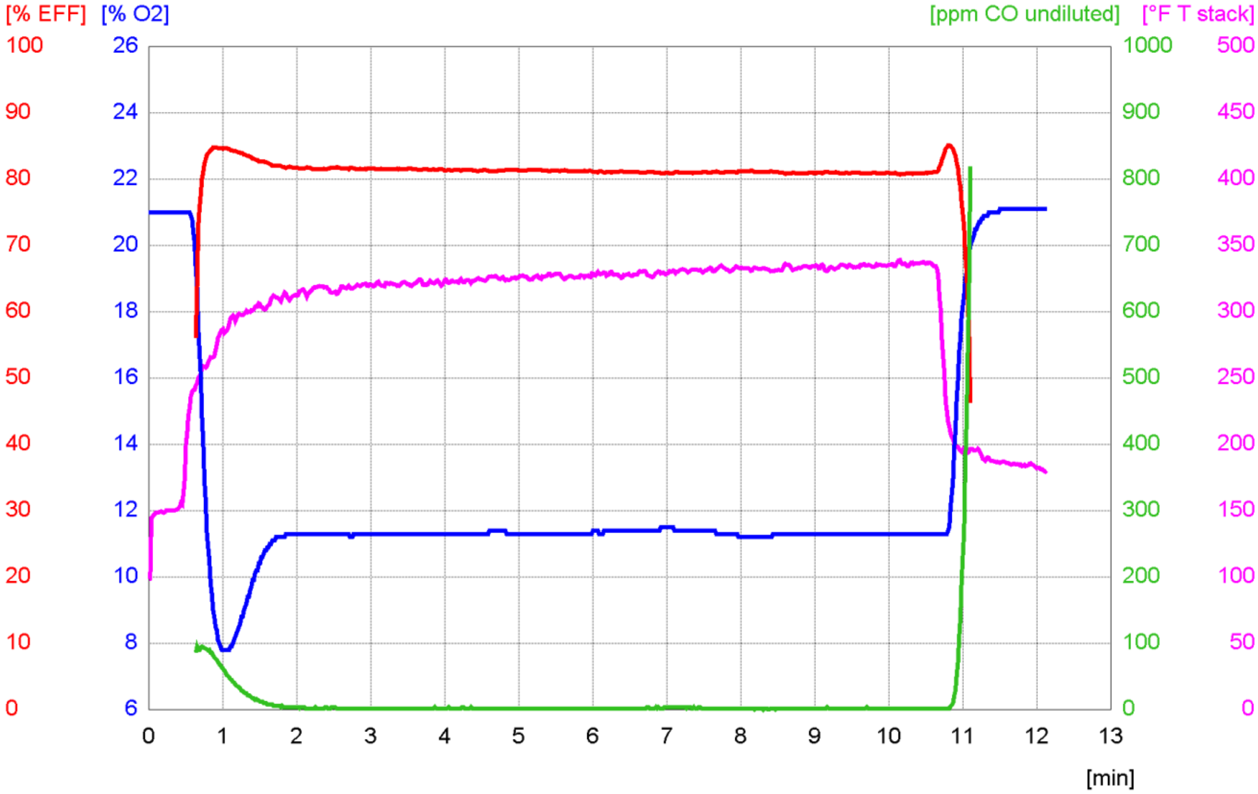
$25.00

TruTechTools

Combustion Analysis of Gas and Oil Appliances



i. Preface

This book was written as a general guide. The author has neither liability not can he be responsible to any person or entity for any misunderstanding, misuse, or misapplication that would cause loss or damage of any kind, including the loss of rights, material, or personal injury, or alleged to be caused directly or indirectly by the information contained in this publication.

The author does not assume and expressly disclaim any obligations to obtain and include any additional information. The reader is expressly warned to consider and adopt all safety precautions that might be indicated by activities herein, and to avoid all potential hazards. By following instructions contained herein, the reader willingly assumes all risks in connection with such instructions.

WARNING

Information contained is only for use by formally trained competent technicians practicing within the HVAC/R building science and or weatherization community. The manufacturers tion, operation, and service information should always be consulted, and should be considered the first and best reference for installing, commissioning and servicing equipment. The author and publisher assume no liability for typographical errors or omissions of information in this guide.

For additional information please contact:

Author:
James L. Bergmann
Technical Specialist
695 Longacre
Akron, OH 44319
Tel : 330-618-3472
Jimbergmann3@gmail.com

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ii. Credits and Acknowledgements

Some graphics courtesy of COAD (Corporation for Ohio Appalachian Development)

The equipment inspections covered in this publication meet industry standards as outlined by:

1. The National Fuel Gas Code (ANSI Standard Z223.1 and NFPA 54);

2. State building codes;

3. RSES Publication 630-92 9/86;

4. The Gas Appliance Manufacturers Association (GAMA);

5. BPI Technical Standards v2/28/05mda

6. The International Fuel Gas Code; and

7. Many manufacturers' equipment installatio guides.

Using this Manual

Notes : suggestions and insights to more effective work

Cautions : information that may effect testing accuracy, consistency, or might lead to equipment or product damage

Warnings : information relating to potential physical harm

For additional information on servicing gas appliances, please see **Section 21** the **Servicing Gas Appliances Checksheet.**

1 Introduction

This applications guide is intended to supplement and enhance the knowledge of a trained and qualified HVAC building science and weatherization service technician. This applications guide is not intended as a substitute for formal technical training by authorized training installation, operation and or service instructions. Although the standards referenced at time of publication were current, it is the responsibility of the technician to obtain and implement the most current standards and practices.

The appliance manufacturers' installation, should always be consulted, and should be considered the first and best reference for installing, commissioning and servicing equipment. The author assumes no liability for typographical errors or omissions of information contained herein.

2 Why Testing is Required for Equipment Setup and Verification

Making and interpreting measurements is a crucial part of any job involving service, installation, design verification, engineering, or factory support of HVAC/R equipment. When it comes to verifying proper operation of the installed equipment it is critical that measurements made in the field are just as accurate as those made the laboratory. We all have an obligation to assure that the equipment is operating at peak performance levels for the benefit of consumers or end users of HVAC/R equipment, equipment manufacturers, utilities, the nation's energy future and the environment.

Combustion analysis is only part of the equipment installation and commissioning procedure. A complete installation includes but is not limited to proper equipment selection and sizing, proper airflow and fuel pressure, verification of proper draft, combustion and ventilation air, verification of proper operation of all limit and safeties as recommended by the manufacturer and as outlined in the International Fuel and Gas Code, and a final combustion analysis along with written and printed verification of the commissioning procedure.

Safety Considerations: ***Carbon Monoxide (CO)***

Carbon monoxide is a pollutant that is readily absorbed in the body and can impair the oxygen-carrying capacity of the blood (hemoglobin). Impairment of the body's hemoglobin results in less oxygen to the brain, heart, and tissues. Even short-term over exposure to carbon monoxide can be critical or fatal to people with heart and lung diseases, the young or the elderly. It may also cause headaches and dizziness and other significant medical problems in healthy people.

During combustion, carbon in the fuel oxidizes through a series of reactions to form carbon dioxide (CO_2). However, 100 percent conversion of carbon to CO_2 is rarely achieved under field conditions and some carbon only oxidizes to the intermediate step, carbon monoxide or CO.

In today's equipment, high levels of carbon monoxide emissions primarily result from incomplete combustion due to poor firing conditions. Examples would include an improper air-to-fuel ratio or possibly a misaligned burner. Through proper burner maintenance, inspections, and operation, the formation of carbon monoxide can be controlled at an acceptable level. Upgrading equipment, performing regular inspections and combustion testing will also help keep the carbon monoxide levels under control.

No standards for CO have been agreed upon for indoor air. The U.S. National Ambient Air Quality Standards for outdoor air are 9 ppm (40,000 micrograms per cubic meter) for 8 hours, and 35 ppm for 1 hour (time weighted).

Obviously, no CO (0 ppm) is the best level in the home. This cannot always be achieved due to smokers in the home and/or appliances like stoves that produce acceptable levels of CO during operation. When CO is present in the home, the source should be determined and corrective action taken. The goal is to assure occupant safety and minimize the occupants'

The local authority having jurisdiction should be consulted when determining the maximum safe CO level allowed in the home before shutting down the appliance and or making it inoperable, however, may localities have no standards referenced or adopted. In this case, it is the responsibility of the technician to follow industry standards such as those published by BPI, ARI, ASHREA, RSES or other standard writing organizations. Note: when performing testing, **An appliance with rising CO production should always be shut down no matter how low CO production is at the time of testing**. Rising CO problems are typically the result of improper venting and/or lack of combustion air.

3 The Need to Test with Digital Instruments

Today, most oil fired equipment is still being serviced and adjusted with traditional manual combustion efficiency test equipment (or wet kits) for field service and seldom is testing is done on gas, coal, or wood burning appliances. These kits generally consist of a stack thermometer, draft gauge, wet chemical CO_2 gas tester, slide rule and smoke pump. Although this equipment has served the industry well over the years, faster, more accurate, real time flue gas analysis is necessary.

Many service technicians are reluctant to used digital instruments; there is a certain comfort in using what we are used to, and in some cases we figure if we don't know, we cannot be held responsible. truth. Failure to test does not absolve you of liability. Information is power whether it is used for you or against you.

With digital equipment, many errors with the measurement process are reduced or eliminated. Analog measurement errors can be the result of interpolation errors, calibration errors, poor repeatability of the measurement, and most importantly not having a procedure in place to consistently repeat the measurement process.

Tuning a system should happen in *real time*, not "after the fact" with a very highly "averaged" sample. (Each squeeze of a wet kit bulb represents a different snapshot of the flue gas. A traditional test blends all those snapshots together into one reading.)

Only digital analyzers allow you to take *real time* tests. You ***cannot*** do a *real time* test with a wet kit; it is physically impossible to take the sample fast enough and do the slide rule calculation.

Today testing is not an option, but a necessity on every gas, oil, wood, or coal appliance that you might service. The truth is digital instruments are faster, more accurate, more reliable, and have a higher repeatability than most analog tools. Digital instruments stay in calibration, allow trending, allow more complex functions and save time. Digital instruments allow data to be recorded and reported without human error, and provide reliable and accurate results for you and your customers. Data can be recorded much faster than any technician could ever do the calculations and data can also be recorded whether or not the technician is there to see it (eg. using features like the online mode on certain analyzers). In most cases, the data is an un-editable record, so what you see was what was measured at the jobsite. Permanent records allow the user to track system changes and determine if the system is operating within the design parameters or if changes have taken place.

4 Benefits of proper system setup through testing

Whether working on gas, oil, coal, or wood fired appliances it is imperative to perform a combustion analysis during routine service, or any time changes are made that will affect the combustion process. This can be as simple as adjusting an air shutter, changing gas pressure or as involved as changing an oil nozzle. A combustion analysis is performed for four primary reasons:

1. To verify the safety of the appliance prior to and after service
2. To measure the combustion efficiency of the appliance
3. To determine the amount of pollution the appliance is producing
4. To review operation in conformance with t
5. To assess equipment longevity/warranty issues (eg. Improper fuel pressure or airflow settings may cause excessive CO production, or burned out heat exchangers, etc.)

Combustion testing provides numerous benefits to the service technician, end user of the appliance, and the appliance manufacturer.

Combustion Testing:

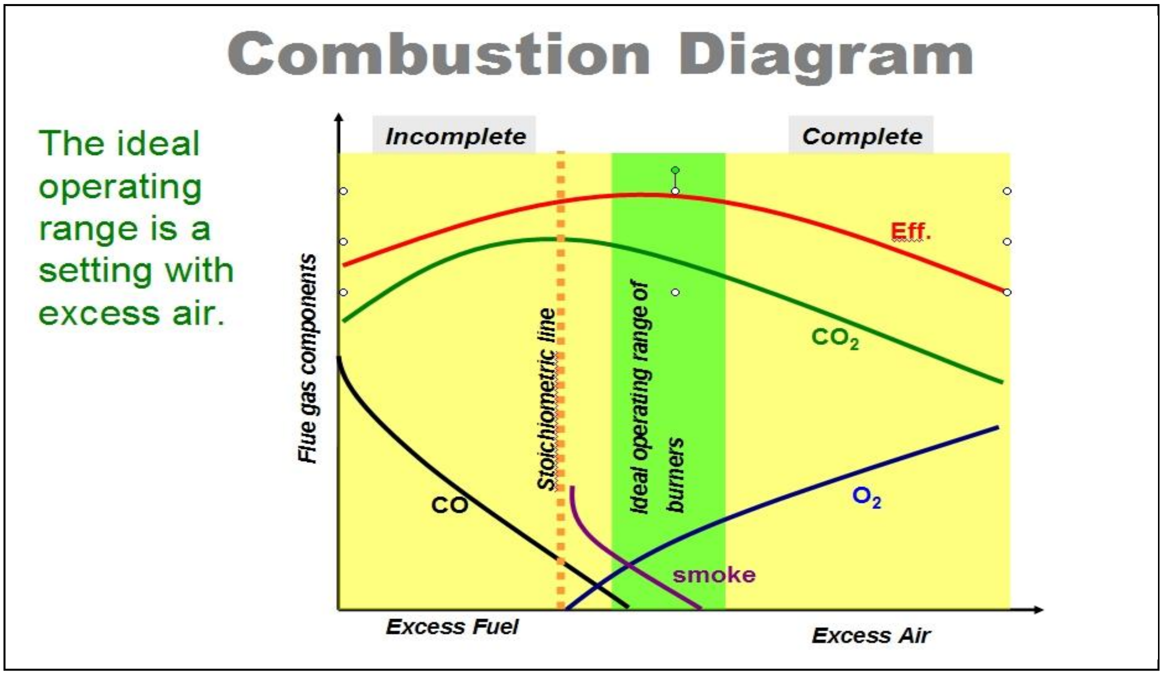
- Saves money
- Saves time
- Avoids callbacks
- Limits liability
- Maintains equipment warranty
- Provides confidence
- Provides increased comfort
- Provides increased safety
- Increases energy efficiency
- Lowers environmental emissions (Pollutants)

5 The Combustion Process

Combustion is a chemical reaction of rapid oxidation started by the correct mixture of fuel, oxygen and an ignition source. The chemical reaction for natural gas is:

$$\mathbf{CH_4 + 3O_2 = Heat + 2H_2O + CO_2 + O_2}$$

Where:
CH_4 = 1 cubic foot of Methane Gas (Natural gas)
$3O_2$ = 3 cubic feet of Oxygen
Heat = 1027 BTU's of energy produced from th
$2H_2O$ = 2 cubic feet of Water Vapor
CO_2 = 1 cubic foot of Carbon Dioxide
O_2 = 1 cubic foot of Excess Oxygen



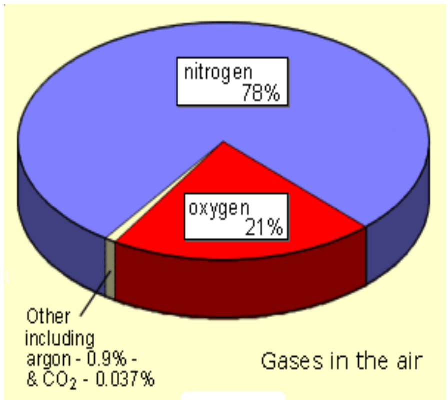
If there is not enough air for proper combustion, carbon monoxide could be generated. **Carbon Monoxide is a deadly gas.**

A yellow flame could be an indicator of carbon monoxide, but a blue flame could be producing CO as well. If you don't test with combustio
you cannot tell.

