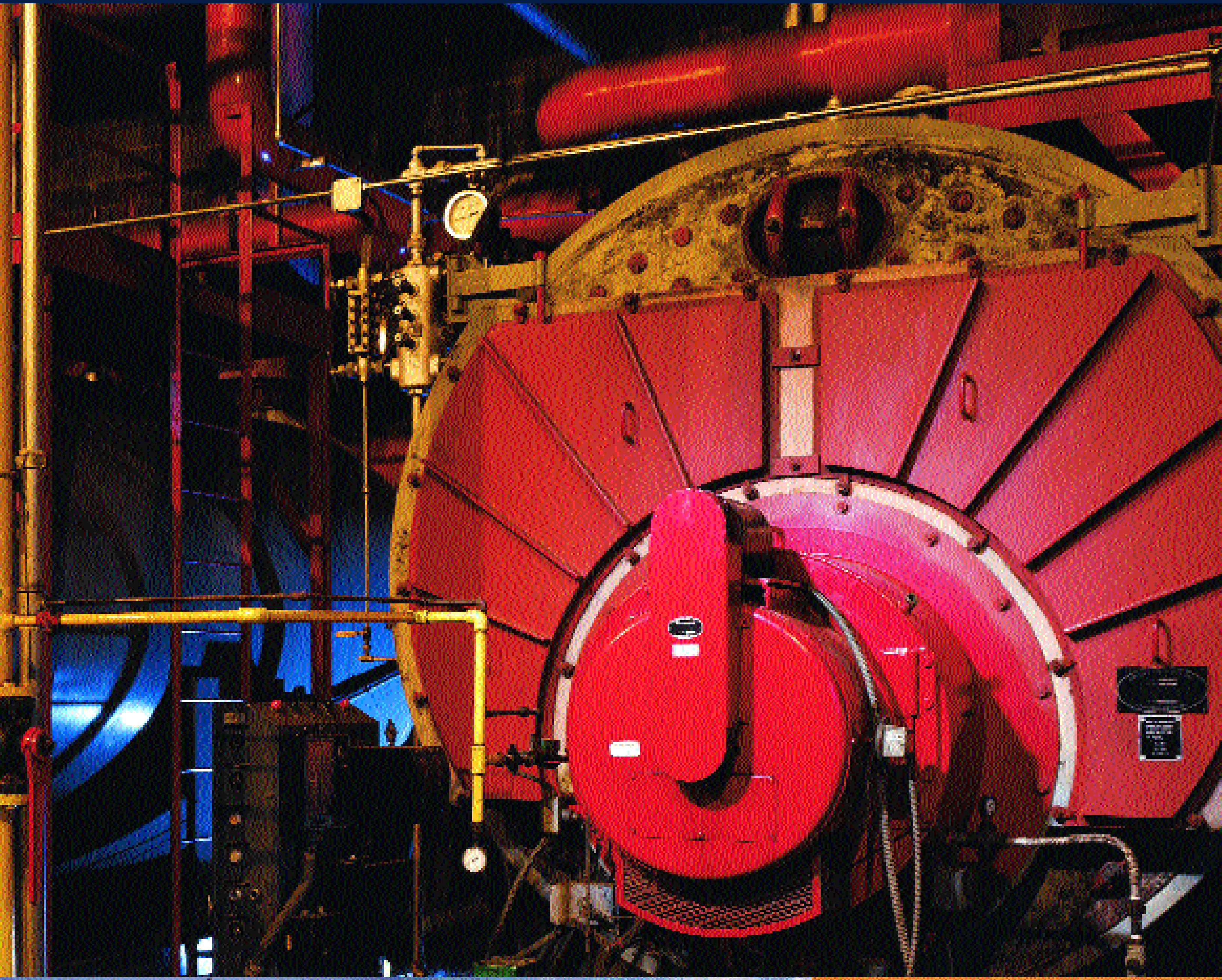
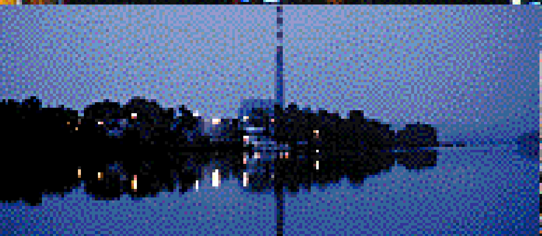
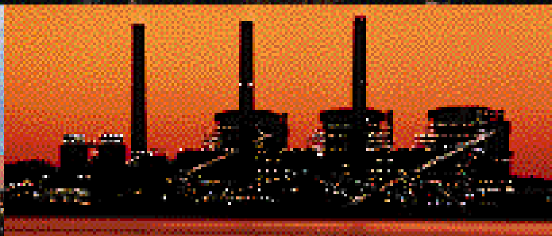
BACHARACH®

The Measurable Difference

COMBUSTION EFFICIENCY • COMBUSTION SAFETY • ENVIRONMENTAL MEASUREMENTS







Since the 1930's, Bacharach has been the global leader in the manufacture of portable combustion testing analyzers and environmental monitors. Beginning with the introduction of our low cost CO_2 Fyrite® Indicator Kit in 1935, Bacharach engineers have pioneered the state of the art combustion instrumentation. With over 90 years of instrumentation manufacturing and applications experience, Bacharach continues to develop the most comprehensive, accurate and easy to use combustion and environmental testing instrumentation available. Our dedication to providing high quality instrumentation, backed up by the best customer support and service departments in the industry, has never been greater. Our worldwide distribution, repair, and service network has allowed Bacharach to maintain our leadership position in combustion analysis for over six decades. Our commitment to the research, design and engineering of new, leading edge combustion and environmental instrumentation will allow us to maintain our leadership position well into the 21st century.

BACHARACH. THE MEASURABLE DIFFERENCE.

MONOXOR® II
Hand-held CO Analyzer

On board electronics quickly and accurately measure and display ppm levels of CO in stack gas and room air. Also available in a family of toxic and oxygen analyzers: NO_X, SO_2, CO and oxygen.

FYRITE® PRO
Combustion Analyzer

An all-in-one instrument providing quick and accurate information to conduct a combustion test on residential combustion appliances.

PCA®
Portable Combustion Analyzer

Fast, accurate and easy CO safety and efficiency test in a rugged and reliable electronic instrument.

MODEL 300 NSX
Combustion & Environmental Analyzer

Long a standard in the industry for electronic measurement of combustion efficiency, the Model 300 now also measures, displays, and outputs ppm NO_X and ppm SO_2.

