

Direct Gas-Fired Air Heating Systems

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Introduction

This course is intended to provide the student with an understanding of the operation and application of heating systems that utilize Direct Gas-Fired Burners to provide comfort heating of building spaces.

Typical applications are shown. Symptoms of problems that may be addressed using this type of equipment are described.

Basic system configurations are discussed, with descriptions of options that are available. Basic operation of units, with a discussion of fuels, air quality requirements, operational limits, and installation requirements are presented.

Industry Construction Standards and Codes are listed. Insurance standards are also explained. Safety issues are addressed.

Finally, a method for estimating operational costs of this type of equipment is presented.

Disclaimer

All information presented in this course is intended for **educational purposes**. Statements are correct and factual, to the best knowledge of the provider. No liability for errors is accepted.

Informational sources are documented to the best ability of the writer. However, some information assumed as “common knowledge” may originate from a particular author or source. Any examples of this will be corrected immediately upon notification of the writer.

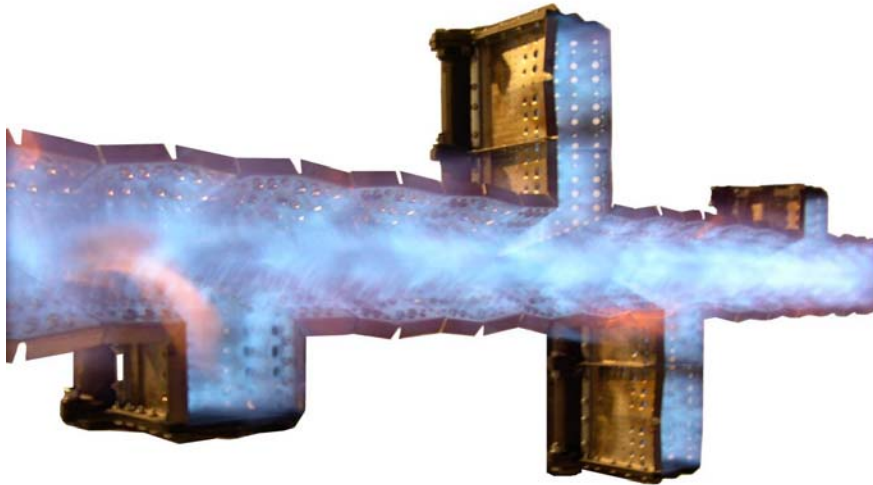
This document has been prepared under the auspices of a manufacturer of this type of equipment. However, every effort has been made to provide an impartial general overview of Directed Gas-Fired Air Heating Systems, **with no bias for or against any provider**.

General:

Direct Gas-Fired Air Heating Systems are a class of equipment utilized primarily in industrial and commercial environments to provide for worker comfort. To a lesser extent, these systems are used to condition air for process and finishing applications such as material drying and paint curing.

These systems have gained widespread use due to the fact that they are inexpensive to build, maintain, and operate compared to other furnace types of comparable heating capacity.

The feature that differentiates a Direct Gas-Fired Heating System from other types of heating equipment is its burner system. A “**trough**” or “**line**” burner is installed directly in the supply air stream. Combustion products are introduced into the building space during operation.



The key advantages are simplicity and efficiency. No heat exchanger is required. This eliminates component installation and maintenance costs. With no heat transfer losses, the unit is nearly 100% efficient.

The primary disadvantage is the introduction of waste products into the airstream. For this reason, both ANSI Z83.4/CSA3.7 and ANSI Z83.18 standards state:

“Heaters covered by this standard are intended for use in industrial and commercial applications.” ANSI Z83.18 states further that: “Heaters covered by this standard are not intended for use in any area containing sleeping quarters.”

Carbon Monoxide and Nitrogen Dioxide are the primary pollutants. These are limited to no more than 5.0 PPM for CO and 0.5 PPM NOX, a fraction of OSHA allowable Permissible Exposure Limits (PEL's).

Applications:

A Direct Gas-Fired Air Heating System may be used in an industrial or commercial application for any or all of the following purposes:

- Make-Up Air Heating – Air is introduced to a building to replace air being exhausted.
- Space Heating – A unit provides primary or supplementary heating to a building space.
- Space Pressure Control – Building or Room Pressurization is held within a range.

Make-Up Air Heating:

Basic Definitions:

Make-Up Air – Outside Air that Replaces Exhaust Air.

Make-Up Air Heater – Used to filter and temper incoming air as part of an overall system to maintain Indoor Air Quality.

