Emerson Steam University Virtual Series

A Practical Approach To Understanding Steam Systems

Day 5 – Boiler Feedwater, Boiler Level Monitoring & Feedwater Pump Protection

R.E. MASON
Emerson Impact Partner

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Safety Moment: House Fires

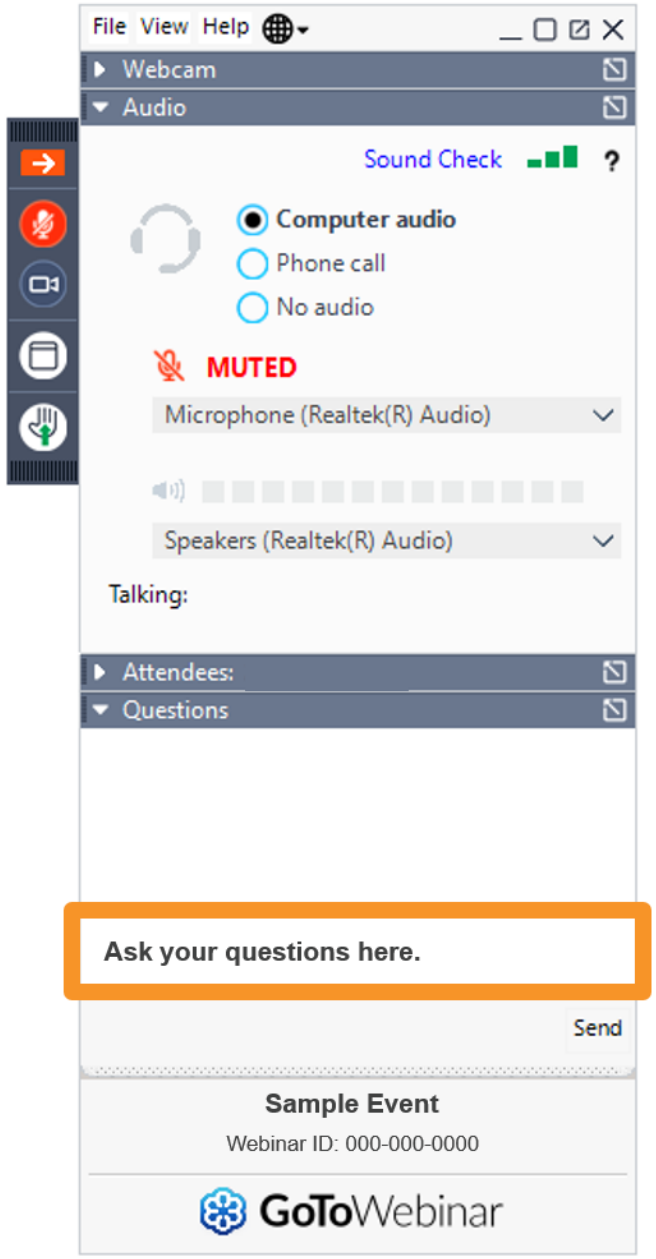
- House fires peak around the dinner hours between 5:00 and 8:00 p.m.
- Cooking equipment is responsible for a majority of fire related injuries
- Only 20% of reported house fires occurred between 11:00 p.m. and 7:00 a.m. However, these fires caused half (51%) of all home fire deaths.
- 60 percent of house fire deaths occur in homes with no working smoke alarms.

Ways to Prevent a Fire in the Home

- Keep combustible items at least three feet away from objects that create heat such as heaters.
- Never smoke in bed or while lying down on a couch.
- Do not leave portable heaters on overnight.
- Keep lighters and matches out of reach where kids cannot get to them.
- Do not leave the kitchen unattended when cooking.
- **Other Safety Measures**
- Install smoke alarms on every floor of the house and in every bedroom. Test the alarms at least once a month and change the batteries as needed.
- Have an approved and functional fire extinguisher in the kitchen.
- Have a plan of evacuation and teach kids what to do if there is a fire. Have backup plans in case the fire blocks the primary route or exit.
- Practice fire drills periodically with the whole family.

Housekeeping

- Today's webinar is scheduled to last 1.5 hrs including Q&A and closing
- All participants will be muted to enable the speakers to present without interruption
- Questions can be submitted via the GoToWebinar Questions Panel at any time
- Slides will be emailed 72 hours after the last session in this series has concluded
  - Wednesday, June 2
- Complete polls & surveys to mark attendance for PDH credits.
  - Total PDH credits for today's session: 1.25 (Live Session ONLY)
- Tell us how we did by completing the survey
  - The survey will launch after this session



Session Agenda

1	Boiler Feedwater	Tim Dwyer
2	Break	
3	Boiler Level Monitoring	Tim Dwyer
4	Feedwater Pump Protection	Tim Dwyer
5	Q&A	
6	Closing	Jake Henault

Meet Our Experts

Tim Dwyer

Business Development Manager
Emerson

Tim Dwyer is the Business Development Manager of Steam and Industrial Regulators with Emerson. He covers pressure control devices and steam equipment.

Tim has been with Emerson for 5 years and held multiple roles that have given experience with many of the various valves found in process industries.

Tim has a BS in Mechanical Engineering from Iowa State University.

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Boiler Feedwater

Tim Dwyer
Emerson

R.E. MASON
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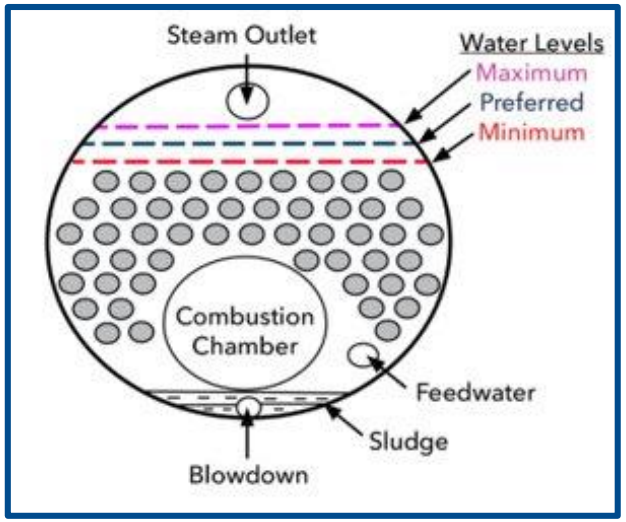
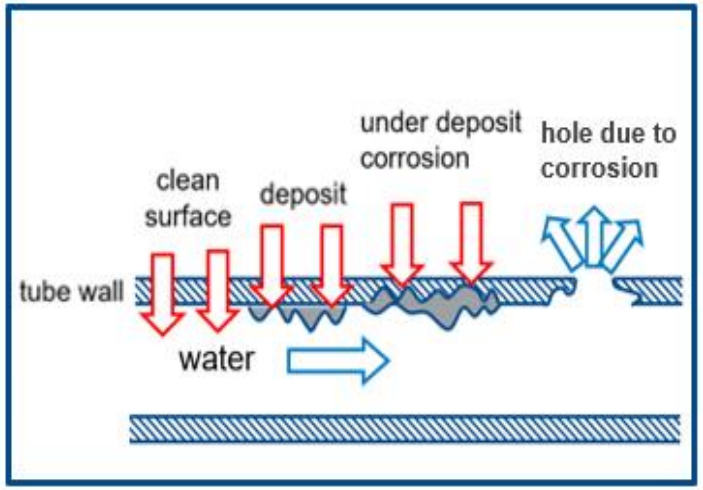
EMERSON

Boiler Feedwater Overview

- **Water quality is critical for effective operation of boiler and downstream equipment**
- As steam is generated **more water** is needed **to maintain water levels in boilers**
- Pressure Vessel designed to heat water and convert it to steam



(Source: Smart Energy)

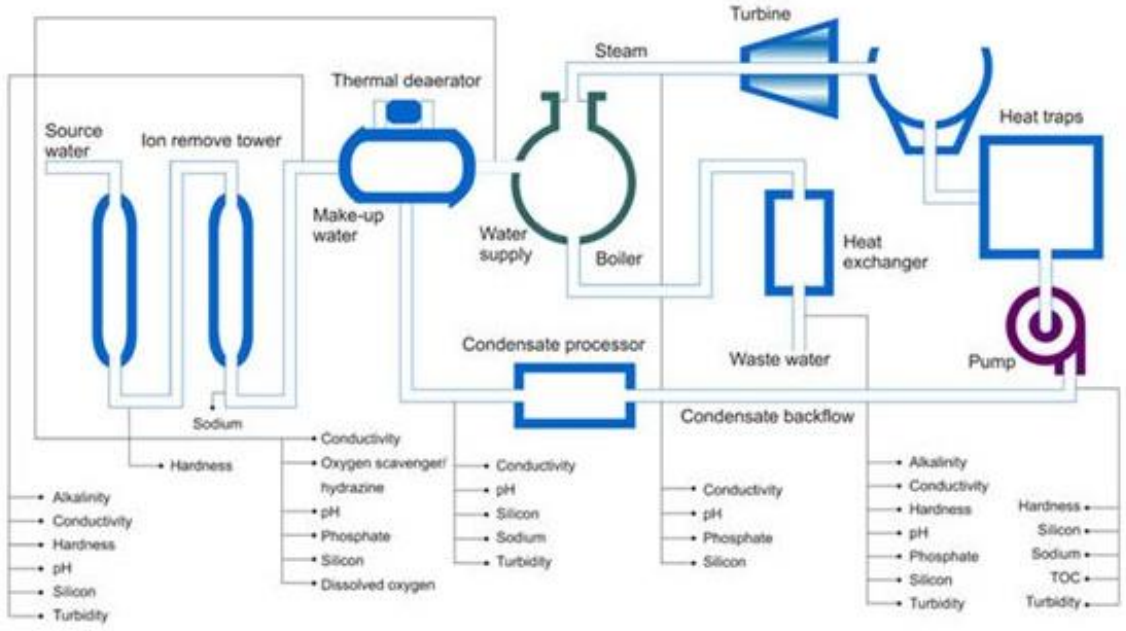


Overview of Boiler Feedwater Issues

Four main issues should be addressed to improve the feedwater quality

- **Hardness:** produces scaling and sludge which reduces the efficiency of the boiler
- **Dissolved or Suspended Solids:** high concentrations in the boiler can produce foaming which if allowed to leave the boiler can damage downstream equipment (carryover)
- **Dissolved Gases:** causes corrosion in the boiler and steam system piping
- **pH:** causes corrosion in the boiler and steam system piping

Boiler Water Treatment Flowchart



Source: Zhengzhou Boiler Group

Hardness

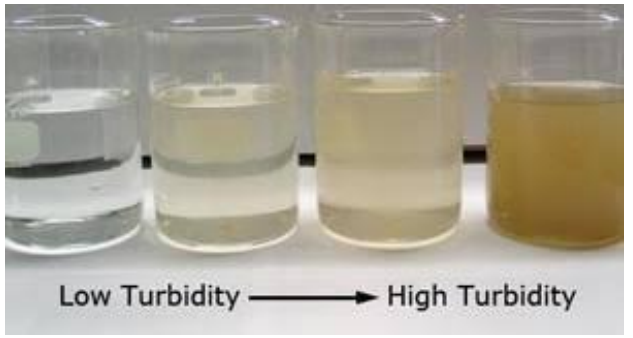
- **Hardness can create deposits that damage equipment and lower efficiency**
- **Hardness:** amount of **dissolved calcium and magnesium** in the water
- Hardness scale can reduce the life of equipment, raise the costs of heating the water, lower the efficiency of electric water heaters, and clog pipes

Source: USGS

Source: USGS

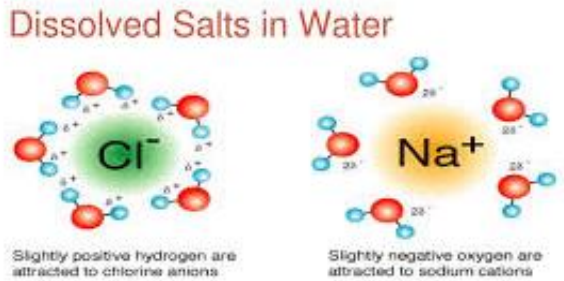
Dissolved and Suspended Solids

- **Solids can create deposits and carryover that damage equipment and lower efficiency**
- **Suspended solids** are all solids that **can be removed through a filter of a certain size**
- **Dissolved solids** are all the solids in a liquid which **can't be removed through filter of certain size**
- These solids can create scale on pipe that are harmful to equipment
- Steam bubbles become more stable (do not burst) as the concentration of dissolved solids increases which can also create carryover



Source: Lake Pepin Legacy Alliance

Source: Lenntech

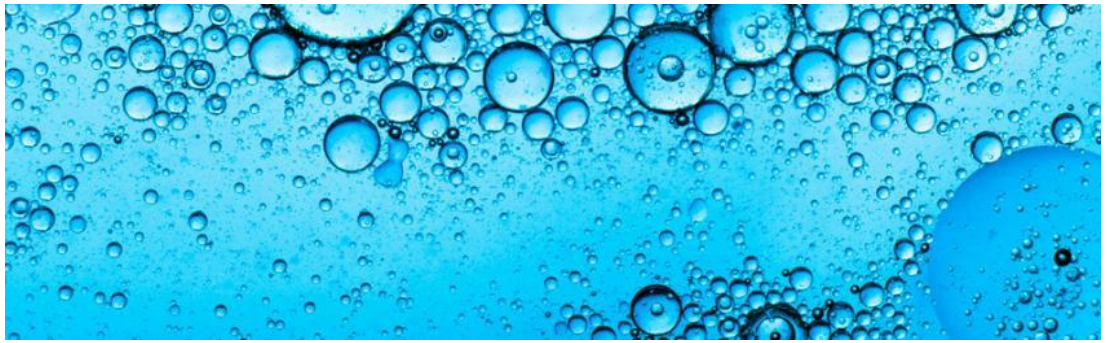


Source: Slide player

Dissolved Gases

- **Dissolved gasses can create new compounds and react with pipe walls to cause corrosion and pitting**
- Dissolved **oxygen** refers to the level of free, non-compound oxygen present in water that **causes pitting in the system**
- **Carbon dioxide increases corrosion** by forming carbonic acid

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$$



Source: Elga Veolia

Source: Black Powder Solutions

pH and Oxidation Reduction Potential (ORP)

- **The reactivity of the water can create pitting and corrosion to equipment**
- **pH and Oxidation Reduction Potential (ORP)** is how much **reactivity** the water will have **with the metal piping, causing corrosion of the system**
- Acidic and very basic solutions will cause the destruction of piping more rapidly
- Pitting can be caused to the piping if these are not maintained

Improving Performance with Liquid Analysis

Measurement	Benefit
pH	**Analysis of pH** Helps Detect Changes That Impact the Effectiveness of Water Treatment and Potential Corrosion of the System
Conductivity	Provides an **Indication of Total Dissolved Solids** and Susceptibility to Scaling
Dissolved Oxygen	**Monitoring of Dissolved Oxygen Levels** Helps to Keep the Corrosion in Check. Also Monitoring of Deaerator Efficiency.
Application Dependent	
Silica	Volatizes in Steam and it is Carried into the Turbine. Silica Deposits are not Corrosive, but They Can Severely Reduce Efficiency
Hydrazine	Dissolved Oxygen Scavenger, Passivating Agent Which Also Produces a Protective Oxide Coating on Metal Tube Wall

