Welcome to TruTech Training!

We’ll be starting in just a few moments……..

www.TruTechTools.com
888-224-3437

Making Measurement Science Work!

If you are having trouble connecting, please email:
Bill@TruTechTools.com
COMB 100
Combustion Basics

TruTech Tools
515 E. Turkeyfoot Lake Rd.
Akron, Ohio 44319
Who are we?

- One of the largest internet distributors of test and measurement products
- Experienced professionals delivering CEU training to the HVAC, Energy Auditor and related trades
- 45+ years combined experience
- Practical, related and hands-on training
- Learn while you earn
  - UP TO 1 BPI Recognized CEU for this class
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 the time of registration
  - If not email to Marilyn@TruTechTools.com
  - With your name and date of this webinar and your BPI#
- Data automatically collected by the webinar system is sent to BPI for determination of attentiveness of attendees and the eventual awarding of up to 1 CEU
Agenda

1. Understanding Combustion and combustion efficiency
2. Common causes of CO and related safety
3. Performing a complete combustion analysis
4. Heat exchanger examination and testing
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
  - ACCA- Quality Installation/Verification
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 or quality
  - Affected by changers in blower speed
  - Affected by duct or air sealing
  - Affected by the environment it is installed in.
  - Affected by the installation itself

- For the safety of yourself and the consumer!!!
Basic Combustion Theory

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

- Heat
- CO₂
- H₂O Vapor 100%
- Oxygen
- Fuel (H + C)
- Heat
Composition of the air

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

10 CF of air is required to get 2 CF $O_2$

*(because air is basically 1/5 Oxygen)*
The problem with air

- Because air is the source of oxygen for combustion, 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.
Complete Combustion

HEAT → CO₂ → H₂O VAPOR

OXYGEN

FUEL (H + C)

HEAT

100%

Undiluted Combustion
INCOMPLETE COMBUSTION

- SOOT
- HEAT
- CO
- CO₂
- EXCESS AIR (O₂)
- (O₂ + N₂)
- H₂O VAPOR 100%
- TOXICS NOₓ SOₓ Acids
- AIR (O₂ + N₂)
- FUEL (H + C)
- HEAT
- STUFF (O₂ + N₂)
- OXYGEN
Why do we care about air?

**SOURCES**
- Ventilation
- Infiltration
- Make up air - maybe

**USES**
- Combustion
- Dilution
- Breathing

DON’T UPSET THE BALANCE ! !
Draft assisted/induced

- Cover your mouth with your hand
- Is there suction?
- Are you getting enough air?
- Hello?
Combustion Efficiency Equations

• Considers combustion efficiency and stack losses.
  • Part thermal
  • Part combustion efficiency

• High efficiency equations
  • Very good approximation
  • Perfect measurement requires condensate measurement
The ideal operating range is a setting with excess air.
Combustion Analysis

The efficiency measurement is COMBUSTION EFFICENCY - Stack Losses

It is not:

- AFUE
- Thermal efficiency
- COP
- SEER
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)
- Pick-up truck analogy
- Reasons for the formation:
  - fuel rich mixture
  - Improper venting
  - flame impingement
  - burner alignment
Characteristics of CO

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

• Persistent headaches
• Dizziness, blurred vision, nausea
• Fatigue or drowsiness
• Shortness of breath and confusion
• Feeling ill/tired in one location, but fine when some where else
So how big is a ppm?