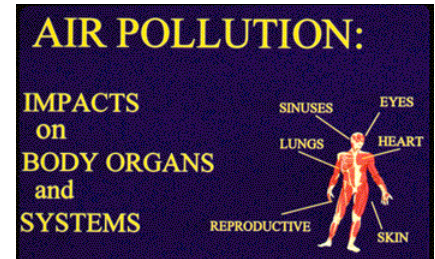
Reason for need:

Heat and contamination generated in a process are generally removed from an indoor environment using exhaust equipment. This can create a negative pressure or air deficit in the building space.

Problems:

Negative Air Pressure can create problems such as:

- Exhaust fans losing performance, as the building pressure becomes negative
- Pilot light outages and exhaust system failure on natural draft gas equipment
- Cold air drafts and infiltration of dirt and contamination from outside
- Difficulty opening or closing exterior doors
- Nausea and headaches among personnel due to inadequate ventilation



In temperate climates or during mild weather, moderate amounts of make-up air can be supplied by simply opening windows or overhead doors. However, this is usually not the case in industrial and commercial facilities. Forced ventilation Make-up air is required.

Direct Gas-Fired Make-up Air Units supply tempered and filtered air to the indoor environment. In summer, a direct-fired unit may be used as an air handler, with the heater disabled. By adding a DX or evaporative cooling section to the unit, it may be used to supply conditioned air year round.

Make-Up Air Applications:

There are three general applications for Make-Up Air Units:

- Direct Compensating Ventilation
- General Area Ventilation
- Door Heating

Direct Compensating Ventilation.

Conditioned Air is Delivered to the Immediate Vicinity of Exhaust. This is the case for welding fume extractors, stovetop exhaust hoods, paint booths, or similar applications.

General Area Ventilation.

Conditioned Air Blankets Entire Area of Building to Compensate for Many Exhausts. Introduced in Cleanest Part of Building - Flows to Negative Pressure Areas - Picks up Dust, Vapors, and Odors en route.

Door Heaters

Heated Air is introduced at open doors to warm incoming air or compensate for loss. Heater may also be used as part of an "air door" system.

Typical Industrial Uses:

Plating Tanks, Paint Spray Booths, Welding Operations, Chemical Exhaust, Degreasing, Factory Ventilation, Plastic Molding, Foundry Works, Grinding & Buffing Operations

Typical Commercial Uses:

Warehouses, Kitchens, Entryways, Gymnasiums, Pools, Exposition Buildings, Garages

Make-Up Air Volume Requirements:

The recommended method for calculating Make-up Air Volume is to determine the total CFM capacity of exhaust fans, blowers, stacks, etc. in the building and add 10%. This will create a positive pressure in the building.

When information is not available, the following estimates may be used to determine approximate requirements:

Paint / Spray Booth:	125 to 175 CFM per sq. ft. of face opening
Oven Exhaust:	One air change per minute.
Fume Exhaust:	Area of Pipe (in square feet) x velocity (3,000 feet/min average) = CFM
Roof Ventilator:	same as Fume Exhaust
Canopy Hoods:	100 to 300 CFM per square foot of hood open area.
Furnace Combustion Air:	Minimum CFM = BTU/hr rating / 6,000
Drying, Baking, Curing Ovens:	100 CFM per square foot of booth cross section.
Pickling or Cleaning Tanks:	150 CFM per square foot of door opening or 200 CFM per square foot of hood face opening.

Space Heating:

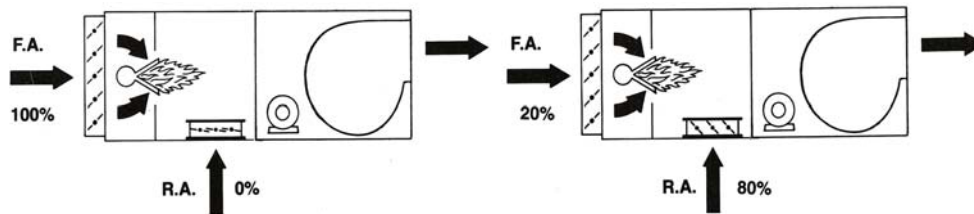
A Direct Gas-Fired Heating System may be used as a primary or secondary source to heat a building space. When used for this application, a room thermostat controls unit outlet air temperature.

On a call for heat, a space-heating unit will provide air at the desired room temperature. A unit may also be designed to increase outlet temperature when room temperature is low. A duct stat or probe at the outlet of the unit prevents outlet temperatures from exceeding the maximum allowable value.

When a unit blower runs continuously, room air is monitored and the outlet air temperature is modulated to maintain the temperature.

Systems are usually designed for either Space Heating or for Make-Up Air use. However, standard Make-up Air Units may be provided with a room thermostat that monitors indoor temperature. When room temperature falls below minimum set point, a signal is sent to the unit to override outlet temperature set point and turn the unit to full fire. When minimum room temperature is satisfied, unit returns to outlet air temperature control mode.

