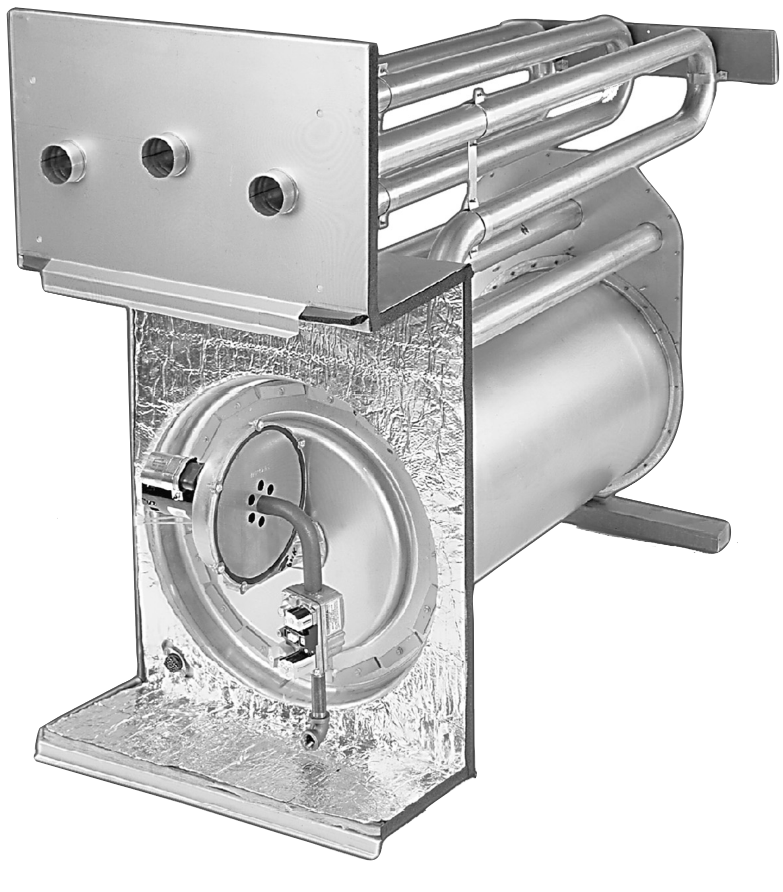
Light Commercial Rooftop Power Burner

Ignition and Combustion



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Combustion Process

Combustion (burning) will only take place if fuel, oxygen, and heat are present. Without any one of these three components, combustion will not occur nor be sustained. If enough air and heat is present, fuel gases will burn in their normal or natural state. Solid or liquid fuels must be changed to a gas (vaporized or atomized) before they will burn.

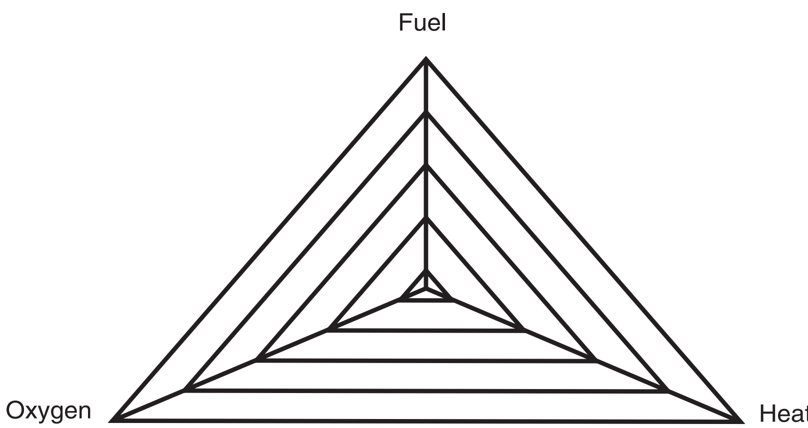


Figure 1.

The primary elements of fuel gases are “Carbon” (C) and “Hydrogen” (H). When hydrogen is burned water vapor is produced, when carbon is burned carbon dioxide is produced (the reaction of fuel gas and oxygen in the presence of heat yield these harmless vapors). Proper amounts of oxygen are required to completely burn a fuel, and a proper mixture will yield the harmless vapors of complete combustion.

Two molecules of oxygen are required to burn one molecule of natural or methane gas, likewise two cubic feet of oxygen would be required to burn one cubic foot of natural or methane gas. Air, however, is a mixture of approximately 80% nitrogen and 20% oxygen, and is used to burn the different fuel gases. Due to the ratio of gases in this mixture, ten cubic feet of air is required to supply the two cubic feet of oxygen necessary to burn one cubic foot of natural or methane gas. There are ratios for all other fuel gases, as well, illustrated in Table 1.

Table 1.

Type of Fuel Gas	Required Air (Cubic Feet)	Fuel Gas (Cubic Feet)	Combustion Ration (Air to Gas)
Methane (natural)	10	1	10:1
Propane	24	1	24:1
Butane	31	1	31:1

Usually, more air than is actually required to create the combustion ratio is supplied to the combustion chamber. This additional air is called “Excess Air” and is vented out the flue with the resulting gases from the combustion process. To assure complete combustion, excess air is supplied in an average of 30% as illustrated in Table 1.

Table 2.

Type of Fuel Gas	Required Air (Cubic Feet)	Fuel Gas (Cubic Feet)	Combustion Ration (Air to Gas)
Methane (natural)	13	1	13:1
Propane	31	1	31:1
Butane	40	1	40:1

Products of Combustion and Incomplete Combustion

Water vapor is a natural product of combustion and is usually exhausted through the flue. However, if the flue products are substantially cooled, the water vapor may condense and cause corrosion in heat exchangers. This may be detrimental to the integrity of the heat exchanger if it is not designed with the capability for handling condensation.

If the combustion process is not provided with sufficient quantities of heat, air, or a combination of both, products of incomplete combustion may result. Compounds such as carbon monoxide (CO) and aldehydes are produced, and may be harmful or fatal if introduced into the conditioned space. Table 3 illustrates just how harmful and detrimental even the slightest exposure to concentrations of carbon monoxide (CO) may be.

Table 3.

Concentration of CO in Air (parts per million)	Inhalation/Exposure Time and Toxic Symptoms Developed
9 ppm (0.0009%	Maximum allowable concentration for short term living area according to ASHRAE.
35 ppm (0.0035%)	Maximum allowable concentration for continuous exposure in an 8 hour period, according to federal law.
200 ppm (0.02%)	Slight headache, tiredness, dizziness, nausea after 2-3 hours.
	Maximum CO concentration for exposure at any time as prescribed by OSHA.
400 ppm (0.04%)	Frontal headaches within 1-2 hours, life threatening after 3 hours, also maximum parts per million in flue gas according to EPA and AGA.
800 ppm (0.08%)	Dizziness, nausea and convulsions within 45 minutes. Unconsciousness within 2 hours. Death within 2-3 hours.
1,600 ppm (0.16%)	Headache, dizziness and nausea within 20 minutes. Death within 1 hour.
3,200 ppm (0.32%)	Headache, dizziness and nausea within 5-10 minutes. Death within 30 minutes.
6,400 ppm (0.64%)	Headache, dizziness and nausea within 1-2 minutes. Death within 10-15 minutes.
12,800 ppm (1.28%)	Death within 1-3 minutes.

