*How **NOT** to Design a Steam System*

Sizing a Steam Boiler

- Many Steam boilers are undersized for the actual NET load

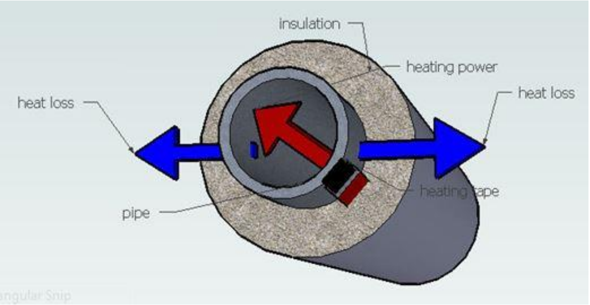
- Determine the BTU required for the heat load
- Add losses for the piping, distribution, etc.
- Correct for the operating pressure of the boiler
- Correct for the feedwater temperature of the boiler

Sizing a Steam Boiler

Calculated Load x Pick-Up Factor = Gross Load BTU/HR
(BTU/HR) (1.33)

NET Load

X



Piping and Pick-Up

=

Gross Load

Sizing a Steam Boiler

- The boiler rating is FROM and AT *212°* F
- Must account for the Lower Boiler Steam Flow at pressures above 0 PSIG and for feedwater temperatures below 212°F
- Example:
  - 400 HP Boiler
  - Operating Pressure: 100 PSIG
  - Feedwater Temperature: 140 °F

Sizing a Steam Boiler

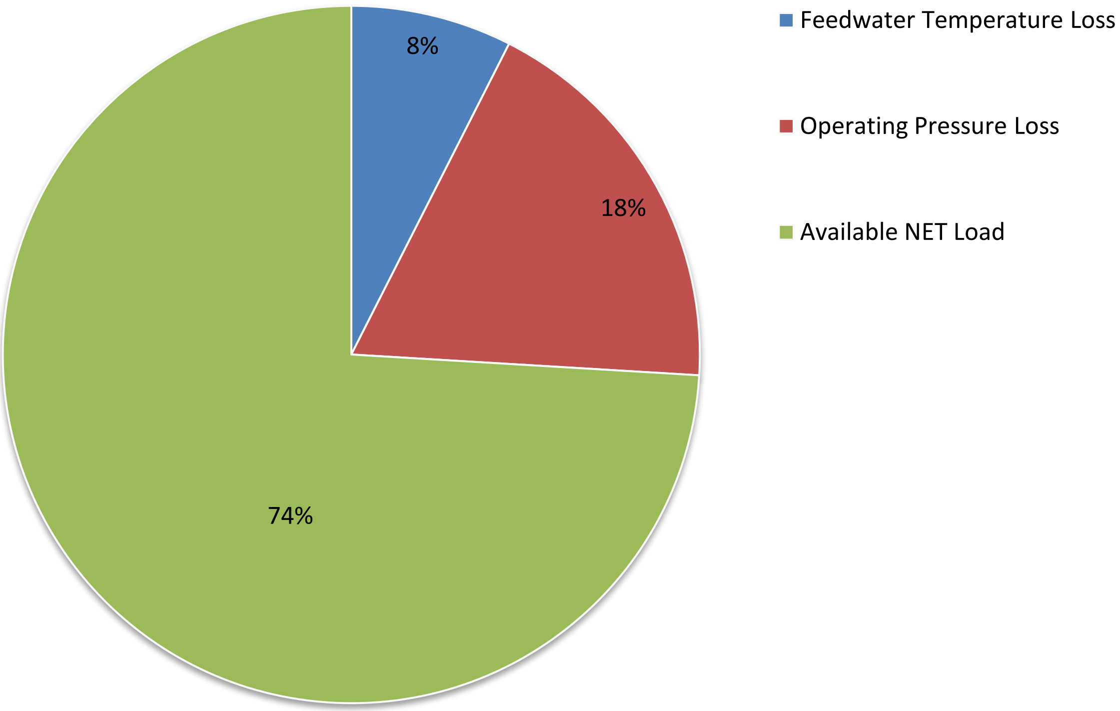
- Feedwater Heating:
  - Evaporation Rate:
    - 400 (BHP) x 0.069 (GPM/BHP) x 60 (MIN/HR) = 1,656 (GPH)
- BTU Content of 212 °F Feedwater:
  - 1,656 (GPH) x 180 (BTU/LB) x 8.4 (LB/GAL) = 2,503,872 (BTU/HR)
- BTU Content of 140 °F Feedwater:
  - 1,656 (GPH) x 108 (BTU/LB) x 8.4 (LB/GAL) = 1,502,323 (BTU/HR)
- Feedwater loss (from 140 °F) = <u>1,001,548 (BTU/HR)</u>

Sizing a Steam Boiler

- Rated Boiler output:
  - 400 (BHP) x 33,475 (BTU/HR/BHP) = 13,390,000 (BTU/HR)
- Output after heating feedwater:
  - 13,390,000 (BTU/HR) - 1,001,548 (BTU/HR) = 12,388,451 (BTU/HR)
  - Enthalpy of steam at 100 PSIG = 1,190 (BTU/LB Steam)
- **Actual** Boiler output:
  - 12,388,451 (BTU/HR) / 1,190 (BTU/ LB Steam) = 10,410 (LBS/HR Steam)
- 400 HP **Nameplate** output (At 0 PSIG and 212 °F Feedwater)
  - 400 (BHP) x 34.5 (LBS/HR Steam/BHP) = 13,800 (LBS/HR Steam)

