Carbon Monoxide

A Clear and Present Danger

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Introduction

A technician should always answer the following questions before finalizing an install or service call.

- Is it measurable?
- Did I measure it?
- Did I document my measurement?
- Is it safe to leave the appliance or combustion system running or in operation?
- Did I properly warn or alert the building occupants or supervisors of hazards?
- Would it be safe for my family or me to live or work in this building?

Anyone installing or servicing equipment should examine their own performance.

This text is intended for use by students, installers, service technicians, and first responders.

When installing new equipment and servicing existing systems, it is important to make sure the systems are operating within the measurable definitions of the equipment manufacturer and local code. Proper installation of combustion systems and thorough inspections can reduce loss of life, illness related to combustion by-products, property damage, liability and help reinforce confidence in consumers.

It is impossible to cover every circumstance in the countless situations found in the field. As instructors, authors and collaborators, this material is presented in an effort to provide information that is accurate and field-tested.

Material contained within this manual has been used to conduct seminars around North America for local HVAC and IAQ technicians, manufacturers, inspectors, fire safety and emergency response technicians, fuel suppliers and others.

This text is a collaborative effort of several authors and contributors.

The authors wish to express their gratitude to the growing number of technicians who test and measure the equipment installed or serviced, and who acknowledge the whole building as a factor in controlling air temperature, air quality, system efficiency and safety.

This text contains three sections:

CARBON MONOXIDE SAFETY

This section is intended to help raise awareness to the generation, distribution, detection, remediation and prevention of carbon monoxide (CO).

COMBUSTION ANALYSIS

This segment is intended to present opportunities for economizing fuel & energy use by encouraging the diagnosis of flue gases from theory to manufacturers suggested measurements.

BUILDING PRESSURE DIAGNOSTICS

This section is intended to provide information on easy to use differential pressure tests that help troubleshooting the following problems; fuel pressure and orifice problems, air balancing, appliance venting, duct and building heat loss issues.

AUTHORS

Bob Dwyer - Director of the Bacharach Inc., Institute of Technical Training

Mr. Dwyer has conducted Carbon Monoxide and Combustion Safety Seminars for thousands of people throughout North America.

Mr. Dwyer has been involved with government and public utility energy programs, combustion and environmental testing, HVAC associations, public education and community response coordination. He chaired the Combustion Safety Training Committee in Montana, promoted by the Public Utility Commission, 1991 through 1994.

Rudy Leatherman - Instructor

Mr. Leatherman has been performance testing combustion systems since 1980.

Mr. Leatherman worked with the Energy Office for more than 15 years. His responsibilities included; combustion testing, and evaluating, installing and troubleshooting a wide variety of commercial, industrial and residential HVAC systems. Mr. Leatherman was also involved in educational development and training for thousands of utility company personnel, mechanical contractors, code officials, home inspectors, energy auditors, maintenance technicians, plant/boiler technicians, fire departments, trade associations and others.

Currently, Mr. Leatherman conducts residential/commercial/industrial combustion testing training with Bacharach's Institute of Technical Training throughout North America. He also works closely with Bacharach's Customer Service Representatives to provide technical assistance for customers with application related concerns.

Bruce Manclark

Mr. Manclark has more than 20 years of experience in residential energy conservation.

Mr. Manclark has coordinated training in air sealing, duct sealing, mobile home and standard home weatherization for Pacific Power's Home Comfort program, Oregon Energy Coordinator's Association, Portland General Electric, and the Eugene Water & Electric Board. Mr. Manclark has also published articles in *Home Energy.*
He has offered consumer lighting workshops, and has served as an instructor for auditor and contractor training in computerized audit, blower door and infrared camera techniques, pressure diagnostics, and air and duct sealing.

Mr. Manclark was recently a beta tester for the Energy Conservatory Automated Performance Testing System for Duct Sealing, and for the Lawrence Berkeley Laboratory Aerosol Duct Sealer. He continues to manage the Energy Outlet, an ongoing "market transformation" project, and Delta-T, an energy service company with utility contracts in Oregon.