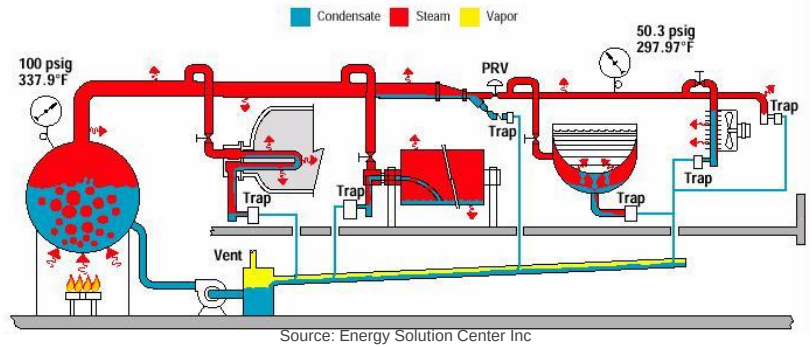
Water Sources

Raw Water Make up

- Raw water can be taken from many sources such as wells or municipal water
- Raw water can have many impurities such as hardness, dissolved gasses, and other solids
- Makes up water lost from various reasons

Condensate Recovery

- Condensate has had many of the impurities removed from previous treatment
- Some condensate might not be economical to return to boiler



Source: Energy Solution Center Inc

Emerson Confidential

Water Treatment Methods

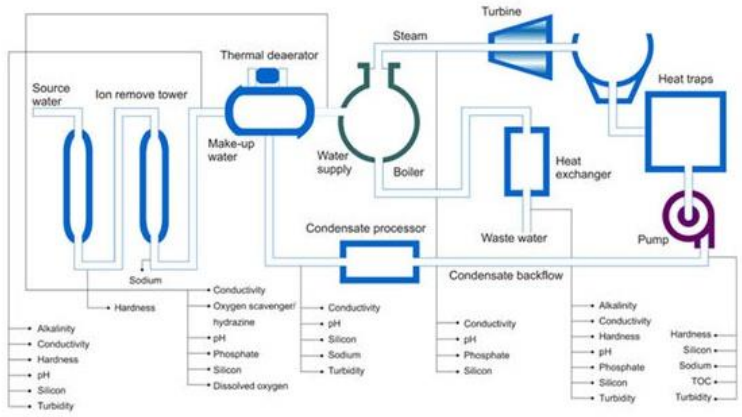
Internal Treatment

- Water treated **inside the boiler** or in the feed lines to the boiler
  - Internal feedwater treatment methods are sufficient for most low-pressure applications
  - Used in systems where condensate is returned

External Treatment

- Removes (or reduces) impurities **before the water enters the boiler**
  - Higher pressure boilers
  - Raw water make up

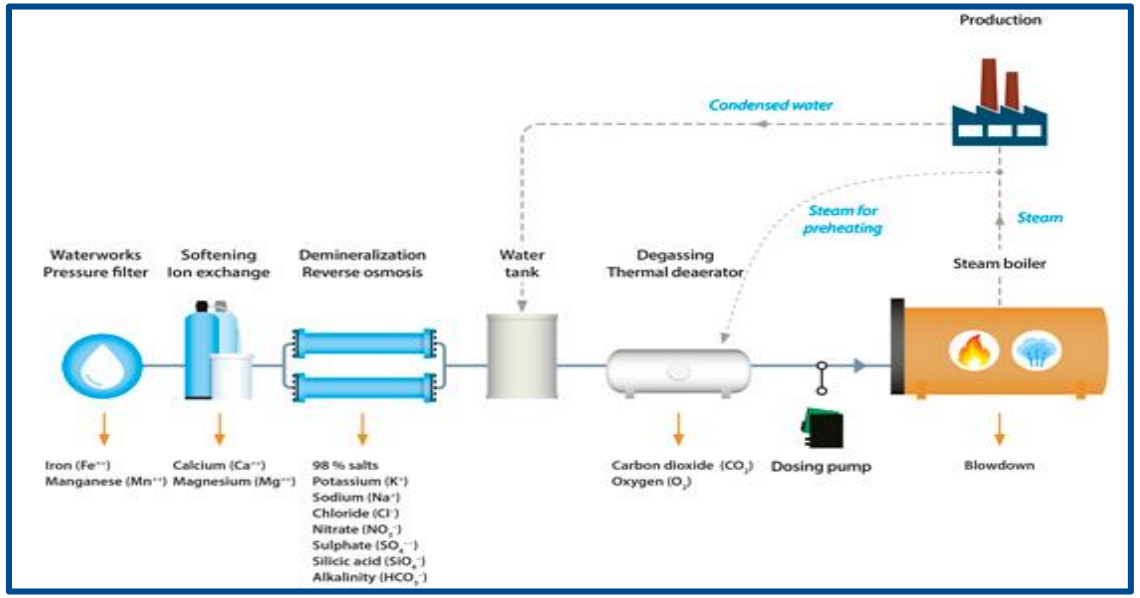
Boiler Water Treatment Flowchart



Source: Zhengzhou Boiler Group

External Feedwater Treatment

- Key methods include **softening, demineralization and dealkalization**
  - **Softening:** lime chemicals used to reduce hardness and alkalinity to prevent scaling on the boiler metal
  - **Dealkalization:** Similar to water softening with different chemicals to introduce less dissolved solids
  - **Reverse Osmosis:** used to physically separate minerals from the feedwater
  - **Demineralization**: chemical method for reducing the concentration of dissolved minerals in the water

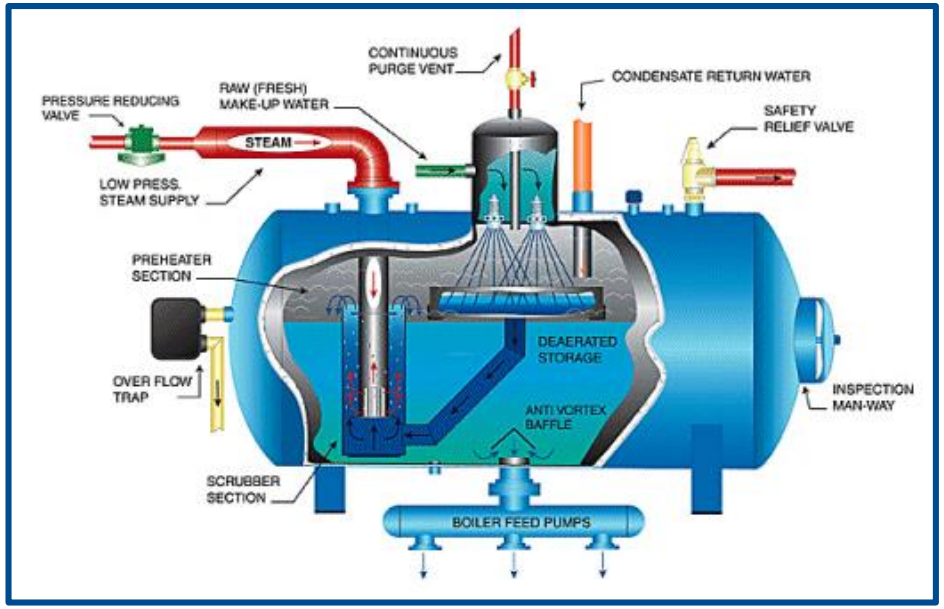


Source: Eurowater

Deaerators

Removing dissolved gases from feedwater by using steam to heat water droplets to saturation temperature

- As **water approaches boiling point, less gasses can remain in water**
- Creating **pressure drop or vacuum** is **another method to remove gas** from water



Source: DieselShip

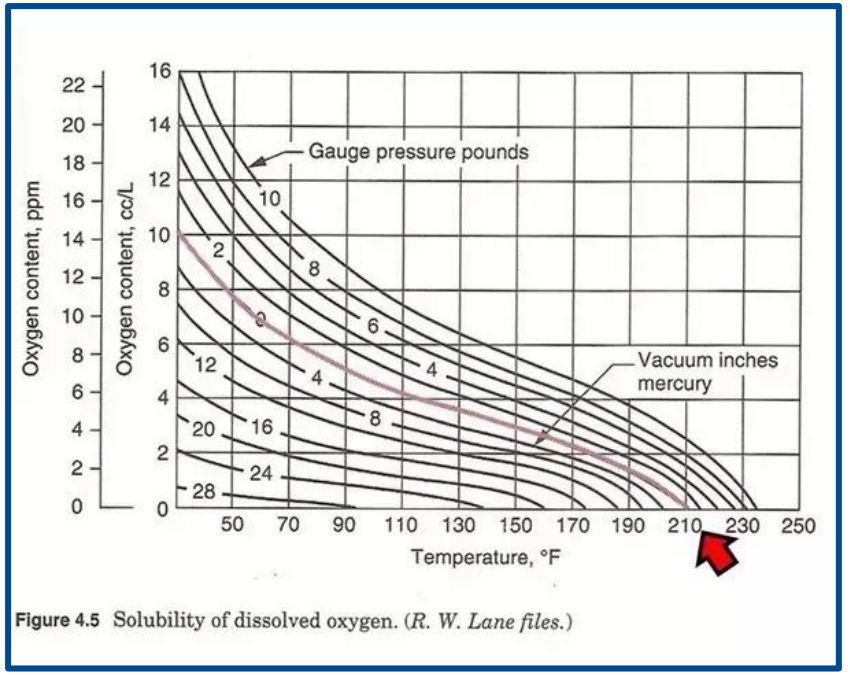


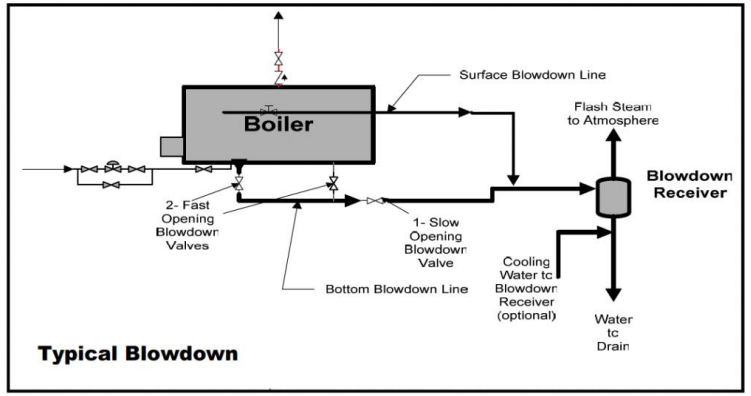
Figure 4.5 Solubility of dissolved oxygen. (*R. W. Lane files.*)

Internal Feedwater Treatment

Chemical Treatment

- Key components include **softening chemicals, oxygen scavengers and anti-scaling / anti-foaming agents**
  - **Softening Chemicals:** neutralize the water hardness by forming an insoluble compound that can be removed during the blowdown process
  - **Oxygen Scavengers:** reduce the concentration of oxides or dissolved oxygen to prevent corrosion
  - **Anti-Scaling Agents:** prevent the feedwater treatment products from adhering to the boiler metal
  - **Anti-Foaming Agents:** reduce foaming and prevent carryover of water particles in the steam
- Main objective is to **convert scale-forming impurities to sludge or dissolved solids**
- **Blowdown removes sludge or controls the concentration of dissolved solids in the water**

Solid Scale Around Boiler Tubes
Source: Discover Live Steam

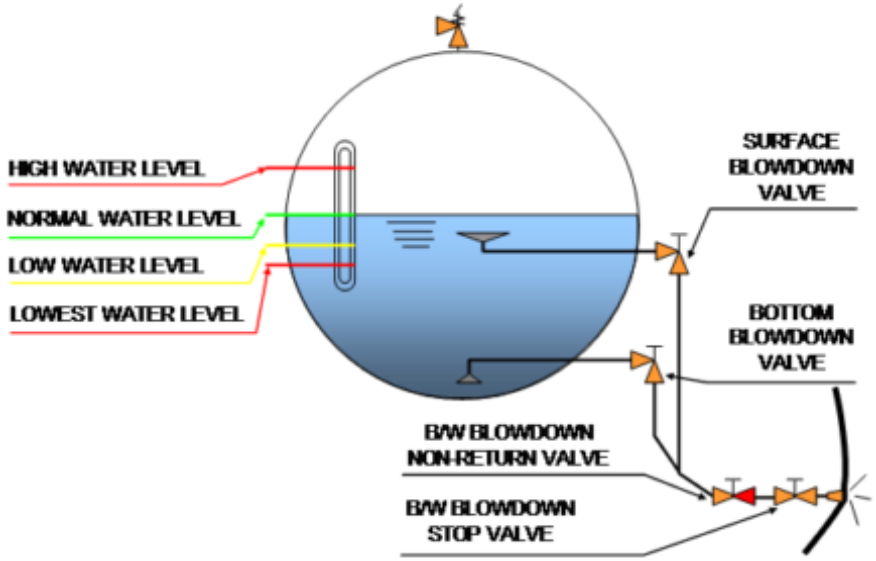


Source: Industrial Steam

Internal Feedwater Treatment

Boiler Blowdown

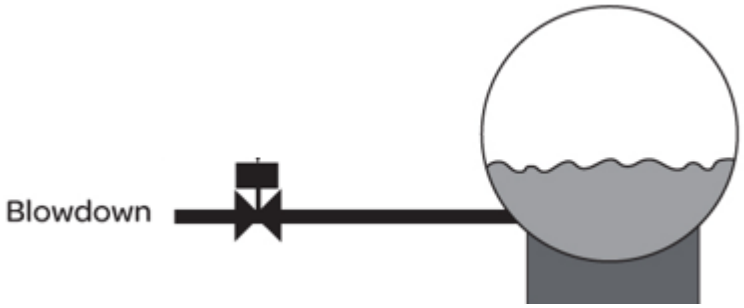
- System consists of the **valves and controls for Surface and bottom blowdown**
- **Surface Blowdown** – removal of a specific amount of boiler water to keep the concentration of dissolved solids in the boiler at a certain level
  - Also referred to as Surface Blowdown
  - Amount of water removed is typically calculated based on flow rate and TDS
  - Can be manual or fully automatic (controller)
- **Bottom Blowdown** – periodic removal of particulates / sludge from the bottom of the boiler
  - Also referred to as Blowoff or Intermittent Blowdown



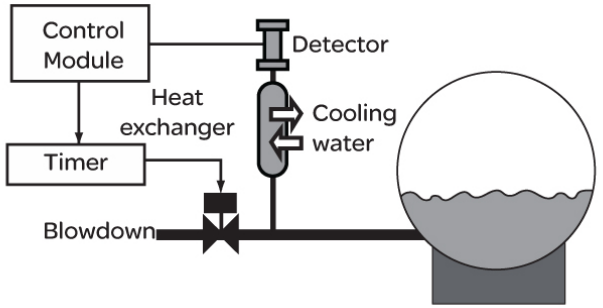
Source: marinewiki.net

Surface Blowdown / Total Dissolved Solids (TDS) Control

- **TDS level in the boiler water must be controlled to prevent carryover**
- Some of the boiler water (<=10%) is **continuously removed by skimming the surface of the water in the steam drum to remove the entrained solids**
- **Surface blowdown** can be **done manually** or with an **automated system** by **measuring TDS levels**
  - Key components for blowdown are **sample cooler**, **blowdown valve,** and TDS level **measurement device**
  - Automated system also includes **blowdown controller**
- **ASME Requirements: Surface blowoff connection size shall not exceed NPS 2 ½**



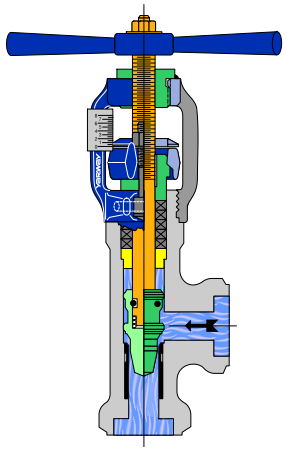
Blowdown Control Schemes (Source: Eurotherm)



Blowdown Control Schemes (Source: Eurotherm)

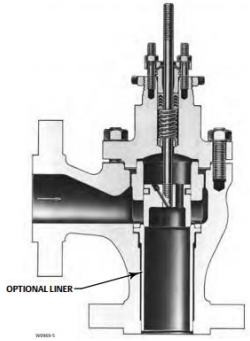
Surface Blowdown Valve Challenges

Challenge	Solution
Since the water leaving the boiler is at saturation temperature, flashing occurs due to the drop in pressure over the valve orifice. This increases the probability of erosion of the valve seat	Special materials and geometries to prevent valve damage through flashing and cavitation
Valve must be able to handle changing flow conditions	Adjustable and repeatable flow rates
Costs associated with field repair and maintenance	In-line repairable valves reduce maintenance cost and total cost of ownership