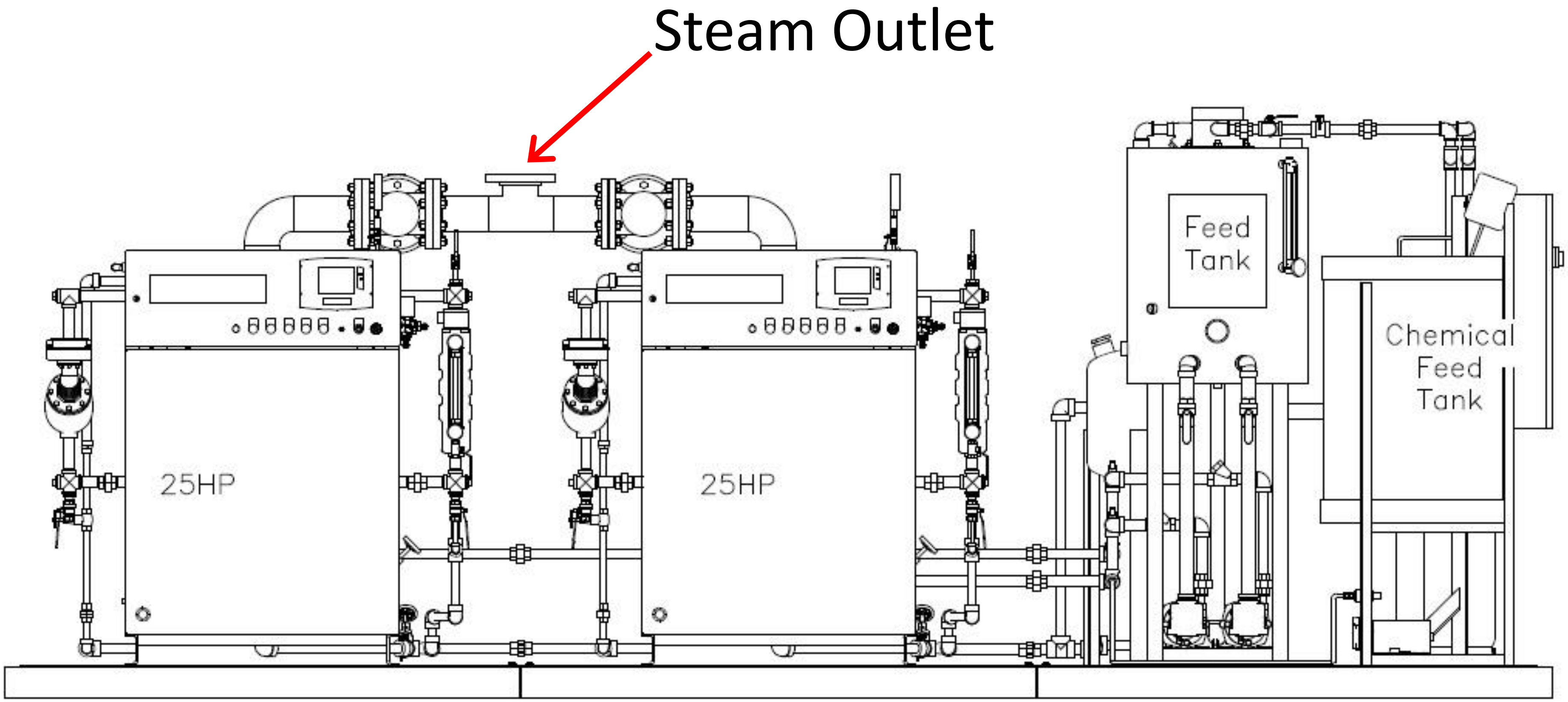
Sizing a Steam Boiler

- Total loss:
  - 13,800 (LBS/HR) - 10,410 (LBS/HR) = 3,390 LBS/HR or 26% less steam
  - **Actual** Steam flow Versus **nameplate** steam flow is **26% LESS**



Near Boiler Piping

- Poor piping examples



Near Boiler Piping

Steam outlet velocity at Actual operating pressures

4,500 ft/min	Ideal top end velocity which will allow for some upset water conditions
5,000 ft/min	OK velocity with high quality boiler water and perfect steam system piping
5,500 ft/min	Some bouncing waterline will occur even with high quality boiler water
6,000 ft/min	Definite problems will occur (bouncing water line, LWCO, etc)

Near Boiler Piping

Steam skid with a 4” steam nozzle, steam orifice plate and set pressure of 21 psig

12 psig	5,921 ft/min
15 psig	5,365 ft/min
20 psig	4,644 ft/min
30 psig	3,669 ft/min
40 psig	3,040 ft/min

Near Boiler Piping

Good:
- (2) Isolation Valves
- (1) Check Valve
- High Vertical Height

Bad:
- Incorrectly sized check valve
- Non-code spool piece
- No free blow drain in between valves

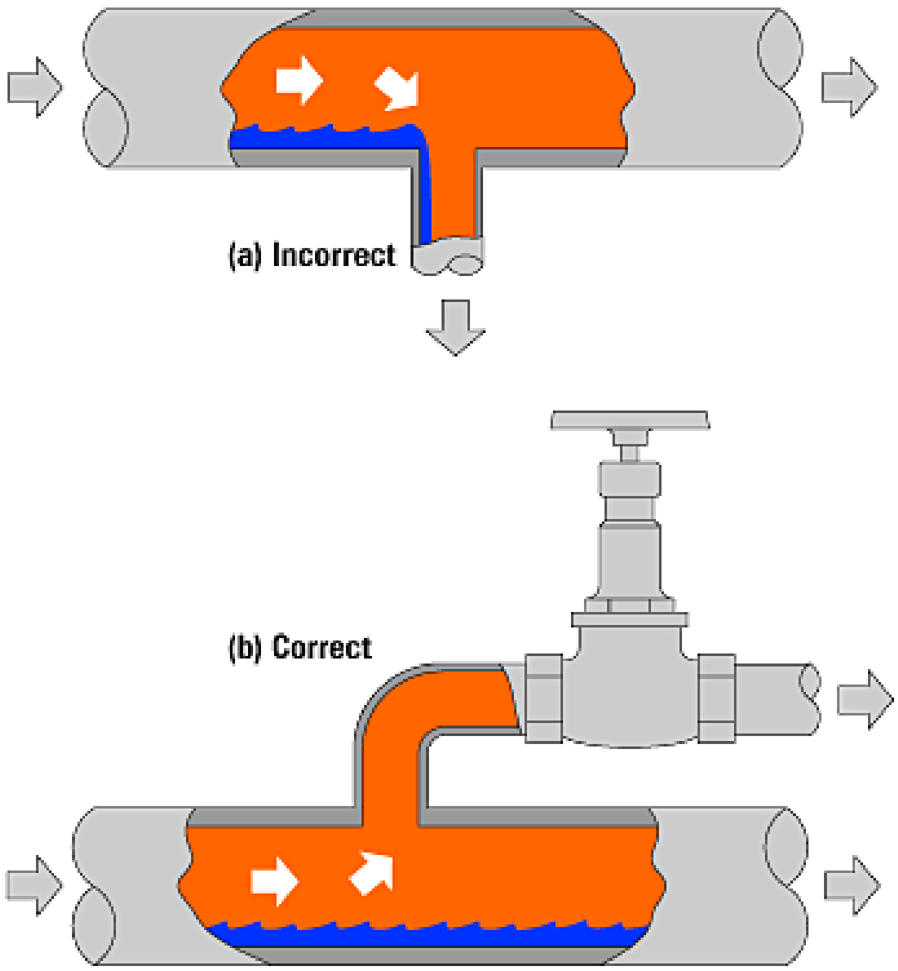
Near Boiler Piping

Main Steam Header

- **Operating pressure**
  - The header should be designed for the lowest anticipated boiler operating pressure during normal operation.
- **Diameter**
  - The header diameter should be calculated with a maximum steam velocity of 4,500 ft./min. under full load conditions. Low velocity is important as it helps any entrained moisture to fall out.

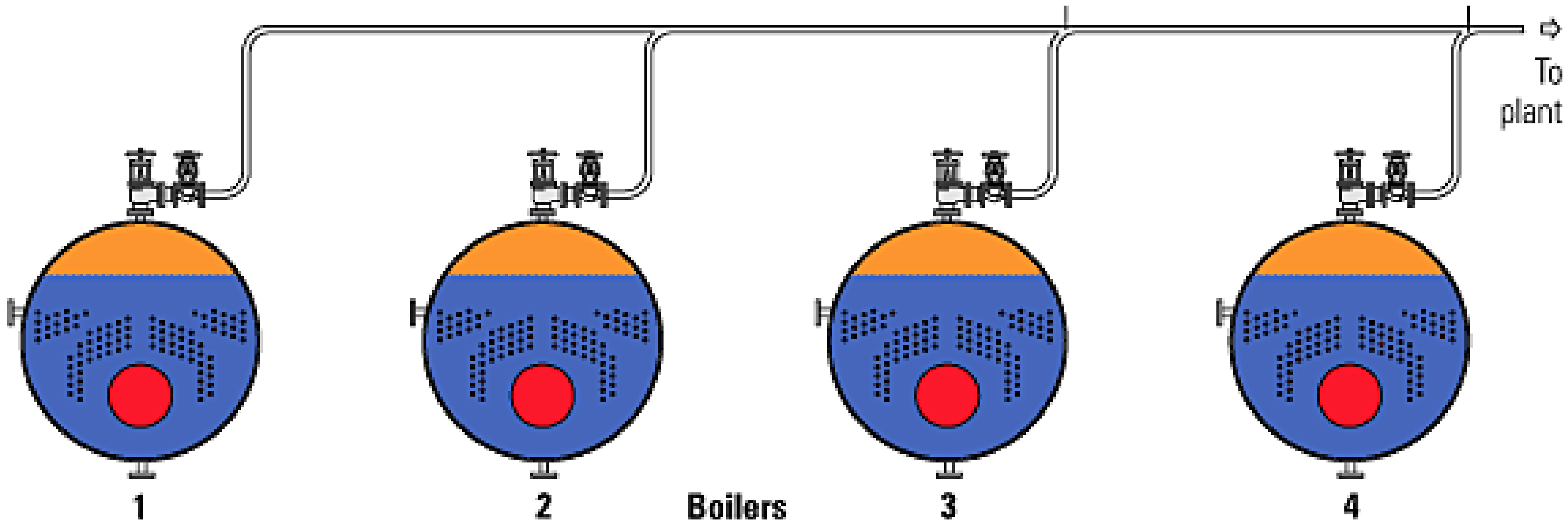
Main Steam Header

- **Off-takes**
  - Always taken off of the top of the header. Gravity and low steam velocity help to allow condensate to drain from the header. This helps to ensure a high steam quality.



