Lecture 6: Steam Generators & Cooling Systems

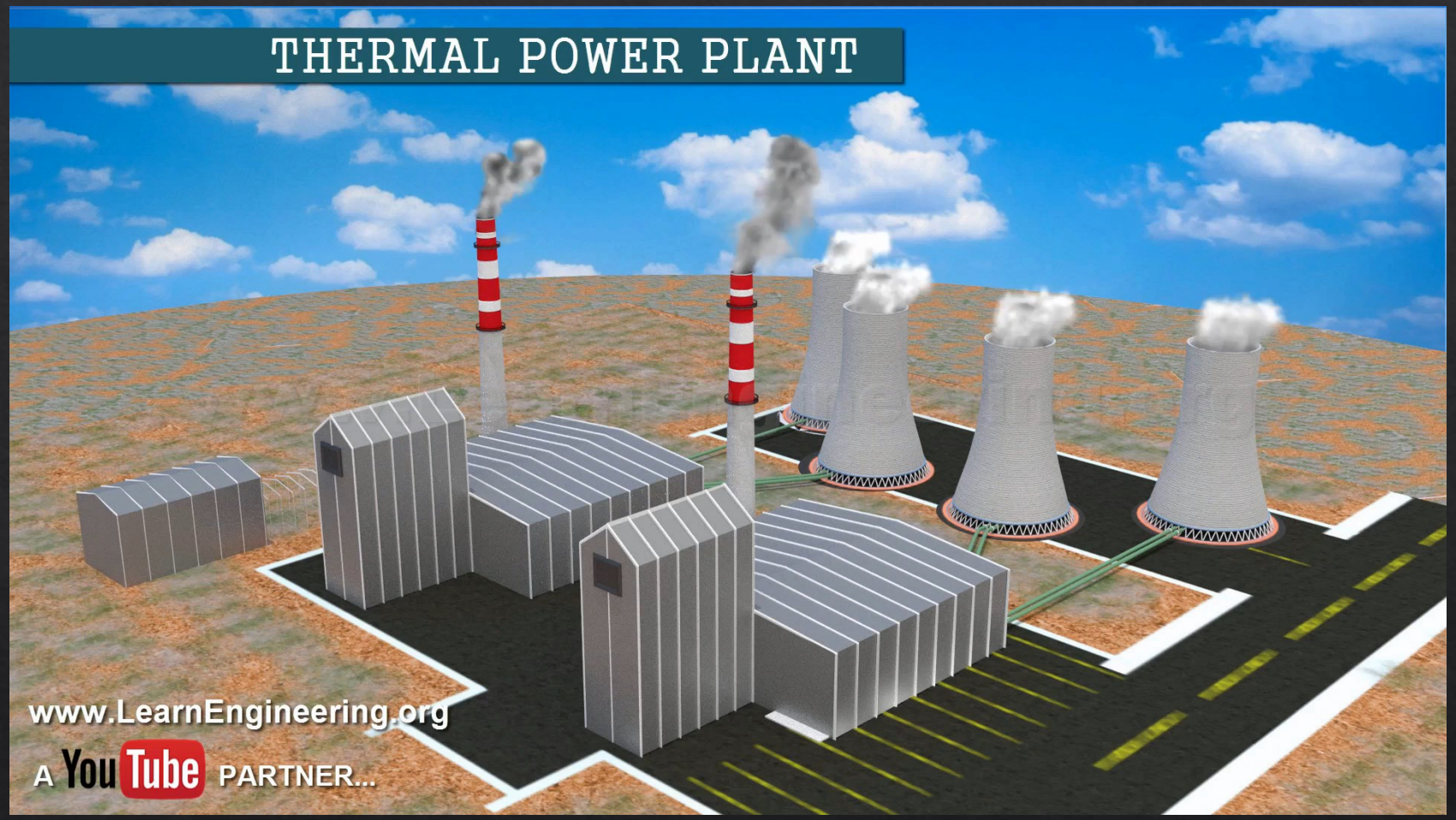
Course: MECH-422 – Power Plants

Instructor: Kashif Liaqat

Term: Fall 2021

BUITEMS – DEPARTMENT OF MECHANICAL ENGINEERING

Recap: Steam Power Plants



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Steam Generators

LEARNING OUTCOMES

After successful completion of this chapter, you will be able to:

• describe the function of steam generators

• list components of a typical steam generator

• briefly explain historical development of steam generators and their components

• explain operation of modern drum-type and once-through steam generators

• describe functions of various components of modern steam generators and their operational principles,

including waterwalls, drums, superheaters, reheaters, economizers, and control components

Objective:

The overall objective of any steam generator is to integrate different components to use thermal energy from fuel combustion to raise steam at desired conditions with maximum efficiency and reliability in the most economical manner (considering both capital and operating costs) with minimal environmental impacts.

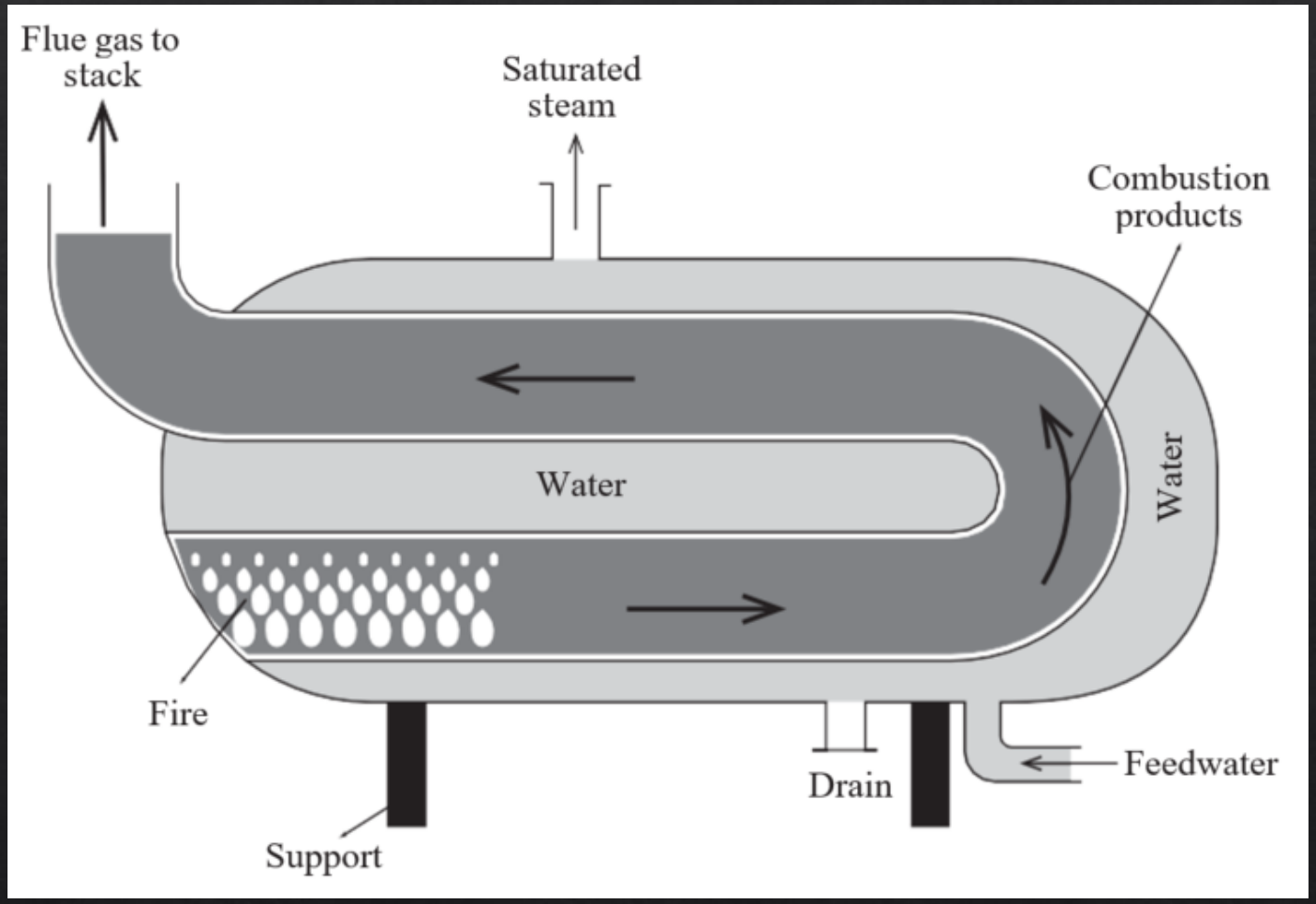
Historical Development of Steam Generators:

- Humanity has boiled water for cooking since 40,000 BC.
- However, the early steam generators for power generation started to appear in the late 17th and early 18th centuries.
- Today's modern steam generators are the result of over 300 years of experience in the industry.

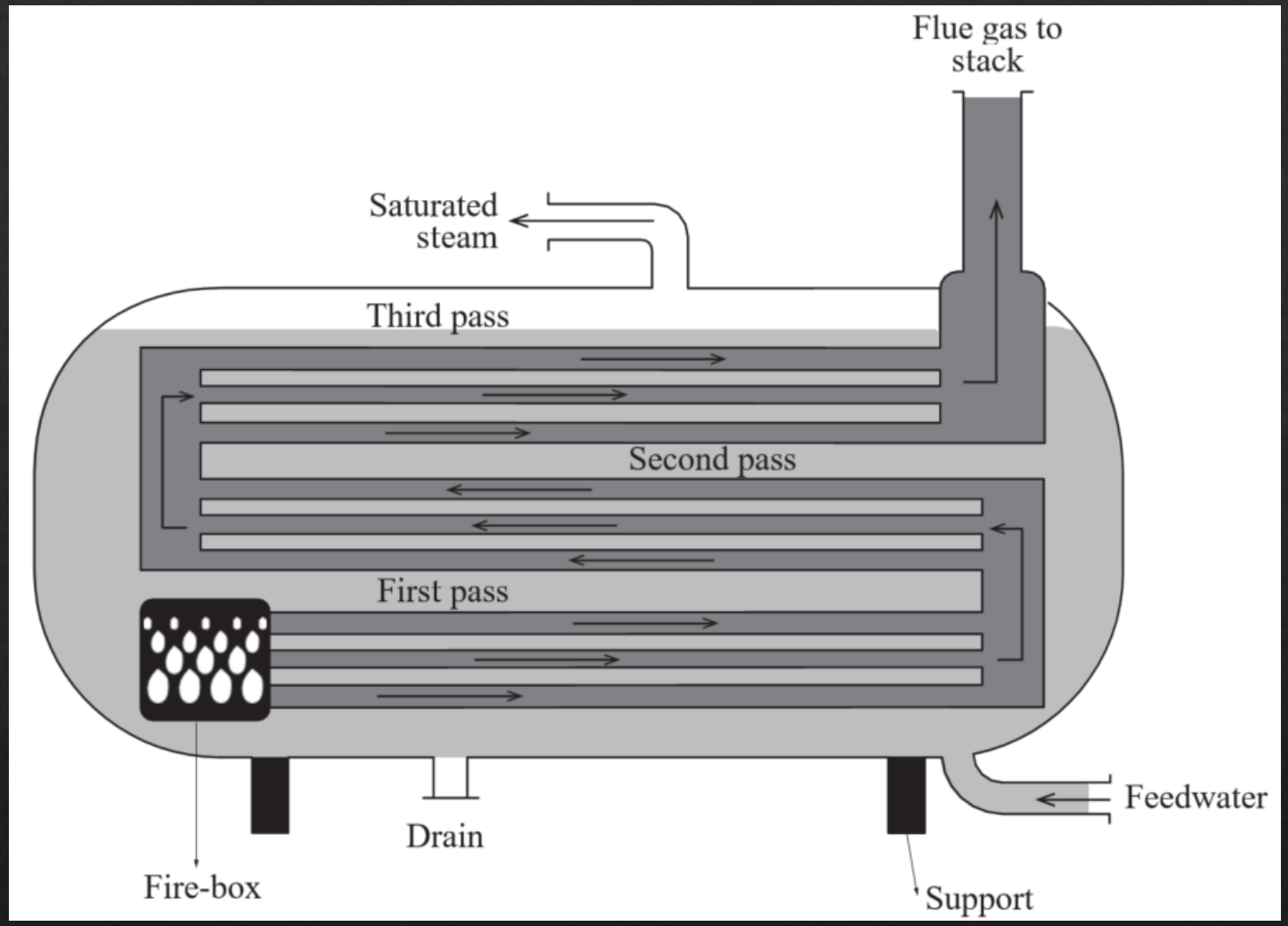
Early Steam Generators:

- The early steam generators were just like large kettles, hence the name shell type or kettle boilers.
- In these boilers, fire directly heated the outer surface of the shell which, in turn, heated the water inside the vessel

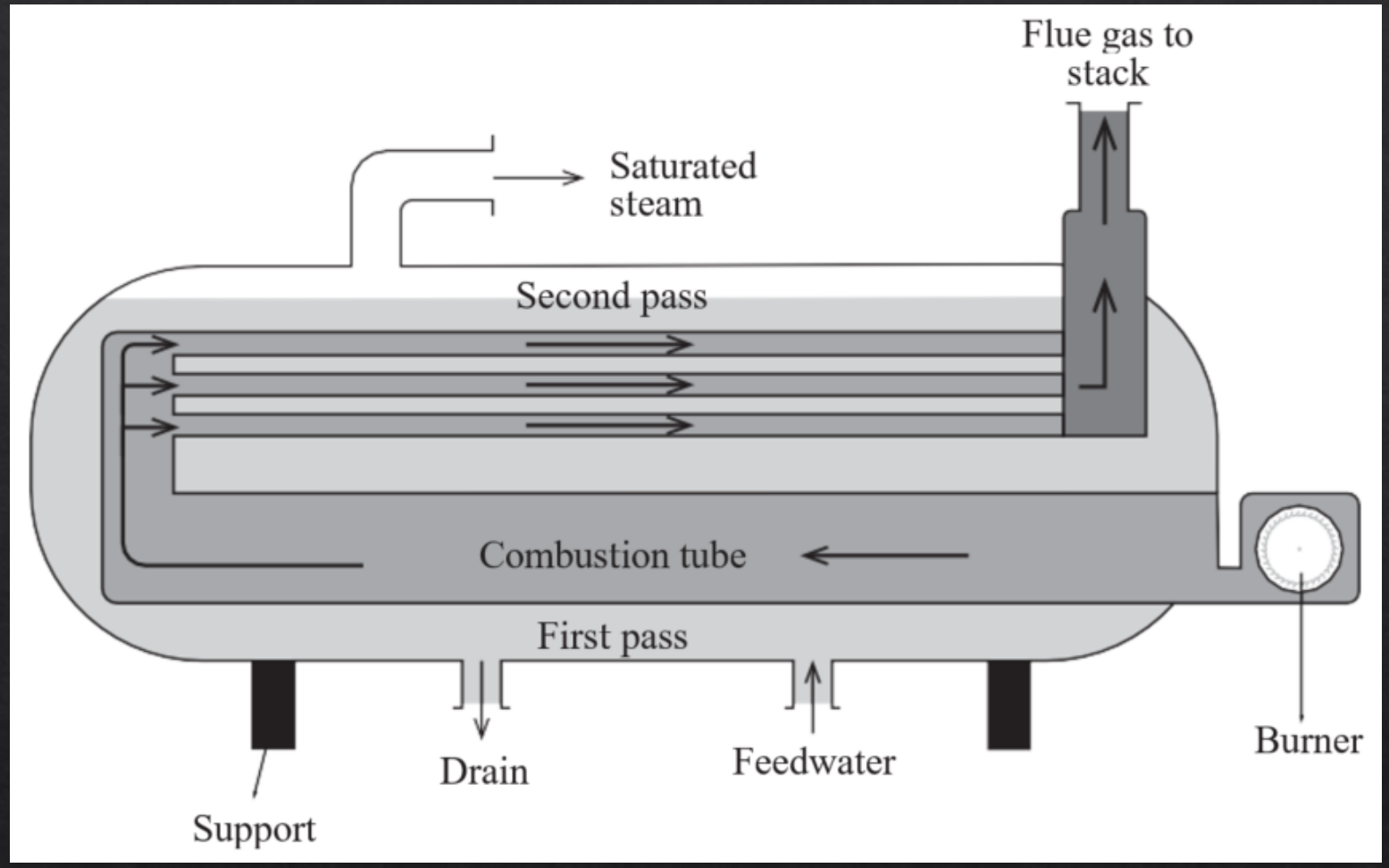
Early Steam Generators:



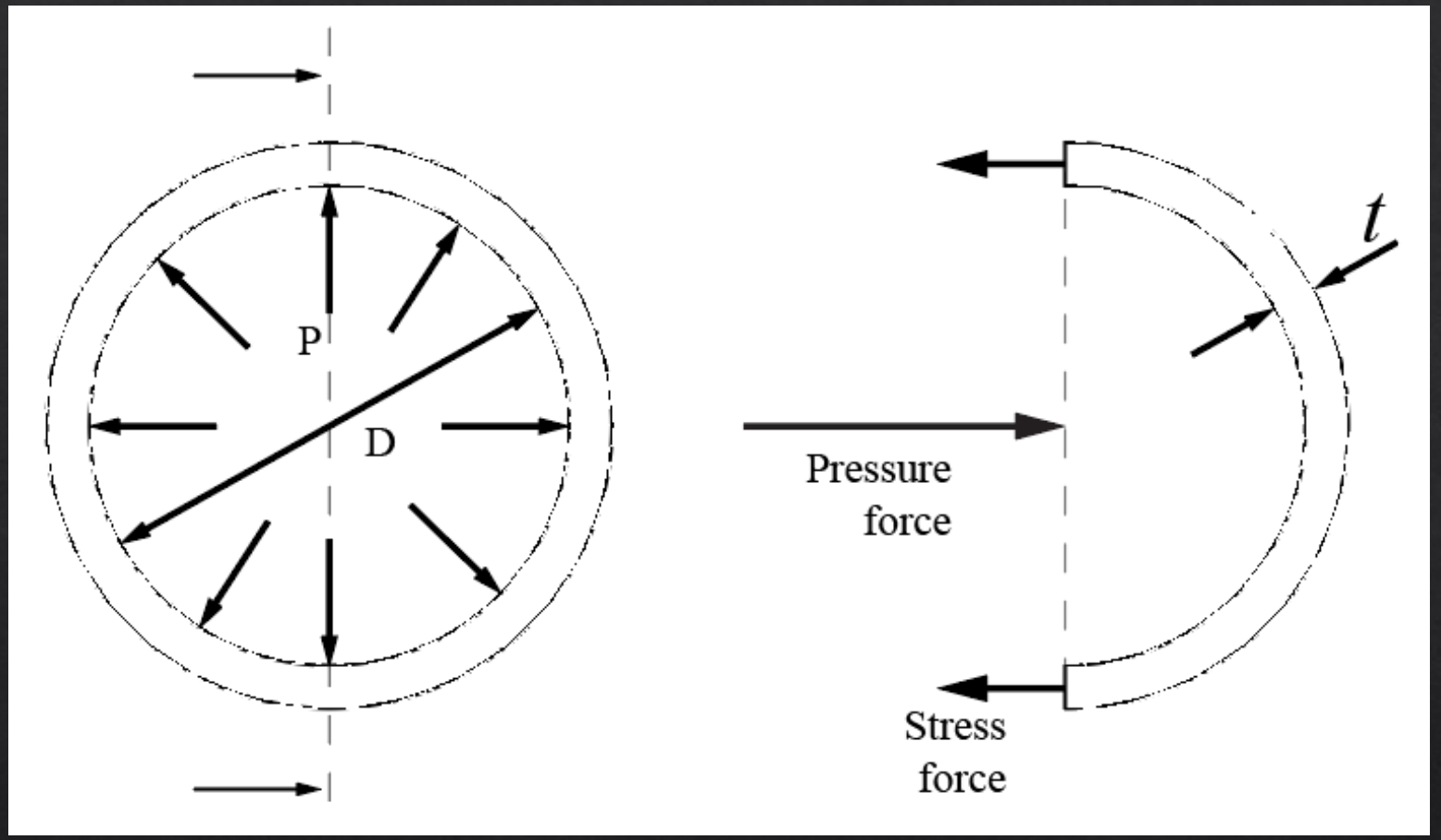
Schematic of Trevithick fire-tube boiler