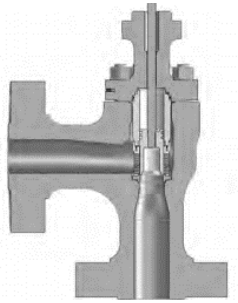


Yarway Hydrop Valve

Hancock 5505



Fisher EAD/T



Fisher HPAD/T

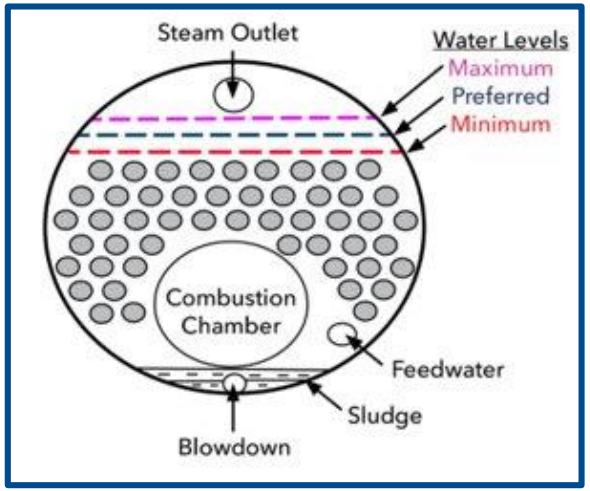
Continuous Blowdown Valves Can Also Be Used for Sampling, Boiler Feed Pump Bypass Relief and Other Applications Where a High Pressure Drop Causes Erosion or Cavitation

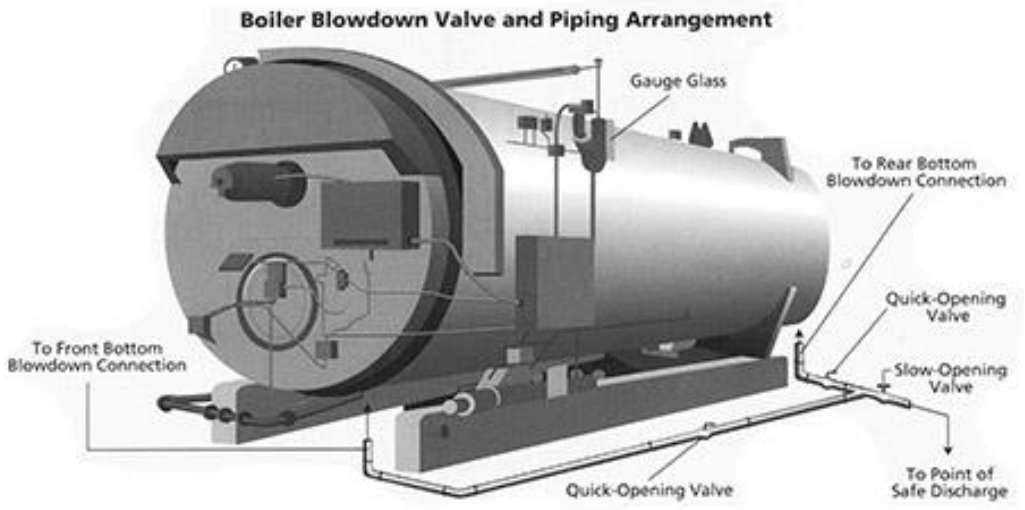
Bottom Blowdown

- Suspended solids will accumulate at the bottom of the boiler (sludge) and eventually inhibit heat transfer from the boiler fire tubes

- **Bottom Blowdown involves brief, intense blasts to agitate and remove the sludge**
  - Water from Bottom Blowdown typically goes to a Blowdown or Blowoff Vessel

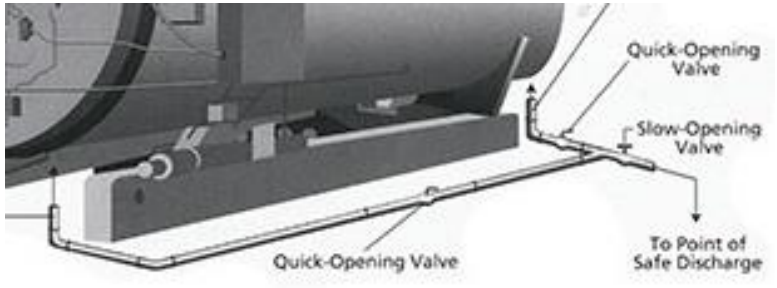
- Bottom Blowdown (or Blowoff) valve is the main component and controls the flow
  - Blowdown rate depends on the boiler pressure, size of the blowdown line and the length of the line between the boiler and the blowdown vessel

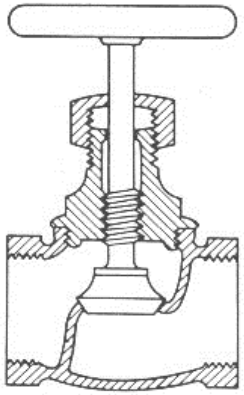


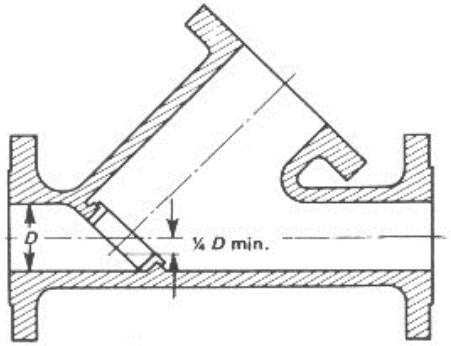


Source: R.F. MacDonald Co.

Bottom Blowdown Valve ASME Requirements







- **Two Blowoff valves in series**
  - **one must be slow-opening**
  - **5 full 360 deg. turns**
- Two valves can be combined in one body to meet code requirement
  - **Unit Tandem**
- **Bottom blowoff** connections shall be **NPS 1 minimum** and shall be **NPS 2 ½ maximum**

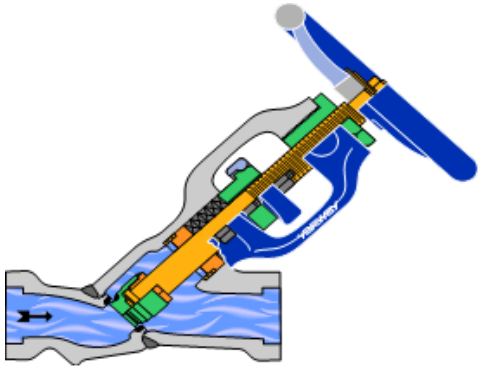
- Ordinary globe valves and other **valves that have dams or pockets shall NOT be used**

- The **lowest edge** of the opening through the seat is **at least 25%** of the inside diameter **below** the **center line of the valve**

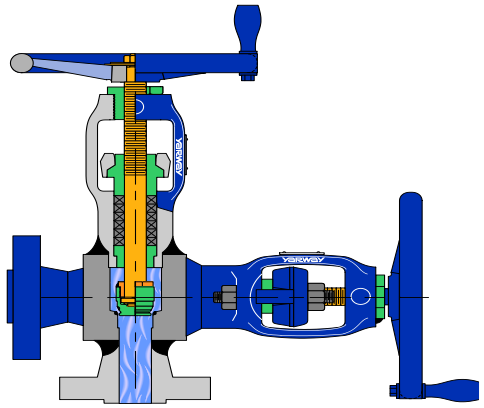
Bottom Blowdown Valve Challenges

Challenge	Solution
Dirt or sediment removed from the boiler during the bottom blowdown process can damage the valve seat	Seatless valves minimize the risk of dirt damage, plugging and leaks. Hardseat valves have stellite seats which resist wear and extend service life
Installing 2 valves in series per the ASME code can be challenging with space constraints	Combining 2 valves into one reduces the space needed to meet the ASME code requirement
Opening both valves too quickly can rapidly drain the boiler drum	ASME requires at least one slow-opening valve to ensure that the boiler drum is drained at a controlled rate
Costs associated with field repair and maintenance	In-line repairable valves reduce maintenance cost and total cost of ownership

Seatless Valve



Hardseat Valve



Unit Tandem Valve

Key Takeaways

1. Improving the boiler water and incorporating automated systems reduces energy loss in blowdown process.

2. Analyzed water determines proper treatment of the water. If it is not measured, how do you know?

3. ASME code has requirements for the boiler and valves on the boiler. Are you code complient?

Quiz

Please take a moment to answer the question about to pop up on your screen.

Reminder: This also serves as an attendance requirement for PDH credits.

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Boiler Level Monitoring

Tim Dwyer
Emerson

R.E. MASON
Emerson Impact Partner

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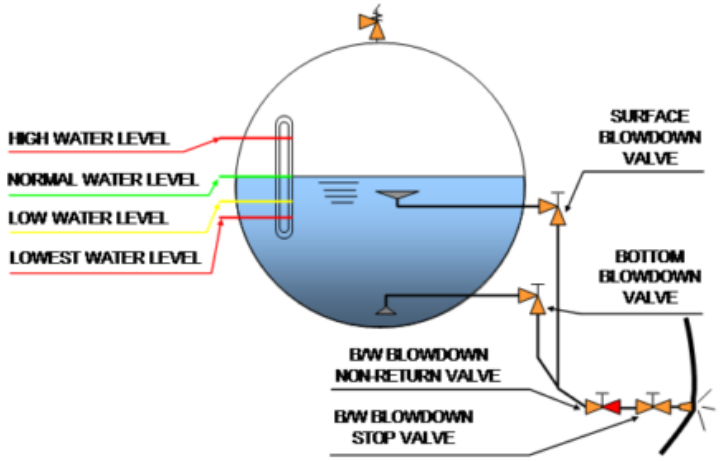
Boiler Level Overview

- **Proper water levels are crucial for proper boiler function and safety, level monitoring is the first line of defense**
- **Water levels are constantly changing** in boilers due to adding and removing water and need to be maintained for boilers to run properly
- Water Level is critical for effective operation of boiler and downstream equipment by preventing overpressure situations and carryover

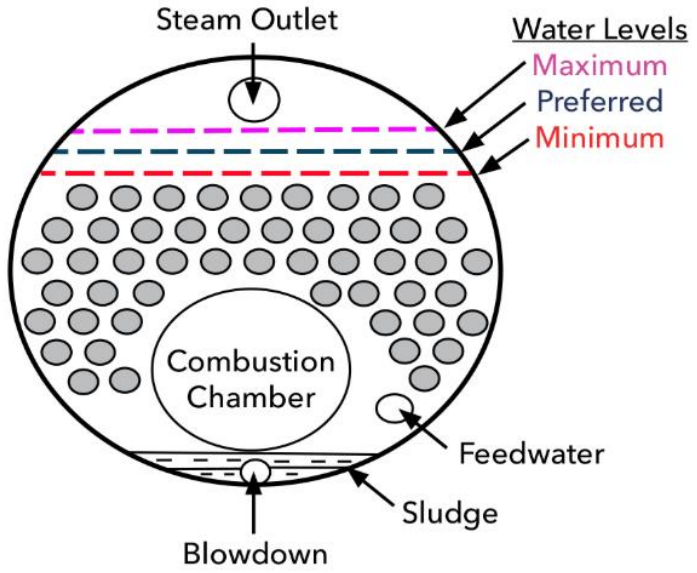


Source: marinewiki.net

Boiler Water Level Overview

Boiler Design Fundamentals

- **Normal water level (NWL)** is the level boilers are designed to operate safely and efficiently
- The steam take-off from the boiler must be a minimum height above the NWL to prevent carryover
- Minimum water level must be above the tubes to ensure they are constantly covered



Reasons for Boiler Level Monitoring and Control

- Boiler water evaporates as steam is generated so **water must be replenished to maintain the required level**
- **High water level increases the likelihood of carryover (priming)**

ASME Boiler Code Excerpt

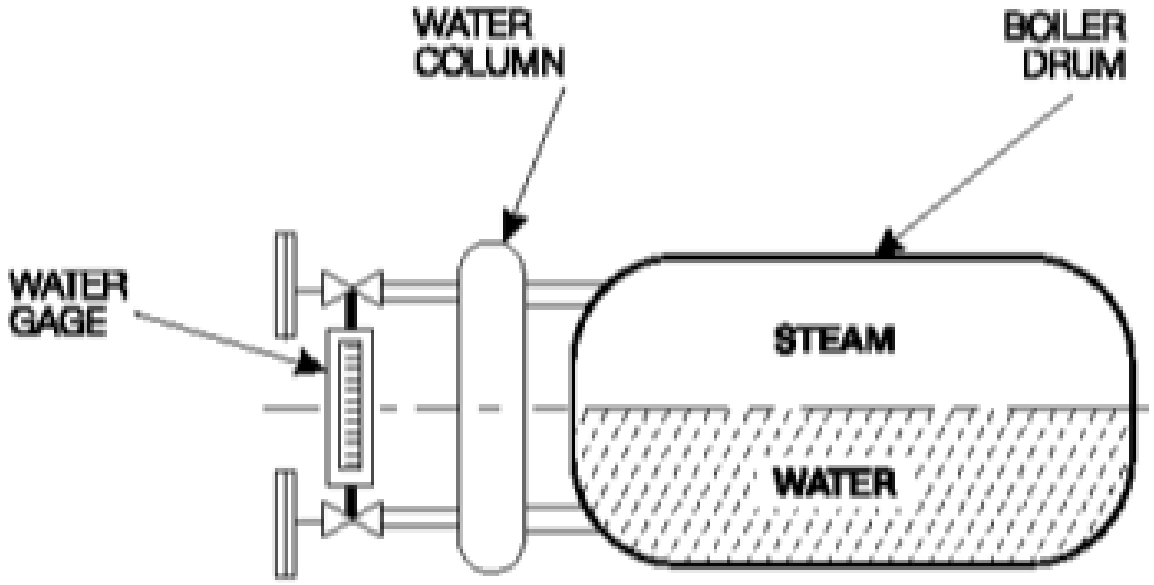
Section I PG-60.1

“All boilers having a fixed water level (steam and water interface) shall have at least one gage glass.”

ASME Boiler Code Excerpt

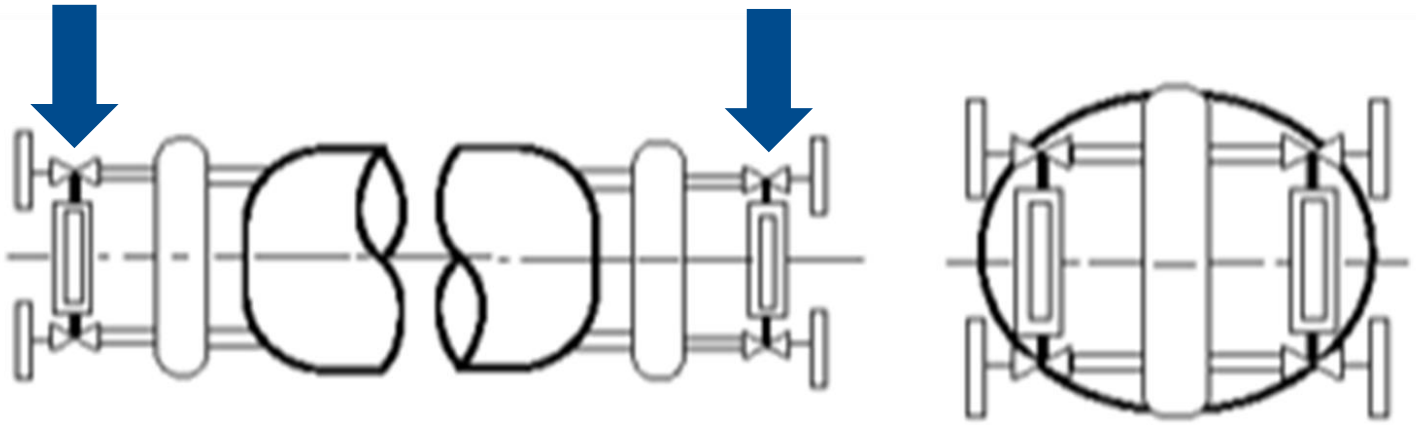
Section I PG-60.1.1

“Boilers having a MAWP of 400 psi or less shall have at least one gage glass in service at all times.”