The harmful effects of CO exposure depend on the concentration of the gas in the air, exposure time, and factors such as age, health, size and sex. CO is regularly encountered, unknowingly, because it is invisible and odorless. That's why victims of CO poisoning often have no warning that they are in danger until it's too late. Symptoms include headache, nausea, chronic fatigue, confusion and dizziness. Extreme exposure can even cause a coma or death.

Carbon Monoxide is a product of incomplete (poor) combustion. It's a direct and cumulative poison. When combined with blood hemoglobin, CO replaces oxygen in the blood until it completely overcomes the body. Death from CO occurs suddenly. The victim inhaling the toxic concentration of the gas becomes helpless before realizing that danger exists.

To ensure safe and efficient combustion, it is imperative that HVAC service contractors, energy auditors, plant engineers and utility workers measure CO concentrations. There are many different combustion analyzers commercially available that will allow for accurately conducting analysis of the products of combustion exhausted from a furnace flue.

Gas Heating Values

The heating values of fuel gases are determined by the amount of heat released when one cubic foot of gas is completely burned. This heating value is expressed in BTUs per cubic foot of gas at standard conditions (barometric pressure at 30" of mercury and 60° F).

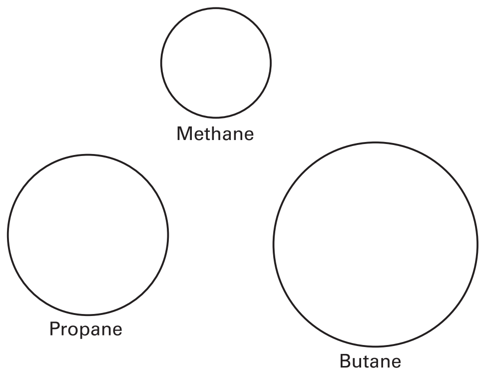


Figure 2.

Methane or Natural Gas has an approximate heating value of 950-1,150 BTUs per cubic foot, while the heating value of Propane is quite higher at approximately 2,500 BTUs per cubic foot, and Butane higher still at approximately 3,200 BTUs per cubic foot.

These are averages only. Many LP (liquefied petroleum) gas systems are a mixture of propane and butane. The heating values of these mixtures will be between 2,500 and 3,200 BTUs per cubic foot.

In some areas, during peak demand, the local natural gas utility may bump up the heating capacity of their natural gas by adding and mixing small amounts of propane or butane.

Table 4.

Type of Fuel	Heating Value (BTUs per Cubic Foot)
Methane (Natural Gas)	950-1,150
Propane	2,500
Butane	2,500
Propane/Butane Mixture	2,500-3,200

In some cases, it may be necessary to utilize the heating value for a particular fuel gas. This heating value may then be used in an equation to calculate things such as system airflow. The heating value of the fuel gas can only be obtained from the supplier or utility on a given day. All utilities have a calorimeter to provide them with the fuel gas heating value. Do not estimate the value for use in calculations.

Combustion Process

Figure 3 represents an internal view of the burner end plate assembly, illustrating the location of the Hot Surface Igniter (HSI) and its proximity to the burner screen in the center of the assembly.

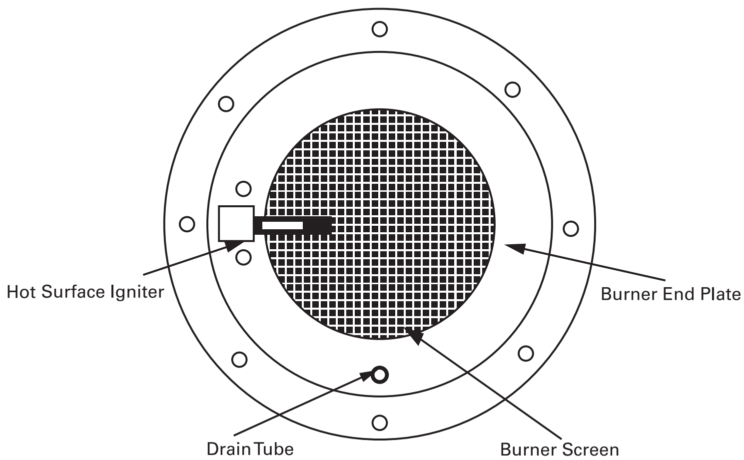


Figure 3.

The burner end plate assembly is made up of several primary components: the burner end plate, constructed of aluminized steel; the burner screen itself is constructed of stainless steel and should have a slight convex shape and be smooth to the touch as shown in Figure 4; the drain tube, also constructed of stainless steel.

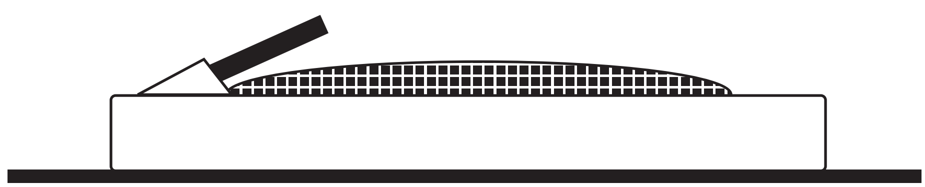


Figure 4.

The hot surface igniter (HSI) is not an integral part of the burner end plate assembly. The hot surface igniter heating element is a wafer type element, which is manufactured of "recrystallized silicon carbide". This material is virtually impervious to absorbing moisture. The heating element is potted in the ceramic bushing with ceramic cement.

The hot surface igniter is a line voltage (115V AC) heating element, which also doubles as a flame sensor when the ignition control module switches to the flame rectification mode. This type of flame sensing is known as "direct sensing", as opposed to remote sensing, which would require the use of both an igniter and a flame sensor.

Combustion Process

The light commercial rooftop has a true power burner, which is significantly different from induced draft and forced combustion type systems. This is a burner that completely mixes the primary air (used for the combustion process) and the fuel gas, prior to the mixture being forced through the burner screen.

When the ignition process is initiated, the combustion blower motor is energized and the ignition control module (IGN) energizes the hot surface igniter (HSI) with 115V AC. The hot surface igniter (HSI) is energized / pre-heated for 30 - 45 seconds (depending on ignition module) to approximately 2,000+° F.

The combustion blower motor (CBM) in the standard heaters is a permanent split capacitor (PSC) motor, which offers extremely high starting torque. This is very beneficial when starting under low ambient conditions. Most other manufacturers utilize shaded pole motors (much less expensive), which have low starting torque, and struggle to overcome low ambient starts. Modulating Heat units utilize a variable speed combustion blower motor that enables the motor to operate at the necessary speed to provide the required amount of heat to satisfy the current heating load of the building.