The formula for **incomplete combustion** is in a gas fired furnace is

$$\mathbf{CH_4 + 3O_2 = Heat + 2H_2O + CO\ (+/- O_2)}$$

> **Note: CO can be produced with or without excess air. That is primary reason why there is a diluted and undiluted flue gas test available in a combustion analyzer. CO is Carbon Monoxide and CO_2 is Carbon Dioxide. CO is deadly, CO_2 is normally not considered to be harmful (poisonous, deadly).**



The air is composed of 20.9% oxygen, 78% nitrogen and 1% other gasses. For every cubic foot of oxygen needed, approximately 10 cubic feet (CF) of air are needed to provide complete combustion for natural gas. For most residential appliances, an additional 5 CF of air is added to assure there is ample oxygen to burn all of the fuel. In other words, 15 CF of air are required to support the combustion process, and provide enough excess air to insure complete combustion. An additional 15 CF of air are required if the furnace has a draft hood, bringing the total to 30 cubic feet air per cubic foot of gas burned. The combustion process creates exhaust gasses that contain heat that will be extracted to heat a heat exchanger, and transfer the generated energy to air, water, or any other desired heat transfer medium.

Exhaust gasses along with any excess air are vented outdoors through vent pipes, chimneys or plastic exhaust pipes after the majority of their useable heat has been transferred. The venting materials must be sized properly to insure the flue gasses can be vented without creating a positive (back pressure) within the heat exchanger. If the gasses back up in the heat exchanger, the flames will come out of the front of the combustion chamber, creating dangerous conditions called rollout and/or spillage.

6 Understanding Combustion Efficiency

Combustion efficiency is a measurement of how well the fuel being burned is being utilized in the combustion process. This is different from the efficiency number produced on the analyzer, which is reflective of the total amount of heat available from the fuel minus the losses from the gasses going up the stack. Stack loss is a measure of the heat carried away by dry flue gases and the moisture loss. It is a good indicator of appliance efficiency. The stack temperature is the temperature of the combustion gases (dry and water vapor) leaving the appliance, and reflects the energy that did not transfer from the fuel to the heat exchanger. The lower the stack temperature, the more effective the heat exchanger design or heat transfer and the higher the fuel-to-air/water/steam efficiency is. The combustion efficiency calculation considers both the stack temperature and the net heat and moisture losses. This would include losses from dry gas plus losses from the moisture and losses from the production of CO.

Combustion converts the carbon and hydrogen in the fuel to CO_2 and H_2O. For each type of fuel there is a maximum CO_2 that can be converted. When you select the fuel in the analyzer, the CO_2 is calculated from the fuel type by the percentage of O2 left in the flue gas. Typically for natural gas the ultimate CO_2 is 11.7%. This would be achieved when the O2 in the flue gasses was at 0% Some analyzers also allow for the max CO_2 to be input by the user if the heat content of the fuel is known.

Again, the ultimate CO_2 would be derived during stoichiometric combustion in which there is no excess air and no excess fuel present during the combustion process. In reality, in the HVAC industry we are striving not for stoichiometric combustion, but complete combustion in which all hydrogen and carbon in the fuel are oxidized to H_2O and CO_2. For complete combustion to occur, we have to have excess air, or air supplied in excess of what is needed typically because of poor mixing of the fuel and air during the combustion process. If excess air is not provided we will not have the complete conversion of carbon to CO_2, and will end up with the formation of partially oxidized compounds, such as carbon monoxide and aldehydes. While ideal operating range for burners is not as efficient as stoichiometric combustion, it does provide us with an additional factor of safety.

The percentage of excess air required is based upon several things including

1. Equipment application (commercial, residential, industrial)
2. Expected variations in fuel properties (wobble numbers)
3. Combustion air supply rates and air density
4. Degree of operator supervision required or available (summer winter adjustments and maintenance)
5. Control requirements such as O_2 trim

For maximum combustion efficiency low excess air is desirable. For residential furnaces it is typically 50% however additional air may be required for dilution to prevent condensation of the flue gasses. This could be introduced into the appliance after the point of combustion through a draft diverter or as excess air which goes completely through the combustion process.

Each type of fuel has specific measurable heat content. The maximum amount of heat that can be derived from a fuel is based on using pure oxygen as the oxidizer in the chemical reaction and maximizing the fuel gas mixture. In field practice, the oxygen is derived from the air which is 20.9% oxygen, 78% nitrogen and 1% other gasses. Because the oxygen is not separated from the air prior to combustion, there is a negative effect on the chemical reaction. Air is primarily nitrogen. While nitrogen is inert, and plays no role in the combustion process, it cools the chemical reaction (burning temperature) and lowers the maximum heat content deliverable by the fuel. Therefore, it is impossible to achieve *combustion efficiencies* above 95% for most fuels, including natural gas, when air is used as the oxidizer in the combustion process.

The combustion efficiency or maximum heat content of the fuel is then based upon the quality of the mixture of fuel and air, and the amount of air supplied to the burner in excess of what is required to produce complete combustion. <u>The efficiency calculated by the combustion analyzer is a modified equation that considers combustion efficiency and stack losses.</u> It is a part thermal, part combustion efficiency calculation. The equation is a reasonable estimation of the steady state thermal efficiency of the appliance. This is true of all analyzers currently manufactured.[1]

The entire system (furnace/boiler, ducting, and piping) must be evaluated to determine the true efficiency of the system. Combustion efficiency is a valuable part of the system evaluation, but it is only one part of the evaluation process and cannot be used as the sole reason or justification for keeping or replacing existing equipment.

If the excess air is carefully controlled, most furnaces are capable of performing at higher levels than their rated Annualized Fuel Utilization Efficiency or AFUE level, AFUE levels typically range from 80% to 97% [2]

The ultimate thermal efficiency of the appliance is determined by dividing the heat output rate of the appliance by the rate of fuel input. During the combustion process, all furnaces that operate with the same combustion efficiency will produce the same amount of heat with the same fuel input. **The *combustion efficiency* has no bearing on how well the appliance utilizes the heat produced <u>after</u> the combustion process has taken place.** Heat exchanger design and its ability to transfer the sensible[3] and possibly the latent[4] heat to the room air determine how well the heat produced by the combustion process is utilized.

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[1] Manufacturers use differing forms of combustion equations. This modified equation is often referred to as combustion efficiency, even though as a matter of pure science it is not.

[2] AFUE is also known as the Department of Energy Minimum Seasonal Efficiency

[3] Sensible heat is the heat measured with a thermometer

[4] Latent heat is the heat available when the water vapor in the exhaust gas has been condensed out

During combustion, new chemical substances are created from the fuel and the oxidizer. These substances are called **exhaust gasses.** Most of the exhaust gas comes from chemical combinations of the fuel and oxygen. When a hydrocarbon-based fuel (Natural Gas) burns, the exhaust gasses include water (hydrogen + oxygen) and carbon dioxide (carbon + oxygen). But the exhaust gasses can also include chemical combinations from the oxidizer alone. If the natural gas is burned with air, which contains 21% oxygen, 78% nitrogen and 1% trace gasses, the exhaust can also include carbon monoxide (CO), oxides of nitrogen (NO_X, nitrogen + oxygen) and if sulfur is present in the fuel, sulfur dioxide, SO_2 (Sulfur + oxygen).

The temperature of the exhaust will be high because of the heat that is transferred to the exhaust during combustion. Because of its high temperature, exhaust usually occurs as a gas, but there can be liquid or solid exhaust products as well. Water (H_2O) is always present in natural gas and oil combustion in residential furnaces. **Soot,** which is incompletely burned fuel, is a form of solid exhaust that occurs in some combustion processes, particularly carbon luminous flames.

During the combustion process, as the fuel and oxidizer are turned into exhaust products, heat is generated. Interestingly, some **source of heat** is also necessary to start combustion. Gasoline and air are both present in your automobile fuel tank; but combustion does not occur because there is no source of heat. Since heat is both required to start combustion, and is itself a product of combustion, we can see why combustion takes place very rapidly. Also, once combustion gets started, we don't have to continue to provide the heat source, because the heat produced by the combustion process will keep things going. We don't have to keep lighting a campfire, it just keeps burning.

Flue gasses are the gasses produces by burning fuel. These gasses are hot, but have not given up all their heat in the combustion process. Depending on the type of furnace, a certain amount of heat must go out of the flue to prevent the gasses from condensing. With high efficiency furnaces, condensing is desirable because of the additional heat extracted from the flue gasses.

A digital combustion analyzer performs all of the mathematical calculations and measurements necessary to determine efficiency, safety, dew point, and the amount of pollution the appliance is producing. For most technicians, the safety (CO) and efficiency (EFF.) readings will be the most important and most frequently referenced numbers. When safety or efficiency is compromised, other portions of the chemical reaction (CO_2, O_2) will be referenced, along with calculated values like excess air, to determine the cause of the problem in the combustion process. Other variables like NOx and SO_2 are referenced and controlled to keep them at levels that are safe for the environment and acceptable to the local authority having jurisdiction over these matters. Some areas do not currently regulate levels of NOx and SO_2 and where they are not controlled they are also not typically measured. Usually, larger exhaust sources (higher BTU systems) are targets of NOx and SO2 regulations. (NOTE: Several manufacturers have a full lines of affordable emissions products to measure regulated emissions.)

As a service technician, unless a component has failed, there are only three things can be adjusted on a gas/oil appliance that will affect the combustion process.

Fuel pressure
Primary air (on newer furnaces this is not adjustable)
Draft, which will impact secondary air

Other factors can affect the combustion process. These include impingement for example from an improperly placed pilot, excess air from a cracked heat exchanger, insufficient combustion air due to tight construction or improper ventilation, an improperly installed venting system, or incorrect orifices. These are considered defects or installation problems, and require mechanical correction rather than adjustment. It is t determine if combustion problems are caused by improper adjustment, incorrect installation, component failure, or equipment defect. Therefore, it is important that the technician completely understands how each of the subsystems affects the chemical reaction called combustion.

It should be noted that there is not a national industry standard for calculating measured efficiency with a combustion analyzer. Manufacturers of analyzers use differing calculations to derive efficiency values. Oftentimes this discrepancy is due to values that have been extrapolated into the condensing range.

Heat removed from the flue gasses on a condensing furnace is latent or hidden heat. A combustion analyzer that measures only temperature and not volume of condensate cannot measure the quantity of heat removed from the flue gas during the condensing process. Although terms of thermal and combustion efficiency are often used interchangeably on non-condensing units, they cannot be used in the same manor on condensing appliances.

The thermal efficiency of a condensing appliance and combustion efficiency will be different. The only way to calculate the actual thermal efficiency of an appliance is to measure the exact airflow across the heat exchanger and the change in air temperature across the heat exchanger and input the measured values into the sensible heat formula to calculate the heat energy input into the conditioned air. There will be some minimal loss to the furnace cabinet by radiation and conduction. Depending on how much of the heat energy is extrapolated from the water in the flue gas, an average of 970 BTU per pound, the efficiency readings can differ by as much as 10%. This assumes that either *all latent heat energy was extracted from the flue gasses after they reached the dew point or none of the latent heat energy was extracted.*

This extrapolation of values can be distorted, and has led manufacturers of appliances to inadvertently post higher than actual thermal efficiency numbers. Due to the readings achieved on an analyzer. (NOTE: This calculation does not affect the AFUE numbers, which are derived by a different means.) By not taking this discrepancy into account, some in the industry have suggested that fuels are being delivered with low BTU levels. This leads them to suggest that fuel pressures be raised to provide the net heat output that the manufacturer has published. For this reason, we recommend that the fuel pressure be set per the manufacturer's instructions. The combustio *the actual dry flue gas and not of the thermal efficiency of a condensing appliance. This avoids use of a calculated rather than a measured parameter. Some manufacturers have chosen to use a combustion calculation that does not extrapolate the thermal efficiency values of flue gasses below the dew point, as those values are not representative of the heat that is removed from the flue gasses during the condensing process. Although this may result in the appearance of a lower thermal efficiency of the appliance, the science used for measuring combustion efficiency is not artificially high. Once differences in combustion and appliance thermal efficiency are understood, the methodology of scientific measurement verses extrapolation of measured values can be appreciated and applied, allowing manufacturers to publish combustion and thermal efficiencies that are representative of the actual efficiency of their appliance, thereby creating a standard that is based upon actual measurement rather than an extrapolation.*

7 Common Combustion Measurements and Calculations

Measured

CO: (Carbon Monoxide) Dangerous byproduct produced by incomplete combustion.

Stack Temperature: (Gross Stack Temperature) Temperature of the flue gasses + combustion air temperature.

O_2: (Oxygen) Measured oxygen in flue gasses after combustion has occurred.

NO: (Nitric Oxide) Byproduct of combustion also called: mononitrogen monoxide or nitrogen monoxide. (Pollutant)

Calculated

EFF: (Efficiency) a calculation of the maximum heat available in the combustion process minus the stack losses.

NO_x: (Nitric Oxide) The mixture includes nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen trioxide (N_2O_3), nitrogen tetroxide (N_2O_4), and nitrogen pentoxide (N_2O_5).

CO_2 (Carbon Dioxide) Carbon Dioxide is byproduct of normal combustion, considered a greenhouse gas.

Excess Air: The calculated air that passed through the combustion process without acting as an oxidizer in the combustion process. A certain amount is usually required to assure complete combustion. Excess air dilutes the flue gasses and should be kept to a minimum to keep combustion efficiency at its maximum.

CO Air Free: A calculated measure of the undiluted CO in the flue gasses.

Dew point: A calculated temperature below which the H_20 in flue gas will start to condense.

8 Performing a Complete Combustion Test

When using a combustion analyzer we are watch for four things

1. safety
2. compliance
3. consistency
4. efficiency

(SCCE) **Safety** with regard to acceptable COaf levels, **compliance** with the manufacturer's guidelines, **consistency** or stability with regard to stable CO, O_2, and stack temperature readings, and **efficiency** with regard to overall energy usage/savings.

While digital analyzers make the process simple, the information they provide to most maybe overwhelming if not properly understood and interpreted. Technicians and manufacturers are looking typically only looking at three measured variables (four if your analyzer is equipped to measure NO gas).

Combustion testing of an existing appliance should be preformed prior to and also after servicing the appliance or making changes to the building envelope. This will provide the service technician pre and post results that can determine how equipment is operating before and after service. Combustion analysis should not be considered final until the complete commissioning procedure has been performed. This would include proper air or water flow across the heat exchanger, proper fuel pressures and draft. Additionally verification of combustion and ventilation air by performing the ventilation air test/combustion safety test outlined in this manual, with all panels and or burner covers in place. Any mechanical or operational changes made after the combustion test is performed can affect the final combustion test results. Therefore a combustion test should always be the first and final test performed at the appliance.

Prior to entering an existing home installation, ambient CO levels should be checked and the equipment should be run through a complete cycle.

8.1 CO Ambient Air* Testing –(*Combustion Air Zone & Living Space)

For your safety and for your customer's sa ***not skip this step!!***

WARNING: If at any time during this test ambient CO levels exceed 35 ppm stop testing immediately. CO producing appliances must be disabled and repaired before proceeding with additional diagnostics.

For lower CO concentration levels consult the ambient CO limits in ***Ambient CO Recommendations of this guide*** *or contact the local authority having jurisdiction over these matters. Perform ambient CO testing* ***prior*** *to entering any home, boiler room, basement or crawl space where or near where an appliance is located and continue during testing to assure your and the occupants safety. The CO level in the home should always be verified prior to entering the space and prior to zeroing the analyzer for a combustion test of the appliance. If an ambient combustion air temperature probe is not used, the analyzer must be re-zeroed with the probe in air similar in temperature that used for combustion if CO is present.*

Single gas meters for CO and O2 can provide additional protection for the technician during testing.

Safety of the appliance should be the primary goal of all technicians. The production of CO in the flue gasses should be kept below 100 ppm air free, even though the maximum allowable limit in the stack by ANSI standards is 400 ppm air free. Anytime CO is rising and unstable at any level from 1 ppm to 400 ppm during the combustion process, the burner should be shutdown and/or immediately repaired. A burner with rising CO under operation is far more dangerous than a stable reading because the CO can continue to rise far above dangerous levels. Levels above 400 ppm are not permissible and require immediate repair and or shutdown of the appliance.