(a) Boiler pressure less than 400 psi

ASME Boiler Code Excerpt



(b) Boiler pressure greater than 400 psi

Section I PG-60.1.1

"Boilers having a MAWP exceeding 400 psi shall have two gage glasses. Instead of one of the two required gage glasses, two independent remote water level indicators…may be provided"

Glass Gauge / Remote Indication

Glass Gauges – a transparent device that permits visual determination of the water level

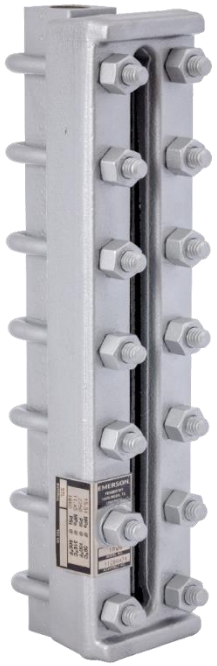
- Tubular
- Reflex
- Transparent
- Ported

Remote Indication – a discrete systems that continuously measure, transmit, and display water level

- Conductivity probe
- Magnetic gage
- Differential Pressure
- GWR

Glass Level Indication – Direct Indication

Tubular Up to 250 psig	Reflex Up to 350 psig	Transparent Up to 1500 psig	Ported Up to 3000 psig



Tubular Glass Gauge

Steam Rating:

Up to 250 psig @ 434° F

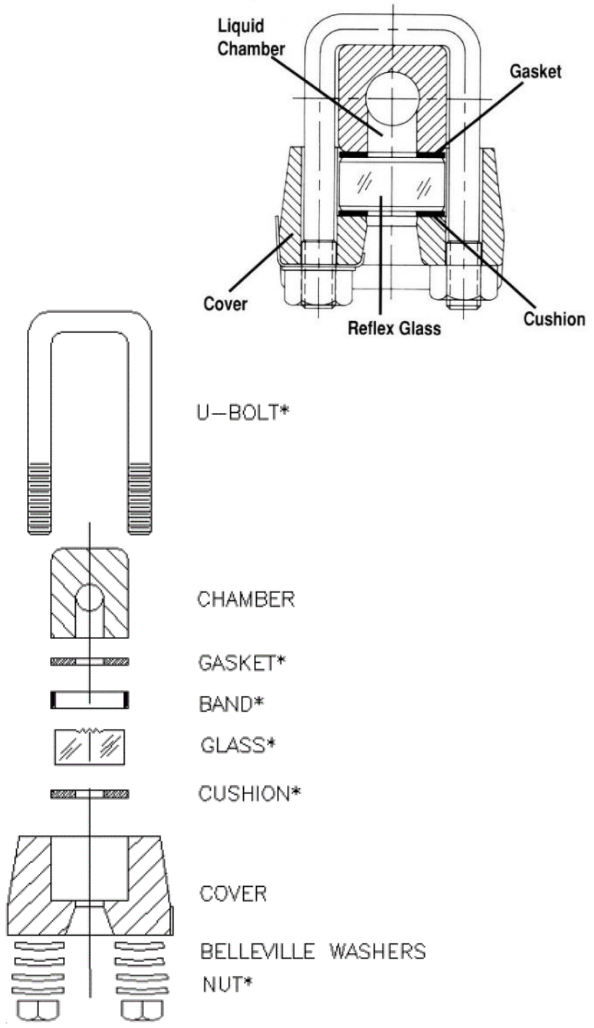
- Offers the **least protection for plant personnel**
  - Guard rods are available
- Typically used for Boil-out or chemical cleaning purposes
- Glass cannot be protected by mica shield
- Not a permanent installation
- **Replace Tubular Glass with Armored Gauge**

Reflex Glass Gauge for Steam Service

Steam Rating:

Up to 350 psig @ 434° F

- **Glass has Molded Prisms on one side**
- Belleville Washers are added for steam applications
- **Glass and Gaskets are 100% replaceable**
- Nuts and U-Bolts are recommended for replacement



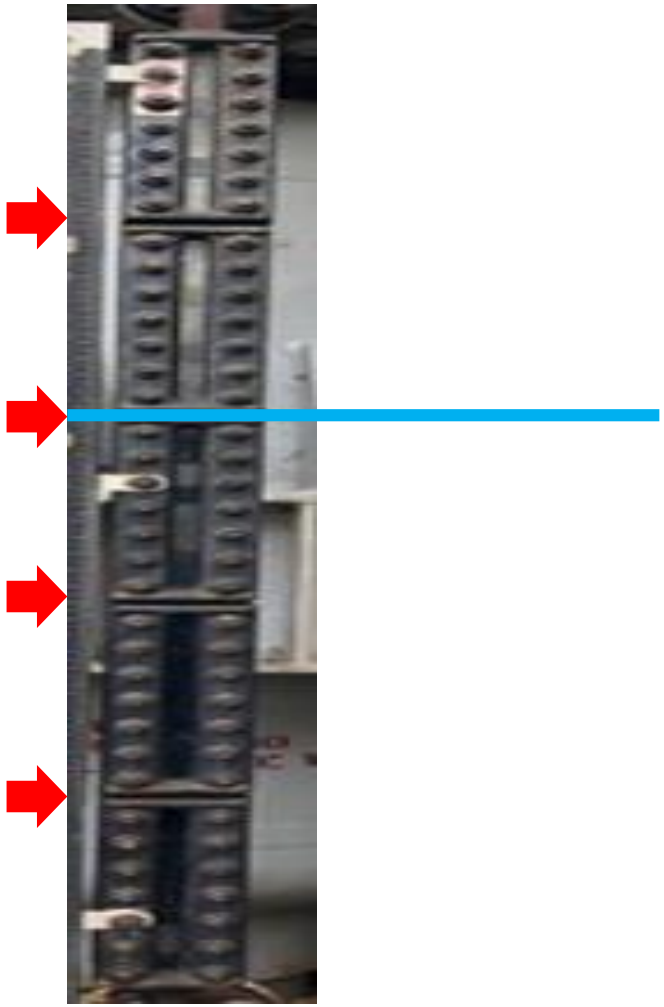
Glass Gauge Chamber

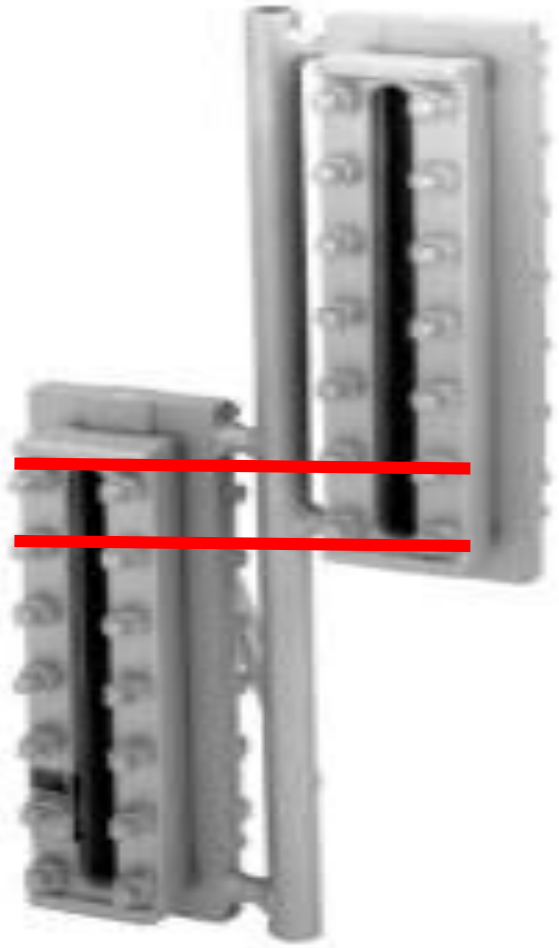
AMSE code

- Cross Webs – “transverse structural members as a means to strengthen the body of the gage”

- **Gauges must be continuous over the entire vertical length of the gage glass**

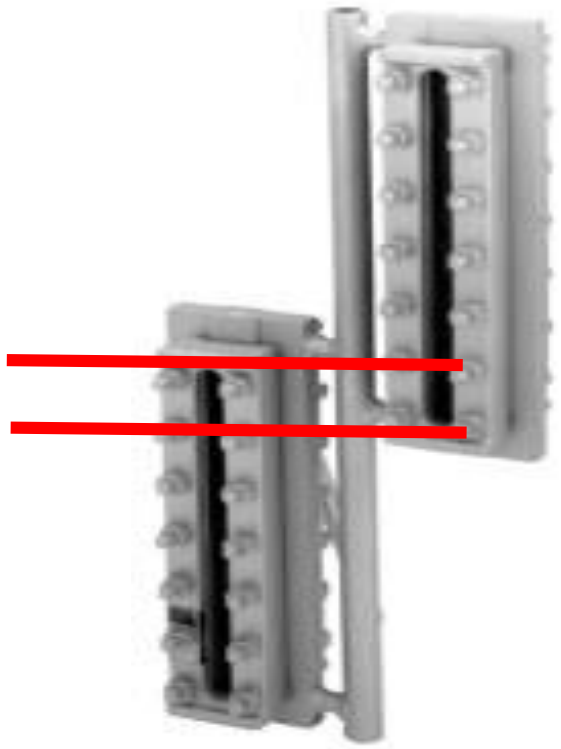
Transparent Glass Gauge for Steam Service





Transparent Glass Gauge

TSL
650 psig @ 494ºF



Transparent Gauge

- Available in single section or multi-section
  - **1” overlap is required per code**
- Belleville washers and mica shields are standard
- **Glass, Gaskets, and Mica Shields are 100% replaceable**
- Nuts, studs, and belleville washers are highly recommended

TSM
1500 psig @ 596°F

Ported Glass Gauge / Color Port

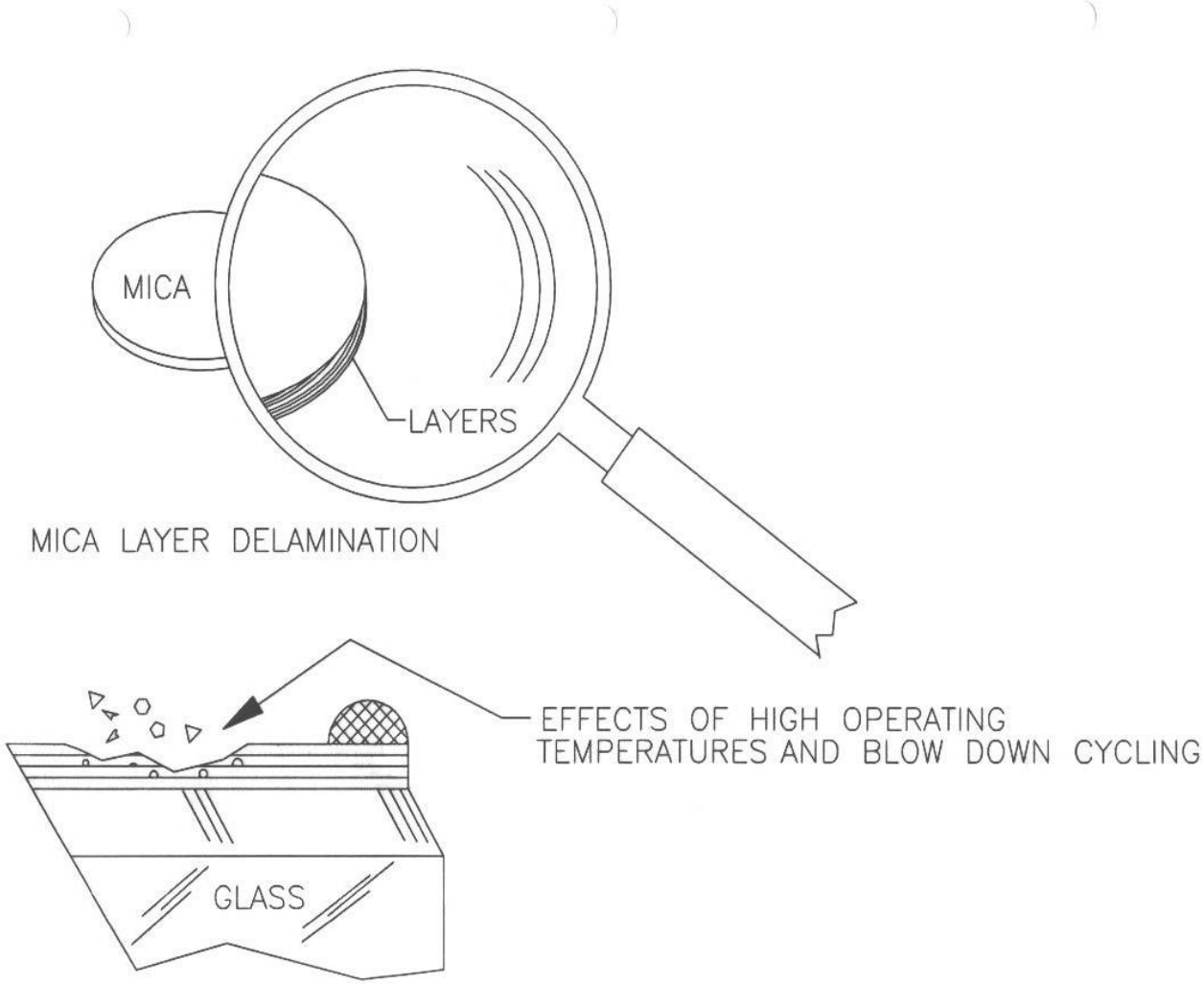
Steam Rating:

Up to 3000 psig @ 700ºF

- Design changes:
  - Round glass
  - Aluminosilicate glass
  - Trapezoid body

- **Illuminator is required** in order to properly tell if the there is liquid or steam present