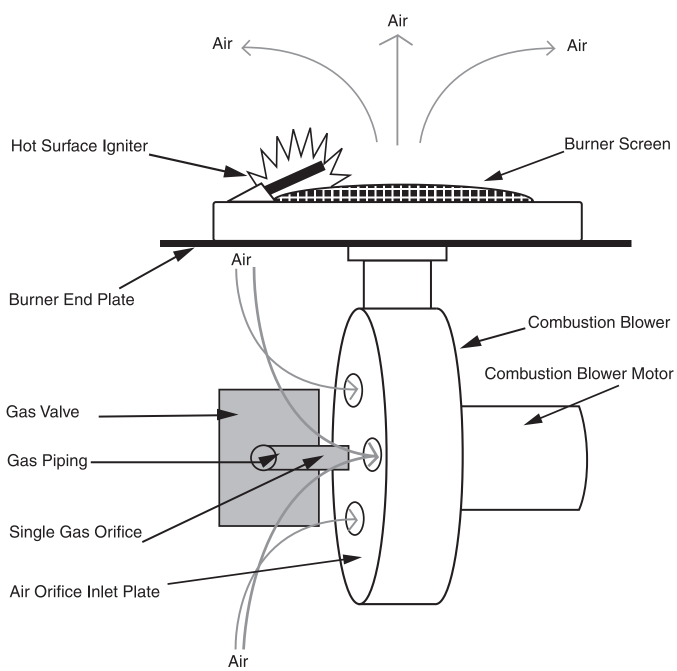


Figure 5.

Air is drawn in through the air orifice inlet plate, which is located at the inlet of the combustion blower. This air is forced through the burner screen, and then effectively purges the drum and tube heat exchanger, as illustrated in Figure 5.

Standard Units: The light commercial rooftop combustion process does not require a combustion airflow proving device, such as a sail switch, centrifugal switch, or pressure differential switch. The function of combustion airflow proving is provided by the use of a negative pressure regulated gas valve. There will be no gas flow when the gas valve is energized unless there is a negative pressure (suction) present at the outlet of the gas valve. In order to maximize performance and efficiency at all operating points, the modulating heat units utilize a positive pressure gas valve and a pressure switch to prove the combustion blower is in operation before the valve opens.

Upon the completion of the hot surface igniter (HSI) pre-heat, the gas valve is energized by the ignition control module (IGN) for a nominal 7 second trial for ignition. Air and fuel gases are pre-mixed in the combustion blower housing before being forced over the burner screen.

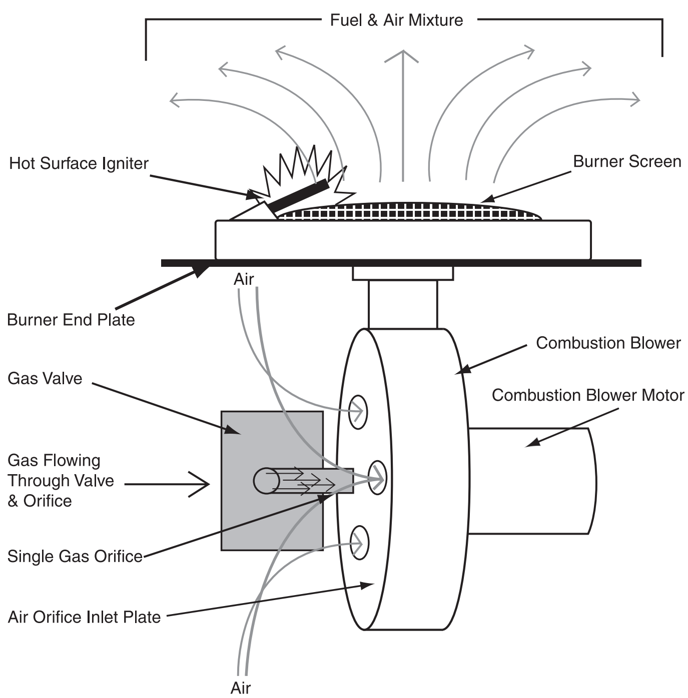


Figure 6.

When the fuel and air mixture flows across the hot surface igniter (HSI), which remains energized for the 7 second trial for ignition (@ 2,000+° F.), ignition should take place.

If ignition fails to take place on the first attempt, the ignition control module (IGN) will immediately recycle for a second trial for ignition. The ignition control module (IGN) will go through three trials for ignition prior to locking out.

The ignition control module may be reset by cycling power at the equipment disconnect, or by removing and reinstating the call for heat by turning the zone sensor or thermostat “OFF” and “ON”. This may also be accomplished by lowering the heating setpoint below the space temperature and allowing remote reset on an ICS job. If the ignition module is not manually reset, it will reset itself automatically after approximately one hour (the Fenwal model 05-24 will not reset itself automatically and must be manually reset).

Combustion Process

At the end of the 7 second trial for ignition, the ignition control module (IGN) removes the line voltage (115V AC) from the hot surface igniter (HSI). A small AC signal is applied to the igniter as it becomes the flame sensor and attempts to prove a flame path to ground (as the flame conducts the positive half of the AC signal).

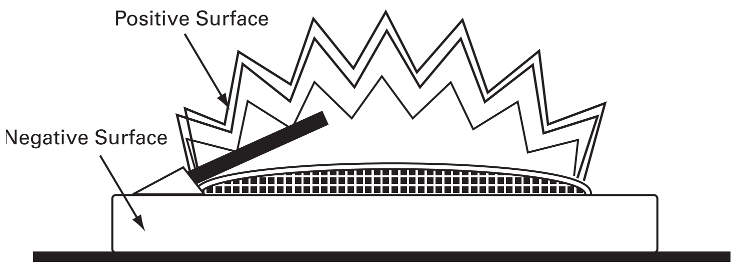


Figure 7.

This type of flame proving is known as flame rectification—two surfaces are in contact with the flame (the hot surface igniter and the burner) and the flame acts as a rectifier to conduct the positive portion of the AC signal.

The surface with the largest area (the burner) attracts more free electrons, and as a result, becomes the negative surface or probe. The direction for the conduction of current through the flame is from the positive surface to the negative surface. The current is conducted to ground potential, and a flame path to ground is established.

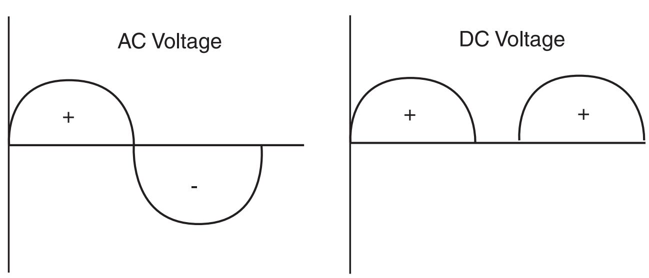


Figure 8.

As the current is conducted through the flame, the negative portion of the sine wave is chopped off (as illustrated in Figure 8) effectively leaving DC current.

The ignition control module (IGN) flame sensing circuit utilizes this DC current flow to energize an internal relay and keep the main gas valve for the burner energized (as long as a flame is present).

Flame rectification based ignition control systems are extremely responsive to loss of flame. These systems respond to loss of flame in less than 0.8 seconds. If flame is lost, the ignition control module (IGN) will recycle and try for ignition again (unless loss of flame occurred during 7 second trial for ignition).

