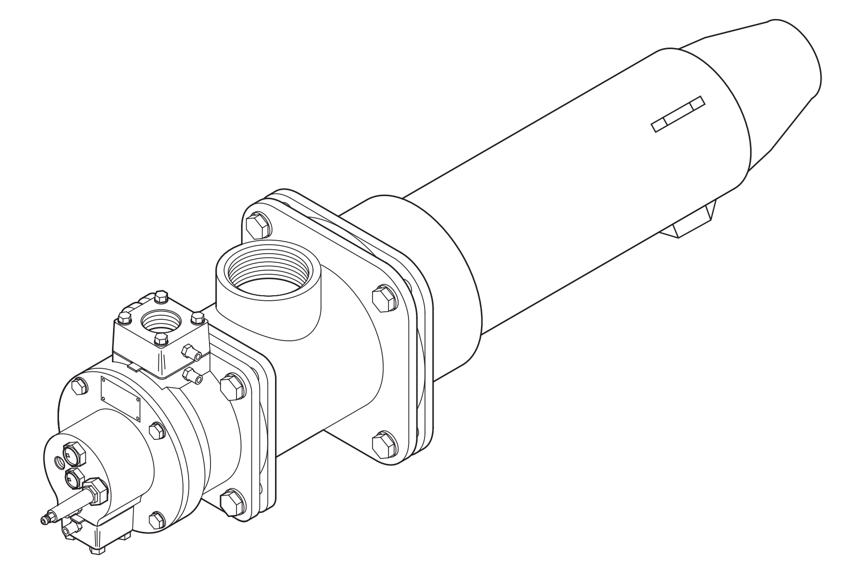
Design Guide
315, 8/26/04

P-Tube
Recuperative Burners

Models PTB600 & PTB750

Version 1



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Innovative Thermal Solutions

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About this manual

Audience

This manual has been written for people who are already familiar with all aspects of a nozzle-mix burner and its add-on components, also referred to as "the burner system."

These aspects are:

- design/selection
- use
- maintenance.

The audience is expected to have had experience with this kind of equipment.

Purpose

The purpose of this manual is to ensure that the design of a safe, effective, and trouble-free combustion system is carried out.

PTB Documents

Design Guide No. 315

- This document

PTB Data Sheets, Series 315

- Available for individual PTB models
- Required to complete design, selection & installation

Installation Guide No. 315

- Used with Data Sheet to complete installation

PTB Price List No. 315

- Used to order burners

Related Documents

- EFE 825 (Combustion Engineering Guide)
- Eclipse Bulletins and Info Guides: 684, 710, 732, 742, 756, 760, 930,

DOCUMENT CONVENTIONS

There are several special symbols in this document. You must know their meaning and importance.

The explanation of these symbols follows below. Please read it thoroughly.

Danger:

Indicates hazards or unsafe practices which WILL result in severe personal injury or even death.
Only qualified and well trained personnel are allowed to carry out these instructions or procedures.
Act with great care and follow the instructions.

Warning:
Indicates hazards or unsafe pratices which could result in severe personal injury or damage.

Act with great care and follow the instructions.

Caution:
Indicates hazards or unsafe practices which could result in damage to the machine or minor personal injury, Act carefully.

Note:
Indicates an important part of the text. Read thoroughly.

HOW TO GET HELP

If you need help, contact your local Eclipse Combustion representative. You can also contact Eclipse Combustion at:

1665 Elmwood Rd.

Rockford, Illinois 61103 USA

Phone: 815-877-3031

Fax: 815-877-3336

http://www.eclipsenet.com

Table of Contents

Introduction

1

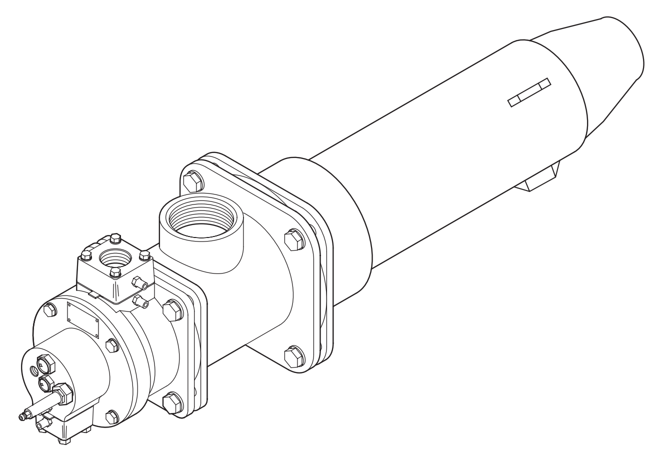
Product Description

The P-Tube burner is a nozzle-mixing velocity burner designed for P-Tube applications. The burner design provides flue gas recirculation entrained by the products of combustion. The recirculation provides lower NOx emissions and better tube temperature uniformity. This burner provides preheated combustion air resulting in higher efficiencies than stand alone tube firing burners.

Features:

- Direct spark ignition
- Reliable burner operation
- Self recuperative
- Simple burner adjustment
- Multi-fuel capability

The P-Tube Recuperative Burner



Safety

2

INTRODUCTION

This section is provided as a guide for the safe operation of the PTB burner system. All involved personnel should read this section carefully before operating this system.

SAFETY

Danger:

The PTB burners, described herein, are designed to mix fuel with air and burn the resulting mixture. All fuel burning devices are capable of producing fires and explosions if improperly applied, installed, adjusted, controlled, or maintained.

Do not bypass any safety feature; fire or explosion could result.

Never try to light a burner if it shows signs of damage or malfunction.

Warning:

The burner might have HOT surfaces. Always wear protective clothing when approaching the burner.

Note:

This manual provides information in the use of these burners for their specific design purpose. Do not deviate from any instructions or application limits described herein without written advice from Eclipse Combustion.

Read this entire manual and all related documents before attempting to start this system. If you do not understand any part of the information contained in this manual, contact your local Eclipse representative or Eclipse Combustion before continuing.

Capabilities

Only qualified personnel, with good mechanical aptitude and experience on combustion equipment, should adjust, maintain, or troubleshoot any mechanical or electrical part of this system.

Operator Training

The best safety precaution is an alert and trained operator.

Train new operators thoroughly and have them demonstrate an adequate understanding of the equipment and its operation. A regular retraining schedule should be administered to ensure operators maintain a high degree of proficiency.

Replacement Parts

Order replacement parts from Eclipse Combustion only. All Eclipse Combustion approved, customer supplied valves or switches should carry UL, FM, CSA, CGA, and/or CE approval, where applicable.

System Design

3

DESIGN

Design structure

The design process is divided into the following steps:

1. **Burner option selection:**
2. **Control methodology:**
3. **Ignition system:**
4. **Flame monitoring control system:**
5. **Combustion Air system**
6. **Main gas shut-off valve train:**

Step 1: Burner option selection

Step 1 describes how to select burner options to suit an application. Use the PTB Price List & Data Sheets No. 315-1 and 315-2 when following this selection process.

Caution:

Consult EFE-825, Eclipse Combustion Engineering Guide, or contact Eclipse Combustion if you have special conditions or questions.

Burner Model / Size Selection

Consider the following when selecting the burner size:

- **Heat Input.** Calculate the required heat input to achieve the required heat balance.
- **Power Supply Frequency.** Burner capacity will vary with power supply frequency (50Hz or 60Hz power).
- **Altitude.** The maximum burner capacity is reduced by approximately 3% each 1000 feet (300 meters) above sea level.
- **Combustion Air Supply.** Combustion air should be fresh (20.9% O_2) and clean (without particles or corrosives).
- **Fuel Type.** Variation in calorific value and density will affect burner performance. Nominal burner performance is based on fuel properties in Table 1 on page 10.

Step 1: Burner option selection (continued)

Fuel Type

Table 1 Fuel Type

Fuel	Symbol	Gross Heating Value	Specific Gravity
Natural gas	CH_4 90%+	1004 BTU/ft^3 (40.1 MJ/m^3)	0.60
Propane	C_3H_8	2564 BTU/ft^3 (101.2 MJ/m^3)	1.55
Butane	C_4H_{10}	3333 BTU/ft^3 (133.7 MJ/m^3)	2.09

If using and alternative fuel supply, contact Eclipse Combustion with an accurate breakdown of the fuel components.

