Speaking of Wood Stoves

Regulatory Influence On Design & Function
Pre EPA 1983 Oregon DEQ First
#1’s That Year!
Oregon Develops Test Method

- State Of Oregon & Industry Developed Method To Test Wood Stoves
- June 1984 Oregon Begins Emissions Limits For Wood Stoves Measuring PM10
- Oregon Standards Enforced
  - 1986 Non Cat 15 Gr/Hr & Catalytic 6 Gr/Hr
  - 1988 Non Cat 9 Gr/Hr & Catalytic 4 Gr/Hr
So What Happened?

• Manufacturers Take Their Wood Stoves To The Test Labs
• Manufacturers Learn Many Of Their Stoves Won’t Pass Emissions Tests
• Manufacturers Insert Catalytic Combustors Into Their Wood Stoves
• Manufacturers Pass The Tests (Happy Day!)
Industry Sees The Future....Regulations Inspire 91 Stove Manufacturers To Use Cats In The 1980’s

<table>
<thead>
<tr>
<th>Aladdin Hearth</th>
<th>Kingsman</th>
<th>American Eagle</th>
<th>Kuma</th>
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<tr>
<td>American Road</td>
<td>Lancaster Fab</td>
<td>Appalachian</td>
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<td>Arrow</td>
<td>Lennox</td>
<td>Ashley</td>
<td>Lilly Stoves</td>
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<td>Aspen</td>
<td>Long Mfg</td>
<td>Atlanta Stove Works</td>
<td>Marks Custom</td>
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<td>Blaze King</td>
<td>Martin Industries</td>
<td>Buck Corp.</td>
<td>Miracle Heat</td>
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<td>Carolina Stove</td>
<td>Nu-Tec</td>
<td>Chippewa</td>
<td>Oakridge SL</td>
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<td>Citation Stove</td>
<td>OK Doke LTD</td>
<td>Clayton</td>
<td>Olix Air Flow</td>
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<td>Consolidated DW</td>
<td>Country Comfort</td>
<td>Oregon Wood Stove</td>
<td>Opel</td>
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<td>Orley Mfg</td>
<td>Craft Stove</td>
<td>Orrville Products</td>
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<td>Derco</td>
<td>Panda Stove DK Metals</td>
<td>Regal Metal</td>
<td>Dominion Sierra</td>
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<td>Regency</td>
<td>Doorwood</td>
<td>Riteway</td>
<td>Energy King</td>
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<td>Dovre</td>
<td>Earth Stove Rupp</td>
<td>Efel N.A.</td>
<td>Security Chimney</td>
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<td>Russo Products</td>
<td>Elmira Stoves</td>
<td>Salvo</td>
<td>Elmwood</td>
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<td>Scandia</td>
<td>Energy Harvester</td>
<td>Sears</td>
<td>Englander</td>
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<td>Shennandoah</td>
<td>FPX</td>
<td>Sierra Mfg.</td>
<td>Georgetown Woodstove</td>
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<td>Silent Flame</td>
<td>Hardy Mfg Company</td>
<td>Suburban Mfg.</td>
<td>Harman/Vansco</td>
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<td>Timberblaze</td>
<td>Hearth Heat</td>
<td>Timbereeze</td>
<td>Travis Industries</td>
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<td>Hearthstone</td>
<td>US Stove</td>
<td>Heatilator</td>
<td>Heating Energy</td>
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<td>Vermont Castings</td>
<td>Hi Teck</td>
<td>Vestal Mfg.</td>
<td>High Sierra Stove</td>
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<td>Webco Industries</td>
<td>High Valley</td>
<td>Horstman Industries</td>
<td>Hutch Mfg.</td>
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<td>King</td>
<td>Wet Industries</td>
<td>Woodchief</td>
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<td>Woodmaster</td>
<td>XTEC</td>
<td>Woodstock Soapstone</td>
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But……..

