, and then by turning the screw in (CW) or out (CCW) the ratio of gas to air can be adjusted. The proper setting is achieved when the flame sits on the burner surface, without gaps and “blow offs.” When proper mixture is obtained, the cap should be replaced. Due to the use of a zero gas regulator, the burner mixture ratio will now stay the same regardless of the setting of the air valve.

Spark ‘N Sense™ Ignition

The Spark ‘N Sense™ module contains an output connection for both high voltage and flame sensing. Make sure this wire does not run with any other electrical cables to avoid noise. The ignition electrode must have a 1/8” gap to spark across, and is usually at the feed end of the burner. The sensor electrode will need at least 1/2” of electrode tip fully immersed in the flame, without being close enough to short circuit to ground.

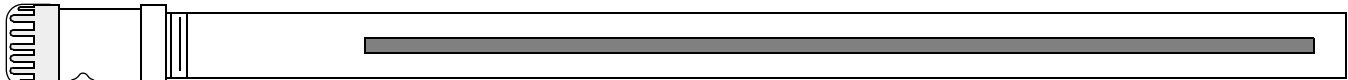
Troubleshooting

If the burner fails to light, there is usually either too much or too little gas available. First check that there is air coming out of the burner. If the air comes through the mixer, then you need to check if the gas is being induced or not. Too much gas usually will result in a flame, but the flame will be very long and weak, the spark monitoring will not be able to sense it, and unit will shut off again. If the gas is too lean, the burner will just refuse to light at all. It is very important to check the gas proportioning screw (under the cover) of the gas cocks. Normal you start with the screw backed out from the fully closed position about 4 or 5 turns and adjust from there. If a burner lights and then fails at approximately 10 seconds, this is an indication that the sensor failed to read the flame. If failure occurs later (after a few minutes), the problem may be traced to two possibilities. First, the electrode tip has moved when it heated up (it is normal for it to glow red), causing it to contact ground, and thus shutting off the burner. By the time you get back to it, it may look as if nothing is wrong, so after noticing a few failures, watch that burner continuously until it goes into failure. Second, the burner may fail due to the oven having reached temperature, and thus the burners move to low fire. At this point the flame may no longer contact the flame rod. Generally, the minimum firing rate needs to be turned up, as extremely low mixture pressures which worked with continuous ignition are now too low. If this higher minimal flow causes the temperature to override the setpoint, then you need to use fewer burners.

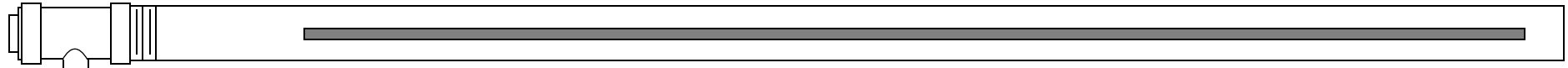
PRESSURE CONVERSION TABLE

		Kg/cm2	bar	atm	PSI lb/in2	KPa	MERCURY		WATER	
							Hg m	in	H2O(Aq) m	ft
Kg/cm2		1	0.981	0.968	14.220	98.070	0.736	28.960	10.000	32.810
bar		1.020	1	0.987	14.500	100.000	0.750	29.530	10.197	33.430
atm		1.033	1.013	1	14.700	101.320	0.760	29.920	10.330	33.900
PSI	lb/in2	0.070	0.069	0.068	1	6.894	0.052	2.036	0.703	2.030
KPa		0.010	0.010	0.010	0.145	1	0.007	0.296	0.102	0.334
Hg	m	1.359	1.333	1.316	19.340	133.320	1	39.370	13.600	44.600
	in	0.035	0.034	0.033	0.491	3.383	0.025	1	0.345	1.133
H2O(Aq)	m	0.100	0.098	0.097	1.422	9.807	0.073	2.896	1	3.281
	ft	0.030	0.030	0.029	0.433	2.991	0.022	0.880	0.305	1

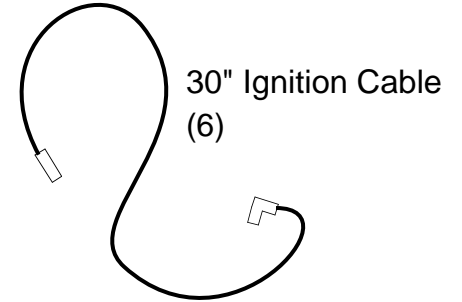
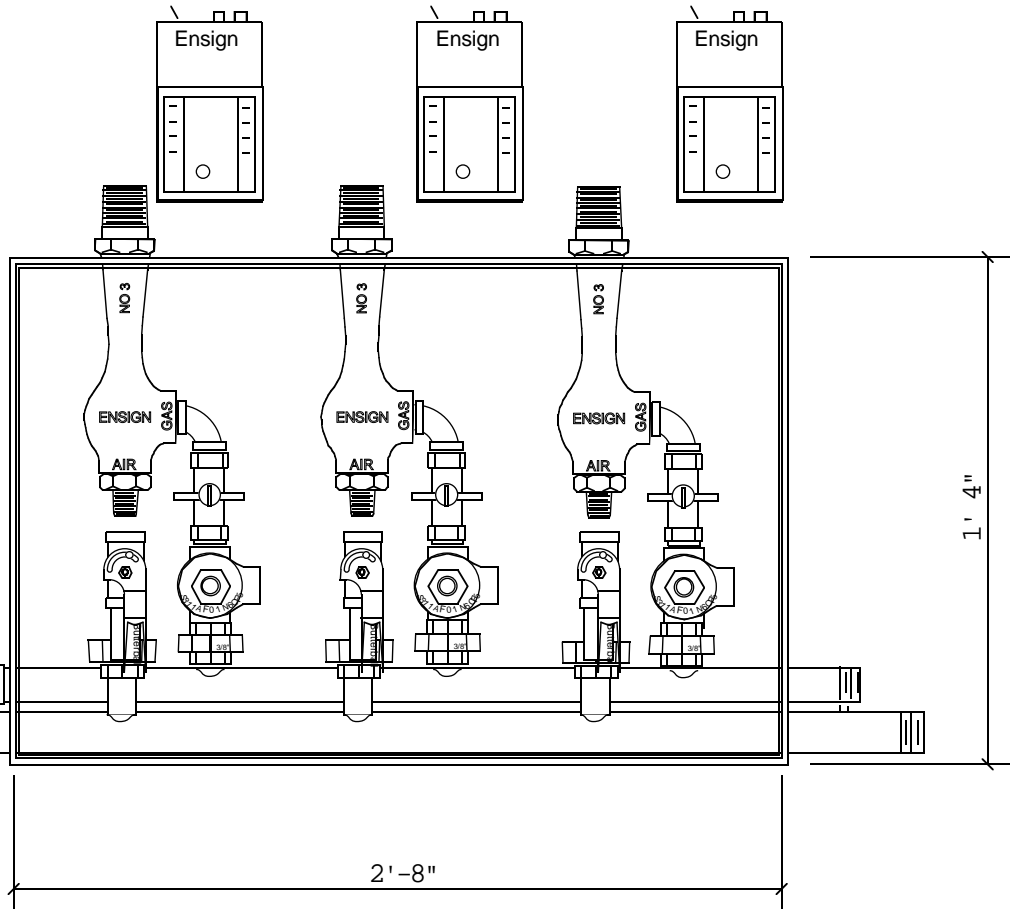
Convert Units on left into units on top by multiplying



Three Zone Adjustable Feed Equalizer 48" FS (2)



Standard Pipe Burner 72" FS (4)



(2) Sets Remote Mixer Panels with Hinged Covers, support chain and keyed latch.

1,050,000 BTU Combustion Supply System
Outputs to (2) 3 Burner remote panels with all
Required Safeties

ENSIGN Ribbon Burners LLC
101 Secor Lane Pelham Manor NY 10803

Remote Mixer System for 3 Burners

ENSIGN Ribbon Burners LLC

101 Secor Lane Pelham Manor NY 10803

Combustion Supply System 1MBTU

10/23/98

RevisionE

Combustion Supply system comes complete with 3 HP Regenerative type combustion air blower, with pressure relief valve, air filter, all piping, Double gas safety valve, flame monitoring and all electrical components. The system is fully prewired. To supply (6) Burners at 175,000 BTU's Each. (2) Hinged cover remote boxes for (3) #3-FJ Fueljectors, valves and solenoids w/ mini manifold. (6) Spark N Sense modules to be supplied for remote mounting. System to be capable of supplying 1,050,000 BTU's Total.

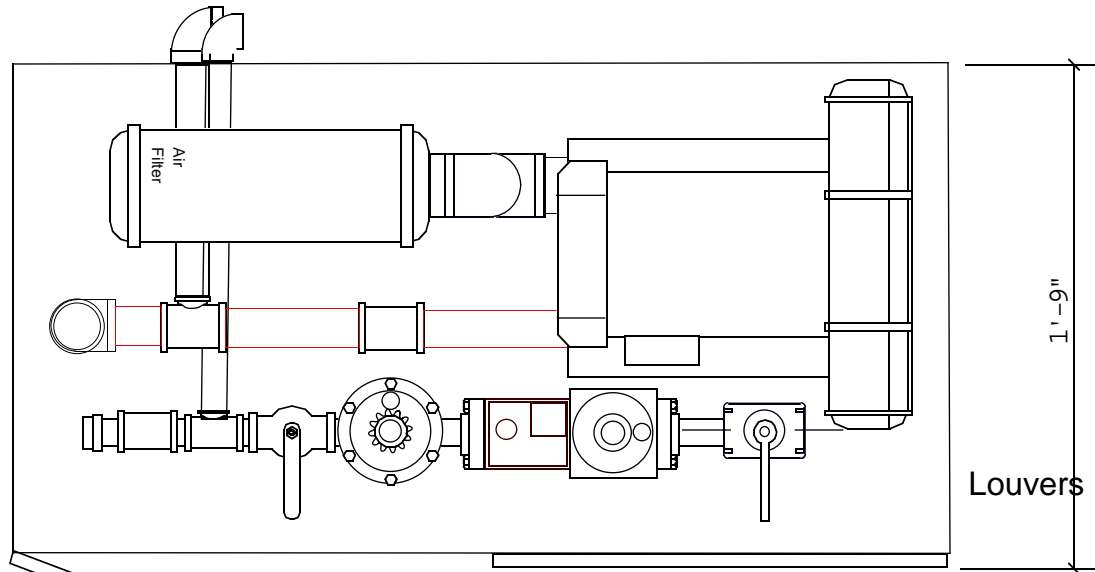
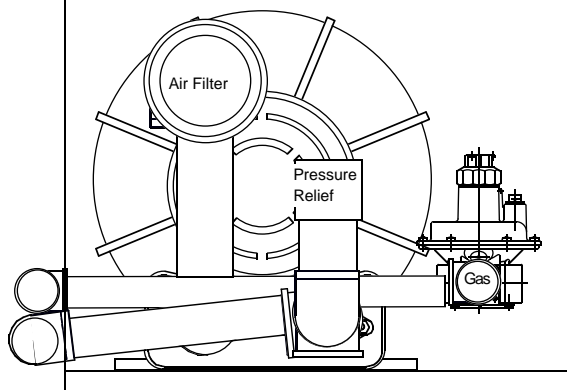
System STCUHE-RW

Electrical Control Panel

13 1/4"

2'-8 1/2"

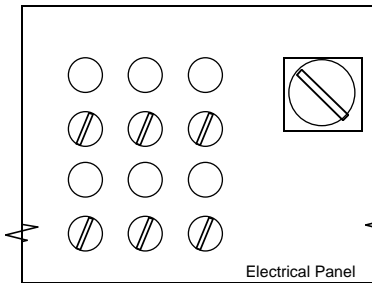
1'-9"