LEAKATOR® 10
Leak Detector

Inexpensive instrument to quickly and easily locate a variety of gas leaks.

SNIFIT® 50
Hand-held CO_2 Analyzer

Hand-held digital CO analyzer, electronically measures CO in room air. Also Snifit 40 is available to be used in conjunction with digital multimeter.

TABLE OF CONTENTS

Bacharach has been providing advanced combustion analysis equipment and technical support to engineers, HVAC contractors, and boiler maintenance specialists around the world for over ninety years. To be sure that we are providing our customers with the tools that they need, we talk to our customers, we listen to our customers, and we ask questions.

In the past only two important questions needed to be answered: *Can I get better fuel efficiency? and Is the equipment operating safely?*

Today, you are faced with more complex questions than ever before, with a new question at the top of the list: *Will my combustion equipment meet environmental regulations?*

There is no doubt that environmental legislation has changed the way we all must evaluate combustion efficiency and safety. As the leading manufacturer of electronic and mechanical combustion testing instrumentation, Bacharach has developed this catalog to help you to answer many of the demanding technical questions which you face every day.

The questions answered here are the questions that we have received from professionals like yourself. The charts and graphs have been designed to make your job easier. We have attempted to answer every question as thoroughly and clearly as possible. If you have further questions about how Bacharach can help you to maintain efficient, safe, environmentally sound combustion equipment operations, please call Bacharach at 412-963-2000 or send e-mail to: help@bacharach-inc.com.

COMBUSTION ANALYSIS

CA-1 What is combustion?

Combustion is the act or process of burning. For combustion to occur, fuel, oxygen (air) and heat must be present together.

CA-2 What is combustion efficiency?

Combustion efficiency is the calculation/measurement, in percentage, of how well your equipment is burning a specific fuel. Complete combustion efficiency (100%) would extract all the energy available in the fuel. However, 100% combustion efficiency is not realistically achievable. Various combustion processes produce combustion efficiencies from 0% to 95+%.

Combustion efficiency calculations assume complete fuel combustion and are based on three factors:

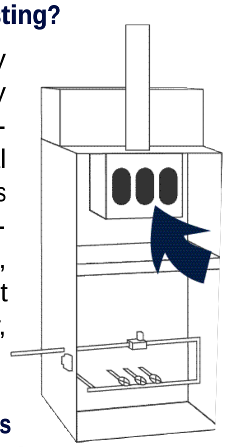
1. The chemistry of the fuel.
2. The net temperature of the stack gases.
3. The percentage of oxygen or CO_2 by volume after combustion.

If your calculation shows that your equipment is losing 25% of the heating value of the fuel through stack losses, your equipment is running at 75% efficiency.

Chart 1

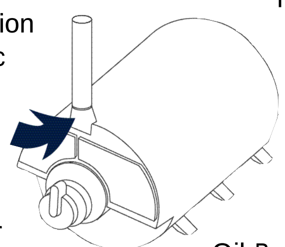
COMBUSTION PROCESSES AND THEIR COMBUSTION EFFICIENCY RANGES	
Process	Typical Combustion Efficiency Range
Home Fireplace	10-30%
Space Heater	50-82%
Commercial Gas Boiler	70-82%
Residential Gas Furnace with Atmospheric Burner “low efficiency”	70-82%
Oil Burner Heating System	73-85%
Induced Draft Furnace “Medium Efficiency”	74-82%
Boiler with Gas Powered Burner	75-83%
Condensing Furnace (gas & oil) “High Efficiency”	85-93%

CA-3 I’ve always just eyeballed the flame. Is it really important to do combustion testing?



Looking at the flame color, shape and stability has been used as a “rule of thumb” for many years but eyeballing will not allow you to optimize the efficiency, safety, or environmental compliance of your equipment. Just as doctors make use of the most sophisticated instrumentation possible when diagnosing their patients, the best way to make sure that your equipment is operating safely, and at maximum efficiency, is by using combustion instrumentation.

CA-4 Are traditional instruments just as good as continuous sampling electronic instruments?



Traditional instruments will give you information that is comparable in accuracy to electronic instrumentation, but electronic instruments have several advantages that can be very important.

For example, many electronic instruments monitor on a continuous basis, like a movie or video camera. Traditional instruments are more like a still camera that takes only one picture at a time. With traditional instrumentation (the still camera), you might miss the most important picture because your camera is only capable of taking one picture at a time.

Because most electronic instruments sample on a continuous basis, like a video camera, you can see all the information that will help you to evaluate the operating condition of your equipment.

Electronic instruments will also do sampling and efficiency calculations rapidly and automatically. Some models will print out complete reports of test results or transfer the stored data to a computer while adding time and date information of the data collected.

CA-5 What do I have to do to measure for combustion efficiency?

You only need to measure gas concentration (oxygen or carbon dioxide) and temperature to determine combustion efficiency.

Although other gases (NO_X, CO, SO_2) do not significantly effect combustion efficiency, these gases are an important safety and environmental concern.

CA-6 Where should I take my sample?

The measurement for gases and temperature should be taken at the same point. Make sure that the sample point is before any draft diverters and barometric damper so the gases are not diluted and the temperature has not been decreased by outside air. A proper sampling location for a residential gas furnace would be inside the heat exchanger tubes.

For residential and light commercial or industrial equipment, use the following guidelines:

Oil Burners - Locate the sampling hole at least six inches upstream from the furnace side of the draft regulator and as close to the furnace breaching as possible.

Gas Burners - Locate the sampling hole at least six inches upstream from the furnace side of the draft diverter or hood, and as close to the furnace breaching as possible.

For Larger Equipment - Locate the sampling point downstream from, and as close as is practically possible to, the last heat exchange device (economizer, recuperator, or similar device). This will insure that the net temperature will provide an accurate indication of the effectiveness of the exchangers.

CA-7 I know that O_2, CO, CO_2, temperature and smoke can tell me a lot about combustion. How do they all relate to efficiency?

Theoretically, peak fuel efficiency is achieved by "perfect" combustion, also called the Stoichiometric Mix (see charts #2 and #3).

If it were possible to have perfect combustion, CO_2 would be maximized and O_2 would be at, or close to, zero in the flue gas stream. Because perfect combustion is not practically possible, most combustion equipment is set up to have a small percentage of excess O_2 present. The lower the temperature for a given O_2 or CO_2 reading, the higher is your combustion efficiency. This is because less heat is lost up the stack.

