Welcome to TruTech Training!

We'll be starting in just a few moments……

www.TruTechTools.com

888-224-3437

Info@TruTechTools.com

TruTechTools

COMB 101
Combustion Principles & Safety Testing

START RECORDING

TruTech Tools
66 Swartz Rd.
Akron, Ohio 44319

TruTechTools

- Experienced professionals delivering CEU training to the HVAC and related trades
- 45+ years combined experience
- Practical, related and hands-on training
- Earn while you Learn
  - BPI Recognized CEUs

TruTechTools

If you desire BPI CEUs…

- Full attention is required
  - Refrain from surfing off to other screens!
- INTERACTION with instructor is required during the session.
  - Ask a question
- Your BPI # should have been entered at registration
  - If not email to *Marilyn@TruTechTools.com*
  - With your name and date of this webinar

TruTechTools

Agenda

1. The Combustion Process
2. Understanding Combustion and combustion efficiency
3. Common causes of CO and related safety
4. Performing a complete combustion analysis
5. Ventilation air testing
6. Heat exchanger examination and testing
7. Field modification of equipment
8. Measuring appliance output and thermal efficiency

TruTechTools

Hidden Agenda

-
-
-
-
-

TruTechTools

Why is combustion analysis important?

- Verification of the safety of the appliance before and after servicing and/or weatherization
- Calculation of the combustion efficiency
- Monitor the pollution the appliance is producing
- To verify conformance with manufacturers' guidelines
- To minimize warranty issues and assure equipment longevity

TruTechTools

Combustion Testing Results

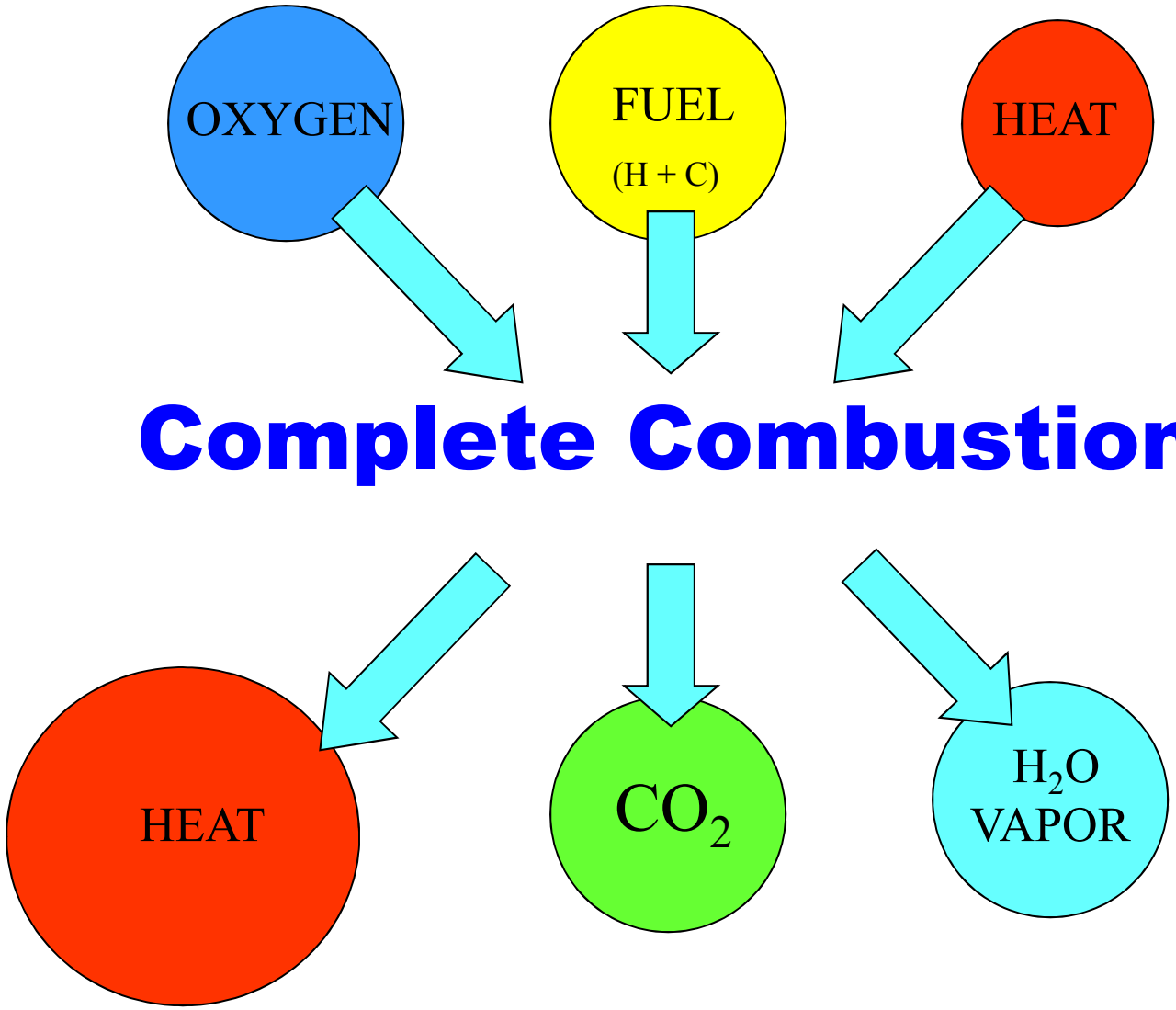
- Saves money
- Saves time
- Avoids callbacks
- Limits liability
- Maintains equipment warranty
- Provides confidence
- Provides increased comfort
- Provides increased safety
- Increases energy efficiency
- Lowers environmental emissions (Pollutants)

TruTechTools

Basic Combustion Theory

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

TruTechTools

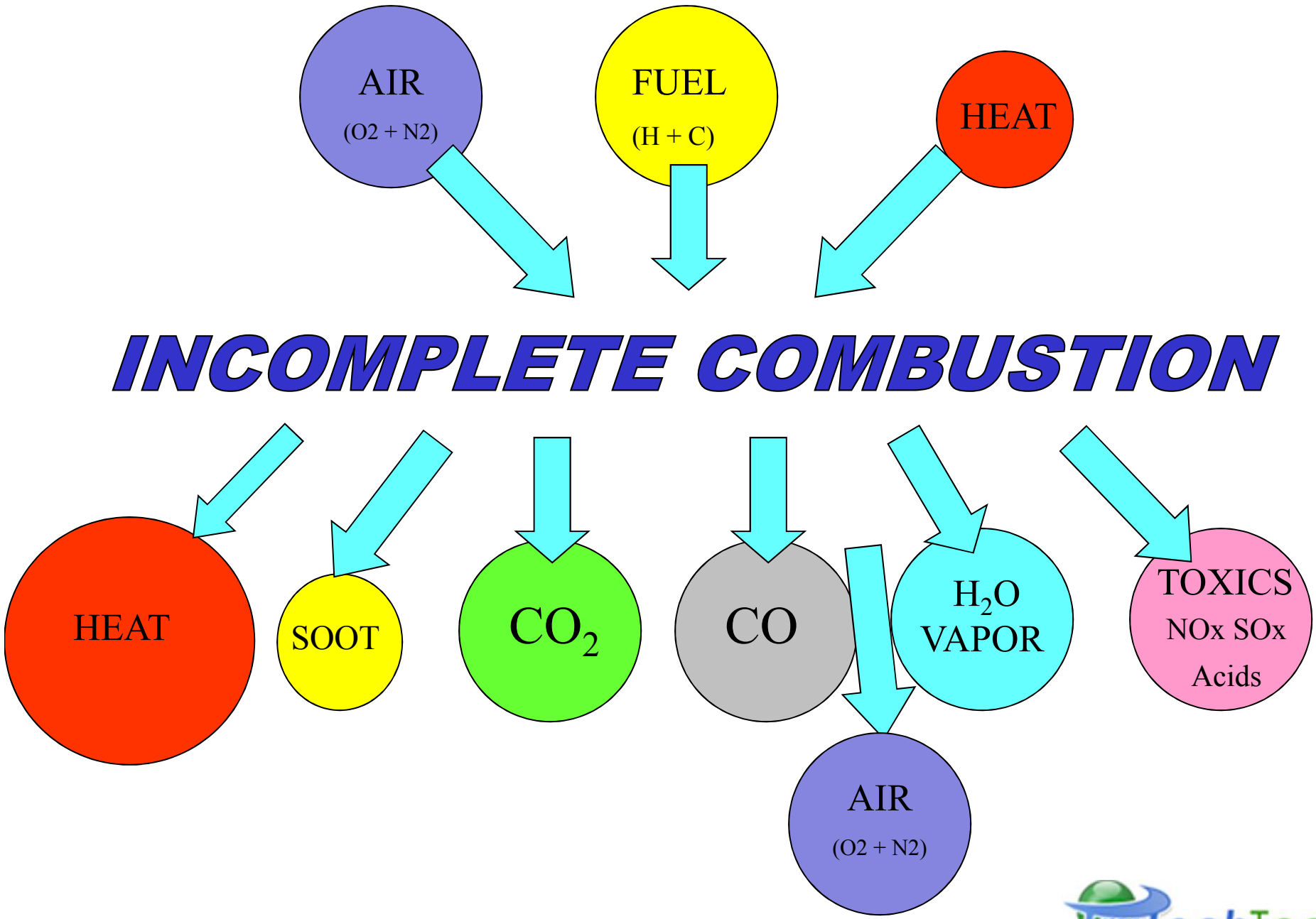


TruTechTools

This never happens in reality

Air is the oxidizer used for combustion
NOT oxygen, so perfect combustion can never be achieved!

TruTechTools



Sources of Toxins

(Typically change to Acids)

- Chlorine bleach
- Salts (eg. water softener)
- Dryer softener sheets
- Household chemicals
- Paint thinner
- Gasoline/Kerosene

Always recommend removal from the immediate CAZ!

TruTechTools

The Combustion Process

$$CH_4 + 3O_2 = Heat + 2H_2O + CO_2 + O_2$$

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 the chemical reaction
- $2H_2O$ = 2 cubic feet of Water Vapor
- CO_2 = 1 cubic foot of Carbon Dioxide
- *O_2 = 1 cubic foot of Excess Oxygen*

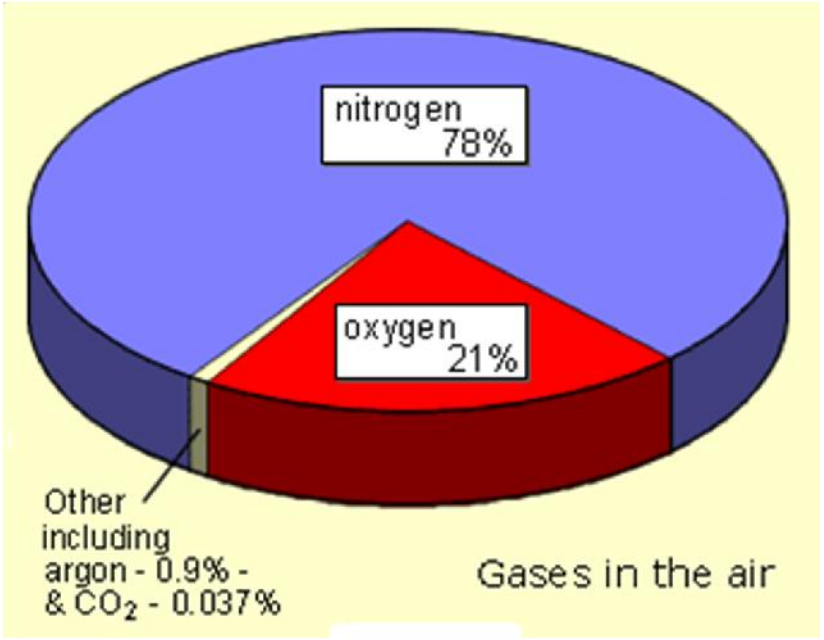
TruTechTools

The problem with air

- Because we use air as the oxidizer in the combustion process, and not oxygen, perfect combustion can never be achieved.
- Large amounts of heat energy are absorbed by the nitrogen in the air which plays no role in the combustion process

Composition of the air

- 20.9% Oxygen
- 78% Nitrogen
- 1% Other gasses



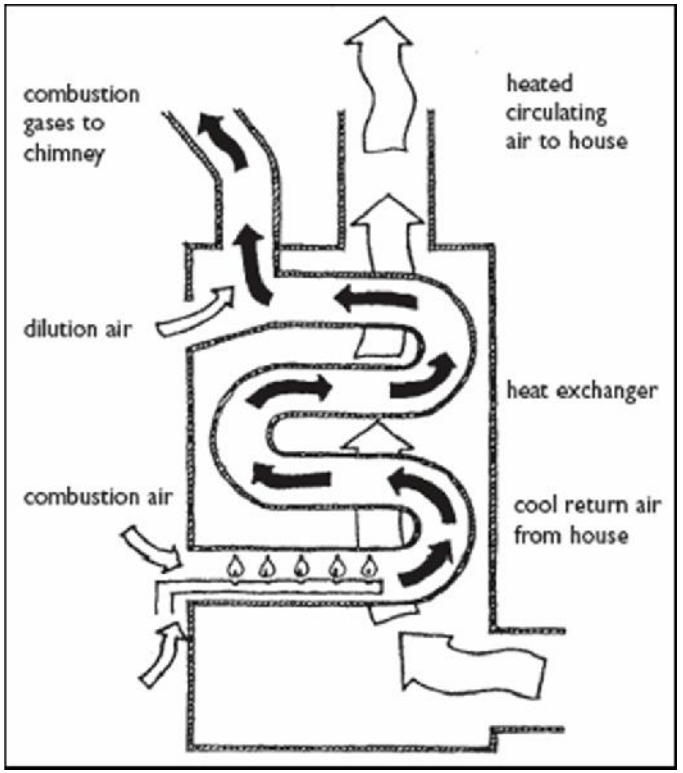
10 CF of air is required to get 2 CF O_2

(because air is basically 1/5 Oxygen)

TruTechTools

Why do we care about air?

1. Ventilation
2. Infiltration
3. Combustion
4. Dilution



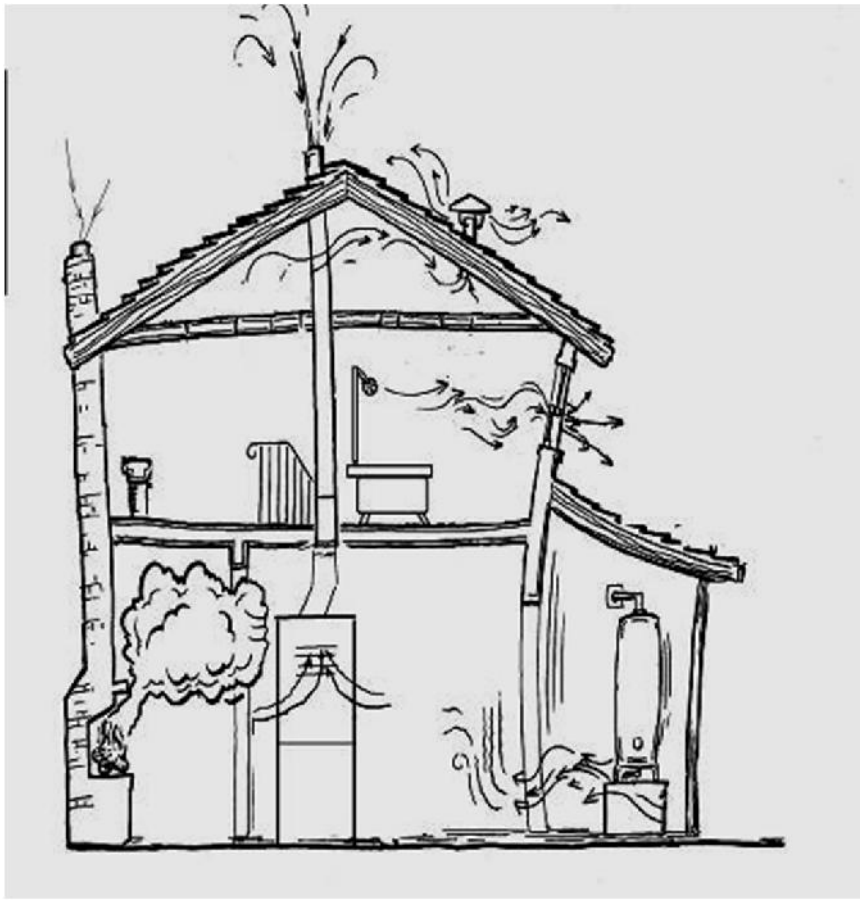
The danger is the things that compete for it!