Schematic of horizontal fire-tube fire-box boiler

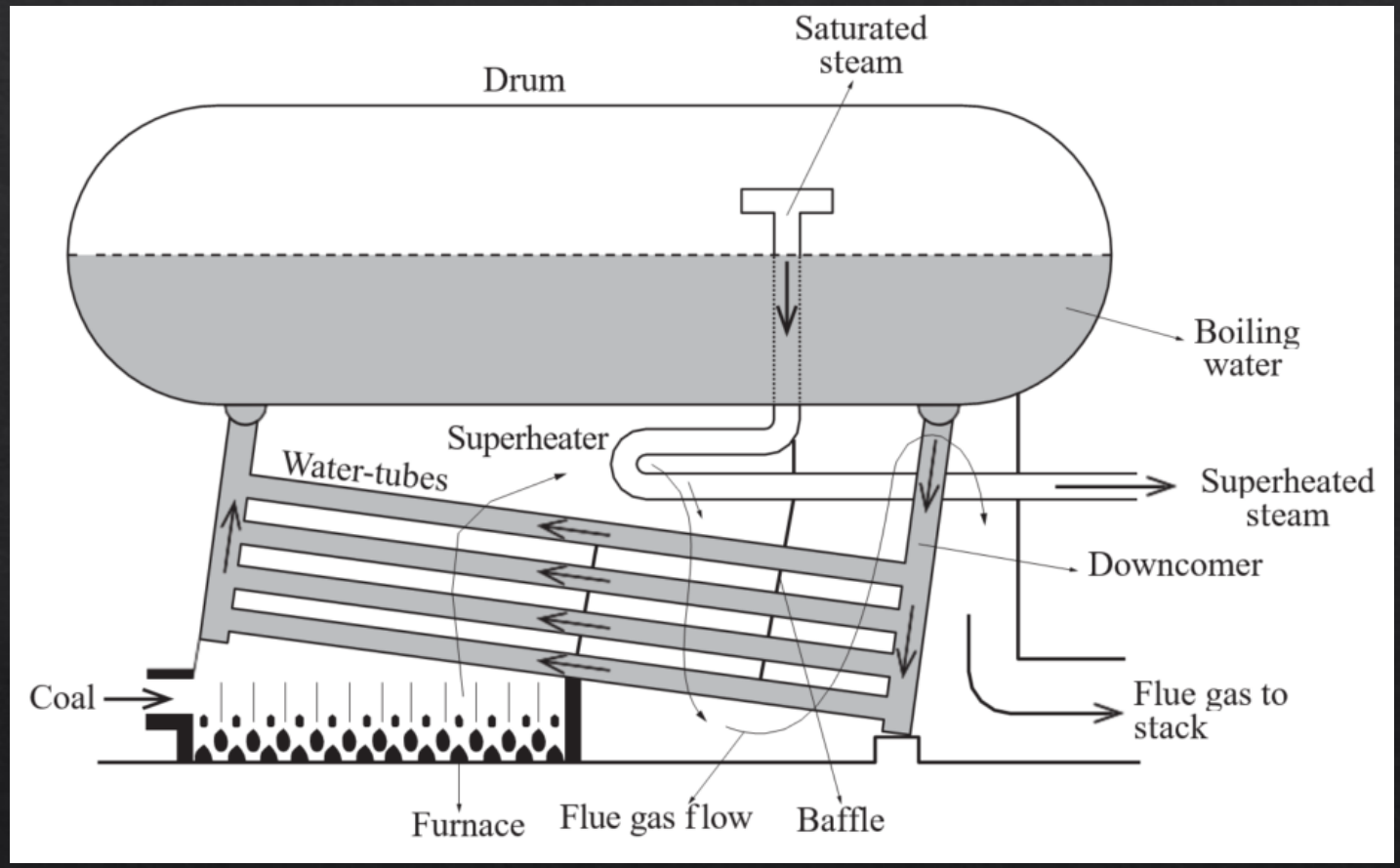


Schematic of horizontal fire-tube Scotch marine boiler

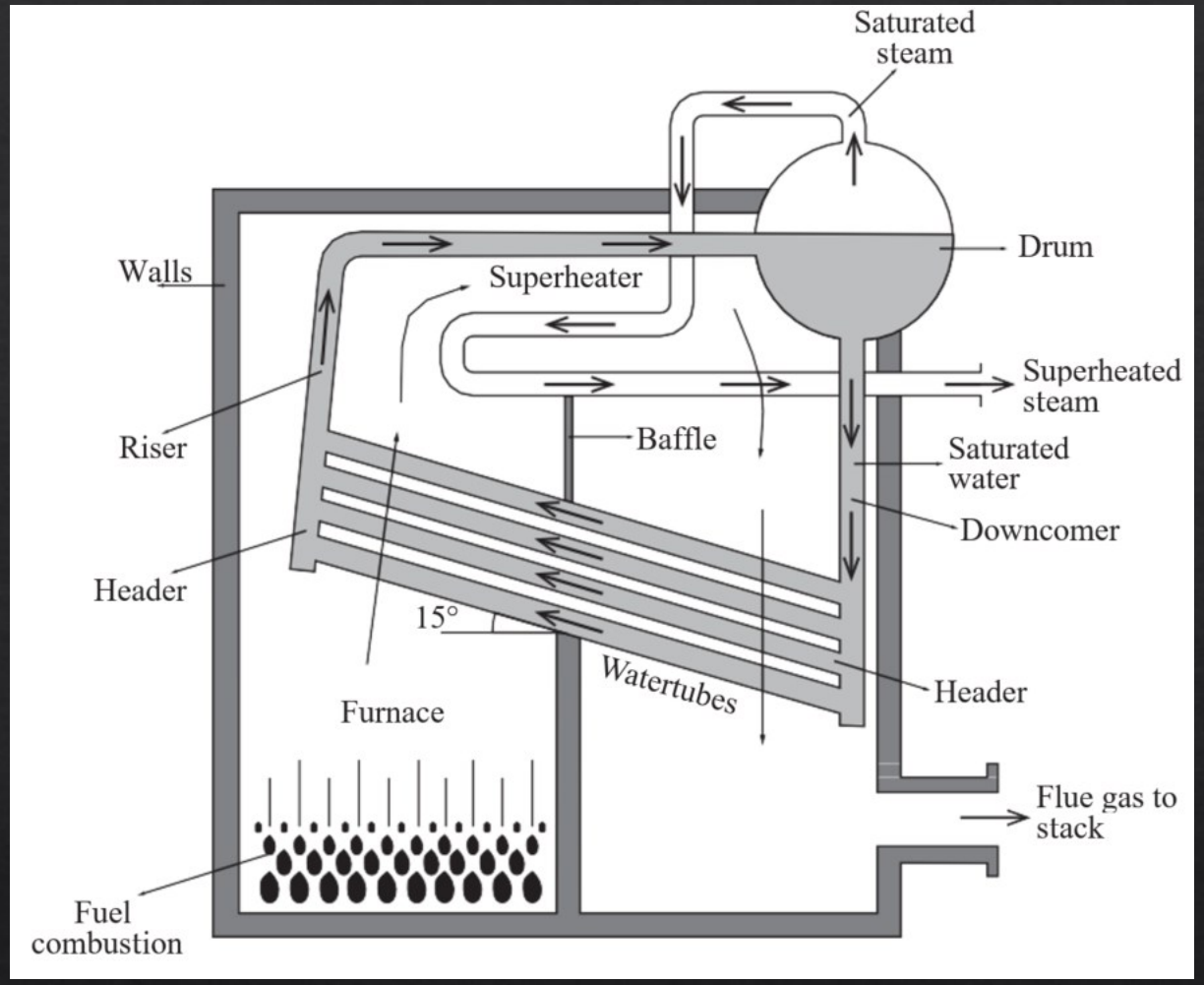


Schematic of circumferential stress in walls of cylindrical containers

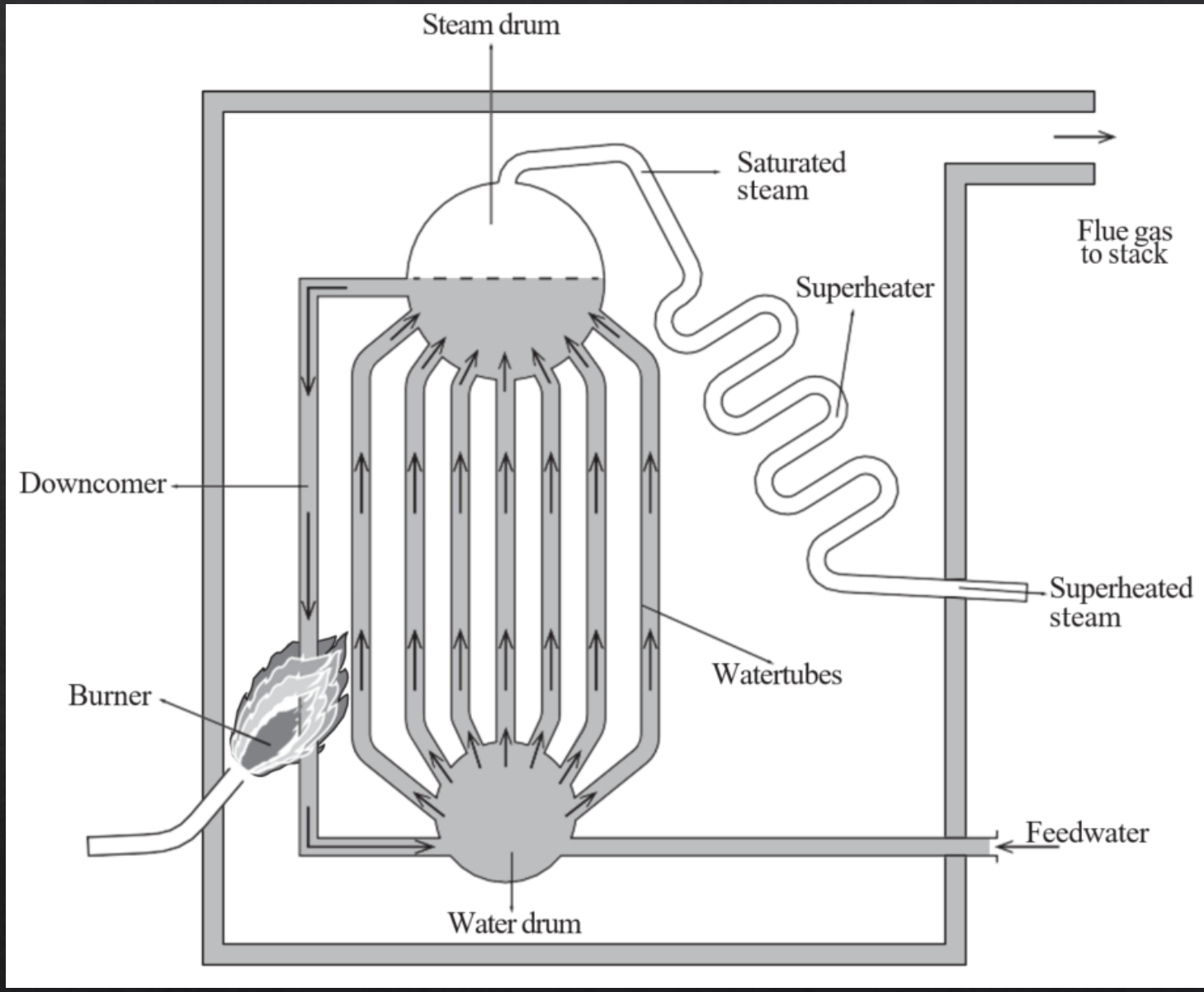
Water Tube Steam Generators:



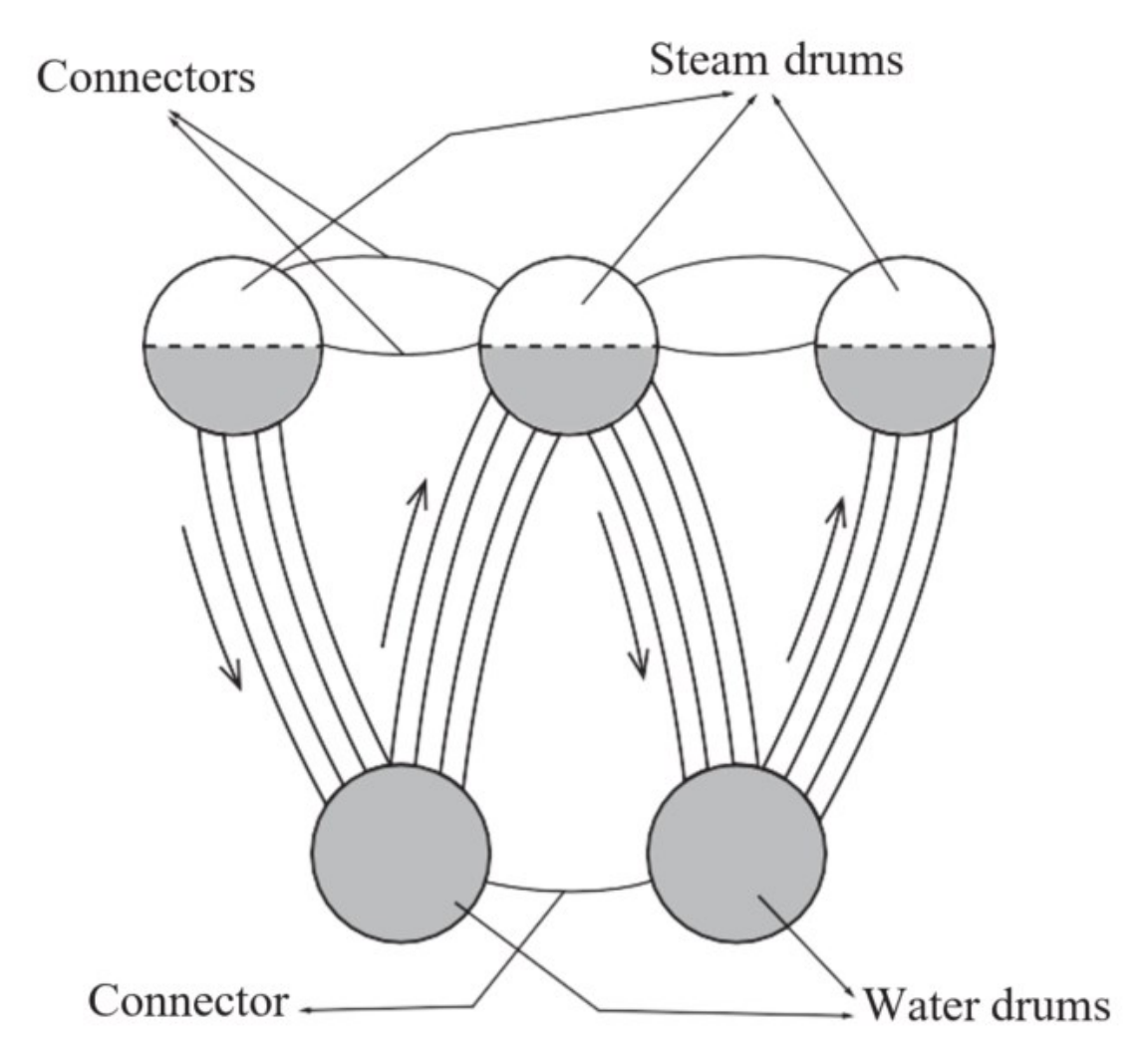
Schematic of a parallel-drum inclined water-tube steam generator with a superheater



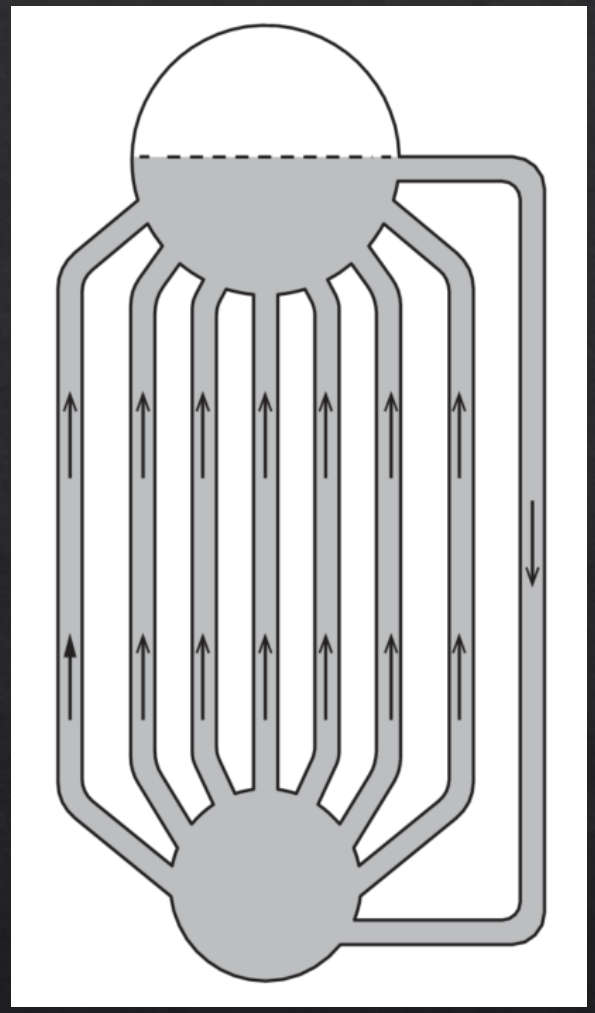
Schematic of a cross-drum inclined water-tube steam generator