In a Stoichiometric Mix, all the fuel and oxygen (O_2) present combines to generate only heat, water and carbon dioxide (CO_2).

Smoke is the usual indicator of incomplete combustion in oil burners. In addition to indicating poor combustion, smoke can deposit soot on your heat exchangers which will further reduce fuel efficiency; and smoke coming out of the stack can be cause for air quality violation.

To give you a graphic illustration of how dramatically smoke and soot can effect fuel combustion efficiency, we have included chart #4. We have also included a common fuel characteristics chart (chart #5) for several of the common fuels used in combustion equipment.

CA-8 Is measuring draft important?

Draft measurement is important because draft controls how rapidly the gases (O_2, CO, CO_2 - and even fuel) pass through the furnace and boiler.

Chart 2

THEORETICAL AIR CURVE/FUEL OIL

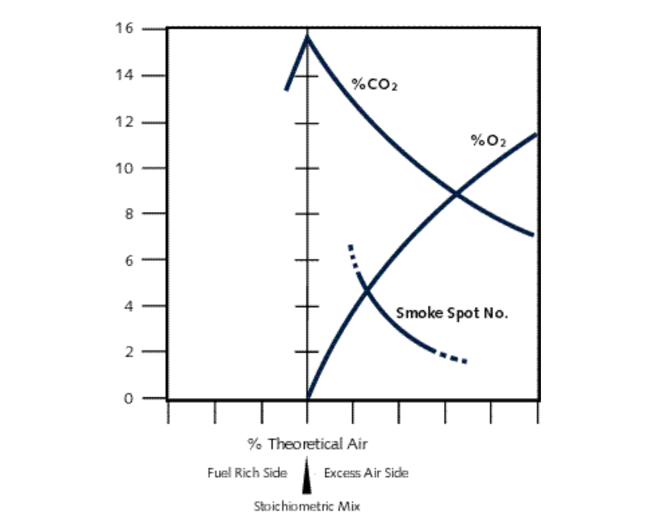


Chart 4

EFFECT OF SOOT ON FUEL CONSUMPTION

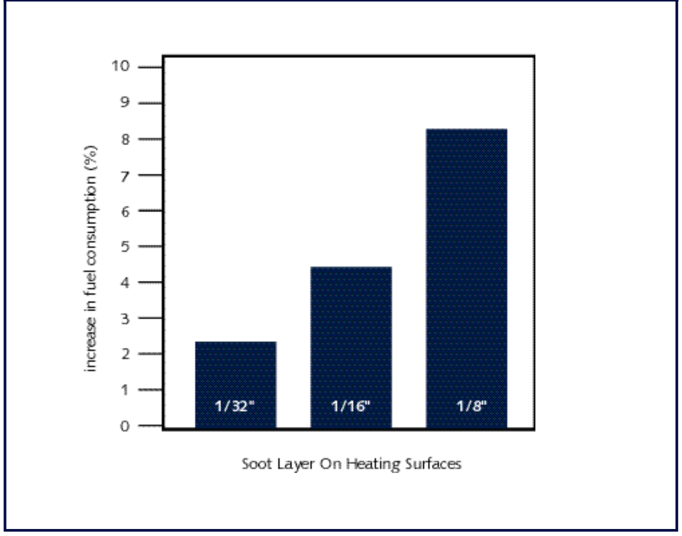


Chart 3

THEORETICAL AIR CURVE/NATURAL GAS

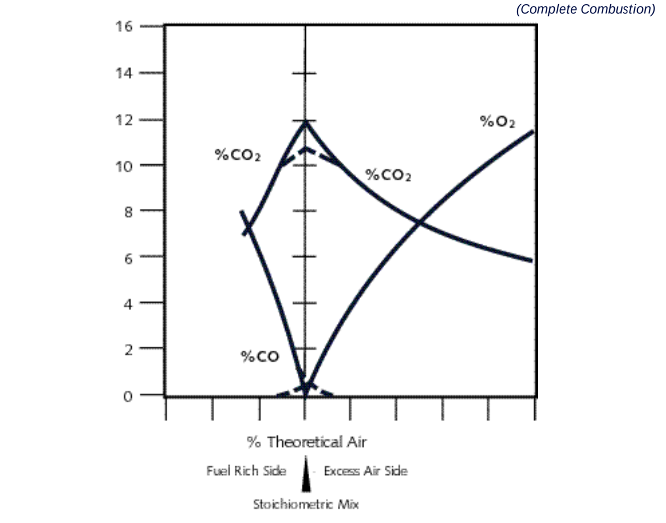


Chart 5

COMMON FUEL CHARACTERISTICS

	Higher Heating Value	Carbon	Hydrogen	Ultimate	Moisture
NATURAL GAS	21,830 BTU/lb.	69.4%	22.5%	11.7%	-
KEROSENE	19,942 BTU/lb. 137,000 BTU/gal.	86.5%	13.2%	15.12%	-
PROPANE	21,573 BTU/lb.	81.6%	18.4%	13.8%	-
FUEL OIL NO.2	18,993 BTU/lb. 137,080 BTU/gal.	87.3%	12.5%	15.7%	-
FUEL OIL NO.6	18,126 BTU/lb. 153,120 BTU/gal.	88.5%	9.3%	16.7%	-
ANTHRACITE COAL	12,680 BTU/lb.	80.6%	2.4%	19.9%	-
BITUMINOUS COAL	14,030 BTU/lb.	80.1%	5.0%	18.5%	-
BAGASSE	8,200 BTU/lb.	45.0%	6.4%	20.3%	50.0%
WOOD (10%moisture)	8,800 BTU/lb.	50.0%	6.5%	20.0%	10.0%

Typical draft overfire measurements* (0.02 inches H_2O) and flue draft measurements** (0.04 to 0.06 inches H_2O) insure that there is continuous negative pressure in the combustion system. Excess draft will increase your stack temperature and decrease your combustion efficiency.

It is important to measure draft on the chimney side, well downstream from a draft diverter. This measurement will tell you if there is sufficient draft to move the flue gases up the chimney and vent them to the outside air.

CA-9 Will frequent testing increase my fuel savings?

The most basic and simplest way to save fuel is by adjusting the combustion process to obtain optimum combustion efficiency. Improving combustion efficiency will ultimately save on fuel. Every situation is different, but frequent testing to improve combustion efficiency will maintain fuel efficiency.