TruTechTools

Air Tight Homes

- Negative pressure conditions in homes or commercial buildings can create back-drafting of combustion appliances

- Common exhaust equipment (ie attic fan, bathroom exhaust, fireplace) can compete with the normal venting process of combustion appliances



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. Typically however the industry refers to ventilation air as "indoor and outdoor air ventilation."

TruTechTools

Infiltration Air and Ventilation Air Testing

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

TruTechTools

Infiltration Air and Ventilation Air Testing

- **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.

Infiltration Air and Ventilation Air Testing

- **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

How much air is needed

- 1 CF natural gas requires 10 CF air
  - For complete, “perfect” combustion
- + an additional 5 CF excess air
  - To assure safe combustion
- + an additional 15 CF dilution air if draft hood equipped.
  - To dilute the moisture in the flue gasses and prevent condensing

15-30 CF of air/CF of natural Gas

TruTechTools

How much air might a typical furnace need?

- 1000 Btu/Ft^3
- 1000 Btu/Ft^3 x 100 = 100,000 Btuh
- 100 Btu/Ft^3 gas required per hour of operation
- 15+15=30 Ft^3/ air required per cf natural gas
- 100 x 30 = 3000 Ft^3/hr
- 3000 x 24 hr/day = 72,000 Ft^3/day
- or 30 CFM/minute of operation

That air has to come from somewhere!

TruTechTools

Combustion Analysis

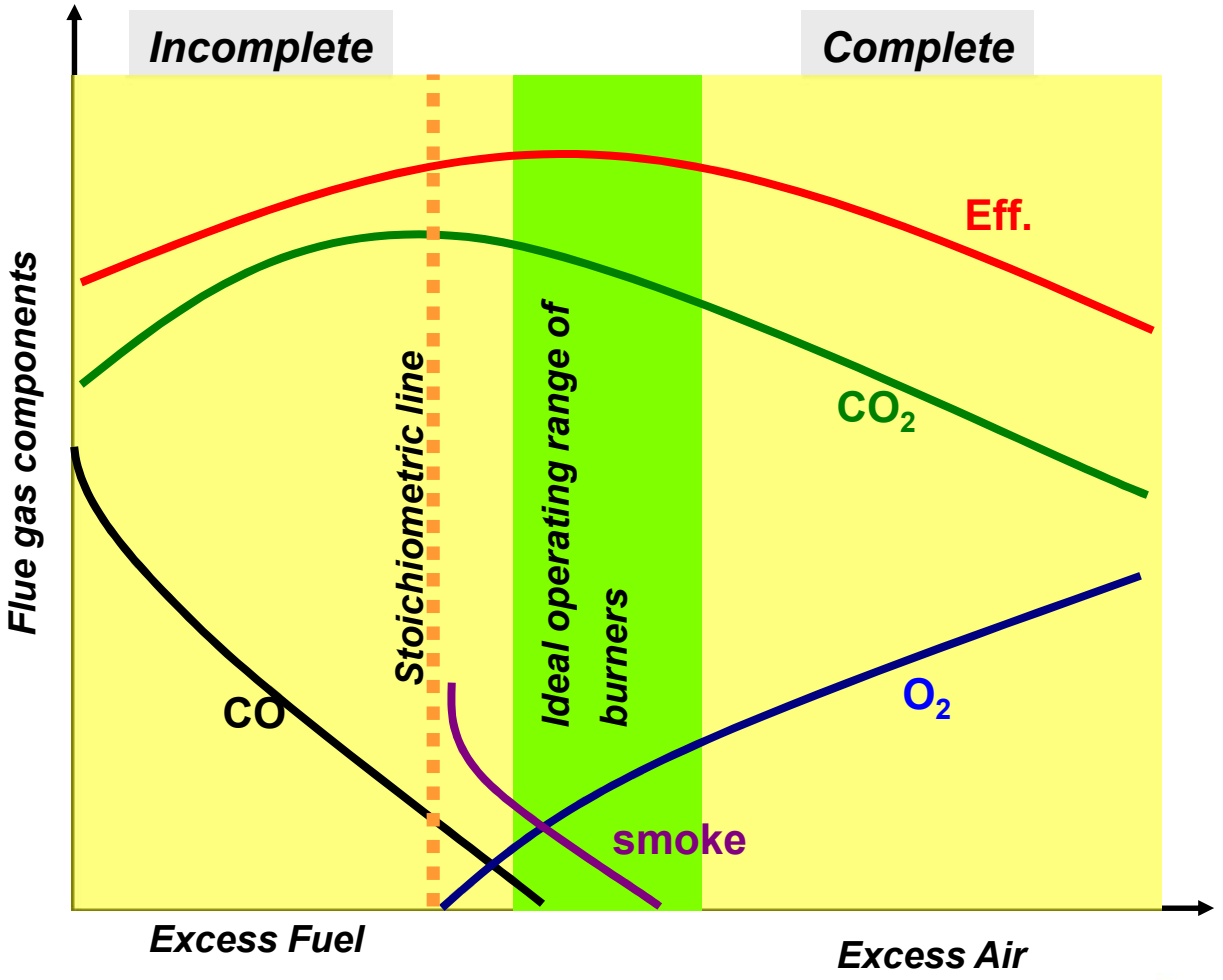
The efficiency calculated by the combustion analyzer is a modified equation that considers combustion efficiency and stack losses.

- Part thermal
- Part combustion efficiency

TruTechTools

Combustion Diagram

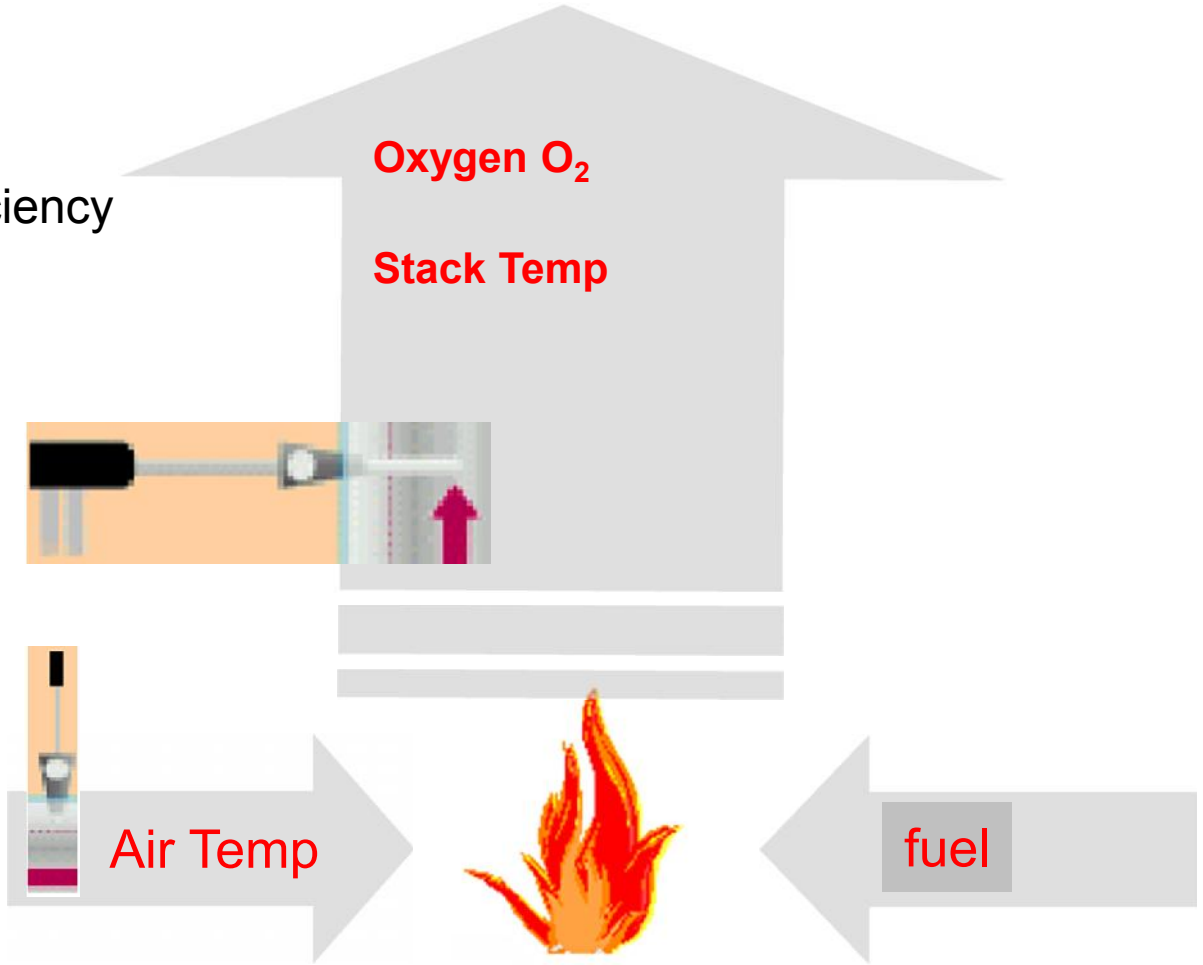
The ideal operating range is a setting with excess air.



TruTechTools

Calculating Combustion Efficiency

The analyzer uses the oxygen and net temperature measurements in fuel specific equations to give the efficiency, CO2 and excess air readings.



TruTechTools

Combustion Analysis

The efficiency equation is a reasonable estimation of the steady state operating efficiency of the appliance.

- Some analyzers perform dry gas calculations ONLY
- Some estimate latent energy removal
  - It is impossible to determine the amount of latent energy removed without measuring the volume of condensate produced!

TruTechTools

Combustion Analysis

The efficiency measurement is
COMBUSTION EFFICENCY- Stack Losses

It is not:

- AFUE
- Thermal efficiency
- COP
- SEER

TruTechTools

Combustion Analysis

What is 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) If your analyzer is equipped. Byproduct of combustion also called: mononitrogen monoxide or nitrogen monoxide. (Pollutant)

TruTechTools

Combustion Analysis

What is 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.

TruTechTools

Combustion Analysis

Calculated (continued)

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.

TruTechTools

What do we care about?

- Safety
- Compliance
- Consistency
- Efficiency

TruTechTools

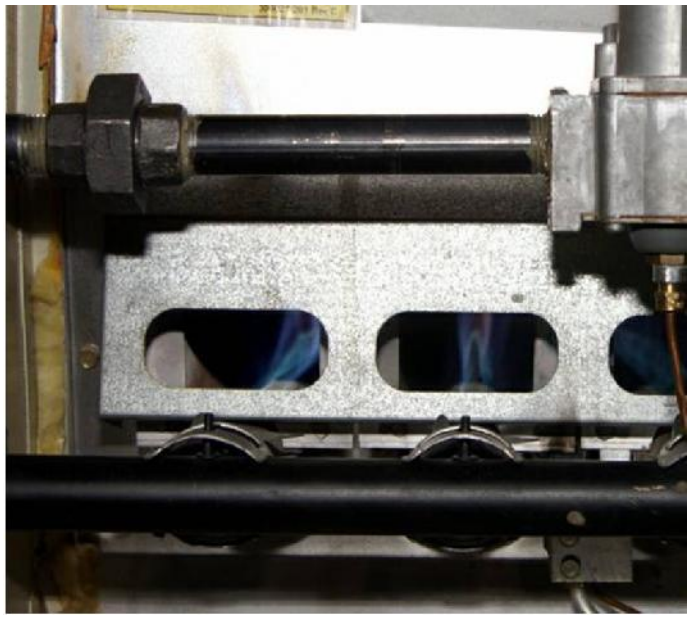
Safety
Understanding CO and how it's produced

- Ambient CO testing
- Ventilation air testing
- Stack CO testing
- Pressure switch cutout setting

TruTechTools

What is Carbon Monoxide ?

- CO originates from incompletely burnt (oxidized) carbon (fuel).
- It is very dangerous for human and animals, because it prevents the absorption of oxygen in the blood stream. Creating Carboxyhemoglobin (CO-Hb)
- Reasons for the formation:
  - fuel rich mixture
  - Improper venting
  - flame impingement
  - burner alignment



CO

TruTechTools

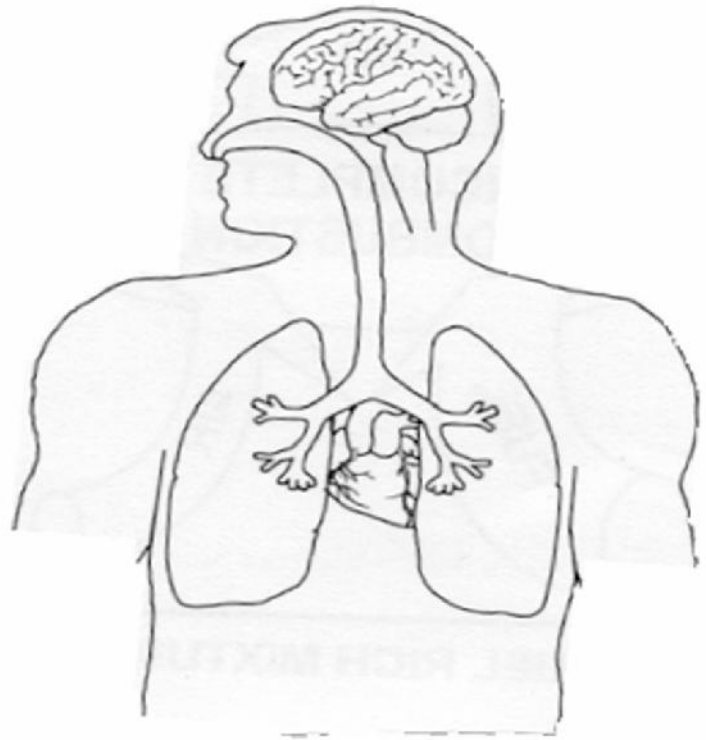
Characteristics of CO

- Odorless
- Colorless
- Tasteless
- Mixes well in air
  - Does not stratify
  - Follows air flow in a structure
- Poisonous

TruTechTools

CO Symptoms

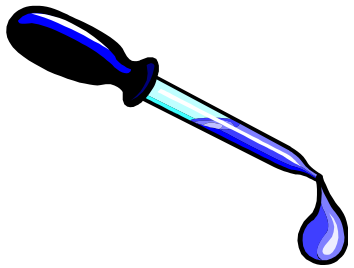
- Persistent headaches
- Dizziness, blurred vision, nausea
- Fatigue or drowsiness
- Shortness of breath and confusion
- Feeling ill/tired at home, but fine upon leaving home or building



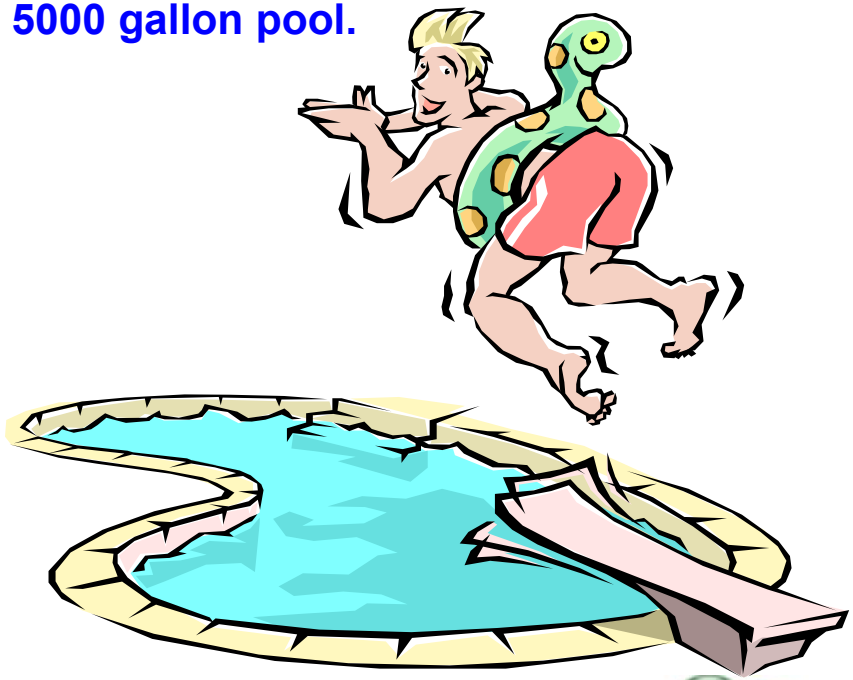
TruTechTools

So how big is a ppm?

1 ppm = 1/1,000,000 parts



Or consider a dropper of oil in a 5000 gallon pool.