Schematic of a bent-tube water-tube steam generator

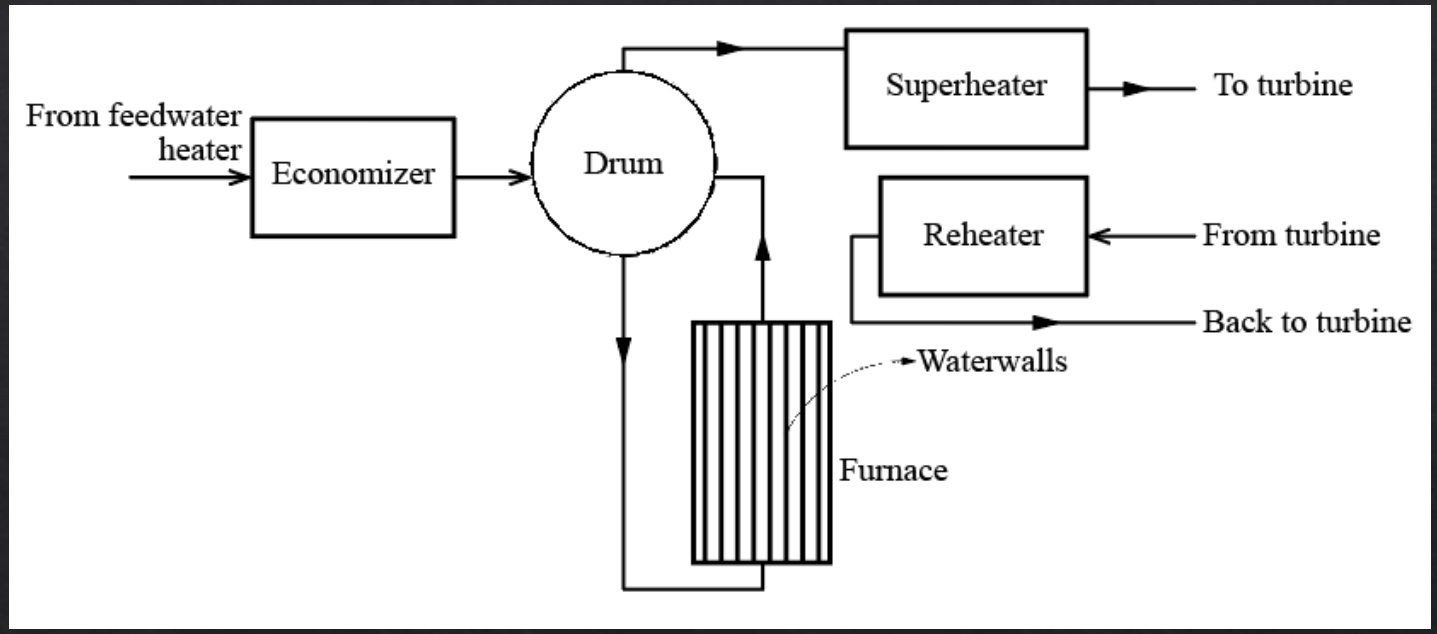


Schematic of a Stirling steam generator with five drums and four tube banks

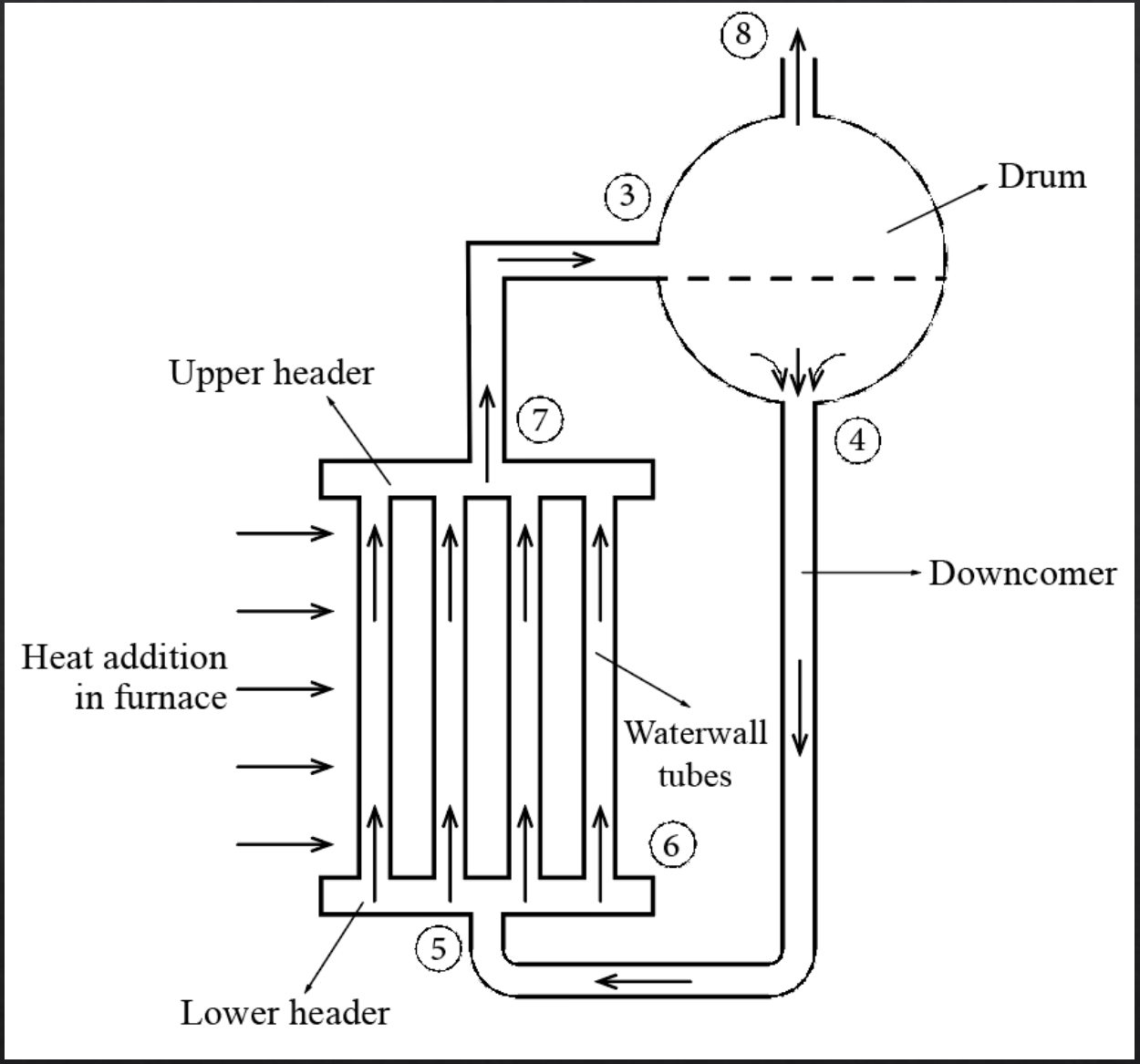


Schematic of a Milne boiler

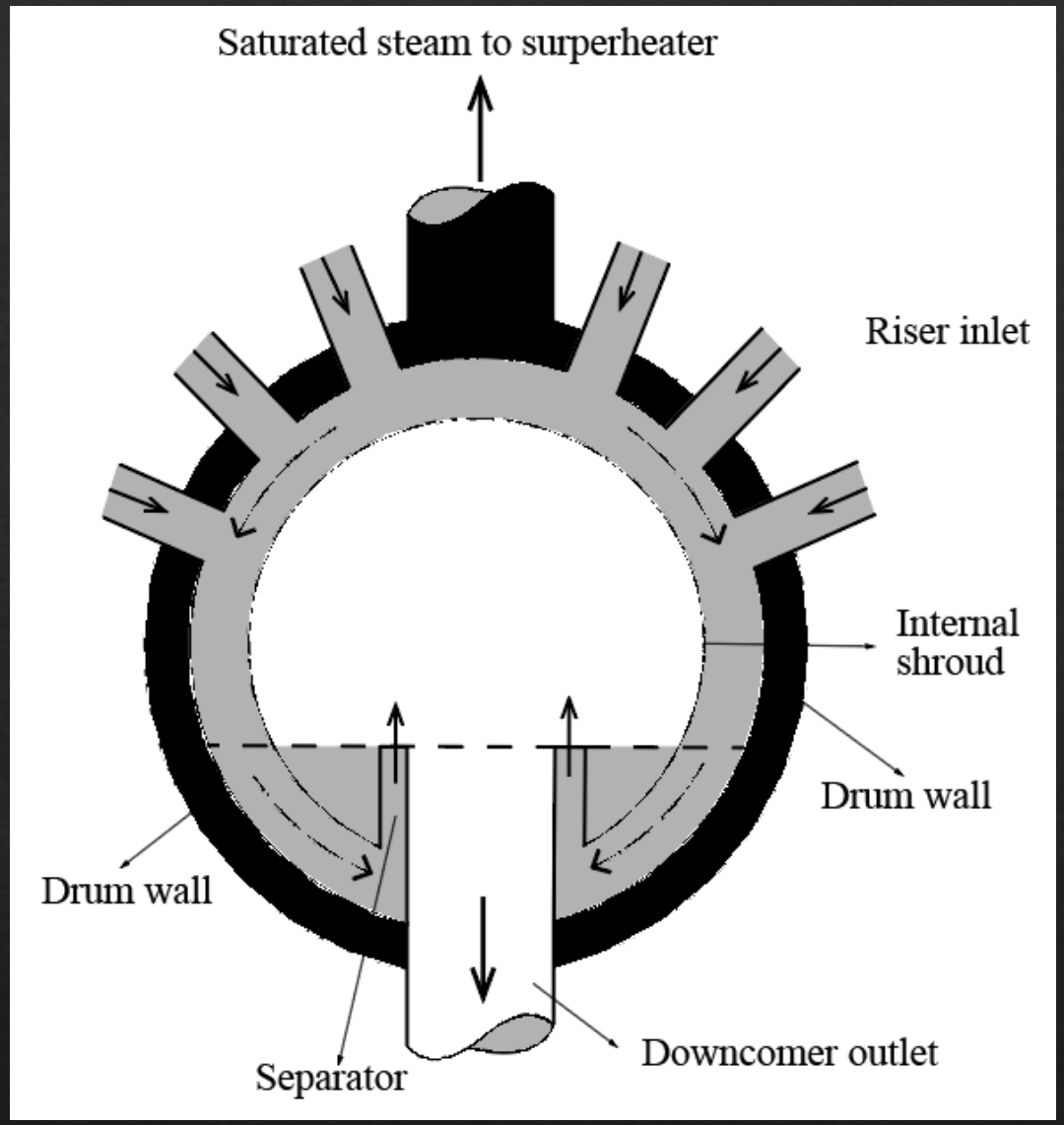
Arrangement of Modern Steam Generators



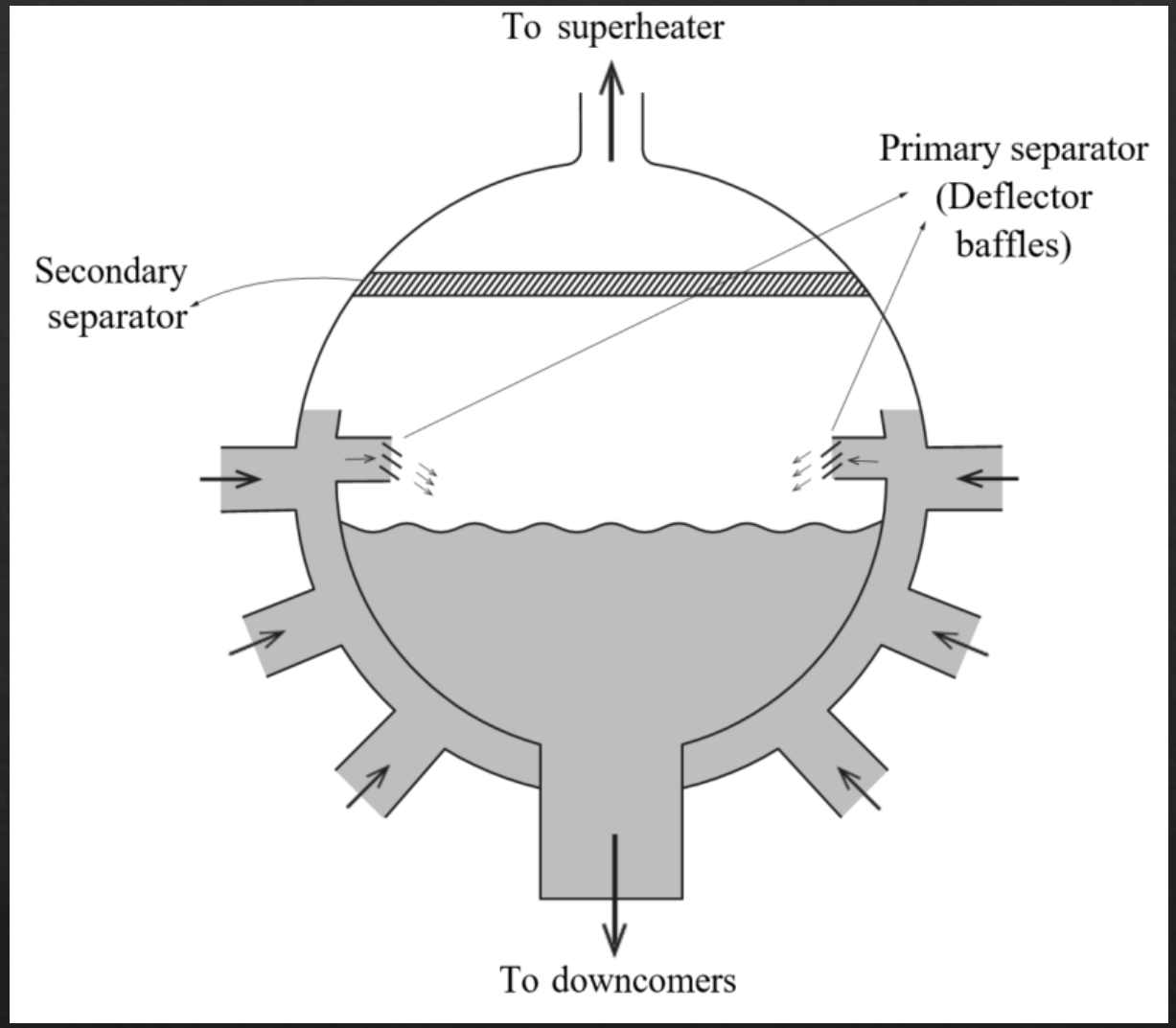
Schematic diagram of a typical modern drum-type steam generator



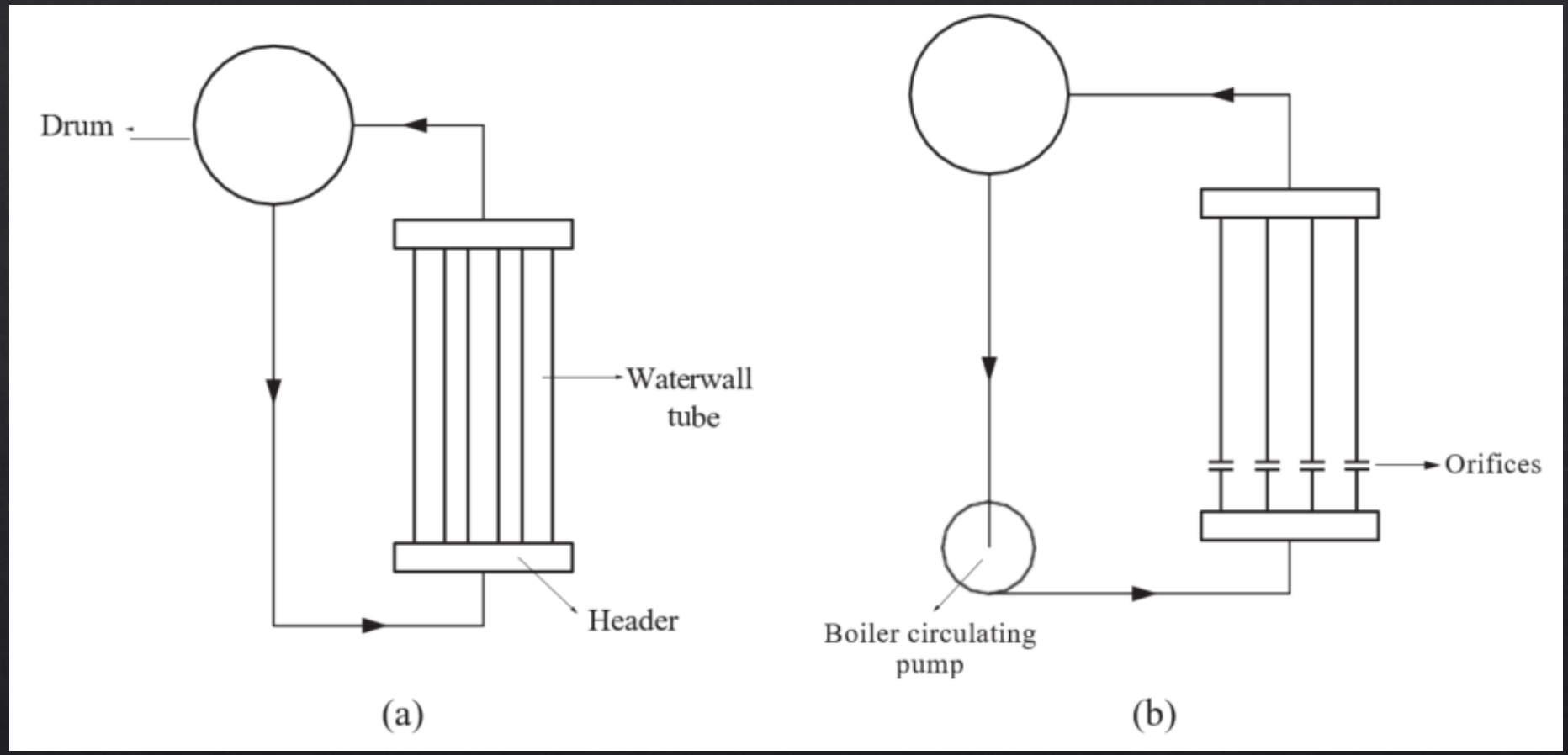
Schematic diagrams of an evaporator loop in a drum-type steam generator



