

Wholistic Approach to Carbon Monoxide

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Wholistic Approach to Carbon Monoxide

How CO is Produced in Combustion Appliances

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Carbon Monoxide from Combustion

- "In all combustion sources of CO
 1. the ratio of carbonaceous fuel to oxygen is either too high to permit the complete formation of CO₂, or
 2. the temperature is too low to permit oxidation to occur."

Source: An Introduction to Air Chemistry, Samuel Butcher and Robert Charlson, Academic Press, 1972, pp. 139 - 140

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Carbon Monoxide from Combustion

- "In all combustion sources of CO
 1. the ratio of carbonaceous fuel to oxygen is either too high to permit the complete formation of CO₂. . ." **Caused by**
 - a. Too much fuel for amount of oxygen
 - b. Not enough oxygen for amount of fuel
 - 1) Improper air adjustment
 - 2) Wrong fuel for setup (LP for nat. gas setup)
 - 3) Dirty or improperly aligned burners

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Carbon Monoxide from Combustion

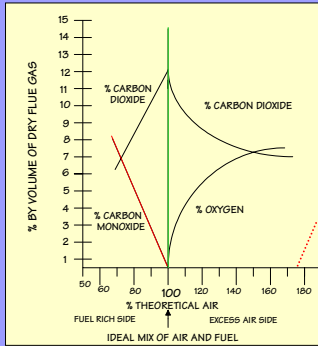
- "In all combustion sources of CO. . .
 2. the temperature is too low to permit oxidation to occur." **Caused by**
 - a. Quenching by impingement
 - 1) Pots and pans, no grate, improper grate spacing
 - b. Quenching by too much airflow
 - 1) Strong draft, air blowing across burner

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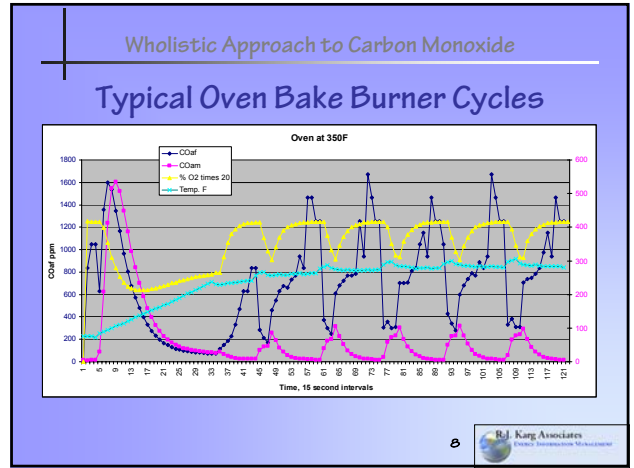
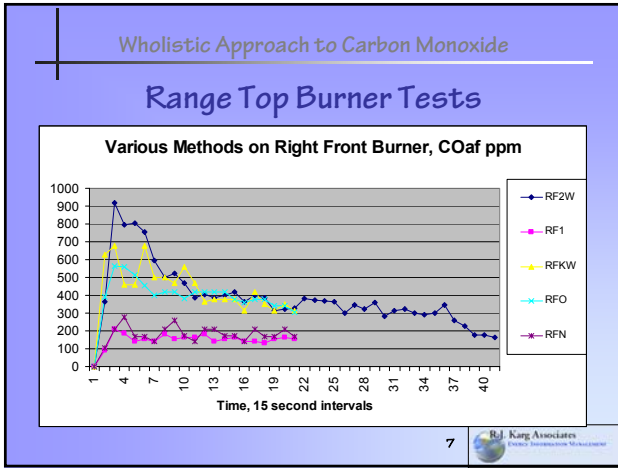
Theoretical Combustion Air Curves



Actual percentage values vary for fuel being measured

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American National Standard Institute (ANSI) Standards for Manufacturers

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- Wholistic Approach to Carbon Monoxide
- ### ANSI Standards for CO - Manufacturers
- Household Cooking Gas Appliances (Z21.1)
 - 800 ppm air-free after all burners operate for five minutes (range top burners have 5 pounds of water on each).
 - Storage Water Heaters, 75,000 Btuh or less (Z21.10.1).
 - 200 ppm air-free for natural and induced draft and for power burners.
 - Unvented Room Heaters (Z21.11.2).
 - 200 ppm air-free.
 - Gas-Fired Low-Pressure Steam and Hot Water Boilers (Z21.13).
 - 400 ppm air-free.
 - Gas-Fired Central Furnaces, except Direct-Vent (Z21.47).
 - 400 ppm air-free "with outlet of drafthood blocked"
 - Decorative Gas Appliances for Installation in Solid-Fuel Burning Fireplaces (Z21.60).
 - 25 ppm as-measured or 400 ppm air-free.
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Suggested CO Action and Allowable Levels

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Ambient CO Standards

C O LEVELS OF CONCERN.....VARIOUS AUTHORITIES	
@ 9 PPM.....	ASHRAE, [Indoors], ...EPA, [Outdoors] [8 Hrs. TWA]
@ 25 PPM.....	ACGIH, [8 HRS. TWA]
@ 35 PPM.....	NIOSH / Dept of Labor, [OSHA, Canada] [8 Hrs. TWA]
@ 50 PPM.....	OSHA, [USA] [8 Hrs. TWA]