Return Air Units are a design that includes a damper to bring room air back into the unit. These re-circulate indoor air through a unit with a minimum of outside air added. This type of unit is able to provide air movement for indoor comfort and reduced temperature stratification, but with a minimum of heat added to the building.



Return Air Units are widely used for direct fire space heating applications. They can be supplied with a maximum 80% return/20% fresh air, per ANSI standards. Other options include a 50/50 arrangement. "80/20" Units are configured to modulate from the 80% return/20% fresh air to up to 100% outside or fresh air. 50/50 units are generally designed to switch from 50% return / 50% fresh to 100% fresh, with no modulation between.

All return air should be brought in downstream of the burner and not recirculated through the burner. This is to prevent buildup of waste products from the combustion process within the building. It also prevents contaminants originating within the building environment from being passed through the direct fire burners. The combustion of unknown contaminants can be a serious Safety or Indoor Air Quality problem, and so must be avoided.

Space Pressure Control:

Space Pressure Control is used to minimize and control the exchange of air between the building and the outside environment or from one building area to another. This may be accomplished in three ways:

- Constant air supply with variable-speed exhaust
- Variable air supply with constant-speed exhaust
- Variable Return-Air

Constant air supply with variable-speed exhaust is recommended where a hot or contaminated environment must be ventilated while maintaining room pressure. Unit may be interlocked to that it only operates with the exhaust system.

Variable Air Supply with constant-speed exhaust may be preferred where fume exhausters or fume hoods are used to provide critical ventilation of contaminants from a “clean” environment while make-up air is used to maintain a positive pressure to prevent infiltration.

In either case, when the system is enabled, a pressure sensor (such as a Dwyer Photo-Helic) in the building space monitors room pressure. When a high or low pressure reading is detected, the air supply or exhaust is adjusted to compensate.

When controlling a Variable Air Supply unit (or VAV - Variable Air Volume), two methods are available:

- Damper Control - Unit discharge damper is adjusted using the damper motor
- VFD (Variable Frequency Drive) – Controller adjusts the speed of the blower motor

Discharge Damper adjustment is an older method of controlling discharge air volume. Its chief advantage is that it only requires positional control of a small discharge damper motor. The major disadvantage is the wasted Horsepower of the blower motor at lower delivery rates.

In recent years, fan speed control using VFD's has become economical. In this application, a standard energy efficient motor is usually adequate down to 75% of normal motor speeds. For a fan speed down to 25%, a premium efficiency motor is required. Inverter duty motors are not usually necessary since at 25% of normal fan speed, air delivery is minimal.

Variable Frequency Drives are also programmable. They are used to provide soft starts and to ramp motor speed up or down in response to signals from the control system.

Finally, in a generally “clean” environment without a critical need to remove large quantities of contaminants, a simple solution to building pressurization is a Return Air Unit with the return air damper motor controlled by building a pressure sensor. When building pressure increases, more inside air is returned through the unit, relieving the pressure. When building pressure falls, more outside air is supplied to the building in order to “pump up the pressure”. Precise control of building pressure by a single piece of equipment can thus be achieved.



Control Systems:

General:

For Make-Up Air and Space Pressurization Applications:

- Outlet Temperature is usually monitored with a probe mounted near the outlet of the unit.
- Discharge Air Temperature is set at the control panel or using a remote control station.
- Gas input is “modulated” using a butterfly valve, actuator, and controller.

The most common supplier of valves and controls is Maxitrol. Using the basic Series 14 system, a sensor probe with a mixing tube is mounted and wired to the A1014 Amplifier. A Remote Temperature Selector is also wired to the A1014 Amplifier, and used to set the desired temperature. Based on the difference in desired and required temperatures, a DC control signal is sent to the modulating valve (a series M-XXX or MR-XXX: 0-5 V, low-fire; 5-15 V, modulation range; 15-approx. 24V, high-fire).

An override option may also be supplied. In this case a room thermostat is supplied in addition to the basic system. The unit is set to full-fire when room temperature falls too low.

Other control solutions could include the use of a more advanced system, supplied by the equipment manufacturer or by a controls contractor. A Maxitrol M-XXX or MR-XXX Valve may be coupled with an A-200 signal conditioner. The A-200 signal conditioner requires 24V DC power. It can respond to either a 0-10V or a 4-20mA signal, converting it to a 0-20V DC signal to control the valve.

For Space Heating Applications, a room thermostat is used to control outlet temperature. On a call for heat, the unit will provide air heated to the maximum allowed temperature until the room thermostat is satisfied. Once satisfied, the unit will either turn off or will continue to operate at a reduced outlet temperature.