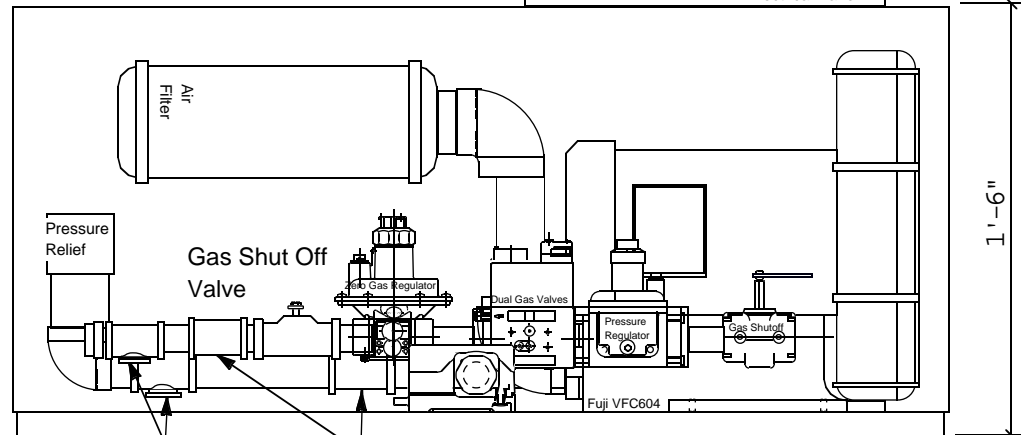
Louvers

Hinged Doors

Enclosure to have back & 2 sides removable, Hinged Doors



Electrical Panel



Air & Gas to Panel 1
Air & Gas to Panel 2

3'-3"

1'-6"



Ensign Ribbon Burners LLC

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Standard Pipe and Threads

Nominal Diameter	Wall Thickness Schedule 40	Wall Thickness Schedule 80	Actual Outside Diameter	Inside Area (Sq. In) Schedule 40	Net Wgt per foot (Lbs) Schedule 40	Threads per inch	Length of thread (engagement)
1/8"	0.068	0.095	0.405	0.057	0.244	27	
1/4"	0.088	0.119	0.540	0.104	0.424	18	
3/8"	0.091	0.126	0.675	0.191	0.567	18	0.360
1/2"	0.109	0.147	0.840	0.304	0.850	14	0.430
3/4"	0.113	0.154	1.050	0.533	1.130	14	0.546
1"	0.133	0.179	1.315	0.864	1.678	11-1/2	0.683
1-1/4"	0.140	0.191	1.660	1.496	2.272	11-1/2	0.707
1-1/2"	0.145	0.200	1.900	2.036	2.717	11-1/2	0.724
2"	0.154	0.218	2.375	3.356	3.652	11-1/2	0.756
2-1/2"	0.203	0.276	2.875	4.788	5.793	8	1.137
3"	0.216	0.300	3.500	7.383	7.575	8	1.200
3-1/2"	0.226	0.318	4.000	9.887	9.109	8	1.250
4"	0.237	0.337	4.500	12.730	10.709	8	1.300
5"	0.258	0.375	5.563	20.006	14.617	8	
6"	0.280	0.432	6.625	28.890	18.974	8	
8"	0.322	0.500	8.625	50.027	28.554	8	
10"	0.365	0.593	10.750	78.854	40.483	8	
12"	0.406	0.687	12.750	113.097	49.562	8	

Rules of thumb for piping

Adding up the cross sectional areas of multiple pipes will approximate the area of the required manifold pipe.

Manifolds should have 4-5 pipe diameters between outlets and at each end.

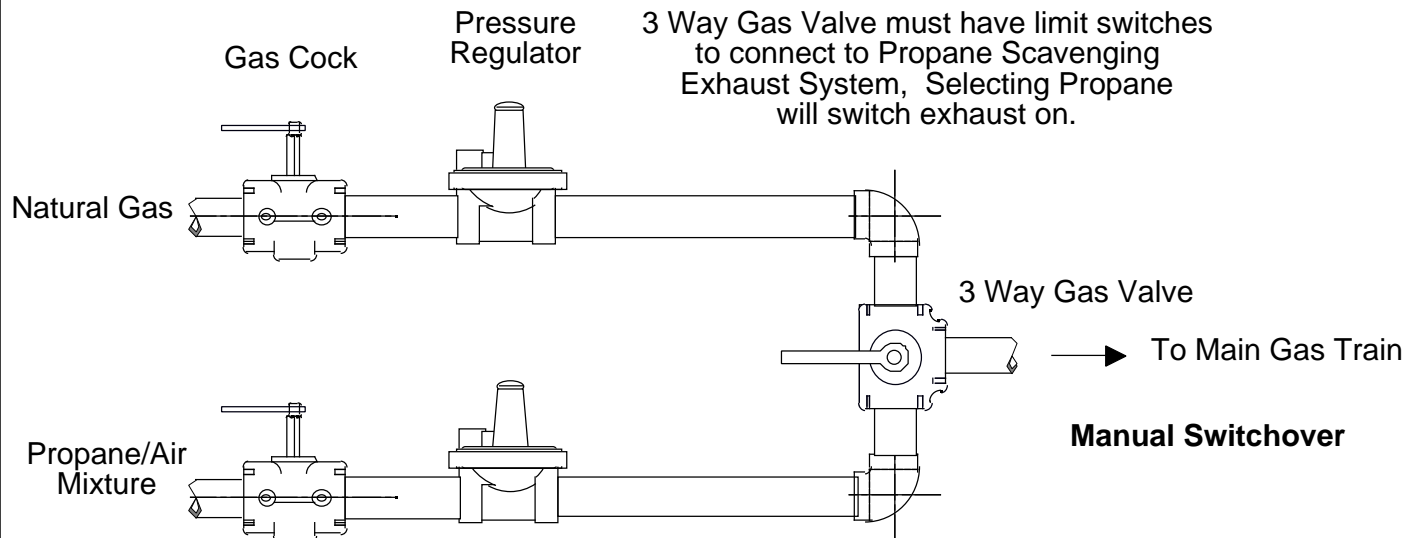
NEVER use street elbows, as their cross section is severely restricted.

Never use an elbow at the end of a manifold, as it will make it impossible to balance along the length.

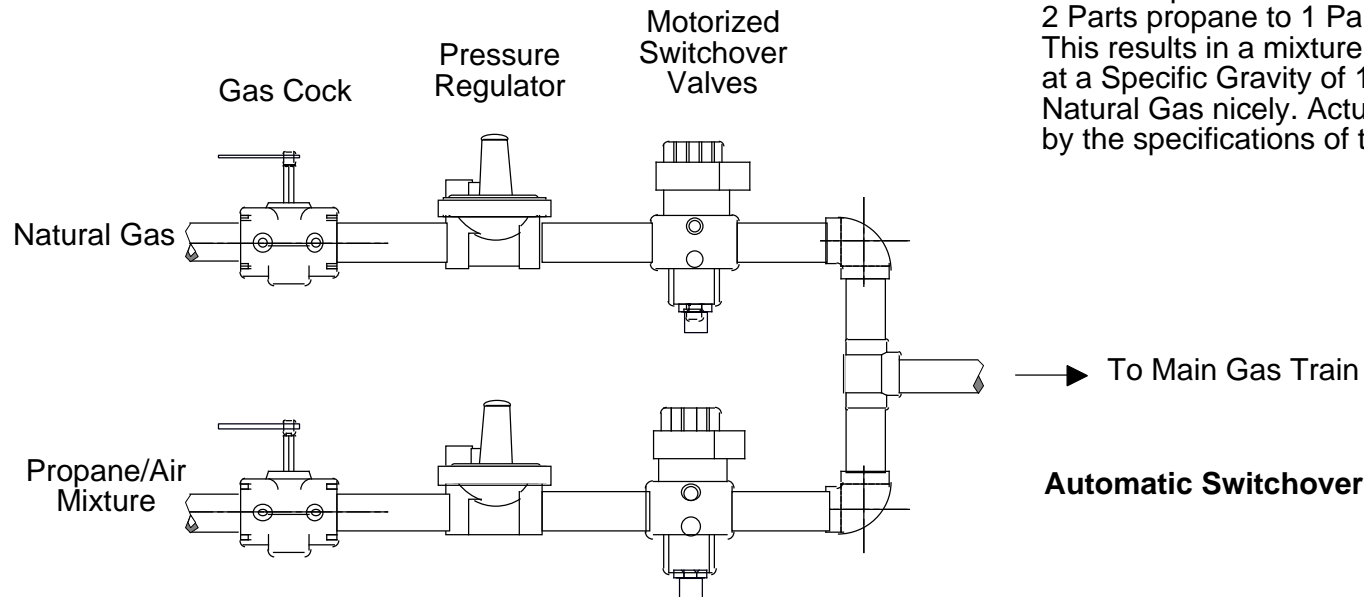
Keep all pipe manifolds the same size along their length, never step down after each fitting.

It is illegal to install control valves in the piping between the mixer and the burner.

If balancing is required, then you must use orifice plates.



Note: Propane / Air Mixture is approximately 2 Parts propane to 1 Part Air. This results in a mixture of 1300 BTU's per Cu Ft, at a Specific Gravity of 1.3, and will substitute for Natural Gas nicely. Actual percentages are determined by the specifications of the gas supply.



Propane Valve must connect to Propane Scavenging Exhaust System, Selecting Propane will switch exhaust and open this valve.

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Propane Standby Systems

SURFACE TREATMENT OF POLYOLEFINS FOR DECORATING AND ADHESIVE BONDING

Reprinted courtesy of
Phillips Petroleum Co.
Plastics Service Center
Bartlesville, OK

Polyethylene and polypropylene have chemically inert and non-polar surfaces. Surface treatment is required for acceptable adhesion of decorations, coatings and adhesives. Oxidation of polyolefin surfaces may be performed by the flame, chemical or electronic method to produce a receptive polar surface. Polyolefin resins may be decorated by any of the know methods of decorating plastic. Adhesive bonding may be accomplished by any adhesive which will "wet" a polar polyolefin surface.

All three methods of surface treatment are effective when properly used. Each is designed for particular applications and has stringent limits. The following comments are offered as a guide for the surface treatment of specific fabrication methods:

1. Film - The electrical method is the preferred approach. Electrical treating equipment is in-expensive, clean and easily adapted to in-line operations. The low amount of heat associated with electrical treatment is the primary reason for its preference over the flame method. The flame technique may be used but it is considerably more difficult.
2. Sheet - The electrical method is not normally associated with treatment of sheet because of the thickness limitations of corona discharge treatment. Approximately 25 mils is the maximum thickness of sheet that can be treated by the electrical method. For most sheet applications, the flame method is preferred. Occasionally, confusion arises over whether or not the thermoforming process provides sufficient surface oxidation to maintain adhesion of printing inks. Not only does thermoforming not provide any treatment, but it will remove any surface oxidation or treatment performed prior to forming. For thin wall thermoforms, warpage may be avoided by increasing the conveyor speed, moving the part further away from the flame tips or reducing the BTU output of the burner. All three separate, or any combination, will reduce the treatment level, so that care must be exercised to keep the level of treatment high enough for excellent adhesion .
3. Injection Molded Products - Flame treatment is normally used because of the thickness, size and shape of the parts. Avoid placing excess heat in the part which may relieve molded-in stresses and bring out flow marks. These same comments apply to thermoforming. Excess heat will also remove the gloss from a part. Sometimes this is objectionable and can be prevented as stated above. The Appendix covers the requirements and parameters of flame treatment in detail.
4. Blow Molded Products - Again, because of the wall thickness and shape of the parts, the flame method is generally used. In the case of bottles or other blow molded items which have a matte finish, the flame does not present the problem of maintaining a glossy surface. Bottles may also be treated by the suppressed spark method. This method is effective and relatively easy to use. The suppressed spark method treats the entire surface of the part so that no registration or alignment of the part to the treater is required. Parts may be placed at random on the conveyor system. The lone drawback to the suppressed spark method is the equipment cost.
5. Rotational Molded Products - The same comments apply as discussed for treating blow molded or injection molded products.

Chemical treatment is normally reserved for applications that require the entire surface of the part to be treated. Chromic acid does provide a very good treatment, but the acid weakens and must be changed

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periodically. The system is hazardous and is not recommended unless proper handling facilities are available for the acid. Vacuum metallizing and dip coating operations normally will use this method.

With proper equipment, a good lasting treatment may be achieved without undue difficulties. Properly stored parts will retain the surface treatment for a minimum of one year. Care should be taken to avoid contaminating the parts prior to treatment. Contaminants will hinder the treatment except where the chemical method is used. The acid cleans the part prior to treating. Following are some contaminants which will reduce the treatment.