Ken Kimball - **Regional Manager, Technical Trainer for Bacharach**

Ken Kimball has a life-long building industry background, having grown up in the family window and door manufacturing business. From 1984 through 1990, Ken owned and operated his own general construction company. Ken has focused his efforts working in the gas heating industry for the past seven years, working with Western South Dakota Community Action Agency, U.S.D.O.E., and A.Y. McDonald Supply. He is a certified trainer and technical advisor in the HVAC and energy industries.

Erik Rasmussen - **Bacharach Technical Education Specialist**

Erik Rasmussen has a long history and extensive background in the HVAC industry, having been an independent service contractor and manager for over 12 years. He has completed training and certification in the HVAC fields of oil burners, gas burners, air conditioning concepts, duct design, heat gain and loss calculations. Erik has been trained by TSSA (Technical Standards and Safety Authority) as an oil and gas burner upgrade certification instructor in the province of Ontario, and has been employed by Bacharach for 5 years, during which time he has conducted combustion and carbon monoxide training and certification programs all across North America.

The main body of text in this book is mostly derived from "***Carbon Monoxide Safety, Combustion Analysis & The Driving Forces of Building Pressures***" by the Bacharach Institute of Technical Training .

Located in Western Pennsylvania since 1909, Bacharach, Inc. is a world leader in the design, manufacturing and service of advanced equipment for the measurement and detection of gases and liquids. Bacharach engineers and scientists have spent decades developing instrumentation and procedures that help assure combustion safety and support indoor air quality.

Important Pressure Measurements and Conversions

PSI (Pounds per Square Inch)
WC" (Water Column Inch)
PA (Pascal)

Atmospheric pressure at sea level = 14.7 PSI
1 PSI = 27.7 WC "
PSI (Standard unit of measure for oil burner pump pressures)

1 WC" = .036 PSI

WC" measurement commonly used in gas manifold pressure delivered to appliance burners (Typical natural gas pressure 3.5 WC") (Typical Propane Pressure 11 WC")

External Static Pressure (ESP) in duct work commonly measured in tenths of WC "

Draft pressure measurements in combustion system vents & chimneys commonly measured in hundreds of an inch WC.

1 WC" = 249.0889 Pascal
Pascal is a common building pressure measurement

1 Pascal = .004 WC"

Common Category I Vent Pressures (systems with non-positive exhaust pressures)
-.02 WC" = 05 Pascal
-.04 WC" = 10 Pascal
-.06 WC" = 15 Pascal

Standard atmosphere or standard conditions: Air at sea level at 59F when the atmosphere's pressure is 14.696 psia (29.92 in. Hg).

Carbon Monoxide

Carbon monoxide (CO) is a toxic gas that can occur in homes and buildings when combustion by-products are generated and allowed to disperse. CO is colorless, odorless, tasteless and is an asphyxiant. **CO is deadly.**

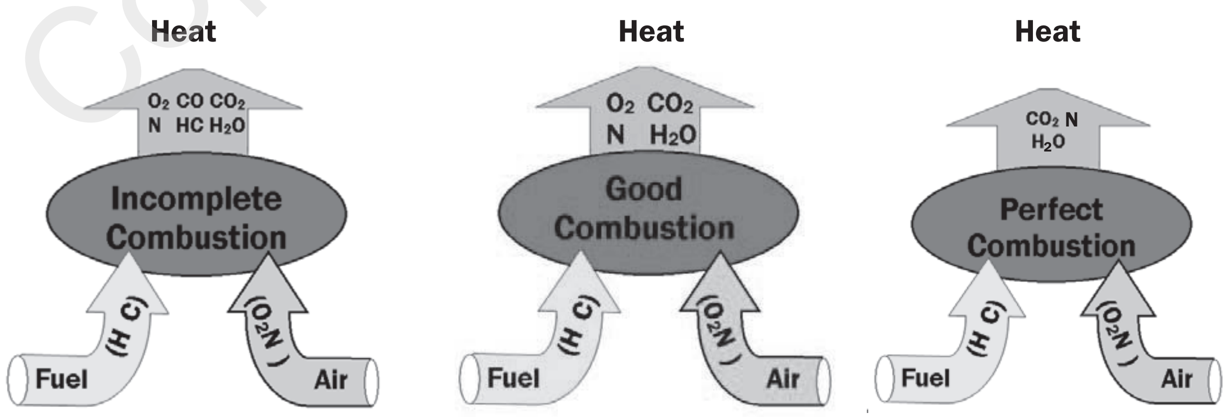
At low concentrations, CO can contribute to existing cardio and respiratory illnesses. It can compound pre-existing health conditions and can go undetected as a cause in premature deaths.