10000 ppm	**=**	**1 %**
1000 ppm	**=**	**0.1%**
100 ppm	**=**	**0.01 %**
10 ppm	**=**	**0.001 %**
1 ppm	**=**	**0.0001 %**

TruTechTools

CO Health Effects

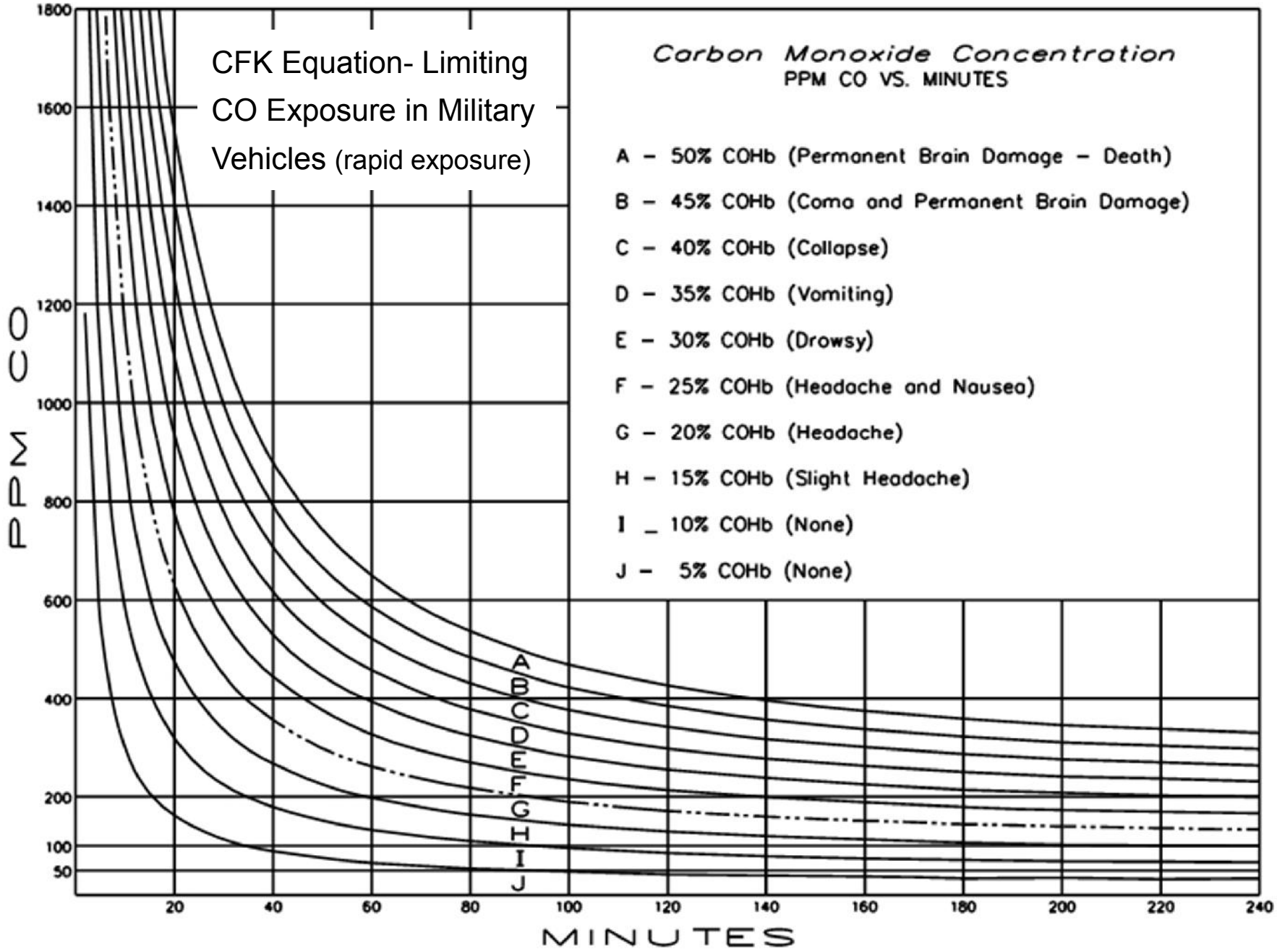
-a cumulative poison-

• 9/13 ppm	US-EPA/Health Canada 8 hour outdoor
• 25 ppm	Alberta Occupational Exposure Limit – 8 hours
• 35/30 ppm	US-EPA/Health Canada 1 hour outdoor
• 50 ppm	US-OSHA Permissible Exposure Limit – 8 hours
• 200 ppm	slight headache with 2-3 hours
• 400 ppm	Headache within 1-2 hours
• 800 ppm	Sickness & twitching of limbs within 1-2 hours; unconsciousness in 2 hours
• 1600 ppm	Headache within 20 minutes; **death** within 2 hours
• 3200 ppm	**Death** in 30 minutes
• 6400 ppm	**Death** in 10-15 minutes
• 12800 ppm	**Death** in 1-3 minutes

TruTechTools

Carbon monoxide concentration (ppm CO) versus time (minutes)

Figure 38.1 revised October 15, 1997



Combustion Safety Test Action Levels

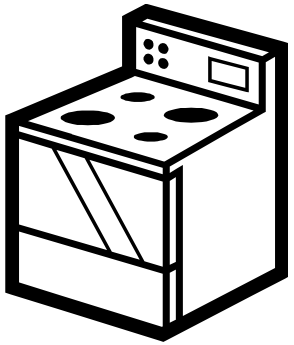
CO Test Result*	And/ Or	Spillage and Draft Test Results	Retrofit Action
0 – 25 ppm	*And*	**Passes**	Proceed with work
26 – 100 ppm	*And*	**Passes**	Recommend that the CO problem be fixed
26 – 100 ppm	*And*	**Fails at worst case only**	Recommend a service call for the appliance and/or repairs to the home 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*

Courtesy of BPI standards

Some Possible Sources

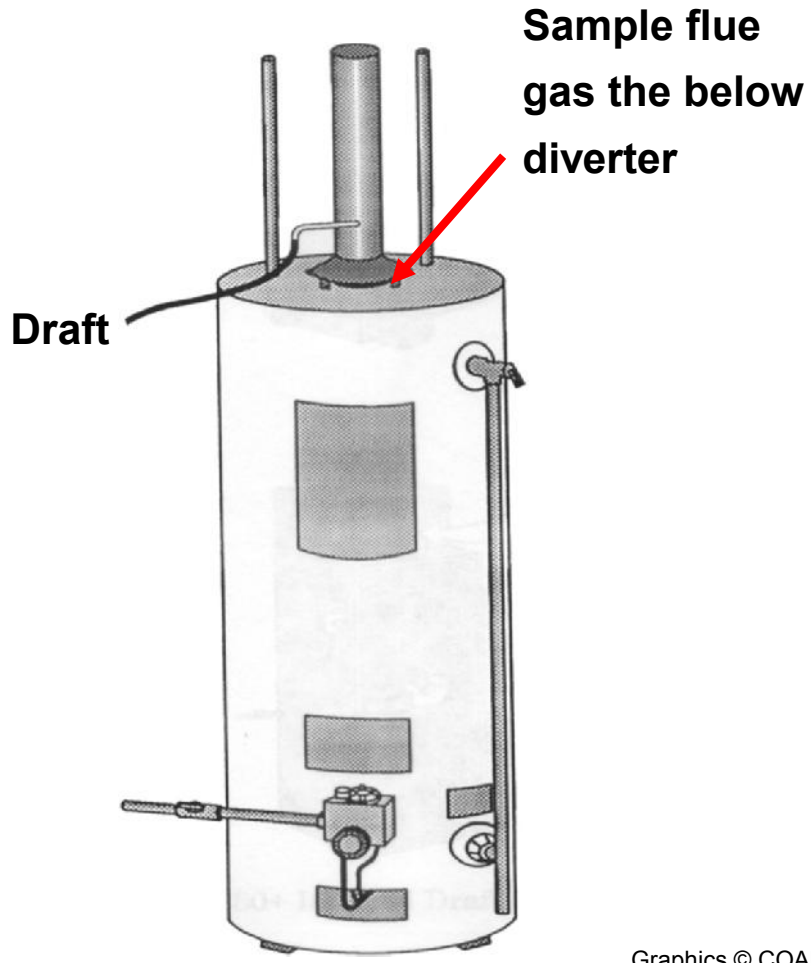
- Fuel burning furnaces and hot water heaters
- Kitchen ranges & ovens
- Auto emissions
- Fireplaces
- Tobacco smoke
- Fuel burning space heaters
- Fuel burning boilers



TruTechTools

CO Testing...
Fuel Burning Appliances

- Sample from entry to exit
- Sample around all un-vented appliances
- Sample in stack of vented appliances
- Sample where you may suspect CO



TruTechTools

National Standards for CO Exposure

- Less than 9 ppm CO (ASHRAE 62-89)
  - Indoor air vs. outdoor air
- Less than 50 ppm CO (OSHA)
  - Worker exposure limit over 8 hours
- Recommends less than 9 ppm CO (EPA)
  - Living area
- Less than 400 ppm air-free flue gas (ANSI Z21.1)
  - Sampled flue gas on an air-free basis

TruTechTools

Ambient Air Action Levels for CO - BPI

- 1 to 9 ppm CO
  - Normal – No Action Required
- 10 to 35 ppm CO
  - Marginal – Advise - Ventilate
- 36 to 99 ppm CO
  - Excessive – Medical Alert – Check-Mitigate and Ventilate (Stop all work from here on!)
- 100 to 200 ppm CO
  - Dangerous - Medical Alert – Evacuate – Check Occupants (911)

TruTechTools

CO Home Alarms

- UL 2034 Standard (3/8/05)
- Table 38.1 (A) Alarm must sound
  - 65-75 PPM between 60-240 minutes
  - 145-15 5 PPM between 10-50 minutes
  - 390-410 PPM between 4-15 minutes
- Table 38.1 (B) Alarm must ***NOT*** sound
  - 27-33 PPM if exposed for 30 **DAYS**
  - 65-75 PPM if exposed for 60 minutes
- No symptoms – call an authorized Contractor
- Symptoms – call 911

Based on 10% COHb level, table last updated 11/14/01

TruTechTools

Low Level Alarms

- Alarm as low as 7 ppm
- Protects the infirm, infants, elderly and housebound
- Additional peace of mind
- Recommended for weatherized homes

TruTechTools

Why test an unadjustable appliance??

- It is installed in a dynamic environment!!
  - Affected by pressures in the combustion air zone (CAZ)
  - Affected by fuel pressure
  - Affected by changers in blower speed
  - Affected by duct sealing
  - Affected by the environment it is installed in.
  - Affected by the installation itself
  - For the safety of yourself and the consumer!!!

TruTechTools

So, why safety and performance Test?

- Insure Appliance Safety
- Minimize your Liability
- Improve Preventive Maintenance & Fuel Savings (commercial accounts)
- Improve Company's Professional Image
  - Demonstrate to equipment mfr.
- Increase Company's Profits
  - Quicker service calls
  - Minimize call backs
- Satisfy your Customer's Interest & Security
- National installation verification programs
  - Coming in future

TruTechTools

Why to avoid nuisance lock-outs

TruTechTools

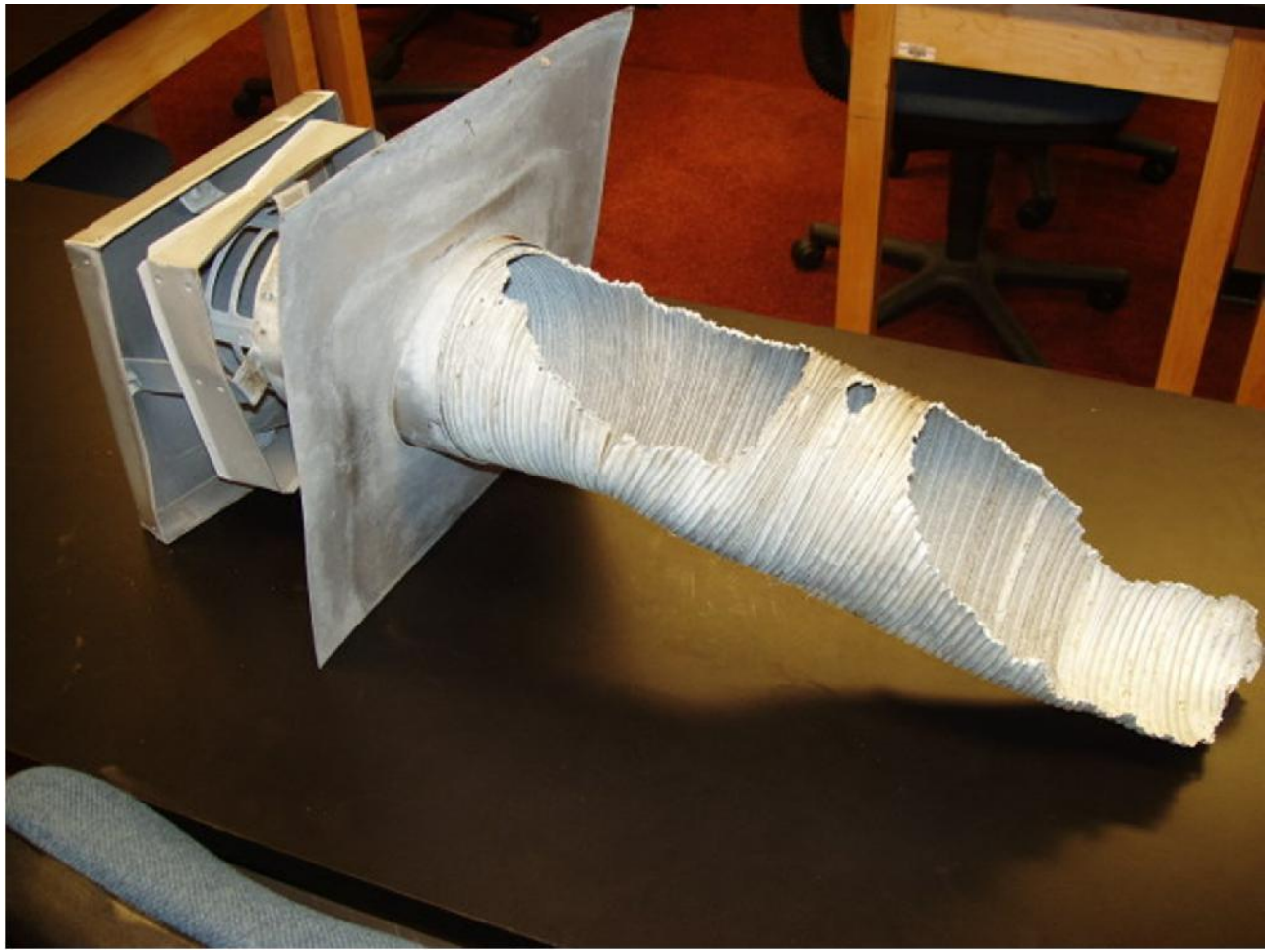
And….. Because everyone does such GREAT routine maintenance!!!

Combustion air intake in a boiler room!!!

mmm TASTY…

TruTechTools

And… Because things like this never happen….



Damage from condensation

TruTechTools

And….If it looks good outside…….

It must look good inside too…..