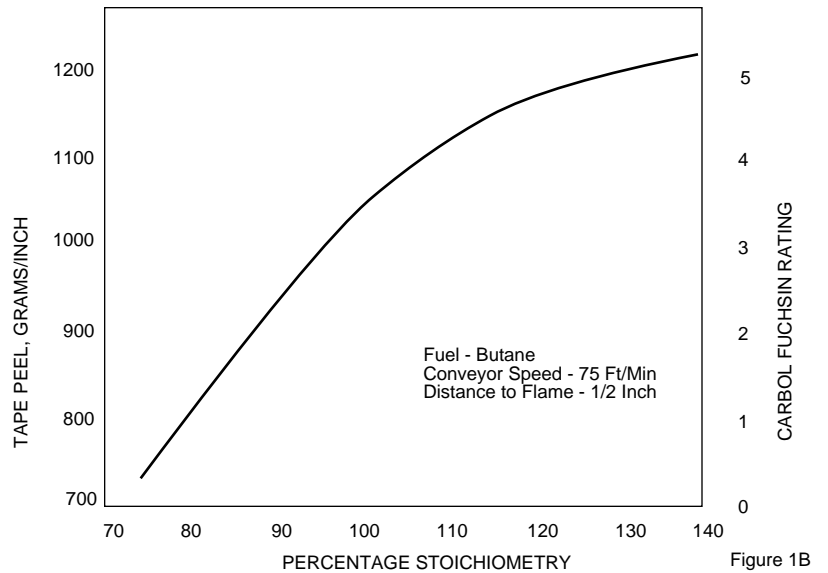
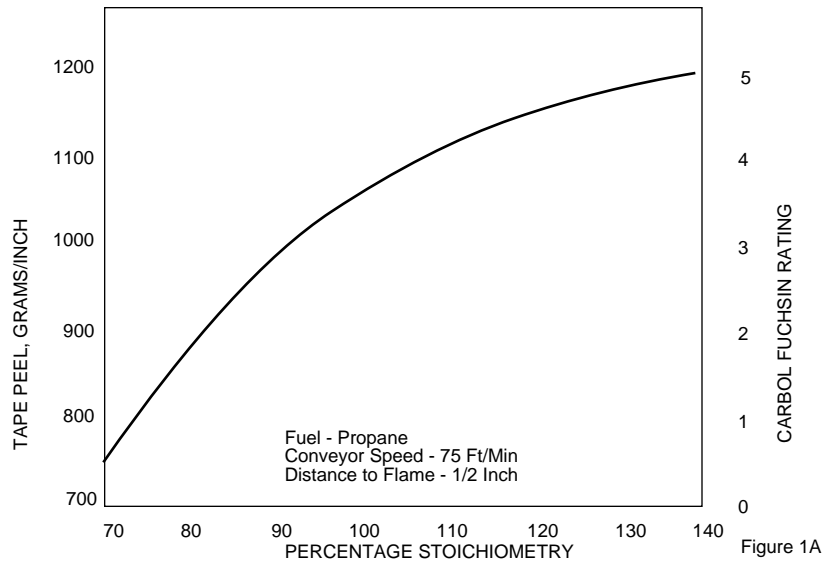
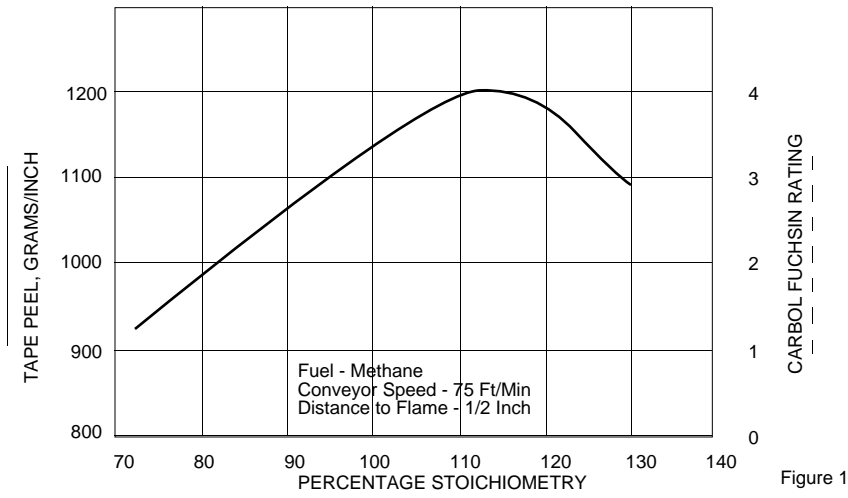
1. Additives - High concentrations of slip, antiblock and antistats can adversely affect the level of treatment. Additive blooming can be counteracted by early treatment and decorating after processing.
2. Handling - Areas handled with oily hands will not treat. Use clean white gloves to handle parts.
3. Machine Oil and Grease - Keep parts away from dirty equipment. Grease and oil spots will not treat.
4. Mold Releases - No mold releases should be allowed regardless of the advertising claims by the manufacturer.

Along with attaining good surface treatment, care should be taken to retain the treatment because surface treatment is easily removed. Since neither presence nor absence of treatment is noticeable to the naked eye, it is essential to avoid circumstances that would remove the treatment. To maintain good quality control avoid the following:

1. Excess Handling - White, clean gloves should be worn by all personnel handling the treated parts. Oily hands remove treatment. Under no circumstances should the area to be decorated be handled.
2. Wiping the Parts - Wiping treated areas with paper or cloth towels will remove the treatment. Dust or dirt should be blown off or rinsed with water and allowed to air dry. Keep parts free from dusty, dirty areas.

Since surface treatment is invisible, a good quality control method of testing the treatment is a must. The best test method to determine whether an ink or adhesive will or will not stick to the treated surface is to print or adhere a few samples, and test the samples with the Cross-Hatch Adhesion Test, or as it is sometimes called, "The Scotch Tape Test". Be sure the ink or adhesive has thoroughly cured before testing. Check manufacturer's recommendations for proper curing procedures. Discussion of decorating polyolefins is best when directed to a specific application and is beyond the scope of this TSM. Should additional advice be required for any type of decorating, please contact your nearest Phillips Sales Representative or the Sales Service Laboratory in Bartlesville, Oklahoma.

EFFECT OF AIR/GAS RATIO ON TREATMENT LEVEL



EFFECT OF DISTANCE BETWEEN PART AND INNER CONES OF FLAME

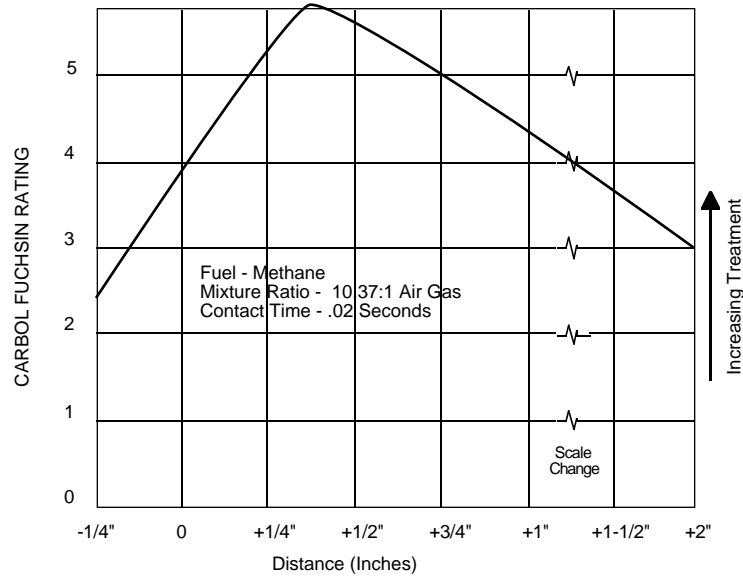


Figure 2

EFFECT OF CONTACT TIME ON FLAME TREATMENT

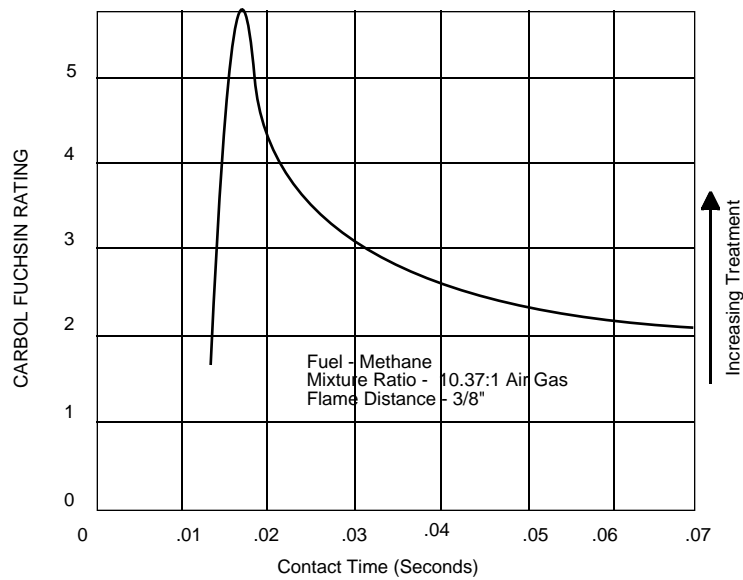


Figure 3

APPENDIX

FLAME TREATING

Flame treating is one method whereby the surface of polyolefins may be made polar through oxidation. The exact mechanism of this reaction is not known. *(Later research has led to the conclusion that the heat of the reaction serves as a catalyst, and that a chemical change takes place caused by the free reactive elements in the flame's active zone and the substrate. The basis for surface treatment success is the combustion reaction of a hydrocarbon gas. During the formation of the flame, free radicals are generated that penetrate the material being treated, thus modifying its surface wettability to achieve the optimum dyne level.)* Although many theories have been advanced, the mechanism is not essential to this treating method. The treatment by an oxidizing flame is accomplished by operating within the parameters of three main variables involved in this method. The closer to optimum each variable can be set, the higher the resulting treatment level.

Any part of reasonable size or shape may be treated. The primary consideration will be the uniformity with which the flame will contact the area to be treated. The surface should not vary in distance from the burner more than one inch. In the case of cylindrical parts, they may either be rotated through a straight burner flame or dropped through a ring burner.

The surface to be treated must be free from dust, moisture, grease, mold release agents or any other foreign contaminants. Under no circumstances should the area to be treated be touched, handled or contaminated before or after treatment.

Apparatus

1. Gas Flow Meter - Capable of delivering a required volume of gas to achieve BTU rating of burners.
2. Air Flow Meter - Capable of delivering at least 15% greater volume of air than required for combustion of gas.
3. Air-Gas Mixer - Venturi type, capable of mixing total volumes of air and gas.
4. Calibration Flow Curves - Required for both air and gas flow meters. Flow rates should be given in SCFH or SCFM at standard conditions of 14.7 psia and 70°F for air (specific gravity of 1).
5. Air Regulator - Capable of reducing from plant pressure to a constant 25 psig. Size to permit required air flow with no restriction.
6. Gas Regulator - Capable of reducing pressure to a constant 0.25 psig to 1.0 psig. Size to permit required gas flow with no restriction.
7. Air Pressure Gauge - 0 to 50 psi range.
8. Gas Pressure Gauge - 0 to 1 psi to 5 psi range.
9. Needle Valves - Required on air and gas mixer to closely control flow rates.
10. Burner - Designed to give adequate flame pattern for treating.
11. Conveying Method - To move the part through the flame at a constant rate of speed. Provision should be made to allow rapid adjustment of speed of the conveyor such as a variable speed drive or adjustable incline platform. Provisions for proper alignment and support of part are required .
12. Provisions for adjustment of the distance between the burner and the part.

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Standardization and Calibration of equipment

For the flame treating system to function properly, the equipment must be properly sized and installed in a specified manner. Various factors must be calculated to insure maximum efficiency of the system.