Additionally, frequent testing will give you a "running history" of the maximum operating capability of each piece of combustion equipment that you test. By using this history to establish a benchmark, you can maintain your equipment at peak efficiency.

Although some combustion experts test on a weekly basis, many other experts test only three or four times per year. Annual testing is the minimum acceptable level of testing that must be done on small furnaces.

CA-10 As my combustion efficiency improves, how do I calculate my fuel savings?

First you have to determine the change in efficiency with instrumentation. Then you can use chart #6 to calculate your fuel savings.

CA-11 How much does temperature and CO_2 affect efficiency?

A decrease in stack temperature of 40°F (20°C) will result in increased combustion efficiency of 1-2%. An increase of 1% in CO_2 will increase combustion efficiency by 1/2% to 1%.

CA-12 What should my O_2, CO_2 and CO be on the common fuels?

Chart #7 (pg. 5) will give you a guideline for common fuels and percentage of gas, but you should also check the manufacturer's recommendations for excess air. Carbon Monoxide (CO) should always be minimized.

CA-13 How do I run a combustion test on a high efficiency furnace?

Testing of a high efficiency furnace is not much different from the testing of a natural draft furnace. The biggest differences are the sampling points (see chart #7, pg. 5) and the need to be able to calculate higher efficiencies: up to 99.9%.

CA-14 Is is important to measure smoke in oil fired furnaces?

Yes, because smoke is a primary sign of incomplete combustion and fouling, it is very important. Using an authentic smoke spot testing instrument will determine oil burner condition and operating efficiency and safety (see chart #8, pg. 5). However, smoke spot testing of modern oil burning equipment may not indicate the presence of CO. Because smoke and CO may coexist, or exist independently, and both affect combustion efficiency, both smoke and CO tests are necessary.

Chart 6

SAVINGS FOR EVERY $100 FUEL COSTS BY INCREASE OF COMBUSTION EFFICIENCY

Assuming constant radiation and other unaccounted-for losses

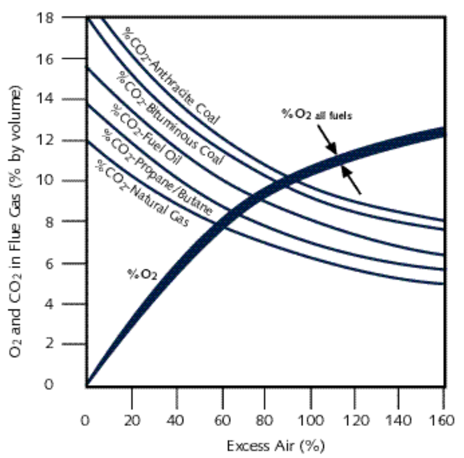
From an original efficiency of…	To an increased combustion efficiency of… 55%	60%	65%	70%	75%	80%	85%	90%	95%
50%	$9.10	$16.10	$23.10	$28.60	$33.30	$37.50	$41.20	$44.40	$47.40
55%	-	8.30	15.40	21.50	26.70	31.20	35.30	38.90	42.10
60%	-	-	7.70	14.30	20.00	25.00	29.40	33.30	37.80
65%	-	-	-	7.10	13.30	18.80	23.50	27.80	31.60
70%	-	-	-	-	6.70	12.50	17.60	22.20	26.30
75%	-	-	-	-	-	6.30	11.80	16.70	21.10
80%	-	-	-	-	-	-	5.90	11.10	15.80
85%	-	-	-	-	-	-	-	5.60	10.50
90%	-	-	-	-	-	-	-	-	5.30

* Always be sure to follow manufacturer's recommendations.

** 1 inch H_2O = 2.5 hla

Chart 7

RELATIONSHIP BETWEEN O_2, CO_2 AND EXCESS AIR



CA-15 In an oil fired furnace, when do I measure smoke?

Smoke is best measured when the burners have stabilized, normally one minute after ignition for small combustion equipment.

CA-16 Can oil furnaces and boilers produce CO?

Oil burners, and any other piece of combustion equipment, will produce CO (carbon monoxide) when there is not sufficient mixing of O_2 and fuel for complete combustion.

COMBUSTION SAFETY

CS-1 What is Carbon Monoxide (CO) and where is it found?

Carbon Monoxide (CO) is a highly toxic, lighter than air gas which is most often found in an area surrounding a combustion source (a furnace, boiler or space heater) where there is insufficient oxygen to allow for complete combustion of the fuel in use.

Carbon Monoxide is very dangerous because it is colorless, odorless, tasteless, and non-irritating. It is virtually impossible to detect Carbon Monoxide without a testing instrument.

Carbon Monoxide is also flammable and burns in air with a bright blue flame.

CS-2 How dangerous is Carbon Monoxide?

Carbon Monoxide is very dangerous: over 800 people die each year from CO poisoning in the United States.

Most of us know that high levels of CO are harmful. What is less well known is that CO is a cumulative poison. CO can slowly build up in the bloodstream. In the bloodstream CO combines with blood hemoglobin and replaces the oxygen in the bloodstream until there is too little oxygen in the bloodstream to support life.

Some of the danger signs of CO poisoning are: headaches, dizziness, tiredness, and nausea. Frequently, CO poisoning is confused with other diseases because the symptoms are similar to flu or the common cold.

Death from CO poisoning can happen suddenly. Victims of CO poisoning are overcome and helpless before they realize that any danger exists.

We have included a chart which illustrates the effects of CO at various PPM and hours of exposure (chart #9).

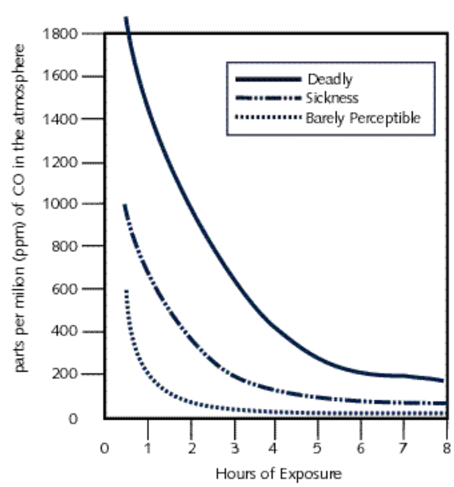
Chart 8

BURNER PERFORMANCE

Smoke Scale Reading	
1	**Excellent** – Little, if any, sooting of furnace or boiler surfaces.
2	**Good** – May be slight sooting with some types of furnace or boiler but little increase in flue gas temperature.
3	**Fair** – Substantial sooting with some types of furnace or boiler and require cleaning more than once a year on most types of furnace or boiler.
4	**Poor** – This is a borderline smoke-some units may soot only moderately, others may soot rapidly.
5	**Very Poor** – Heavy sooting in all cases- may require cleaning several times during the season.
6	**Extremely Poor** – Severe and rapid sooting-may result in damage to stack control and reduce overfire draft to danger point.