• Those Early Woodstoves Were Built and Then Had Catalytic Combustors Added
• Consumers Complained About Failing Catalytic Combustors
• Stove Manufacturers Blamed The Catalytic Combustors For Not Being Robust
• Consumers Were Blamed For Over-Firing Stoves
• The Truth Is The Stoves Were NEVER Properly Designed To Be Used With Catalytic Combustors

This Left Folks Scratching Their Heads
The Result.......Total Cat Failure
(Not Cat Scratch Fever)

• More On Cat Failure Later........
40 CFR Part 60 Introduced In 1988 As Part Of the NSPS

- EPA Guidelines To Testing, Approving & Receiving & Keeping A Valid Certificate For A Wood Heater
- It Also Outlines The Responsibilities Of The Retailer For The Sale Of Certified Wood Heaters
- And So Much More…. 
The 1988 NSPS (Federal EPA) (New Source Performance Standards)

- It Gave Us Test Method 28 (Refined From Oregon Method)
- It Also Continued With Oregon’s Bifurcated Standards

1988 Phase I
- 8.5 Gr/Hr Non Catalytic 5.5 Gr/Hr Catalytic

1990 Phase II
- 7.5 Gr/Hr Non Catalytic 4.1 Gr/Hr Catalytic

- 1998 Washington State Goes Alone & Lowers
  Non Catalytic 4.5 Gr/Hr  Catalytic 2.5 Gr/Hr
What Is A Bifurcated Standard & Where Did It Come From?

• In-Situ Testing In New York, Oregon And Other States That Showed A Reduction In Effectiveness Of Catalytic Combustors Over Time (Remember In Old Designs)

• It Was Assumed Stoves Without Catalyst Did Not Degrade
EPA To Be Sued

- Coalition Of States (WESTAR & NESCAUM) Force EPA With Threat Of A Law Suit To Promulgate The NSPS.
- Clean Air Act Requires EPA To Do So Every 8 Years…
- EPA Missed By 20+ Years
- After Nearly 25 Years We Have A New NSPS
2015 NSPS.....What Changed?

• Pellet Stoves Now Regulated
• Wood Heaters >20 Cu/Ft No Longer Exempt
• Exemption For Wood Heaters That Burned 5Kg/Hr (11 lbs) Goes Away
• Exemption For >35:1 Goes Away
  – No More Exempt Wood Stoves (Never The Intent)

Much, Much More…….
All Wood Stoves Now Have Equal Emissions Requirements

• Elimination Of Bifurcated Standards
  – All Wood Stoves Must Be 4.5 Gr/Hr or Less
  – In The Year 2020 All Wood Stoves Must Be 2.0 Gr/Hr or Less (Cord wood 2.5 Gr/Hr)
  – Once Again, Regulation Will Direct Design
  – Hang Tags Eliminated
  – Some Compliance Requirements Not Renewed
So How Does Regulation Effect Stove Design

- Many Test Methods
  5H, 5G-1, 5G-2, 5G3
- Dilution Tunnels
  Filter Trains & Size
- Complexity Creates
  Mad Scientists
Cont... Regulations & Testing Affect Firebox & Combustion Design

- The Size Of The Firebox
- The Shape Of The Firebox
- The Type Of Refractory
- The Size and Number Of Brick Retainers
- The Method Of Air Introduction & Flow
- The Consumption Or Burn Rates
- The Construction Materials
- So Much More

And It's All Because Of The Fuel That We Test With!
The Very Fuel That We Test With
Do You Know Your Cribs?

\[ > 3 \text{ ft}^3 \]

\[ < 3 \text{ ft}^3 \]

(1.5 cu ft) All 2x4's
3 Ways To Currently Meet The EPA Standards

- Thermal Destruction
- Catalytic Oxidation/Destruction
- A Combination Of Both Thermal And Catalyst Destruction (Referred To As Hybrid)
Most Common Way To Deal With Emissions (currently)

- Thermal Destruction
  Secondary Combustion Design

  Requires >1200°F to Control PAH Emissions

  Requires >1700°F to Control CO

  Low Burn Rates Usually Above 1.0 kg/hr
Another Way To Deal With Emissions

• Catalytic Oxidation

Start to Control Emissions at 550°F to Control Emissions, including VOC’s, PAH’s and CO

Low Burn Rate Usually Below 1.0 kg/hr

Stove Not Subjected To As High Temperatures In Order To Burn Clean
3rd Option Is The Hybrid-A Combination of Secondary & Catalytic

First Hybrid Wood Stove Introduced In 1983

Some Hybrids Burn Clean At All Burn Rates

Tend To Be More Costly To Engineer & Manufacture
Lowering EPA Standards Effect Stove Design & Can Encourage The Use Of Catalytic Elements

• What is Catalytic “Cat” Combustor?

• How Are They Made?

• How Do They Work?

• How Are They Damaged?

• Substrate Types-Advantages.
Catalytic Combustor Consists Of….

- **Carrier**: Physically Supports for Active Metal Catalyst

- **Catalyst Coatings**: Precious (noble) metals or base metal elements which are “active in the combustion reaction”. Some catalyst manufactures also use a pre-coating, also known as a wash coat. Wash coat provides for greater surface area.
How They Are Made!