Sizing the flow meters: The flow meter sizes will be determined by the BTU/hr. rating of the burner or burners being used. The heat of combustion of the fuel gas being used will set the maximum flow rates of the meters. The heat of combustion of the common fuel gases are

Methane (city gas)	1000. BTU/SCF
Propane	2500 BTU/SCF
Butane	3100 BTU/SCF

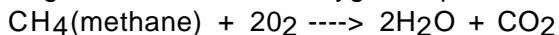
If a burner is rated at 30,000 BTU/hr., it will require 30 SCFH of methane, 12 SCFH of propane or 9.68 SCFH of butane. The gas flow meter will then be sized to permit these values to be the maximum flow rate. A sizing correction factor must also be used and is discussed in detail later in this TSM.

The air flow meter is then sized according to the maximum gas flow rate by the following method

Maximum flow rate of air = maximum flow rate of gas x amount of air required for combustion x sizing correction factor. (10 CF Air / 1000 BTU's of Gas to be burner)

Calculation of the Stoichiometry of the Gas

All hydrocarbon gases combine with oxygen to produce heat in the following manner:



The prior equation indicates complete combustion of the fuel gas methane. The problem is how much air is required to complete this combustion for a given volume of any hydrocarbon gas. The following equation can be used to determine this value:

Equation 1

$$V = \frac{(A \times \% \text{CH}_4) + (B \times \% \text{C}_2\text{H}_6) + (C \times \% \text{C}_3\text{H}_8) + (D \times \% \text{C}_4\text{H}_{10}) + (E \times \% \text{H}_2 + \text{CO})}{100}$$

V = volumes of air required to complete combustion for 1 volume of gas.

A = 9.56 = volumes air required to combust one volume CH₄ .

B = 16.7 = volumes air required to combust one volume C₂H₆.

C = 23.8 = volumes air required to combust one volume C₃H₈.

D = 31.0 = volumes air required to combust one volume C₄ H₁₀

E = 2.40 = volumes air required to combust one volume H₂ and CO.

If any of the above components are not present in the mixture, equate their volume percent to zero. Non-combustibles such as nitrogen and carbon dioxide are neglected

The composition of the fuel gas may be obtained from the gas service company or from an analyst. The percent composition must be in volume percent. If the molar percent is given, it must be converted to volume percent.

A fuel gas has the following composition by volume percent:

Methane	(CH ₄)	85.0 %
Ethane	(C ₂ H ₆)	4.5 %
Propane	(C ₃ H ₈)	2.1 %
Butane	(C ₄ H ₁₀)	1.6 %
Hydrogen	(H ₂)	2.0 %
Carbon Monoxide	(CO)	0 %
Nitrogen	(N ₂)	3.4 %
Carbon Dioxide	(CO ₂)	<u>1.4 %</u>
		100 %

$$V = \frac{(9.56 \times 85) + (16.7 \times 4.5) + (23.8 \times 2.1) + (31.0 \times 1.6) + (2.4 \times 2.0)}{100}$$

V = 9.92 volumes of air required for complete combustion of one volume of gas.

This figure now represents 100% stoichiometric ratio. An addition of excess air will increase this ratio resulting in an oxidizing flame, whereas a decrease in air will decrease the ratio resulting in incomplete combustion. Example: 15% excess air = 115% stoichiometric ratio = 11.41/1 air gas ratio for the above gas. A flame containing an excess of air is referred to as an oxidizing flame; a flame that does not have sufficient air to complete combustion is a reducing flame.

SIZING CORRECTION FACTOR

The sizing factor compensates for the operating temperature, pressure and specific gravity of the gas versus the values used for calibration. Calibration values are 70 F, 14.7 psia and specific gravity of air (1.0).

The sizing factor is calculated as follows:

Equation 2

$$\text{Sizing Factor} = \sqrt{\text{SpGr}_2 / \text{SpGr}_1 \times T_2 / T_1 \times P_1 / P_2}$$

Where:

SpGr₁ = specific gravity of air (1.0).

SpGr₂ = specific gravity of gas to be metered.

(City gas = approx. 0.62, propane = 1.56, butane = 2.06).

T₁ = 530°R or absolute 0 (460° R + 70 F = 530° R)

T₂ = absolute operating temp. (+ 460 °R + operating temp.).

P₁ = absolute pressure of one standard atmosphere - 14.7.

P₂ = absolute operating pressure (14.7 + gauge reading).

This formula will yield the sizing factor to obtain the maximum equivalent air flow rate.

Example; Flow meters are required for a flame treating system that will produce 90,000 BTU/hr. The

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Example; Flow meters are required for a flame treating system that will produce 90,000 BTU/hr. The fuel gas is methane (1000 BTU/SCF) and has an air to gas ratio of 10.5/1. The average plant temperature is 90°F and four ounces (0.25 lb.) of gas pressure is available. The operating pressure for the air will be 25 psig.

$$\text{Gas Sizing Factor} = \sqrt{0.62/l \times 550/530 \times 14.7/14.95} = \sqrt{0.63} = 0.79$$

$$\text{Air Sizing Factor} = \sqrt{1/1 \times 550/530 \times 14.7/39.7} = \sqrt{0.384} = 0.61$$

Thus, sizing factor x maximum metered gas flow (SCFM)= maximum air flow equivalent (SCFM).

In the example, 90 SCFH of methane will be required to produce 90,000 BTU/hr., or 90 SCFH/60 =1.5 SCFM of gas required. The 1.5 SCFM of gas flow must be converted to air flow for meter sizing. The conversion calculation is: Required SCFM of gas times gas sizing factor equals air flow equivalent (i.e. 1.5 x 0.79 = 1.19).

Since the air/gas ratio is 10.5/1, 10.5 more volumes air will be required than gas. Thus, 10.5 x 1.5 = 15.75 SCFM of air will be required for 100% combustion. Since 15% excess air will be needed, the total required air flow will equal 15.75 x 1.15 =18.13 SCFM. Equivalent air flow will equal 18.13 SCFM x 0.61 (air sizing factor) = 11.06 SCFM. Therefore, meters with 1.19 SCFM and 11.06 SCFM maximum flow rates for air at 70°F and 14.7 psia would be required.

Correction Factor

The calibration curves obtained with the flow meters are for a given set of conditions, as mentioned earlier. The following correction factor formula is used to obtain the actual flow rates.

Equation 3

$$\text{Correction Factor} = \sqrt{\text{SpGr}_1/\text{SpGr}_2 \times P_2/P_1 \times T_1/T_2}$$

The nomenclature is the same as for the sizing factor.

The value obtained from this equation is then multiplied by the flow rate of the calibration curve to obtain the exact flow rate in SCFM or SCFH.

Example: A flow meter is operating at 25 psig, 90°F with Butane (Sp.Gr. = 2.06). The calibration curve indicates flow to be 2.25 SCFM.

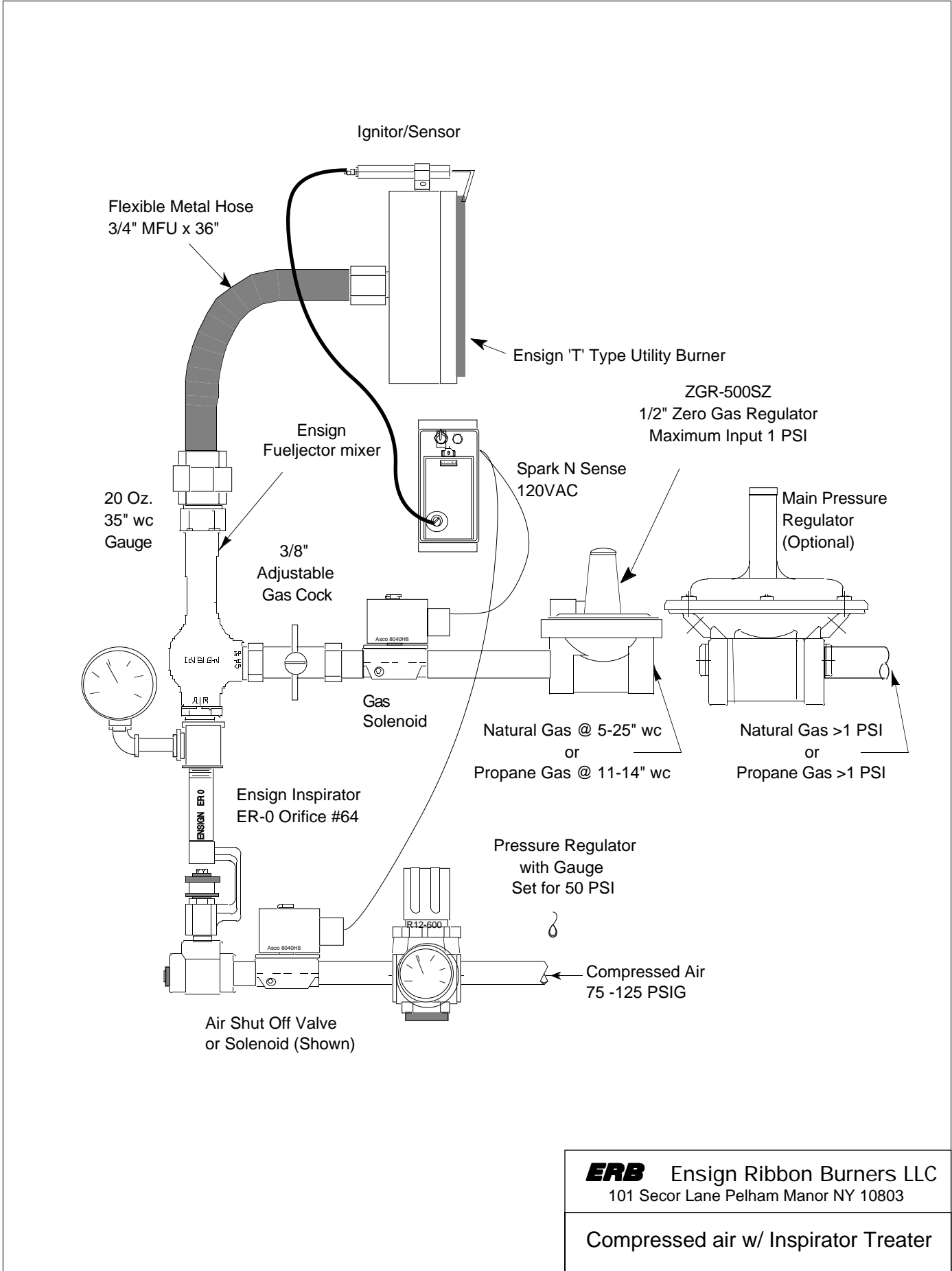
$$\text{Correction Factor} = \sqrt{1/2.06 \times 39.7/14.7 \times 530/550} = \sqrt{1.26} = 1.12$$