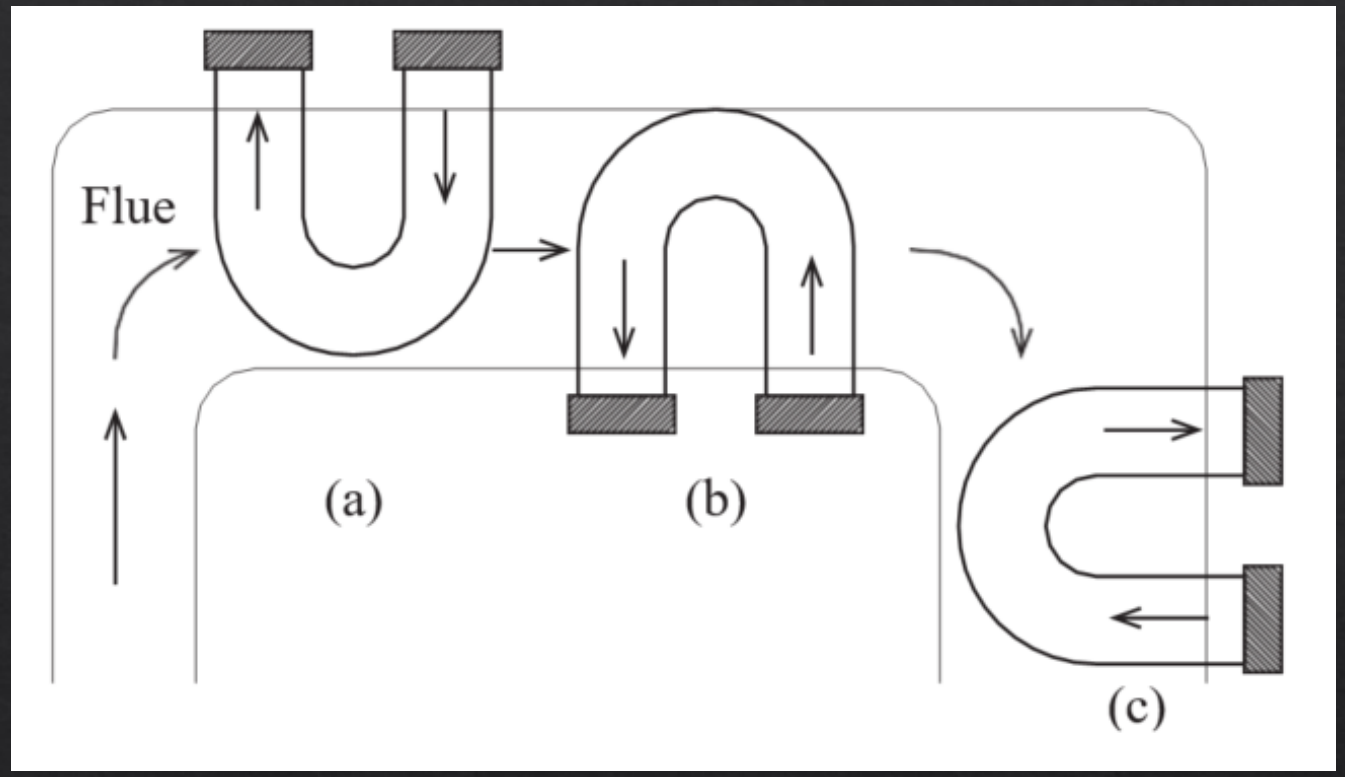
Schematic of a steam drum (internal components are not shown)



Schematic of a primary separator (deflector baffles) and secondary separator



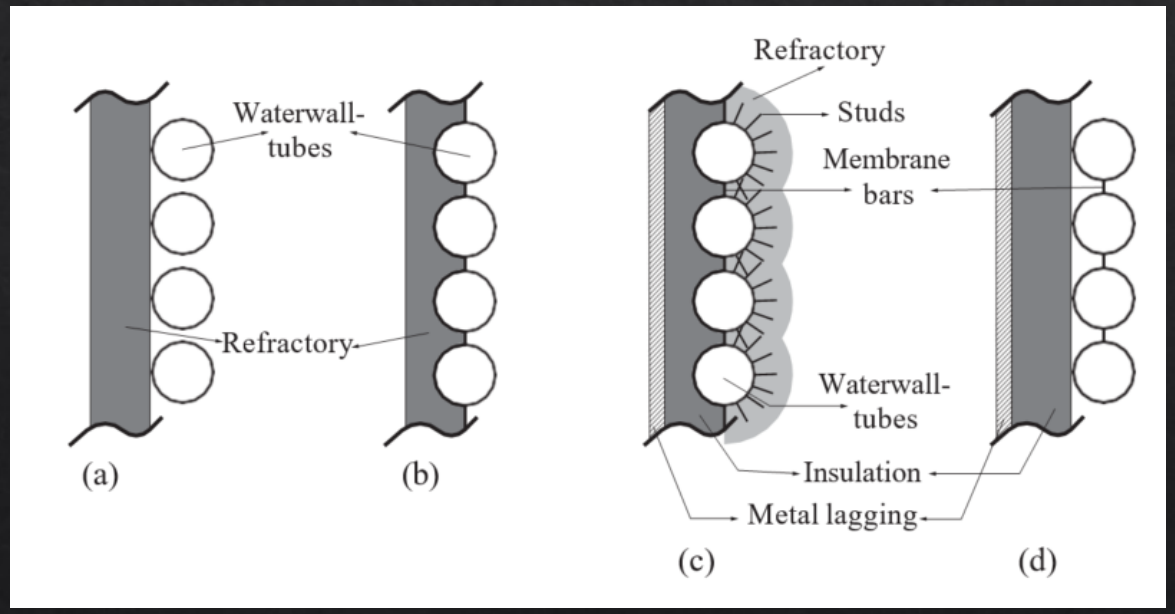
Schematics of (a) natural circulation and (b) forced-circulation steam generators



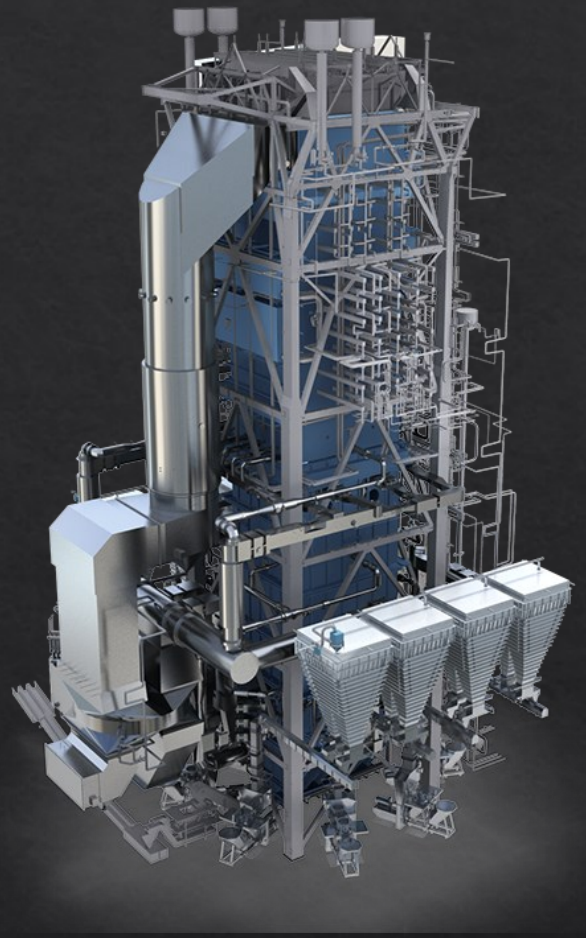
Schematics of superheater and reheater support systems
(a) pendant (b) inverted (c) horizontal

Waterwall Tubes

In modern utility steam generators, waterwall tubes form the entire walls, roof, and bottom of the steam generator, and **no other physical structure is needed to contain combustion gases** in the furnace and other components.



Different types of waterwall tubes: (a) bare tubes, (b) embedded in the refractory, (c) studded tubes, (d) membrane



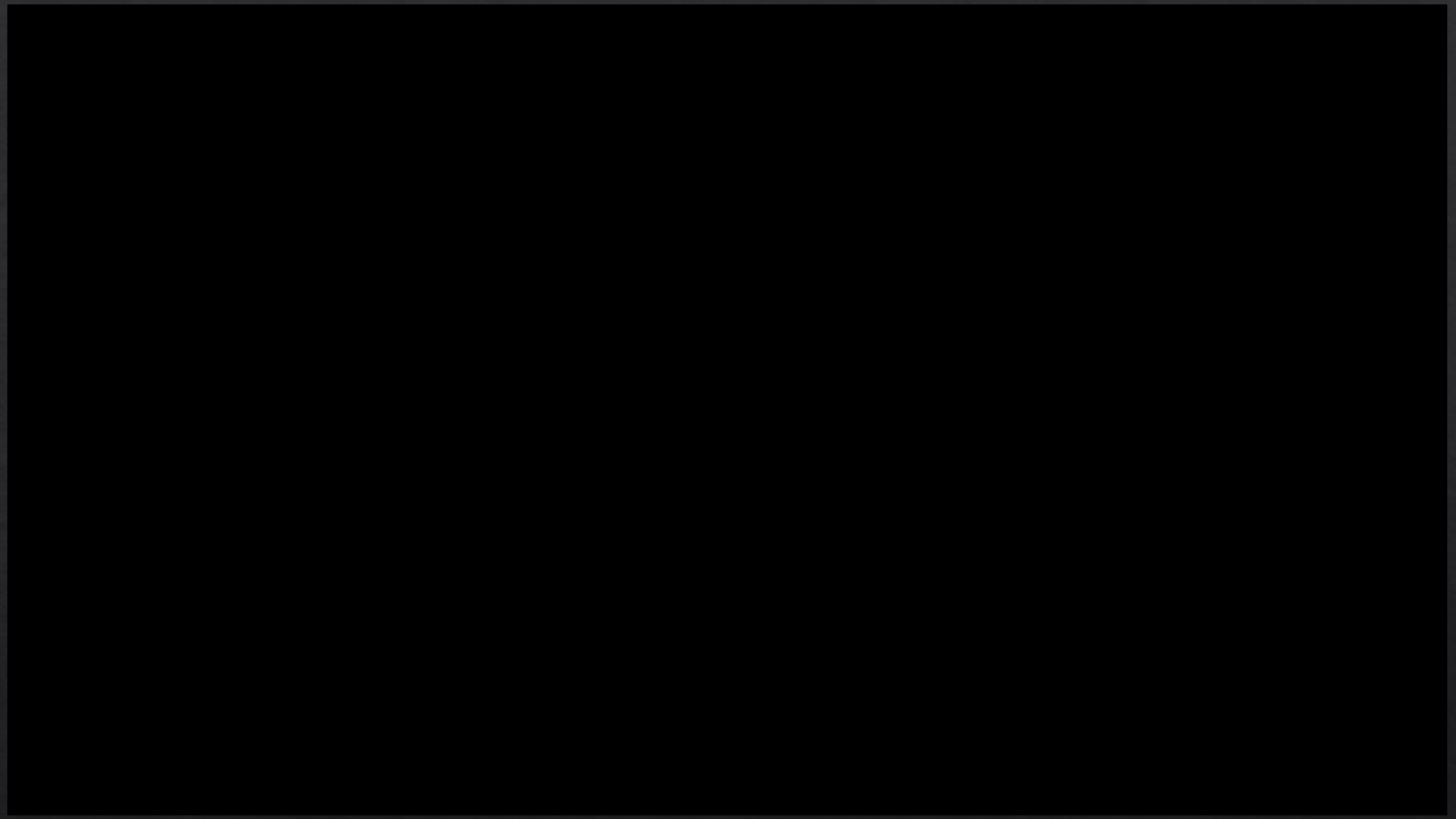
General Electric: Steam Boiler

Steam Boiler Tubes

Calculation of Wall Thickness of Pressure Vessels

The ASME was established to regulate the steam generator manufacturing industry. The ASME Boiler & Pressure Vessel Code (BPVC) is the result of this effort. The ASME BPVC is an extensive series of documents to ensure the high quality of all aspects of steam generator and pressure vessel design and manufacturing.