TruTechTools

Safety Testing
Combustion Analyzers
When & how to make a CO measurement

- Zero adjustment important
  - How to handle in contaminated environment
- In the flue
  - Undiluted sample
  - “Core Sample” (Hot spot)
  - CO-Air free or undiluted samples
- Ambient
  - Near combustion sources
- Unvented Combustion Appliances

TruTechTools

CO "Air Free Measurements

- "Air-free" or undiluted samples
  - CO **Undiluted** = CO x 20.9/(20.9-O_2)
  - Corrected for excess air dilution
- Requires an oxygen sensor
  - combustion analyzer
- Usually used for Appliance Measurement
  - E.g. Un-vented Ovens and Ranges
- ANSI Z21.1
  - <400 PPM CO, Measured on an Air Free basis in the flue gases

TruTechTools

Notes on NOx

- NOx = Oxides of Nitrogen
  - NO, NO_2 , N_2O_5 , etc.
- Created by N_2 in air flame or in fuel
- NO converts to NO2 in ambient conditions
- NO “fools” a CO sensor!
  - Factor of 0.4 to 0.5
    - For example 100 ppm NO = 40/50 ppm false CO
  - As does Hydrogen – at ultra-low excess air values

TruTechTools

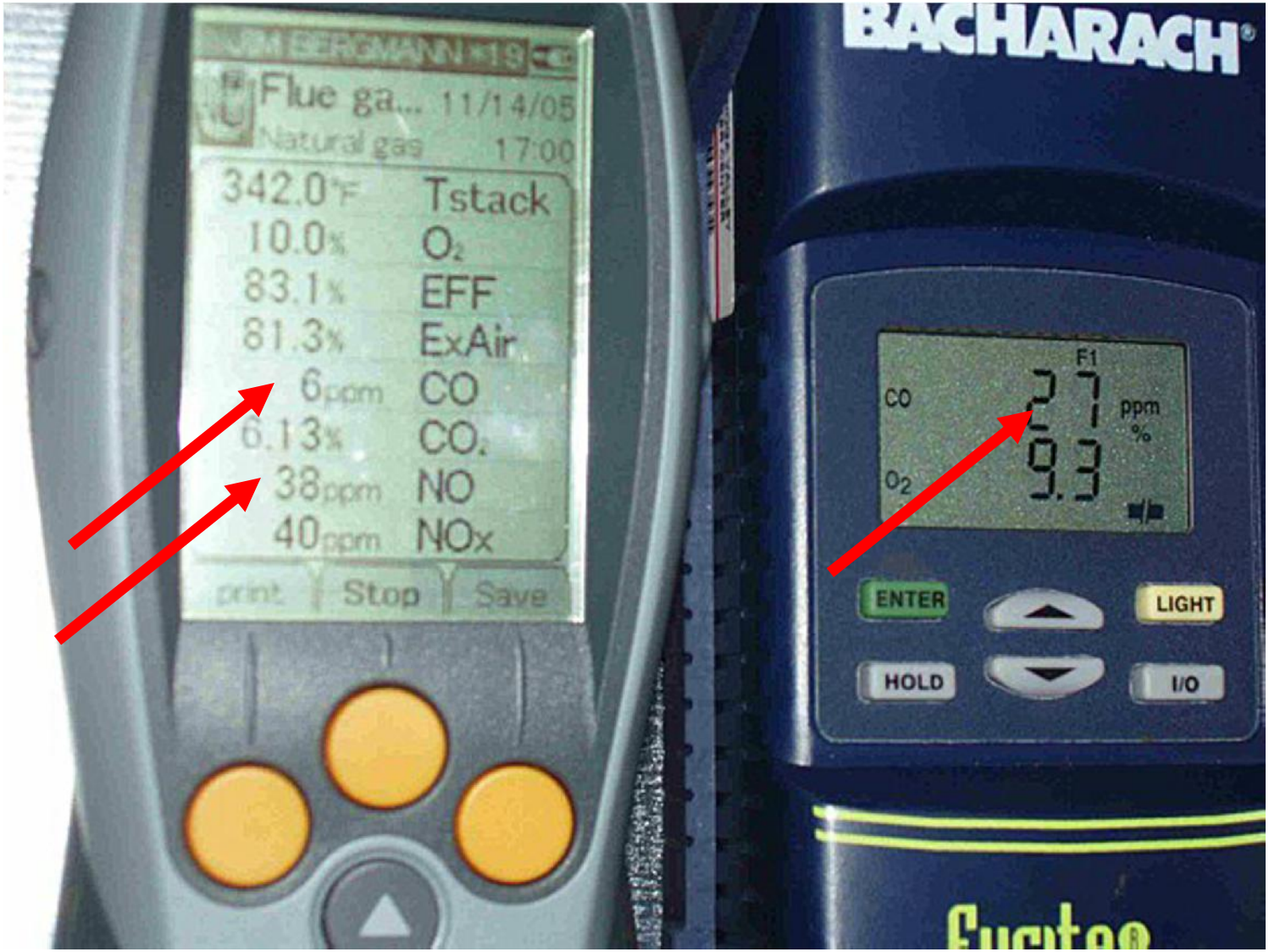
When CO matters

Never measure without a NOx filter

- Comes standard on all Testo
- Available for Bacharach products

And it always does!

TruTechTools



At 40 ppm NOx, an unfiltered CO sensor is off by 21 ppm

TruTechTools

Performing a Complete Combustion Analysis

TruTechTools

Single Gas CO/O_2* Monitors

- Save Lives
- Always on
- Auditory (Beeps)
- Visual (Flashes/display)
- Vibrate (Sensit P100)

* *For confined space entry- commercial*

TruTechTools

Date: ***04/18/2009***
Location: ***Hampton Inn, Richfield, OH***
Event: ***HVAC Protech Training Symposium***

While eating Breakfast!

Personal CO Detector Alarms!

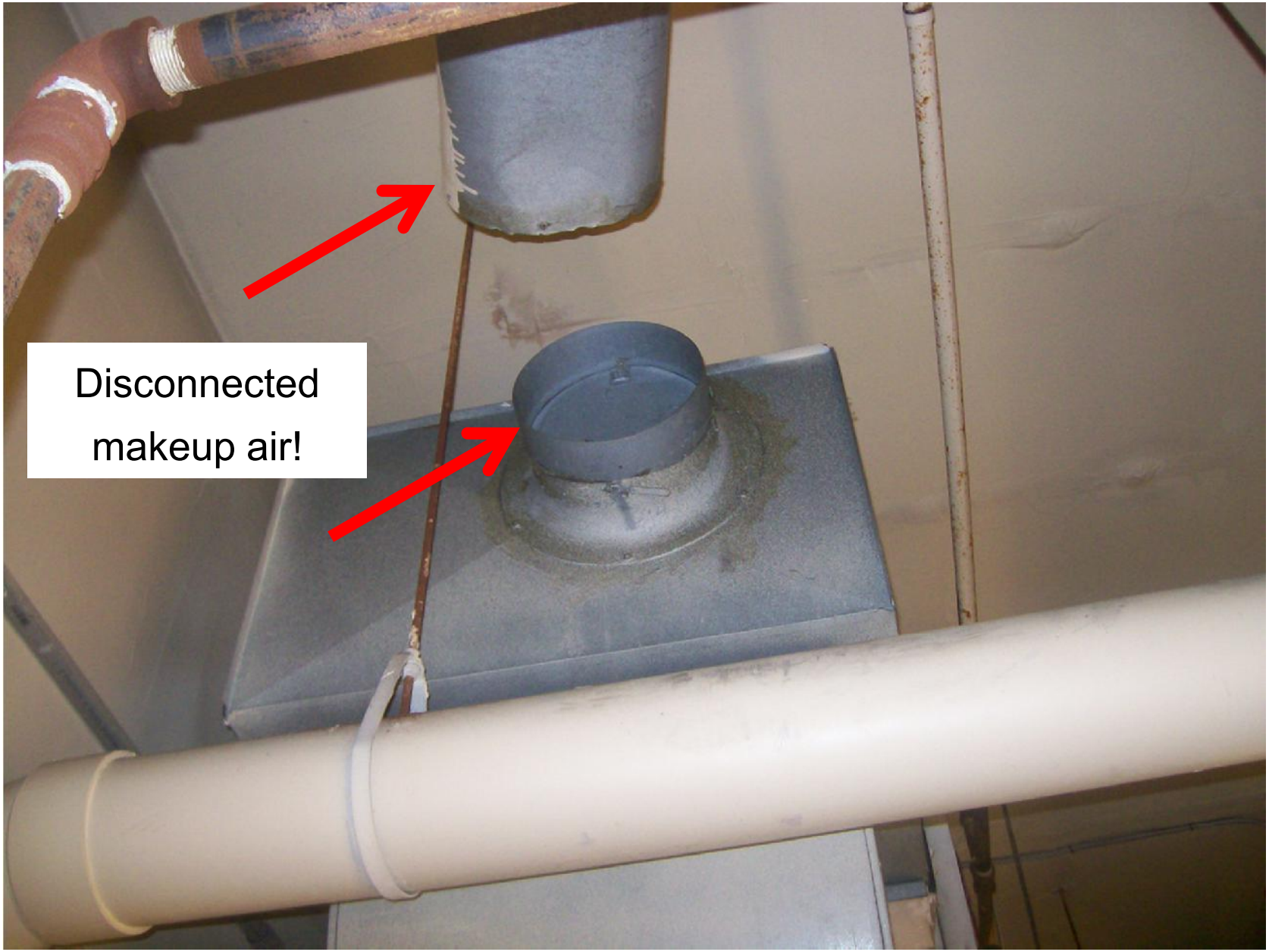
- 35 ppm hotel lobby
- 56 ppm hotel hall
- CO climbing going toward boiler room

At this point what do you do?

TruTechTools

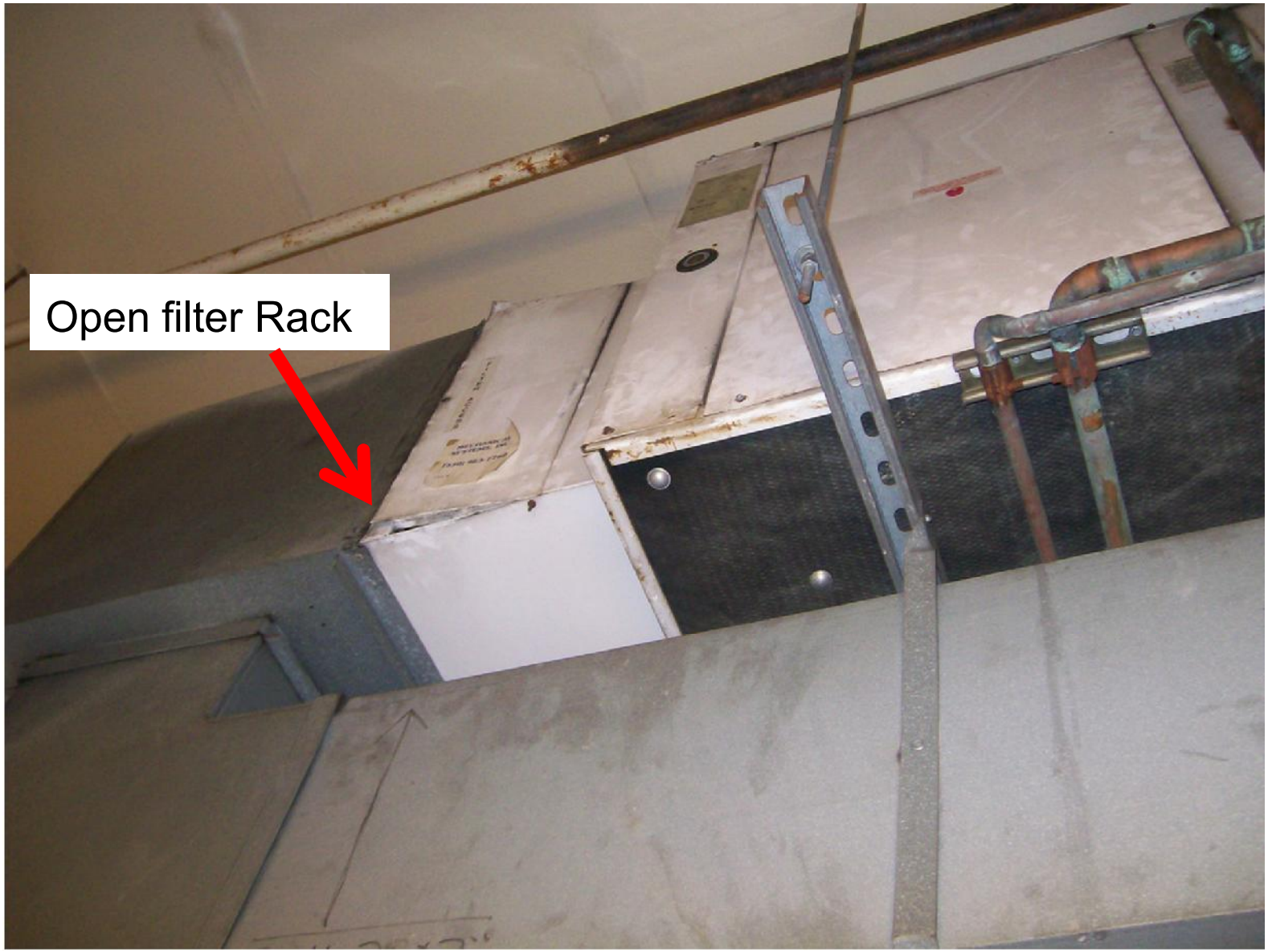
TruTechTools

Above 35PPM
Fire Departments use a SCBA



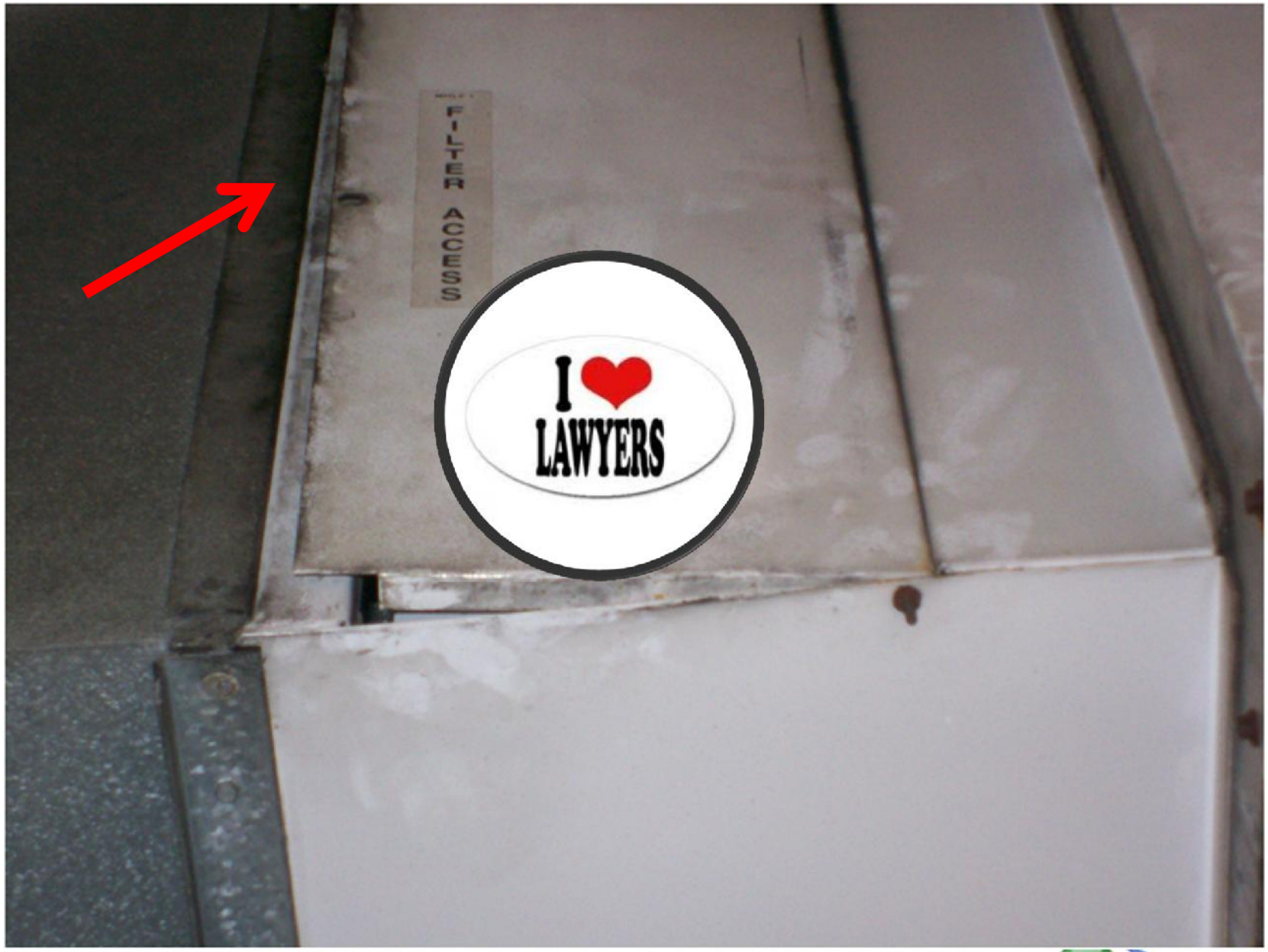
TruTechTools

TruTechTools


Open filter Rack

Take time to look!
If you don't
Somebody else will!

TruTechTools



TruTechTools

Dear Tech/Contractor

THE BUILDING IS A SYSTEM !