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Suggested Appliance CO Limits

Carbon Monoxide (CO) Action Levels and Allowable Levels			
Appliance	Action CO Level	Allowable CO Level	Comments
Gas Furnace / Boiler	100 ppm / 200 ppm	200 ppm / 400 ppm	as-measured / air-free
Gas Water Heater	50 ppm / 100 ppm	100 ppm / 200 ppm	as-measured / air-free
Gas Range Bake Burner	800 ppm	800 ppm	air-free
Oil Furnace / Boiler	100 ppm	200 ppm	as-measured
Oil Water Heater	100 ppm	200 ppm	as-measured

Action CO Level indicates level above which repair or adjustment to appliance is recommended to lower CO emissions.
 Allowable CO Level indicates maximum CO emission levels recommended.

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Measuring Carbon Monoxide

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Monoxor II from Bacharach

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Fyrite Pro from Bacharach

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Bacharach PCA

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Testo 325-1

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Testo 300


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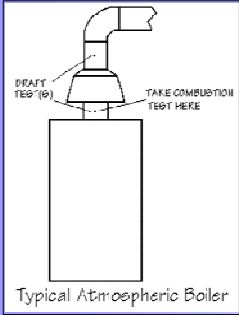
Category I Gas Atmospheric Furnace

Efficiency and CO must be tested in gases **before** dilution air enters vent system.

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Gas Atmospheric Boiler Testing




DRAFT TEST (A)
TAKE COMBUSTION TEST HERE

Typical Atmospheric Boiler

Boiler efficiency, CO, and draft testing



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Any sign of flame rollout?

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CO Emissions Test




Wrong!

Click1

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Atmospheric Boiler Box Diverter



Spill switch
Bottom of draft diverter

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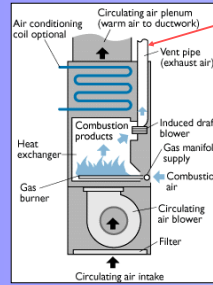
Oil-Fired Boiler



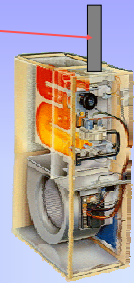
Any signs of problems here?

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Category I Fan Assisted Furnace



Test for efficiency and CO here



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Water Heater CO Emissions Tests



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Category I Appliance



Typical natural draft, atmospheric, water heater.

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Category I Appliance



Induced draft unit, but still negative pressure and high temperature in vent connector.

Induced draft fan

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Category I Appliance

Concentric, double-wall vent connector



In vent connector, negative pressure and high temperature.

Direct vent unit.

Sealed combustion chamber.

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Category III Appliance



Forced draft water heater with high temperature plastic vent connector.

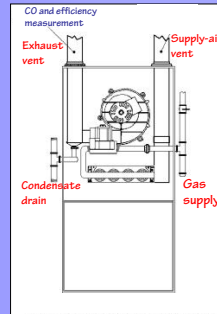
Non-condensing

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Category IV Gas Furnace



Positive pressure in vent connector, draft-proving switch and a condensate drain make efficiency and CO testing questionable.

Direct-vent unit

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Category IV Furnace



Low-temperature plastic vent connector

Mechanical fan for draft

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Standing-pilot range



Don't forget to test gas ranges

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Oven Bake Burner Testing



For more information, see www.karg.com/rangeprotocol.htm

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Oven Bake Burner Test




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Range Top Burner Testing





For more information, see www.karg.com/rangeprotocol.htm

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CO Hot Pot



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Two Methods of Measuring Carbon Monoxide: As-Measured & Air-Free

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CO_{as-measured} vs. CO_{air-free}


- ANSI Standards usually state air-free values.
- CO_{as-measured} is percentage or concentration.
- CO_{air-free} is emission rate, adjusted (normalized) for zero excess-air conditions.
- Indoor ambient air CO must always be read as-measured.

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CO_{as-measured}


- Measured as percentage or ppm: 0.08% = 800ppm
- Measured with, e.g., Monoxor II or Testo 325.
- Diluted to varying degrees by excess air (oxygen).
- Not a rate of emission, but a concentration.
- Indoor ambient air CO must always be read as-measured.

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CO_{air-free}

- Diluted CO_{as-measured} sample is adjusted to simulate oxygen-free (air-free) conditions, that is, conditions with zero excess air (excess oxygen).
- This normalized CO_{air-free} reading is still expressed as a ppm value, but it is actually an emission rate.
- ANSI Standards are usually expressed in air-free values.
- Read with, e.g., Testo 300 or Bacharach PCA.


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*CO*_{as-measured} vs. *CO*_{air-free}

Oven A
As-Measured CO = 18 ppm
Oxygen = 20%
Air-Free CO = 400 ppm

Oven B
As-Measured CO = 209 ppm
Oxygen = 10%
Air-Free CO = 400 ppm

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From *CO*_{as-measured} to *CO*_{air-free}

$$CO_{air-free} = \left(\frac{20.9}{20.9 - O_2} \right) \times CO_{ppm}$$

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