1 ppm = 1/1,000,000 parts

One PART in One MILLION 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 %
<table>
<thead>
<tr>
<th>Concentration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/13 ppm</td>
<td>US-EPA/Health Canada 8 hour outdoor</td>
</tr>
<tr>
<td>25 ppm</td>
<td>Alberta Occupational Exposure Limit – 8 hours</td>
</tr>
<tr>
<td>35/30 ppm</td>
<td>US-EPA/Health Canada 1 hour outdoor</td>
</tr>
<tr>
<td>50 ppm</td>
<td>US-OSHA Permissible Exposure Limit – 8 hours</td>
</tr>
<tr>
<td>200 ppm</td>
<td>Slight headache with 2-3 hours</td>
</tr>
<tr>
<td>400 ppm</td>
<td>Headache within 1-2 hours</td>
</tr>
<tr>
<td>&lt;400 ppm</td>
<td>Air-free flue gas (ANSI Z21.1)</td>
</tr>
<tr>
<td>800 ppm</td>
<td>Sickness &amp; twitching of limbs within 1-2 hours; unconsciousness in 2 hours</td>
</tr>
<tr>
<td>1600 ppm</td>
<td>Headache within 20 minutes; death within 2 hours</td>
</tr>
<tr>
<td>3200 ppm</td>
<td>Death in 30 minutes</td>
</tr>
<tr>
<td>6400 ppm</td>
<td>Death in 10-15 minutes</td>
</tr>
<tr>
<td>12800 ppm</td>
<td>Death in 1-3 minutes</td>
</tr>
</tbody>
</table>
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)
### Combustion Safety Test Action Levels

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

*CO measurements for undiluted flue gases at steady state

Shows the complex relationship between CO formation, draft/spillage and health and safety factors.

Vent issue can create CO issues, as well as fail to vent CO.

Source: BPI Building Analyst Professional, v 1/4/12, Page 13
Some Possible Sources

- Fuel burning furnaces and hot water heaters
- Kitchen ranges & ovens
- Auto emissions
- Small engines, lawnmowers
- Fireplaces, grilles
- Tobacco smoke
- Fuel burning space heaters
  - Kero, Propane, Nat gas
- Fuel burning boilers
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
Why test? Because everyone does such GREAT routine maintenance!!!

Combustion air intake in a boiler room!!!

mmm TASTY…
Why test? Because things like this never happen....

Damage from condensation
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
CO “Air Free Measurements

- “Air-free” or undiluted samples
  - CO Undiluted = CO x 20.9/(20.9-O₂)
  - 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
Notes on NOx

- NOx = Oxides of Nitrogen
  - NO, NO$_2$, N$_2$O$_5$, etc.
- Created by N$_2$ in air flame or in fuel
- NO converts to NO2 in ambient conditions
- NO “tricks” a CO sensor!
  - Factor of 40% - 50%
    - For example 100 ppm NO = 40/50 ppm false CO
- Hydrogen also fools a CO sensor
  - But H2 only produced at EXTREMELY low excess air values
If you want an accurate FLUE GAS CO reading...

Never measure without a NOx filter

- Comes standard on all Testo
- Included or available for Bacharach products
- It may be an internal or external cartridge or built in to the sensor itself
At 40 ppm NOx, an unfiltered CO sensor is off by 21 ppm

Single Gas CO/O$_2$* Monitors

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

* For confined space entry - commercial
Draft Testing

- Draft removes flue gasses
- Controls flow through the heat exchanger*
- Must be established with 5 minutes
- Measured when at its maximum (hot stack)
- Mainly on 70%
  - 80%, 90% mechanically assisted
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.
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
3 Categories of 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
    - *HetKit no longer made*
  - Sodium ion (salt spray test) - 60% units
    - Not recommended - corrosion
  - Change in flue gas readings $O_2$, CO

Mfr. std (1/8” hole equiv. leakage)
- Impossible to do in field

“Industry standard” – 1986 most current
GAMA adopted RSES Pub. 630-9296/86
Change in FlueGas: CO or O$_2$

1. Start the furnace with the blower off
2. Watch for O$_2$ and CO to stabilize
3. Observe the O$_2$ and the CO when the blower starts
4. If the O$_2$ increases or decreases or the CO dramatically increases, there is a high probability a crack exists
5. Repeat the test to verify
6. Try to visually find the crack or air leak into the heat exchanger
Visual Examination

Look for the signs

- Rusting
- Staining
- Cracks
- Failures at welds
- Holes
- Pitting
Heat Exchanger Guide Book

• A roadmap to results!
• Common failure areas by make and model
• Step By Step
• 150 pages, full color

www.TruTechTools.com/HXBOOK
“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 or *vice versa* *
- 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
  - Thermal fatigue (heat up/cool down)
  - Improper venting
  - Over-firing
Combustion Ventilation air problems

[Graph showing various data points related to combustion efficiency, oxygen levels, and other parameters over time.]
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
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)
- Angle probe down
  - Avoid sucking in condensate

- Follow Mfr’s Specs
TESTING TYPE B-VENT

SEAL IT RIGHT!