Main Steam Header

- Poor header examples:



Main Steam Header

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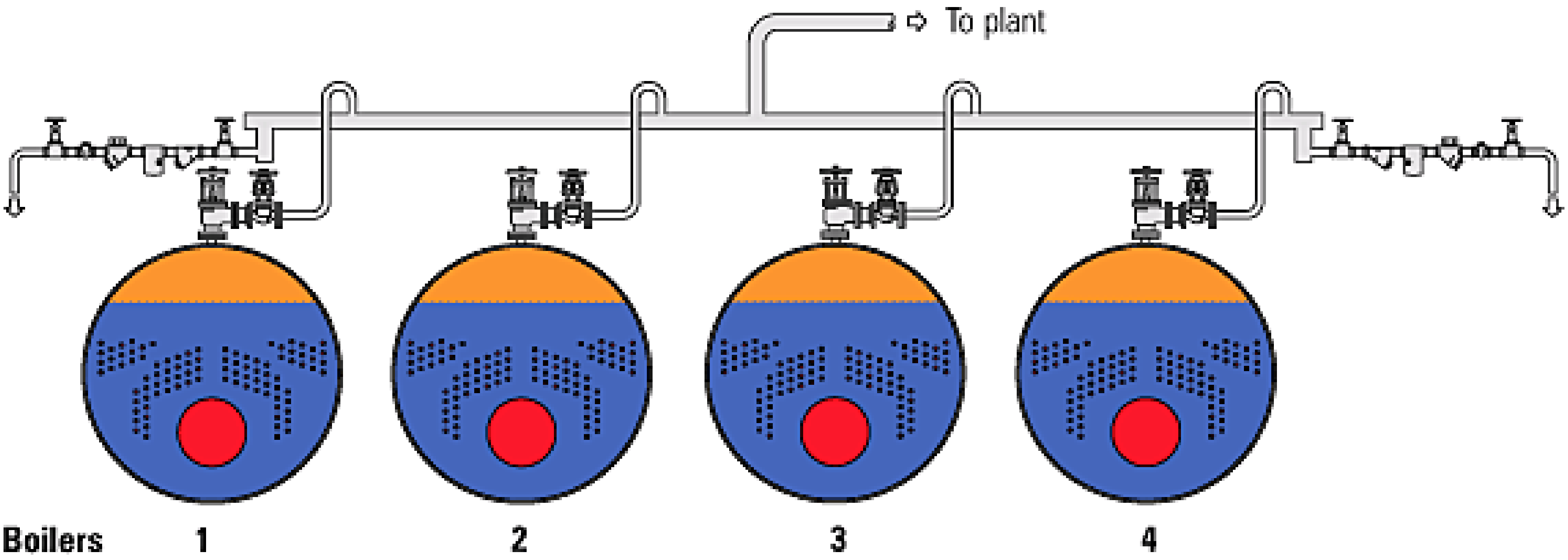

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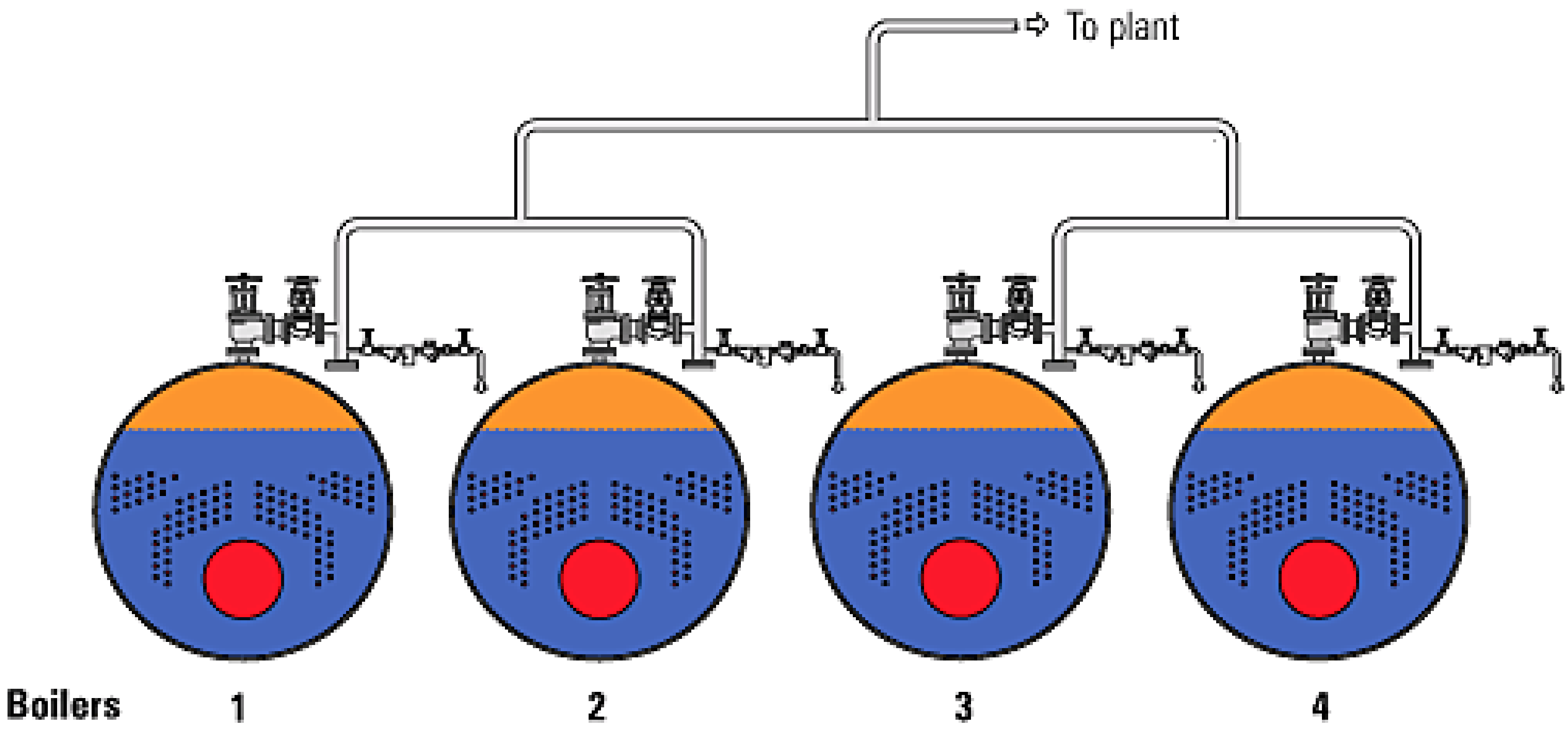