Burner Model

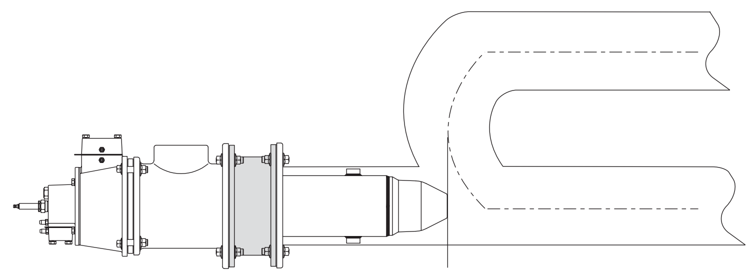
Available models include PTB 600 for 6” to 7.5” diameter tubes and PTB 750 for 7.5” diameter or greater tubes.

Burner Length

Three options are available, 350mm, 500mm, and 650mm. Typically chosen with mounting flange to align the burner nozzle in the P-tube. The longer the burner the greater the recuperative length thus providing higher preheated air temperatures.

Mounting Flange Length

Available in 50-250mm lengths in 25mm increments. Choose flange length with burner length to position nozzle in the P-tube bend as shown below.



Pipe Connections

Available in BSP and NPT thread standards.

Input Level

Burner input level is determined by the heat required. See calculations following. Orifices are selected based on model, fuel type and input level to achieve a 2.5” to 7” w.c. pressure drop.

Calculate the tube surface area

The burner radiates its heat to the process though the wall of the tube. To calculated the required burner input you must know the total area of the tube inside the furnace. This is called the effective surface area of the tube.

Effective surface area = OD x π x L

Where
OD is the outside diameter of the tube in inches
π is 3.142
L is the length of the tube in the furnace in inches

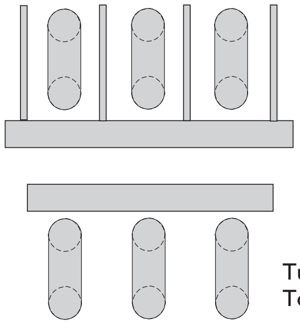
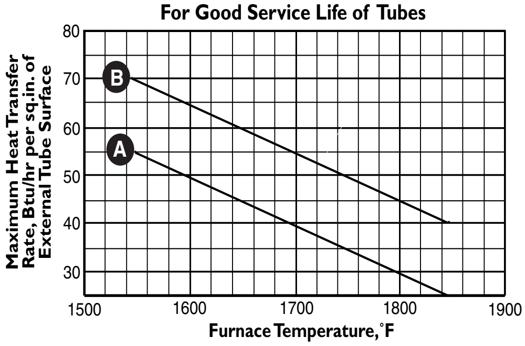


Figure 1

Maximum Heat Transfer Rates For Good Service Life of Tubes



A Tube enclosed on three sides

B Tube free to radiate

Determine the maximum heat transfer rate

The maximum heat transfer rate is the maximum amount of heat that the tube can radiate to the process while having the tube temperature stay within recommended limits. The tube temperature hence the maximum recommended heat transfer rate will be affected by temperature of the chamber and the ability of the tube to radiate heat. The ability of the tube to radiate heat is effected by how the tube is mounted in the furnace. If the tube is free to radiate (see illustration at left) it will have a higher allowable heat transfer rate than a tube which is enclosed and not as able to release heat.

Calculate the maximum heat release

The maximum heat release for the tube is determined by multiplying the tube surface area by the maximum heat transfer rate. (See Figure 1.)

Maximum heat release = tube surface area x max. heat transfer rate

Compare the heat releases

Compare the required heat release with the maximum heat release determined above. If the required heat release is greater than the maximum heat release, then the number or size of radiant tubes must be increased.

Caution:

Exceeding the maximum heat release will significantly shorten the tube life.

Determine efficiency

Efficiency of the system is effected by many factors including: burner length, furnace temperature and inputs. Efficiency can be estimated as .70. If calculations show the maximum input is within 10% of t6he capacity rating of the burner, a more precise determination of efficiency may be required.