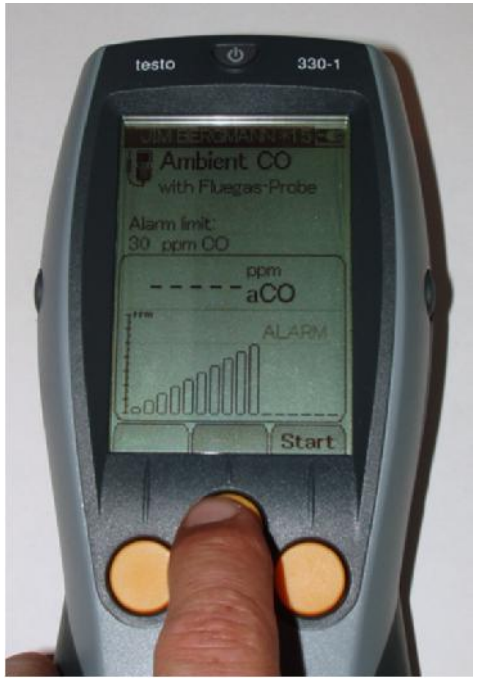
Sincerely,

The Building Science Community

Step1
Ambient CO testing

Prior to entering an existing home or boiler room installation

- **ambient CO levels should be checked continuously!**
- **equipment should be run through a complete cycle**



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

WARNING: If at any time during this test ambient CO levels exceed 35 ppm stop testing. If above 100 ppm vacate then ventilate

TruTechTools

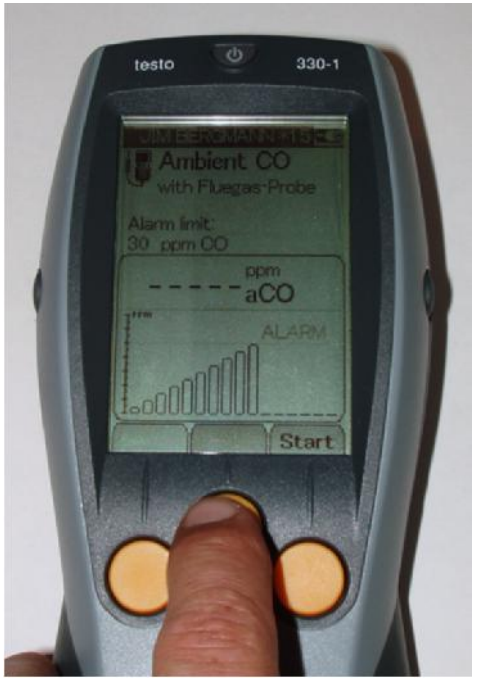
Ambient CO testing

- Zero the analyzer outside if required
- Test all levels of the home
- Test around the heating appliance and hot water tank at all times during testing
- If ambient CO levels exceed 35 ppm at any time during testing turn off the appliance immediately and make repair recommendations.
- If levels above 100 ppm are detected, vacate then call 911 from outside.
  - Leave the front door open on the way out.

TruTechTools

Combustion Analyzers
CO
How to interpret measurements

- Test for ambient CO from front door to the combustion appliance
- Pressure conditions (fans, appliance, etc.)
- Room air and flue gas sampling
- Print info with date and time
- Instrument accuracy vs. resolution
  - +/-5% accuracy; 1ppm resolution



TruTechTools

Step 2
Ventilation Air Testing
Create Worst-Case

- Required by BPI (Building Performance Institute)
- Not part of the National Fuel and Gas Code but recommended by it
- Monitor CO and the stability of the combustion process during this test!
- Watch for spillage and rollout!

TruTechTools

The question is…

Will I create enough competition to back draft the heater or water heater?

TruTechTools

Worst Case Depressurization

Practical Limits

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

Courtesy BPI Standards

TruTechTools

Spillage Testing under worse case

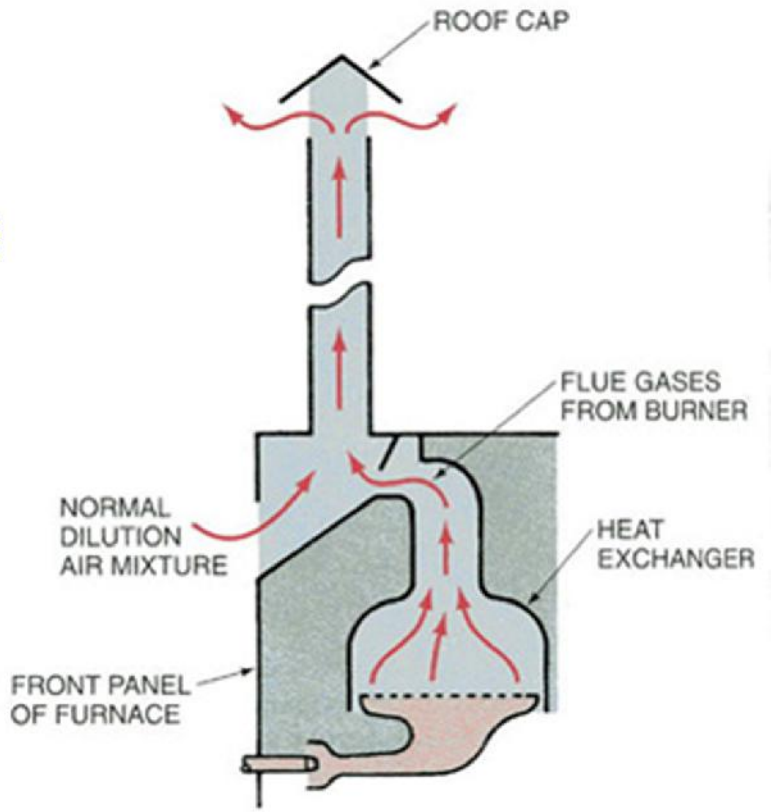
- Test ½” down and ½” out from the edge of the draft hood
- Test the entire hood left to right or 360°

After 1 minute of operation is the flue gas pulled up the hood?

TruTechTools

Step 3
Test Draft

- Draft removes flue gasses
- Controls flow through the heat exchanger*
- Must be established with 5 minutes
- Measured when at its maximum (hot stack)



TruTechTools

Draft Hoods

Separates the draft from the appliance.

Because the draft pressure is below the house pressure the flue gasses and dilution air flow from high to low pressure

Spillage occurs when the draft is overcome or simply not enough.

TruTechTools

Draft Testing under worse case

- Test at least 2x the diameter of the flue from the draft hood
- Hold the test probe perpendicular to the stack when testing.

After 1 minute of operation is the flue gas pulled up the hood?

TruTechTools

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

Acceptable draft readings for common ambient temperatures

>10°F (-2.50)	30°F (-2.00)	50°F (-1.50)	70°F (-1.00)	>90°F (-0.50)
20°F (-2.25)	40°F (-1.75)	60°F (-1.25)	80°F (-0.75)	

Excessive draft lowers appliance efficiency!

Not enough draft compromises safety!

Courtesy BPI Standards

TruTechTools

BPI Standard
Acceptable Draft Test Ranges

Outside Temperature (degree F)	*Minimum Draft Pressure Standard (Pa or Pascal)*
less than 10	***-2.5***
10	-2.5
12	-2.5
14	-2.4
16	-2.4
18	-2.3
20	-2.3
22	-2.2
24	-2.2
26	-2.1
28	-2.1
30	-2.0
32	-2.0
34	-1.9
36	-1.9
38	-1.8
40	-1.8
42	-1.7
44	-1.7
46	-1.6
48	-1.6

Outside Temperature (degree F)	*Minimum Draft Pressure Standard (Pa or Pascal)*
50	-1.5
52	-1.5
54	-1.4
56	-1.4
58	-1.3
60	-1.3
62	-1.2
64	-1.2
66	-1.1
68	-1.1
70	-1.0
72	-1.0
74	-0.9
76	-0.9
78	-0.8
80	-0.8
82	-0.7
84	-0.7
86	-0.6
88	-0.6
90	-0.5
More than 90	-0.5

table courtesy of

www.TruTechTools.com
888-224-3437
info@TruTechTools.com

No Draft?

Return to natural conditions!

Still no draft?

Stop here until CAZ problems are fixed

TruTechTools

What causes typical failures?

Too little draft

- Too much competition for air
- Not enough air available
- Blockage in the chimney
- Poor system design
- Duct leakage

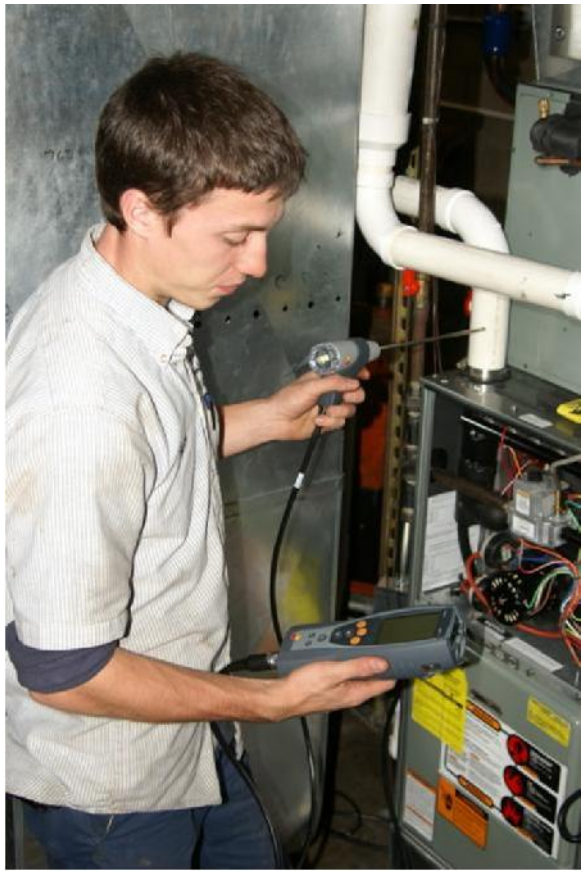
Too much draft

- Oversized chimney
- Excessive stack temperatures
- Power vent equipped

TruTechTools

Step 4
Test In Under **Worst Case** Conditions

- Combustion test through a full cycle
- Print out the measurements and calculations
- Verify they fall within manufacturers' specifications if available
- Record as pretest results



TruTechTools

Testing and Examining Heat Exchangers

TruTechTools

3 Step Heat Exchanger Examination

- Flame Disruption Test
  - Blower cycling disrupting flame
  - Minute airflows at cell exit with blower
- Visual examination
  - Mirrors & Scopes
- Chemical Test
  - Methane fill, gas leak detection
  - Sodium ion (salt spray test)
  - O_2 Oxygen change in flue

Mfr. std (1/8” hole equiv. leakage)

- Impossible to do in field

“Industry standard” – 1986 most current

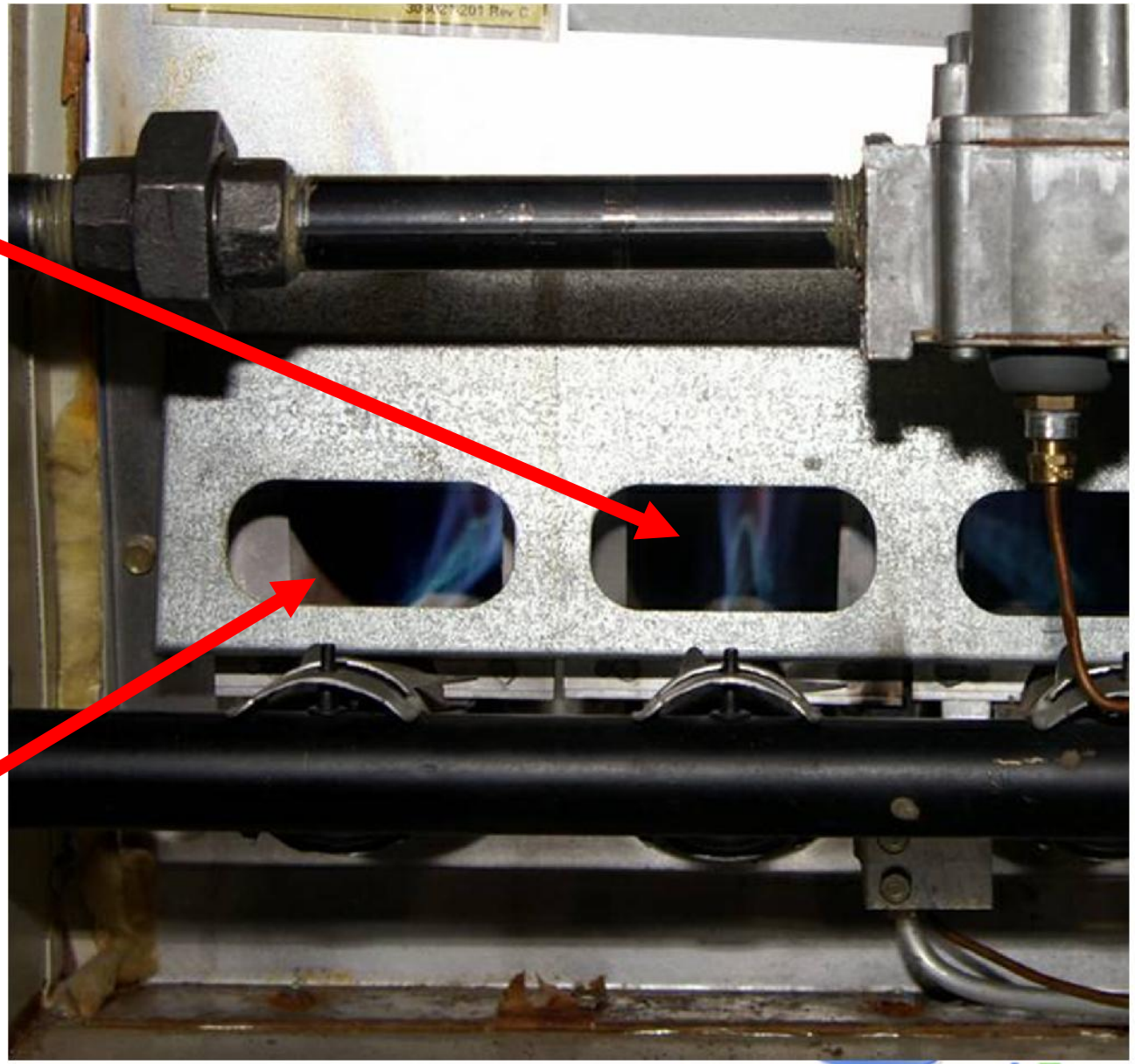
GAMA adopted RSES Pub. 630-9296/86

TruTechTools

Flame disruption test

Normal Flame

Flame affected by blower disruption

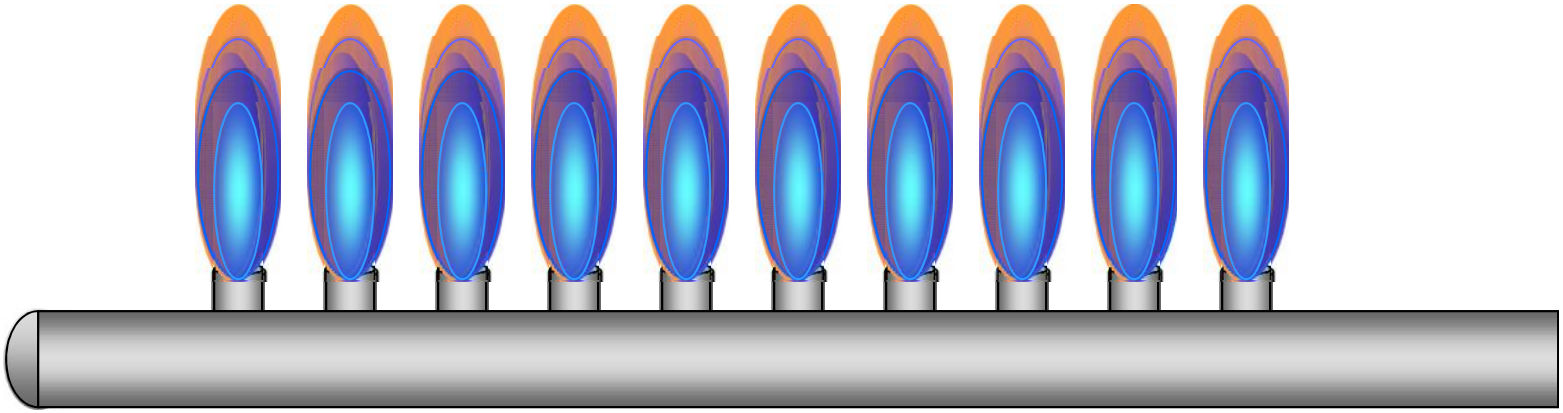


TruTechTools

What should a flame look like to the eye?

Blue with slight orange tipping and stable!