Main Steam Header

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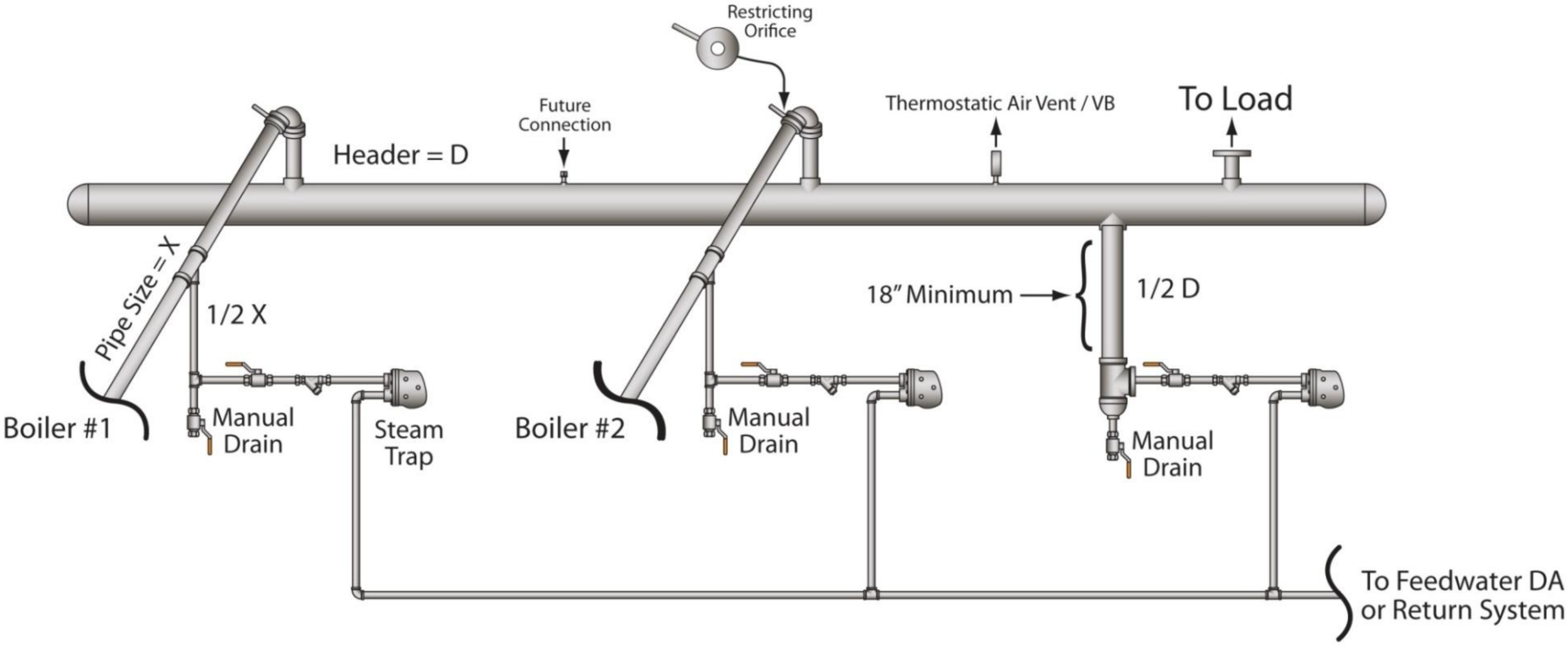


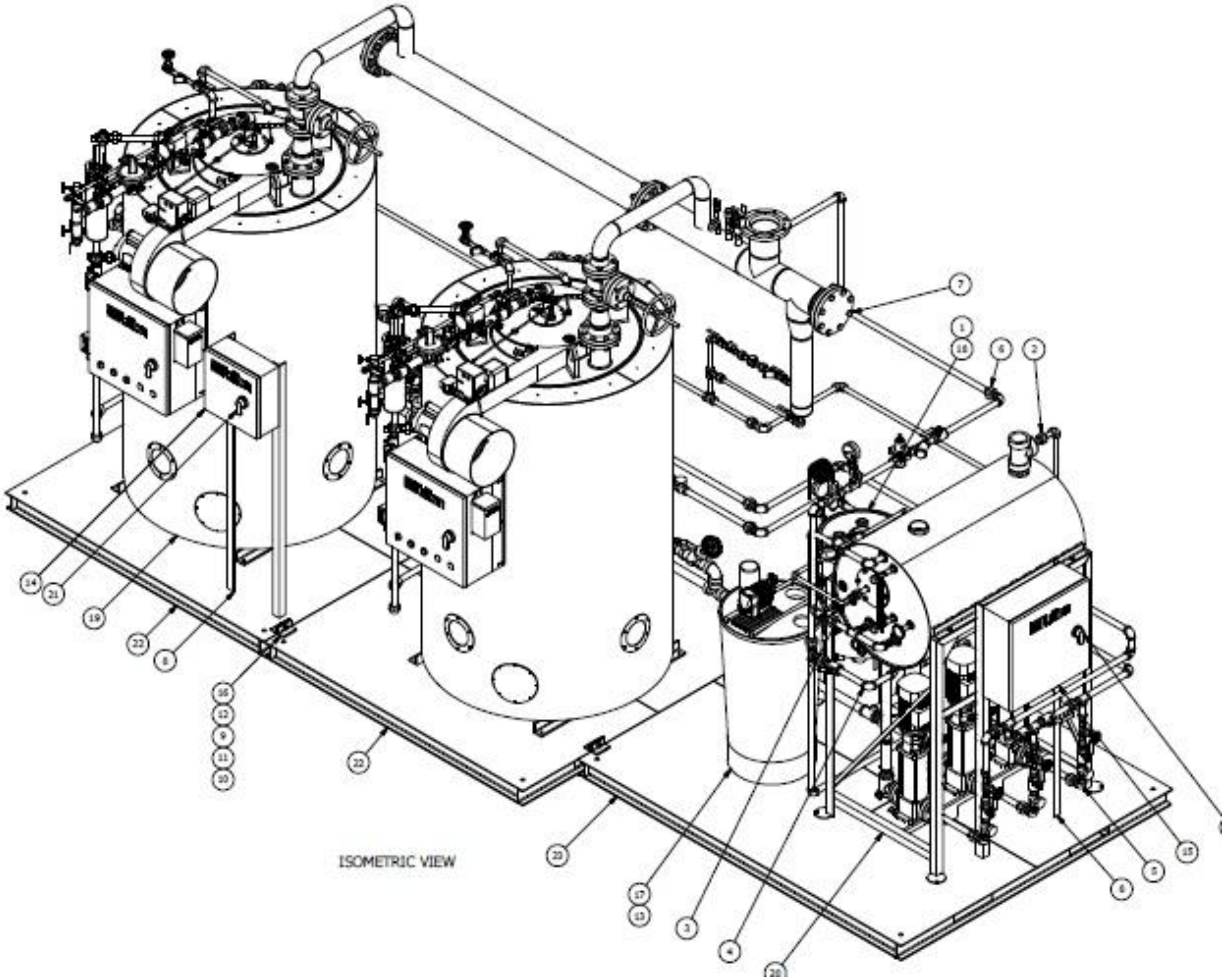
Typical steam header design

Main Steam Header

- Poor header examples:

Main Steam Header

- Good header example



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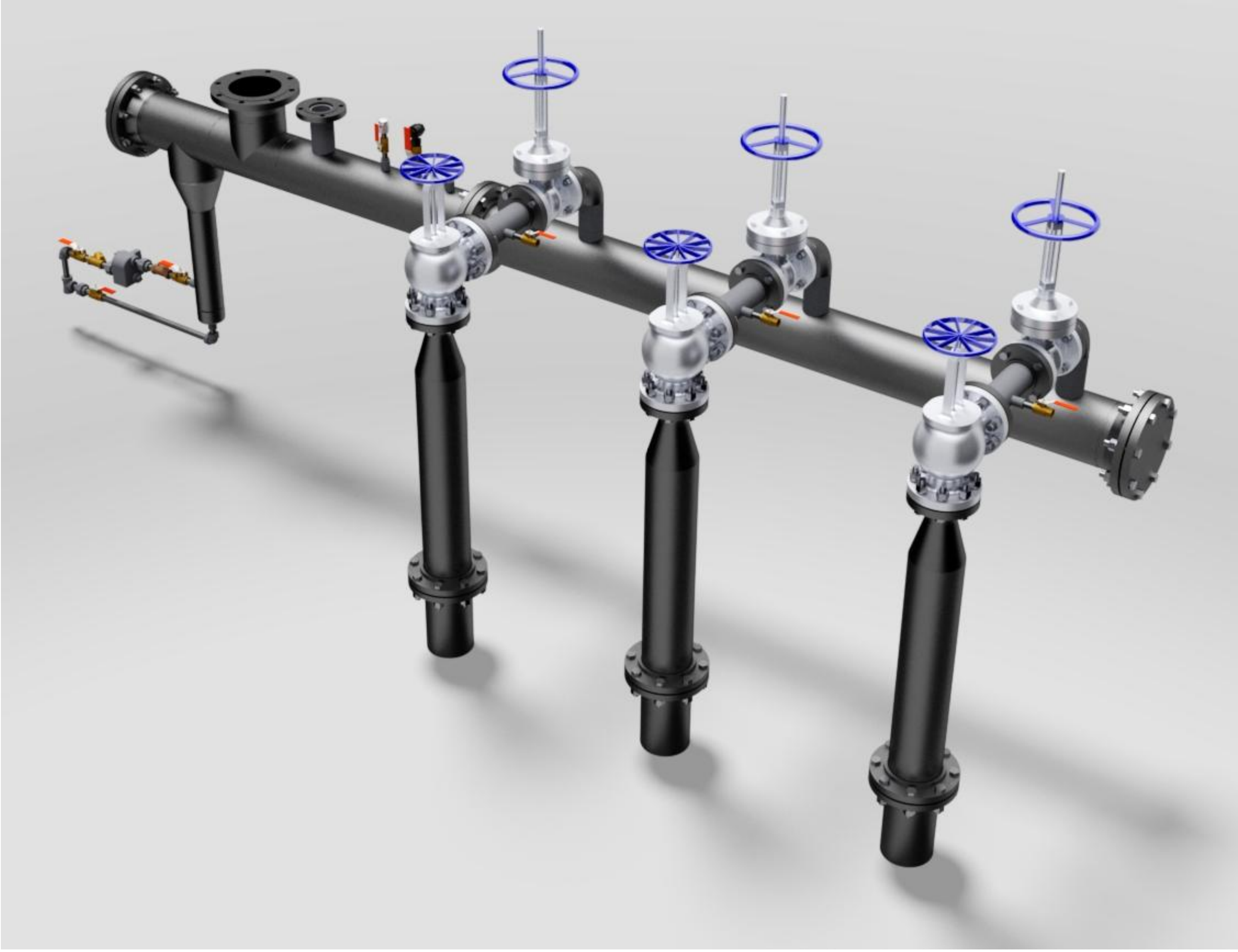
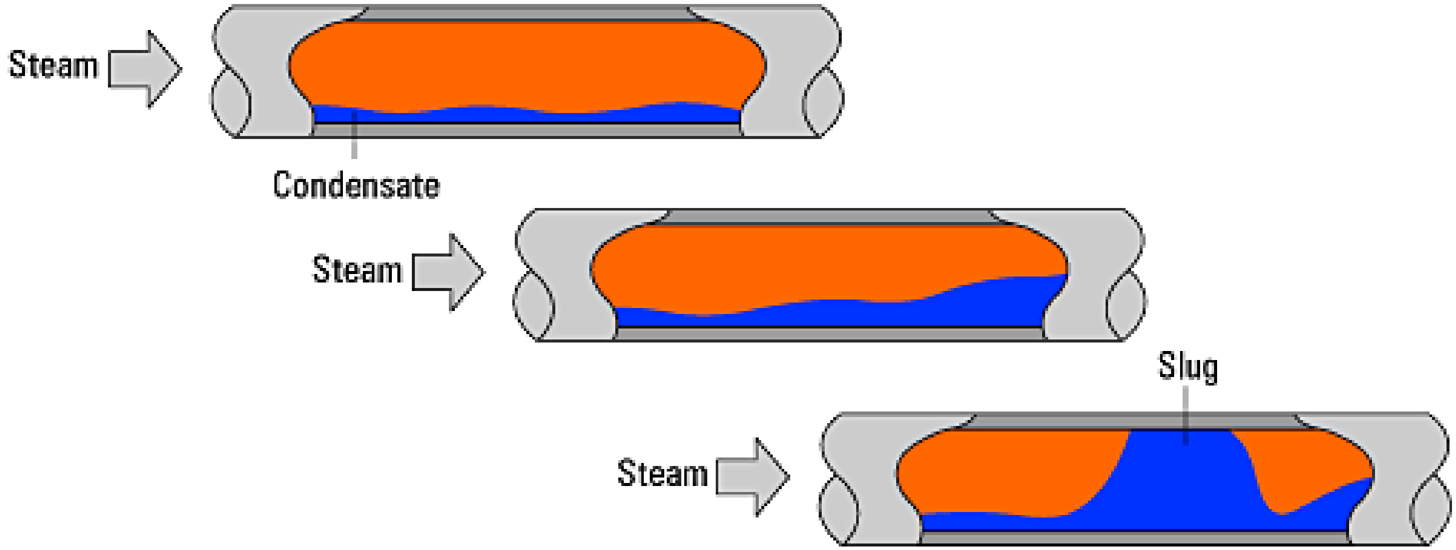


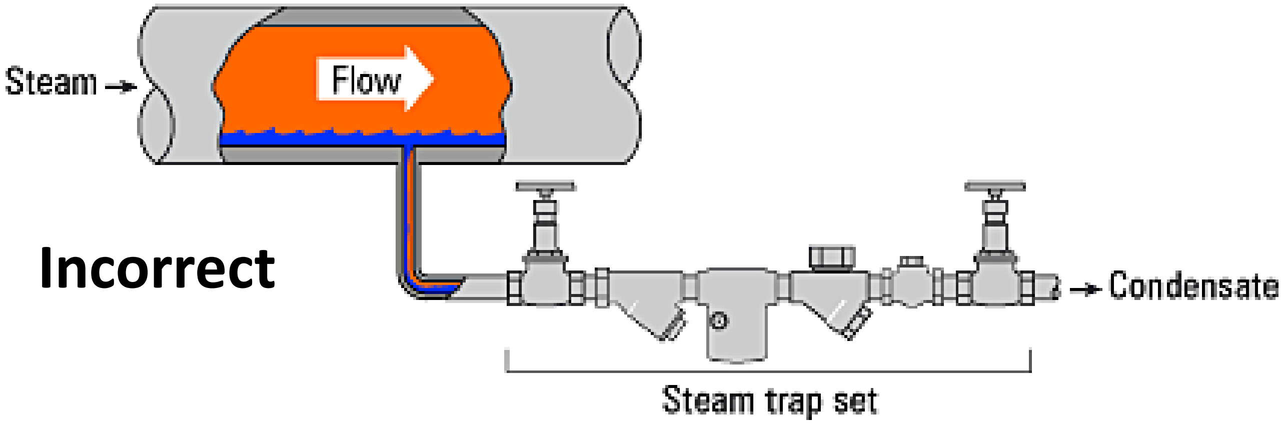
Need to Properly Drain Condensate

- **Steam trapping**
  - It is important that condensate is removed from the steam header as soon as it forms. For this reason a properly sized drip leg with appropriate steam trap must be installed at the end of the header to avoid water hammer.