CO levels in ambient air are not normally from a cracked heat exchanger. More often than anything else it is the result of auto exhaust from an attached garage, and or depressurization of the home resulting in insufficient air for combustion. If CO is detected, all possible sources of CO should be checked including but not limited to hot water tanks, gas ovens and stoves, the furnace, (non-electric) space heaters, vented or unvented appliances like gas logs.

All homes equipped with an attached garage should have a CO detector installed on each floor. BPI requires at least one CO detector meeting UL-2034 requirements shall be installed according to manufacturer's instructions in every home with an attached garage and/or combustion appliances. It is recommended that additional CO detectors are installed, as needed, to provide a separate detector for each floor of the building.

Ambient CO Limits (Recommended)

1-9 ppm	Normal levels within the home. If there are no smokers, investigation is recommended. These levels will be measured above ambient levels in most cases because the CO instrument has been zeroed in outdoor air. 9 ppm is the maximum recommended level for 24 hours continuous exposure.
10-35 ppm	Advise occupants, check for symptoms, (slight headache, tiredness, dizziness, and nausea or flu like symptoms.) check all unvented and vented appliances, including the furnace hot water tank and or boiler, check for other sources including attached garages or small engine operation
36-99 ppm	Recommend fresh air, check for symptoms, ventilate the space, recommend medical attention
100+ PPM	Evacuate the home (including yourself!) and contact emergency medical services (911). Do not attempt to ventilate the space. Short-term exposure to these levels can cause permanent physical damage.

8.2 Maximum CO Levels in Equipment

Stack Carbon Monoxide Tests

CO must be measured in undiluted flue gas and measured with a combustion analyzer as COaf or undiluted CO in per million (ppm). The CO measurement must be made in each cell of an atmospheric draft appliance and at least 2x the diameter of the flue pipe away from the induced draft motor on induced draft equipped appliances. Where practical, do not drill holes in flues for power vented or sealed combustion units. Instead, measure CO at the exterior outlet of the flue and proceed with appropriate actions according to the CO limits identified in the BPI Combustion Safety Action Level table. For all combustion appliances, CO should be measured at steady-state operating conditions.

With the exception of unvented gas or propane cooking appliances, CO must be tested in all combustion appliances under worst-case conditions and/or normal draft conditions (when the appliance fails under worst-case). In addition, it is recommended by BPI that CO be tested under a mild down-draft if conditions are safe.

For gas ovens, CO shall be measured at steady state (usually after 5-10 minutes of operation) at the highest setting. When measuring CO on gas ovens, it is recommended to turn on the exhaust hood and open a window to reduce risk of exposure to elevated ambient CO levels. Ambient CO levels shall be monitored upon entering the combustion appliance zone and during the test period for all appliances. If ambient levels exceed 35 ppm at any time, turn off the appliance immediately and make appropriate repair recommendations according BPI recommendations.

Measurements shall be taken of undiluted flue gases.

Vented (Note CO reading must remain stable and are measured on an air-free basis)

400 ppm (CO-Air Free: CO-AF) Stack ANSI Z 21.1
100 ppm CO Stack recommended BPI

ALWAYS FOLLOW REQUIREMENTS of AUTHORITY HAVING JURSIDICTION

Unvented including ovens and ranges

30-50 ppm stable
Less than 10 ppm recommended
BPI: No unvented combustion appliances may operate in the living space with the exception of gas ranges and ovens.

BPI Level Action 1 (for unvented appliances)
100-300 ppm as measured in the stack, a carbon monoxide detector must be installed and recommendation of service must be made to the consumer

BPI Level Action 2 (for unvented appliances)
Greater than 300 ppm as measured, the unit must be serviced prior to insulating or air sealing work. If greater than 300 ppm after servicing, exhaust ventilation must be provided with a capacity of 25 CFM continuous or 100 CFM intermittent.

8.3 Light off CO levels:

Gas and oil appliances have no manufacturer-prescribed maximum CO level at light off. High CO levels at light off may be an indication of rough or delayed ignition warranting further investigation, but they are not considered by manufacturers or by most in the industry to pose health concerns due to low volume of CO produced (short times at this higher rate of CO production). The CO readings should peak under 400 ppm (there is no prescribed light off level), then drop below the prescribed level allowed in the stack. CO readings should stabilize within 10 minutes of operation and should never be rising during operation.

Technicians should also be aware that several manufacturers of combustion testing equipment do not filter out the Nitric Oxide (NO) from the combustion gas sample. NO is an acid gas which is a cross-interferant to all electrochemical CO sensors. (A cross-interferant will add "false CO" to the amount of NO present. EG. 100 ppm of NO gas will show on an unfiltered CO sensor as an additional 25 to 50 PPM CO.) analyzers incorporate replaceable NO filters that remove NO_x gas from the CO sample to provide an accurate CO reading. Such filters are not important when measuring ambient CO as NO rapidly converts to NO_2 in ambient air. NO_2 is not a cross-interferant.

It is common to see readings of 0 (zero) ppm CO when testing with analyzers utilizing NOx filters. Many appliances do not produce measurable levels of CO during operation.

Make sure the equipment you are using is specifically designed to measure low levels of CO and incorporates a NO filter. Many combustion analyzers manufactured toady and some methods used for low-level CO detection have inherent error in instrumentation or the measurement process.

8.4 Mechanical Problems, Flame Interference and CO

Many times there is sufficient combustion/ventilation and infiltration air, but the appliance being tested is still producing higher than acceptable CO air-free levels. Normally this is the result if a mechanical problem. Burners should be inspected for cleanliness and proper alignment. Gas pressures should be

checked and set to manufacturer’s specified
examined for evidence of impingement.

Impingement occurs when the flame hits an object that has sufficient mass, or can transfer enough heat from the flame to lower flame temperatures and cause incomplete combustion. This can be as simple as a screw poking into the heat exchanger or as major as a warped or cracked heat exchanger cell. Burners should always be carefully removed and reinserted to assure proper placement and alignment.

Missing burner covers, improper air band adjustment on fuel oil or improper manifold pressure or oil pressures can also contribute to higher than normal CO levels. Too much excess air can cool the flame lowering the flame temperature creating higher than acceptable levels of CO. This is one of the reasons two stage furnaces produce slightly higher CO levels on low fire. The excess air on a two-stage appliance is often significantly higher by percentage than required for safe combustion.

8.5 Infiltration Air and Ventilation Air Testing

Ventilation Air: Total air, which is the combination of the air brought inside from outdoors and the air being re-circulated within the building. Sometimes, used in reference only to the air brought into the system from the outdoors. This document defines ventilation air as "indoor and outdoor air ventilation."

Infiltration Air: A term used to describe the outdoor air that enters a building through cracks or unintentional openings**.**

Combustion Air: The air supply brought into the furnace's combustion chamber and supplied from within the basement or from the outdoors. Combustion air is necessary to burn fuel.

Dilution Air: Air that enters a draft hood or draft regulator and mixes with the flue gasses. Dilution air enters through the burners on modern furnaces and is measured as excess air in the stack. If the dilution air level is too low, condensation of the flue gasses will occur.

Natural and induced draft gas appliances use air from inside the building to burn the fuel. If air used during the combustion/ventilation process from inside the building is not replace by outdoor air, the following may occur:

A. There will be insufficient air in the building for proper combustion.
B. There is a very high probability that carbon monoxide (CO) will be generated due to the lack of air (Oxygen) inside of the building.
C. Poor ventilation/infiltration can cause a negative pressure inside of the building.

D. If the building is under a negative pressure, the chimney will not draft. The higher pressure outdoors will force air down the chimney or flue vent spilling the flue gasses into the building.
E. Vent spillage will increase the probability that the flue gasses will contain Carbon Monoxide (CO) due to recirculation of flue gasses resulting in poor combustion.

The Ventilation Air Test/Combustion Safety Test:

A. The ventilation air test or combustion safety test is a worst-case test used to determine whether or not enough indoor air and infiltration air is coming into the building; used to test for proper ventilation/infiltration under actual operating conditions.

B. The procedure for the ventilation air test is outlined in the International National Fuel Gas Code. (ANSI Standard Z223.1) and BPI Technical standards for the Building Analyst Professional.

C. It is should be performed on every gas appliance installation and every gas appliance service call **prior to servicing the appliance, and or completing any insulation or air sealing of a dwelling.**

Background Information: The Ventilation Air Test

This procedure should be performed **prior to any attempt** at modification of the appliance or of the installation. For HVAC technicians this includes servicing, clean and checks, and/or mechanical changes like duct sealing.

If it is determined there is a condition that could result in unsafe operation, the appliance should be shut off and the owner advised of the unsafe condition.[5] If there is not sufficient air for combustion and/or ventilation, the homeowner and/or technician will be at risk by operating the appliance under worst-case conditions.

This test is performed to insure that the building into which you are going to install, or have installed, a fossil fuel appliance has enough ventilation/infiltration air to replace the air used in the combustion and venting process. This test should be performed on an annual basis.

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[5] If conditions can be changed to temporarily correct the condition, for example removing the door from the adjoining space, cracking a window in the basement, or locking out another appliance that is not deemed critical for heating the structure, the heating appliance can be left in operation provided the corrections to the combustion/ventilation system are incorporated prior to returning to normal conditions. Any changes made should be noted on the work order and signed off by the customer before any changes are made. Any appliance left in operation must not show any signs of combustion/ventilation problems.

Modern buildings may be much tighter than old buildings; some do not allow enough leakage for the infiltration air to enter the building from the outdoors. Winterization practices on older homes have sealed many of the openings that formerly provided combustion and ventilation air. Duct sealing may also have affected the combustion process

If the building does not allow enough infiltration air in, provisions must be made to bring in the outdoor air to replace the air used in the combustion and ventilation process. This could mean the installation of natural or mechanical combustion air to assure proper combustion and venting.

This test should be performed even if you are installing a 90+ furnace that takes all of the combustion air directly from the outdoors. This test is recommended by the International Fuel Gas Code and BPI since you are making changes in the venting system by removing the old appliance.

This test should be performed on all furnaces, boilers, hot water tanks, or other fuel burning appliance inspections or installations including the installation of woodstoves or other fossil fuel appliances.

8.6 Gas Supply Safety

The entire gas/propane line must be examined and all leaks repaired. Particular care should be made in the immediate vicinity of the appliances and at the joints, shutoff valves, and pilot lines. Identify the general area of leaks using an electronic gas leak detector at a rate of about 1 inch or travel per second and accurately locate the source of the leak using an approved soap bubble solution.

Flexible gas lines must be replaced if they are: kinked, corroded or show signs of visible wear, the line was manufactured before 1973 (date is stamped on the date ring attached to the line), or the line has any soldered connections.

8.7 Building Performance Institute (BPI)

Combustion Safety Test For Vented Appliances

v2/28/05mda

Please reference www.BPI.org for current standards

1. Measure the Base Pressure. Start with all exterior doors, windows, and fireplace damper(s) closed. Set all combustion appliances to the pilot setting or turn off the service disconnect, including: boiler, furnace, space-heaters, and water heater. With the home in this configuration, measure and record the base pressure of the combustion appliance zone (CAZ) WRT outside.

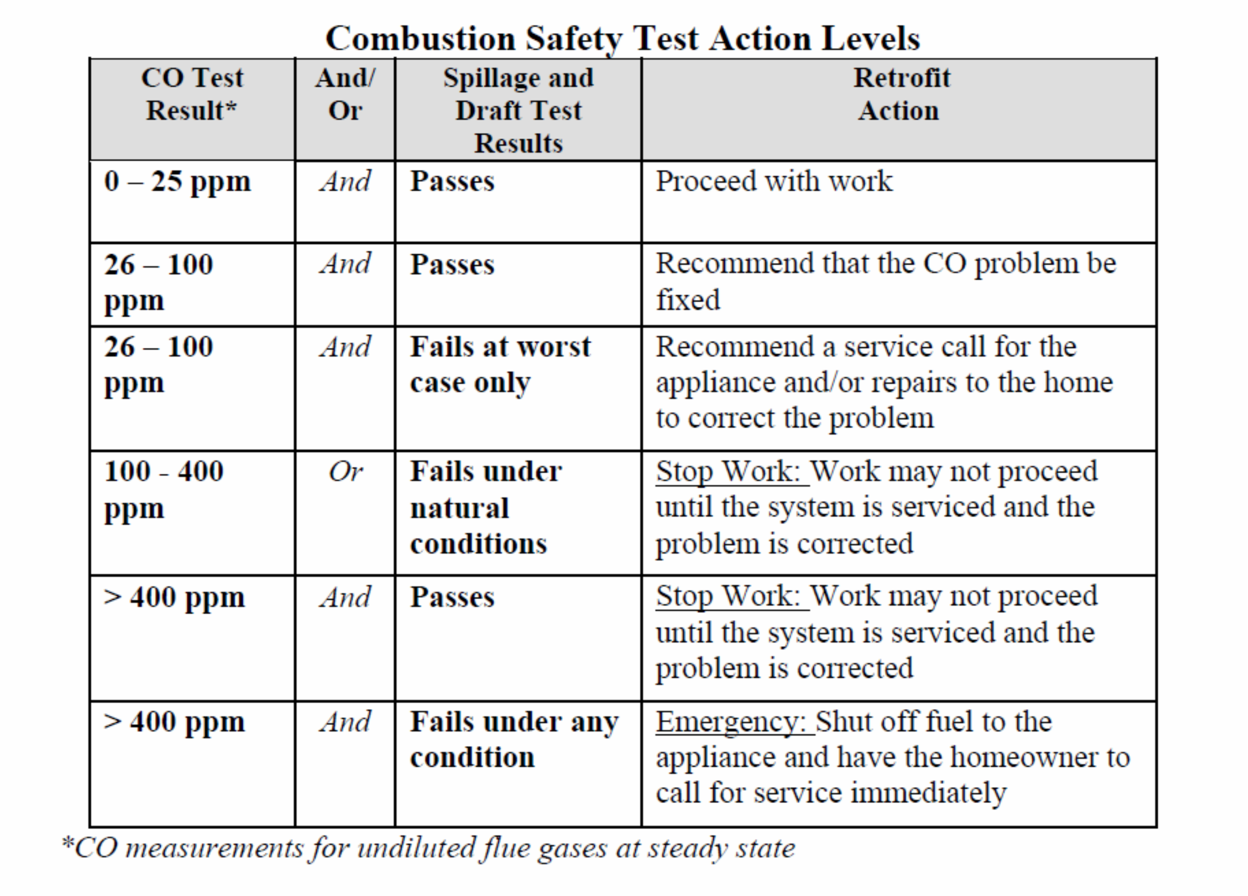
2. Establish the Worst Case. Turn on the dryer and all exhaust fans. Close interior doors that make the CAZ pressure more negative. Turn on the air handler, if present, and leave on if the pressure in the CAZ becomes more negative, then recheck the door positions. Measure the net change in pressure from the CAZ to outside, correcting for the base pressure. Record the “w
case depressurization” and compare to the CA

3. Measure Worst Case Spillage, Draft, CO. Fire the appliance with the smallest Btu capacity first, test for spillage at the draft diverter with a mirror or smoke test, and test for CO at the flue at steady state (if steady-state is not achieved within 10 minutes, take CO readings at the 10 minute mark). If the spillage test fails under worst-case go to step 4. If spillage ends within 1 minute, test the draft in the connector 1-2’ after the diverter or fir
connected appliances simultaneously and test the draft diverter of each appliance for spillage. Test for CO in all appliances in the flue, before the draft diverter.

4. Measure Spillage, Draft, CO under Natural Conditions. If spillage fails under worst case, turn off the appliance, the exhaust fans, open the interior doors, and allow the vent to cool before re-testing. Test for CO, spillage, and draft under “natural.” Measure the net change in pressure from worst case to natural in the CAZ to confirm the “
step 2. Repeat for each appliance, allowing the vent to cool between tests.

5. Ambient CO. Monitor the ambient CO in the breathing zone during the test procedure and abort the test if ambient CO goes over 35 ppm. Turn off the appliance, ventilate the space, and evacuate the building. The building may be reentered once ambient CO levels have gone below 35 ppm. The appliance must be repaired and the problem corrected prior to completing the combustion safety diagnostics. If the ambient levels exceed 35 ppm during testing under natural conditions, disable the appliance and instruct the homeowner to have the appliance repaired prior to operating it again.