The orange in the flame is the result of dust particles drawn in with the primary air



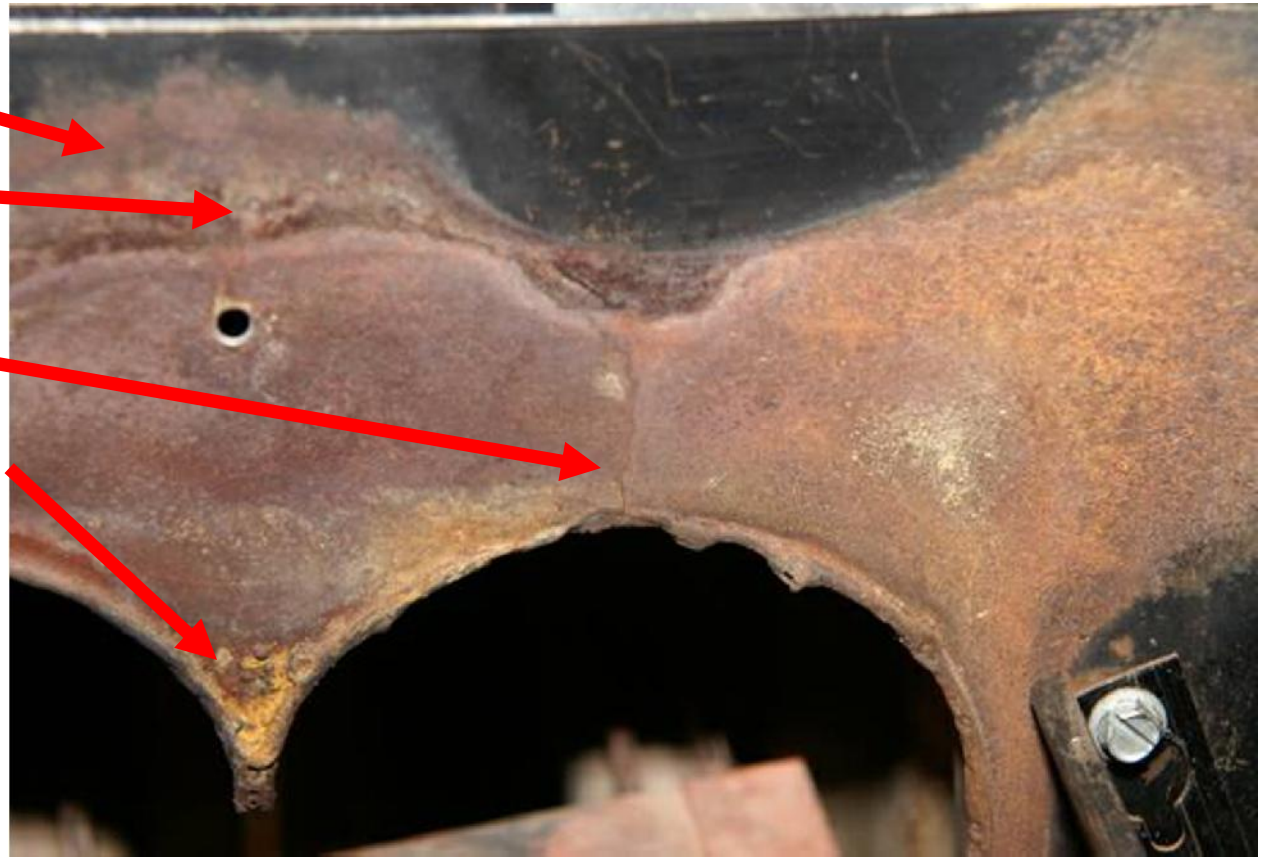
There should never be YELLOW TIPPING of the flame.

TruTechTools

Visual Examination

Look for the signs

- **Rusting**
- **Staining**
- **Cracks**
- **Failures at welds**
- **Holes**
- **Pitting**



TruTechTools

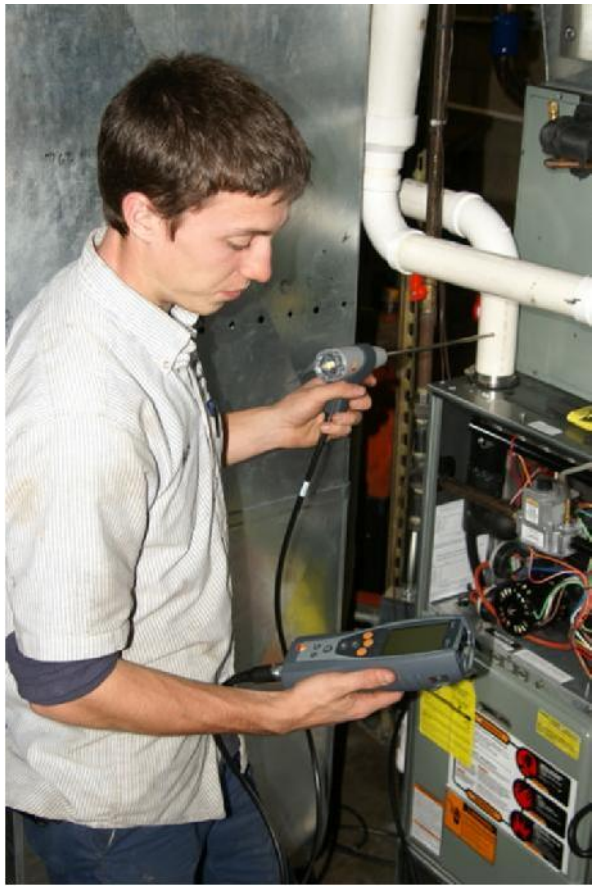
Cracks leak in as often as out.

If not more so!!!

TruTechTools

Chemical Test O_2

- Start the furnace with the blower off
- Watch for O_2 to stabilize
- Observe the O_2 when the blower starts
- If the O_2 increases, a high probability of a crack exists
- Repeat the test to verify
- Try to visually find the crack or air leak into the heat exchanger



TruTechTools

Severe rollout caused by heat exchanger blockage.

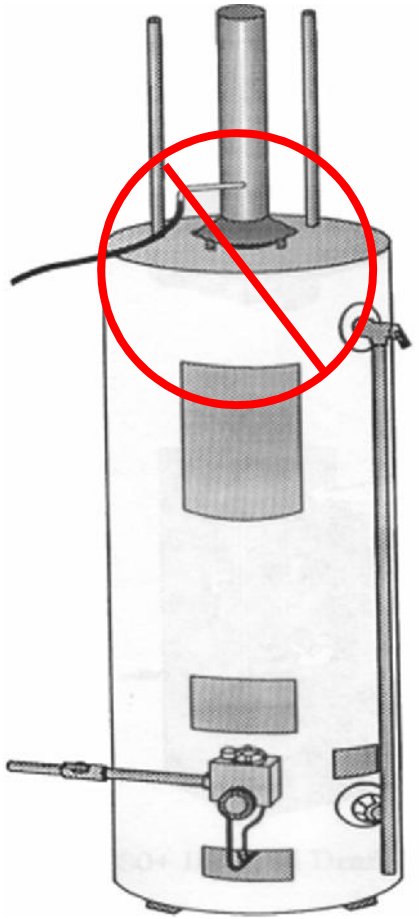
“Facts on Cracks”

in Heat Exchangers

- Cracks or holes do not ***necessarily*** cause CO
- Cracks are pathways for flue gas to mix with room air
- Corrosion, discoloration and mineral deposits are signs
- Cracks may have appearance of rust lines
- Cracks or corrosion occur because:
  - Uneven air flow over HX
  - Clogged filters
  - Heating and Cooling Down
  - Improper Venting

CO Testing...
Fuel Burning Appliances

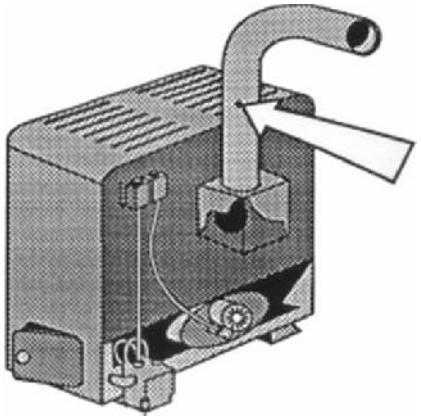
- Sample from entry to exit
- Sample around all un-vented appliances
- Sample before draft diverter of atmospheric devices
- Sample where you may suspect CO

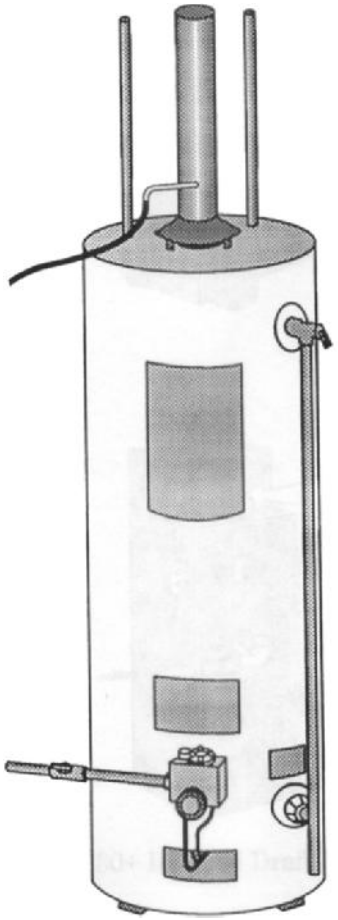


TruTechTools

Other equipment that requires testing

- Hot water heaters
- Vent-free space heaters
- Gas ovens and cook tops





Compliance Section

For service

Technicians ONLY

TruTechTools

Step 5
Test and adjust the appliance

- Perform manufacturer recommended maintenance or commissioning procedure

  to

- Verify Safety
  - CO levels
  - Draft
- Verify compliance
  - Installation
  - Operation

TruTechTools

Two Types of Appliances

- Non adjustable primary air
- Adjustable primary air
  - With or without pressure switches

TruTechTools

Non-Adjustable Appliances

1. Set fuel pressure
2. Verify input (clock meter, check orifices)
3. Adjust blower for correct temperature rise
4. Verify proper operation of safeties
   - Limits
   - Pressure switch
   - Spill switches
   - Pilots (turn down test)

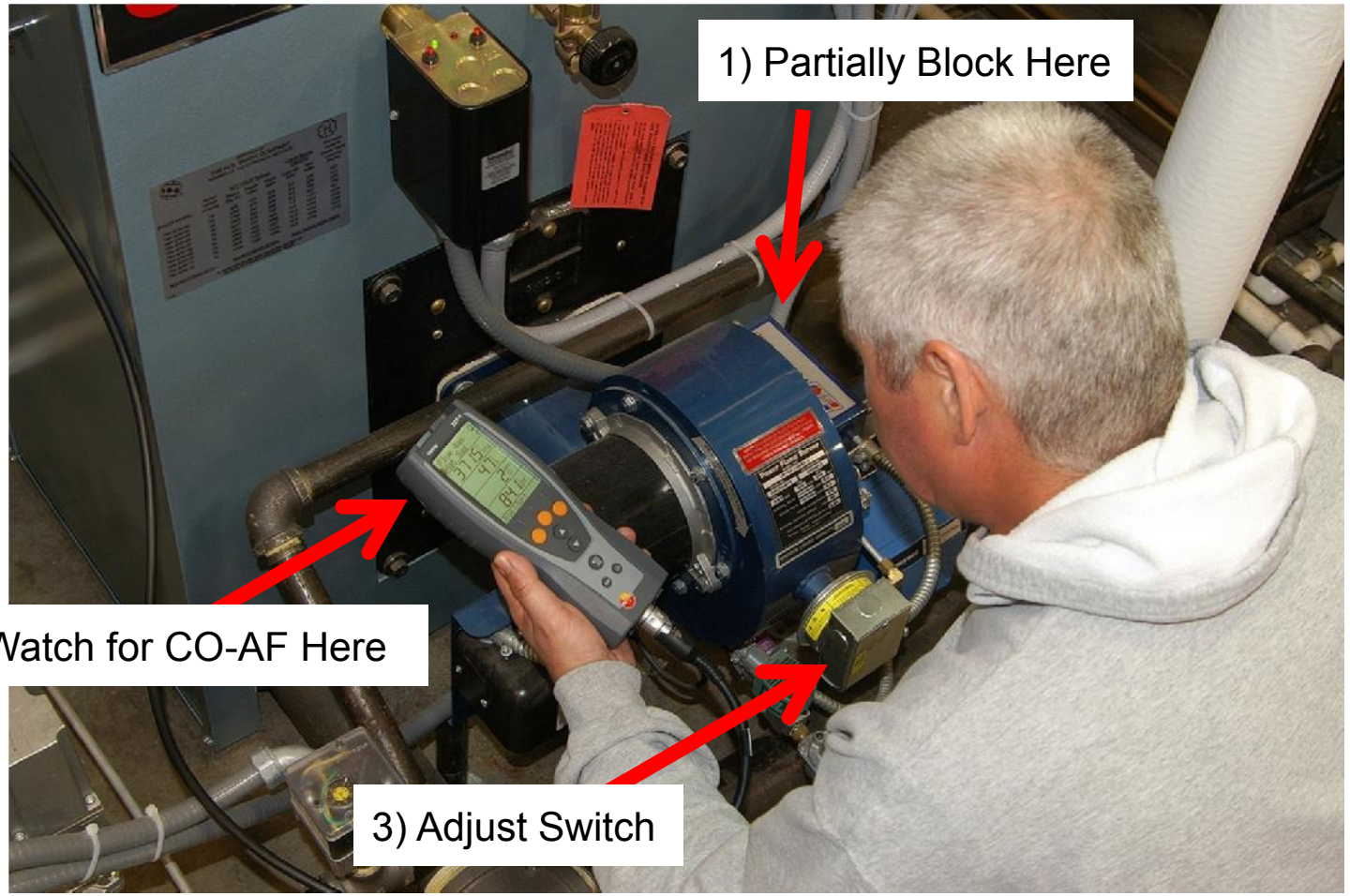
Adjustable Appliances

Same as nonadjustable +

5. Verification of proper operation of the adjustable combustion/draft proving air pressure switch
   - Slowly block air inlet to burner while monitoring CO-AF
   - When CO-AF starts to rise, adjust pressure switch to cut out at that point.
   - CO-AF can not exceed 400 ppm at any time during operation.

TruTechTools

Setting the Pressure Switch



TruTechTools

Combustion Air Adjustment

Set to manufacturer's recommended stack O_2 reading

If not specified, set to (2X) the O_2 level measured at the pressure switch cut out setting.

(Recommend: Never less than 20%)