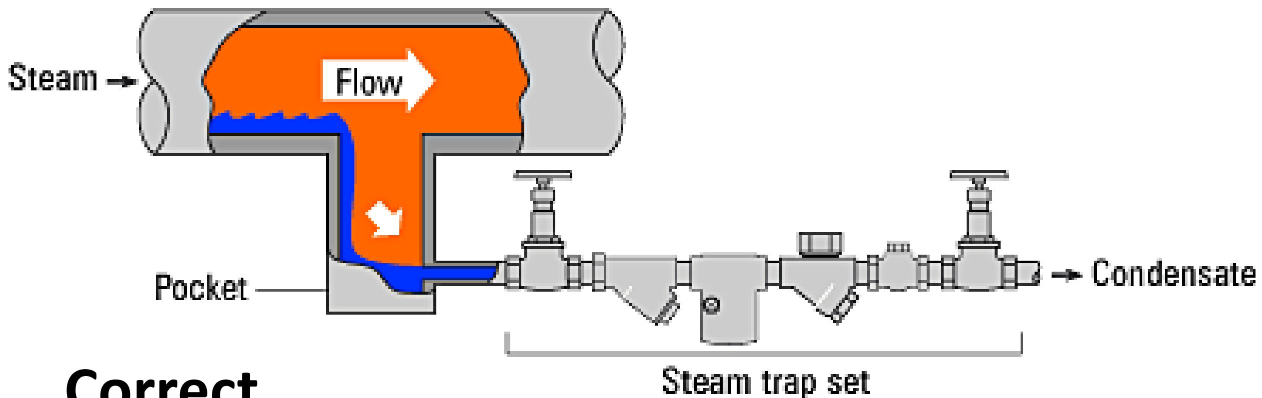


Need to Properly Drain Condensate

- **Steam trapping/Drip Legs**



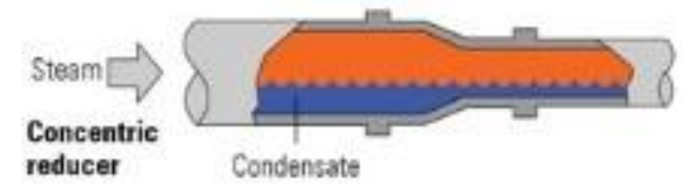
Incorrect

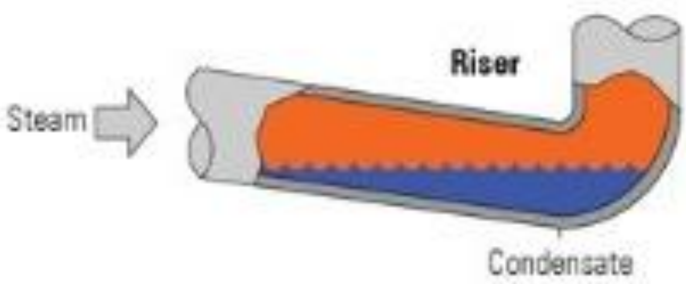


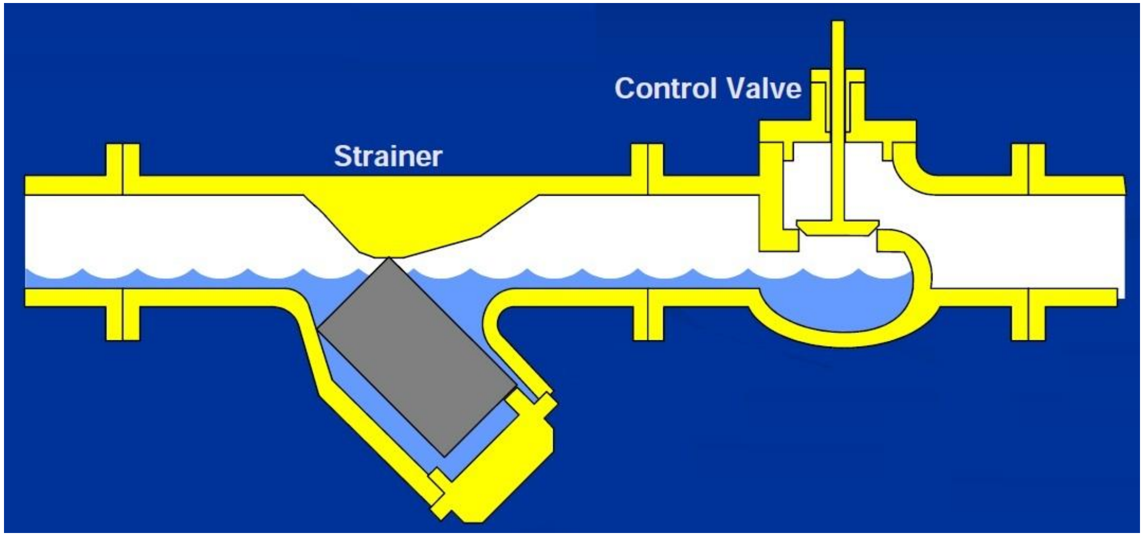
Correct

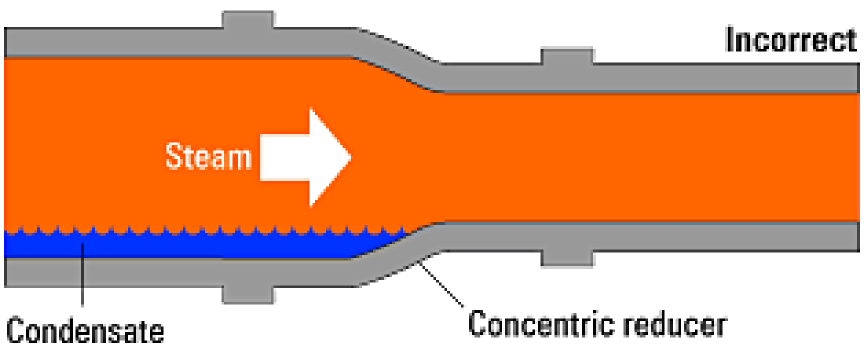
Need to Properly Drain Condensate

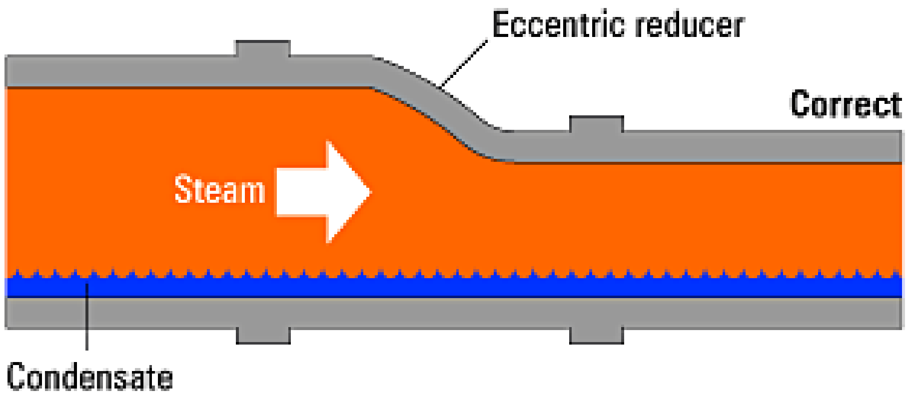
- **Other causes of water hammer:**











Need to Properly Drain Condensate

Steam Trap Installation

Need to Properly Drain Condensate

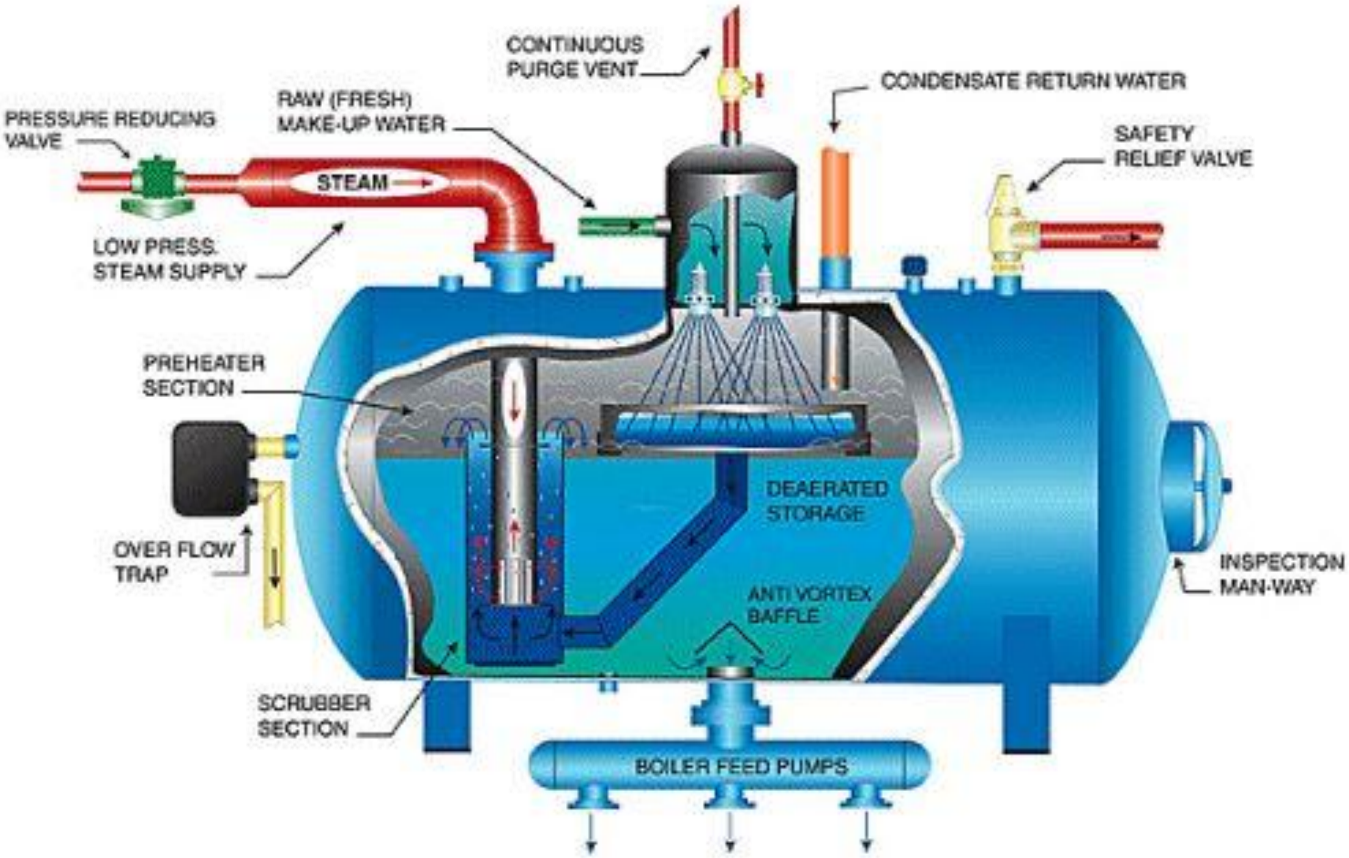
Need to Properly Drain Condensate