$$\text{Actual Flow} = 1.12 \times 2.25 = 2.52 \text{ SCFM.}$$

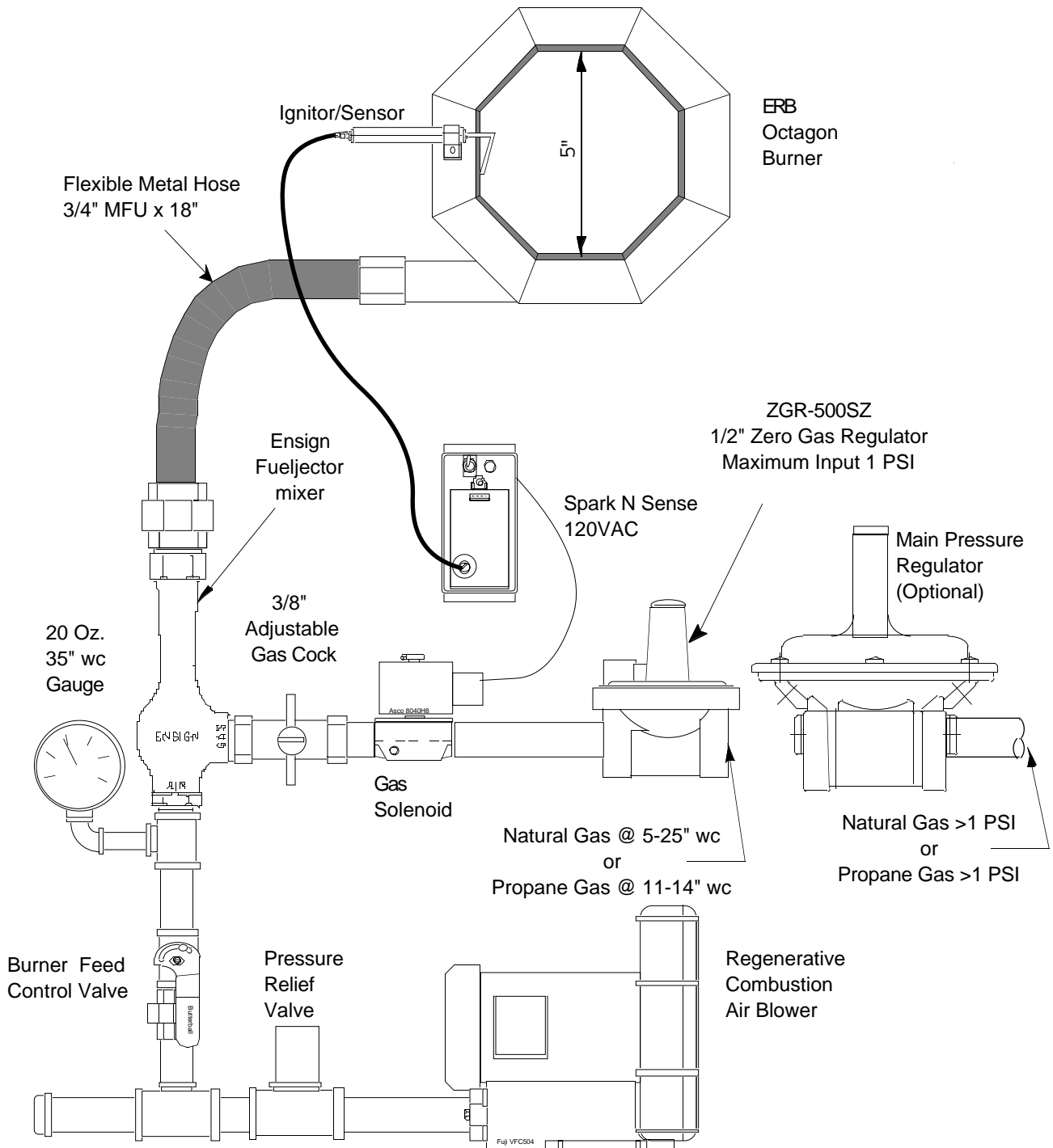
NOTE: Calibration values are given in either standard cubic feet per hour (SCFH) or standard cubic feet per minute (SCFM). Caution should be exercised to work with the same units. Example: SCFH 60 = SCFM, SCFM x 60 = SCFH.

The flow meters, valves, gauges and pressure regulators must be installed as per the following schematic flow diagram.

SCHEMATIC VIEW - AIR/GAS MIXTURE SYSTEM

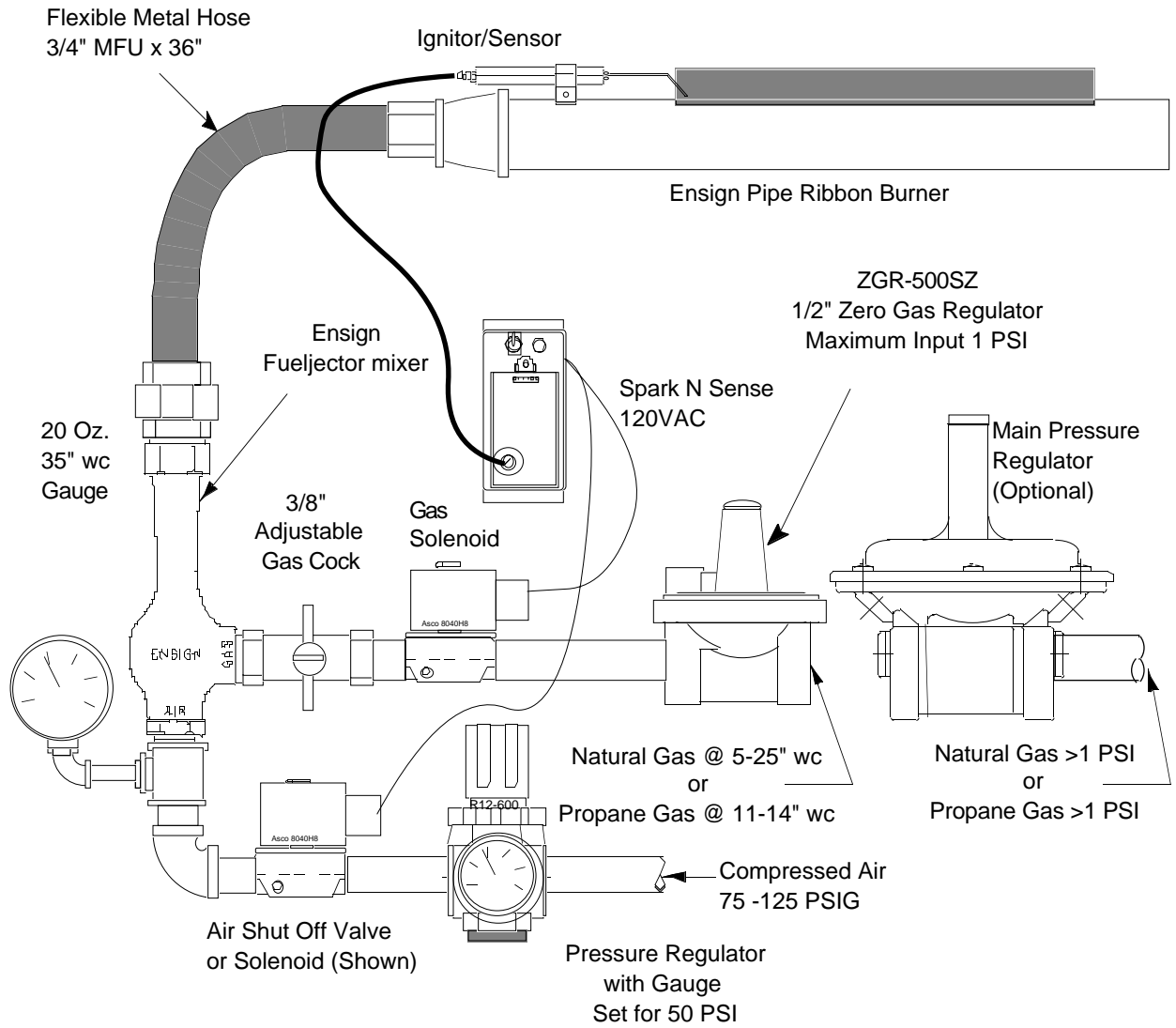


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 Compressed air w/ Inspirator Treater



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Pressure Blower Treater



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Compressed Air Treater

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Procedure

1. Calculate gas flow to give required BTU output of burners. Use flow correction factor to find millimeters flow setting for the gas flow meter.
2. Calculate air to gas ratio.
3. Using air to gas ratio, calculate air flow required to obtain 110% stoichiometric ratio. Use correction factor to find millimeters flow setting for the air flow meter.
4. Set air and gas flows on values obtained and ignite burners. Ignition should occur only after the proper stoichiometric ratios have been attained. This will prevent a flash fire.
5. Set distance between visible blue tip of flame and surface to be treated at 1/2".
6. Start conveyor and set speed at 75 fpm (feet per minute).
7. Treat part and perform suitable surface treatment test.
8. If part did not treat, increase or decrease conveyor speed until treatment is obtained to a water wet level.
9. A slight adjustment may now be made in the air/gas ratio of the flame to obtain the optimum treatment. To determine optimum treatment, the water film in the water wet test should hold till evaporation.

Interpretations

Three main variables control the maximum treatment level. These variables are: 1) air to gas ratio; 2) distance of surface to be treated from visible blue tips of flame; and 3) speed with which part passes through flame. These variables may change slightly with resin type, BTU output of the burner or burner design.

1. Air to Gas Ratio - The most critical of the three variables is the air to gas ratio, which must be closely controlled to achieve consistent flame treating. Air combusts with a hydrocarbon gas according to the following equation : $\text{CH}_4 \text{ (Methane) } + 2\text{O}_2 \text{ --> } 2\text{H}_2\text{O} + \text{CO}_2$.

Equation 1 permitted the calculation of the volumes of air required to complete combustion of any hydrocarbon gas. A flame that has an excess amount of air is called an oxidizing flame and one that does not have enough air to complete combustion is called a reducing flame. A part may be treated only to the level that the flame is capable of producing in an optimized system regardless of the number of passes through the flame. Treatment level increasing with repeated passes indicates surface contamination being removed by flaming or excessive conveyor speeds. The effect of air to gas ratio is shown in Figure 1.

Normal operating values for the air to gas ratio will be in the range of 105 to 115% stoichiometric. The exact amount will depend on the gas being used and the resin type. This optimum value should be found by trial and error methods using a surface treatment test.

2. Distance of Surface From Flame Tips - The optimum distance has been proven from numerous tests to be 3/8" to 1/2". It may not always be possible to achieve this exact distance over the entire area to be treated due to surface variation. In this event, 3/8" should be considered a minimum distance between the flame and the innermost surface to be treated. The actual treating portion of the flame extends approximately 1 1/2" beyond the flame tip, with 1/2" being capable of producing the highest level of treatment. The surface to be treated should never

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come in contact with the blue tip of the flame. This is the reducing zone of the flame and treatment will be greatly decreased. Figure 2 illustrates the treating distance of the flames.

3. Contact Time - This variable must be closely controlled to achieve optimum treatment. Contact time is controlled by how fast the part is passed through the flame and depends on burner width, heat of combustion of gas, BTU output of the burner and resin type. The optimum speed must be determined by trial and error using the following guidelines:
 - A. Set conveyor speed at 75'/minute and treat a part.
 - B. If part is distorted or surface melting is observed, increase speed in increments of 10'/minute until acceptable treatment is accomplished.
 - C. If no treatment is present and part is not dulled or excessively warm, pass part through flame again. If treatment is noted, slow conveyor down and repeat previous step. Continue to decrease speed until treatment is accomplished.
 - D. Polypropylene requires a higher conveyor speed than polyethylene.
 - E. If the BTU output of the burners is decreased by 50%, the conveyor speed must be increased by 50%. An exact amount of energy must be imparted to the surface to achieve treatment.

Figure 3 shows the relationship of contact time versus treatment level. With high density polyethylene, the BTU output of the burner was held constant at 30,000 BTU/hour and the distance of the flame tip to the part was 3/8". All three variables should be adjusted to optimum levels to attain the highest level of treatment possible. It will then be possible to properly store treated parts for extended periods of time with no significant decrease in treatment.

FUCHSIN DYE TEST

Significance

This test is primarily concerned with determining the degree to which the dye will stain a treated polyolefin surface. The dye is absorbed onto a treated surface and the color intensity produced is a measure of the surface treatment level. When applied as specified in the SPI Recommended Practice for Determining Level of Surface Treatment for Decoration of Polyethylene, the results can be used as part of production control or customer specifications. A relationship regarding the success with which a satisfactory decoration can be applied may be derived from the results.

Apparatus

1. Carbol Fuchsin Stain, Matheson, Coleman & Bell, CX390 or equivalent.
2. Distilled Water
3. Beaker
4. Disposable Gloves

Test Specimens

A treated polyolefin item regardless of size, weight or shape may be tested. No set number of specimens

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is required Specimens with surface contaminants are to be avoided, for they may interfere with the color intensity produced by the test procedure.

Conditioning

Care should be taken that dust, dirt, grease, release agents or additives are not present or do not collect on the surface of the test specimens. Under no conditions should there be handling of the test area. Standard conditions are not a paramount consideration; however, tests should be performed under a reasonable temperature and humidity environment.

Procedure

1. Prepare the dye solution by dissolving one gram of carbol fuchsin in 100 ml of distilled water. Agitation will be required to insure that all particles of dye are in solution. The dye solution can be reused. Store in tightly closed container to prevent contamination.
2. Immerse the test area in the dye solution for four to six seconds.
3. Remove the test area from the dye solution and allow to drain in a vertical position for four to six seconds.
4. Flush test area with a gentle stream of tap water for 10-15 seconds to remove excess dye solution.
5. Allow test area to dry without wiping.