Component and Layout

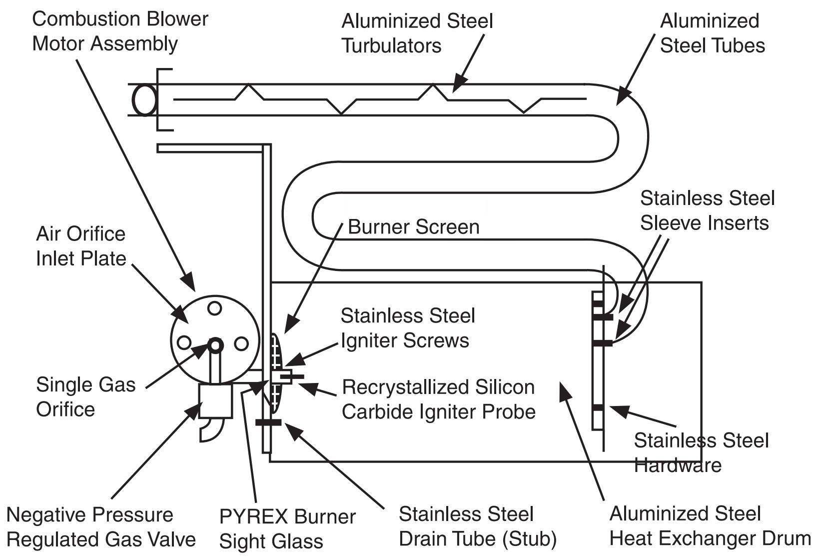


Figure 9.

The light commercial rooftop drum and tube heat exchanger is manufactured primarily of aluminized steel, which is coated on both sides with molten aluminum. Aluminized steel has been widely accepted throughout the industry as an excellent heat exchanger material for over 50 years. Due to resistance to corrosion and scaling, it has proven to be more than adequate for the great majority of applications.

Components which may be exposed to extreme heat or condensation are manufactured of stainless steel to further resist fatigue and corrosion (i.e., Drain Tube Stub, Igniter Screws, Sleeve Inserts, Burner Screen, Turbulators, and other assorted hardware). A PYREX burner sight glass is provided to allow the viewing of igniter operation and the burner flame itself.

The direct fired burner has the fuel gas supplied to it by a single gas orifice. The fuel gas flow is regulated by the gas valve. The manifold is set at a nominal -0.2" water column (+/- 0.15" wc) on the standard furnaces. Modulating furnaces use a gas valve set at +0.3" water column (+/- 0.15" wc). When converting from natural gas to LP, the only modification required is the changing of the single gas orifice. There are no other modifications or adjustments required. The negative pressure regulated gas valve remains set at the factory manifold pressure.

Note: *These pressure measurements should be taken at high fire only by using the second stage of heating in the service test mode.*

Note: *The LP conversion only applies to standard heaters and not modulating heat furnaces.*

Measuring and Adjusting Gas Pressure

Note: *The negative pressure valve is present in the standard furnaces but not in the modulating heat option.*

The light commercial rooftop series of products operate with a negative pressure regulated (redundant) gas valve (GV). The concept of the negative pressure regulation, while not new to the industry, is not a common application. This concept actually allows the reduction of combustion air proving devices, such as centrifugal switches, vane or paddle switches and pressure differential switches, notorious for causing nuisance heat problems.

The concept of this operation is such that there will be no gas flow, if no suction is present at the outlet of the gas valve (GV). The outlet of the gas valve (GV) is tied to the inlet of the combustion blower motor (CBM), which creates a negative pressure or suction at the outlet of the gas valve (GV). So in the event of a combustion blower motor failure, there will be no gas flow even if the valve is electrically energized.

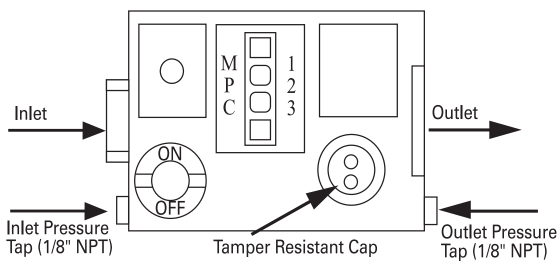


Figure 10.

Negative pressure burners rely on the combustion fan to “pull” the gas through the gas valve as opposed to positive pressure burners that “push” the gas through the gas valve. In order to properly measure negative pressure gas flow, the gas gage must be able to read down to a negative 4 inches water column (-4.0”w.c.). A digital magnehelic is the preferred instrument for accurate measurements, but an analog magnehelic will also work.

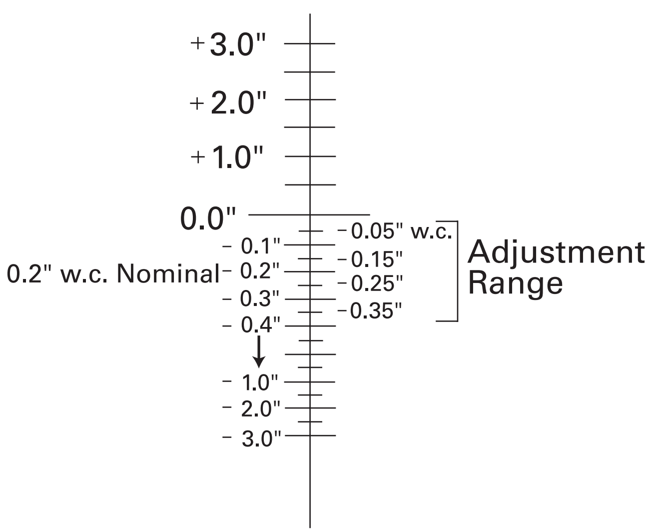
When the combustion fan is running, and before the gas valve opens, the pressure reading on the outlet side of the gas valve will be in the range of –2.5” to –3.5” w.c. When the gas valve opens during normal ignition, the pressure will increase upwards to –0.2” w.c. The maximum allowable pressure for proper ignition is –0.05” w.c. From the factory, the valve should not require readjustment.

Refer to Figure 10 to understand how the pressure increases from a larger negative number to a smaller negative number. The larger the negative number—the greater the negative pressure relative to zero. Everything above zero is a positive pressure, and everything below zero is a negative pressure. So, movement up the scale toward zero, even though in a negative range, increases pressure in the positive direction.

The inlet pressure is regulated by a field supplied and installed external pressure regulator. The inlet pressure for natural gas applications should be no less than +2.5 or +3.5″ of water column (model specific), while the maximum for all models and applications is +14.0″ of water column (1/2 PSIG). The optimum inlet pressure setting is in the middle of the regulation window, or approximately 7.0″ of water column, this helps eliminate nuisance problems in areas where gas supply pressures may vary or fluctuate during peak demand. The inlet pressure for LP applications should be no less than 8.0″ of water column, while the maximum is again 14.0″ of water column (1/2 PSIG). Here again the optimum inlet pressure setting is in the middle of the regulation window, or approximately 11.0″ of water column.

The outlet or manifold pressure is measured at the outlet pressure tap, and is factory set to -0.2″ of water column, with a tolerance of +/- 0.15″ of water column (Range = -0.05″ to -0.35″ of water column). This setting remains the same for both natural and LP applications. The outlet or manifold pressure may be measured with a magnehelic gage, or with a "U" tube, inclined, or digital manometer.