Example cut out 10% O_2, set primary air shutters to 20%

TruTechTools

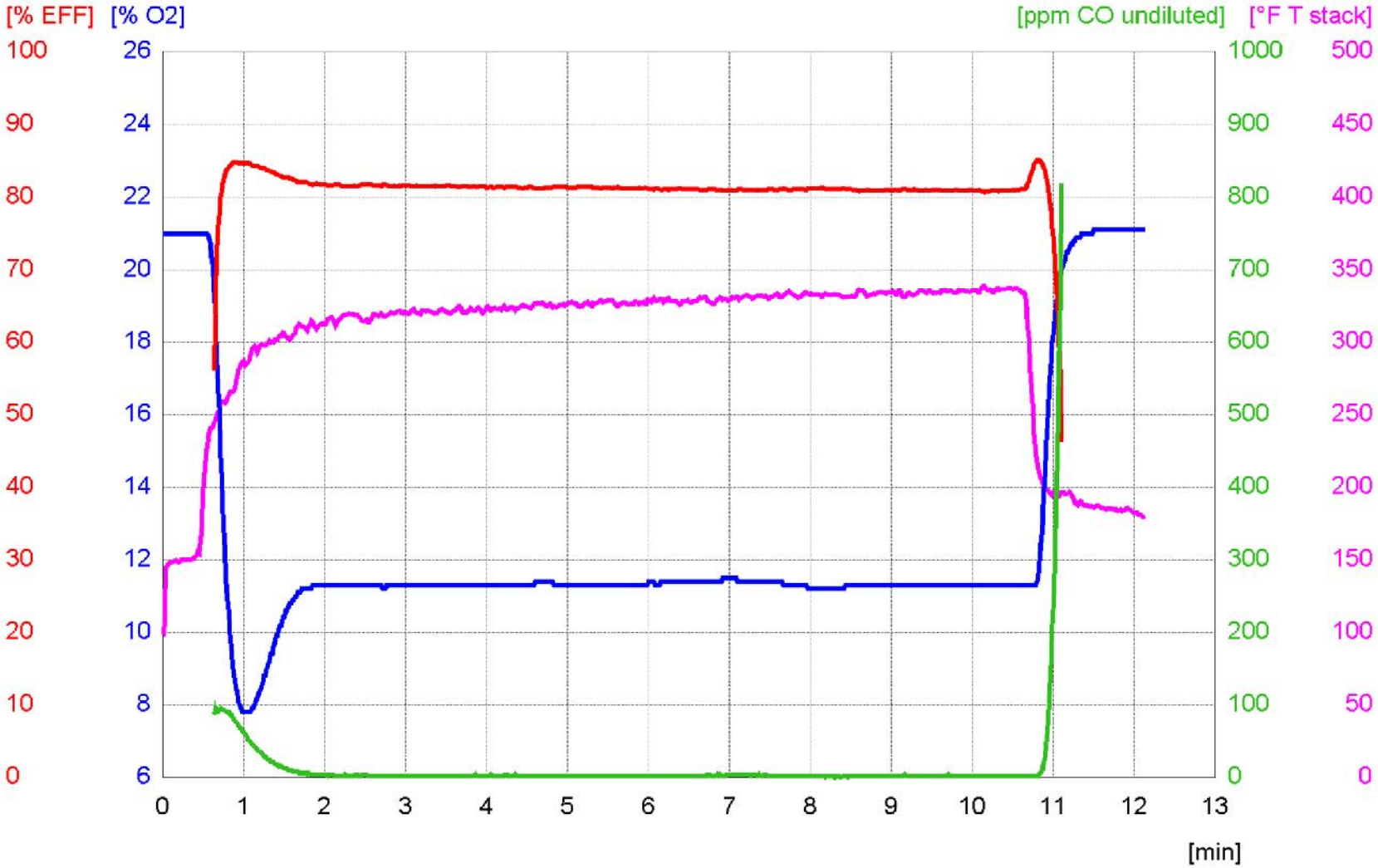
Consistency

Step 6
Verify Consistency

- Safe & Stable
  - Combustion!
  - Draft
  - Flames

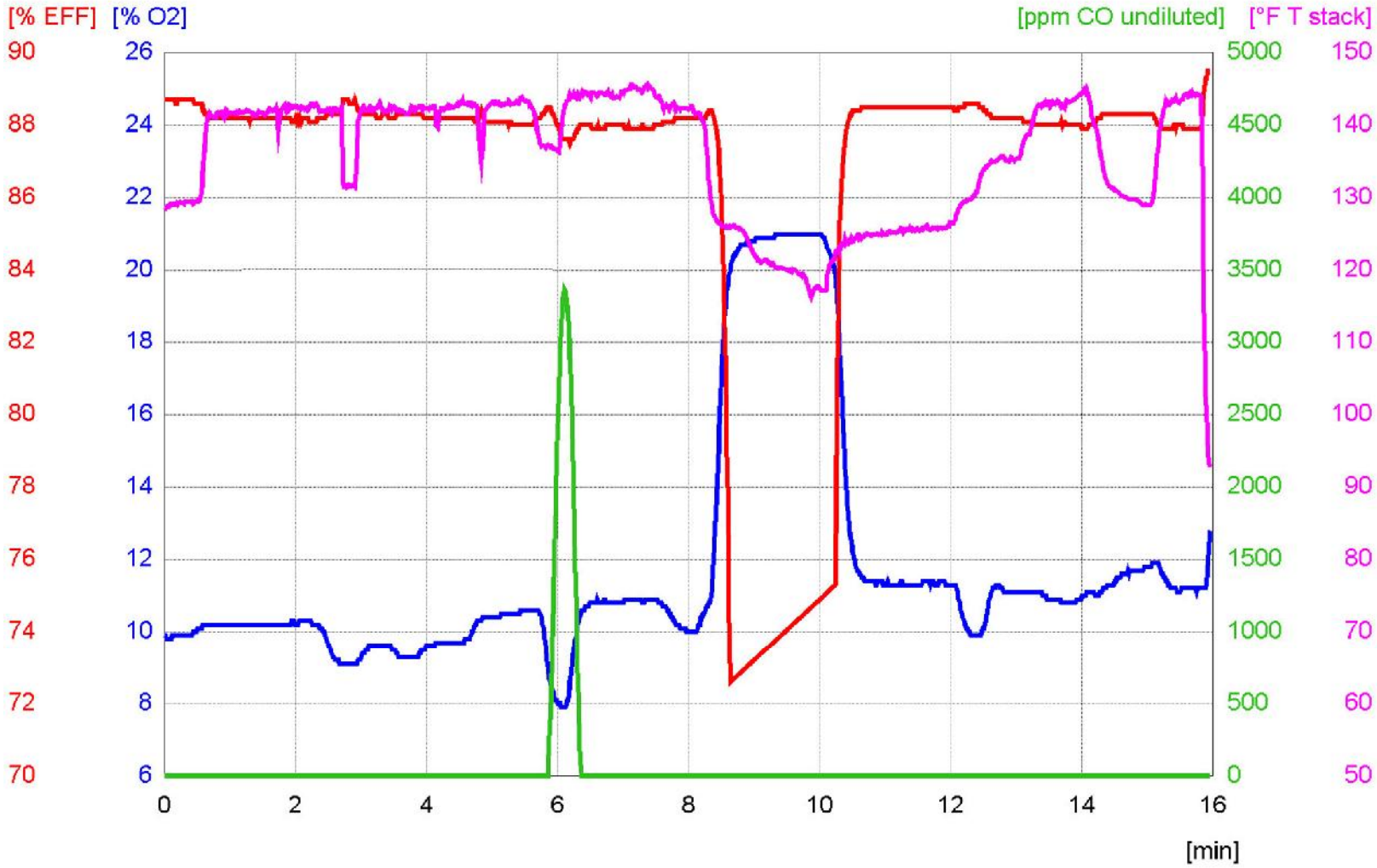
TruTechTools

Normal operation



TruTechTools

Combustion Ventilation air problems



TruTechTools

Low or Falling O_2

- Obstruction of heat exchanger cells due to rust, warping, or blockage
- A blocked vent or vent connector on draft assisted appliances
- Blocked flue or collapsed liner
- Recirculation of flue gasses in the CAZ
- Lack of combustion, dilution and ventilation air.

TruTechTools

High or Rising O_2

- Air leakage into the heat exchanger after the point of combustion
  - Leakage in a heat exchanger of a furnace
  - Cleanouts on draft induced boilers.

Can be extremely dangerous when leaks in the cell rob secondary air from the combustion process resulting in formation of CO.

High or Rising CO

- Obstruction of heat exchanger cells due to rust, warping, or blockage
- Blocked vent or vent connector on draft assisted appliances
- Blocked flue or collapsed liner
- Recirculation of flue gasses in the CAZ
- Lack of combustion, dilution and ventilation air
- Excess primary air quenching the flame
- Flame Impingement / burner alignment

Low or Falling CO

- Desirable and normal operation
  - (No CO is perfectly normal.)
  - Delayed ignition (oil or gas)
  - Fuel oil hitting the refractory (oil)
  - Fuel after-drip (oil)
  - Fuel delivery problems (oil)

TruTechTools

High / Rising / Erratic Stack Temperature

- Changes in air pressure in the CAZ
- Air leakage around combustion air probe
- Low or insufficient heat transfer
- Over fired/high input
- Low airflow/water flow across a heat exchanger
- Soot or rust between the cell sections of boiler

Note: With non-condensing appliances a certain amount of 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.

TruTechTools

Low or Falling Stack Temperature

- Under fired, Low fuel pressure
- Excessive airflow (high blower speed) or excessive water flow across the heat exchanger
- High amounts of excess air
- Low return air or water temperatures.

Results in heat exchanger failure do to corrosion, moisture problems, vent connector failure

TruTechTools

Low or Decreasing Draft

- High outdoor air temperature
- Vent connector blockage
- Vent blockage
- Undersized chimney
- Poor vent installation (height)
- Depressurization of the CAZ

Commonly results in pressure switch problems!

TruTechTools

Low or Decreasing Draft (2)

- 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)

TruTechTools

Excessive Draft

- Oversized chimney
- High stack temperatures
- Improperly adjusted power vent equipped appliance

Commonly results in excess heat going up the stack and related efficiency losses.

TruTechTools

Step 7
Combustion Test Out Under **Worst Case** Conditions

Perform a complete post combustion test if….

- You adjusted the blower speed
- Changed the fuel pressure
- Performed testing without panels or covers installed
- Air sealed anything including ductwork

TruTechTools

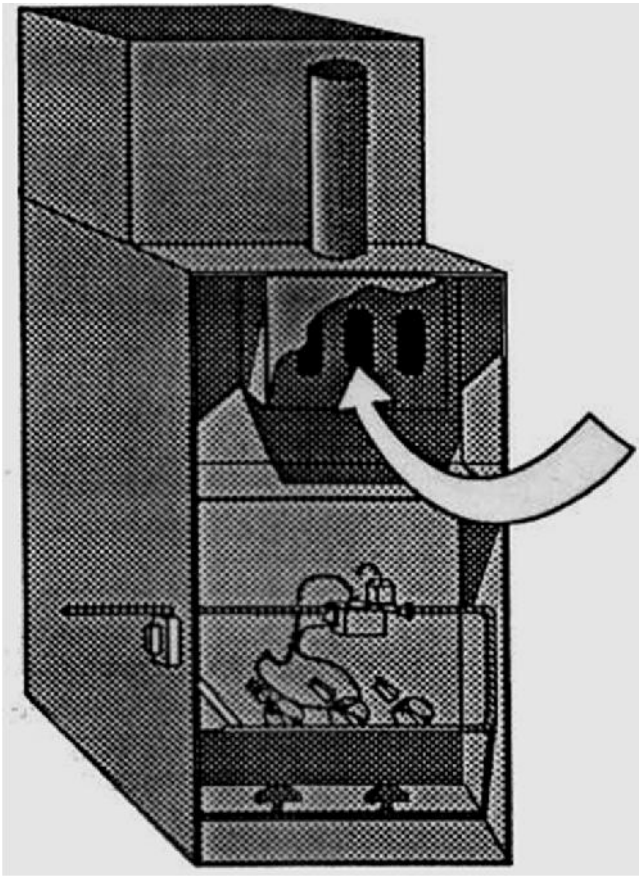
Testing Efficiency

TruTechTools

Testing…
Atmospheric,Warm Air Furnaces

- Steady State Operating Conditions
- Sample around CAZ (CO)
- Sample in the Heat Exchanger cells (EFF)
- Check CO around burner area
- Conduct Draft Test in Stack
- Check Fuel Pressure

- **Follow Mfr's Specs**

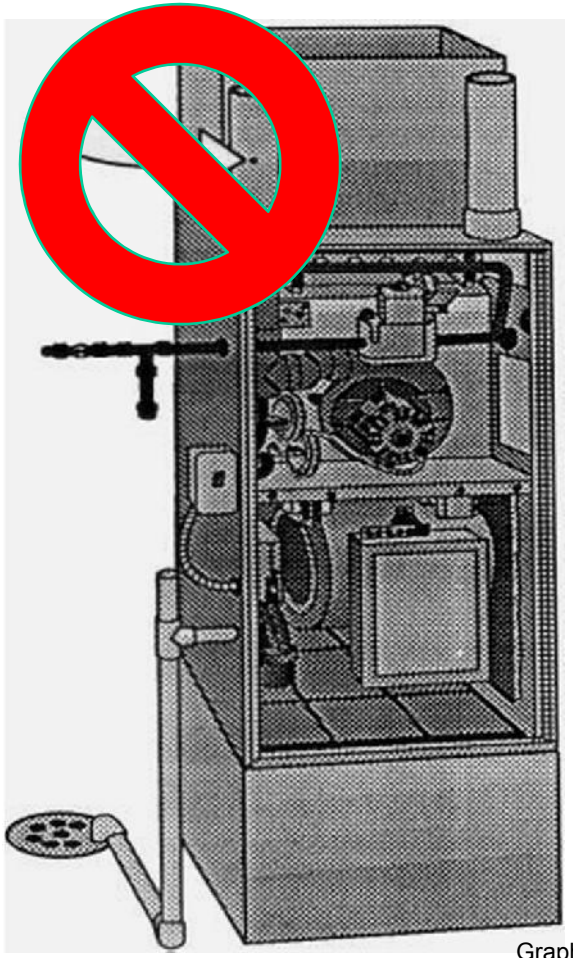


TruTechTools

Testing…
Condensing Furnaces

- Steady State Operating Conditions
- Sample around burner (CO)
- Sample Eff. in plastic vent pipe (MFG or authority)
- Or sample in stack termination (CO)

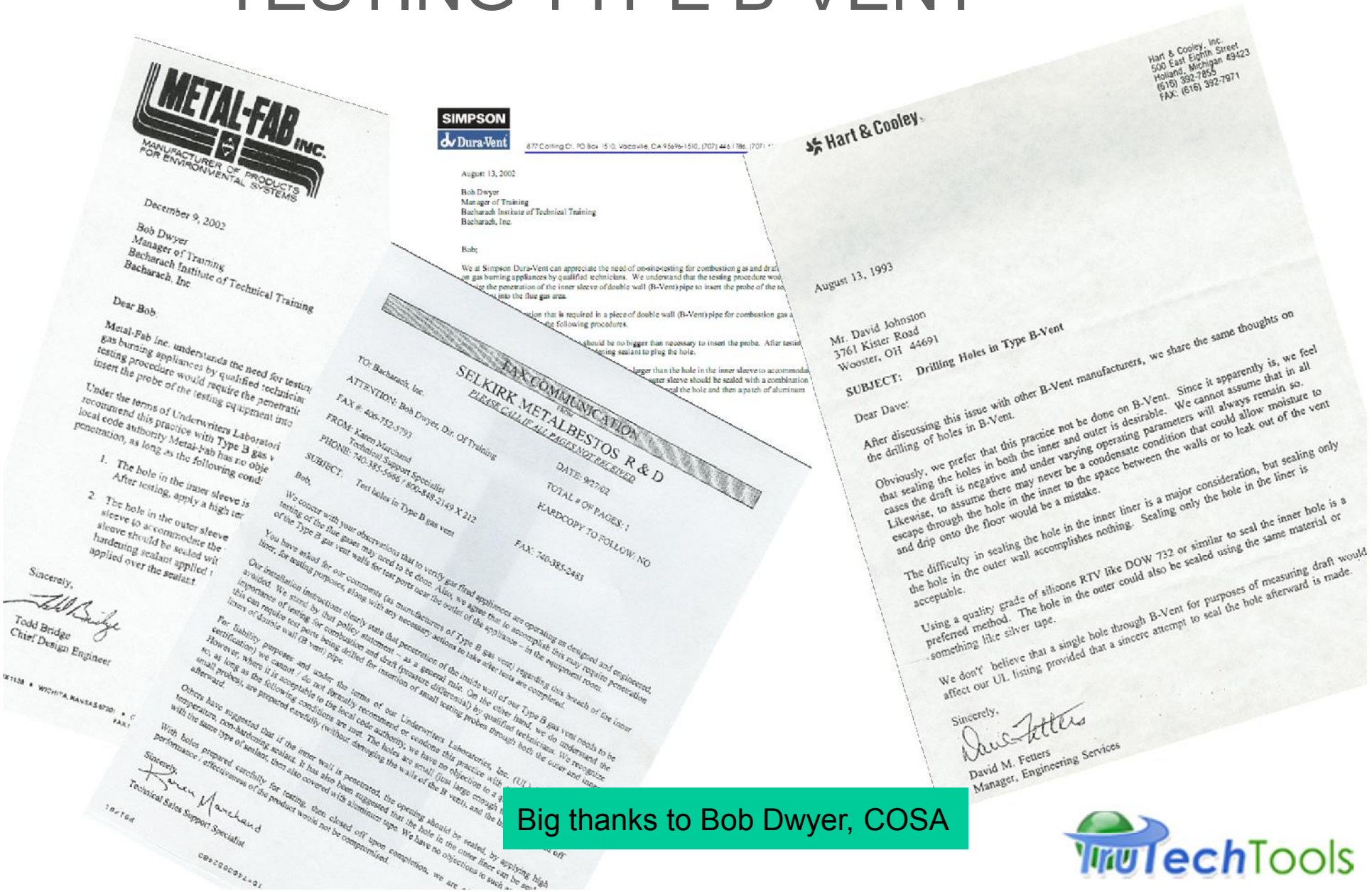
- **Follow Mfr's Specs**



TruTechTools

Courtesy Anthony Cox

TESTING TYPE B-VENT



Big thanks to Bob Dwyer, COSA

TruTechTools

Testing… Boilers

- Probe insertion from 1/3 to ½ into stack
- Sample during several firing rates
- Operate analyzer and make adjustments
- Tune for maximum eff. and safe,clean comb.
- **Always follow Mfr's Specs**