Calculate the gross burner input

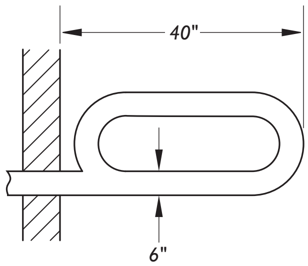
The gross burner input is the required heat release divided by the efficiency.

$$\textit{Gross burner input} = \frac{\textit{Required heat release}}{\textit{Efficiency}}$$

Compare the gross burner input

Make sure the gross burner input does not exceed the maximum input capabilities of the P-tube. (See Data 315-1 or -2)

Sizing example



Application parameters

- 6 P-tubes - 6" OD x 80" effective length
- 500,000 Btu/hr total required heat release
- 1650˚F chamber temperature
- free to radiate (not enclosed tubes).

1. The required heat release per tube:

$$\frac{\textit{total required heat release}}{\textit{number of tubes}} = \textit{Required heat release per tube}$$

- 500,000/6=83,333 Btu/hr

2. Tube surface area for each tube:

OD x x *n* x *L* = *Tube surface area*

- 6 x 3.142 x 80 = 1508 in^2.

3. From Figure 1 "Maximum heat transfer rate" on page 11, find the maximum heat transfer rate:

- 60 Btu/in^2/hr.

4. The maximum permissible heat release (per tube) is:

tube surface area max heat transfer rate = Maximum heat release

- 1508 x 60 = 90,490 Btu/hr.

5. Maximum heat release is greater than heat required (83,333 Btu/hr).

6. Using estimated efficiency of .60

7. The gross burner input (per tube) is:

$$\frac{\textit{Required heat release}}{\textit{Efficiency}} \quad 100 = \textit{Gross burner input}$$

- (125,000 / .60) x 100 = 208,333 Btu/hr.

Size the system for 210,000 Btu/hr per burner.

8. The result from step 7 is less than the maximum input of 340,000 Btu/hr as indicated in the Data Sheet.

Step 2: Control methodology

The control methodology is the basis for the rest of the design process. Once the system is designed, the components can be selected. The control methodology chosen depends on the type of process to be controlled.

Note:

The stated operational characteristics only apply if the described control circuits are followed. Use of different control methods will result in unknown operational performance characteristics. Use the control circuits contained within this section or contact Eclipse Combustion for written, approved alternatives.

Control methods

There are three main methods to control the input of a P-tube system. These methods may be applied to single burner as well as multiple burner systems.

The methods and variants are:

1. High/low control (Preferred):
- High/low air & gas biased control with excess air at low fire (pulse firing) on page 14.

2. On/off control:
- High/off air & gas control (pulse firing) on page 14.

3. Modulating control (Consult your Eclipse Representative):
- Modulating gas & air, biased ratio control with excess air at low fire on page 15.

In the pages that follow you will find schematics of these control methods. The symbols in the schematics are explained in the "Key to System Schematics" (see Appendix).

Note:

The following control methods do not illustrate flame safety. Flame safety is discussed in Step 4 on page 16 of this guide. Any decisions regarding the use and/or type of flame safety should be made in accordance with local safety and/or insurance requirements.

Step 2: Control methodology (Continued)

High/Low air & gas control (pulse firing) (Figure 2)

A burner system with high/low control gives a high or low fire input to the process. No input between high and low fire is possible.

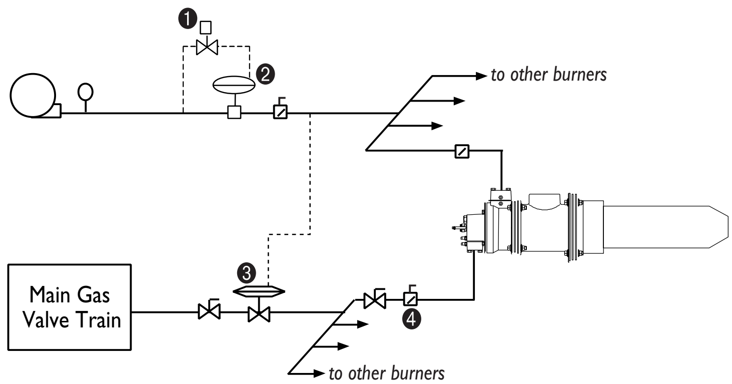
1. Air

- ***a.*** Low fire:
  A control input closes the solenoid valve ❶. As a result, the CRS valve ❷ quickly moves to low fire.
- ***b.*** High fire:
  A control input opens the solenoid valve ❶. As a result, the CRS valve ❷ quickly moves to high fire.