In the event that a manifold pressure regulation adjustment is necessary, the tamper resistant cap (which covers the regulation adjustment screw) must be removed. This cap utilizes two round indentations that a "Spanner" wrench will fit, in the event that a spanner wrench is unavailable, a pair of snap ring pliers, a jumbo paper clip (cut and bent to fit), or two small pointed devices may be used to remove the cap. Once removed, the regulator can be adjusted with a small flat tip screw driver. Turning the adjustment screw clockwise (CW) will increase the manifold pressure (bring it closer to -0.05″ of water column) and richen the mixture. Turning the adjustment screw counterclockwise (CCW) will decrease the manifold pressure (become increasingly negative and bring it closer to -0.35″ water column) making the mixture leaner.



Measuring Flame Current with the Different Ignition Control Modules

The flame current generated during the flame rectification (flame proving) process is very easy to measure and determine with the Texas Instruments ignition control module (IGN). There are two pins located on the module with flame check screened beside it. Measuring the DC voltage at these two pins will yield a direct reference to the flame current that is present on a 1:1 ratio (1 volt DC = 1 micro amp DC).

The minimum flame sense signal required is 1.0 µA DC (micro amps) +/- 5%. The nominal flame sensing current is typically between 2 and 8 mA DC.

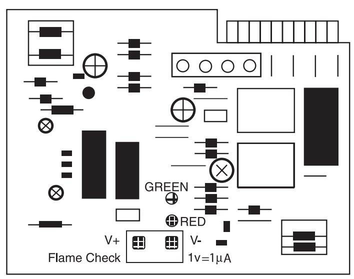


Figure 11.

The Fenwal model 05-24 ignition control module, previously used, required a different procedure for flame current measurement. The use of a flame current test adapter was recommended (Fenwal part # 05-080223-001 or Mnemonic part # ADP-0229). The purpose of this test adapter is to isolate the flame current (micro amp) meter from the igniter line voltage (present during igniter preheat). When the ignition module goes into the flame sense mode, the test adapter inserts the flame current meter into the circuit.

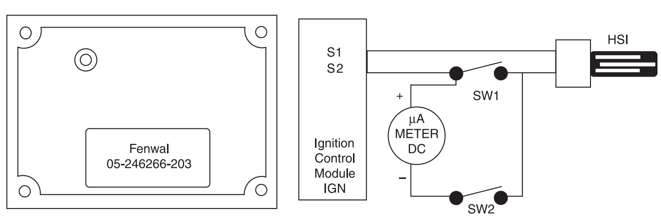


Figure 12.

In the event that a test adapter is not present, two switches may be used to manually switch the micro amps meter in and out of the circuit. To measure flame current, connect meter and switches as shown in Figure 12. Open Switch 2 (SW2), close Switch 1 (SW1), and initiate a heating cycle. After approximately 60 seconds (providing ignition has occurred), close Switch 2 (SW2), and open Switch 1 (SW1). The minimum flame sense signal required is 5.0 µA DC (micro amps) +/- 5%. The nominal flame sensing current for the Fenwal is typically between 8 and 16 µA DC.

Diagnosing and Trouble Shooting with the Texas Instruments Ignition Control Module

There are two LEDs located on the Texas Instruments Ignition Control Module (IGN), one GREEN LED and one RED LED, which are capable of providing important status and diagnostic information.

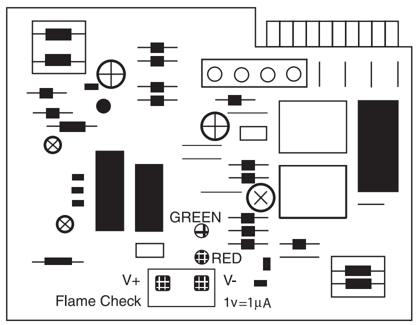


Figure 13.

Table 5.

Status or Diagnostic	Green LED Status	Red LED Status
Powered with no call for heat	OFF	OFF
Call for heat - no fault detected	Flashing (1)	OFF
Locked out on failure to establish flame signal	OFF	Flashing (1)
No flame signal on try for ignition or signal lost during ignition try	OFF (2)	Flashing (2)
Gas valve miswired or flame signal present at a call for heat	Continuous	Flashing (1)
Internal fault (at any time)	OFF	Continuous

Note 1. Flashing 1 time per second at a 50% duty cycle.
Note 2. At the start of each retry for ignition, the Red LED will Flash for 5 seconds along with a Flashing Green LED.

Figure 13 depicts a graphic display of the Texas Instruments Ignition Control Module (IGN) showing the location of the Status / Diagnostic LEDs. Table 5 represents status and diagnostic information displayed by the operation of the Red and Green LEDs.

When the Ignition Control Module (IGN) is locked out due to failure to establish a flame signal, the Combustion Blower Motor (CBM) will continue to run, provided a call for heating is still present.

The ignition control module may be reset by cycling power at the equipment disconnect, or by removing and reinstating the call for heat by turning the zone sensor or thermostat “OFF” and “ON”. This may also be accomplished by lowering the heating setpoint below the space temperature and allowing reset to be accomplished remotely on an ICS job. If the ignition module is not manually reset, it will reset itself automatically after approximately one hour.

Troubleshooting the Fasco Motor Control Board (CFMB), Mod Units Only

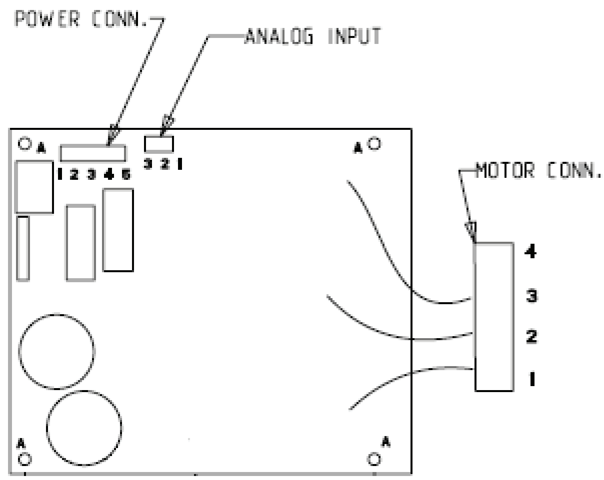


Figure 14.

The Fasco motor control board is shown in Figure 14 and can be used as a troubleshooting tool if the combustion blower motor is not operating when a heat call has been initiated on a modulating heat unit. If the board has shut down due to overcurrent or over voltage faults, there will be a blinking red LED light in the center of the board. In this case, the board can be reset by turning off power to the unit. If there is no error code showing on the board, but the motor still does not operate, first check that the board is getting power. The same LED will have a continuous green light when the board is powered and functioning normally. Next, check connections of the three plugs on the board, the power connections, the analog input, and the flying leads connected to the blower motor. If the board is wired correctly, check the DC voltage on the analog input to the board. This voltage can be measured from the contacts on the plug or from J5-1 and J5-2 on the RTOM board. This voltage controls the speed of the modulating blower motor and if it is zero, the blower will not run. At 2 Volts DC, the blower should be at low fire and be turning around 950 rpm. At 10.5 Volts DC, the blower will be operating at high fire, around 4600 rpm.

Identifying Gas Pressure Related Problems

In the event that a problem relating to combustion occurs, a related problem with gas pressure may exist. The potential cause may be readily identified by measuring the inlet and outlet (manifold) pressures.