6. Action Levels. Make recommendations or complete work order for repairs based on test results and the Combustion Safety Test Action Level Tables below.



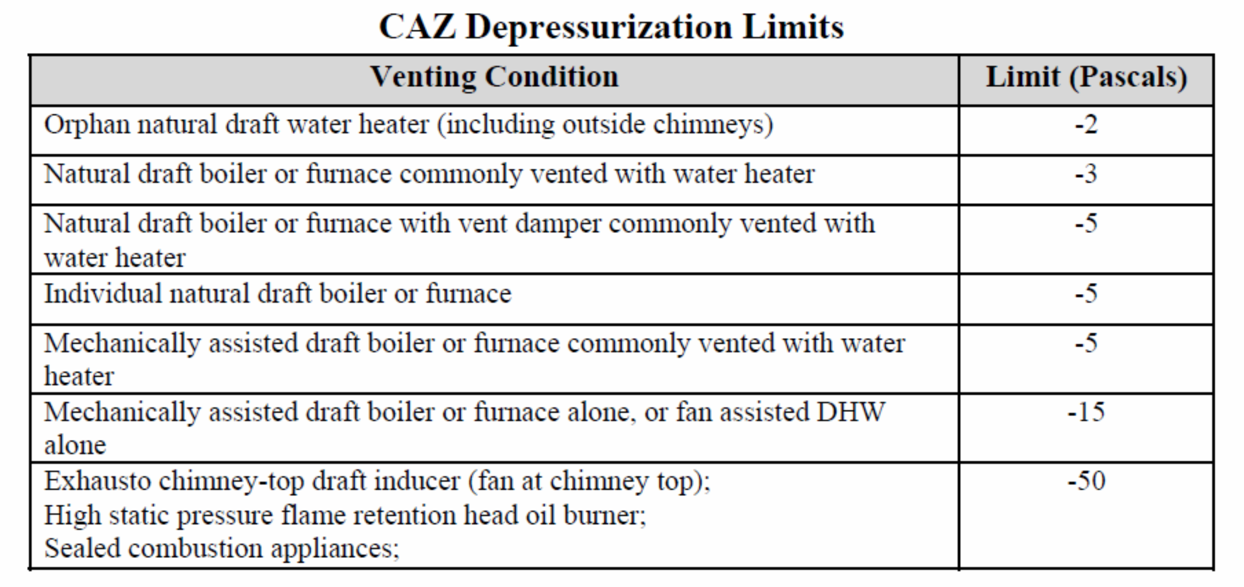
Combustion Safety Test Action Levels

CO Test Result*	And/ Or	Spillage and Draft Test Results	Retrofit Action
0 – 25 ppm	*And*	**Passes**	Proceed with work
26 – 100 ppm	*And*	**Passes**	Recommend that the CO problem be fixed
26 – 100 ppm	*And*	**Fails at worst case only**	Recommend a service call for the appliance and/or repairs to the home to correct the problem
100 - 400 ppm	*Or*	**Fails under natural conditions**	Stop Work: Work may not proceed until the system is serviced and the problem is corrected
> 400 ppm	*And*	**Passes**	Stop Work: Work may not proceed until the system is serviced and the problem is corrected
> 400 ppm	*And*	**Fails under any condition**	Emergency: Shut off fuel to the appliance and have the homeowner to call for service immediately

**CO measurements for undiluted flue gases at steady state*

When CAZ depressurization limits are exceeded under worst-case conditions according to the CAZ Depressurization Limit table, make up air must be provided or other modifications to the building shell or exhaust appliances must be included in the work scope to bring the depressurization within acceptable limits.

Worst-case CAZ depressurization limits are shown below:



CAZ Depressurization Limits

Venting Condition	Limit (Pascals)
Orphan natural draft water heater (including outside chimneys)	-2
Natural draft boiler or furnace commonly vented with water heater	-3
Natural draft boiler or furnace with vent damper commonly vented with water heater	-5
Individual natural draft boiler or furnace	-5
Mechanically assisted draft boiler or furnace commonly vented with water heater	-5
Mechanically assisted draft boiler or furnace alone, or fan assisted DHW alone	-15
Exhausto chimney-top draft inducer (fan at chimney top); High static pressure flame retention head oil burner; Sealed combustion appliances;	-50

If the stack CO in any appliance is measured greater than 100 ppm during diagnostic testing, or the ambient CO in the home exceeds 35 ppm during appliance operation, an appliance clean and tune must be completed as part of the work scope.

The homeowner shall be notified of the results of all combustion safety tests.

In addition to the BPI standards for combustion safety testing vented appliances, the following section from the National Fuel and gas code provides some additional specific mechanical tests for gas furnaces and boilers that should be followed by the heating contractor.

RECOMMENDED PROCEDURE FOR SAFETY INSPECTION OF AN EXISTING APPLIANCE INSTALLATION AS OUTLINED IN THE 2003 INTERNATIONAL FUEL GAS CODE™

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Note: If appliance fails this test, do not proceed until repairs are made.

The following procedure is intended as a guide to aid in determining whether an appliance has been properly installed and is in a safe condition for continued use. This procedure is predicated on central furnace and boiler installations, and it should be recognized that generalized procedures cannot anticipate all situations. Accordingly, in some cases, deviation from this procedure is necessary to determine safe operation of the equipment.

(a) This procedure should be performed prior to any attempt at modification of the appliance or of the installation.
(b) If it is determined there is a condition that could result in unsafe operation, the appliance should be shut off and the owner advised of the unsafe condition. The following steps should be followed in making the safety inspection:

1. Conduct a test for gas leakage. (See Section 406.6 IFGC)

2. Visually inspect the venting system for proper size and horizontal pitch and determine there is no blockage, restriction, leakage, corrosion, or other deficiencies that could cause an unsafe condition. (This will require removal of the vent from the chimney in most cases)

3. Shut off all gas to the appliance and shut off any other fuel-gas-burning appliance within the same room. **Use the shutoff valve in the supply line to each appliance.**

4. Inspect burners and crossovers for blockage and corrosion.

5. **Applicable only to furnaces.** Inspect the heat exchanger for cracks, openings, or excessive corrosion.

6. **Applicable only to boilers.** Inspect for evidence of water or combustion product leaks.

7. Insofar as is practical, close all building doors and windows and all doors between the space in which the appliance is located and other spaces of the building. Turn on clothes dryers. Turn on any exhaust fans, such as range hoods and bathroom exhausts, so they will operate at maximum speed. Do not operate a summer exhaust fan. Close fireplace dampers. **If, after completing Steps 8 through 13, it is believed sufficient combustion air is not available, refer to Section 304 of this code for guidance.**

8. Place the appliance being inspected in operation. **Follow the lighting instructions.** Adjust the thermostat so appliance will operate continuously.

9. Determine that the pilot(s), where provided, is/(are) burning properly and that the main burner ignition is satisfactory by interrupting and reestablishing the electrical supply to the appliance in any convenient manner. If the appliance is equipped with a continuous pilot(s), test the pilot safety device(s) to determine if it is operating properly by extinguishing the pilot(s) when the main burner(s) is/are off and determining, after 3 minutes, that the main burner gas does not flow upon a call for heat. If the appliance does not have a pilot(s), test for proper operation of the ignition system in accordance with the appliance manufac
operating instructions.

10. Visually determine that the main burner gas is burning properly (i.e., no floating or lifting of flames, or flashback). Adjust the primary air shutter(s) as required. If the appliance is equipped with high and low flame controls or flame modulation, check for proper main burner operation at low flame.

11. Test for spillage at the draft hood relief opening after five minutes of main burner operation. Use the flame of a match, a candle or smoke.

12. Turn on all other fuel-gas-burning appliances within the same room so they will operate at their full inputs. **Follow lighting instructions for each appliance.**

13. Repeat Steps 10 and 11 on the appliance being inspected.

14. Return doors, windows, exhaust fans, fireplace dampers, and any other fuel-gas-burning appliance to their previous conditions of use.

15. **Applicable only to furnaces.** Check both the limit control and the fan control for proper operation. Limit control operation can be checked by blocking the circulating air inlet or temporarily disconnecting the electrical supply to the blower motor and determining that the limit control acts to shut off the main burner gas.

16. **Applicable only to boilers.** Determine that the water pumps are in operating condition. Test low water cutoffs, automatic feed controls, pressure and temperature limit controls, and relief valves in accordance with the manufacturer's recommend
that they are in operating condition.

NOTES:

1. To properly burn 1 Ft^3 of natural gas, 15 Ft^{3}of air is needed for combustion and to meet excess air requirements.

2. If the gas appliance is a natural draft appliance, an additional 15 Ft^3 feet of dilution air is vented through the draft hood.

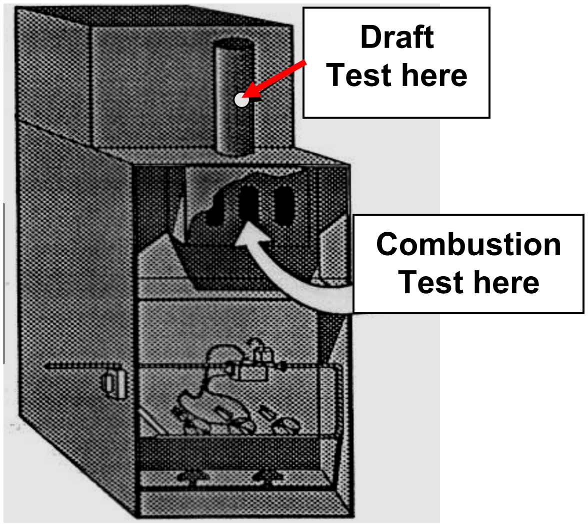
   A. A mid efficiency furnace will consume 15 Ft^3 of air/1Ft^3. of natural gas. (1 Ft^3 of natural gas ≈ 1,000 BTUH)

   B. A natural draft appliance will need 30 Ft^3. of air/1 Ft^3 of natural gas burned.

This means a 100,000 BTUH furnace would require 3000 Ft^3 of ventilation/combustion air for each hour of continuous operation. If make-up air provisions are not made, the air must be replaced through infiltration air openings.

8.8 Performing a Draft Test:

Verifying draft and checking for spillage is an important safety consideration. Draft is required to remove the flue gasses from the heat exchanger or draft hood on all atmospheric and draft induced appliances, and most power burner equipped appliances.



All appliances requiring draft are required to have and maintain draft during operation.

An appliance has 5 minutes under the ANSI standards to prove draft.

If following BPI standards, Vented appliances, regardless of type, that spill flue gases for more than 60 seconds after startup, fail the spillage test.

During steady state operating conditions, the draft should be stable. The draft will increase as the flue warms until it reaches maximum flue temperature and stabilizes. The analyzer will record and store the draft reading for the flue gas measurement screen and printout.

NOTE: Draft is always checked upstream of the draft diverter on atmospheric appliances, and upstream of the draft inducer motor on induced draft appliances. In both cases, the draft should always be negative.

Note: *If the appliance and chimney are cold it can take up to five (5) minutes to establish draft. (a spill switch must trip within ten (10) minutes if spillage occurs. A system that has been under operation should have or establish draft very quickly. If draft induced and atmospheric appliances are common vented, always verify the atmospheric appliance is not spilling when both appliances are operating. Verify that flue gasses are not spilling through the draft hood on the atmospheric appliance when it is operating by itself.* If both *appliances are common vented, both should be draft tested. Kitchen exhaust fans, basement doors opening or closing etc, should not affect draft. If multiple draft-induced appliances are common vented, assure that spillage does not occur through the heat exchanger and out through the burner openings of the adjoining appliance while it is in its stand-by position (OFF)*

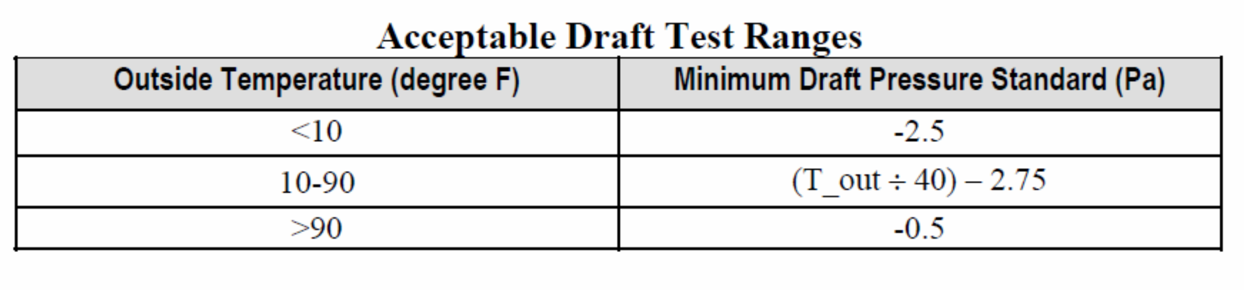
Spillage and Draft Tests

Spillage and draft tests must be completed for all natural and induced draft space heating systems and water heaters. Spillage and draft must first be tested under worst-case conditions (See page 19) and then repeated for natural conditions if the appliance fails under worst-case.

When a chimney is shared by multiple appliances the appliance with the smallest Btu input rating shall be tested first and remaining appliances tested in order of increasing input rate.

Induced draft heating systems shall be checked for spillage at the base of the chimney liner or flue. If a chimney is shared between and induced draft heating system and a natural draft water heater, spillage shall be checked at the water heater draft diverter. If the furnace is common vented with another furnace, make sure that flue gasses are not being directed out the second furnace during the off cycle

Vent draft pressure shall be measured at steady-state operating conditions for all natural draft heating and hot water appliances. Draft test location should be approximately 1- 2' downstream of the appliance draft diverter or at least two diameters distance away from the connecter. The test hole must be sealed with an appropriate plug after the test. Acceptable draft test results (BPI Standard) are shown below:



Acceptable Draft Test Ranges

Outside Temperature (degree F)	Minimum Draft Pressure Standard (Pa)
<10	-2.5
10-90	(T_out ÷ 40) – 2.75
>90	-0.5

Note 1 inwc = 249.09 pa

Example to convert inwc to pa: -.02 inwc x 249.09 = -4.98 pa

8.9 Efficiency Measurement and Considerations:

Since it is not possible in the field to measure the theoretical temperature of a combustion process due to dilution of the gases and absorption of the heat by radiation to the surrounding areas, the combustion equation has been developed to determine whether a combustion process is being properly handled. The efficiency calculation is based from the theoretical heat value of the fuel being burned minus the stack losses and is representative of the thermal efficiency of the appliance being tested. See the Section 6 for additional information on the efficiency calculation.

8.10 Oxygen (O_2) Reading:

The O_2 reading is by far the most important reading an analyzer measures with regard to combustion efficiency and safety. The oxygen level in the atmosphere remains constant (20.9%), and is the only true constant in the combustion process we have. The O_2 reading should be monitored to produce a flame with the lowest excess air reading possible while maintaining a safe level of CO in the stack. Excess air readings should always fa guidelines if provided. Always make sure that all burner shields and equipment doors are in place to avoid the entry of excess secondary air or depressurization of the CAZ. Residential furnaces often do not provide combustion air adjustment provisions because manufacturers have determined that the safety gained by providing additional air to assure complete combustion outweighs any potential savings that adjustment might provide. Also, excess air lowers the dew point of the flue gasses by dilution, thereby lowering the probability of condensation in the stack.