Chart 9

EFFECTS OF CARBON MONOXIDE



CS-3 How can I prevent Carbon Monoxide poisoning?

The best way to prevent Carbon Monoxide poisoning is to make sure that your combustion equipment is functioning properly. Combustion air openings (vents, flues, exhausts and ducts) must be kept open, clean and free of blockages such as dirt, dust, lint and trash.

Never obstruct a draft hood, wind cap or exhaust vent on any combustion appliance. Don't store anything against or near the equipment that could restrict the air flow.

In a private home or apartment, a roaring fireplace is always nice on a cold day. But when combined with a marginal air flow to the furnace room, the fireplace might draw enough air to starve the furnace, producing a potentially hazardous backdraft of Carbon Monoxide in the living areas.

The best way to prevent CO poisoning is to be constantly aware that CO is a deadly gas: testing is the only way to detect its presence.

CS-4 What are the best ways to test for Carbon Monoxide?

Because CO is colorless, tasteless, odorless and non-irritating, the only way to detect its presence is to use a testing device or instrument.

Electrochemical sensors make detection much faster and easier and allow you to find fluctuating CO levels which would be difficult or impossible to measure any other way: changes as small as 1 ppm can be detected.

There are two types of chemical stain length tubes that may be used. Indicating tubes give you a go/no go reading and detect a wide range of CO concentrations. Detector tubes allow you to make more accurate and refined measurements which give you concentration measurement in the 0-5,000 ppm range.

CS-5 If I do find dangerous levels of Carbon Monoxide, how do I get rid of it?

If the level of CO is dangerous, evacuate the area immediately and provide as much ventilation of fresh air as possible to the area where the CO is concentrated.

After determining, with instrumentation, that the CO level has been reduced to a safe level, use your instrumentation to find the source of the CO and correct the conditions which caused the CO formation. (Some local codes may require that you immediately shut down the equipment and notify the owner/operator).

CS-6 What are the federal safety standards for Carbon Monoxide?

The Occupational Safety and Health Administration (OSHA) has set a maximum limit of 50 ppm for eight hours exposure in the workplace. In some states this limit may be lower.

The Environmental Protection Agency (EPA) and the American Gas Association (AGA) have set a maximum allowable of 400 ppm (on a CO air free basis) in flue gas.

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) recommends 9 ppm as the maximum acceptable level of CO in a residential setting (ASHRAE Ventilation Standard 62-89).

CS-7 Why is a cracked heat exchanger dangerous?

In a warm air furnace, a cracked heat exchanger can cause a build-up of toxic gases, including CO, which would be distributed by the blower into the living or working area causing sickness or death.

Chart 10

CO CONCENTRATIONS & SYMPTOMS DEVELOPED

Concentrations of CO in the air	Inhalation time and toxic symptoms developed
9 ppm (0.0009%)	The maximum allowable concentration for short term exposure in a living area, according to ASHRAE.
50 ppm (0.0050%)	The maximum allowable concentration for continuous exposure in any 8-hour period, according to federal law
200 ppm (0.02%)	Slight headache, tiredness, dizziness, nausea after 2-3 hours
400 ppm (0.04%)	Frontal headaches within 1-2 hours, life-threatening after 3 hours, also maximum parts per million in flue gas (on an air free basis), according to EPA and AGA
800 ppm (0.08%)	Dizziness, nausea and convulsions within 45 minutes. Unconsciousness within 2 hours. Death within 2-3 hours.
1,600 ppm (0.16%)	Headache, dizziness and nausea within 20 minutes. Death within 1 hour.
3,200 ppm (0.32%)	Headache, dizziness and nausea within 5-10 minutes. Death within 30 minutes.
6,400 ppm (0.64%)	Headache, dizziness and nausea within 1-2 minutes. Death within 10-15 minutes.
12,800 ppm (1.28%)	Death within 1-3 minutes.

CS-8 How do I check for a cracked heat exchanger?

Visual inspection of the heat exchanger should always be done first. It may not be possible with visual inspection alone to make sure that the heat exchanger has no cracks or pinhole leaks caused by corrosion.

One sign of a cracked heat exchanger is a change of oxygen concentration in the flue gases of greater than 1/2% oxygen, or a change in the carbon monoxide level greater than 25 ppm. This change is measured by comparing readings before and after the circulation blower has turned on. For this test to be valid, CO levels must be present in flue gas.

Although some cracks may be seen with visual inspection alone, the method described above can be used to find "invisible" cracks or cracks that may expand as the furnace heats up.

CS-9 What's the relationship between indoor air quality (IAQ) and combustion safety?

Good, efficient combustion is safe combustion: safe combustion maintains good indoor air quality.

CS-10 What are the most common chimney problems?

Simple blockages caused by birds nests, chimney deterioration, soot build-up and other "natural" occurrences restrict the air flow through the combustion equipment and can cause incomplete, inefficient combustion which will produce dangerous levels of toxic gases which could infiltrate the living/working area.

High levels of moisture in chimneys can cause the lining materials to decompose, creating restrictions which reduce the ability of the chimney to draw sufficient air to assure efficient, safe combustion.

Performing draft measurements will allow you to be sure that the chimney has vented flue gases to the outside air.

CS-11 How does inadequate ventilation increase the hazard of CO?

Weathertight homes and increased use of exhaust fans will create a negative pressure within a home.

Negative pressure conditions and blocked flue stacks can result in combustion appliance backdraft into the living areas.

Also, weathertight homes may have insufficient fresh air to support complete combustion, producing CO.

ENVIRONMENTAL

EC-1 How important is it to measure NO_X, SO_2, and CO for environmental compliance?

If your local regulatory authorities require measurement of these gases, it is very important to comply. Non-compliance (ignoring these gases) could result in fines, penalties and eventually, the shutdown of your equipment.

Air quality regulations vary from state-to-state and from region-to-region.

Contact your EPA office or state environmental office for the most current information about the specific environmental regulations which affect you.

Because regulations change, and new regulations are always being written into law, you should check at least twice a year with the EPA and/or DER to make sure that you are in compliance with current regulations.

