California Boiler Inspectors Association

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THE NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS

SINCE 1919

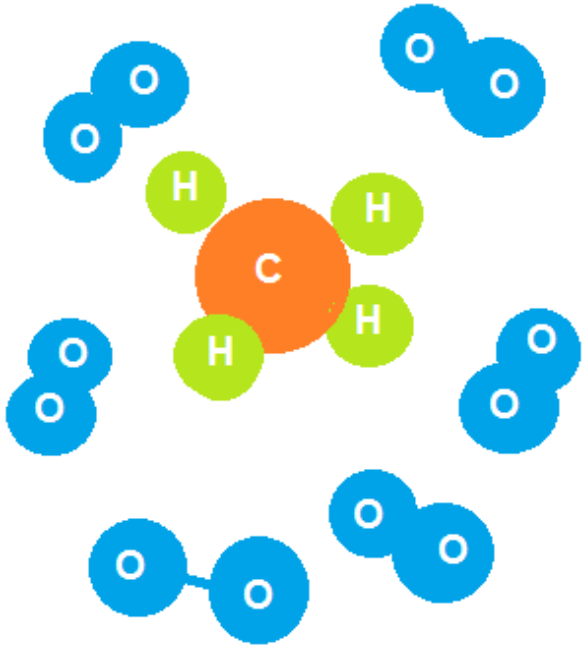
Topic of Discussion – Condensing Boilers

- What causes condensation in a boiler?
- Condensing boiler design
  - General design considerations
  - Example – drainpipes
  - Example – flues
- Condensing boiler control systems
  - General control system considerations
  - Burner controls
  - Primary safety control systems

How Does a boiler condense?

A by-product of the combustion process is water vapor (steam). This is due to the combustion of the hydrogen content of the fuel and not from the water from within the vessel. As the exhaust cools the water vapor turns from a gas to a liquid. If the return water piping is below the dew point (~140 F) this can cause condensation of the water vapor. As the temperature water of the water decreases there is more oxygen within the water that aids in the corrosion