Ceramic Body Extrusion Is Similar to A Child's Play Dough Machine
How A Catalyst Works!
How A Combustor Works!

• Definition: A catalyst is a substance which lowers the activation energy for a given reaction, without being consumed by the reaction.
  – Catalysts create a Combustion Reaction (Also Referred to As “Oxidation Reaction”)
• Carbon in any compound Combines with Oxygen to form Carbon Dioxide and Water

To oxidize organic compounds, HEAT is the activation energy necessary to complete the reaction.
How They Are Damaged!

- **Excessive Temps**
  - 1600F Flattens Out Wash Coat/Less Effective
  - 1800F Destroys Substrate/Possibly Stove Components
  - Excessive Draft Leading To Flame Impingement

- **Thermal Shock & Air Leaks**
  - Maintain Tight Door Gasket Seals
  - Ice covered or Frozen Wood or Very Wet Wood

- **Contamination of Catalyst Surface**
  - Deposition of foreign elements blocks active catalyst sites
  - Burning of materials with heavy magazine inks/metals/plastics

- **Physical Abuse**
Effects of Extreme Temperature on Catalyst Surface

- **Fresh Catalyst**
  - Finely dispersed, Palladium / Platinum Particle
  - High Surface Area, Alumina Based Washcoat

- **Thermally Deactivated**
  - Thermally Sintered, Less Active, Palladium / Platinum Particle
  - Collapsed Low Surface Area, Alumina Based Washcoat

> 1600°F
Advantages Of Each Type of Catalyst Support

**Ceramic:**
- Proven To Work - Reliable
- Increased Mass = Longer Activity
- Higher Efficiency
- Multiple Suppliers

**Stainless-Specialty FeCrAlloy Foil:**
- Less Mass = Lights Off Quicker
- Less Fragile In Shipping & Handling
- Less Emissions
Combustors Do More Than Just Reduce Particulate Emissions

NOTE: WHILE NOT ALL THE GASES BELOW ARE PRESENT IN WOOD SMOKE EMISSIONS, THIS CHART PROVIDES EVIDENCE AS TO THE POWER OF A COMBUSTOR TO DESTROY SPECIFIC GASES.

<table>
<thead>
<tr>
<th>Percent Conversion (% DRE)</th>
<th>Temperature (°F)</th>
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<tbody>
<tr>
<td>100%</td>
<td>100</td>
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<tr>
<td>90%</td>
<td>200</td>
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<td>80%</td>
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<td>10%</td>
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<tr>
<td>0%</td>
<td>1100</td>
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- Acetaldehyde, 180 ppmv
- Methane, 1000 ppmv
- Benzene 32 ppmv
- Toluene 26 ppmv
- Xylene 13 ppmv
- CO 1000 ppmv
- Methanol 200 ppmv
- Propylene 480 ppmv
- Hexane 500 ppmv as C1
- Acetone 550 ppmv as C1
What Really Caused The Failure?

• Stove Manufacturers Did Not Know How To Built A Catalytic Wood Stove
• Killers Of Catalytic Combustors Had Not All Been Identified
• Prolonged Exposure to temperatures > 1600 F will collapse the surface area of the catalyst washcoat (surface chemistry)
• Exhaust Exceeding 1800° F destroys the catalyst and potentially damage the stove
A Tempting Perfect Fit

• A Flue Collar Is Perfect For A 5.66” Round Combustor!
Poor Integration Lead To.....

1. Hot Gas Stream
2. Catalytic Combustor
3. By Pass Plate/Opening
4. Flame Shield
5. Cat Thermometer
   Direct Flame Contact
   Excessive Temps
   -1600F to 1800F
   Resulting Thermal Shock
Do You Know What To Look For?

- By Pass Designs, Thicknesses Of Metals Used
- By Pass Metal to Metal or Gaskets (Ease of Replacement)
- Dome Area-Look For Strong-backs, Brackets or Reinforcements
- Combustor Position Orientation and Location?
- Flame Shield Design (What’s their role? Ease Of Removal)
- Adjustable Door Gasket Tension Or Other Potential Air Leaks
- Ask For Data On Threshold Temps
- Ease Of Inspection. EPA insists!
- Inspection & Serviceability .. No Tools Needed!
- Ask Questions About Baffles, Temp Test Ratings Of Components
- In Hybrid Designs Look for Pre Heated Air Near Combustor (Not room temp)
Thank you for Attending
Any Questions?