EC-2 Is it difficult to convert ppm gas measurements to other units of measurements?

Other units of measurement are used to determine the weights of each of the pollutants for an amount of each fuel burned. Sometimes regulations are written which include these other units of measurement.

Chart #11 below, will allow you to easily convert ppm to other units of measurement.

Chart 11

POLLUTANT CONVERSIONS

To convert from ppm to any of the units below, multiply ppm by the number in the correct column and row.

Fuel	Pollutant	LB/MBTU	MG/NM3	MG/KG	G/GJ
NAT GAS	CO	0.00078	1.249	12.647	0.338
NAT GAS	NO_X	0.00129	2.053	20.788	0.556
NAT GAS	SO_2	0.00179	2.857	28.949	0.775
OIL (#2, #6)	CO	0.00081	1.249	15.118	0.354
OIL (#2, #6)	NO_X	0.00134	2.053	24.850	0.582
OIL (#2, #6)	SO_2	0.00186	2.857	34.605	0.811
COAL	CO	0.00107	1.249	27.178	0.460
COAL	NO_X	0.00167	2.053	42.418	0.718
COAL	SO_2	0.00233	2.857	59.1847	1.000

Definitions:
All numbers apply to values as corrected to 3% excess Oxygen (6% for coal) and dry gas.

LB/MBTU: pounds of pollutants per Million BTU (British Thermal Unit)
MG/NM3: milligrams of pollutant per Normal cubic meter of gas sampled
MG/KG: milligrams of pollutant per Kilogram of fuel burned
G/GJ: grams of pollutant per GigaJoule (10^9 Joule)

EC-3 What is the difference in NO and NO_2 in stack gases?

Nitric oxide (NO) and Nitrogen Dioxide (NO_2) are the toxic gases which constitute NO_X. All combustion processes can produce NO_X.

NO_X emissions contribute to the formation of acids in the earth's lower atmosphere; these acids contribute to the formation of acid rain.

Additionally, NO_X and hydrocarbons can react with sunlight to produce a potent respiratory irritant that is commonly called smog.

NO_X from combustion comes from three different sources: thermal NO_X, prompt NO_X and fuel bound NO_X.

In boilers or furnaces which burn fuels low in nitrogen (gas and light oils), thermal NO_X predominates. When fossil fuels rich in nitrogen (heavy oils) are burned, higher concentrations of fuel NO_X are generated.

Prompt NO_X is a small amount of total NO_X emissions that occur during low temperature stages of combustion.

Typically, Nitric Oxide (NO) comprises over 95% of the NO_X found in stack gases. However, a significant amount of NO converts to NO_2 in the atmosphere.

Because NO and NO_2 combine to form NO_X, which contributes to smog and acid rain, legislation to reduce and control these emissions has become much tougher.

EC-4 Where do I get information about specific environmental combustion regulations that could affect my organization?

The best source of information is your local or regional EPA and DER office. You can find them listed in the telephone directory.

EC-5 What is the Clean Air Act and does it apply to everyone with a furnace or boiler?

The Clean Air Act of 1970, including the amendments made in 1990, is a federal law which was created to reduce air pollution (smog), acid rain and other air pollutants which have been identified as toxic emissions.

The Act itself is 868 pages in length and encompasses virtually every conceivable form of air pollution, air pollution abatement programs and even requires that methods used in testing, for example SO_2, meet legislated criteria. Some of the provisions of The Clean Air Act are:

- SO_2 emissions from utilities reduced by 50%.
- 189 toxic substances will be measured by peer review.
- Five year federal operating permits to be issued.
- EPS continues to develop federal regulations to assure compliance.

The 1990 amendments to the Federal Clean Air Act of 1970 have established a dramatically different air toxins program.

This Act requires the EPA to establish operational and monitoring guidelines for industrial and commercial boilers and empowers state and local authorities to enforce the regulations.

These new regulations will affect combustion processes in facilities as diverse as large petrochemical plants and small local schools; regulatory compliance will become commonplace for nearly every industry, company and institution.

Already the South Coast Air Quality Management District (SCAQMD) in Southern California has developed its own legislation that will enforce the EPA guidelines. Rule 1146 requires that boilers over 2 million BTU per hour in capacity operate with NO_X emissions of less than 40 ppm. To meet these stringent requirements, routine testing of stack gases for NO_X and other combustion by-products is legislatively mandated in Southern California. Using the SCAQMD as a model, other states and regions are developing similar regulatory programs across the United States.

Internationally, the regulatory climate is becoming much tougher. Germany has passed legislation which mandates the NO_X testing of residential furnaces.

TC-1 I've always been able to get along by eyeballing the flame. Why should I use a mechanical or electronic instrument?

As amazing as the human eye is, it is not capable of performing quantitative analysis of changing colors in widely varying surroundings and situations.

The only quantifiable analysis that you can depend on is achieved through the use of mechanical or electronic instrumentation.

TC-2 If mechanical instruments will do the job why should I use electronic instruments?

As mentioned in the combustion analysis section, electronic instrumentation has several other benefits which are important.

The speed and accuracy of electronic instrumentation, coupled with the convenience of a computer, allows you to create hard copy reports which eliminates tedious, time consuming and frequently inaccurate, handwritten reports.

In our society, the increasing demand for pollution control and the increased possibility of severe fines or legal actions has made all of us more aware of the need to be able to demonstrate, in a tangible way, that we have performed as professionals and have done everything possible to insure environmental and safety compliance.

Electronic instrumentation combines higher levels of accuracy with faster testing, and demonstrable hard copy evidence of date, time and results of testing. This will provide you the most accurate and most cost effective way to assure that the information you need to perform as a professional is always available and easy to retrieve.

In addition to continuous testing, many electronic instruments will allow you to transfer and store information in a computer. This information can be identified and logged to allow you to generate a "history" of each individual piece of combustion equipment that you test.

By referring to this "history," you will have a solid reference point for the levels of fuel efficiency, safety, and environmental compliance achievable for any boiler or furnace that you test.

TC-3 What is the biggest difference between mechanical and electronic instruments?

The most important difference is the elimination of potential human error.

Electronic instruments simplify testing, eliminate the need for interpretation of measurements, and perform error free combustion calculations automatically.

TC-4 What are the advantages of using electronic instruments for combustion testing?

In addition to the advantages which we have detailed before, many service personnel have told us that the advantages of using electronic instruments are: speed and ease of use, automatic sampling, automatic calculations and automatic report generation.