- ASME BPVC Section I: Rules for Construction of Power Boilers
- ASME BPVC Section II: Materials
- ASME BPVC Section III: Rules for Construction of Nuclear Facility Components
- ASME BPVC Section IV: Rules for Construction of Heating Boilers
- ASME BPVC Section V: Nondestructive Examination
- ASME BPVC Section VI: Recommended Rules for the Care and Operation of Heating Boilers
- ASME BPVC Section VII: Recommended Guidelines for the Care of Power Boilers
- ASME BPVC Section VIII: Rules for Construction of Pressure Vessels
- ASME BPVC Section IX: Welding and Brazing Qualifications
- ASME BPVC Section X: Fiber-Reinforced Plastic Pressure Vessels
- ASME BPVC Section XI: Rules for Inservice Inspection of Nuclear Power Plant Components
- ASME BPVC Section XII: Rules for the Construction & Continued Service of Transport Tanks



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Cooling Systems (Circulating Water Systems)

Mount Storm Power Plant in Grant County, West Virginia. (By Raeky – Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=3658660.)

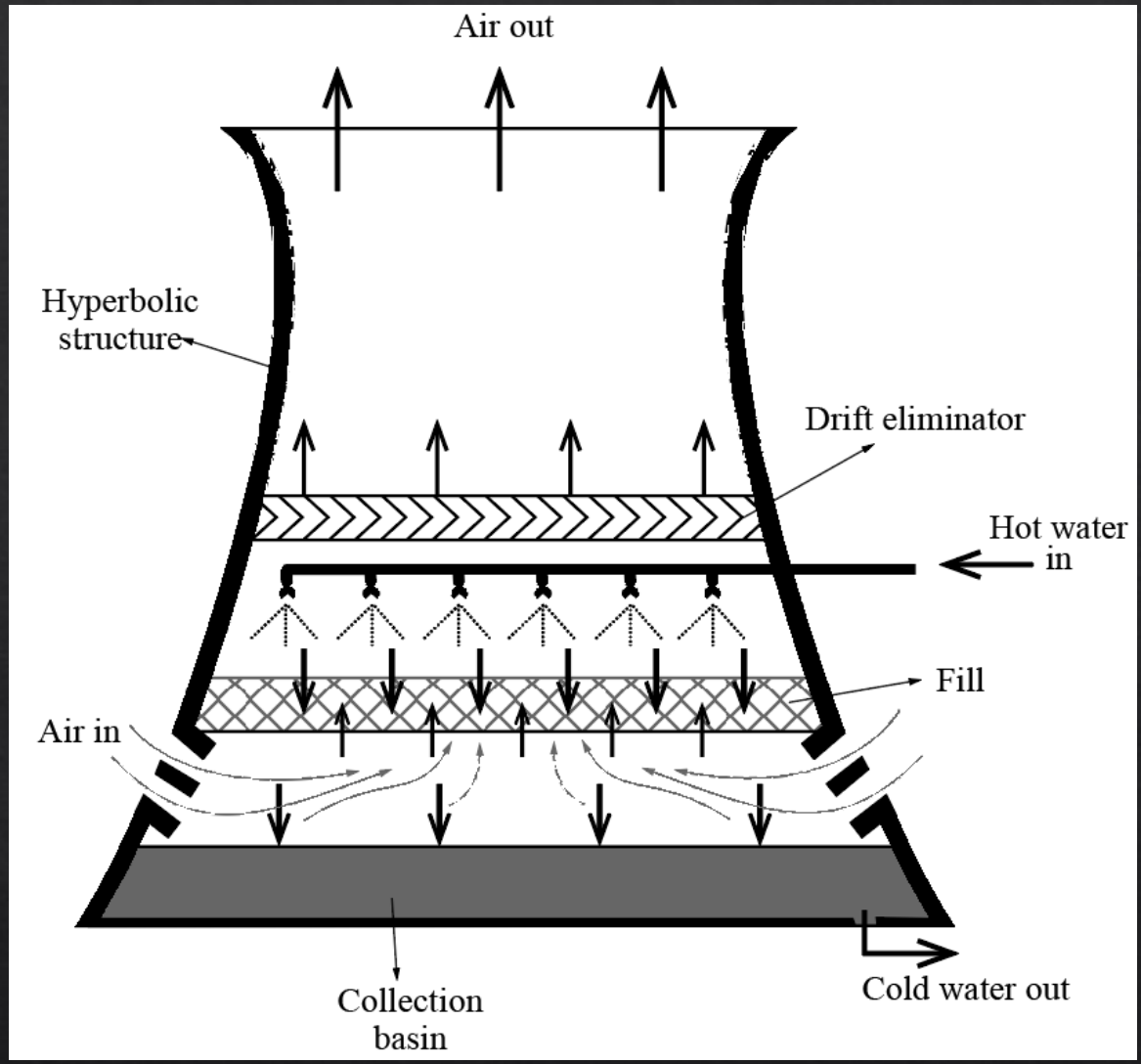
Evaporative Condensers

Sheer size of a natural draft cooling tower (use the high-voltage power lines in fore- ground as reference). (Image by Marc Pascual from Pixabay, https://pixabay.com/photos/ nuclear-energy-central-electricity-4600565/.)

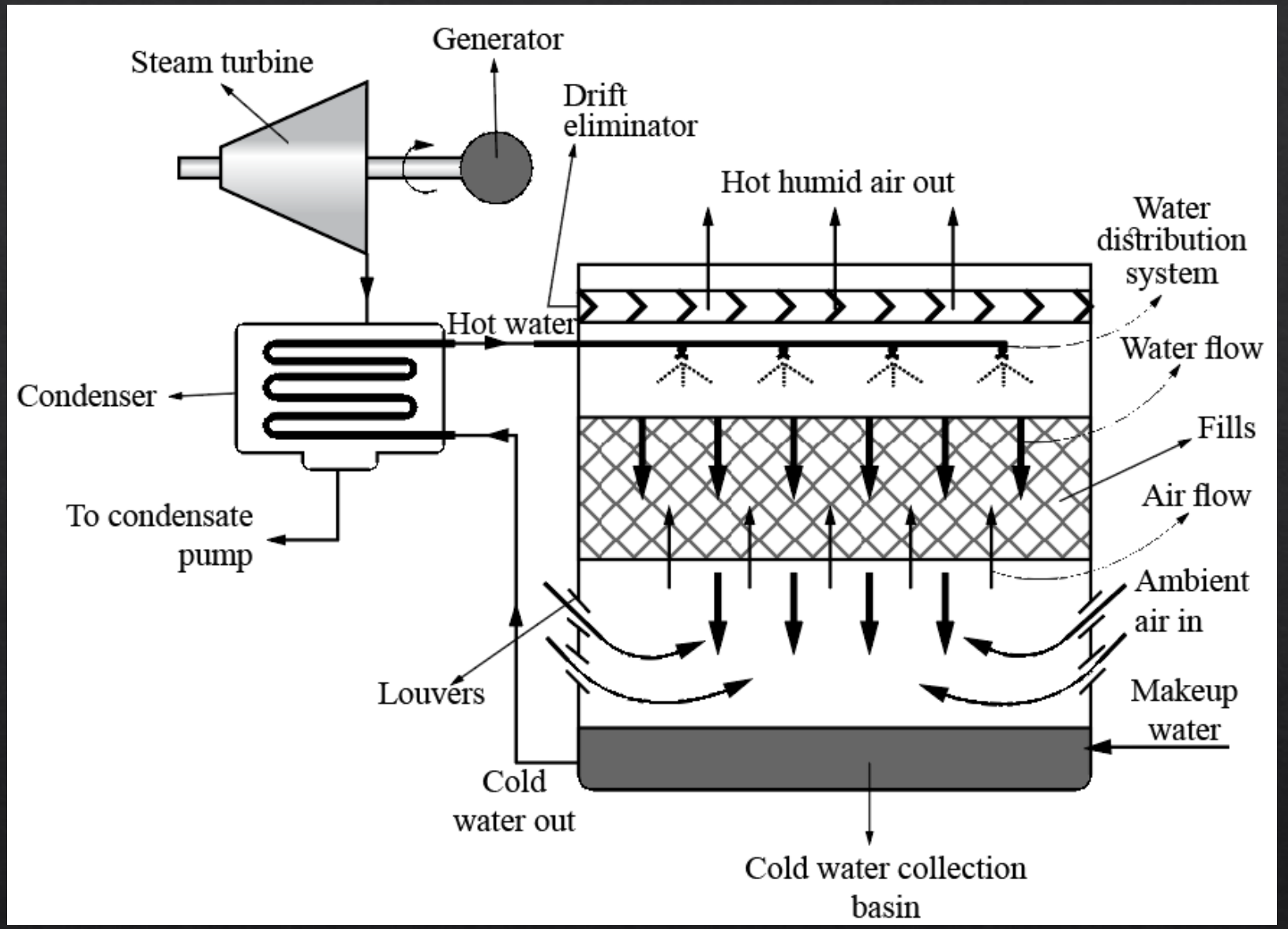
Natural draft cooling towers as the most visible structures of steam power plants. (Image by Bruno/Germany from Pixabay, https://pixabay.com/photos/industry-power-plant-2663191/.)

Similarities of plume from a cooling tower and smoke from a stack. (Image by Monika P. from Pixabay, https://pixabay.com/photos/power-plant-industry-flame-2012377/.)

A natural draft cooling tower with a steel structure. (Image by 2427999 from Pixabay, https:// pixabay.com/photos/power-plant-power-plant-electricity-1367316/.)