To identify whether a problem exists, some preliminary measurements are required. Referencing "Inlet and Manifold Pressures - Measuring and Adjusting Gas Pressures", begin first by making an outlet (manifold) pressure measurement. Prior to the gas valve being energized the suction created by the combustion blower will be between -0.8 to -3.3" w.c. Reference the Gas Heating Data for the particular unit model. The combustion blower suction pressure should be recorded in the space provided.

Outlet (manifold) Combustion Blower Suction	"w.c. (inches water column)

After making an outlet measurement of the combustion blower suction, a flow measurement of the regulated outlet (manifold) pressure should be made. This pressure should be -0.2" w.c. +/- 0.15" w.c. (between -0.05 and -0.35" w.c.). If the regulated outlet (manifold) pressure is out of range and cannot be adjusted to stay within the range, the inlet pressure will need to be measured. Record the regulated outlet (manifold) pressure in the space provided.

Regulated Outlet (maniford) Pressure	w.c. (inches water column)

Next, a "static" measurement of the inlet (supply) pressure will need to be made. A static measurement consists of measuring the inlet pressure with the gas valve de-energized. This information should be recorded in the space provided.

Inlet (supply) Static Pressure Measurement	"w.c. (inches water column)

After making a static measurement, an inlet (supply) pressure measurement with gas flow must be made. This is accomplished by initiating a heating cycle and making a measurement with the combustion blower motor and the gas valve energized. This information should be recorded in the space provided.

Inlet (supply) Gas Flow Pressure Management	"w.c. (inches water column)

Providing that the gas distribution system has been sized properly (per the National Fuel Gas Code), the difference in the Inlet (supply) Static and Gas Flow Pressure Measurements should be negligible (not much greater than 0.5" w.c.).

If an excessive pressure drop is observed (5.0" w.c. or greater), a restriction in the gas distribution system (upstream of the equipment) is present. The restriction to flow could be in the form of undersized piping, an undersized gas regulator, or an inadequate gas supply.

If it is questionable as to whether or not the gas valve is regulating properly, it may be verified by turning the external gas cock "OFF", breaking the union open (exposing the gas train to atmospheric pressure) and making a Regulated Outlet (manifold) Pressure measurement. This procedure will remove any doubt about whether the internal regulator in the gas valve is or is not functioning properly.

Table 6.

Outlet (manifold) Combustion Blower Section	Regulated Outlet (manifold) Pressure	Inlet (supply) Static Pressure Measurement	Inlet (supply) Gas Flow Pressure Management	Solutions/Additional Checks or References
Normal per service facts gas heat data, +/ -10%.	More negative than-0.35" w.c, cannot be adjusted.	Normal, between 5 and 14" w.c.	Drops excessively 5" w.c. or more	Restriction present in gas distribution
Normal per service facts gas heat data, +/ -10%.	More negative than-0.35" w.c., cannot be adjusted	Normal between 5 and 14" w.c.	Normal, between 5 and 14" w.c., remain stable	Restriction present in gas valve. Clear or replace valve.
Normal per service facts gas heat data, +/ -10%.	Normal, between-0.05" and -0.35" w.c.	Normal, between 5 and 14" w.c.	Normal, between 5 and 14" w.c., remains stable	Restriction present between gas orifice and outlet of valve
Normal per service and outlet of valve by more than 10%.	More positive than-0.05" w.c cannot be adjusted.	Normal, between 5 and 14" w.c	Normal, between 5 and 14" w.c., remains stable.	Regulator or diaphragm in gas valve has failed.
Lower than service facts gas heat data by more than 10%.	Normal, between-0.05" and -0.35" w.c.	Normal, between 5 and 14" w.c	Normal, between 5 and 14" w.c., remains stable	Excessive leakage around air orifice inlet plate
Higher than service facts gas heat data by more than 10%	Normal, between-0.05" and -0.35" w.c	Normal, between 5 and 14" w.c.	Normal, between 5 and 14" w.c., remains stable	Air orifice inlet plate restricted.

Table 6 is a matrix chart for troubleshooting and diagnosing gas pressure related combustion problems. Should a gas pressure related problem exist, use this chart for proper diagnosis and resolution.

Identifying Gas Pressure Related Problems

Some symptoms of pressure related combustion problems may be identified by sounds emitted by the burner. Sounds such as pulsating ignition, which makes a woofing type noise, is indicative of a gas and air mixture which is too lean. This would also be evident by an unstable (or hunting) manifold pressure. The regulator in the gas valve responds to the excessive pressure when the mixture finally ignites. It will immediately close down in response to the higher pressure and will then open completely in response to the lower pressure (repeating the process). In this instance a determination must be made as to whether the gas valve has an internal regulation setting which is too lean, or if a restrictive condition exists.

Another symptom of a pressure related combustion problem is a condition referred to as "burner screech". This condition is identified by a high pitched whistling, or screeching sound, being emitted by the burner. This is an indication of the burner being severely over fired. There are several conditions or circumstances which can cause over firing:

1. Gas valve regulator setting adjusted too high.
2. Wrong gas orifice installed (too large).
3. Air orifice inlet plate restricted.

When an over firing condition exists, the flame has a tendency to move closer to the burner screen—not further away. When this occurs, it causes a whistling effect through the ports of the burner screen.

Flue Product Analysis

In many types of combustion processes (induced draft, forced combustion and natural draft) it may be necessary to analyze flue products to determine whether or not complete combustion is occurring, or if incomplete combustion is taking place. Most often, these types of combustion processes have the capability of adjusting the primary airflow for the respective combustion process (the light commercial rooftop power burner combustion process has no primary airflow adjustment capability).

Note: *It is not usually necessary to analyze the flue products on light commercial rooftop equipment unless an ongoing combustion problem without a possible solution is present. Contact your local Technical Representative for recommendations.*

There are several commercially available devices for the specific purpose of analyzing flue products, both conventional and digital. These devices will typically allow the measurement of CO_2 (Carbon Dioxide), O_2 (Oxygen), and flue stack temperature.

Table 7.

Flue Stack Temperature Rise Above Ambient	Flue Gas Content % CO2 Natural Gas	Flue Gas Content % CO2 LP
350°-600°F	7.8-9.5% CO2	9.5-11.0%CO2

Note 3. The flue stack temperature and flue gas content (in % CO2) in table 7 are dynamic values based upon many factors (outdoor ambient, altitude, gas heating value, heat exchanger capacity and design, system airflow, fuel and air ratio etc.). Reference the specific Gas Heating Data for the particular unit model.

Factors that Affect Flue Stack Temperature Rise:

Outdoor Ambient: The outdoor temperature has an effect on the flue stack temperature. As the outdoor dry bulb temperature decreases, the specific volume decreases. This is the volume occupied by a mixture of water vapor and air that would weigh 1 lb. if all water vapor were extracted.

For example (assuming 50% relative humidity at both conditions), the specific volume of air @ 53° F. (dry bulb) is approximately 13 cubic feet per pound, and @ 16° F. (dry bulb) the specific volume is approximately 12 cubic feet per pound.