Steaming Valve on the night of the Accident (right) and the next day (above)

Blown out Strainer upstream of 120 psi PRV Station that was being re-energized after a brief shut down for maintenance

New York Water Hammer Explosion

A Deaerator is NOT just a Deaerator



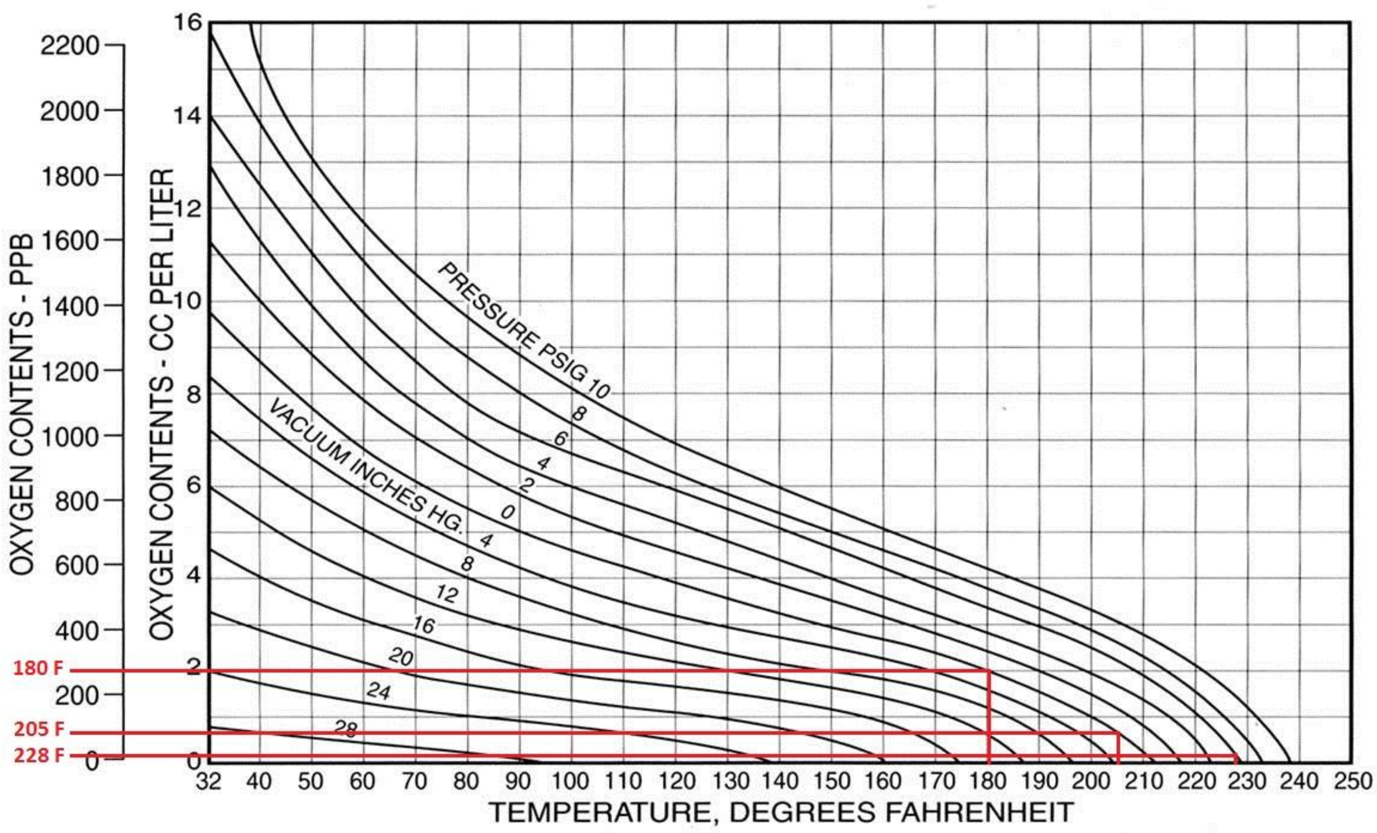
A Deaerator is NOT just a Deaerator

- Remove Oxygen and Carbon Dioxide
  - To protect boiler from oxygen pitting
  - To protect return lines from carbonic acid tracking

- Improves Heat Transfer
  - Air acts as an insulator in the system
  - Raise Feed Water Temperature Reduces thermal shock to boiler