Graphics Clever Brooks

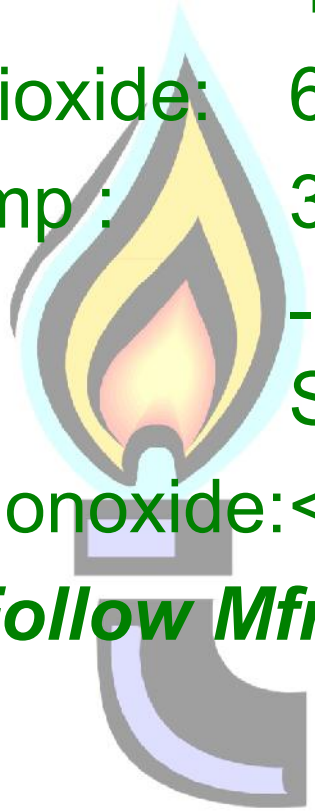
TruTechTools

Typical Combustion Readings

TruTechTools

Typical Readings

- Atmospheric Gas Fired Burners
  - Oxygen : 4 % - 9 %
  - Carbon Dioxide: 6.5 % - 8 %
  - Stack Temp : 325 ºF to 500 ºF
  - Draft: -.02“WC to -.04“WC in the Stack
  - Carbon Monoxide:< 50 ppm (undiluted)
  - ***Always Follow Mfr‘s Specifications***



TruTechTools

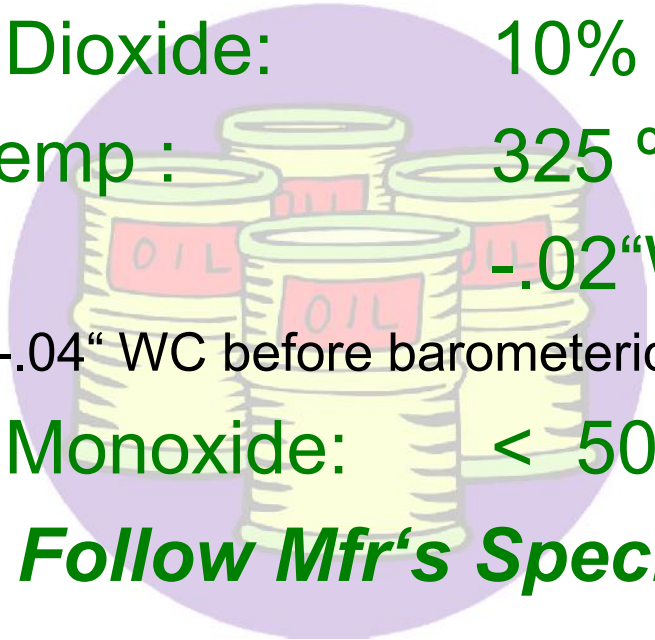
Typical Readings

- Gas Fired Power Burners / draft induced
  - Oxygen : 3.8 % - 6 % (as high as 13%)
  - Carbon Dioxide: 8.5 % - 11 %
  - Stack Temp : 275 ºF to 500 ºF
  - Draft: -.02“WC to -.04“WC in the Stack
  - Carbon Monoxide:<100 ppm (undiluted)
  - ***Always Follow Mfr‘s Specifications***

TruTechTools

Typical Readings

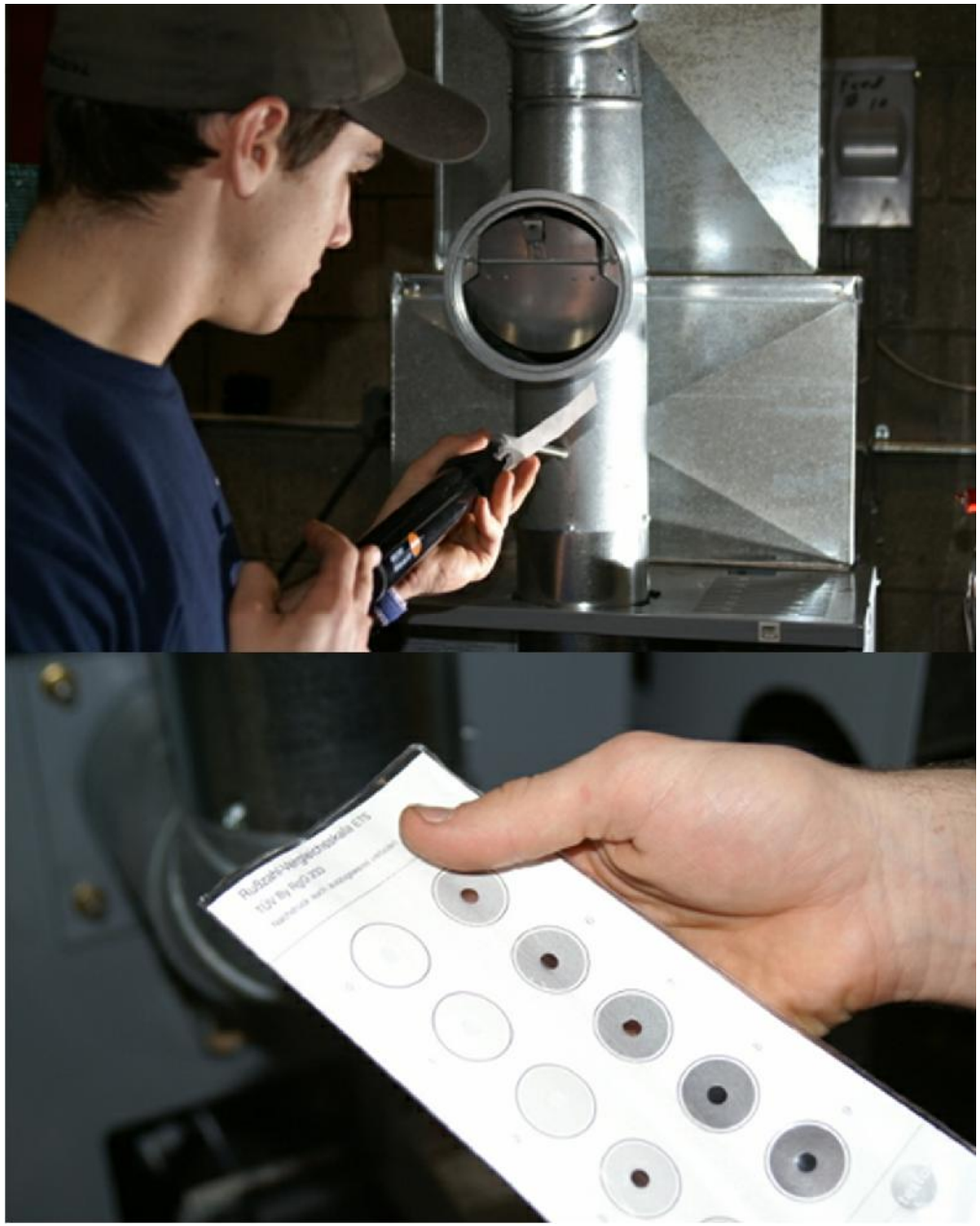
- Oil Fired Power Burners
  - Oxygen : 4% - 7 %
  - Carbon Dioxide: 10% - 12.5%
  - Stack Temp : 325 ºF to 600 ºF
  - Draft: -.02“WC Overfire
    - -.04“ WC before barometeric damper
  - Carbon Monoxide: < 50 ppm (undiluted)
  - ***Always Follow Mfr‘s Specifications***



TruTechTools

Measuring Smoke (Oil)

- Another sign of incomplete combustion
- Smoke scale reading:
  - 0 spot is recommended
  - >1 spot is not recommended
- Soot increases fuel consumption



Testo 308 Digital Smoke Spot Meter

Measures without pumping

Optically determines smoke spot number

Can transmit data to Testo 330

TruTechTools

Combustion Analyzers

Taking care of your investment and your results

- Calibration (~1 per year)
- Service
  - Pumps, filters and probes
- Storage temperature limits
  - Condensation
- Fresh Air Purge
- Sensor Range (CO)
  - Exceeding range can limit sensor life
  - Automatic over-range protection available in some models

TruTechTools

Care of Combustion Analyzers - The Basics

- Batteries
  - Proper type (Alkaline, battery packs or rechargeables)
  - New or fresh
  - Leakage
  - Do not mix old and new
  - Power supplies and rechargeables
- Cold storage
  - Impact on sensors
  - LCD displays
  - Batteries
  - Remaining condensate
- High temperature exposure
  - Analyzer body
  - Probes

TruTechTools

Filters

- Condensate and water traps
  - Emptying
  - Cleaning
  - Maintaining
  - Changing
  - Air tightness
- Particulates and filters
  - Cleaning
  - Maintaining
  - Changing

TruTechTools

Probes

- Thermocouples
  - Temperature exposure
  - Mechanical damage
  - Straining wires and plugs
  - Thermocouple connections
  - - wear and tear
- Hoses
  - Temperature exposure
  - Cracks and holes
  - Leak testing
  - Hose connections, seals, o-rings, lubes

TruTechTools

Pumps & Printers

- Pumps
  - Break down
  - Clogging
  - Cleaning diaphragms
  - Change out
- Printers
  - Fresh batteries
  - Proper paper loading
  - High temp exposure of printer paper (fade to black)
  - Use of "office supply" brands
  - Longer life papers (up to 10 years)

TruTechTools

Using your head!

- Read the manual
  - Familiarize yourself with analyzer before using – re-read before season starts
- What to look for if readings do not look right
  - Eg. An unusually high O2 or low CO2 reading is likely a sampling system leak, torn hose assembly, etc.
  - Do not lose faith in the unit.
- You **can** understand it!

TruTechTools

Products Needed

NECESSARY

- Combustion analyzer
- Smoke Spot tester (oil)
- Gas Leak Detector
- Digital Manometer with accessory
- Personal CO Monitor

NICE

- High res Digital manometer (0.1 Pa)
- Smoke Pencil/Puffer
- Visual Inspection Scope & Mirror
- Low Level CO Alarms (to re-sell)
- Heat Exchanger Examination guidebook

TruTechTools

BPI CEUs

- Your BPI # should have been entered at registration
  - If not email to *Marilyn@TruTechTools.com*
  - With your name and date of this webinar

TruTechTools

Thank you

for your time and attention!

Get a $10 TTT Gift certificate

for completing a

PRODUCT REVIEW of this webinar

on our site

See more from TruTech on YouTube®

The "jimbergmann3" channel

www.TruTechTools.com 888-224-3437

Bill Spohn, Co-Owner: Bill@TruTechTools.com

Jim Bergmann, Co-Owner: Jim2@TruTechTools.com

Eric Preston, Sales Manager: Eric@TruTechTools.com

TruTechTools

CO Analyzers
Basic & Advanced features

- Ambient or flue gas use
  - Sensor, probe, pump
- Zero adjustment
  - Important for low level measurements
- Calibration issues
- Digital display
- Draft/Pressure measurements (advanced)
- Differential Temperature (advanced)

TruTechTools

Tools for the Trade…
You should have the right tools

- **Thermometer**
  - digital that can read up to at least 900 F
- **Draft gauge**
  - U-tube, Magnehelic®, or digital manometer
  - Resolution: 0.01”WC; Accuracy: +/-0.01”WC
- **Electronic analyzer**
  - calculates efficiency, CO2, excess air
- **CO Analyzer for flue gas and room air**
  - Electronic with pump
- **Printer or PC**
  - Document and verify

TruTechTools

Electronic vs. Manual Kits

- One Device
- Sealed sensors
- Automatic pumps
- Digital readout
- Automatic calculations
- Continuous readings
- Automatic, “tamperproof” printouts saved at job site
- Time savings

- Many pieces
- Handling of chemicals
- Manual sampling
- Visual interpretation of reading
- Operation of slide rules
- Snapshot measurements
- Manually recorded data

TruTechTools

Selecting and Maintaining combustion analysis equipment

TruTechTools

Choosing the Right Instrument

Price

Amb-CO

CO

FG-CO

co

Combustion Analyzer

+ O2, calcs

Comm.-Ind. Analyzer

+ NOx, Data (USB)

Emission Analyzers

+ SO2, NO2, semi-continuous,

++

Features

TruTechTools

Analyzer features...

Digital readouts with automatic pumps

Continuous measurements

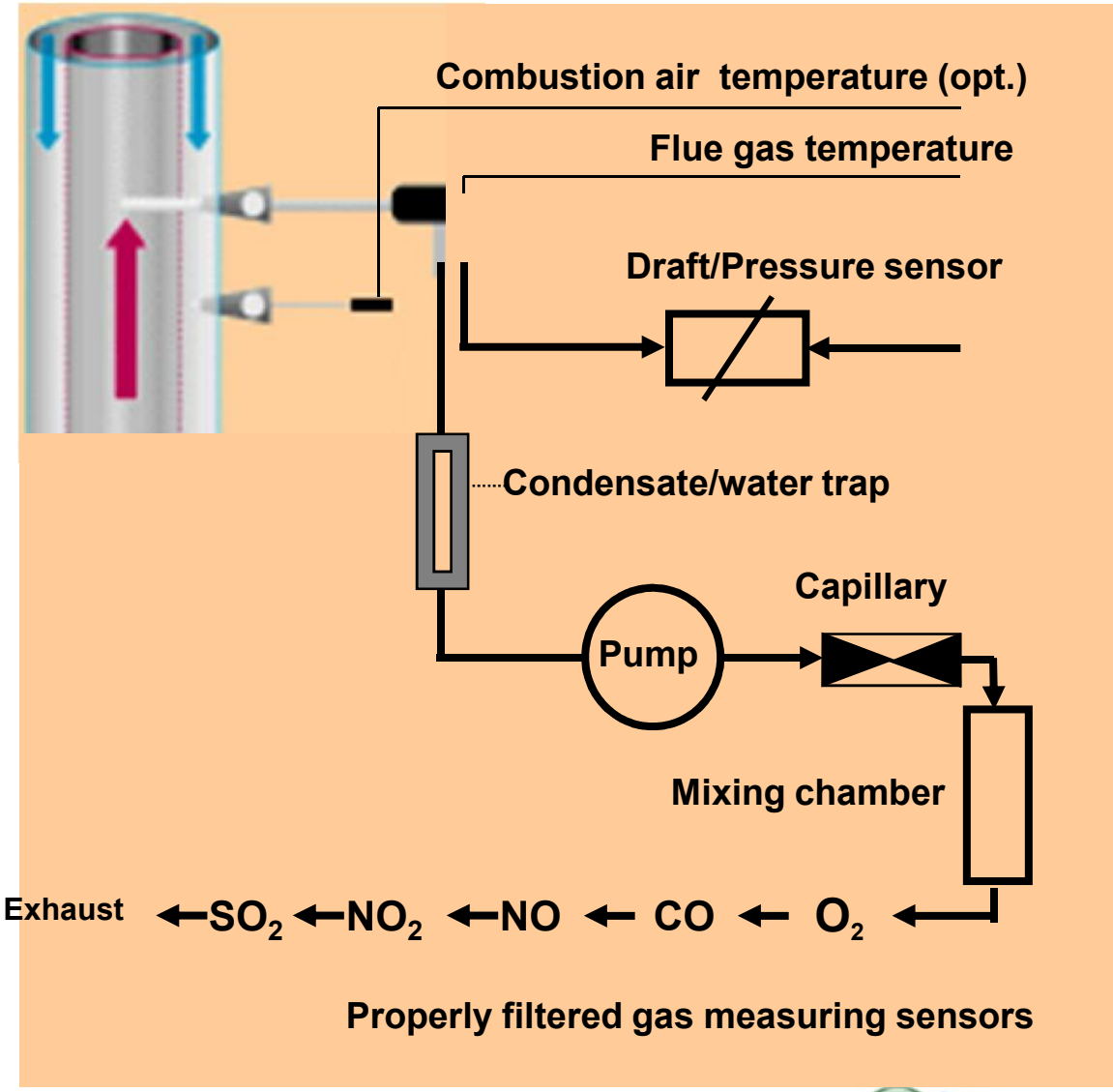
Integrated data recording, printing &

Simplified, professional computer reporting

Easy to use and field serviceable

TruTechTools

Design of a flue gas analyzer



TruTechTools

Combustion Analyzers - Basic features

- Ambient or flue gas sampling
  - Continuous Measurements for adjustments
- Zeroing CO/O2 Calibration
  - Important for low level CO measurements
  - Important for Efficiency testing
- Calibration issues
  - Develop your own calibration procedure and interval
  - Interpreting readings (digital vs. analog)
- Calculated values (automatic vs. slide rule)
- Extremely accurate and long lasting sensors

TruTechTools

Important Accessories

- Magnetic boot
  - Protects from bumps and drops
  - Keeps analyzer off floor and out of danger
- Carry case
  - Protects during transport
  - Insulates from ambient temperature changes

TruTechTools

Dwyer 460 Air meter

- Cost effective
- Easy to use
- Low maintenance
- Does not lie
- Great visual indicator

TruTechTools