Interpretations

- A. The dye solution is not light stable and grading the color intensity should be done immediately after test area is thoroughly dry.
- B. The completeness of the correlation would depend on the object of testing. For example, in order to judge if a specific container has been treated sufficiently to accept a particular decoration, only one correlation is required. All test specimens equal to, or greater than, the standard in color intensity would be acceptable, while all less than the standard would be rejected.
- C. The grading of color intensity is arbitrary; and consequently the test cannot be accurately correlated between laboratories.
- D. A rating scale of 5 has been established using variable treatment levels:
 - 0 - untreated
 - 3 - Water wet level
 - 5 - highest level

WATER WET TEST

Significance

This test is concerned with determining the degree to which a water film will adhere to a treated polyolefin surface. Water does not form a continuous film on an untreated polyolefin surface. Alteration of the surface by treating enhances the adhesion of a water film to some degree, relative to the level of treatment. When applied as specified in the SPI Recommended Practice for Determining Level of Surface Treatment for Decoration of Polyethylene, the results can be used as part of production control or customer specifications. A relationship regarding the success with which a satisfactory decoration can be applied may be derived from the results.

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Test Specimens

Any treated polyolefin item, regardless of size, weight or shape, may be tested. No set number of specimens are required. The area to be tested should not contain surface imperfections which will mechanically aid in maintaining a water film.

Conditioning

Care should be taken that dust, dirt, grease, release agents or additives are not present or do not collect on the surface of test specimens. Under no condition should there be handling of the test area. Standard conditions are not a paramount consideration; however, tests should be performed under a reasonable temperature and humidity environment.

Procedure

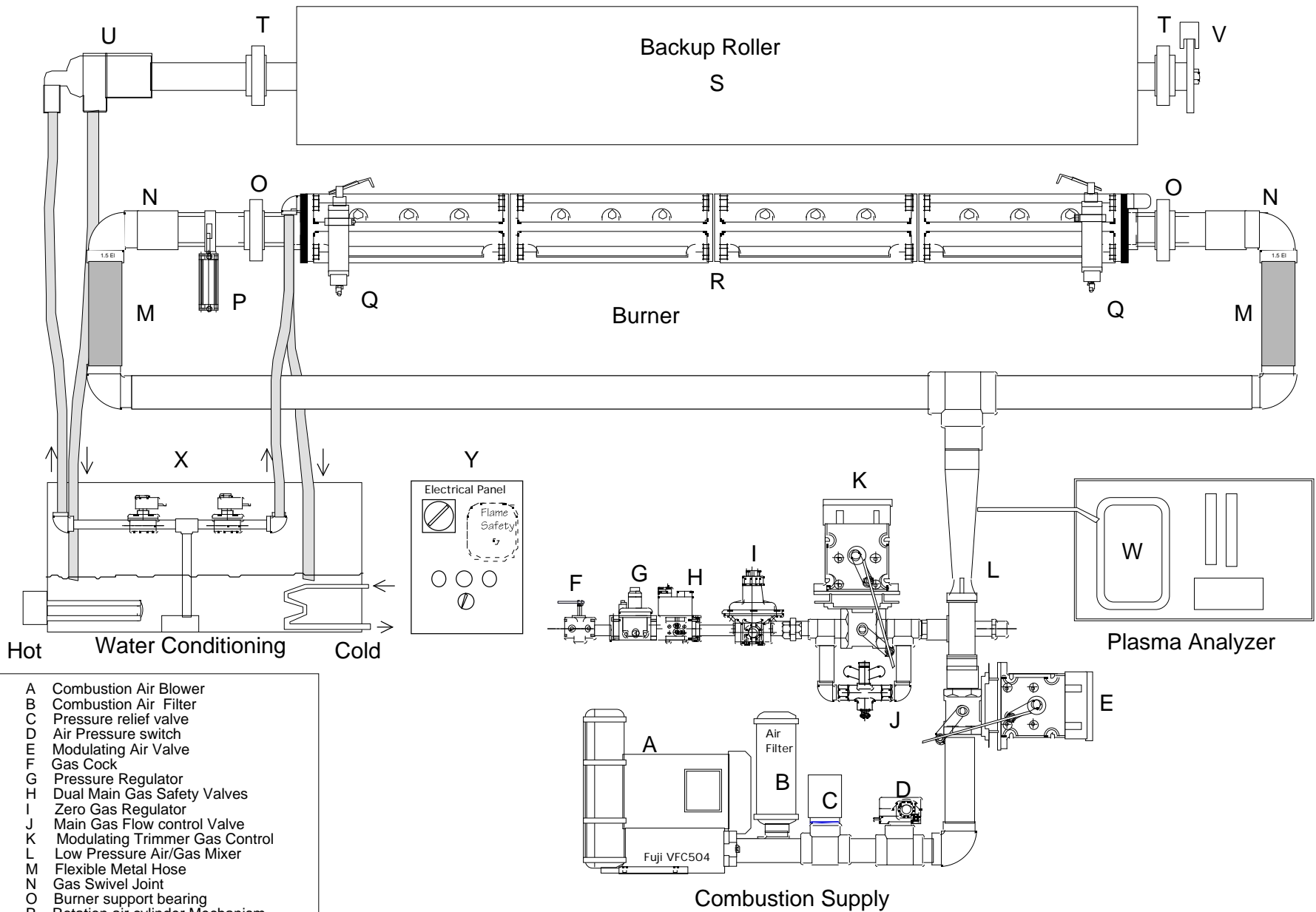
1. Immerse the test area in distilled water for at least three seconds to wet the entire surface (Note 1). An alternate technique for large test areas is to flush the test area for at least three seconds.
2. Remove or cease flushing the test area, please test area in a vertical position, and observe the time that a continuous water film remains in the test area. Sixty seconds is a sufficient observation time.

NOTE 1: Water should be changed periodically to make sure that surface active agents do not contaminate the test water. The test water temperature should be between 65°F and 95°F.

Interpretations

- A. A film of water which breaks immediately is considered to be below the water wet level.
- B. A film of water which remains continuous for 5-10 seconds is considered to be water wet.
- C. The time the water film remains continuous is directly related to a treatment level above water wet.
- D. A continuous film may exhibit peripheral shrinkage and the speed of the shrinkage is dependent on the treatment level.
- E. Higher levels of treatment will maintain a continuous film of water until evaporation occurs.

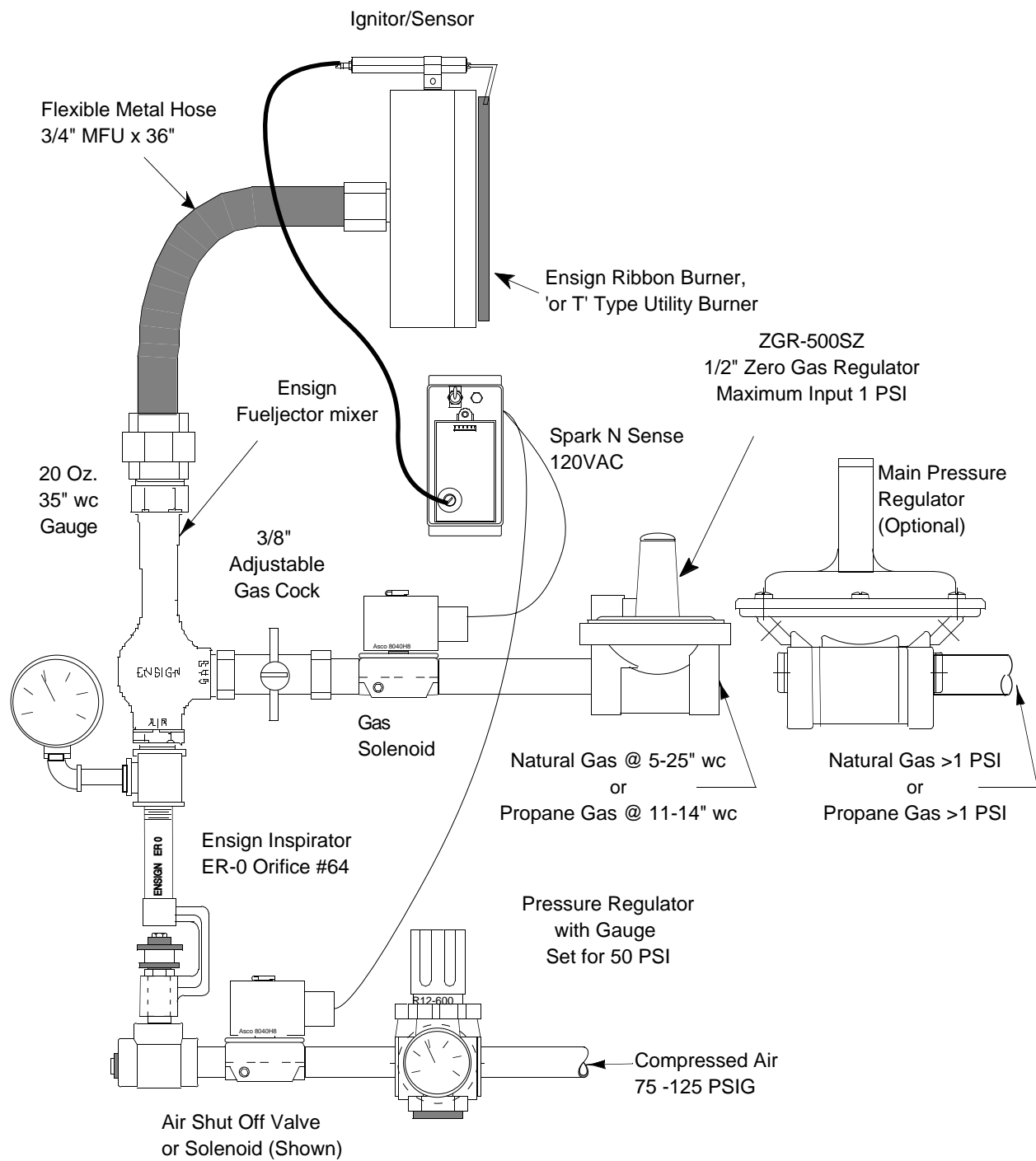
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- A Combustion Air Blower
- B Combustion Air Filter
- C Pressure relief valve
- D Air Pressure switch
- E Modulating Air Valve
- F Gas Cock
- G Pressure Regulator
- H Dual Main Gas Safety Valves
- I Zero Gas Regulator
- J Main Gas Flow control Valve
- K Modulating Trimmer Gas Control
- L Low Pressure Air/Gas Mixer
- M Flexible Metal Hose
- N Gas Swivel Joint
- O Burner support bearing
- P Rotation air cylinder Mechanism
- Q Ignition / Sensing Probes
- R Ensign Water cooled burner
- S Water Cooled Backup roller
- T Roller support bearings
- U Water Rotary Joint
- V Speed pickup tachometer
- W Plazma Analyzer
- X Water conditioning system
- Y Main Electrical control panel