The following calculation shows how to determine the mass flow rate for a 350 Mbh furnace with a combustion blower motor, which moves 70 CFM. Utilizing basic mathematics, the mass flow rate for the furnace at both conditions can be determined:

Mass Flow Rate (lbs. per minute) = CFM/Specific Volume.

Mass Flow Rate @ 53° F. = 70 CFM/13 cubic feet per pound = 5.38 pounds per minute

Mass Flow Rate @ 16° F. = 70 CFM/12 cubic feet per pound = 5.83 pounds per minute

Thus, the decrease in specific volume increases the mass flow rate, which in turn increases the combustion blower suction, firing rate, and flue stack temperature rise at lower outdoor temperatures.

Altitude: An increase in altitude causes an increase in specific volume. This increase in specific volume causes a decrease in mass flow rate, combustion blower suction, firing rate and flue stack temperature rise. In other words, as the density of air decreases, the combustion blower suction also decreases. The light commercial rooftop power burner automatically compensates for higher altitudes.

Gas Heating Value: The flue stack temperature rise is directly related to the heating value (BTUs per Cubic Foot) of the fuel gas being used. An increase in the gas heating value will result in an increase in flue stack temperature. A decrease in gas heating value will result in a decrease of flue stack temperature.

Heat Exchanger Capacity And Design: The design and capacity of the heat exchanger may affect the flue stack temperature rise. Typically (but not always), the higher the input rate of the furnace—the higher the flue stack temperature rise may be.

Factors that Affect Flue Stack Temperature Rise (continued):

System Airflow: The effects of system airflow directly affect flue stack temperature rise. The lower the system airflow—the higher the flue stack temperature rise. This is due to the decrease in heat transfer from the heat exchanger surface to the surrounding air. Likewise, the higher the system airflow—the lower the flue stack temperature rise will be.

Factors that Affect Flue Gas Content %CO2:

Excessive Amount of Fuel Present: If an excessive amount of fuel is present (the mixture is too rich) the CO2 levels present in the flue products will be greater than the values present in the Gas Heating Data for the particular unit model.

Lack of Combustion Air: If not enough combustion air is present (the mixture is too rich) the CO2 levels present in the flue products will be greater than the values present in the Gas Heating Data for the particular unit model.

Lack of Fuel: If not enough fuel is present (the mixture is too lean) the CO2 levels present in the flue products will be less than the values present in the Gas Heating Data for the particular unit model.

Excessive Amount of Air Present: If an excessive amount of air is present (the mixture is too lean) the CO2 levels present in the flue products will be less than the values present in the Gas Heating Data for the particular unit model.

Table 8.

Flue Product Levels %CO2 or %O2	Combustion Air Possibilities	Fuel Gas Possibilities
High CO2 Level or Low O2 Level	Restricted or wrong (too small) air orifice inlet plate	Gas valve misadjusted (too rich), or failed. Wrong gas orifice installed (too large), or gas orifice loose or missing.
Low CO2 Level	Leakage around, or wrong (too)	Restriction in gas train. Gas valve misadjusted (too lean), or failed. Wrong gas orifice installed (too small).

Factors that Affect Flue Gas Content %O2:

While there is no published data regarding the levels of O2 (oxygen) present in the flue gases for the light commercial rooftops, it should typically be between 4.5 - 7.5 %O2. The relationship between O2 (oxygen) and CO2 (Carbon Dioxide) is an inverse relationship. If the O2 level increases, the CO2 level decreases. If the O2 level decreases, the CO2 level increases.

Excessive Amount of Fuel Present: If an excessive amount of fuel is present (the mixture is too rich), the O2 levels present in the flue products will be less than 4.5%.

Lack of Combustion Air: If not enough combustion air is present (the mixture is too rich) the O2 levels present in the flue products will be less than 4.5%.

Lack of Fuel: If not enough fuel is present (the mixture is too lean) the O2 levels present in the flue products will be greater than 7.5%.

Excessive Amount of Air Present: If an excessive amount of air is present (the mixture is too lean) the O2 levels present in the flue products will be greater than 7.5%.

The flue product troubleshooting chart in Table 8 may assist in identifying combustion related problems upon completion of flue product analysis.

Identifying Sources of Leaks

In the event that gas / flue product odors are entering the conditioned space, though usually not high enough in concentration to be dangerous, they can be very noticeable and a nuisance. Any such occurrence or report should be treated seriously and immediately to ensure that a dangerous condition does not exist. A methodical approach should be taken to identify the source of the odor and rectify the problem.

Leading Causes of Gas / Flue Product Odor Infiltration or Introduction:

Outdoor Air Intakes: Outdoor air hoods, dampers, economizers and other devices used for building ventilation purposes are a primary path for the introduction of gas / flue product odors into the conditioned space. The possible paths should be closed or disabled one at a time to determine which, if any one of them, is the actual path. Once the path is identified, steps must be taken to isolate the path from the source of the gas / flue products. In some cases a flue stack extension may resolve or alleviate the problem. Reference informational service bulletin YC-SB-27.

Infiltration Internal to Cabinetry: In the event that the infiltration is internal to the equipment cabinetry, inspection of the following areas internal to the equipment should be made.

Note: *If gas / flue products are leaking into the burner compartment, infiltration may occur through the left side block off panel that separates the burner compartment from the negative side of the evaporator fan. If this occurs, remove the evaporator fan access panel and ensure that there are no holes in the block off panel described above. If holes are present, they should be sealed appropriately.*

Sight Glass - If the pyrex sight glass (located in the right-hand side of the combustion blower motor mounting flanges) is missing, gas / flue products will be introduced into the burner compartment. If the sight glass is not present, equipment service may be reinstated by removing the combustion blower motor and inserting two pennies into the milled area of the flange that normally holds the sight glass.

Igniter Gasket - If the integrity of the igniter gasket has been compromised or is missing, or if the igniter screws are loose, this may facilitate the leakage of gas / flue products into the burner compartment.

Burner End Plate Gasket - If the integrity of the burner end plate gasket has been compromised, or if the screws are loose, this may facilitate the leakage of gas / flue products into the burner compartment. The burner end plate should also be inspected for damage (warpage, cracks, etc.)

Air Orifice Inlet Plate Gasket - If the gasket around the air orifice inlet plate is not sealed properly, it may facilitate leakage of the gas / air mixture into the burner compartment.

Gas Train - The remainder of the gas train should be inspected to insure that excessive leakage of fuel gas is not occurring within the burner compartment.

Note: *Minor leakage may be present at the gas valve body. This is perfectly normal and expected. This normal leakage, when tested and examined with soap bubbles, will yield approximately one small bubble per second. As per ANSI Z21.21-1987 article 2.4.1 automatic valves and combination controls shall not leak externally at a rate in excess of 200 cubic centimeters per hour.*

Heat Exchanger - The heat exchanger should be inspected for leakage by removing the top panel (horizontal models) or the large panel opposite the service access side of the unit (downflow models). A visual inspection of the heat exchanger should be conducted to verify the integrity of the drum and tubes. The collector end of the heat exchanger (the end where the flue tubes carry the flue products out of the drum) should be examined as well. The gasket should be inspected to verify integrity and the bolts, which hold the collector to the drum, should be checked to insure all are present and tight.