8.11 Carbon Dioxide (CO_2)

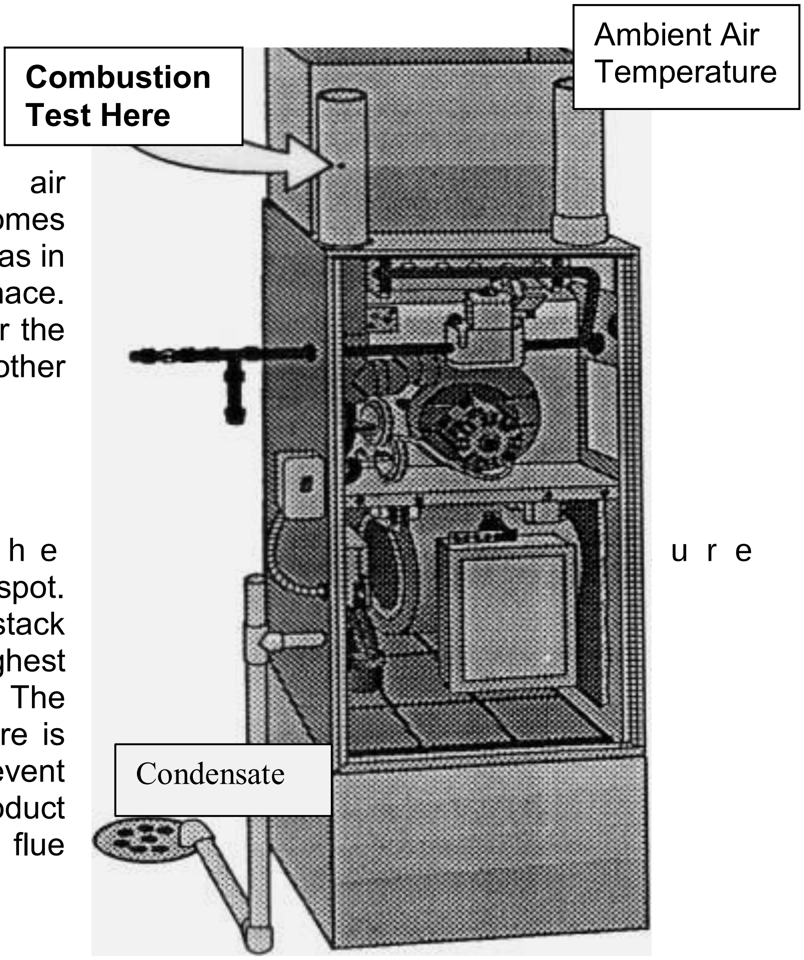
The carbon dioxide level in the flue gas provides an indication of the efficiency of the burner. If the production of CO_2 is as high as possible with slight excess air (complete combustion), the flue gas heat losses are at their lowest. The CO_2 reading is calculated from the O_2 reading by the analyzer.

For each fuel there is a maximum possible CO_2 level (CO_{2max}), which is determined by the chemical composition of the fuel. This maximum theoretical level is never reached in practice.

$CO_{2\,max}$ values for different fuels:
- Light Fuel Oil - 15.4% by volume CO_2
- Natural Gas - 11.8% by volume CO_2

8.12 Ambient Air Temperature

The ambient air temperature is measured at the burner inlet. Often this measurement requires an additional probe to measure inlet air temperature when combustion air comes into the burner directly from the outside as in the case of a sealed combustion furnace. The ambient air temperature is used for the efficiency calculation and will not affect other combustion gas calculations.



8.13 Stack Temperature

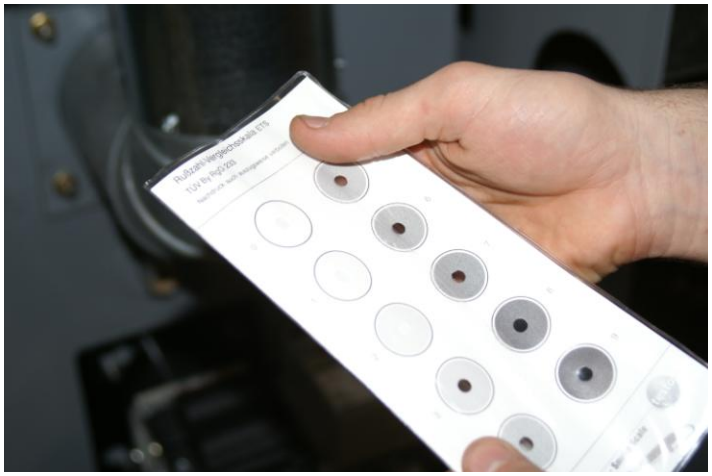
“The Hot Spot”: The ure should be measured in the flue gas hot spot. This is the point in the flue where the stack temperature and the CO_2 are at the highest level and the O_2 is at its lowest level. The primary importance of stack temperature is to provide enough heat in the flue to prevent water formation. Water can be a byproduct of combustion from condensing in the flue and or the chimney. Condensing on non-condensing appliances can cause chimney deterioration liner failure and rusting of the appliance.

Reducing the temperature of the flue gasses provides only a small benefit in the appliance efficiency. For every 50° the stack temperature is lowered, there is less than a 1% gain in efficiency. The stack temperature should be 270-370° above the supply air temperature or supply water temperature on non-condensing atmospheric appliances, and 170-270° above supply air temperature on draft induced appliances. On condensing appliances, ideally the stack temperature will be approaching the return air temperature and always below 125 F. The lower the return air temperature the higher the efficiency will be on a condensing appliance. Until the flue gasses are lowered to the condensing range, there is not a significant increase in thermal efficiency of the appliance. Remember the analyzer is looking at a modified equation that considers combustion efficiency and stack losses of the dry gasses. The efficiency calculation many not be reflective of the thermal efficiency of a condensing appliance with some analyzers. Consult the manufactures instructions to determine the type of calculation.

8.14 Dew Point Temperature

The dew point temperature is the temperature below which the water vapor contained in the flue gas would turn into a liquid state. This change is often referred to as condensation. Below the dew point temperature, moisture exists; above the dew point temperature vapor exists. If the chimney or venting material falls below the dew point temperature, condensation in the flue will occur. The dew point temperature is a calculated value the technician can use to reference if condensation of a non-condensing appliance is suspected.

8.15 Smoke Spot Number



The smoke spot number is determined by using a smoke spot tester. A standard quantity of flue gas is drawn through a filter paper by a certain number of strokes. The degree of blackening of the resulting spot on the filter paper is compared to a scale of gray tones with different numbers. The smoke spot number derivative determined in this way (according to ASTM D2156) is between 0 and 9. The smoke spot number is not measured in gas burners. Ideally the smoke spot number will be a 0 to 1 with a trace of soot. Smoke numbers above this will result in poor combustion and formation of soot on the heat exchanger.

Yellow spotting on the filter paper is an indication of incomplete combustion due to insufficient atomizing of the fuel. This condition is usually accompanied by high CO readings and is often eliminated by reducing the amount of excess air to the burner.

8.16 Fuel Pressures

Only two factors affect the input to an appliance, fuel pressure and orifice or nozzle size. The fuel pressure should always be measured and set to the manufacturer's prescrib Under circumstances should fuel pressures be adjusted outside of the designed range or over firing or under firing will result which could lead to premature equipment failure. Adjustment of the fuel pressure can compromise the operation of the pressure switch, and effect the fuel gas mixture resulting in the formation of CO and or other undesirable effects.

9 Pollution Parameters

Oxides of Nitrogen (NO_x) Optional Measurement

Measurement of NO_x and other pollutants are required in some jurisdictions on certain types of equipment. As a safety factor to assure complete combustion, appliances are fired with excess air. One of the factors influencing NOx formation in a furnace or boiler is the excess air level. High excess air levels (>45%) may result in increased NOx formation because the excess nitrogen and oxygen in the combustion air entering the flame will combine to form thermal NOx. Low excess air firing involves limiting the amount of excess air that is entering the combustion process in order to limit the amount of extra nitrogen and oxygen that enter the flame. This is accomplished through burner design and can be optimized through the use of oxygen trim controls on commercial applications. Low excess air firing is used on most appliances and generally results in overall NOx reductions of 5-10% when firing natural gas.

High flame temperatures and intimate air/fuel mixing are essential for low CO emissions. Some NOx control technologies used on residential, industrial and commercial burners reduce NOx levels by lowering flame temperatures through modification of air/fuel mixing patterns, or creation of intentional flame impingement. The lower flame temperature and decreased mixing intensity can result in higher CO levels.

Section 17 details the typical operating characteristics of specific categories of appliances.

10 Three-Part Procedure for Checking a Heat Exchanger

CAUTION: If appliance fails this test, do not proceed until repairs are made.

The Gas Research Institute (GRI) funded a study to determine the most effective method for checking a heat exchanger.

1. That study and the recommendations for the testing procedures were published in the RSES Publication 630-92 9/86.

2. They determined that:

   A. A three part testing was necessary to determine the integrity of a heat exchanger.

   B. The three-part procedure they recommended is summarized as follows:
      1. Watch the flame when the blower comes on. The blower operation should not affect the flame pattern.
      2. Perform a visual inspection of the heat exchanger. (This may be limited by the shape of the heat exchanger and by visual obstructions such as an evaporator coil.)[6]
      3. Perform a chemical test on the heat exchanger. (Introduce a chemical that can be detected into the inside of the heat exchanger, then use an instrument that can sense that chemical in the supply air stream.)

   C. The International National Fuel Gas and Oil Codes say that you should check the heat exchanger on all service calls. *They do not specify the method.*

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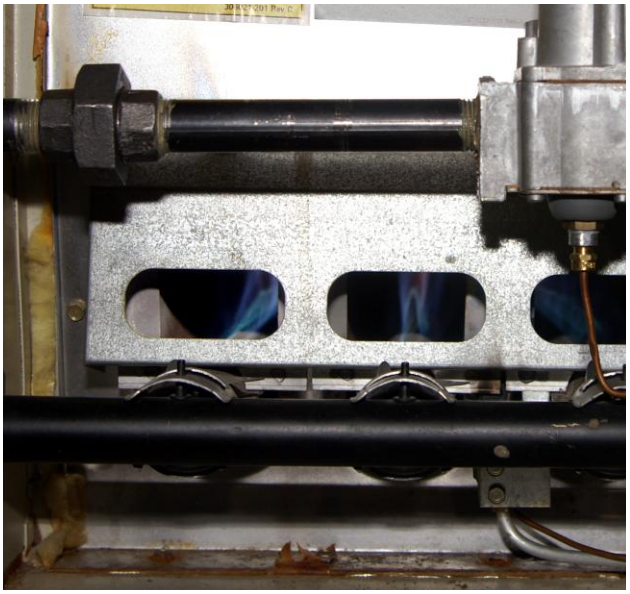
[6] The chemical test was performed with a tracer gas (nitrogen and methane) and a calibrated detector usually calibrated to 1200cc of tracer gas. The study was performed in 1986, and although validated and recommended by GRI to become part of the appendix for heat exchanger testing in the Nation Fuel and Gas Code, no method has been officially adopted into the code.

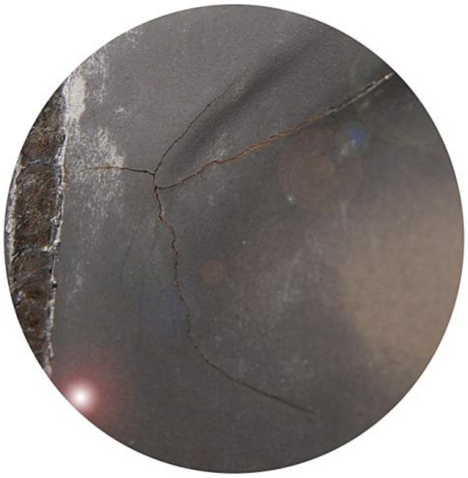
A more modern alternative to the trace gas test is the O_2 test using a combustion analyzer. The O_2 test has several advantages over the trace gas test including testing during normal operation under normal temperatures. Leaks below the burner will be evident. Multiple tests can be performed at once including combustion air testing, heat exchanger testing, CO testing, and efficiency testing. A combustion analyzer can be used to determine unacceptable leakage, atmospheric draft appliances and draft-induced appliances using O_2 as the trace gas. The O_2 will be below 21% and stable during normal operation. When performing this test, it should be noted that as of this writing, there has been no formal field study to document the correlation of minimum leakage rates and O_2 changes. However, during lab testing, we were able to determine leakage through a single 1/8 d several locations in the heat exchanger. After each test the hole was plugged with a screw and an additional location was tested. Multiples of holes were also tested to simulate pin holing in a heat exchanger. Locations were specifically selected that avoided air blowing directly in the heat exchanger, and rather depend upon system static pressure to force additional air from the supply side into the heat exchanger. If the O_2 changes when the blower starts, there is likely leakage into the heat exchanger, and further investigation is warranted. Closing main dampers will increase supply side static pressure and further amplify the leakage rate. If cracks or holes cannot be found, the customer should still sign off in writing that they have been notified there is a potential problem with the operation of their furnace.



Flame disruption when the blower starts is a key indicator of heat exchanger failure.

PERFORMING the O_2 TEST

A flue gas combustion analyzer can be used effectively for finding leaking cracks or holes in a furnace heat exchanger. **Not all cracks or holes will leak.** Smaller cracks and holes found only by a thorough visual inspection may not be leaking during the time of testing. They still pose a potential danger to your customer, as cracks will continue to open over time due to the tremendous thermal forces



on the metal at the ends of the crack due to appliance cycling.

On all furnaces the static pressure achieved by the system blower can usually overcome any positive pressure in an atmospheric draft appliance. On draft-induced appliances, the pressure within the heat exchanger is always negative, causing them to leak in rather than out. Any leakage in a heat exchanger in or out poses a danger to your customer. Leaks out can allow flue gasses that may contain CO into the living space, and pressurization of a draft induces appliance heat exchanger can result in a rollout and possible fire. With all combustion, the readings on the analyzer should be stable after several minutes. When the stack temperature stabilizes, all other gas readings on the analyzer should also remain stable. **CAUTION** ***Readings that change during operation after stabilization has taken place are indicative of a combustion air, venting, or mechanical problem such as a cracked heat exchanger.***

Important notes:

1. Oil furnaces and older gas appliances can have leaking cleanouts that will test positive for leakage. This is not a heat exchanger failure. Inspection gaskets should be replaced and properly sealed following the manufacturer’s recommendations. If recommendations are not available, an industry-approved method should be used to seal the cleanout.

2. No inspection method is “fool proof.” -part method should always be performed to maximize the safety of the appliance.

PROCEDURE:

1. Follow the manufacturer’s instructions to analyzer.

2. Insert the combustion analyzer in the appropriate test position in the furnace.
   a. For atmospheric draft appliances this would be directly in the heat exchanger cell.
   b. For 80+/90+ furnaces this would be in the stack.

3. Start the furnace and observe the oxygen reading for stability. (1-3 minutes)

4. When the blower starts, watch for a change in the O_2 reading. If the blower starts prior to stabilization of the O_2 reading, a piece of cardboard can be inserted and removed during operation to observe if any changes in the combustion readings take place.

Corrective action:
Attempt to visually find the crack or hole.

- A. If you can find the defect, show it to the customer.
- B. On the service invoice, write that your testing indicates presence of a leak in the heat exchanger. (Do this even if you cannot find the leak.)
- C. Inform the customer, in writing, that the heat exchanger has a defect and poses a <u>potential</u> danger. (Do this even if you cannot find the leak.)

- D. Explain the potential health risk:
    1. The defective heat exchanger is allowing the flue gases to enter the home/building.
    2. If poor combustion takes place, there is the <u>potential</u> to allow Carbon Monoxide into the structure.
    3. Carbon Monoxide is a deadly gas. It is colorless, odorless, and displaces Oxygen in the blood stream. High levels of Carbon Monoxide can cause brain damage and/or death.
    4. Ask the customer if you can shut down the furnace for their safety. Open the safety disconnect at the furnace. Record this request on your service invoice.
    5. Possible solutions:
        - A. Replace the heat exchanger.
        - B. Replace the furnace.

Note: You should NEVER attempt to repair a heat exchanger.

11 Field Modifications

Adjusting Gas Pressure Outside of Manufacturers

Although not published in a field or scientific study, some in the industry have recommended adjusting appliance input to improve appliance operation.