Electronic instruments also provide individual displays of O_2, CO, NO_X, etc., which allow immediate monitoring and independent analysis of each adjustment as it is made on a boiler or furnace.

TC-5 What type of sensors are used in electronic instruments?

Although sensors are manufactured for specific gases and have small but significant differences, the basic concept for sensors used to measure carbon monoxide (CO), nitric oxide (NO) and sulphur dioxide (SO_2) are very similar.

Electrochemical sensors are entirely contained within a sealed plastic capsule or body. The major working elements are three coated electrodes (sensing, counter and reference) and a small volume of an acid solution.

In use, the gases diffuse through a small orifice on the sensing face of the sensor to the electrode surface and cause a change in the measured gas, which initiates a small electrical current.

The current, which is directly proportional to the concentration of gas being measured, is amplified and scaled by the electronics. The value is then displayed or is available for printing or downloading to the computer, depending on the instrument being used. Electrochemical oxygen sensors are manufactured and operate in a slightly different way.

Oxygen sensors are also entirely contained within a sealed plastic body which contains a consumable counter electrode (usually lead), a sensing electrode and a small volume of a base solution.

In use, oxygen diffuses through a membrane which covers the face of the sensor, the gas contacts the sensing electrode and the base solution and reacts at the wet surface of the electrode. This reaction consumes the counter electrode.

The chemical change in the counter electrode allows a circuit in the instrument to measure a potential (voltage) between the sensing and counter electrodes. This voltage is directly proportional to the concentration of oxygen in the gas being sampled. The value is then displayed or is available for printing or downloading, depending on the analyzer being used.

TC-6 How often do I have to calibrate my electronic instruments?

Calibration consists of zeroing and spanning sensors. The CO, NO_X and SO_2 sensors are zeroed automatically in some instruments. Simultaneously, the oxygen sensor is automatically spanned of 20.9 O_2 in air.

Most manufacturers recommend that calibration using certified concentrations of test gases be done at least every six months.

TC-7 How long do electrochemical sensors last?

Manufacturers' warranties may be different, chart #12 below is a good indication of "average sensor life."

TC-8 What is the easiest way to calculate combustion efficiency?

The easiest way is to use a micro-processor based electronic instrument. Mechanical instruments and slide rule calculations are equal in accuracy but less convenient.

TC-9 How do electronic instruments calculate CO_2?

An equation is programmed into the analyzer which calculates CO_2 from the oxygen and fuel measurements.

By selecting a specific fuel from a preprogrammed "menu" of fuels, and by sampling the flue gas, the electronic instrument will automatically calculate and display the CO_2 value.

Chart 12

TYPICAL SENSOR LIFE

Sensor	Gas	Life
ELECTROCHEMICAL O_2	Oxygen	1 Year Plus
ELECTROCHEMICAL NO	Nitric Oxide	2 Years Plus
ELECTROCHEMICAL NO_2	Nitrogen Dioxide	2 Years Plus
ELECTROCHEMICAL SO_2	Sulfur Dioxide	2 Years Plus
ELECTROCHEMICAL CO	Carbon Monoxide	2 Years Plus

REFERENCES

CSA International
8501 E. Pleasant Valley Road
Cleveland, OH 44131
(216) 524-4990

Bacharach, Inc.
625 Alpha Drive
Pittsburgh, PA 15238-2878
(412) 963-2000

Boiler Efficiency Institute
P.O. Box 2255
Auburn, AL 36831-2255
(334) 821-3095

Department of Energy and Environment
Brookhaven National Laboratory
Upton, NY 11973
(516) 344-7916

Columbia Gas
650 Washington Road
Pittsburgh, PA 15228
(412) 344-9800

Environmental Protection Agency (EPA)
Research Triangle Park
NC, 27711
(919) 541-5544

Department of Environmental Protection
400 Waterfront Drive
Pittsburgh, PA 15222-4745
(412) 442-4000

Peoples Natural Gas
625 Liberty Avenue
Pittsburgh, PA 15222-3197
(412) 471-5100

South Coast Air Quality Management District
21865 E. Copley Drive
Diamond Bar, CA 91765-4182
(909) 396-2000

Southern California Gas
555 West 5th Street
Los Angeles, CA 90013
(213) 244-1200

A.G.A.: American Gas Association

Air-Fuel Ratio: The ratio of weight or volume of air to fuel.

Ambient Air: The atmosphere external to furnace, appliance or process.

ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers

British Thermal Unit: The amount of heat required to raise 1 pound of water 1°F.

Calibration: Comparison of an instrument of lesser accuracy with another standard of known accuracy (calibration gas) to detect, correct and adjust for instrument accuracy.

Calorie: The amount of heat required to raise 1 gram of water 1°C.

Carbon Dioxide: A colorless gas, heavier than air, formed by the complete combustion of carbon.

CO: The chemical symbol for carbon monoxide.

CO_2: The chemical symbol for carbon dioxide.

Combustion Appliance: A fuel-burning (oil, gas, coal or wood) device such as a range, furnace, boiler or water heater.

Combustion Air: The air supplied for combustion of the fuel.

Combustion Chamber: The portion of the heating or process equipment where fuel is burned.

Dampers: Controls that vary air flow through an air outlet, inlet or duct.

DOE: Department of Energy

Environmental Factors: Conditions other than indoor air contaminants that cause stress, discomfort and/or health problems (e.g. humidity extremes, drafts and lack of air circulation).

EPA: Environmental Protection Agency

Excess Air: Air supplied for combustion in excess of that theoretically required for complete oxidation of the fuel.

Flue: A passageway for conveying combustion products to the outside air.

Flue Gases: Gaseous products of combustion.

Heat Exchanger: A device that transfers heat from one system to another, such as in a warm air furnace.

IAQ: Indoor Air Quality

Incomplete Combustion: Combustion in which fuel is only partially burned and is capable of being further burned under proper conditions of temperature and air.

Indoor Air: The air that occupies the space within the interior of a house or other buildings.

Makeup Air: Outdoor air supplied into a building to compensate for air which is exhausted by combustion appliances or other devices such as exhaust fans.

NO: The chemical symbol for Nitric Oxide.

NO_2: The chemical symbol for Nitrogen Dioxide.

OSHA: Occupational Safety and Health Administration

Orsat: A gas analysis apparatus in which the CO_2 or O_2 gaseous constituents are measured by absorption in separate chemical solutions.