2. Gas

- ***a.*** Low fire:
  Low fire is controlled by the proportionator valve ❸.
- ***b.*** High fire:
  High fire gas is limited by the manual butterfly valve ❹.

High/Low air & gas control (pulse firing)



If fast high/low control is not necessary, the CRS valve ❷ and the solenoid valve ❶ can be replaced with a two-position automatic butterfly valve.

Figure 2

On/Off air & gas control (pulse firing) (Figure 3)

A burner system with on/off control gives a high fire input to the process. No input other than high fire is possible.

1. Air

A control input opens and closes the solenoid valve ❶ to supply or "close off" the air supply. A small amount of air can be allowed through to cool the burner nozzle.

2. Gas

A control input opens and closes the solenoid valve ❷ to supply or "close off" the gas supply. High fire gas is set by the manual butterfly valve ❸.

On/Off Control

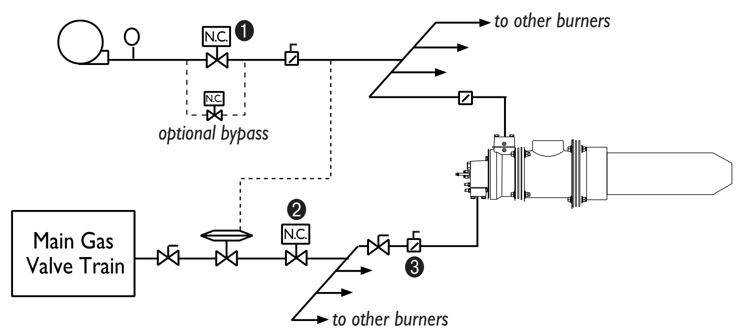


Figure 3

Step 2: Control methodology (Continued)

Modulating gas & air (Figure 4)
Biased ratio control with excess air @ low fire

A burner system with modulating control gives an input that is in proportion with the demands of the process. ANY input between high and low fire is possible.

1. Air

The control valve ❶ is in the air line. It can modulate air flow to any position between low and high fire air.

2. Gas

The ratio regulator ❷ allows the on-ratio amount of gas to go to the burner. Low fire gas is limited by the ratio regulator ❷. High fire gas is set by the manual butterfly valve ❸.

Note:

The ratio regulator should be biased to give excess air at low fire

Note:

Adjustable limiting orif ices (ALO) require more pressure drop than butterfly valves. This should be considered when using an ALO as the high fire gas limiting valve ❸ in a proportional system .

Modulating Control

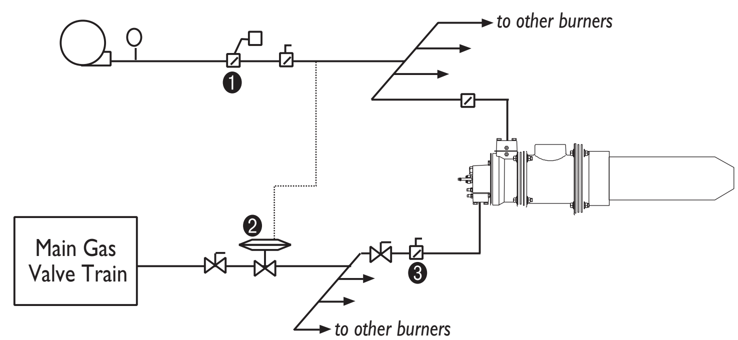


Figure 4

Note:

Modulating control is not preferred. Inputs may be too low. Contact an Eclipse representative to review your aplication.

Step 3: Ignition system

For the ignition system use:

- 6,000 VAC transformer
- full-wave spark transformer
- one transformer per burner

DO NOT USE:

- 10,000 VAC transformer
- twin outlet transformer
- distributor type transformer
- half-wave transformer

It is recommended that low fire start be used for cold starts (furnace temperatures below 400° F (204° C). P-tube burners are capable of direct spark ignition anywhere within the ignition envelope shown on page 2 of the appropriate Data Sheet. See Installation Guide for detailed start information.

Step 3: Ignition system (continued)

Note:

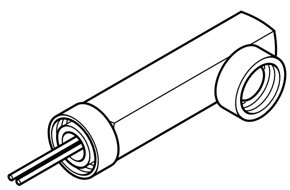
You must follow the control circuits described in the previous section, "Control Methodology," to obtain reliable ignition.