CAUTION: **We do not recommend adjusting the fuel input outside of the** manufacturer's recommended manifold pressure, usually 3.5" WC **(adjustable range of 3.2-3.8") in attempt to lower the excess air reading and or increase the combustion efficiency on appliances with or without adjustable primary air shutters.**

While increasing fuel pressures may result in a slightly (2-5%) more efficient appliance due to increased radiant heat transfer, lower excess air readings, and or a lower CO levels, ***it can and usually will result in over firing the appliance and possibly condensing problems and can cause premature heat exchanger failure*** and leave unnecessary liability for the technician and company by not setting up the equipment to

the large variance in heat content of fuel, and factors that affect air density like temperature and humidity, excess air is a necessary evil. It should be carefully controlled and kept to a minimum whenever possible. Excess air is a required by all commercial and residential burners.

If it is determined that after commissioning an appliance that it is under fired or over fired at the recommended fuel pressure, follow the manufacturer's recommendations to achieve the desired input. This will typically involve changing or resizing the equipment orifices.

13.2 Modification of Draft hood equipped appliances to Control Draft

On furnaces with or without air shutters on the burner, controlling the draft can control the combustion air and in turn the secondary air to the furnace. This would only be true where excess draft is apparent. The addition of a double acting barometric damper to a flue that does not properly draft will not correct a low or no draft problem.

If there is no or low measured draft, the chimney and the vent pipe should be inspected for blockage, shifted tiles and or improper installation or height. Report NO. FT-C-07-93 On Performance of Drafthood Equipped Gas appliances Modified by the Addition of Barometric Dampers. A.G.A. Laboratories Field Test Program details a procedure to control draft and increase efficiency. Although this is a field report and not equivalent to a design certification, the factual information is intended to assist the code enforcing authorities and others involved in judging acceptance of the device for use in their jurisdiction. The field-testing suggested that addition of draft controls on draft hood equipped appliances can improve performance, lower CO production and improve overall operation. We cannot recommend this course of action because of the number of factors that must be determined in the field, but we do believe you should be aware of its findings.

Under Section 503.12.4 of the IFGC, the addition of a draft regulator is allowed provided the code requirements are followed. An important factor to remember when installing draft control devices is they control draft, not create it. The addition of a draft control device is only desirable when the draft would prove to be in excess of what the manufacturer requires at the vent connector. If the draft hood is modified as suggested in the A.G.A. study, the installation shall be in accordance with recommendations of the equipment manufacturer and shall be approved IFGC 503.12.2.2.

In the case of an atmospheric burner, the combustion air is drawn in by buoyancy of the heated flue gasses and mixes with the gas as it enters the combustion chamber. The fuel/air mixture burned in the combustion chamber quickly releases its heat to the heat transfer surfaces surrounding it, and the hot flue gas escapes through a draft hood into the flue.

The role of the draft hood is to prevent excessive flue draft or a back draft in the flue system from affecting the combustion process. It is designed to physically separate the appliance from the draft. Because flue gasses have natural buoyancy, it is not necessary for the appliance to be connected directly to the flue by design of natural draft appliances. As warm air rises and moves toward the vent connector, fresh air will be required to replace it.

So long as draft is provided at the vent connector, the low-pressure zone created in the draft hood will direct all of the flue gasses and the proper amount of dilution air into the vent pipe and chimney. If a negative pressure is created in the appliance combustion/venting zone that is greater than the draft provided at the vent connector, spillage will occur. The flue gasses will always move to the area of lowest pressure. This will occur whether a draft hood or barometric damper is installed; hence the requirement of spill switches on both to improve safety.

12 Classification of Equipment (Gas Furnaces- AFUE)

Determination of the exact equipment Annual Fuel Utilization Efficiency (AFUE) is not possible in the field. There are several types of efficiency ratings including Annual Fuel Utilization Efficiency (AFUE), Combustion Efficiency, Thermal System Operating Efficiency, and Steady State Operating Efficiency. An older furnace can have 85% combustion efficiency yet have an AFUE of 60% because of the amount of heat going up the stack, which is heat not being transferred by the heat exchanger. A 95% AFUE furnace can be operating in the 60% range due to poor installation or operation In general; furnace efficiency (AFUE) can be generalized by the following chart and guidelines provided the installation is adequate.

60-70% AFUE range:	Standing pilot, draft diverter, belt drive blower, and a single upshot burner. Single wall flue pipe

70-78% AFUE range:	Intermittent pilot direct spark or Hot Surface Igniter (HIS), draft diverter, with/without flue damper, direct drive blower, multi cell construction with ribbon, slotted, or ported burners. Single wall flue pipe

80-89% AFUE range:	Intermittent pilot direct spark or HSI, induced draft, direct drive blower, could be multistage and/or variable speed, jet or in-shot type burners, single or double wall flue pipe. If vented in masonry chimney, chimney must be lined.

90-97% AFUE range:	Intermittent pilot direct spark or HSI, induced draft, direct drive blower, could be multistage or modulating and or variable speed, jet or in-shot type burners, secondary heat exchanger, plastic flue pipe

Thermal efficiency can be field-calculated provided the heating value of the fuel being burned is known, and accurate measurement of the airflow across the heat exchanger is made. The values should be input into the sensible heat formula and then divided by the appliance input.

13 Calculating Field Thermal Efficiency or BTUH Output

To calculate field thermal efficiency or BTUh output, measure airflow across the heat exchanger, preferably using a mini-vane anemometer (eg. a Testo 416.) Or measure total external static pressure using a pocket digital manometer and using a manufacturer's chart to determine C
across the heat exchanger, being careful not to let radiant energy affect the temperature reading. It is preferable to take your temperature measurements in several locations and average them. Enter the results into the sensible heat formula.

This is the heat added that causes a change in temperature of the air without adding or removing humidity to the air.

Total Sensible Heat Formula $TSH=1.08 \text{ x } CFM \text{ x } \Delta t$

Where: TSH = Total sensible heat in BTU per hour
CFM = Airflow in cubic feet per minute
Δt = Change in temperature (ºF) across the heat exchanger

If the heat content of the natural gas is verified, the meter can be clocked and the actual input can be divided into the measured output to calculate the actual operating thermal efficiency.

14 Principals of Heat and Heat Transfer

Once the fuel has been burned and the BTUs (or heat) released, the heat must be transferred to the heat exchanger or directly to the air. There are three basic types of heat transfer: convection, radiation, and conduction.

Convection is the form of heat transfer whereby the temperature of a gas or liquid, passing across another object, normally a heat exchanger, results in a transfer of energy (temperature) from the (flue) gas to the heat exchanger. We normally think of this form of heating as going from a hot gas to a cold, solid object. The more turbulent the flow, the greater the heat transfer by convection.

Convection heating is the most commonly used and important method of heat transfer in the HVAC industry since the hot gases to come into contact with most surfaces of the heat exchanger. To transfer energy to the heat exchanger, the heat energy must penetrate multiple layers of air that are electrostatically bonded to the heat exchanger surface. Air, an excellent insulator, makes this transfer difficult. Therefore, the faster that a fluid (gas stream) passes across the surface, the more rapidly these air layers will be swept away, to be replaced by hotter gases. This continuing process is convective heat transfer, and it has been made more efficient for the heating industry through the development of more complex heat exchanger designs and better burners. Because this heat transfer depends upon time, temperature difference and turbulence, excessive draft will decrease heat transfer by convection and lower the system efficiency.

Radiation is the transfer of energy (heat) between surfaces at different temperatures without the two being in physical contact with each other. The most common example is the sun and the earth. The amount of heat transfer via radiation is proportional to the fourth power of the temperature difference between the heat source (emitter) and that which is being heated (receiver).

Only those surfaces that “see” the heat sou
have their temperature raised. At the higher temperatures, radiation is the most intense form of heat transfer—but only in straight-line radiation. In a furnace heat exchanger, while a significant amount of heat is transferred through radiation, more complex heat exchanger designs have increased the heat transferred by convection and conduction. For maximum radiant heat transfer, the gas pressure must be set to the maximum recommended pressure level prescribed by the manufacturer.

Because the amount of heat given off by a flame depends on both its temperature and emissivity, flames can be of two types, luminous or non luminous. Non-luminous flames (blue) typical to all new gas furnaces are very hot, but give off very little radiant heat energy. Newer appliances rely on convection as the primary heat transfer method.

A carbon luminous flame (bright yellow) owes its light to carbon or fine soot that glows much in the same manner as a wood fire. A carbon luminous flame will emit up to five times the radiant energy of a non luminous flame. Appliances that depend on radiation as the method of heat transfer rely on a carbon luminous flame. This is a very typical flame in old single pass boilers, wood stoves and pellet stoves. A carbon luminous flame will have a yellow appearance which may cause concern, however, an appliance can operate with a carbon luminous flame and very low CO provided that the carbon particles in the flame are consumed in the combustion process. Any attempt to adjust the flame to a non luminous flame in these types of appliance will cause increased stack temperatures, and a significant decrease in efficiency.

Conduction is the mode of heat caused by the increased activity of molecules within a body. An object heated at one end (by convection and/or radiation) will cause the opposite end to get hot by the molecules passing along the heat (energy). The speed at which this transfer occurs is a function of:

> The thermal resistance of the material (the inverse of the conductivity),
> The mass of the object,
> The temperature differential between the energy source and the surface of the body being heated.

While conduction is generally the slowest of the heat transfer mechanisms and depends on the molecular structure of the material, it is the only way to completely heat an object once the energy has been transferred by convection and radiation to the surface of the object being heated. With newer heat exchangers being low mass, the time required to reach steady state efficiency or the point at which a constant rate of input produces a constant rate of output has been significantly reduced.

> NOTE: *Low mass heat exchangers do come at a cost. Stresses produced on a low mass heat exchanger due to loss of airflow or low airflow, over-firing, and/or excessive short cycling can cause premature failure of heat exchanger material, and/or mechanical and or welded connections. Careful inspection should be done on an annual basis. Inspection of the heat exchanger is required if the furnace has been cycling on the high limit control, experiencing blower motor failure or has been over-firing no matter how short the length of time.*

15 *Combustion Testing Specific Appliances*

…. and Other Industry Practices/Procedures a

***CAUTION**: The following operating characteristics are given as typical. Every manufacturer should have published standards (although many do not) for the operating characteristics of all appliances they manufacture. The manufacturer should always be consulted prior to changing the operating characteristics of any fuel-burning appliance. No matter how good-intentioned one is when practicing field adjustment of equipment, it is not possible to consider the varied and many operating characteristics and conditions that the manufacturer has taken into account when designing and testing the appliance simply because we are not privy to design elements that the manufacturer has incorporated into the design. Therefore, the typical operating characteristics listed here are secondary to the* manufacturer's published guidelines *rence to* and are *typical operation of the particular appliance being tested. Commentary contained in the rest of this document is provided to increase awareness of standards and practices common to the HVAC industry.*

Since there is always 20.9% oxygen in normal air, this can be used a measure of combustion efficiency. Ideally, a flue gas analysis of 0% combustibles would be achieved with no excess oxygen in the flue gas. Manufacturers of residential appliances normally require a minimum of 20-40% excess air (5-9% O2) to assure enough air is available for complete combustion and dilution of the flue gasses even if an appliance is dirty and suffering from neglect. If homeowners had their appliances checked on a regular basis, excess air requirements could be more tightly controlled, provided there is ample air for dilution to avoid condensing in the stack. Where clean air is taken from the outdoors as in a two pipe 90+ furnaces, air requirements are more tightly controlled. Additionally, 90% efficient appliances are condensing appliances and the air normally used for dilution of the flue gasses is undesirable for maximum efficiency of the appliance. In all cases the higher excess air requirements and the associated losses in efficiency and cost to the consumer are outweighed by the increase in safety and product reliability.

It is possible for a system to have large quantities of excess air in the area of the flame. This can come from secondary air sources or can be caused by running the burners with excess primary air. This is particularly true in oil powered burner applications. The excess air can cause the flame to be quenched before combustion is completed, forming CO and aldehydes (CH_3CHO) as the resultant products of combustion. With oil furnaces, lowering the excess air by closing the draw band can decrease CO production. This is a required and permissible practice by burner and appliance manufacturers using oil power burners. Provisions are made by the manufacturer for this specific adjustment. Excess air requirements should be carefully controlle specifications to assure optimum performance while minimizing the chance of condensing the flue gasses in non-condensing appliances.

When performing a combustion test, the following process should be followed.

1. Test ambient CO levels prior to entering the work space and continue to monitor while testing.
2. Create worst case conditions (BPI or IFGC)
3. Test for spillage and draft. If there is no draft, return to natural conditions for testing and recommend repairs. If still no draft under natural conditions, STOP testing until corrections are made.)
4. Test in under worse case and print results
5. Perform the three step heat exchanger inspection (If exchanger has failed STOP testing and shut down the appliance until repairs are made)
6. Test and adjust the appliance as required
7. Verify consistency of the combustion process
8. Combustion test out under worse case conditions and print final results.

When performing a combustion analysis, consistency or stability of the combustion process is more important than any single reading on its own. A non-stable process can quickly mean danger for the appliance, the homeowner and even the technician. Using a graphic display analyzer or an analyzer with data logging software will significantly improve your ability to identify these problems. Typically with low mass appliances the combustion process should stabilize within 5-7 minutes of operation, with high mass systems 7 to 15 minutes of operation may be required for thermal stability.

Stability is achieved when O_2 varies less than 1% , CO less than 2 ppm and stack temperature is stable or very slowly rising as the conditioned space warms.

> **Low or falling O_2**: A falling O_2 reading can be caused by many things including obstruction of heat exchanger cells due to rust, warping, or blockage. A blocked vent or vent connector on draft assisted appliances, a blocked flue or collapsed liner, dirt or rust between baffles, recirculation of flue gasses in the CAZ, or lack of combustion, dilution and ventilation air. If we cannot get air out of the furnace it will not come in, and if there is a lack of air available or it has a low O2 content like recirculated flue gasses, the furnace is poised for danger.
>
> **High or rising O_2**: A rising O_2 is typically caused by air leakage into the heat exchanger after the point of combustion. This can easily occur due to leakage in a heat exchanger of a furnace or cleanouts on draft induced boilers. It is a tell tale sign of heat exchanger failure (cracks, splits or holes) and can be extremely dangerous when leaks in the cell rob secondary air from the combustion process resulting in formation of CO. Because the volume of air moved through the heat exchanger is limited by the induced draft motor, air leakage after the point of combustion through a crack split of hole will introduce secondary air (or now dilution air)

downstream of point of combustion and rob the burner of secondary air at the entry of the heat exchanger.

High or rising CO: Formation of CO typically starts with a rich fuel/air mixture but can be created with excess air as well. As with a falling O2, a rising or high CO can be caused by many things including obstruction of heat exchanger cells due to rust, warping, or blockage. A blocked vent or vent connector on draft assisted appliances, a blocked flue or collapsed liner, recirculation of flue gasses in the CAZ, or lack of combustion, dilution and ventilation air. If we cannot get air out of the furnace it will not come in, and if there is a lack of air available or it has a low O2 content like re-circulated flue gasses, the furnace is again poised for danger. CO can also be produced by too much excess air causing quenching or cooling of the flame. This is a common cause of CO on an improperly tuned oil furnace. Technicians trying to lower CO production try to add additional air only end up accelerating the production of CO. On oil furnaces, a high or rising CO level could be caused by flame impingement. Use a service mirror to make sure that the nozzle selection and pattern are correct for the refractory design, and that the refractory is not collapsed or damaged.

Low or falling CO: While a low CO is desirable and normal. (In fact, no CO is perfectly normal.) A dropping CO can help to identify some problems on fuel oil appliances. When an oil furnace experiences a delayed ignition or has no fuel cutoff, the refractory can become oil soaked. The soaked in oil later burns off during the next cycle indicating incomplete combustion and produces CO in excess of normal operation. As the refractory heats up, the oil will begin to burn off and the CO level will drop. Adding a cutoff solenoid to the gun assembly and or correcting other combustion deficiencies will reduce problems with soot and other mechanical problems. Higher CO at light off on gas or oil appliances dropping to an acceptable and stable level is normal and generally not even considered during gas appliance service. With fuel oil however, high CO at light off can be a result of delayed ignition and cause soot buildup of the appliance over time.