Combustion Process

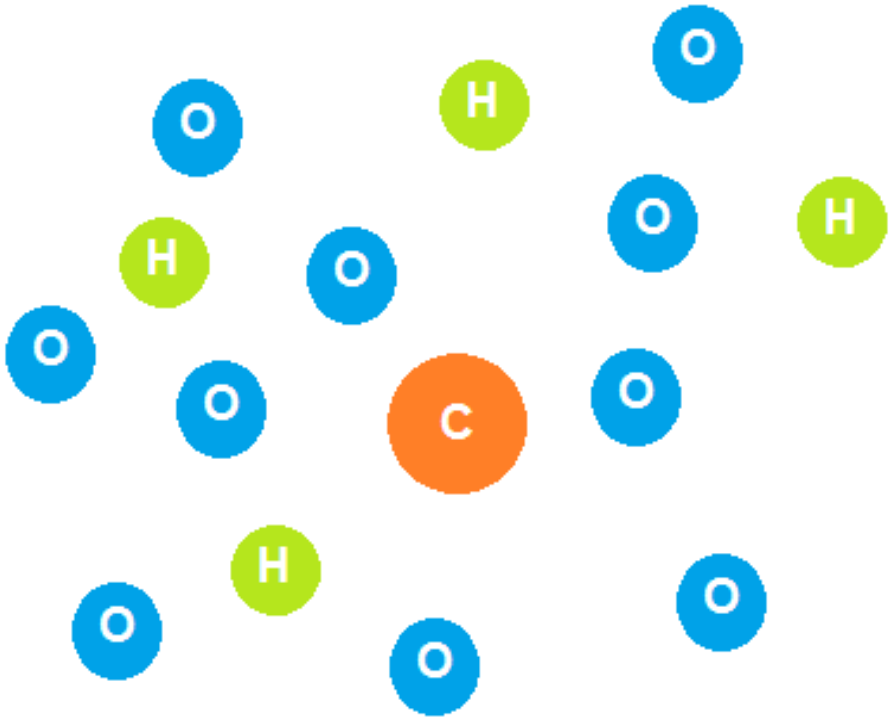


Methane = CH_4

Oxygen = O_2

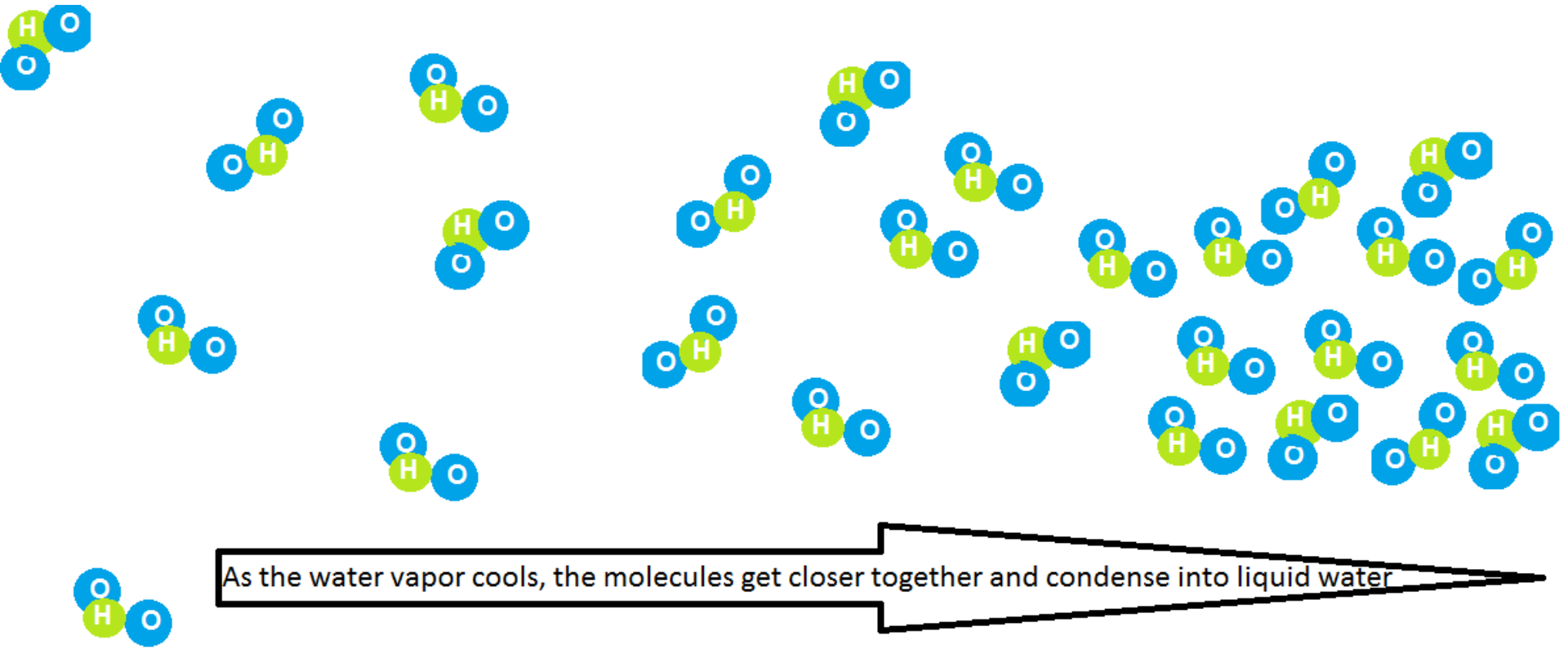
Natural gas is primarily methane, but may include other hydro-carbons

Combustion Process



When energy is added (a spark or flame) the methane and oxygen molecules separate into free atoms.