A Deaerator is NOT just a Deaerator

- Oxygen solubility chart



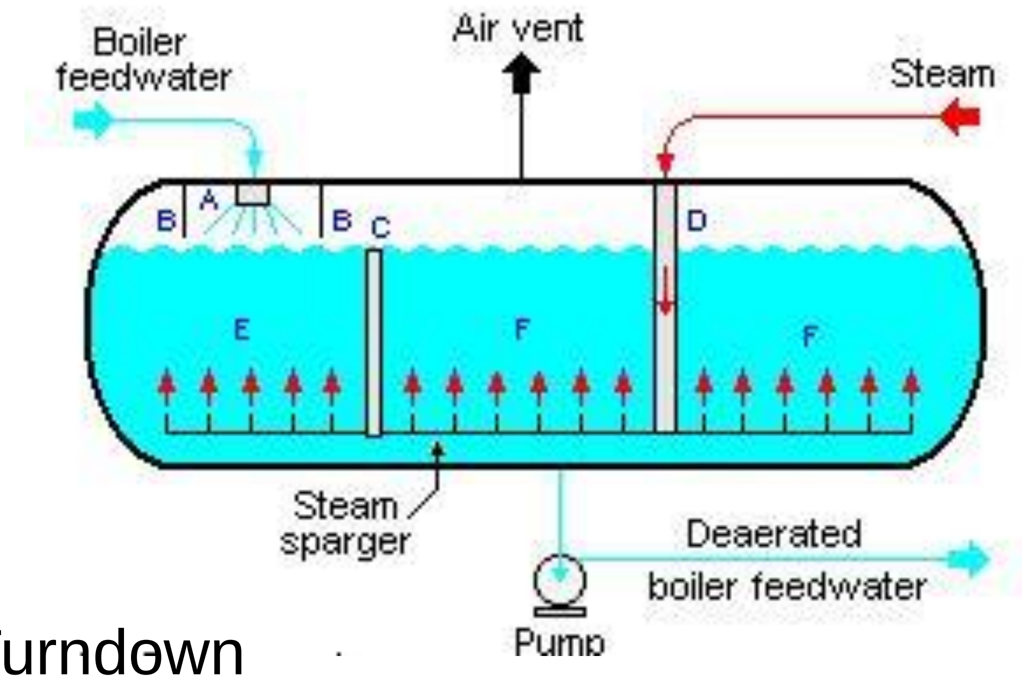
OXYGEN SOLUBILITY IN WATER AT VARIOUS TEMPERATURES AND PRESSURES

A Deaerator is NOT just a Deaerator

- Temperature
- Turbulence
- Time
- Thin Film
- Venting

A Deaerator is NOT just a Deaerator

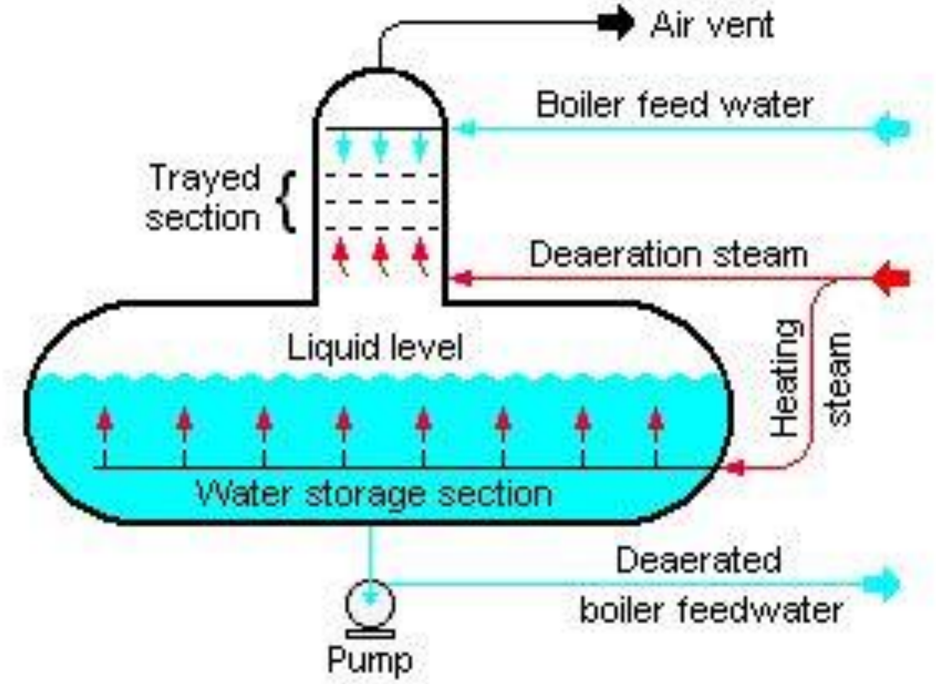
- Spray Type Deaerator:



- Limited Turndown
- High-Maintenance
- Cheap
- Warranted performance per ASME test (steady-state only)

A Deaerator is NOT just a Deaerator

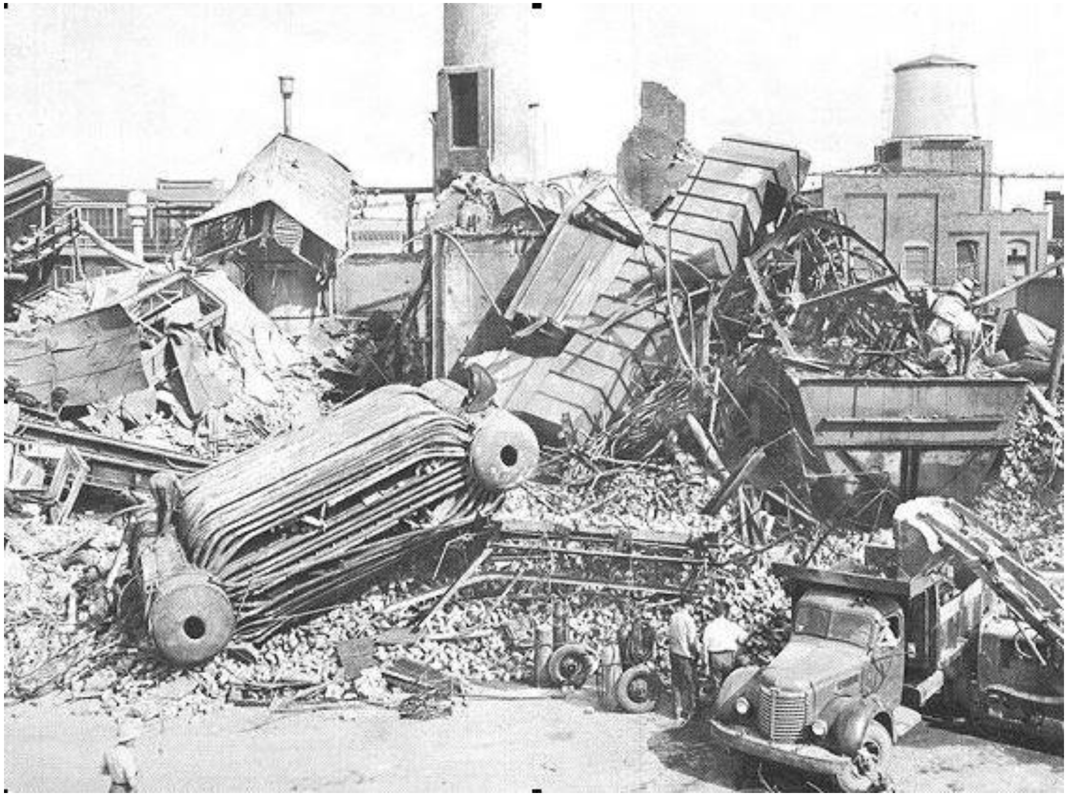
- Tray Type Deaerator:



- Unlimited Turndown
- Zero Maintenance
- More Expensive

Boiler Failures Due to Low Water

- Low Water Failures:
  - 85% of low pressure failures
  - 55% of high pressure failures



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