Local safety and insurance require limits on the maximum trial for ignition time. These time limits vary from country to country.

The time it takes for a burner to ignite depends on:

- the distance between the gas shut-off valve and the burner
- the air/gas ratio
- the gas flow at start conditions

Step 4: Flame monitoring control system



A flame monitoring system consists of two main parts:

- a flame sensor
- flame monitoring control

Flame sensor

Flame sensing is by flame rod (all fuels) or U.V. scanner (natural gas).
Eclipse recommends the following U.V. scanners for use with the Eclipse flame monitoring controls listed below:

- straight UV scanner; Bulletin / Info Guide 854
- 90° UV scanner; Bulletin / Info Guide 852
- self-check UV scanner; Bulletin / Info Guide 856
- solid state UV/IR scanner; Bulletin / Info Guide 855.

Automatic Gas Shut-Off

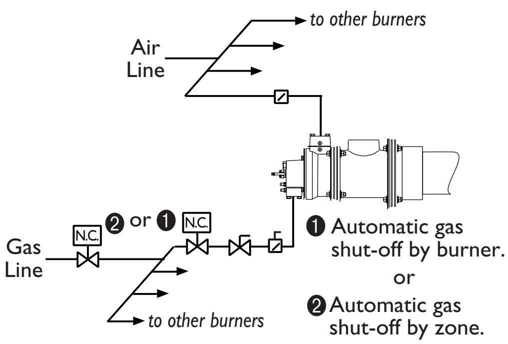


Figure 5

Flame monitoring control (Figure 5)

The flame monitoring control is the equipment that processes the signal from the U.V. scanner or flame rod.
For flame monitoring control selection there are several options including:

1. Automatic gas shut-off by burner

   If the flame monitoring system detects a failure, the gas shut-off valve ❶ closes the gas supply to the burner that caused the failure.

2. Automatic gas shut-off by zone

   If the flame monitoring system detects a failure, the gas shut-off valve ❷ closes the gas supply to all the burners in the zone where the failure occurred.

There are three flame monitoring controls that are recommended:

- Veri-flame (Installation Manual 818)
- Bi-flame series (Installation Manual 826)
- Multi-flame series 6000 (Installation Manual 820)

Eclipse recommends the use of flame monitoring control systems which maintain spark for the entire trial for ignition period with U.V. scanners.

Step 5: Combustion Air System: Blower and air pressure switch

Effects of atmospheric conditions

The blower data is based on the International Standard Atmosphere (ISA) at Mean Sea Level (MSL), which means that it is valid for:

- sea level
- 29.92" Hg (1,013 mbar)
- 70°F (21°C)

The make-up of the air is different. above sea level or in a hot area. The density of the air decreases, and as a result, the outlet pressure and the flow of the blower decrease. An accurate description of these effects is in the Eclipse Combustion Engineering Guide (EFE 825). The Guide contains tables to calculate the effect of pressure, altitude and temperature on air.

Blower

The rating of the blower must match the system requirements. You can find all the blower data in:

- Bulletin / Info Guide 610

Follow these steps:

1. Calculate the outlet pressure

When calculating the outlet pressure of the blower, the total of these pressures must be calculated.

- the static air pressure required at the burner
- the total pressure drop in the piping and valves
- the pressure drop across the P-tube
- recommend a minimum safety margin of 10%

2. Calculate the required flow

The blower output is the air flow delivered under standard atmospheric conditions. It must be enough to feed all the burners in the system at high fire.

Combustion air blowers are normally rated in terms of standard cubic feet per hour (scfh) of air.

An example calculation follows the information tables below:

Table 2 Required calculation information

Description	Unit of measure	Formula symbol
Total system heat input	Btu/hr	Q
Number of burners	-	-
Type of fuel	-	-
Gross heating value of fuel	Btu/ft^3	q
Desired excess air percentage (Typical excess air percentage @ high fire is 15%)	percent	%
Air/Gas ratio (Fuel specific, see table below)	-	α
Air flow	scfh	V_{air}
Gas flow	scfh	V_{gas}

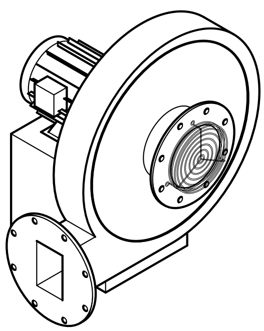
Step 5: Combustion Air System: Blower and air pressure switch (continued)

Table 3 Fuel gas heating values

Fuel gas	Stoichiometric* air/gas ratio α (ft^3_{air}/ft^3_{gas})	Gross heating value q (Btu/ft^3)
Natural gas (Birmingham, AL)	9.41	1,004
Propane	23.82	2,564
Butane	30.47	3,333

* Stoichiometric: No excess air. The precise amount of air and gas are present for complete combustion.