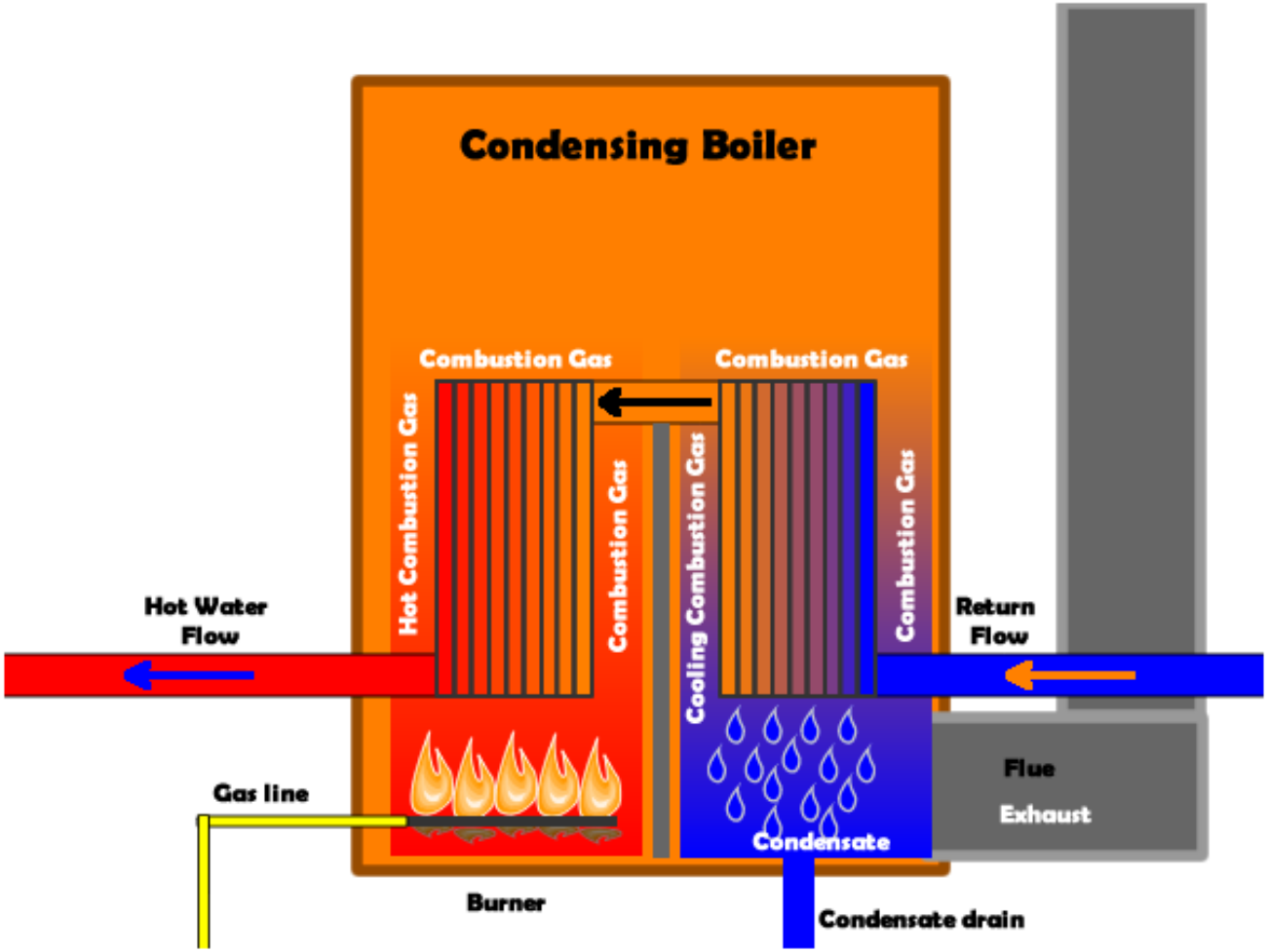
Combustion Process



Condensing Boiler Design

- Despite the acidity of condensate, a condensing boiler uses hot return gases to preheat the return water to the boiler
  - Less fuel expended when return water is preheated
  - Hot return gases condense in heat exchangers
- Any condensate from the flue gas is acidic (pH ~3.5)
  - Over time, the acidic mixture can be very corrosive to the boiler and breeching if not designed to withstand corrosion
- Condensing Boilers designed to withstand the effects of corrosive condensate
  - Normally constructed from aluminum or stainless steel
  - Flue constructed from stainless steel or PVC
  - Chimney needs to be relined with stainless steel
  - Drainpipes designed to withstand corrosion (see next slide)

Condensing Boiler Design



Condensing Boiler Design Example - Drainpipes

- Condensing boilers require a drainpipe for the condensate produced during operation to prevent exhaust gases from being expelled into the building
- The acidic nature of the condensate may be corrosive to cast iron plumbing, waste pipes and concrete floors
  - Poses no health risk to occupants
- Corrosion resistant polymer pipe used for drainpipe
- Alternatively, a neutralizer can be installed to raise the pH to acceptable levels
  - Neutralizer typically a plastic container filled with marble or limestone aggregate or "chips" (alkaline)
- If a gravity drain is not available, then a small condensate pump must also be installed to lift it to a proper drain.