Mica Shield

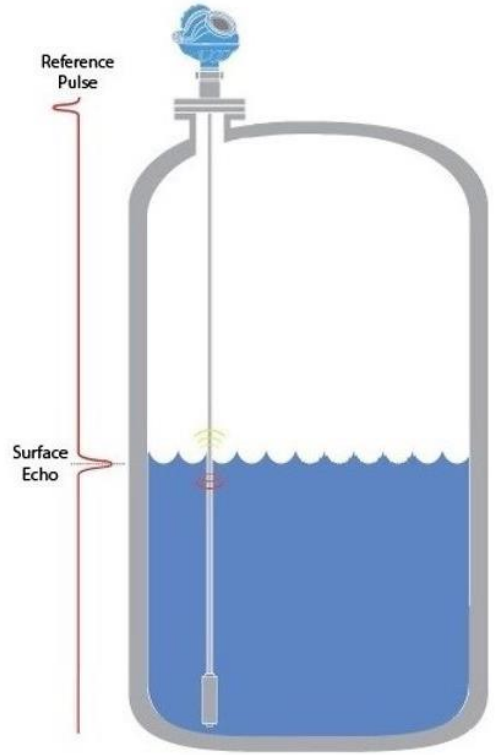

MICA
LAYERS
MICA LAYER DELAMINATION
EFFECTS OF HIGH OPERATING
TEMPERATURES AND BLOW DOWN CYCLING
GLASS

Remote Level Indication – Indirect

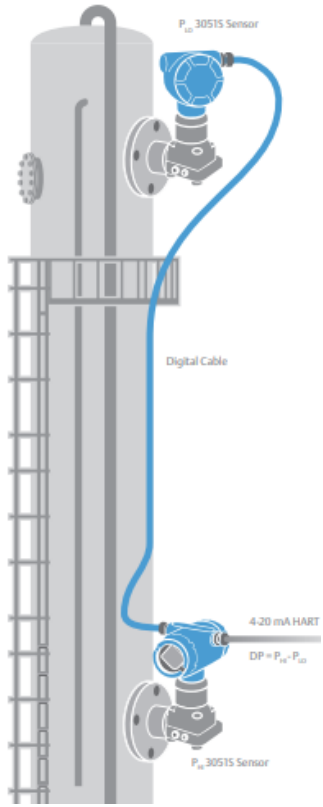
Conductivity Probe System

Magnetic Level Indication

GWR



Differential Pressure



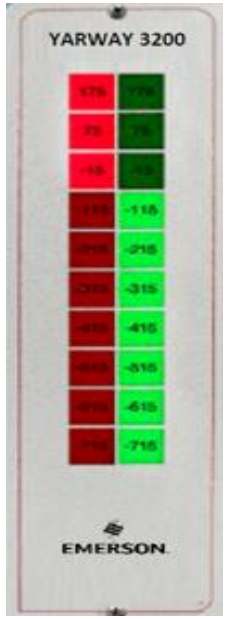
Conductivity Probe System

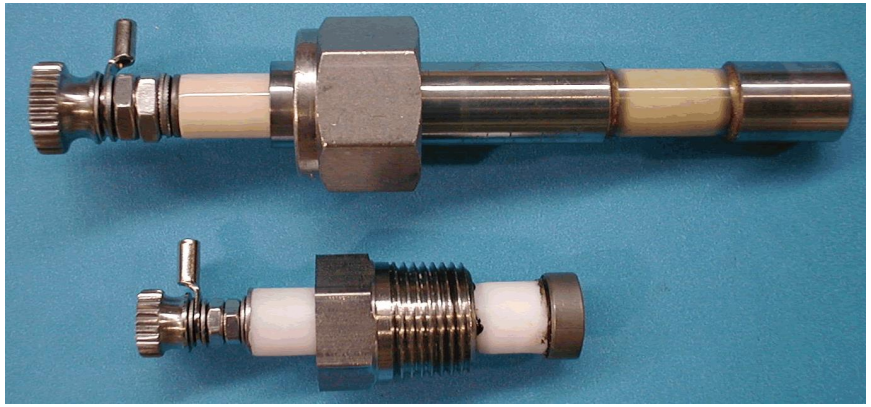
High Pressure

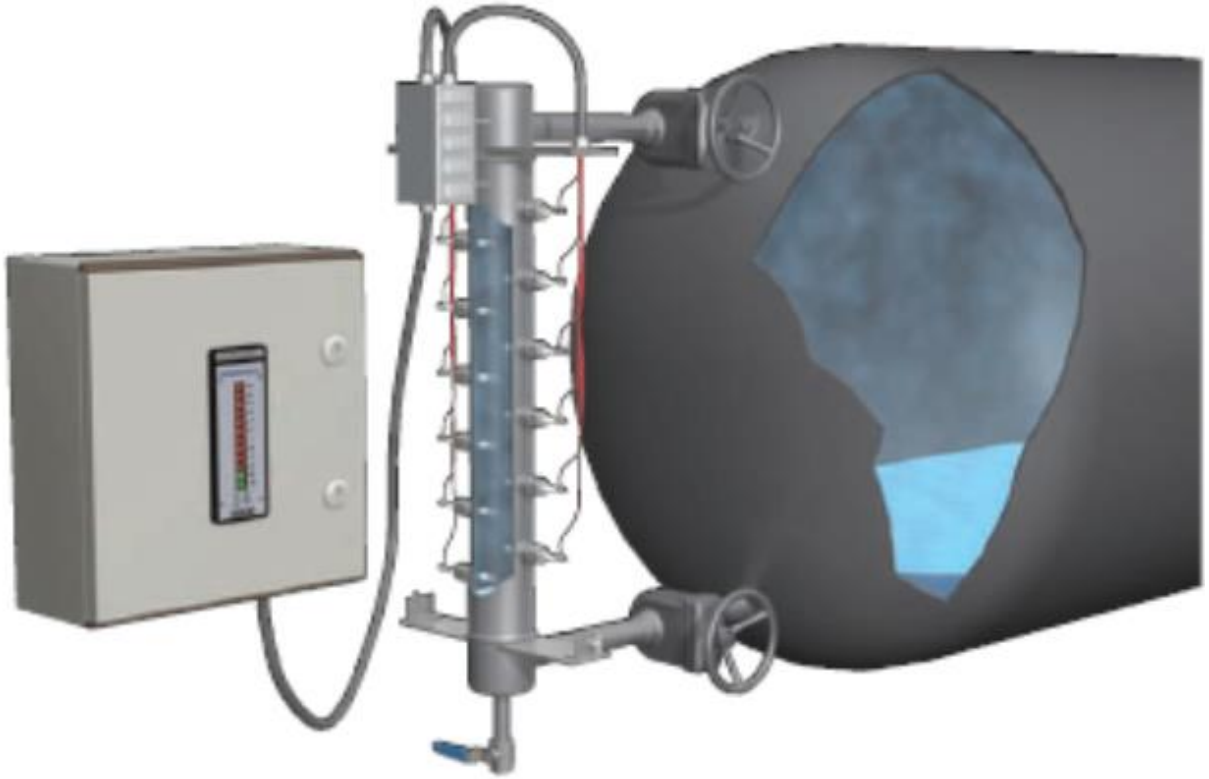
- 1000°F Max Temp
- 3000 psig

Low Pressure

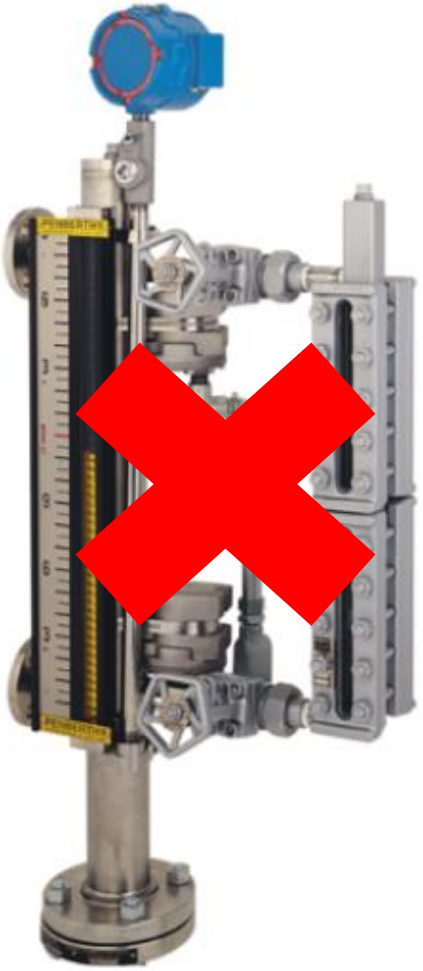
- 525°F Max Temp
- 850 psig







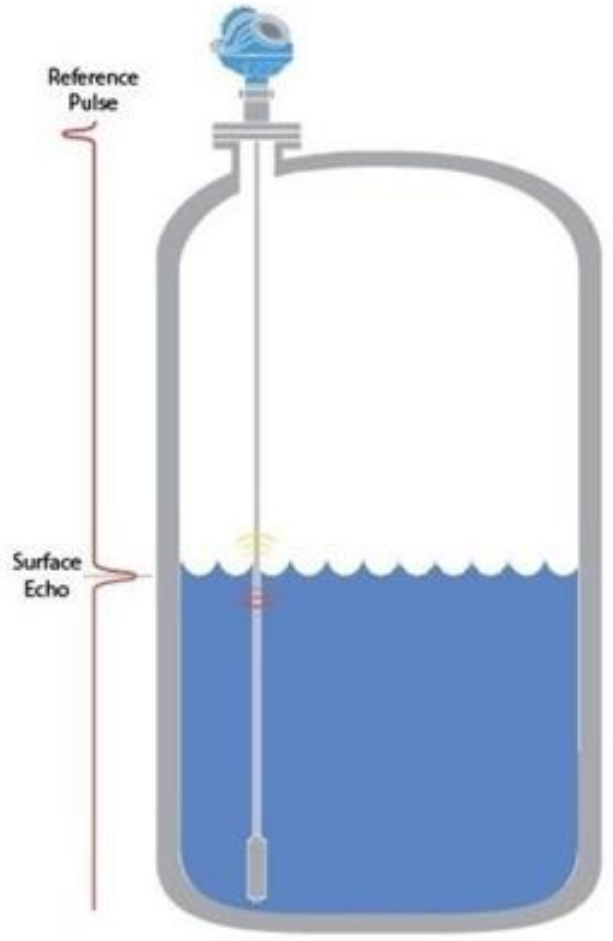
Magnetic Level Indicator



- **Permitted up to 900 PSI (PG-12.2)**
- Must be equipped with sensing device
  - MGT Transmitters – 4 to 20 mA – continuous measure and transmit
- Must not be used as a water column for the attachment of glass gauge or other instrument
- *“Attachment of any control devices for use other than indicating water level is prohibited” (such as low water cut outs)*
- **Why is it NOT Considered DIRECT?**

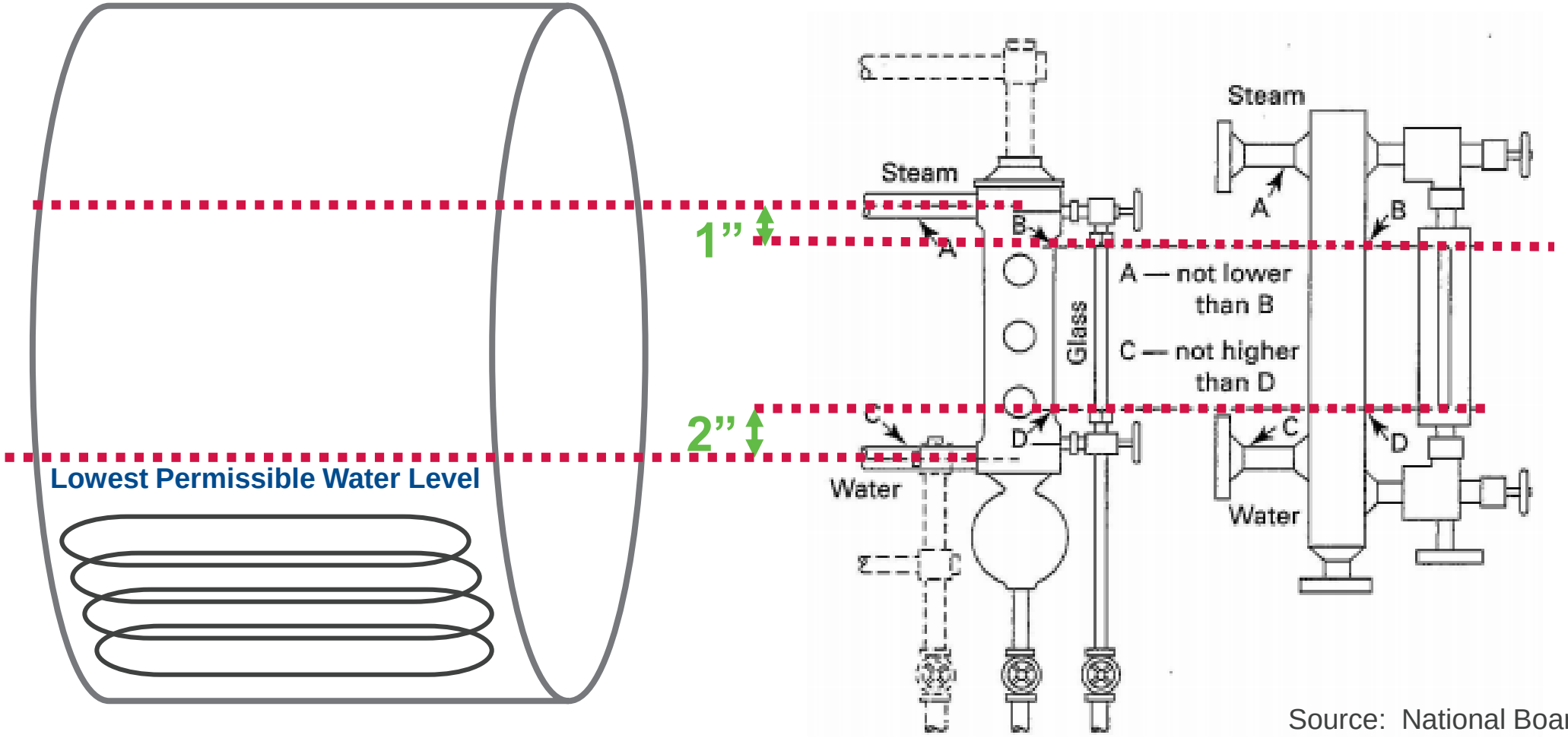
Guided Wave Radar

- Uses Microwaves to sense level by sending down probe and bouncing of surface
- Microwaves are **not affected by temperature variations, dust, pressure, and viscosity and therefore remain accurate with these changes**
- Can also detect interface level of fluids with different characteristics such as unwanted oil level in tanks



Code Requirements for Arrangements

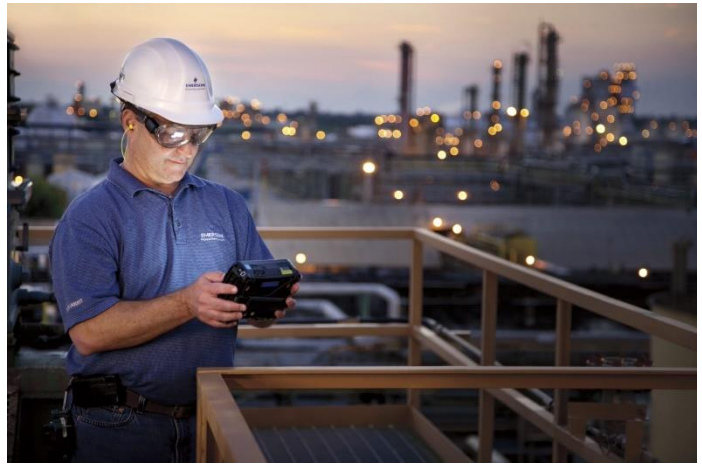
Fig PG-60.3.9 Typical Arrangement of Steam and Water Connections for a Water Column

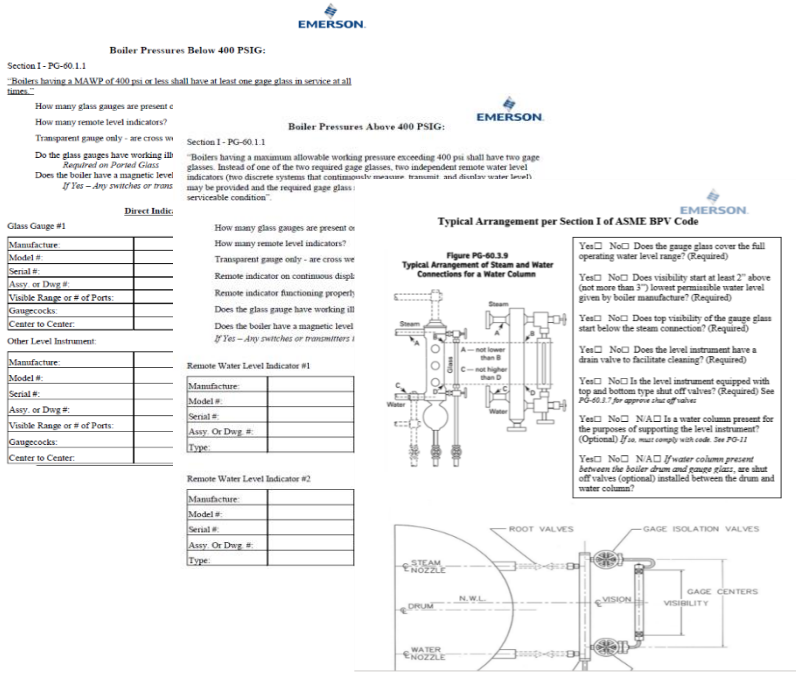


Source: National Board

Boiler Level Survey

- **Contact an Emerson representative to examine your boiler level system today!**
- Examination will determine whether you are code compliant
- Can repair and replace most gauges
- Recommend proper maintenance practices





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Boiler Pressures Below 400 PSIG:

Section I - PG-60.1.1

"Boilers having a MAWP of 400 psi or less shall have at least one gage glass in service at all times."