Unit Controls:

Controls Serve These Functions:

1. Ignition and Flame Supervision
2. Safety Interlocks
3. Temperature Control
4. Operation

1. Ignition and Flame Supervision –

Flame ignition can be provided by:

- A. Direct Spark Ignition – Main Burner is lit with a spark igniter.
- B. Spark Ignition with Intermittent Pilot – Pilot is lit, used to light main burner, stays on while burner operates, and shut off when burner is shut off.
- C. Spark Ignition with Interrupted Pilot – Pilot is lit, used to light main burner, then shut off. Burner continues to operate.
- D. Hot Surface Ignition – Silicon Nitride “probe” is heated to high temperature and used to light main burner.

Notes:

Standing Pilot ignition is not used for Direct Fire applications.

An Igniter is similar to a spark plug, mounted at one end of a burner.

Only a few companies use Hot Surface Ignition for Direct Fire applications.

Direct Spark units are supplied with an ignition transformer for the igniter.

Piloted Units are supplied with a solenoid-operated Automatic Pilot Valve and a small pressure regulator – around 20,000 BTU – as well as an ignition transformer for the pilot spark igniter.

Hot surface igniters are supplied with an ignition transformer

Main Burner Natural Gas supply is around 4½” Water Column.

Flame supervision equipment - monitors the burner and shuts off gas supply in the case of flame failure. The types of supervision used are:

- A. Flame Rod – A thermocouple probe is located at the burner.
- B. UV – Ultraviolet light sensor monitors the flame.

Flame supervision is accomplished using one of the above, with a “Fireye” or similar electronic device to shut down the unit when failure is detected.

Pre-purge of the system (by starting the blower for a specified time to provide a minimum air volume change) before ignition of main burner is not required by ANSI code, but is frequently specified by the user. This should be provided whenever a building contains flammable dusts or vapors that could potentially reach and collect within a direct gas-fired unit while it is idle.

GE-GAPS (GE-Global Asset Protection Services) and FM (Factory Mutual) are insurance codes with additional requirements for heater construction. When applicable, these codes may require the manufacturer to provide a purge timing cycle. Effective pre-purge is often accomplished by the startup requirements of a unit. ANSI Code requires air flow to be established and proven, prior to ignition.

2. Safety Interlocks

To assure safe operation of a direct gas-fired heating system, a number of Safety Interlocks are commonly provided:

- A. Damper Limit Switch – Dampers must be fully open before unit will operate.
- B. Air Proving Switch – Located near outlet of unit to prove air flow before igniting burner.
- C. Flame Supervision – Discussed above. Shuts down unit on flame failure.
- D. High Temperature Limit – Signals unit to reduce gas supply when maximum allowable temperature is reached. If air temperature exceeds limit, the unit is shut down.
- E. High Gas Pressure Switch – Shuts down unit to protect regulator against spikes in inlet gas pressure.
- F. Low Gas Pressure Switch – Shuts down unit when low inlet pressure detected. Redundant safety device, since low flame would also shut down unit.
- G. Safety Shut-off Valve – Responds to various inputs listed above – closes off gas supply.

3. Temperature Controls

Discharge Air Sensor – Located in duct or outlet of unit to detect outlet temperature. Mounted with a probe and “mixing tube”.

Room Air Sensor – Located in room for space heating applications.

Amplifier – Used to calibrate sensor and send a signal to the control system.

Gas Valve Controller – Compares temperature signal to required values. Send signal to valve to increase or decrease gas flow.

Modulating Gas Valve – Generally, a butterfly valve actuated by an electric motor and signal conditioner to “modulate” or provide variable gas supply to the main burner.

Outdoor thermostat – Disables burner system in mild weather. Enables burner system when outdoor temperature is low enough. May also be used to adjust temperature setting as outdoor air changes temperature – i.e. 1° temperature increase for every 7° drop in outdoor temperature below a set point.

Low Outlet Temperature Probe – Secondary outlet temperature sensor used to disable blower and burner when outlet temperature falls below a set limit. Serves as a secondary safety and to disable units unable to provide sufficient heating during severe cold weather.

4. Operation

Main Control Panel – The controls listed above are usually installed on a main control panel, located in a cabinet attached or built into the unit. The main control panel also includes main power, disconnect switches, fuses or breakers, control and ignition transformers as required, motor starter, etc.

Remote Control Panel – Supplied with system switches to start up and shut down units. May be supplied with various indicating lights, depending on configuration of unit. Usually located in occupied space.

Electronic Systems – May be used to set up unit for automatic day/night/weekend/holiday operations, to control unit for operations such as a paint booth with automatic spraying and curing cycles, and to interface units with BMS's (Building Management Systems).