Oxides of Nitrogen (NO_X): The sum of NO (Nitric Oxide) and NO_2 (Nitrogen Dioxide).

Perfect Combustion (Stoichiometric): The combining of the chemically correct proportions of fuel and air in combustion so that the fuel and oxygen are both totally consumed.

Plenums: Enclosures for the collection of air at the termination or origin of duct systems.

Primary Air: Air mixed with the fuel inside the burners.

Secondary Air: Air for combustion supplied to the outside of the flame to supplement the primary air.

SO_2: The chemical symbol for sulfur dioxide.

SALES AND SERVICE CENTERS

Bacharach Sales/Service Center
5151 Mitchelldale, B-4
Houston, TX 77092
Ph: 713-683-8141
Fax: 713-683-9437
Email: TXSERVICE@bacharach-inc.com

Bacharach Sales/Service Center
7300 Industrial Park
Rte. 130, Bldg. 22
Pennsauken, NJ 08110
Ph: 609-665-6176
Fax: 609-665-6661
Email: NJSERVICE@bacharach-inc.com

Bacharach Sales/Service Center
7281 Garden Grove Blvd., Suite H
Garden Grove, CA 92841
Ph: 714-895-0050
Fax: 714-895-7950
Email: CALSERVICE@bacharach-inc.com

Bacharach Sales/Service Center
8618 Louisiana Place
Merillville, IN 46410
Ph: 219-736-6178
Fax: 219-736-6269
Email: INDSERVICE@bacharach-inc.com

Bacharach Service Center
Maplewood Avenue
Fair Oak Court
Fairlea, WV 24902
Ph: 304-645-6166

Bacharach of Canada
181 Bentley Street Unit #5
Markham, Ontario L3R 3Y1 CANADA
Ph: 905-470-8985
Fax: 905-470-8963
Toll Free: 800-328-5217
Email: bachcan@idirect.com

Bacharach Systems International
P.O. Box 44
58 Kongensgade
DK 6070 Christiansfeld Denmark
Ph: 011/45 74 56 31 71
Fax: 011/45 74 56 31 78
Email: Mail@bacharach.dk

Bacharach UK
5 Anson Way
Admirals Quay, Bridgewater
Somerset TA6 3TB England
Ph/Fax: UK 44 1278 421 058
Ph: Malaysia 60 12 273-3057
Fax: Malaysia 60 12 273-3058
Email: aargonofarathon@hotmail.com

Bacharach Mexico
Bretana 178 BIS-12
Mexico D.F. Mexico 09440
Ph: 011-525-532-3930
Fax: 011-525-674-7544
Email: bachamex@df1.telmex.net.mx

Bacharach International
Rua das Laranjeiras 498/704
Rio De Janeiro, RJ 22240/002
Brazil
Ph/Fax: 55-21-556-1156
Email: bacharach@samerica.com

BACHARACH'S INSTITUTE OF TECHNICAL TRAINING

As the global leader in combustion testing and environmental monitoring instrumentation, Bacharach has been developing, designing, engineering and manufacturing portable combustion and environmental measurement instrumentation for almost a century.

Bacharach engineers and scientists have spent decades developing instrumentation and procedures that help assure combustion safety and support indoor air quality.

Now Bacharach's trained specialists can share their expertise with you through several technical training seminars. Plus learn how to:

- Generate new business leads
- Retain existing customers
- Reduce liability

Who Should Attend?

- HVAC Service Technicians & Contractors
- Weatherization Auditors
- Safety and Health Officials
- Gas Utility Personnel
- Home Inspectors
- Fire Departments
- Boiler Contractors
- Plumbing Contractors
- Plant Maintenance Engineers
- Industrial & Commercial Contractors

Why Attend?

Each attendee who attends a four-hour course will receive from Bacharach, a four course training manual ($90 value), four registered hours of instruction and certificate of attendance. Additionally, each attendee will gain access to the full line of Bacharach Services and Departments, including Product, Sales and Marketing. Our trainers will continue to work with attendees requesting technical assistance via telephone or other links. Attendees will also receive a newsletter periodically from Bacharach, highlighting industry news and providing technical updates.

Call Bacharach's Institute of Technical Training today for more information at 1-800-736-4666.

For a schedule of the upcoming training seminars in your area, please visit our website at www.bacharach-inc.com.

OIL BURNER COMBUSTION TESTING KITS

Each kit is designed with the serviceman in mind and is the most economical means of testing for oil burner efficiency during installation or servicing.

SAFESPACE®
Continuous Area Gas Monitor

Installed indoors or outdoors, it monitors one or two gases using sensors mounted up to 1,000 feet away or locally at the monitor.

BODYGUARD® 4
Four-Gas Personal Monitor

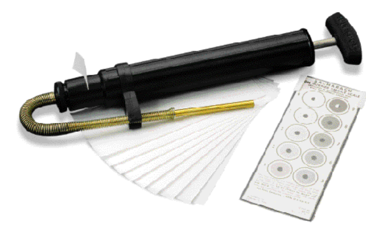
Its ability to monitor four gases simultaneously provides for a wide range of available gas combinations allowing the instrument to be customized to application requirements.

CO_2 ANALYZER 2820
Carbon Dioxide Analyzer

A compact and lightweight carbon dioxide analyzer that provides fast and accurate CO_2 measurement.

GAS POINTER® II
Multi-purpose Gas Detector

An intrinsically safe instrument for measuring concentrations of methane (or propane), carbon monoxide &/or oxygen in ambient air and flue gases.



TRUE SPOT®
Smoke Test Kit

Determines efficient combustion and is internationally recognized as the standard method for evaluating smoke density in the flue gases from distillate fuels.

DRAFT GAUGES

These dependable, service-free draft gauges are small, inexpensive and easy to use. The MZF Draft Gauge and the Draftrite® Pocket gauge can be utilized by both contractors and service technicians.

FYRITE®
Gas Analyzers

Fast, accurate and easy to use instruments for measuring and analyzing carbon dioxide or oxygen.

OIL BURNER COMBUSTION TESTING KITS

The most reliable and economical way of testing gas burner efficiency during installation or servicing.

BACHARACH
The Measurable Difference

Bacharach World Headquarters
625 Alpha Drive
Pittsburgh, PA 15238 USA
Phone: (412) 963-2000
Fax: (412) 963-2091
Website: www.bacharach-inc.com
E-mail: help@bacharach-inc.com

TÜV MANAGEMENT SERVICE ISO 9001

4097-4/99 10M