Condensing Boiler Design Example - Flue

Table 3 - Combustion air and vent pipe fittings must conform with the following:		
Item	Material	Standards
Vent Pipe and Fittings	PVC schedule 40	ANSI/ASTM D1785
	PVC - DWV	ANSI/ASTM D2665
	CPVC schedule 40	ANSI/ASTM D1784/ F441
	SDR-21 & SDR-26 PVC	ANSI/ASTM D2241
	ABS-DWV	ANSI/ASTM D2661
	Schedule 40	ANSI/ASTM F628
Pipe Cement/ Primer	PVC	ANSI/ASTM D2564
	CPVC	ANSI/ASTM F493
	Schedule 40 ABS	ANSI/ASTM D2235

- IPEX is approved vent manufacturer in Canada listed to ULC-S636.
- IPEX System 636 Cements and Primers are approved in Canada listed to ULC-S636.

DO NOT USE CELLULAR (FOAM) CORE PIPE

⚠ WARNING

Only the materials listed below are approved for use with the Infinite Energy boiler. Use only these components in accordance with these instructions. Failure to use the correct material may result in serious injury, death, or major property damage.

Table 3.1: Approved Materials for Exhaust Vent Pipe

Description	Material	Conforming to Standard
Vent Piping & Fittings	PVC (Sch 40 or 80)*	ANSI/ASTM D1785
	CPVC (Sch 40 or 80)	ANSI/ASTM D1785
	PVC-DWV*	ANSI/ASTM D2665
	MUGRO™ PP(s)	ULC-S636
	InnoFlue® PP	ULC-S636
Pipe Cement (PVC & CPVC Only)	PVC/CPVC Cement	ANSI/ASTM D2564

⚠ WARNING

Use of cellular core PVC for venting flue gas could result in death, or serious injury.

Condensing Boiler Control Systems

- Control systems range from simple to very complex
  - Can monitor oxygen levels in the exhaust, flame safeguard, fuel flow, fuel-air ratios, and more
- Control system connected to motors that adjust valves based on sensor readings
  - Each valve may have an individual servomotors for precise control
  - Alternatively, one motor may operate a mechanical linkage that controls all valves

Condensing Boiler Control System Example

- Scenario – an oxygen sensor on a control system indicates the oxygen levels in the exhaust is above expected levels

- Q: What problem would this reading indicate in the boiler?
  - A: This reading indicates incomplete combustion

- Q: What would the burner control system do to correct this problem?
  - A: The control system would reduce the speed of the blower motor so less oxygen is available for combustion

Burner Control Systems

- Gas fired boilers generally have four types of burner control systems; on-off, hi-lo-off, multi-stage, or modulating
  - On-off burner controls have only two flame settings, flame on or flame off
  - Hi-lo-off controls have three flame settings, high flame, low flame, or flame off
  - Multi stage controls have a set number of discrete flame settings that are generally spaced in set increments (e.g., flame off, 25% flame, 50% flame, 75% flame, 100% flame)
  - Modulating controls precisely control the flame setting based on load requirements calculated from an array of sensors

Burner Control Systems

- On-off, hi-low and multi-stage firing configurations are accomplished by opening or shutting one or more staged gas valves.
  - On-off (also known as one stage) control systems usually employ a single gas valve that is either fully open or fully shut
  - Hi-low-off (also known as two stage) control systems and multi-stage control systems typically utilize several one stage or two stage valves to provide an appropriate number of firing increments
- For example, a typical four stage boiler might use two two-stage valves, giving it four incremental firing rates; 100% fire, 75%, 50%, and 25% of full firing rate.

Burner Control Systems

- Modulating fire is accomplished by mechanically varying the size of the gas valve opening of one or more special "modulating" gas valves
  - With the gas valve completely open the boiler fires at it's full fire rate.
- As opposed to the other burner control systems, a modulating burner control system allows for precise control of the flame
  - Creates energy savings because the burner can be set to he most efficient level for current load demands.
  - An outdoor temperature sensor can provide feedback to the controller to tell the boiler how much hot water is needed to match the required indoor temperature.