Unit Construction Types:

Configurations / Locations:

Direct Gas-Fired Heating Systems may be built in a number of configurations. They may be curb mounted as horizontal rooftop systems with down or horizontal discharge or in a vertical configuration for mounting on a pad outside of a building, with air ducted to the interior. They may also be located inside a building, suspended from hangers or mounted on support steel. Various manufacturers can supply any physical configuration required.

Two air flow configurations are available: 100% Fresh Air or Recirculating.

In the 100% Fresh Air arrangement, air is heated as it passes through the unit and supplied to the building space.

In the Recirculating arrangement, a damper is installed to allow a portion of building air to be supplied to the unit and returned to the building. This air is usually introduced downstream of the burner in a pull-through unit. Various percentage settings are available: 80% return / 20% fresh, 50/50, or variable.

It should be noted that demand for recirculating direct gas-fired systems has fallen in recent years. Indoor Air Quality concerns, more stringent regulations passed in recent years, and expense have contributed to this shift. In 2003, new ANSI Standards took effect. Formerly, both recirculating and 100% fresh air units were covered by the same standard. Today, **ANSI Z83.4 applies to 100% Fresh Air Units and ANSI Z83.18 applies to Recirculating Units.**



System Components:

Most manufacturers offer many options with a Direct Gas-Fired Heating Unit. Typical components, options and accessories are listed below:

Mounting Curbs:

For installation on building roof. Note – As a service, some manufacturers will also specify mounting requirements for fabrication by others. This allows a contractor to field fabricate a curb for faster installation or allows for third-party fabrication of curbs where the engineer specifies seismic-resistant construction.

Inlet Hoods:

Generally an add-on item. Prevents rain and trash from being drawn into a unit.

Filters:

Filtration may be accomplished using Cleanable Filters mounted in the Inlet Hood or by using a Flat or V-bank Filter Section. For special applications, Bag Filters or HEPA final filters may be specified, but these are not common.

Clogged filter switches and indicators are often supplied to alert maintenance personnel when filters are dirty.

Fans:

Standard units are generally supplied with DWDI (Double Width, Double Inlet) Forward Incline fans. These are competitively priced and offer good performance characteristics.

For High Static applications due to building pressurization, long ductwork, filtration, or other reasons, Backward Incline (BI) Fans may be required. Other options that may be specified are Backward Incline Curved (BC) or Airfoil Fans. These are BI fans with higher efficiency and performance, but at higher cost.

Insulation & Lining:

Most manufacturers offer the option of insulation and lining. Standard insulation is generally 1" thick fiberglass or foil face fiberglass board.

Linings may be steel or stainless steel to isolate insulation from the air stream. This provides for longer-lasting insulation and eliminates the possibility of contaminating the air stream if insulation breaks down.

A few companies can offer perforated or expanded metal linings. These use the insulation/lining for sound abatement purposes.

Burner Construction:

The standard “Line Burner” is a cast iron pipe assembly with drilled gas orifices, fitted with bolt-on perforated stainless steel baffles. Aluminum burners are also available from some manufacturers.

Adjustable profile plates are installed around the burner to set airflow velocity across the Line Burner / Baffle assembly.

VAV System Profile Plates

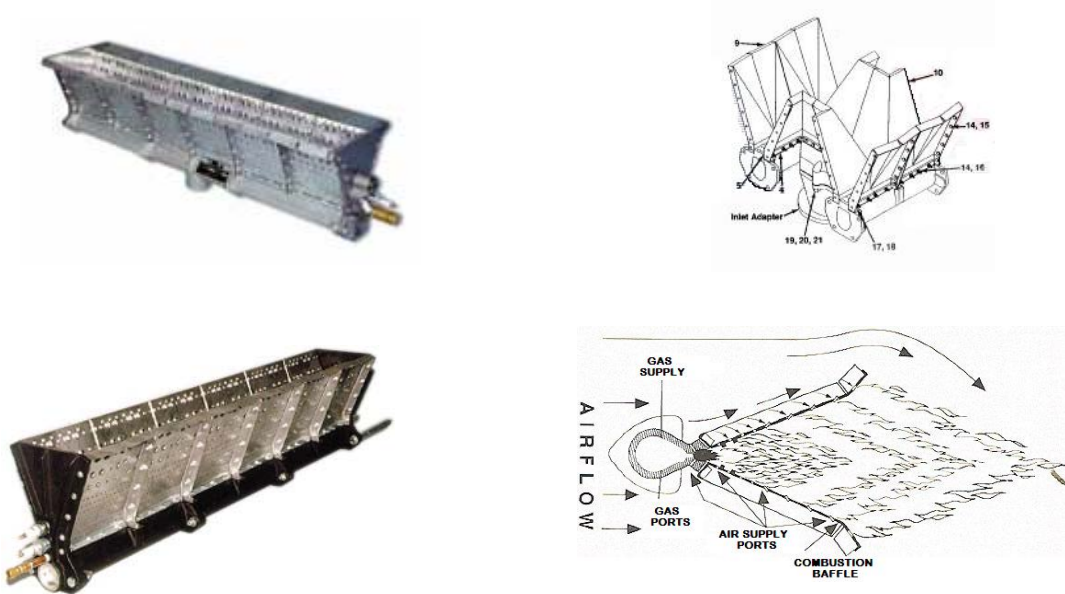
Some manufacturers also offer Variable Air Volume (VAV) systems with automatically adjusting profile plates. These plates control airflow across the burner / baffles to keep velocities within the required operating range. Adjustable plates are usually motorized but some manufacturers have had success with spring-loaded profile plates that respond to air flow, eliminating the need for motors and pressure controllers.