Example Blower Calculation



Application example:

A furnace has been designed and requires a heat input of 2,400,000 btu/hr. The burners will operate on natural gas using 15% excess air at high fire.

Calculation example:

a. Calculate required gas flow:

$$V_{gas} = \frac{Q}{q} = \frac{2{,}4000{,}000 \text{ btu/hr}}{1{,}002 \text{ Btu/ft}^3} = 2{,}395 \text{ ft}^3\text{/hr}$$

- Gas flow of 2,395 ft^3/hr is required

b. Calculate required stoichiometric air flow:

$$V_{air\text{-}Stoichiometric} = \alpha \text{ (air/gas ratio)} \times V_{gas} = 9.41 \times 2{,}395 \text{ ft}^3\text{/hr}$$
$$= 22{,}537 \text{ ft}^3\text{/hr}$$

- Stoichiometric air flow of 22,537 scfh required

c. Calculate final blower air flow requirement based on the desired amout of excess air:

$$V_{air} = (1 + \text{excess air } \%) \times V_{air\text{-}Stoichiometric}$$
$$= (1 + 0.15) \times 22{,}537 \text{ ft}^3\text{/hr} = 25{,}918 \text{ ft}^3\text{/hr}$$

- For this example, total combustion air flow requirement is 25,918 scfh at 15% excess air. Depending on the number of zones (i.e. 4 zones of 8 burners each) 4 blowers would be required each capable of providing 1/4 of the total air requirement (25,918 / 4 = 6,480 scfh).

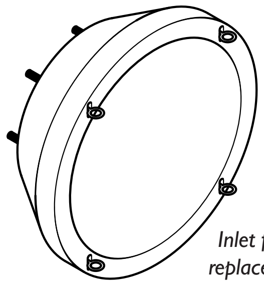
Note:

It is common practice to add an additional 10% to the final blower air flow requirement as a safety margin.

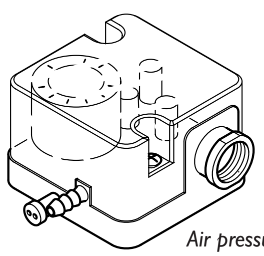
3. Find the blower model number and motor horsepower (hp).

With the outlet pressure and the specific flow, the blower catalog number and motor hp can be found in Bulletin 610.

Step 5: Combustion Air System: Blower and air pressure switch (continued)



Inlet filter with replaceable filter element



Air pressure switch

4. Eclipse Combustion recommends that you select a Totally Enclosed Fan Cooled (TEFC) motor.

5. Select the other parameters:

- inlet filter or inlet grille
- inlet size (frame size)
- voltage, number of phases, frequency
- blower outlet location, and rotation direction Clockwise (CW) or Counter Clockwise (CCW).

Note:

The use of an inlet air filter is strongly recommended. The system will perform longer and the settings will be more stable.

Note:

When selecting a 60 Hz Blower for use on 50 Hz, a pressure and capacity calculation is required. See Eclipse Combustion Engineering Guide (EFE 825)

The total selection information you should now have:

- blower model number
- motor hp
- motor enclosure (TEFC)
- voltage, number of phases, frequency
- rotation direction (CW or CCW).

The air pressure switch gives a signal to the monitoring system when there is not enough air pressure from the blower.

You can find more information on pressure switches in:

- Blower Bulletin 610

Warning:

Eclipse Combustion supports NFPA regulations, which require the use of an air pressure switch in conjunction with other safety components, as a minimum standard for main gas safety shut-off systems.

Step 6: Main gas shut-off valve train

Main gas shut-off valve train

Consult Eclipse

Eclipse can help you design and obtain a main gas shut-off valve train that complies with the current safety standards.

The shut-off valve train must comply with all the local safety standards set by the authorities that have jurisdiction.