How many glass gauges are present
How many remote level indicators?
Transparent gauge only - are cross w
Do the glass gauges have working ill
Required on Ported Glass
Does the boiler have a magnetic level
If Yes – Any switches or trans

Direct Indic

Glass Gauge #1

Manufacture:	
Model #:	
Serial #:	
Assy. or Dwg #:	
Visible Range or # of Ports:	
Gaugecocks:	
Center to Center:	

Other Level Instrument:

Manufacture:	
Model #:	
Serial #:	
Assy. or Dwg #:	
Visible Range or # of Ports:	
Gaugecocks:	
Center to Center:	

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Boiler Pressures Above 400 PSIG:

Section I - PG-60.1.1

"Boilers having a maximum allowable working pressure exceeding 400 psi shall have two gage glasses. Instead of one of the two required gage glasses, two independent remote water level indicators (two discrete systems that continuously measure, transmit, and display water level) may be provided and the required gage glass
serviceable condition".

How many glass gauges are present o
How many remote level indicators?
Transparent gauge only - are cross we
Remote indicator on continuous displ
Remote indicator functioning properly
Does the glass gauge have working ill
Does the boiler have a magnetic level
If Yes – Any switches or transmitters

Remote Water Level Indicator #1

Manufacture:	
Model #:	
Serial #:	
Assy. Or Dwg. #:	
Type:	

Remote Water Level Indicator #2

Manufacture:	
Model #:	
Serial #:	
Assy. Or Dwg. #:	
Type:	

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Typical Arrangement per Section I of ASME BPV Code

Figure PG-60.3.9
Typical Arrangement of Steam and Water Connections for a Water Column

Yes☐ No☐ Does the gauge glass cover the full operating water level range? (Required)

Yes☐ No☐ Does visibility start at least 2" above (not more than 3") lowest permissible water level given by boiler manufacture? (Required)

Yes☐ No☐ Does top visibility of the gauge glass start below the steam connection? (Required)

Yes☐ No☐ Does the level instrument have a drain valve to facilitate cleaning? (Required)

Yes☐ No☐ Is the level instrument equipped with top and bottom type shut off valves? (Required) See *PG-60.3.7 for approve shut off valves*

Yes☐ No☐ N/A☐ Is a water column present for the purposes of supporting the level instrument? (Optional) *If so, must comply with code. See PG-11*

Yes☐ No☐ N/A☐ *If water column present between the boiler drum and gauge glass*, are shut off valves (optional) installed between the drum and water column?

Key Takeaways

1. All boilers are required to have a Glass Gauge with visual over the entire vertical length of the gauge
2. Armored gauges provide best protection for personnel and equipment
3. Indication in control room must be on continuous display

Quiz

Please take a moment to answer the question about to pop up on your screen.

Reminder: This also serves as an attendance requirement for PDH credits.

Feedwater Pump Protection

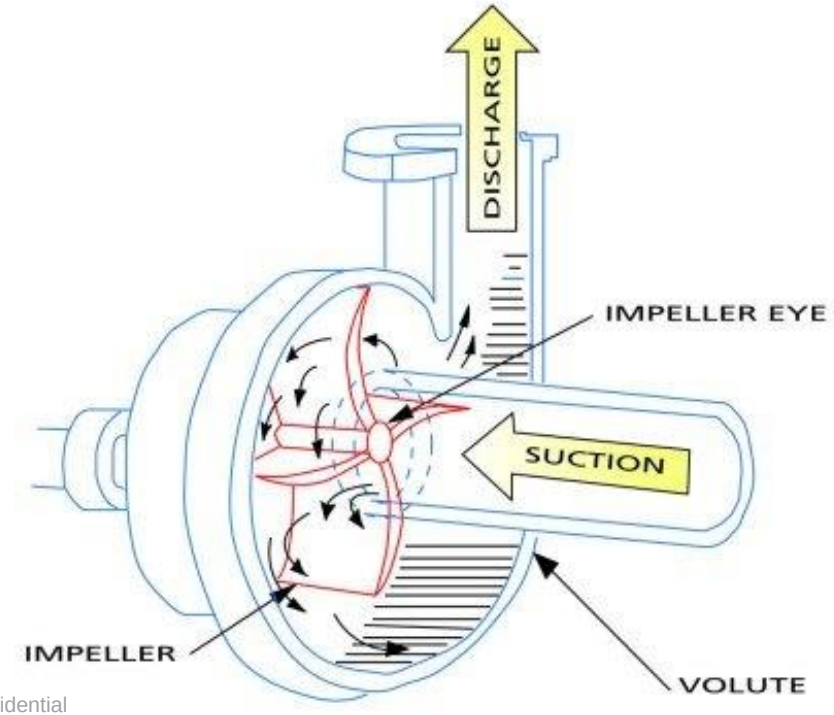
Tim Dwyer
Emerson

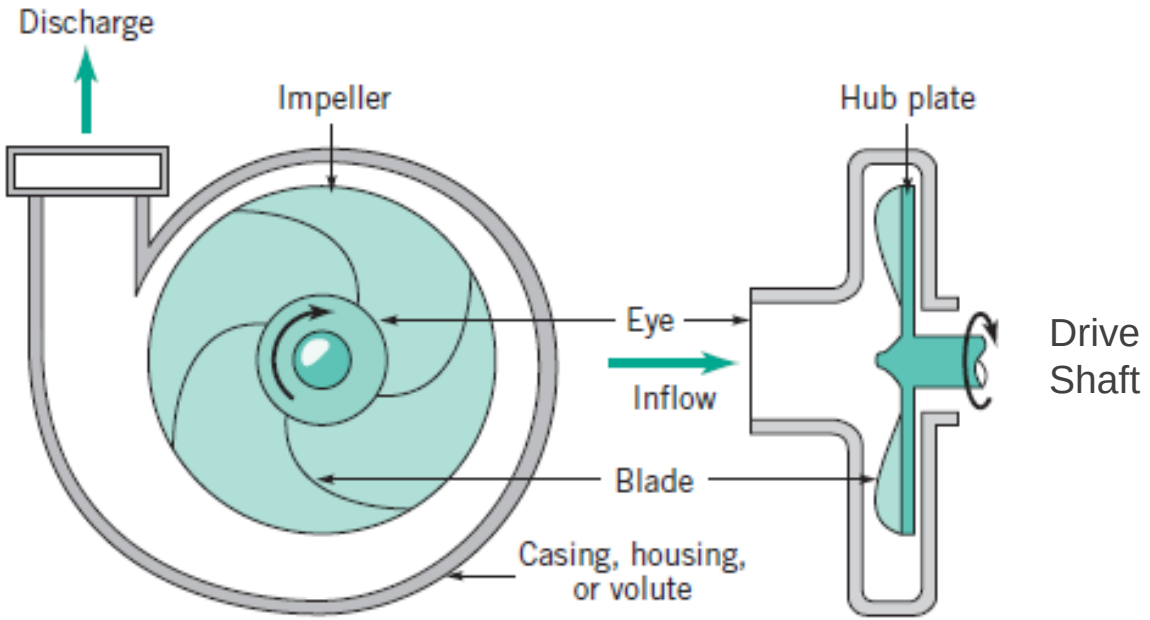
R.E. MASON
Emerson Impact Partner

EMERSON

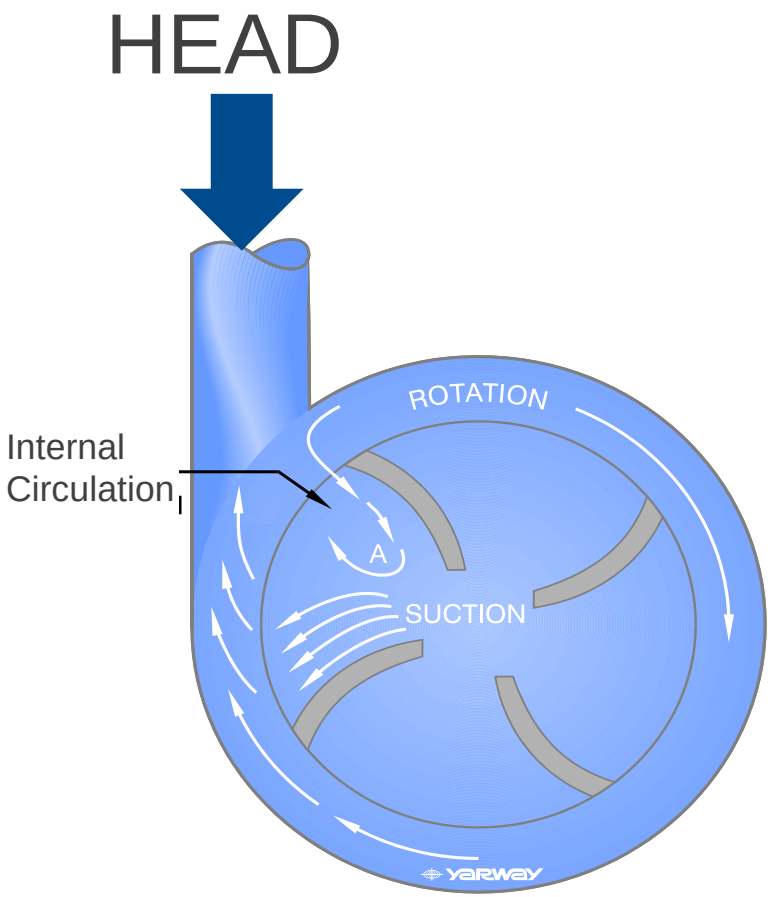
Centrifugal Pump Basic Operation

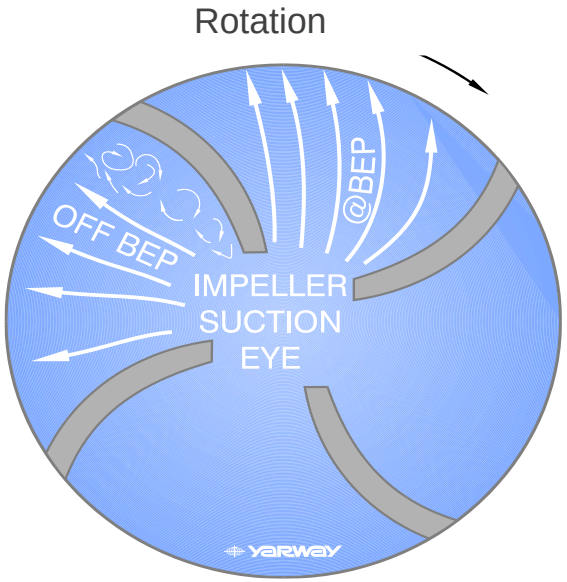
- Impeller
  - Dynamic component that directs liquid outward from suction
- Pump Casing
  - Static component
  - Spiral shaped to increase impeller / wall clearance towards pump outlet

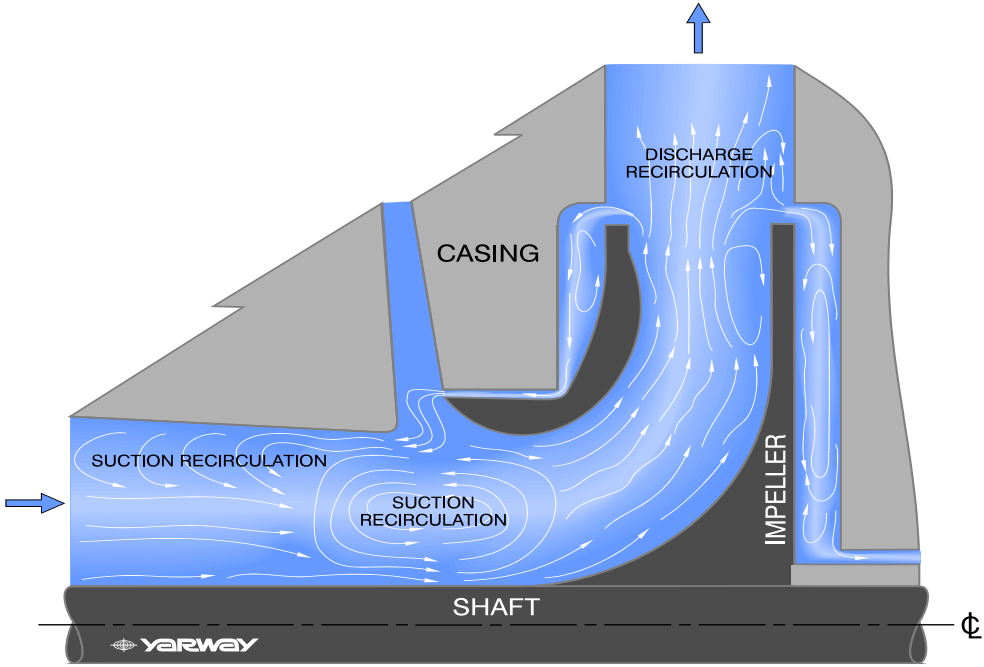




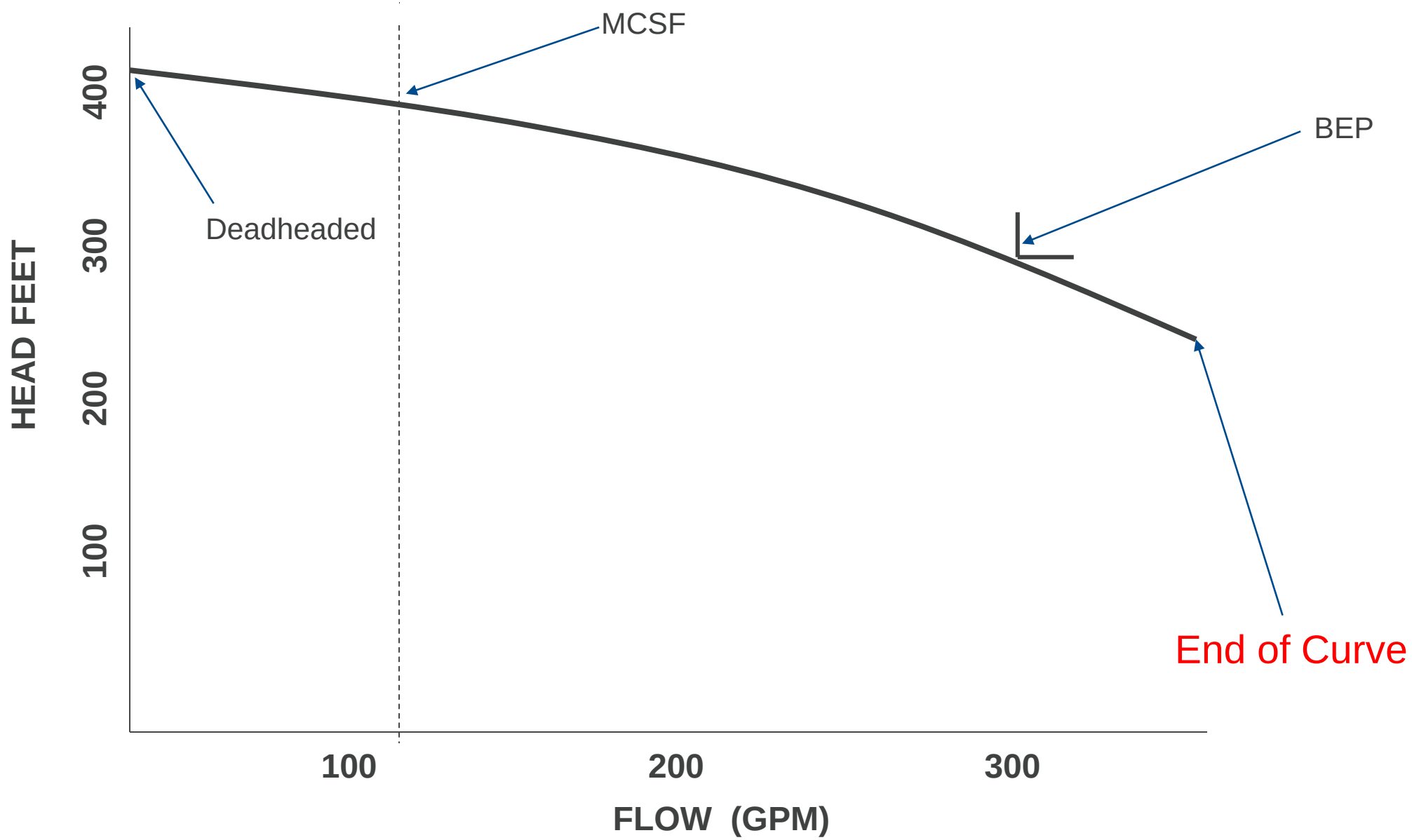
Why do centrifugal pumps need recirculation?