Please note: The required air velocity across the burner for safe operation has an acceptable range of values – typically 2,500 to 3,200 ft/min. This can allow a small amount of adjustment during operation of the unit - +/- 10% (or -20%), adequate for many Space Pressure Control applications. More variation than this will generally require the use of adjustable profiles.

Burner Performance:

Line Burners can produce over 1 Million BTU/Hr per foot of length. However, for use in Direct Gas-Fired Heating Equipment, this must be limited. Burners begin to produce unacceptable levels of Carbon Monoxide and Nitrogen Oxides above 550,000 to 600,000 BTU/Hr.

As noted before, air velocity across a Line Burner must be kept within the acceptable range. Too much or too little air flow can cause release of raw gas, incomplete combustion of fuel or generation of high levels of waste gases. Ideal air velocity across a burner is around 2,850 ft/min, depending on the manufacturer. Profile plates (discussed above) are used to set this velocity.



Fuel Types and Combustion:

By far, the most-utilized fuel type for Direct Gas-Fired Heating Systems is Natural Gas. In addition, LP, propane-air, or low-BTU fuels may be used.

Natural Gas used for fuel is typically a mixture of gases: methane (70-95%), ethane (1-14%), propane (0-4%), butane (0-4%), butane (0-2%), pentane (0-0.5%), hexane (0-2%), carbon dioxide (0-2%), oxygen (0-1.2%), and nitrogen (0.4-17%). The composition depends on the location of its geographical source. Local gas utilities are the best sources of current available gas composition.

Fuel Heating Values of natural gas vary from 900-1200 Btu per cubic foot. Commercially available fuels are generally between 1,000 and 1,200 Btu/ft³.

Liquefied Petroleum (LP) Gases are primarily propane and butane, produced as a by-product of oil refining or by stripping natural gas. Commercial **Propane** contains 5-10% propylene, in addition to propane.

Fuel Heating Values for propane are around 2,500 Btu/ft³. Propane-air mixtures are used by some small utilities and by natural gas companies to supplement supplies at peak loads.

Low-BTU gases such as methane generated in sewage treatment plants are sometimes available and used as fuels for heating. These vary a great deal in Fuel Heating Values.

When specified, all of the above fuels may be used in direct-fired equipment. Equipment must be set up and adjusted after installation, so some variation from specifications is not critical.

Products Of Combustion:

Products of Combustion are limited by applicable ANSI Standards for construction and operation of this type of equipment. In the air stream leaving direct gas-fired units, concentrations of no more than the following are allowed:

Carbon Monoxide:	5	PPM (Parts Per Million)
Nitrogen Dioxide:	0.5	PPM

These exposure levels have been deemed to be safe.

Comparisons of CO levels:



Average CO levels in homes vary from 0.5 to 5 parts per million (ppm). Levels near properly adjusted gas stoves are often 5 to 15 ppm and those near poorly adjusted gas or wood stoves may be 30 ppm or higher.

OSHA Standards for CO Exposure:
The OSHA PEL (Permissible Exposure Limit) is 50 PPM. OSHA Standards prohibit worker exposure to more than 50 parts of the gas per million parts air averaged during an 8-hour time period.

Calculating Performance

Manufacturers use different formulas to calculate expected heating performance during unit operation. These are generally in agreement with ASHRAE and with ANSI standards, but with various simplifications.

For draw-through systems (where the blower is located downstream of the line burner), the volumes of gases introduced as fuel and generated by combustion are generally ignored with respect to outlet volume. Altitude correction factors for various locations may be applied, but it is conservative to ignore them also, unless an installation is at high altitudes.