High or rising stack temperature: While a rise in stack temperature is normal during operation, it should stabilize. If the temperature becomes erratic, changes in air pressure in the CAZ affecting the draft of the appliance may be the culprit. Make sure to use the sealing cone supplied with a combustion air probe to assure that air from the room does not get pulled into the stack by the probe affecting the stack temperature or other readings. High stack temperatures are the result of low or insufficient heat transfer, and/or excessive fuel. These problems can be due to low airflow across a heat exchanger, soot or rust between the cell sections of boiler or simply low water flow. High stack temperatures can mean energy is wasted. But remember, not all the heat going up the chimney is a bad thing. With non-condensing appliances a certain amount or heat is necessary to assure that the water vapor in the flue gasses stays as a vapor and does not condense in the chimney resulting in damage.

Low or falling stack temperature: As with high stack temperature, a falling stack temperature may be normal when the air or water circulator starts. It is typical on gas furnaces to allow a warm up period when the system starts. That results in a slight drop in stack temperatures. However the stack temperature should stabilize at an acceptable level. Low stack temperatures can be cause by several things including low fuel pressure, excessive airflow (high blower speed) or excessive water flow across the heat exchanger, high amounts of excess air, and or low return air or water temperatures. Low stack temperatures can cause a host of problems with flue gas condensation that can lead to premature heat exchanger failure, corrosion or water damage.

Low or decreasing draft: Depending on the type of appliance, draft hooded or draft induced low draft may not affect the combustion of the appliance and be evident by a falling O_2 or rising CO reading. A draft hood is designed to separate the appliance from the draft for this very reason. Good combustion will produce little to no CO, and with a natural draft appliance it is much better to let the flue gasses spill into the space (Heat, CO_2, and H_2O) if the vent of chimney becomes clogged than to disrupt the natural flow of buoyant gasses through the heat exchanger resulting in the flame looking for oxygen. While a draft hood is a pathway for flue gasses to enter the home, it is an engineered and intentional pathway that exists to protect occupants from fire.

Draft should be verified with both a draft gauge and with a smoke tracing pencil to assure that flue gasses are exiting the appliance through the draft hood and not around it. Check a full 360 degrees around the draft hood or all the way across to make sure that the appliance is not spilling into the room. Pressure patterns are not uniform!

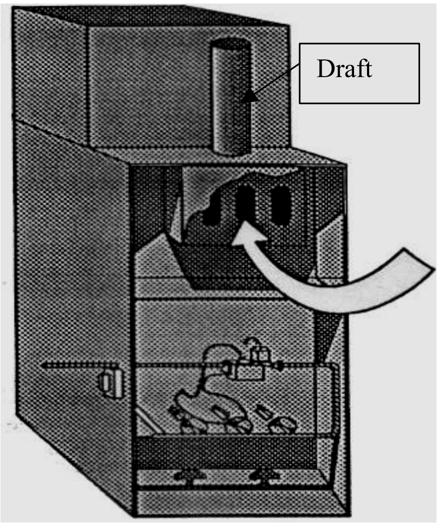
On induced and forced draft appliances, draft can be affected by CAZ pressures, vent design or vent blockage. Typically on these types of appliances a change in the CO or O_2 reading will be apparent as the flow through the heat exchanger will change. This can result in falling or low O_2, high or rising CO, low stack temperatures, and or condensation.

Low draft can be caused by several factors including normal and abnormal conditions. Outdoor air ambient temperature affects draft. The higher the outdoor air temperature, the lower the draft will be. Vent height, design, and material also affect draft. CAZ pressures affect draft, and finally duct leakage. Consult the BPI standards for acceptable CAZ depressurization limits. Low draft can result in a pathway for CO, spillage, excessive moisture in the home, and or death of the occupant if excessive levels of CO in the flue gas are present or develop due to the recirculation of flue gasses.

High or increasing draft: Excessive draft is typically the result of an oversized chimney, excessive stack temperatures, or an improperly adjusted power vent equipped appliance. Excessive draft results in excessive amounts of heat (conditioned air) going up the chimney, drafts within the home, and on induced draft appliance excessive heat going up the stack and or pressure switch problems.

Many stability issues can be corrected by correcting venting and combustion air issues do to substandard installation practices. Consult the manufacturers' installation guidelines and or venting combustion air tables and instructions to determine the required course of action for the repair. It is critical that the system is retested after modification to the combustion air system or venting system to insure that improvements made improve system operation. Although in installation may be "up to code" it does not guarantee that other mechanical systems will not interfere with the appliance operation and that safe operation will occur. If any changes to operation of an appliance are made including but not limited to balancing, blower speed, duct system sealing, or fuel adjustment are made a complete post test should be performed to verify safe operation of the appliance.

15.1 Typical Readings: Atmospheric Draft Gas Fired Burners



• Efficiency	75-80%
• Oxygen:	5% - 9%
• Carbon Dioxide:	6.5% - 8.0%
• Stack Temp:	350 ºF to 475 ºF
• Draft:	-0.02 “WC to -.04 “WC
• Carbon Monoxide:	< 100 ppm (undiluted)

Always Follow Manufactur tion

Atmospheric draft appliances tend to have higher excess air readings and higher stack temperatures due to less complex heat exchanger designs. Remember there is a positive pressure in the heat exchanger and a negative pressure in the vent connector and stack. A heat exchanger crack in this style furnace will be shown with an increase in excess air readings when the blower starts and a decrease when the blower stops. If the primary air shutters or gas pressure are adjusted, it is imperative that a combustion analysis is performed, as operating characteristics of the furnace have changed. For proper combustion and venting approximately 30 cubic feet of air is required per 1000 BTUH. This means a 100,000 BTUH furnace would require 3000 cubic feet of ventilation for every hour of operation.

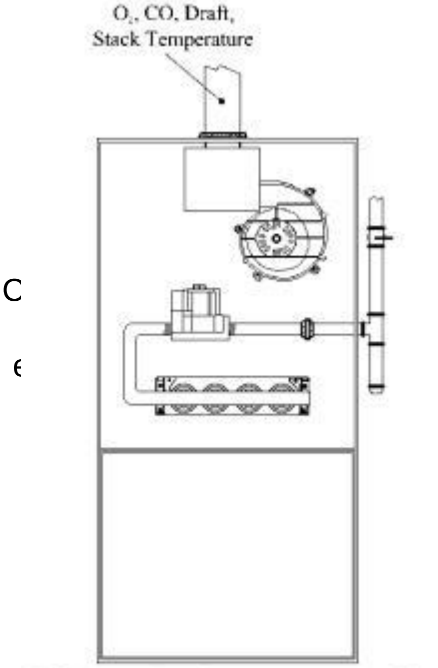
Measurement Procedure

1) Set up the combustion analyzer per manufa
2) Verify combustion analyzer condensate/water trap plug/access is properly sealed, there is no water in the water trap and thermocouple tip is not touching side of probe tube.
3) In uncontaminated air (outdoor) start the analyzer and allow unit to complete zeroing process. Never allow the analyzer to zero in the stack unless the manufacturer's design allows t
4) Measurements **<u>must be made in each cell</u>** of the heat exchanger. If needed a 5/16" hole can be made in the f measurement access.
5) Allow furnace to operate for ten minutes or until stack temperature stabilizes. The furnace must establish draft (measured in the flue pipe) with ten minutes of operation.
6) Measure and print combustion results for each cell in the furnace.
7) Compare results for each cell

15.2 Typical Readings: Draft Induced Gas Fired Burners

Efficiency	80-82%
Oxygen:	7.0% - 9.0%
Carbon Dioxide:	6.5% - 8.0%
Stack Temp:	325 ºF to 450 ºF
Draft:	-0.02“WC to -0.04“WC
Carbon Monoxide:	< 100 ppm (undiluted)

***A**lways Follow Manufacture* ti



80% Fan Assist Furnace/Boiler

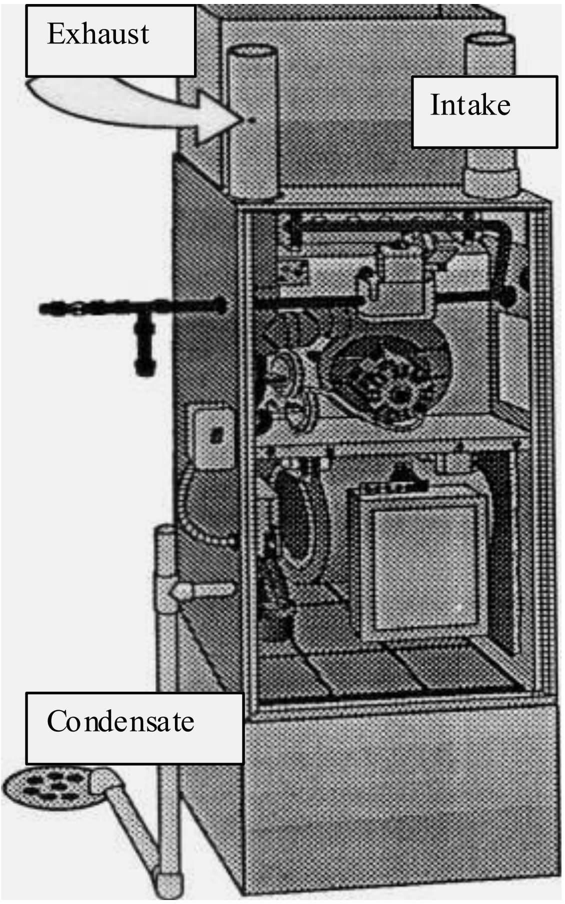
Draft induced appliances have similar operating characteristics to atmospheric draft appliances with the exception of lower flue gas temperatures. The stack draft operates identically, but the heat exchanger pressure is now negative. The function of the draft inducer is to pull combustion byproducts through the heat exchanger, **not** to create a positive pressure in the vent. If the vent pressure is positive the flue pipe is clogged. These furnaces characteristically do not leak flue gas into the house when heat exchanger failure occurs due to the negative heat exchanger pressure. Combustion ventilation air requirements are reduced to 15 cubic feet/1000 BTUH. No dilution air is required for venting other than the excess air required by the appliance manufacturer..

Measurement Procedure

1. Set up the combustion analyzer per manu
2. Verify combustion analyzer condensate/water trap plug/access is properly sealed, there is no water in the water trap and thermocouple tip is not touching side of probe tube.
3. In uncontaminated air (outdoor) start the analyzer and allow unit to complete zeroing process. Never allow the analyzer to zero in the stack unless manufacturer's design allo model 330-2.
4. Measurements must be made in the vent connector or stack.
5. Allow furnace to operate for ten minutes or until stack temperature stabilizes. The furnace must establish draft (measured in the flue pipe) with ten minutes of operation. ***Verify flue gasses are not spilling from the draft hood of the hot water tank if common vented!!***
6. Measure and print combustion results prior to and after making any adjustment to the furnace.

Note: If furnace is multi-stage or modulating, each stage must be checked independently to assure safe operation through the entire operating range.

15.3 Typical Readings: Draft Induced Sealed Combustion Gas Fired Burners 90+



Efficiency	88 - 92%
Oxygen :	5.0% - 7.0%
Carbon Dioxide:	7.0% - 8.5%
Stack Temp :	Less than 120 F
Draft:	+0.10 " WC 24o" W0C.
Carbon Monoxide:	<100 ppm (undiluted)

Always Follow Manuf

Specifications

High efficiency appliances are considerably different in operation. Heat exchanger pressure is negative, vent pressure now becomes positive. Flue gas temperatures drop below 125 F. Often outdoor air is used for combustion, allowing these furnaces to operate without indoor air ventilation requirements. If used with two-pipe configuration the combustion air temperature must be referenced to get an accurate combustion test result. All burner shields and doors must be in place. The high efficiency of these appliances is achieved by removing the latent heat or hidden heat from the flue gasses by condensing the water from the byproducts of combustion. This additional removal of heat through a secondary heat exchanger lowers the flue gas temperature below 125 F. High heat extractions in conjunction with careful control of combustion air allow these furnaces to operate with high combustion efficiencies and very high thermal efficiencies. Combustion air required by these furnaces is reduced to 10 cubic feet/1000 BTUH. Provisions for condensate removal must be made during the installation of condensing type furnaces and boilers.

Measurement Procedure

1. Set up the combustion analyzer per manu
2. Verify combustion analyzer condensate/water trap plug/access is properly sealed, there is no water in the water trap and thermocouple tip is not touching side of probe tube.
3. In uncontaminated air (outdoor) start the analyzer and allow unit to complete zeroing process. Never allow the analyzer to zero in the stack unless manufacturer's -2design allo
4. Measurements must be made in the PVC flue pipe, and temperature of combustion air must be properly referenced in the intake pipe (with an auxiliary temperature probe or other process) to get accurate combustion efficiency results.

5. Allow furnace to operate for ten minutes or until stack temperature stabilizes.
7. Measure and print combustion results prior to and after making any adjustment to the furnace.

Note: If furnace is multi-stage or modulating, each stage must be checked independently to assure safe operation through the entire operating range.

15.4 Typical Readings: Gas Fired Power Burners

Oxygen:	3.0% - 6.0%
Carbon Dioxide:	8.5% - 11.0%
Stack Temp (gross):	320 ºF to 570 ºF
Draft:	-0.02 “WC to -0.04 “WC Over fire
Draft: Positive pressure (Manufacturer’s	
Carbon Monoxide:	<100 ppm (diluted)

Always Follow Manufacturer‘s Specificati

Power burner appliances tend to have lower excess air readings and higher stack temperatures due to less complex heat exchanger designs, although some do approach condensing. Remember there could be a positive pressure in the heat exchanger and a negative pressure in the stack depending on the design. A heat exchanger crack in this style furnace <u>may not show</u> an increase in excess air readings when the blower starts or a decrease when the blower stops. If the primary air shutters/air band or gas pressure is adjusted, it is imperative that a combustion analysis is performed, since operating characteristics of the furnace have changed. For proper combustion and venting approximately 20 cubic feet of air is required per 1000 BTUH. This means a 100,000 BTUH furnace would require 200 cubic feet of ventilation for every hour of operation. Always set gas manifold pressure per manufacturer’s specifi

Measurement Procedure

1. Set up the combustion analyzer per manufacturer’s instru
2. Verify combustion analyzer condensate/water trap plug/access is properly sealed, there is no water in the water trap and thermocouple tip is not touching side of probe tube.
3. In uncontaminated air (outdoor) start the analyzer and allow unit to complete zeroing process. Never allow the analyzer to zero in the stack, unless manufacturer’s-2. design all
4. Measurements must be made in the stack before the barometric damper if equipped.
5. Allow furnace to operate for ten minutes or until stack temperature stabilizes. The furnace must establish draft (measured in the flue pipe) with ten minutes of operation.
6. Measure and print combustion results prior to and after any adjustments are made.

15.5 Typical Readings: Oil Fired Power Burners

Oxygen:	(Cast iron cone)	5.0 –9.0%
Oxygen:	(Flame Retention)	3.0 –6.0%
Carbon Dioxide:		10.0% - 12.5%
Stack Temp : 60 - 79% AFUE		400ºF to 600 ºF
Stack Temp : 80+ AFUE		330ºF to 450 ºF
Stack Temp : 90+ AFUE		less than 125 ºF
Draft:	-0.02“WC Overfire	
Draft (Stack)	-0.02“WC/0.04“WC	
Carbon Monoxide:	< 50 ppm (diluted)	
Smoke spot	#0 to #1	
Oil Pressure	100-150 psi (Per manufacturer)	

Always Follow Manufacturer‘s Specifi

Oil power burner appliances tend to have lower excess air readings and higher stack temperatures, due to less complex heat exchanger designs. Some high and ultra-high efficiency models do approach and operate in condensing mode. Remember these furnaces must operate with a negative pressure in the heat exchanger and a negative pressure in the stack unless otherwise specified by the manufacture. A sizable heat exchanger crack in this style furnace will be indicated by an increase in excess air readings when the blower starts, and a decrease when the blower stops. If the primary air shutters/air band or oil pressure is adjusted, it is imperative that a combustion analysis is performed, since operating characteristics of the furnace have changed. For proper combustion and venting approximately 25 cubic feet of air is required per 1000 BTUH. This means a 100,000 BTUH furnace would require 250 cubic feet of ventilation for every hour of operation.