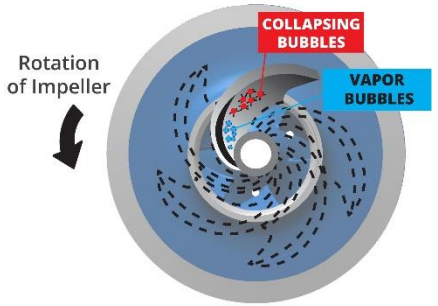
Centrifugal Pump Curve

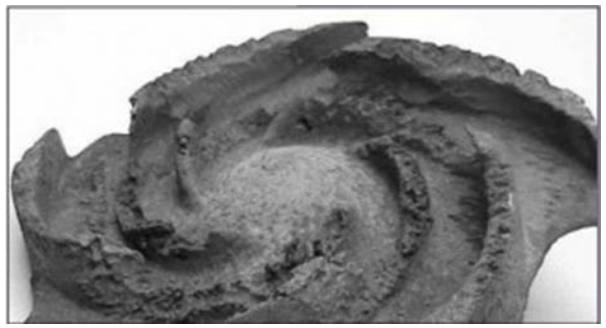


Why do centrifugal pumps need recirculation?

Hydraulic Damage

- Cavitation damage due to vortices that reduce the pressure below the vapor pressure





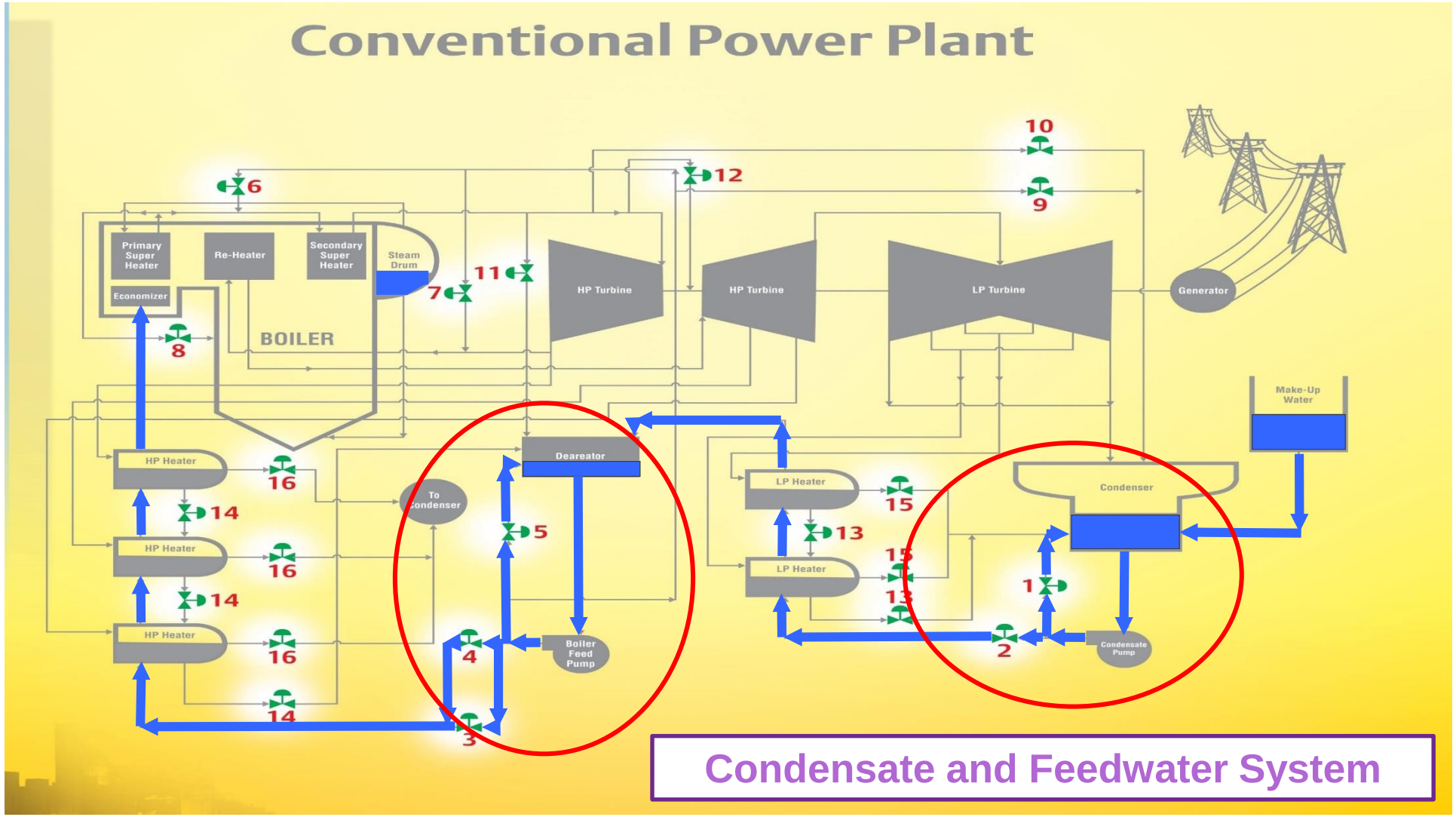
Mechanical Damage

- Non-uniform forces on the impeller transmitted to driveshaft
- Potential to break shaft
- Vibration can also cause bearing/seal failures

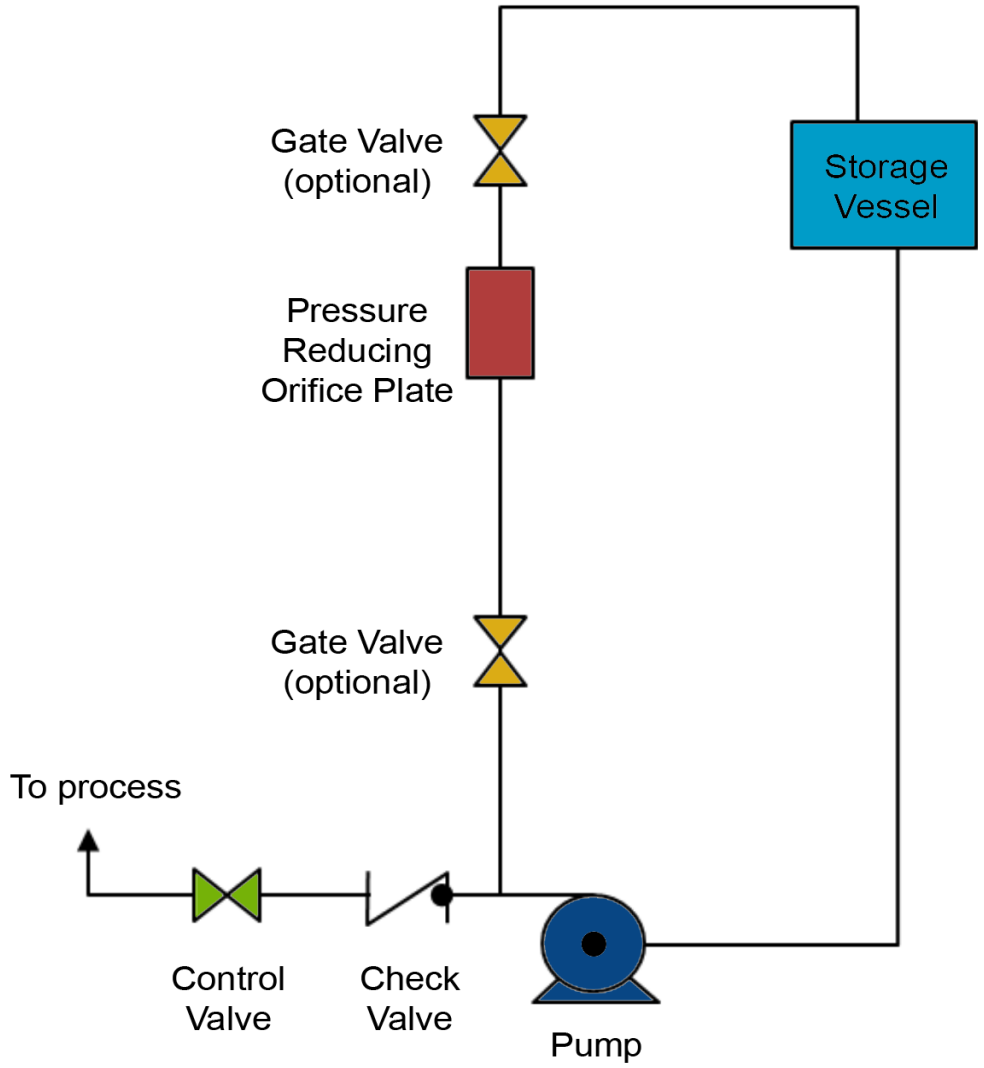
Thermal Damage

- Pumping media is required as a cooling source
- Flow not adequality delivered causes overheating

Centrifugal Pump Application Example

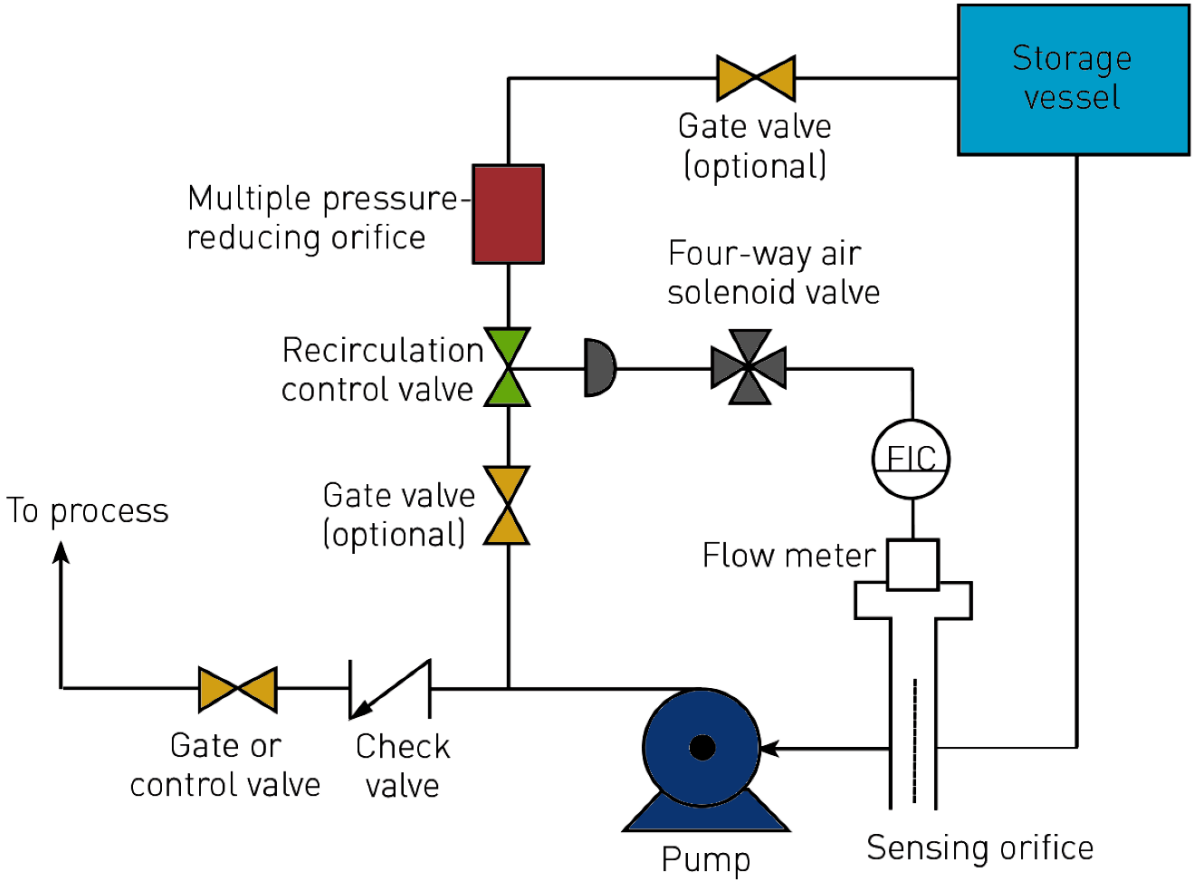


FIXED ORIFICE SYSTEM:



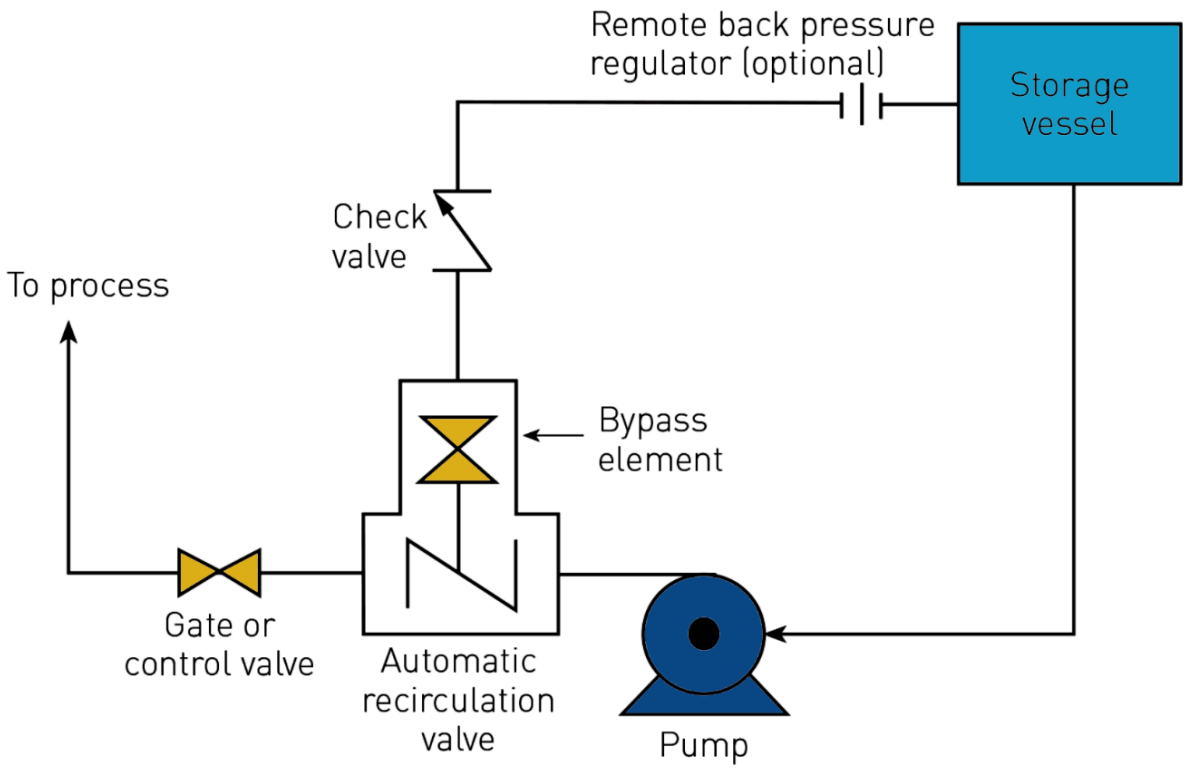
- **HIGHER OPERATIONAL COST DUE TO CONTINUOUS ENERGY LOSS**
- The fixed orifice recirculation system is a common system configuration for centrifugal pumps.
- This continuous recirculation system may require a larger pump