A simple formula for calculating performance used by one manufacturer is as follows:

$$\Delta T = (920 \times MBH) \div (1.08 \times SCFM) \quad \& \text{ Rearranged: } MBH = (1.08 \times SCFM \times \Delta T) \div 920$$

Where:

- ΔT = Temperature rise of air delivered by unit.
- 920 = Constant arrived at by multiplying:
Average ratio of net and gross heating values of common fuel gases
92% sensible (note- 8% latent) X 1,000 BTU/HR per MBH
- MBH = 1,000 British Thermal Unit / Hour
- 1.08 = Constant arrived at by multiplying:
0.075 (air density) by 0.24 (specific heat) by 60 min/hr
- SCFM = Standard cubic feet of air delivered by the air make-up per minute

This formula is within 2-3% of "correct" and is acceptable for draw-through systems.

A more accurate formula used by another manufacturer is:

$$BTUH = (SCFM \times 1.32605 \times 29.92 \times 0.24 \times 60 \times \Delta T) / 0.92 (460 + \Delta T + \text{Inlet Temperature})$$

Where:

- BTUH = British Thermal Units / Hour
- SCFM = Standard cubic feet of air delivered by the air make-up per minute
- 1.3261 = Density of Air Handled By Blower
- 29.92 = Barometric Pressure at Sea Level
- 0.24 = Specific Heat of the Air Handled By Blower
- 60 = Conversion for Minutes to Hour
- ΔT = Temperature rise of air delivered by unit.
- 0.92 = Average ratio of net and gross heating values of common fuel gases
92% sensible (note- 8% latent)

This is within 1% of "correct" and is also acceptable for draw-through systems.

For a blow-through unit, where air is “pushed” through the burner by the blower, the net volume delivery should be corrected based on temperature differences:

$$\text{Net CFM} = \text{Inlet CFM} \times (460 + T_{\text{room}}) / (460 + T_{\text{inlet}})$$

Air volume delivered by blowers should also be corrected for altitude. Selected Altitude Correction Factors for Elevation above Sea Level are tabulated below:

City	Elevation Above Sea Level (ft)	Correction Factor	City	Elevation Above Sea Level (ft)	Correction Factor
Atlanta, GA	1010	1.04	Milwaukee, WI	672	1.02
Baltimore, MD	145	1.01	Minneapolis, MN	834	1.03
Boston, MA	15	1.00	Nashville, TN	590	1.02
Buffalo, NY	705	1.03	New York, NY	10	1.00
Charlotte, NC	736	1.03	Omaha, NE	977	1.04
Chicago, IL	607	1.02	Philadelphia, PA	5	1.00
Cincinnati, OH	758	1.03	Pittsburgh, PA	1137	1.04
Cleveland, OH	777	1.03	Reno, NV	4404	1.18
Columbus, OH	812	1.03	Richmond, VA	164	1.01
Dallas, TX	481	1.02	St. Louis, MO	535	1.02
Denver, CO	5,283	1.21	Salt Lake City, UT	4220	1.17
Detroit, MI	619	1.02	Seattle, WA	449	1.02
Indianapolis, IN	792	1.03	Wichita, KS	1321	1.05
Memphis, TN	258	1.01			

To Calculate Corrected Air Volume, simply determine volume delivery at standard conditions and multiply by the Altitude Correction Factor above.

Operating Costs of Direct Gas-Fired Heating Systems

Listed below are methods for calculating operating costs for Direct Gas-Fired Heating Systems. Please note - Benefits of using this type of equipment should also be considered. These include:

For Heating Systems:

- Low first cost for equipment compared to other types of systems.
- Low operating cost compared to other types of systems.
- Low maintenance cost compared to other types of systems.

For Make-up Air Systems:

- Extended life of other ventilation equipment due to balanced air.
- Extended life of other combustion equipment.
- Better employee comfort and productivity, lower absenteeism and turnover.
- Better control of product quality

Comparison of costs for Heating Systems is fairly straightforward. For Make-up Air Systems, quantifying and calculating the actual reduced costs or increased profits resulting from such items is subjective and difficult to quantify. However, once a need is noted, equipment cost is generally easily justified.

Fuel and Electricity Pricing:

Electricity costs can vary by as much as 90% depending on the State, location within the State and by local Electric Distribution Companies. Electricity rates can be low if the facility is close to a hydroelectric plant. Electricity rates can be very high when served by nuclear plants and regionally (in the northeastern states, California or Hawaii).

Some electric utilities design their rates based on electrical demand peak (KW or KVA) plus KWH consumption. Others tie their rate design to their true electricity generation cost and vary the KWH and KW cost based on the time-of-day and day of the week.