Measurement Procedure

1. Set up the combustion analyzer per manufa
2. Verify combustion analyzer condensate/water trap plug/access is properly sealed, there is no water in the water trap and thermocouple tip is not touching side of probe tube.
3. In uncontaminated air (outdoor) start the analyzer and allow unit to complete zeroing process. Never allow the analyzer to zero in the stack unless manufacturer's des-2.gn allows this
4. Measurements must be made in the stack before the barometric damper if so equipped.
5. Allow furnace to operate for ten minutes or until stack temperature stabilizes. The furnace must establish draft (measured in the flue pipe) with ten minutes of operation.

16 Understanding Air and Airflow

If the airflow is not set correctly, the system cannot operate as designed!

Airflow is one of the most overlooked yet the most important parts of verifying proper operation of heating and air conditioning systems. Low airflow can cause symptoms like heat exchanger damage, evaporator freezing, low system capacity, poor distribution and high-energy consumption. High airflow can cause symptoms of poor heat transfer, poor humidity removal, higher energy costs, noise, drafts and water/equipment damage due to water droplets blowing from the evaporator coil from excessive air velocity.

To operate with the designed capacity the airflow has to be set to the manufacturer's design criteria. Temperature drop across a heat exc
coil will vary therefore it is imperative to set the airflow to the proper range and not to rely on the temperature drop across the heat exchanger to verify system performance.

The most common and easiest way to verify and set airflow is to use one of the following methods:

1) Rotating Vane Anemometer
2) Pressure drop across the heat exchanger or dry evaporator coil
3) Total external static pressure method
4) Pitot tube and digital manometer
5) Velocity Stick (Hot Wire Anemometer)
6) The temperature rise method (Sensible heat formula)
7) RPM and manufacturers fan curve (Belt or VF Drive)

The airflow must first be set according to the equipment design not to the register delivery. While the design of the duct system is imperative for proper air distribution to the conditioned space, air measurements are only to be measured at the appliance for the equipment commissioning procedure. Due to leakage inherent with all ducting systems, airflow cannot be measured at the registers to verify correct airflow across an evaporator coil or heat exchanger. If the system will not heat or cool the home after the airflow is properly set at the appliance and the equipment operation is verified to be correct, the problem is not with the operation of the equipment. The ducting system should then be evaluated for excessive leakage, proper sizing and proper design. A review of the load calculations may be required to verify the equipment selection was correct if the system still will not perform properly. *Do not adjust the airflow to change system-operating characteristics like air noise or low register airflow or decreased capacity and or system damage could result.*

Approximately 50 CFM per ton is lost due to leakage from poorly sealed duct systems.

When making any air flow/quantity measurements for cooling or heating all dampers must be in their normal operating position, all equipment panels and doors must be in place. Many manufacturers have a removable base pan for bottom return. If a side return is used, make sure the bottom return is properly sealed, the return airdrop is securely fastened, and a proper sealant, (like Mastic®) is used to seal the connections. A digital manometer can be used to check for pressure differential between the bottom side of the base pan and the surrounding air. The fan must be operating using the speed that will be operating when the heating is in operation. The condensing unit should not be in operation during the measurement process, as moisture that will accumulate on the evaporator coil will significantly affect the pressure differential readings. It is usually easiest to pull the service disconnect for the condensing unit, locking out the condenser.

Rotating Vane Anemometer

For highly accurate quick measurement the rotating vane anemometer is the best way to measure airflow. Vane anemometers have several advantages over any other method. The primary advantages are speed, accuracy, and ease of use. Vane anemometers do not require air density compensation due to air temperature, humidity, or atmospheric pressure. The mini vane allows for a full duct traverse with an automatic calculation of the CFM in the duct if the dimensions are input into the instrument before the measurement is taken. It is imperative that the ducting attached to the appliance, and the base pan, if side returned is used, is sealed. Air leaks up-stream of where the measurements are made will significantly alter the actual reading obtained with this method. If done carefully the measurement error will be less than 3%. Changes in yaw and pitch of the probe head in the duct as much as 10% will result less than 1% error in the measurement making the mini-vane an ideal probe for field air measurement.

Pressure drop across the dry evaporator coil

An easy way to quickly verify airflow is to measure the static pressure drop across the evaporator coil, and compare the reading to that specific evaporator coil in the manufacturer's literature. With a digital manom
close airflow can be set across a dry coil in a matter of minutes. The positive probe should be inserted ahead of the air entering the coil and the negative probe immediately downstream of the coil. The reading obtained will be the pressure drop in inches of water column or Pascal. While this measurement is accurate enough for setting up equipment, it is not accurate enough to make a field measurement of the system capacity.

Total external static pressure method

The total external pressure method is preformed in the same manner by measuring the pressure difference across the furnace (supply
chart. The CFM can also be set quickly and accurately using this method, but again, the measurement process is not precise enough to use for verification of the system capacity.

Pitot tube and digital manometer

While very time consuming, if the return airdrop is tall and straight enough, the airflow can also be very accurately verified into the appliance using a Pitot tube and a digital manometer. By traversing the duct, (making several pressure measurements in predefined locations) and performing a couple of simple calculations to convert velocity pressure to speed in feet per minute, the air flow is then determined by multiplying the average air velocity by the cross sectional area of the duct to obtain CFM. It is imperative that the ducting attached to the appliance, and the base pan, if side returned is used, is sealed. Air leaks up-stream of where the measurements are made will significantly alter the actual reading obtained with this method.

Velocity Stick (Hot Wire Anemometer)

A hot wire anemometer can also be used in the return air duct to verify flow. With method, (Pitot tube or anemometer), it is important to carefully traverse the duct in order to get accurate results. Until the development of the mini-vane anemometer, the Pitot tube and velocity stick were the most precise field measurement of airflow in a duct. Both however are sensitive to changes in air density outside of standard air conditions. If done carefully most technicians can achieve accuracy within 5%.

The temperature rise method (Sensible heat formula)

The temperature rise method is a last resort, and may be used for fossil fuel and electric furnaces. Because the heat content of natural gas varies from day to day and hour to hour, the temperature rise method should only be used to get the airflow close to the manufactures recommended, and can not be used for system capacity verification.

To verify CFM in a natural gas furnace, let the furnace run for ten minutes or until the stack temperature stabilizes, allowing the appliance to reach steady state efficiency. Using a combustion analyzer determine the steady state operating efficiency of the appliance and multiply it times the BTUH input to get the output BTUH of the furnace. *(Remember, if the heat is not going up the stack, it is going into the house.)*

If a combustion analyzer is not available, alterna could be used to determine the output BTUh of the furnace provided the manifold pressure is correct set and the BTU content of the fuel used is consistent. (The manufacturer's tag is a good place to look for this.)

CAUTION: <u>Do not use</u> *efficiency information from the yellow energy guide label, as this is AFUE, (Annual Fuel Utilization Efficiency) and takes into account the efficiency losses at start-up of the equipment.*

Second measure the temperature rise across the heat exchanger. It is important to be out of the line of sight of the heat exchanger when making these measurements as the temperature probe can be affected by radiant heat from the heat exchanger. If the furnace has a bypass humidifier, make sure the bypass is closed. Then enter your results into the sensible heat formula (shown below). This is an approximate method as the heat content of natural gas varies across the United States and even from the same meter from hour to hour, and there is additional heat added from the blower motor. Heat added by the motor can be as much as 300 watts or 1024 Btu.

NATURAL GAS/LIQUEFIED PETROLEUM (PROPANE)

CFM = (Input BTU x steady state efficiency) / (1.08 x delta T)

Delta T is the temperature rise across the heat exchanger in degrees Fahrenheit

This will give you an approximate CFM; although it will be very close to the actual if the measurements are made accurately and the heat content of the natural gas is near 1000 BTU/cf (BTUs per cubic foot of gas)..

ELECTRIC HEAT

For an electric furnace the procedure is the same. Allow the appliance to operate until the temperature rise stabilizes. Measure the temperature rise again out of the line of sight of the electric heater, along with the incoming volts and current draw in amps to the electric strip heaters. Enter the information into the following formula.

CFM = (Volts x Amps x 3.41) / (1.08 x deltaT)

FUEL OIL

For fuel oil the procedure involves verifying the nozzle size and the correct fuel pressure. After the Nozzle size in GPM (gallons per minute) is known and fuel pressure set, the combustion efficiency must be measured with a stable stack temperature, and the temperature rise across the heat exchanger recorded.

CFM = ((Btu/gal oil) x (Nozzle size GPM) x (combustion efficiency)) / (1.08 x deltaT)

For fuels other than those listed above see the chart in Section 19. For residential applications the standard values will be sufficient as small changes in the heat quantity of fuel will have a very small impact on final calculations.

17 BTU Content of Fuels

Since the actual heat content of different types of fuels varies, the approximate average values are often used. The table below provides a list of typical heating fuels and the BTU content in the units that they are typically sold in the United States. The figures below are general references for residential heating applications only. Commercial and industrial users should obtain more precise values from their fuel vendors.

Table 1: Average Btu Content of Fuels

Fuel Type	No. of Btu/Unit
Fuel Oil (No. 2)	140,000 per gallon
Electricity	3,412 per kWh
Natural Gas	1,027 per cubic foot
Propane	91,330 per gallon 2500 per cubic foot
Wood (air dried)*	20,000,000 per cord or 8,000 per pound
Pellets (for pellet stoves; premium)	16,500,000 per ton
Kerosene	135,000 per gallon
Coal	28,000,000 per ton

From U.S. Department Energy

18 Sample form: Heat Exchanger / Venting / Combustion Problem

(COMPANY NAME HERE)

Heat Exchanger / Venting / Combustion Problem

While inspecting your furnace performing the three-part inspection procedure as outlined in Refrigeration Service and Engineering Society publication 630-92 9/86, and adopted by the Gas Appliance Manufacturers Association, and or during venting/combustion air testing outlined in the National Fuel and Gas Code, we found the following:

1. ______ The heat exchanger has a visible crack, hole, or opening that may allow the flue gasses to enter the home.

2. ______ Testing of your heat exchanger using the salt spray test (Chemical Test) gave a positive result. This indicates that the flue gasses may be entering the home through a crack, hole, or opening that is not visible to the eye.

3. ______ There is a venting or combustion air problem

Any breach in the heat exchanger or a venting/combustion air problem may allow the flue gasses to enter the home creating a potentially dangerous situation for the homeowner.

We highly recommend that you allow us to turn off the furnace until this problem can be corrected.

If you wish to continue operation of the above cited appliance, please read and sign the statement below:

> *I understand that by operating this appliance without correcting the problem, I assume full responsibility for any harm or damage that may result from my decision. I will not hold* <u>*COMPANY NAME*</u> *its heirs, or any of its employees liable for my decision.*

Customer Name: ____________________________ Date: _________________

Customer Signature: __________________PRINTED_____________________

Technician Signature: _________________PRINTED_____________________

Date_____________
Technician_________________

Gas Furnace Inspection Procedures: Information contained in this check sheet follows a specific set of instructions outlined in: **Servicing Gas Appliances Applications Guide And Gas Heating Reference Guide for the Advanced Technician.**

Information contained is only for use by formally trained competent technicians practicing within the HVAC/R community. The manufactures' installation, operation, and service information should always be consulted, and should be considered the first and best reference for installing, commissioning and servicing equipment. The publisher/Testo assumes no liability for typographical errors or omissions of information contained herein.

Unit completed full operating cycle? Y ☐ N ☐
Combustion Ventilation Air Test Pass / Fail
Furnace ☐ **60%** ☐ **70%** ☐ **80%** ☐ **90 %**

Venting
Vent proper size Y ☐ N ☐
Correct vent pitch Y ☐ N ☐
Blockages/restrictions Y ☐ N ☐
Corrosion/pin holes Y ☐ N ☐
Condition of liner Good ☐ Poor ☐
Number of elbows __________
Established draft within 5 minutes Y ☐ N ☐

3 Part Heat Exchanger Test
Type__________________

Visual Inspection ***Pass / Fail***
Blower Test ***Pass / Fail***
Chemical Test ***Pass / Fail***

Thermostat
Type____________________
Model #_____________________
Location_________________
Anticipator Setting_________
Level Y ☐ N ☐

Filter Size________________
Good ☐ Poor ☐ Replaced ☐ Perm ☐
Filter door in place

Blower
Voltage_____ Amps_______
Clean ☐
Aligned ☐
Bearings Good ☐ Poor ☐
Belt Good ☐ Poor ☐

Wiring
Breaker Size___________A
Good ☐ Loose connections ☐
Service Switch Y ☐ N ☐
Polarity Correct Y ☐ N ☐
Properly Grounded Y ☐ N ☐
Proper Wire Sizes Y ☐ N ☐
Door Switch Good Y ☐ N ☐
Incoming Volts________V
Amps________A

Burner Compartment
Btu input____________
Burners clean Y ☐ N ☐
Carry over clean Y ☐ N ☐
Incoming Pressure________"WC
Manifold Pressure________"WC
Pilot Clean Y ☐ N ☐
Flame Rod µ amps_________
T-couple/PP MV_________

Operation
Temperature Rise Range _____ to ______
Actual Temperature Rise __________
Measured Heating CFM___________
Calculated Btuh Output__________
Total External Static Pressure___________"wc
Supply Static _________"wc
Return Static__________ "wc

Limit Circuit
High Limit C/O______°F_____°F
Actual C/O________°F C/I_____°F
Pressure Switch C/O_______"WC
Actual C/O________"WC
Auxiliary Pressure Switch G ☐ P ☐
Spill Switch G ☐ P ☐ C/O ____Min
Roll Out Switch s G☐ P ☐

Combustion Analysis
Ambient CO __________
Stack CO ___________
Combustion air temperature__________
CO_2 _____
O_2_______
Excess Air_______%
Stack Temperature ________°F
Combustion Efficiency _______%
Draft _______"wc

NOTES:

REQUIRED CORRECTIONS

Combustion /Ventilation Air:

Venting:

Thermostat:

Filter:

Blower:

Wiring:

Limit circuit:

Burner Compartment:

Combustion Analysis:

Operating:

Heat Exchanger:

Manufacturer____
Unit M/N ____
Unit Serial Number _____________________________________

22 REFERENCES

BPI (Building Performance Institute)
107 Hermes Road, Suite 110
Malta, New York 12020
PHONE: 877-274-1274 : 518-899-2727
FAX: 866-777-1274 : 518-899-1622
www.bpi.org

GAMA-An Association of Appliance & Equipment Manufacturers
2107 Wilson Boulevard, Suite 600
Arlington, VA 22201
Telephone: (703) 525-7060
Fax: (703) 525-6790
www.gamanet.org
info@gamanet.org

ASHRAE
American Society of Heating Refrigerating and Air Conditioning Engineers
1791 Tullie Circle, N.E.
Atlanta, GA 30329
Telephone: (800) 527-4723
Fax: (404) 321-5478
Web: www.ashrae.org
Email: ashrae@ashrae.org

ANSI
American National Standards Institute
1819 L Street, NW
Suite 600
Washington, DC 20036
Telephone: (202) 293-8020
Fax: (202) 293-9287
Web: Www.ansi.org
Email: info@ansi.org

RSES
Refrigeration Service Engineers Society
1666 Rand Road
Des Plaines, IL, 60016-3552
Telephone: 800-297-5660
Web: www.rses.org
Email: info@rses.org

International Fuel Gas Code
American Gas Association
200 North Capitol Street, NW
Suite 200
Washington, DC 20001
Telephone: (202) 824-7000
Web: www.aga.org
Email: jranfone@aga.org