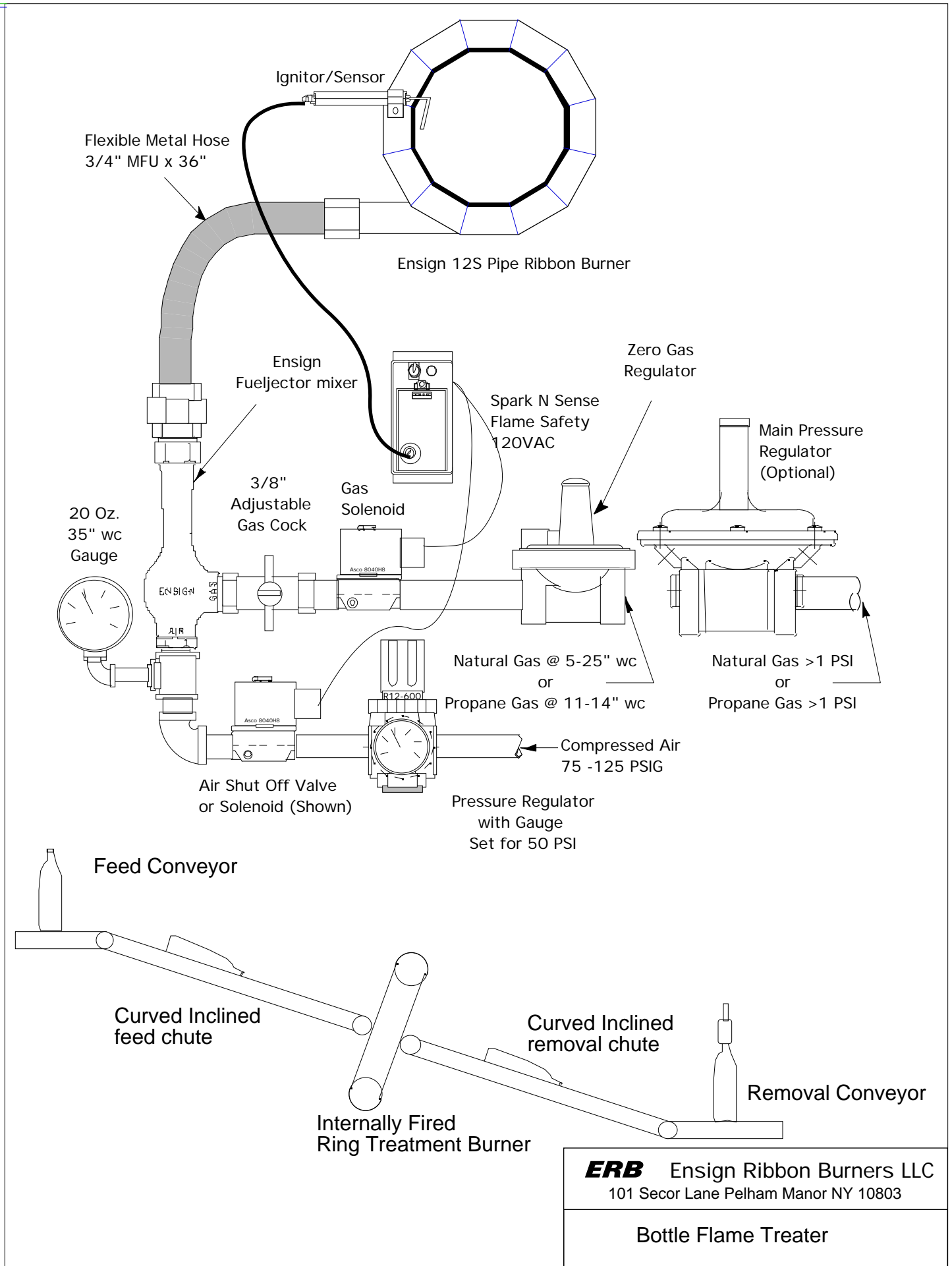
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Pre/Post Treatment System



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Treatment Setup



Flexible Metal Hose
3/4" MFU x 36"

Ignitor/Sensor

Ensign 12S Pipe Ribbon Burner

Ensign
Fueljector mixer

Zero Gas
Regulator

Spark N Sense
Flame Safety
120VAC

Main Pressure
Regulator
(Optional)

20 Oz.
35" wc
Gauge

3/8"
Adjustable
Gas Cock

Gas
Solenoid

Natural Gas @ 5-25" wc
or
Propane Gas @ 11-14" wc

Natural Gas >1 PSI
or
Propane Gas >1 PSI

Compressed Air
75 -125 PSIG

Air Shut Off Valve
or Solenoid (Shown)

Pressure Regulator
with Gauge
Set for 50 PSI

Feed Conveyor

Curved Inclined
feed chute

Curved Inclined
removal chute

Removal Conveyor

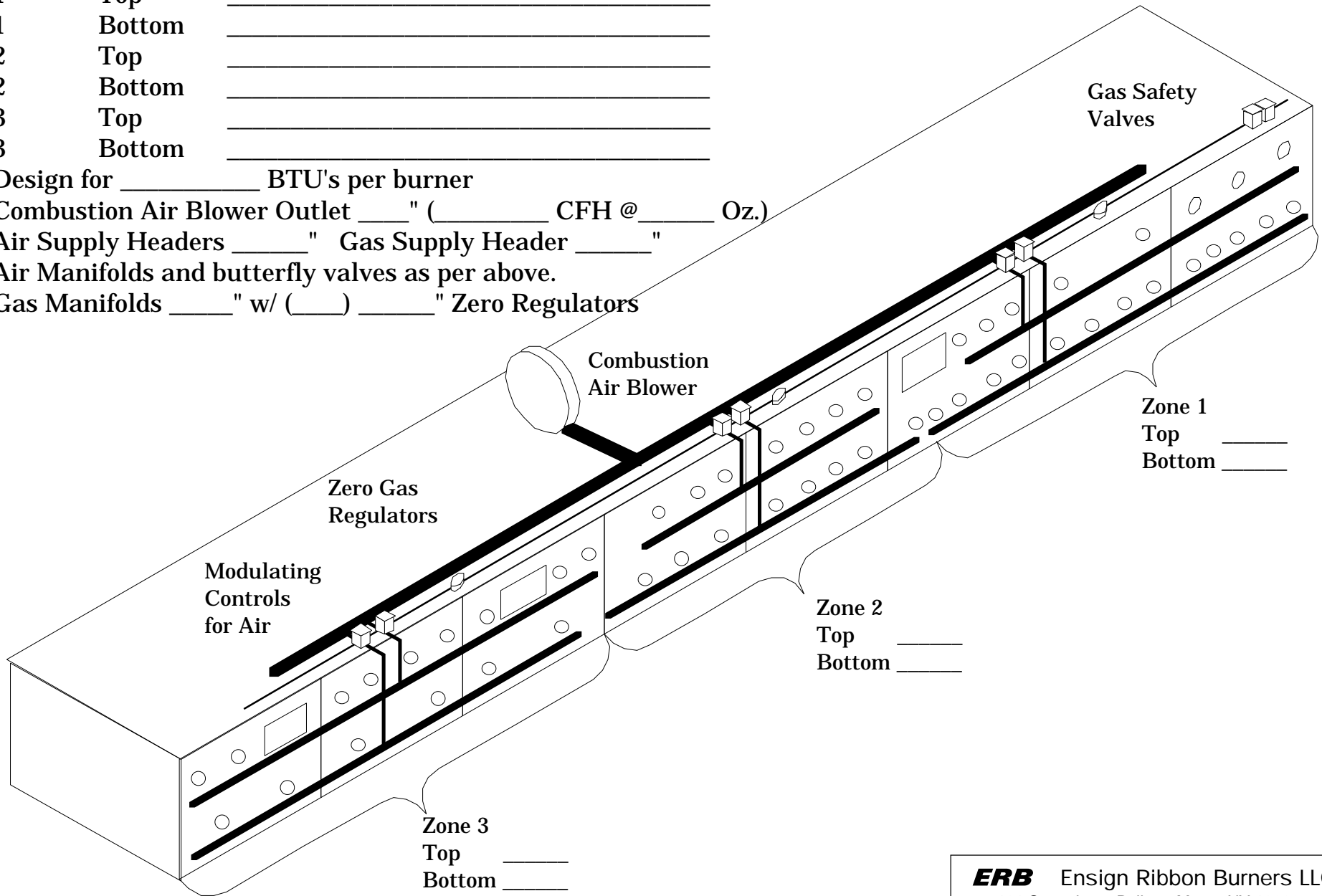
Internally Fired
Ring Treatment Burner

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Bottle Flame Treater

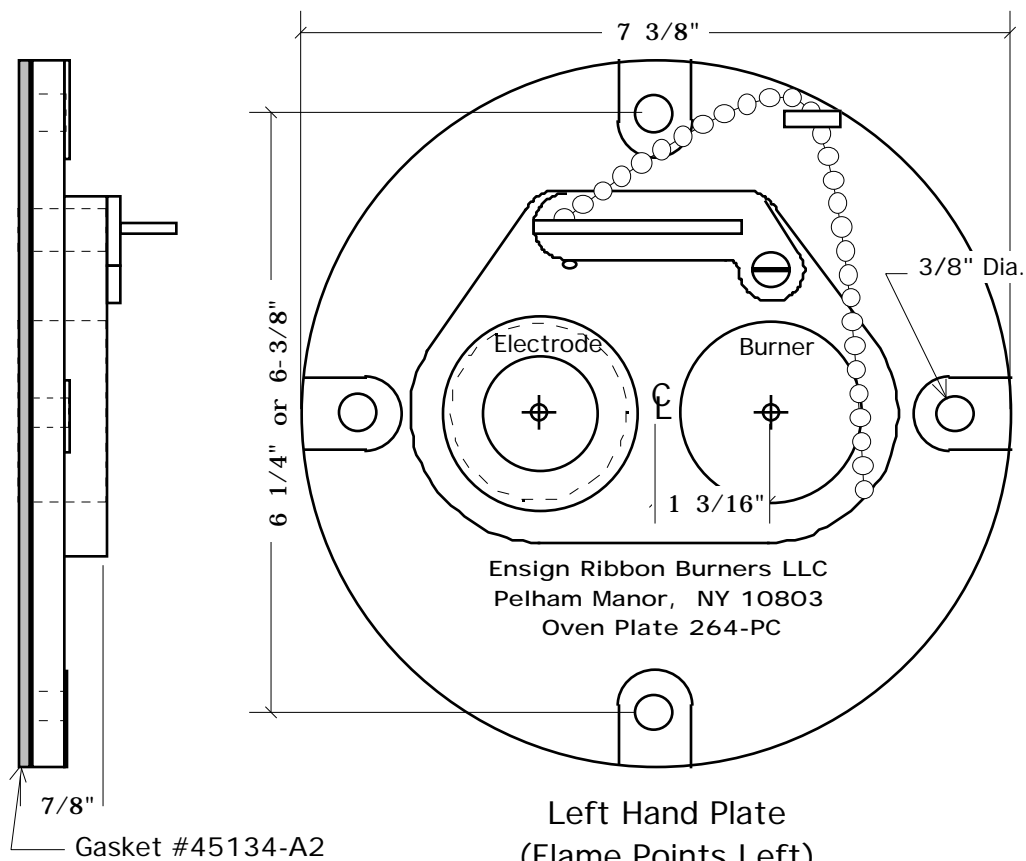
Zone	Position	Burners	Air	Gas	Air Manifold & Valve
1	Top	_____	_____	_____	_____
1	Bottom	_____	_____	_____	_____
2	Top	_____	_____	_____	_____
2	Bottom	_____	_____	_____	_____
3	Top	_____	_____	_____	_____
3	Bottom	_____	_____	_____	_____

Design for _____ BTU's per burner
 Combustion Air Blower Outlet _____" (_____ CFH @ _____ Oz.)
 Air Supply Headers _____" Gas Supply Header _____"
 Air Manifolds and butterfly valves as per above.
 Gas Manifolds _____" w/ (____) _____" Zero Regulators

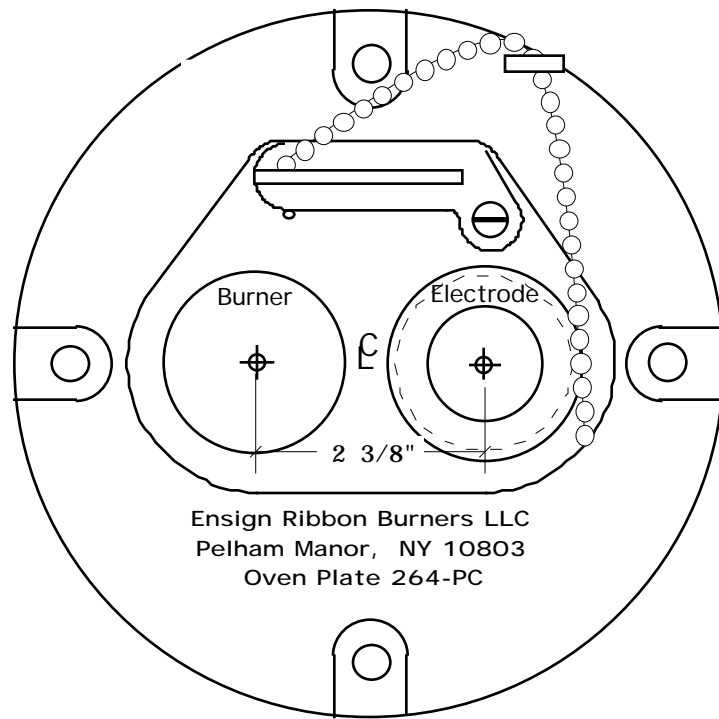


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Burner Layout - Tunnel Oven



Left Hand Plate
(Flame Points Left)
Top Burner Plate*



Right Hand Plate
(Flame Points Right)
Bottom Burner Plate*

* When used with burners firing vertically

Part # for Plates

800-040-4-__ 1" Burner

800-040-5-__ 1-1/4" Burner

800-040-6-__ 1-1/2" Burner

800-040-8-__ 2" Burner

First blank to be E (6-1/4" Bolt Centers) or F (6-3/8" Bolt Centers)