- Proper hole plugs
  - Metal
  - Silicone

- Temperature rating of tapes
  - Eg Nashua 324 rated to 325 F
  - Typical discount store tape rated to 175 F

Big thanks to Bob Dwyer & Rudy Leatherman
Find the letters here: www.bit.ly/B-Vent
Combustion sampling hole plugs

- High efficiency plastic pipe
- Sheet metal
- B-Vent
Typical Readings

• Atmospheric Gas Fired Burners
  • Oxygen: 4% - 9%
  • Carbon Dioxide: 6.5% - 8%
  • Stack Temp: 325°F to 500°F
  • Draft: -0.02“wc to -0.04“wc in Stack
  • Carbon Monoxide: < 50 ppm (undiluted)
  • Always Follow Mfr’s Specifications
Typical Readings

- **Oil Fired Power Burners**
  - Oxygen: 4% - 7%
  - Carbon Dioxide: 10% - 12.5%
  - Stack Temp: 325 ºF to 600 ºF
  - Draft: -0.02"wc Overfire
    - -0.04"wc before barometric damper
  - Carbon Monoxide: < 50 ppm (undiluted)
  - **Always Follow Mfr‘s Specifications**
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

- Measure without pumping
- Optically determines smoke spot number
- Digital Resolution of 0.1 smoke #
- Range up to 6 smoke #
- Can transmit data to Testo 330
Combustion Analyzers
Taking care of your investment and your results

• Calibration (annual)
  • NEW TruTech Calibration and service
    • Bacharach and Testo Combustion analyzers

• Possible Service Items
  • Water, Particulate and Nox Filters, Sensors, Water traps, Probes, Pumps

• Storage temperature limits
  • Condensation

• Fresh Air Purge

• Sensor Range (CO)
  • Exceeding range can limit sensor life
  • Automatic over-range protection available in some models

• Proper printer paper
New TOYS!

- **testo 310**
  - Price Range: $625.50-$787.50

- **testo 320**
  - Price Range: $1075.50-$1314.00

- **Fyrite InTech**
  - Price Range: $471.50-$798.00

- **Fyrite InSight PLUS**
  - Price Range: $1609.10-$1339.10

ON SALE + FREE SHIPPING
FREE Video Training by Jim Bergmann

Two Ways to view

TruTech Tools Video Library

www.YouTube.com/jimbergmann3

Never miss one when you subscribe:
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 and your BPI Certificate #

• We submit webinar attendance reports to BPI within 2-3 days of the webinar.
  • BPI may take a few days to log these in before they are reflected on your BPI account
Get a $10 TTT Gift certificate for completing a PRODUCT REVIEW of this webinar on our site
See you......

www.affordablecomfort.org/national2013

AHR Expo
ACI Regionals
ACCA / IAQA
RESNET 2 Educators’ conferences
ACI National
OSEP (NOAHSM)
ACCA-regionals
Thank you for your time and attention!

For a copy of the slides or link to a recorded session go to: www.TruTechTools.com/webinars

Download our Combustion Guide:

See more videos from TruTech:
www.youtube.com/jimbergmann3

Contact us:
Bill Spohn, Co-Owner: Bill@TruTechTools.com
Jim Bergmann, Co-Owner: Jim2@TruTechTools.com
Eric Preston, Sales Manager: Eric@TruTechTools.com
Bill Sutherland, Calibrations: William@TruTechTools.com

www.TruTechTools.com  888-224-3437

Making measurement science work!
Sponsored by TruTech Tools...

- Let’s take a tour of our website
  - BPI-BSP Cert of Knowledge
  - Intro to Home Performance (webinar/book)
  - Energy Assessment & Improvement Book
  - Thermal Imagers by application / brand
  - Heat Exchanger Inspection Manual
  - Home Performance Diagnostics Book
  - TTT Combustion Applications Guide
  - TTT Calibration and Service (combustion)
  - Tru-Rewards (customer loyalty)