How is carbon monoxide formed? How is it measured?

Carbon monoxide is a result of unburned fuel. Fossil fuels require specific ranges of oxygen and temperature to allow for complete combustion.

CO production is commonly associated with insufficient combustion air. However, excess introduction of combustion air (or insufficient fuel supply) can reduce flame temperatures to the point where CO is produced. When any portion of a flame is reduced below 1128° F, CO will be produced. Flame impingement on heat exchanger surfaces can also result in lowering flame temperature and CO production.

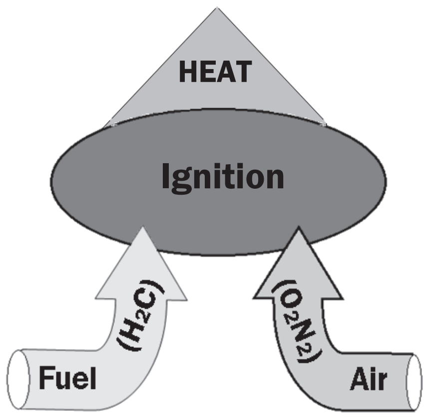
If we completely burn all of the fuel and properly exhaust the by-products of combustion, there should not be any measurable CO.



__Carbon Monoxide__

Certain requirements must be met for combustion to occur. The quality of combustion is dependent upon and rated against the quality of the fuel and its potential to burn completely under perfect conditions.

Fuel that has the potential to burn, like carbon fuels (C), must be surrounded by air or oxygen (O_2) but not flooded with oxygen. Ignition or flash point heat must be enacted and maintained. Fuel, air and heat must all be present or combustion will not occur. In controlled combustion systems, fuel is forced into a combustion zone with limited time constraints because more fuel is being forced into the zone.

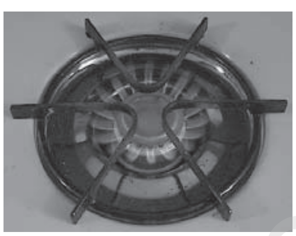


__TIME - TEMPERATURE - TURBULENCE__

Combustion is a very violent action. __Turbulence__ that are controlled help ensure complete burning of fuel and the maintenance of flame __temperature__.

As an example, if the flame temperature is cooled and the turbulence is effected, all the fuel may not have the __time__ to burn because it is being forced out of the system by the force of fuel entering. This fragile window of time that fuel has to burn has now been flooded with fuel that spills where it can or follows the strongest drawing forces, out of and below the ignition temperature zone.

The following pictures of gas burners help illustrate how carbon monoxide is formed in some very basic and easy to see ways. It must be remembered that all gas burners are designed to work with controlled fuel mechanisms and in environments that supply sufficient air and oxygen to the fuel at combustion. These burners are designed to burn all the fuel that is supplied.



The ignition temperature of __natural gas__ is between 1100° F and 1200°F with a flame temperature around 3,000°F. The burner with nothing on it has conditions that allow for the complete burning of the fuel, and no CO is produced. When a cold pan of water is set over that flame, a dramatic cooling of the flame occurs and the violent turbulence pushes or spills the unburned fuel out of the flame before it can fully burn , producing CO.

As the pan surface heats up and the water begins to boil, CO generation may cease due to increased heat. (It is recommended that every gas range top burner be tested this way in front of the consumer to help educate them about intermittent carbon monoxide production.) Additionally, it can also be demonstrated that a cooler flame also results in a longer time period for the water to boil. This may be a fraction of fuel savings, but savings none-the-less and obviously less CO generation and dispersion into their living space.