Second Blank to designate Left Hand (L) or Right Hand (R)

ERB Ensign Ribbon Burners LLC
101 Secor Lane Pelham Manor NY 10803

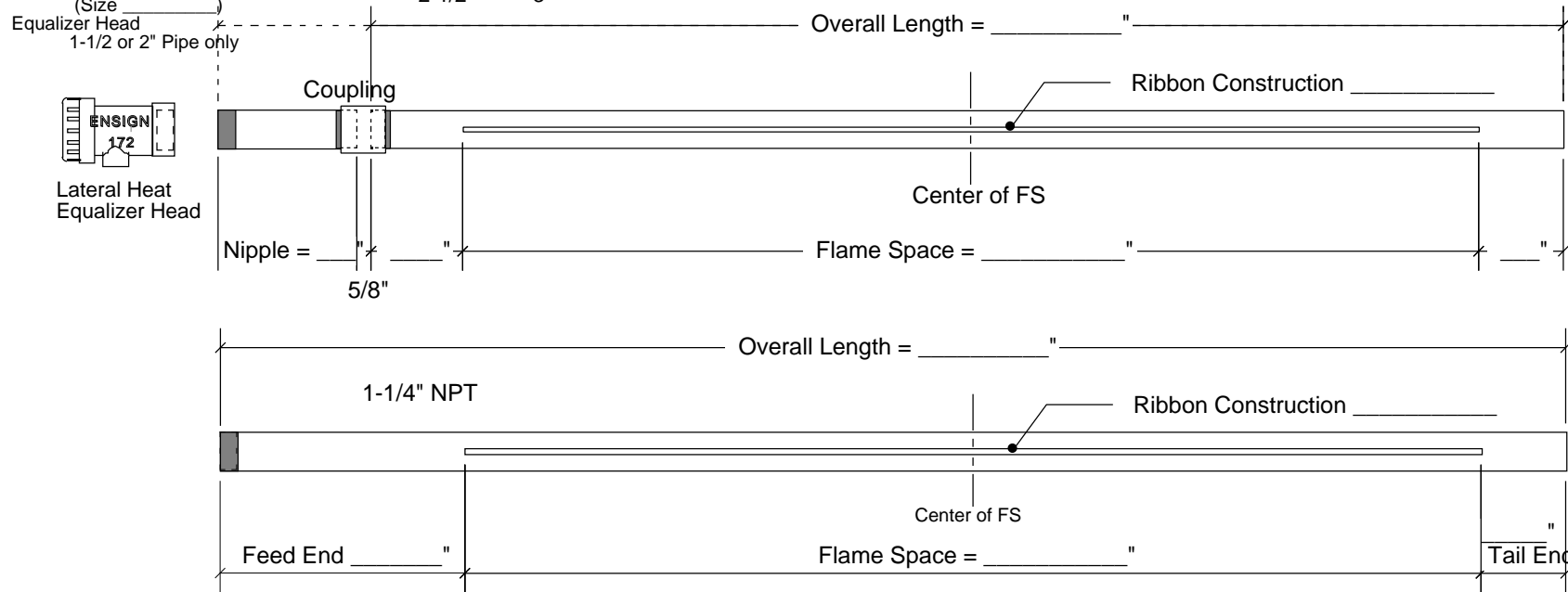
Burner Plates

Pipe Burner Configuration

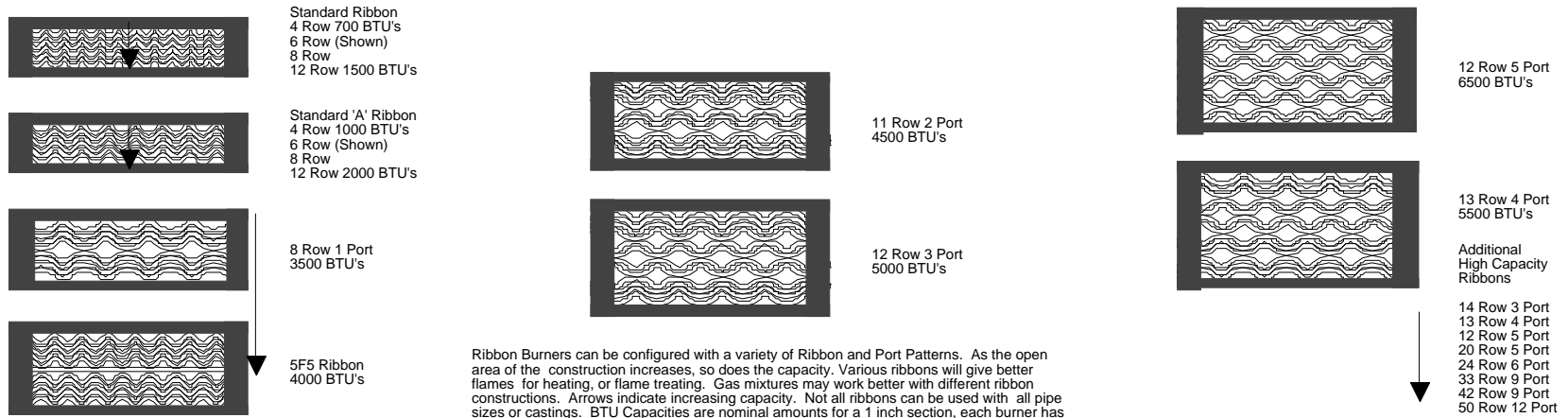
Feed End Styles
 Plain (Open)
 Welded (Closed)
Thread (Open)
 Thread & Cap (Closed)
 Thread w/ Elbow
 (Size)

BURNER SIZE
 1/2" 3/4"
 1" 1-1/4"
 1-1/2" 2"
 2-1/2" 3"

Tail End Styles
 Plain (Open)
Welded (Closed)
 Thread (Open)
 Thread & Cap (Closed)

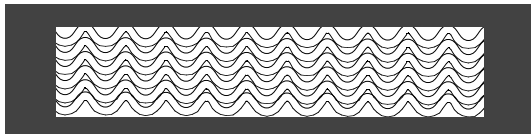


Gas Type to be burned **Natural, Propane, Butane**
 Mixing system used, **Inspirator, Premix or Fueljector, Raw Gas.**

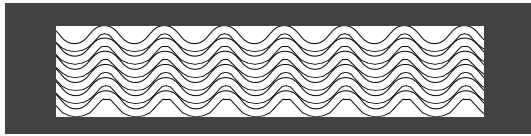


Ribbon Burners can be configured with a variety of Ribbon and Port Patterns. As the open area of the construction increases, so does the capacity. Various ribbons will give better flames for heating, or flame treating. Gas mixtures may work better with different ribbon constructions. Arrows indicate increasing capacity. Not all ribbons can be used with all pipe sizes or castings. BTU Capacities are nominal amounts for a 1 inch section, each burner has slightly different constructions which may allow this value to go up or down. These values are for a mixture pressure of 0.5" wc

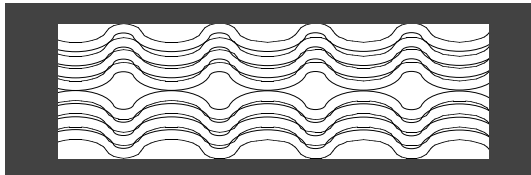
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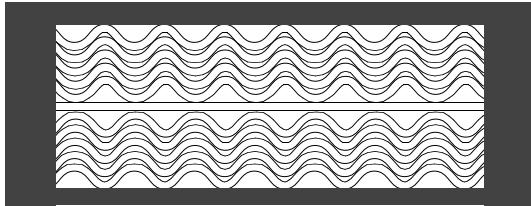
Standard Ribbon
 4 Row 700 BTU's
 6 Row (Shown)
 8 Row
 12 Row 1500 BTU's



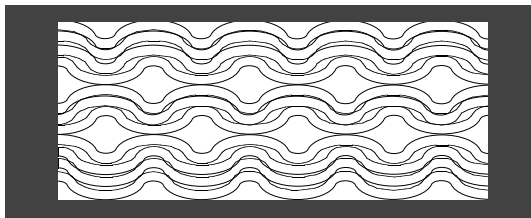
Standard 'A' Ribbon
 4 Row 1000 BTU's
 6 Row (Shown)
 8 Row
 12 Row 2000 BTU's



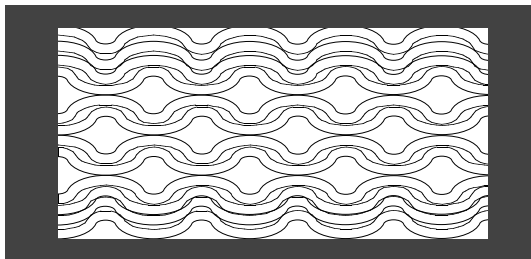
8 Row 1 Port
 3500 BTU's



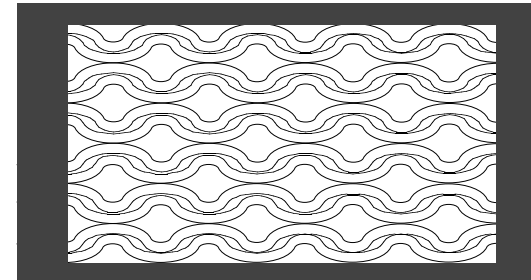
5F5 Ribbon
 4000 BTU's



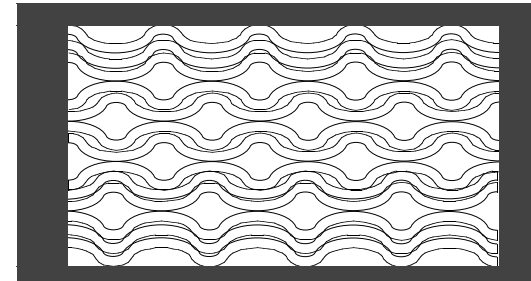
11 Row 2 Port
 4500 BTU's



12 Row 3 Port
 5000 BTU's



12 Row 5 Port
 6500 BTU's



13 Row 4 Port
 5500 BTU's

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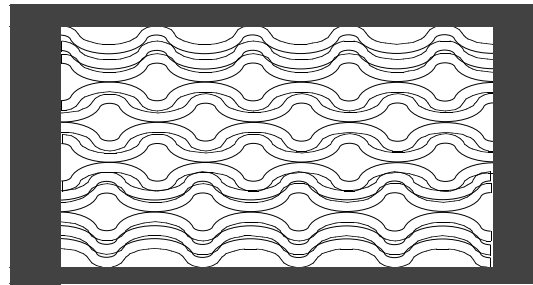
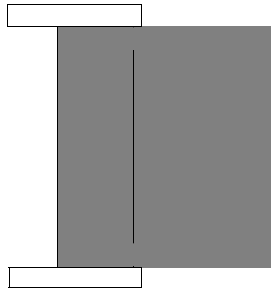
Additional High Capacity Ribbons

14 Row 3 Port
 13 Row 4 Port
 12 Row 5 Port
 20 Row 5 Port
 24 Row 6 Port
 33 Row 9 Port
 42 Row 9 Port
 50 Row 12 Port

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Typical Ribbon Constructions

February 1998



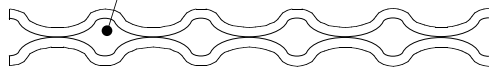
Maximum
Treatment
Level

3/8"



Outer Mantle
Burning Plasma
Inner Cones
Non-Combusted Gas

Ports between Ribbons Provide
Main flame. (High velocity)



Ported Ribbon Strips

Gaps between Ribbons Provide
Pilot flame. (Low velocity)



Meshed Ribbon Strips

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Typical Ribbon Flame Development

April 1999