Burner Control Systems

- Important burner control system definitions:
  - “turndown ratio” - the ratio of full fire rate to full turndown firing rate and is a function of boiler design
  - “full turndown” – the operating point at which a burner is fired at its lowest possible firing rate

- Scenario – A boiler has a burner that is capable of a full turndown firing rate of 20% flame

- Q: What is the boiler’s turndown ratio?
  - A: The boiler’s turndown ratio is 5:1

Primary Safety Control Systems

- Most (if not all) condensing boilers have sensors that monitor temperatures, flame levels, oxygen levels, etc.
- These sensors provide constant feedback to a computer that will shut down the boiler if the sensor readings stray from a specific range of values specified by the manufacturer
- This constant feedback system is known as a “primary safety control system” in ASME CSD-1 and other codes

Primary Safety Control System Definition

- Primary safety control system – “An automatic labeled and listed control that may integrate the functions of other controls, such as operating controls, primary safety controls, safety controls, and sensing devices. This control system integrates separate labeled and listed components that incorporate feedback so that the failure of any of these sensing devices will result in a safety shutdown and lockout.”
- “Operating control,” “primary safety control,” and “safety control” defined on next slide

Primary Safety Control System Definitions

- Operating control - an automatic control, other than a safety control, to start or regulate input according to demand and to stop or regulate input on satisfaction of demand.
- Primary safety control - a control directly responsive to flame properties, sensing the presence of flame and, in event of ignition failure or loss of flame, causing safety shutdown
- Safety (or limit) control - a control responsive to changes in liquid level, pressure, or temperature and set beyond the operating range to prevent the operation beyond designed limits.

Primary Safety Control Systems

The primary safety control system has four functions:

1. Turn the boiler on and off based on demand
2. Regulate gas valves and combustion air based on demand
3. Monitor flame and provide safety shutdown in the event of ignition failure or loss of flame
4. Respond to changes in liquid levels, pressure, or temperature to prevent the operation beyond designed limits

Alternatives to Primary Safety Control Systems

1. Operating limits – a control that cuts off the fuel supply to the burner when the pressure or temperature reaches a preset cutoff point
2. High limits – a control separate from the operating limit that cuts off the fuel supply to the burner in case of failure of other control systems
3. Low water fuel cutoffs – a mechanical device that cuts off the fuel supply to the burner when the water in the boiler drops below a predetermined cutoff level
4. Flow sensing devices – a device that cuts off the fuel supply to the burner when the flow rate within the burner drops below a preset cutoff point

Safety Control Comparisons

- Q: Can low water fuel cutoffs or flow sensing devices be installed incorrectly and the boiler still operate?
  - A: Yes. The boiler will still operate even though incorrect safety control installation may keep the control from functioning as intended
- Q: Can operating limit controls or high limit controls be installed incorrectly and the boiler still operate?
  - A: Yes. The boiler will still operate even though incorrect safety control installation may keep the control from functioning as intended
- Q: Can a primary safety control system be installed incorrectly and the boiler still operate?
  - A: No. The boiler will not operate unless the control system receives continuous sensor feedback within a prespecified range.

Safety Control Comparisons

- Q: Can low water fuel cutoffs or flow sensing devices be miswired or electrically bypassed and the boiler still operate?
  - A: Yes. The boiler will still operate even though incorrect safety control installation may keep the control from functioning as intended
- Q: Can operating limit controls or high limit controls be miswired or electrically bypassed and the boiler still operate?
  - A: Yes. The boiler will still operate even though incorrect safety control installation may keep the control from functioning as intended
- Q: Can a primary safety control system be miswired or electrically bypassed and the boiler still operate?
  - A: No. The boiler will not operate unless the control system receives continuous sensor feedback within a prespecified range.

Safety Control Comparisons

- Q: Can low water fuel cutoffs or flow sensing devices become nonfunctional due to slug or scaling and the boiler still operate?
  - A: Yes. The boiler will still operate even though incorrect safety control installation may keep the control from functioning as intended
- Q: Can operating limit controls or high limit controls become nonfunctional due to slug or scaling and the boiler still operate?
  - A: Yes. The boiler will still operate even though incorrect safety control installation may keep the control from functioning as intended
- Q: Can a primary safety control system become nonfunctional due to slug or scaling and the boiler still operate?
  - A: No. The boiler will not operate unless the control system receives continuous sensor feedback within a prespecified range.

Benefits of Primary Safety Control Systems

- Primary safety control systems provide constant feedback from sensors
- If the boiler conditions move out of the specified safe range, the boiler will shut down until the boiler conditions move back into the specified safe range
- If any critical sensor is tampered with or becomes nonfunctional, the boiler will shut down and lockout until the sensor is fixed
- No other safety control provides the benefits of a primary safety control system