For details, please contact your local Eclipse Combustion representative or Eclipse Combustion.

Note

Eclipse Combustion supports NFPA regulations (two shut-off valves) as a minimum standard for main gas safety shut-off systems.

Appendix

Conversion Factors

Metric to English.

From	To	Multiply By
cubic meter (m^3)	cubic foot (ft^3)	35.31
cubic meter/hour (m^3/h)	cubic foot/hour (cfh)	35.31
degrees Celsius (°C)	degrees Fahrenheit (°F)	(°C x 1.8) + 32
kilogram (kg)	pound (lb)	2.205
kilowatt (kW)	BTU/hr	3414
meter (m)	foot (ft)	3.28
millibar (mbar)	inches water column ("w.c.)	0.401
millibar (mbar)	pounds/sq in (psi)	14.5×10^{-3}
millimeter (mm)	inch (in)	3.94×10^{-2}

Metric to Metric.

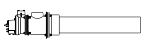
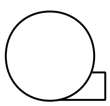
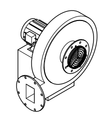
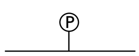
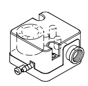
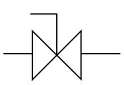
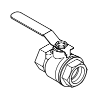
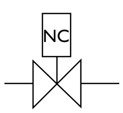
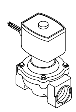
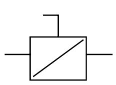
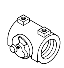
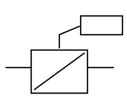
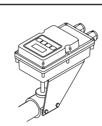
kiloPascals (kPa)	millibar (mbar)	10
meter (m)	millimeter (mm)	1000
millibar (mbar)	kiloPascals (kPa)	0.1
millimeter (mm)	meter (m)	0.001

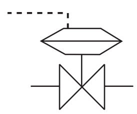
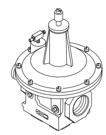
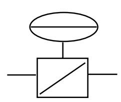
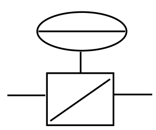
English to Metric.

From	To	Multiply By
BTU/hr	kilowatt (kW)	0.293×10^{-3}
cubic foot (ft^3)	cubic meter (m^3)	2.832×10^{-2}
degrees Fahrenheit (°F)	degrees Celsius (°C)	(°F – 32) ÷ 1.8
foot (ft)	meter (m)	0.3048
inches (in)	millimeter (mm)	25.4
inches water column ("wc)	millibar (mbar)	2.49
pound (lb)	kilogram (kg)	0.454
pounds/sq in (psi)	millibar (mbar)	68.95

Key to system schematics

These are the symbols used in the schematics.

Symbol	Appearance	Name	Remarks	Bulletin/ Info guide
		SER Burner		
Main gas shut-off valve train		Main gas shutoff valve train	Eclipse Combustion, Inc. strongly endorses NFPA as a minimum	756
		Combustion air blower	The combustion air blower provides the combustion air pressure to the burner (s).	610
		Air pressure switch	The air pressure switch gives a signal to the safety system when there is not enough air pressure from the blower.	610 I-354
		Gas cock	Gas cocks are used to manually shut off the gas supply on both sides of the main gas shut-off valve train.	710
		Solenoid valve (normally closed)	Solenoid valves are used to automatically shut off the gas supply on a bypass gas system or on small capacity burner systems.	760
		Manual butterfly valve	Manual butterfly valves are used to balance the air or gas flow at each burner, and/or to control the zone flow.	720
		Automatic butterfly valve	Automatic butterfly valves are typically used to set the output of the system.	720

Symbol	Appearance	Name	Remarks	Bulletin/ Info guide
		Ratio regulator	A ratio regulator is used to control the air/gas ratio. The ratio regulator is a sealed unit that adjusts the gas flow in ratio with the air flow. To do this, it measures the air pressure with a pressure sensing line, the impulse line. This impulse line is connected between the top of the ratio regulator and the air supply line. The cap must stay on the ratio regulator after adjustment.	742
		CRS valve	A CRS valve is used in a high/ low time-proportional control system to quickly open and close the air supply.	744
		Pressure taps	The schematics show the advised positions of the pressure taps.	
— — — —		Impulse line	The impulse line connects the ratios regulator to the air supply line.	