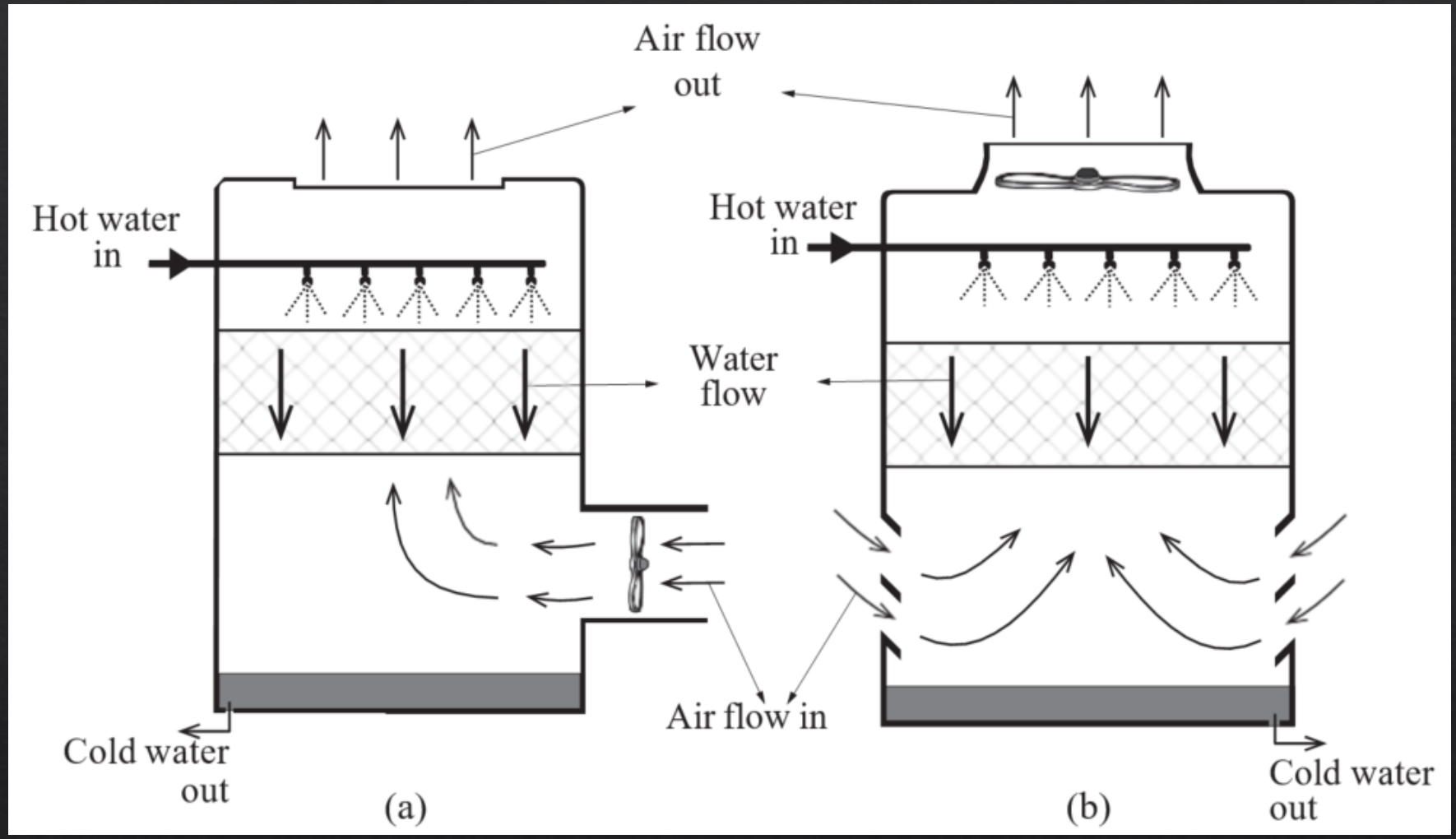


Schematic of the internal components of an evaporative natural draft cooling tower



Schematic of a counterflow wet cooling tower

Hot water distribution systems in a wet cooling tower: an actual spray water distribution system (By Jan Beránek – Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index. php?curid=79463485.)

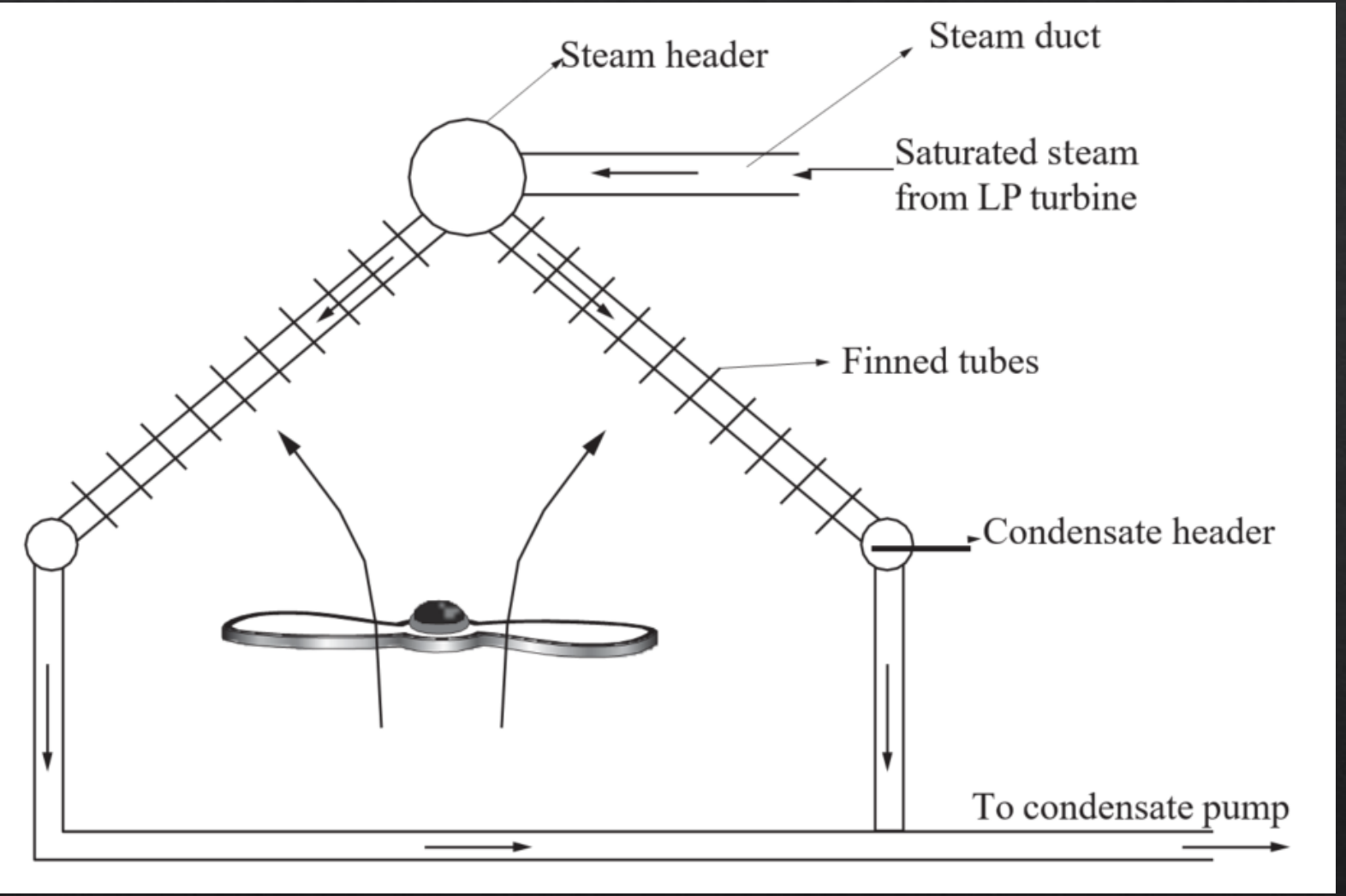


Schematic of forced draft (a) and induced draft (b) cooling towers

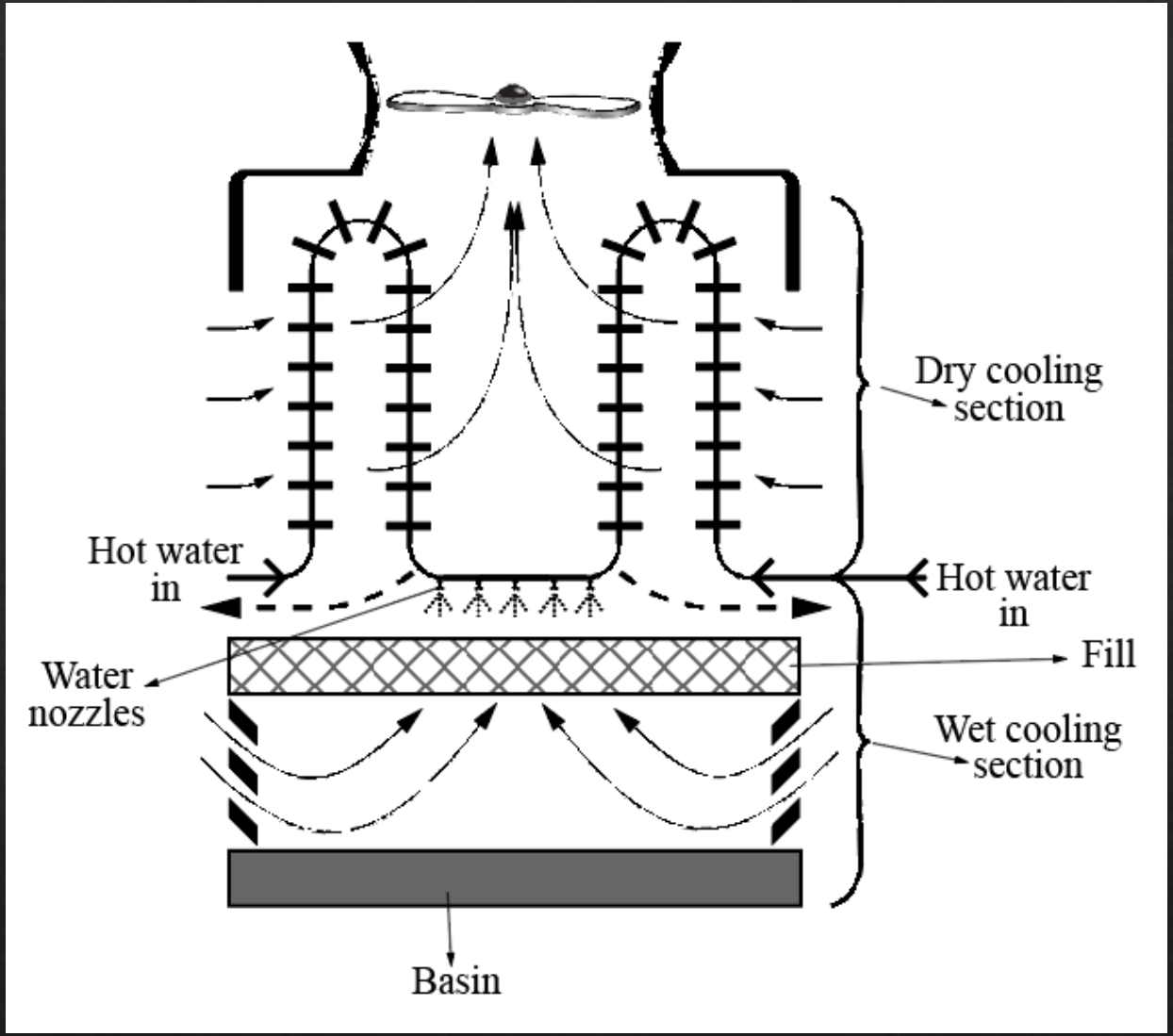
Vast empty volume inside a natural draft cooling tower. (Image by MichaelMep from Pixabay, https://pixabay.com/photos/architecture-cooling-tower-3321995/.)

A fan-assisted hyperbolic cooling tower (hybrid hyperbolic cooling tower) (the photo shows an abandoned one!). (Image by Peter H. from Pixabay, https://pixabay.com/photos/ fan-cooling-propeller-cooler-turn-3645379/.)

An induced draft cooling tower. (By Cenk Endustri – Own work, CC BY-SA 3.0, https:// commons.wikimedia.org/w/index.php?curid=16049857.)



Schematic of a mechanical draft air-cooled condenser (or a direct dry cooling tower)



Schematic of a hybrid wet and dry cooling tower

End of Lecture!