Heat Exchanger Failure Analysis

Air Distribution: Heat released during the combustion process within the heat exchanger is intense. Temperatures approaching 800 °F are normal. If this heat is not carried away, the heat exchanger will overheat.

Insufficient airflow and poor air distribution are leading causes of heat exchanger failure. A sufficient amount of air must be directed through the heat exchanger to prevent overheating, and each surface and section of the heat exchanger must be in the supply air stream.

Flame Impingement: Normally, no part of the gas flame impinges or burns against the inner surface of the heat exchanger. All flames are directed through the center of the heat exchanger.

However, if the gas flame impinges upon an area of the heat exchanger, extremely high surface temperatures will be generated causing rapid failure.

Over Firing: Firing the heat exchanger at a rate exceeding its design will result in over stress of the metal and subsequently, rapid heat exchanger failure. This can occur if the manifold pressure is too high or if the gas orifice is too large. Although the limit controls may prevent a dangerous condition from occurring due to over firing, they cannot protect the heat exchanger if it is constantly subjected to excessive heat.

Condensation of Flue Product Water Vapor: Water vapor is a natural by product of combustion. If allowed to condense in heat exchangers not designed to handle or manage condensation, heat exchanger corrosion and failure can and will occur. About one gallon of water forms when 100 cubic feet of gas burns; this amount of water can be made by a 100,000 BTUH furnace in only one hour.

Contaminated Combustion Air: If concentrations of chlorinated vapor are introduced into the combustion air stream, premature catastrophic failure will occur. When chlorinated hydrocarbon vapors are burned, hydrochloric acid is formed causing accelerated corrosion. Condensation of water vapor from the flue products is also associated with the corrosion process.

This type of corrosive attack occurs on the inner surface (flue gas side) of the heat exchanger. This corrosion is cumulative and does not appear to be related to any minimum atmospheric concentration of chlorides. However, accelerated corrosion can be expected on equipment exposed to greater concentrations.

There are a number of common substances which contain chlorinated hydrocarbons:

adhesives, paint removers, degreasing solutions (solvents), dry cleaning fluids, water treatment chemicals, paints and inks, halogen type refrigerants, spray can propellants, etc.
There are several applications where caution should be exercised, considering the likelihood of premature heat exchanger failure: beauty salons, dry cleaning plants, industrial plants, plastics plants using polyvinyl chloride (PVC), swimming pools, water treatment plants, etc.

Component Specification

Component Status	Component Description	Manufacturer Information	Electrical Data	Mechanical Data	Part Number
Current production	Hot Surface Igniter (HSI), flat/wafer type (used after June 1, 1998)	Norton-Model 231T (same as below except 3/8” longer)	102-132 VAC 40-80W(cold) 3.5-3.9 Amps	Recrystallized silicon carbide 1,800-2900°F.	KIT-3033
obsolete	Hot Surface Igniter (HSI), flat/wafer type	Norton-Model 231T	102-132 VAC40-150W (cold) 3.0-3.55 Amps	Recrystallized silicon carbide 2,000-2,850°F	NLA-superseded by HSI described above
obsolete	Hot Surface Igniter (HSI) round double helical cut	Carborundum	102-137 VAC 50-500W (cold) 2.55-3.25 Amps	Silicon carbide w/ double helix cut 2,000-3,000°F	Superseded by KIT-3033
Current production	Ignition Control Module (IGN), hot surface	Texas Instruments Model 3HS-2 (45 sec. preheat)	18-30 VAC 2.4 VA standby 5.3 VA heating	Maximum Loads Igniter-5 Amps Valve-1.5 Amps	KIT-5137 (blue board)
obsolete	Ignition Control Module (IGN), hot surface	Texas Instruments Model 3HS-1 (30 sec. preheat)	18-30 VAC 2.4 VA standby 5.3 VA heating	Maximum Loads Igniter-5 Amps Valve-1.5 Amps	KIT-3308 (beige board) NLA Superseded by KIT -5137
obsolete	Ignition Control Module (IGN), hot surface	Kidde-Fenwal Model 05-246266-203	18-30 VAC 0 VA standby 2.4 VA heating	Maximum Loads Igniter-6 Amps Valve-0.6 Amps	Superseded by KIT-3308
Current production	Gas Valve (GV), redundant negative	White-Rodgers Model 36E66-301	24 VAC Nominal 0.3 Amps	Inlet1/2” Outlet 3/4” 14 NPT	VAL-4810
Current production	Gas Valve (GV), redundant negative pressure regulated	White-Rodgers Model 36D24-301 and 36D24-401	24 VAC Nominal 0.6 Amps	Inlet 1/2” (301) Inlet 34” (401) Outlet 3/4” (Both) 14 NPT	(301) VAL-3482 (401) CNT-1221
Current production	gas valve GV, modulating gas heat	White-Rodgers Model 36D24-910	24 VAC Nominal 0.6 Amps	Inlet 3/4" Outlet 3/4" 14 NPT	VAL08953
obsolete	Gas valve (GV), redundant negative pressure regulated	ROBERTSHAW Model 7100DERN 71G 01E 043	24 VAC Nominal 0.5 Amps	Inlet 1/2” Outlet 3/4” 14 NPT	Superseded by KIT-2048 (80-135 MBH), KIT-2049 (150-250 MBH)
Current production	Combustion Blower Motor (CBM), 80-135 Mbh	Fasco Industries Model 7162-3973 Single Speed	208-230 VAC 0.28 FLA Capcitor-3mf@440 VAC	3,350 RPM 80 Mbh=16 CFM 90 Mbh=18 CFM 120 Mbh=25 CFM	KIT-2588
Current production	Combustion Blower Motor (CBM), 150 and 205 Mbh	Faso Industries Model 7162-3969 Two Speed	208-230 VAC 0.60 FLA Capacitor-6mf@440 VAC	2,990/3,525 RPM 150 Mbh=31CFM 205 Mbh=42 CFM	KIT-2589
Current production	Combustion Blower Motor (CBM), 250 Mbh	Fasco Industries Model 7162-3971 Two Speed	208-230 VAC 0.50 FLA Capacitor-6mf@440 VAC	2,600/3,525 RPM 250 Mbh=51 CFM	KIT-2590

Current production	Combustion Blower Motor (CBM), 350 and 400 Mbh	Fasco Industries Model 7162-3972 Two Speed	208-230 VAC 0.60 FLA Capacitor-6mf@440 VAC	2,775/3,475 RPM 350 Mbh=70 CFM 400 Mbh=80 CFM	KIT-2591
Current production	Combustion Blower Motor (CBM) 350 and 390 MBH Modulating	Fasco Industries Model 7043-0033 variable speed	208-230 VAC	950 - 4700 RPM	FAN03975
obsolete but still available as service replacement	Combustion Blower Motor (CBM), 80-205 Mbh	Fasco Industries Model 7062-4308 Two Speed	115 VAC 1.10 FLA Capacitor-7.5mf@440 VAC	2,800/3,500 RPM VAC	FAN-1306
Current production	Gas Valve (GV) Mod heat	White-Rodgers Model 36D24-902B1	24 VAC Nominal 0.6 Amps	Inlet 3/4" Outlet 3/4" 14 NPT	VAL08953

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