Control Loop System



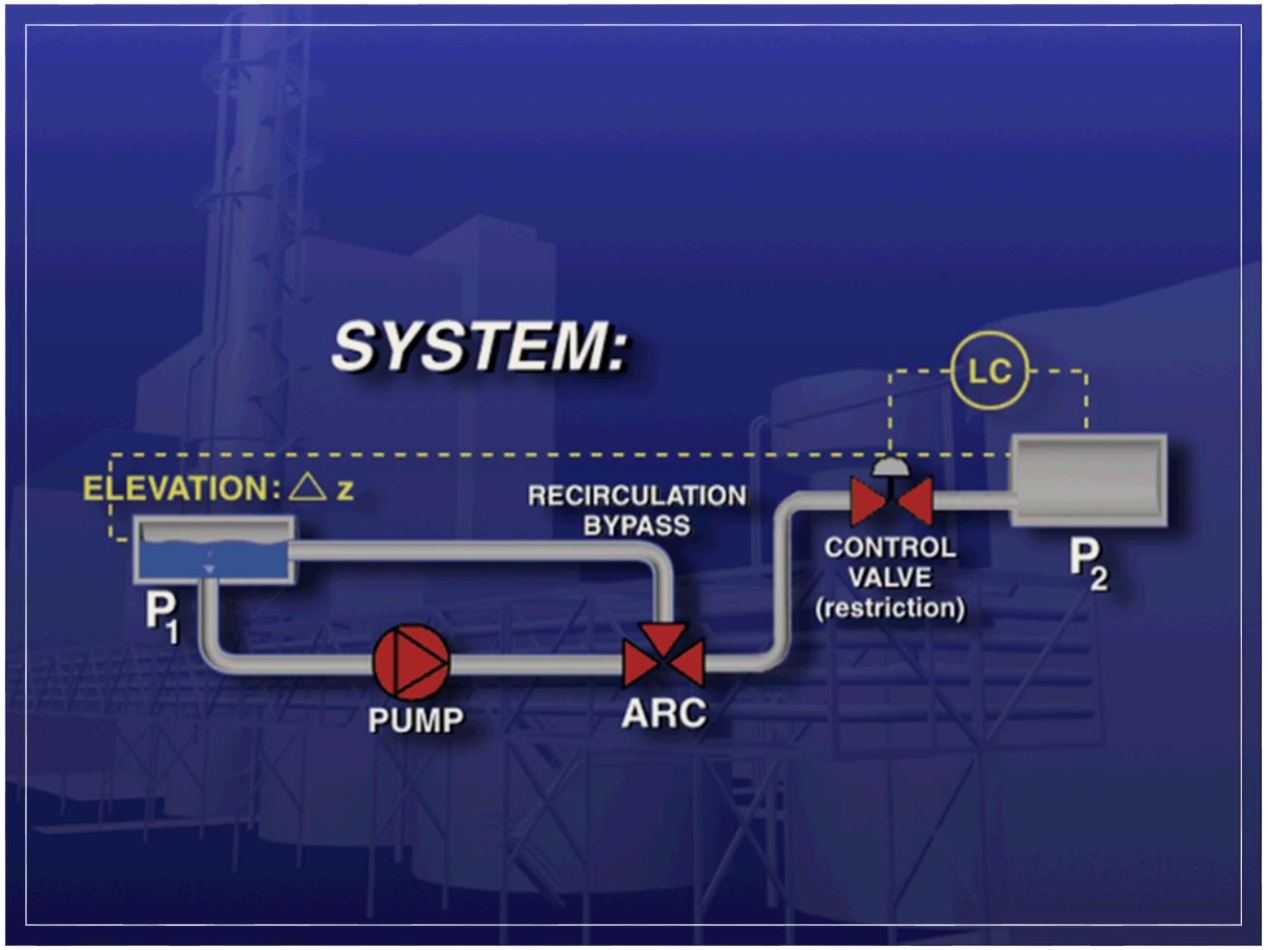
- High installation and operation cost
- Can be manually changed
- More equipment to maintain
- More complicated system = more parts to be serviced

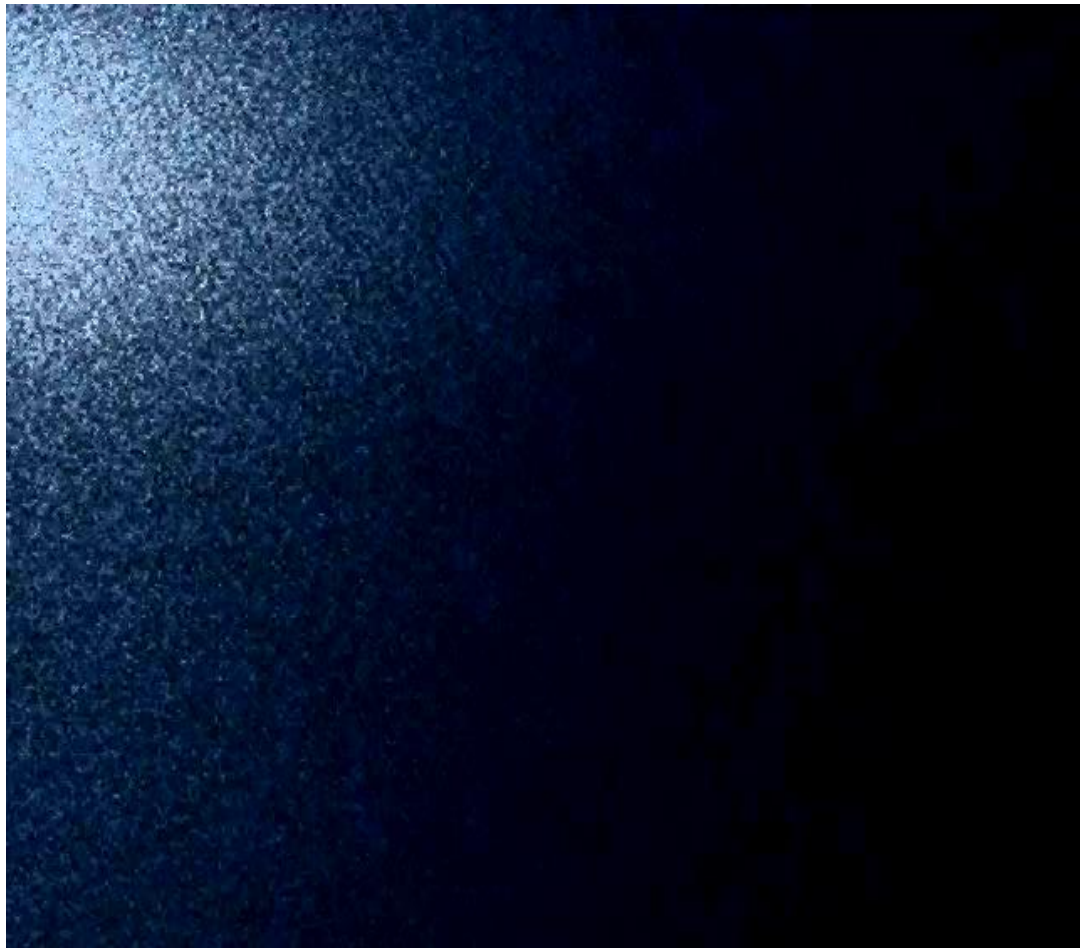
Automatic Recirculation Valve System



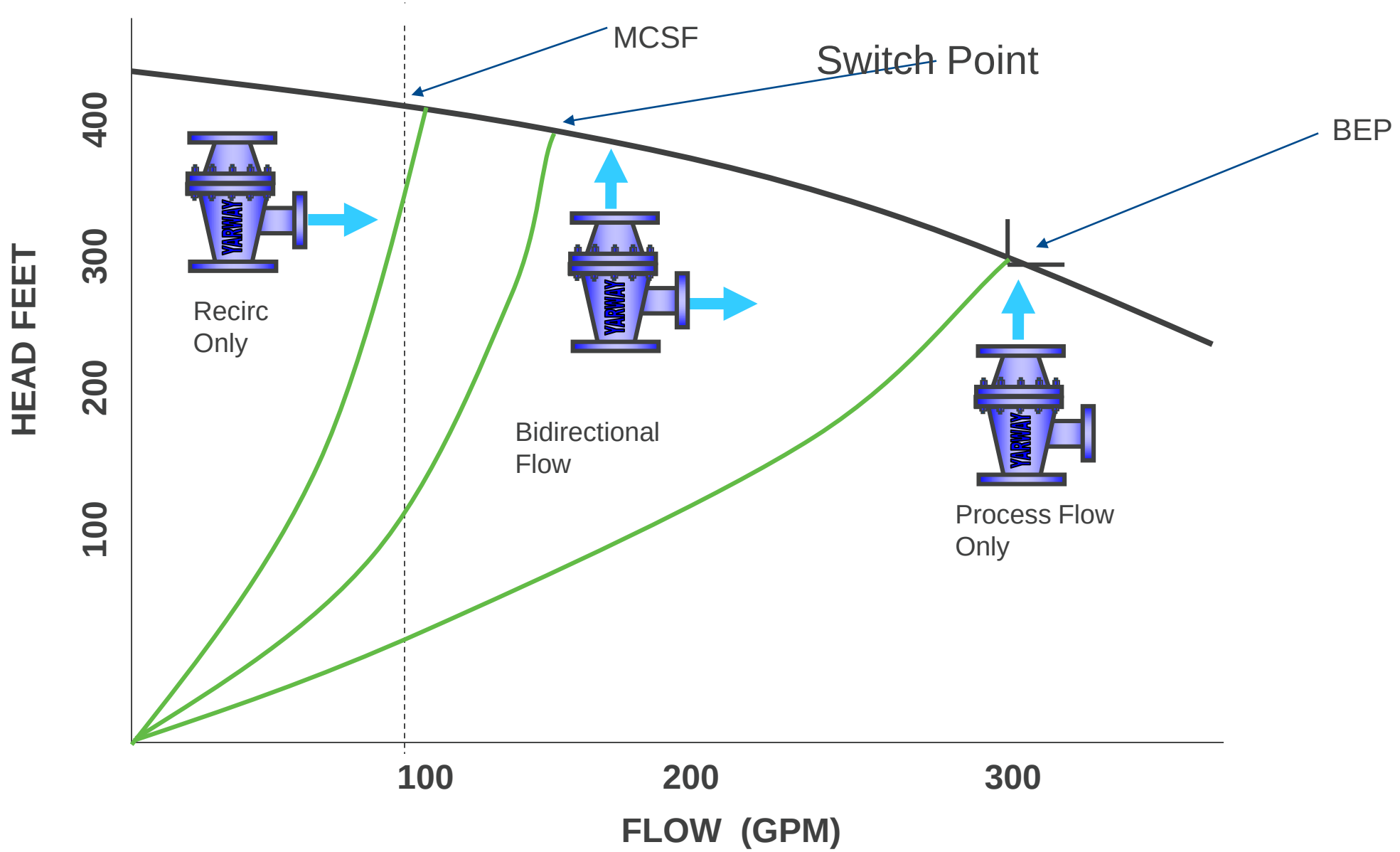
- Automatic Recirculation Control (ARC) valves
- Lower installation cost.
- Less required maintenance.
- Autonomous, continuous pump protection without any external air or signal or supply

System Recirculation





By-pass Flow vs. Process Flow

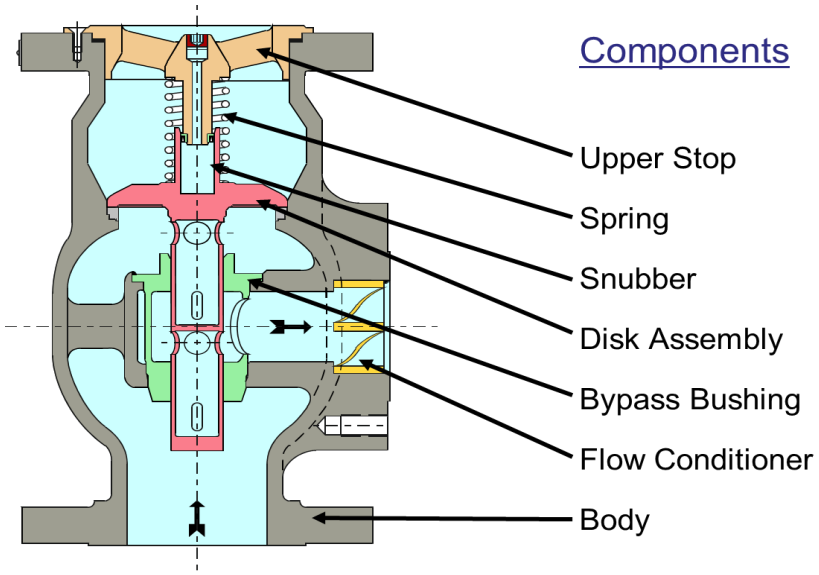


ARC Valve Applications

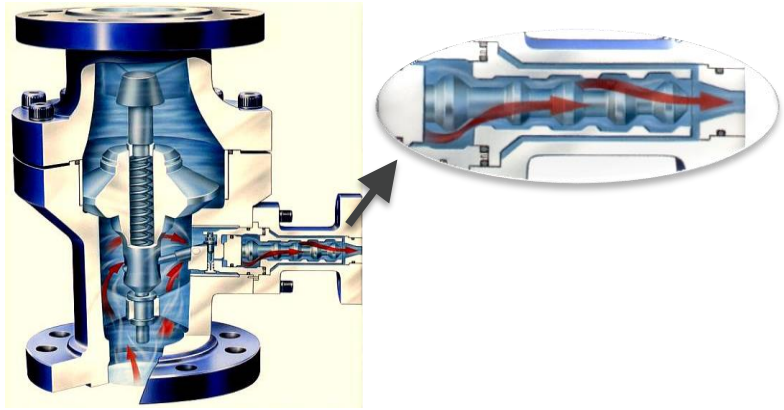
Applications

- Boiler Feed Water
- Condensate Pump
- Cooling Water Recirculation Pump
- Fire Water Pumps
- Fueling Systems
- Cat Cracker Cooling Water
- Ethylene Cracker Feed Water
- Chemical Injection
- Coker Quenching Water
- Booster Pumps
- Loading Systems

ARC Valve Servicing



Pictured is the 9200 ARC



Key Takeaways

1. Centrifugal pumps need continuous flow to prevent thermal, hydraulic and mechanical damage
2. Control and ARC valves Adjust to pump’s performance curve to allow full flow to the process line
3. ARC valves are engineered and selected for the specific pump based on the pump curve

Quiz

Please take a moment to answer the question about to pop up on your screen.

Reminder: This also serves as an attendance requirement for PDH credits.

Thank you.
Questions?

Reminder: Questions can be submitted via the GoToWebinar Questions Panel

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Emerson Steam University Virtual Series

A Practical Approach To Understanding Steam Systems

May 24-28, 2021

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Help us continue to make these sessions better by completing the survey that will launch after this session

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