This being said, U.S. Industrial Average Revenue per KWH rates in 2002 were:

Commercial:	7.93¢ / KWH
Industrial:	5.04¢ / KWH

Example:

Given the following average information we will determine estimated operating costs for a direct gas-fired heating unit.

Ohio – Commercial Rate:	\$0.09 / KWH
1/1/05 – Industrial Rate:	\$0.08 / KWH

Ohio – Commercial Rate for Natural Gas:	\$10.2 / MCF
1/1/05 – Industrial Rate for Natural Gas:	\$10.4 / MCF

A 10,000-cfm air make-up unit in an industrial building in Ohio is operated at 65°F for an average: 12 hours/day – 5 days/ week = 60 hrs per week
Average outside air temperature during heating season: 43.1°F
It is fueled by natural gas.

Calculating Fuel Costs

A formula for calculating fuel costs for heating is as follows:

Annual Fuel Usage = cfm x (T - To) x 1.08 x Hours / FV x Eff.

Annual Fuel Cost = Fuel Usage x Fuel Rate:

Where:

- cfm = Actual cubic feet of air delivered by the air make-up per minute
- T = Temperature of air leaving unit (should be same as space temperature)
- To = Average outside air temperature during heating season
- 1.08 = Constant arrived at by multiplying:
0.075 (air density) by 0.24 (specific heat) by 60 min/hr
- Hours = Total hours of operation from October through April inclusive
- FV = Fuel Value in BTU per one unit of fuel
(generally, 1,021 for natural gas per cubic foot)
- Eff = Efficiency of unit (0.92 for direct-fired air make-up unit)
- Cost = cost of one unit of fuel (must be expressed in the same units as those used for F)

1. Determine Annual Operating Hours:
(7 months/yr / 12 months/yr) x 52 weeks/yr x 60 hrs/wk = 1820 hours/yr
2. Determine Average BTU/hr:
10,000 cfm * (65° - 43.1°) x 1.08 / 0.92 = 257,087 BTU/hr
3. Determine Annual Fuel:
257,087 BTU/hr x 1,820 hr / 1,027 BTU/cf = 458,275.5 CF = 458.3 MCF
4. Determine Annual Fuel Cost:
458.3 MCF * \$10.4/MCF = \$4,766.32

Calculating Electrical Costs

Electrical costs are straightforward, once power usage and rate information is known.

Example (continued):

5. Determine Amps & Voltage required:
5 hp motor @ 240 V, 3ph 17.5A (From motor info - HP varies per Unit)
Controls Allow 5A Max.
6. Determine No. of Hours of Operation / Day:
1 shift – plus overtime 12 Hr. Maximum
7. For 3-phase power:
KWH = 1.73 * Amps * Voltage * Hours/day / 1000
 = 1.73 * (17.5A+5A) * 240V * 12 Hr./day / 1000
 = 112.1 KWH /day
8. Electrical Cost / Day to Run – Industrial: 112.1 * \$0.08 = \$8.97/day
9. Electrical Cost / Year Using for Ventilation in Summer:
Cost/Year = 52 weeks * 5 days/week * \$8.97/day = \$2,332.20 / year

Total Average Yearly Cost to Operate example unit:

Given the following average information

Ohio – Industrial Rate for Electricity:	\$0.08 / KWH	\$2,332.20 / year
1/1/05 – Industrial Rate for Natural Gas:	\$10.4 / MCF	\$4,766.32 / year
Total:		\$7,098.52 / year

This example uses the greatest number of hours per year. Natural Gas costs are for an above average cost rate / area of the country. Actual costs could be lower or higher, depending on gas and electrical pricing. Check with your local utility for actual costs.

References:

ANSI Z83.4-2003/CSA 3.7-2003, Non-Recirculating Direct Gas-Fired Industrial Air Heaters
Canadian Standards Association, Mississauga, ON Canada L4W 5N6
CSA America, Cleveland, OH USA 44131

ANSI Z83.18-2000, Recirculating Direct Gas-Fired Industrial Air Heaters
Canadian Standards Association, Mississauga, ON Canada L4W 5N6
CSA America, Cleveland, OH USA 44131

2001 ASHRAE® Handbook – Fundamentals
The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

Bulletin SBDR/SBD-1, Directflow SBDR/SBD Series Direct Gas-Fired Make-Up Air Systems,
Hastings HVAC, Inc., June 2005

OSHA Fact Sheet: Carbon Monoxide Poisoning, 2002
US Department of Labor, Occupation Safety and Health Administration

Make-Up Air Engineering Manual
Midco International Inc., Chicago, IL

“ELECTRICITY COSTS”
Think Energy Management LLC, Silver Lake, Ohio

Bulletin CC2001-1/00
Selectra Series 14 & 44 Condensed Catalog
Maxitrol Company, Southfield, MI