Boiler - Fundamentals

Steam production and steam uses

Steam purity and steam quality

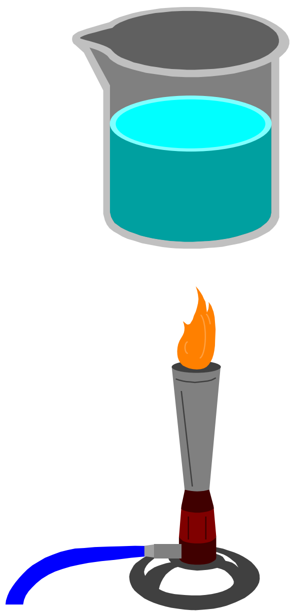
Types of boilers

Basic boiler principles

Basic boiler calculations

Steam Production
and
Steam Uses

Steam Production



When heat is added to water, its temperature rises at a rate of 0.56°C (1°F) for each heat input of 2.095 kJ/kg (1 Btu/lb)

If we take water at 0°C (32°F) and we add 419 kJ/kg (180 Btu/lb) then we will increase the temperature of the water by 100°C (180°F)

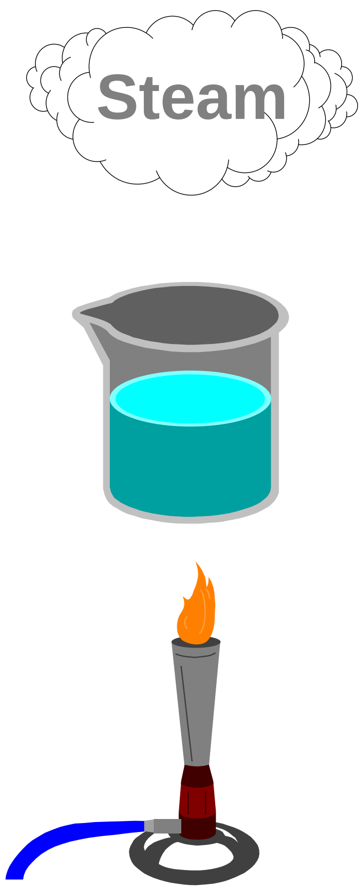
This rise in temperature can be detected and is called Sensible Heat (Specific Enthalpy - Water)

Steam Tables

Pressure psig	Temperature °F	Sensible Heat Btu/lb	Latent Heat Btu/lb	Total Heat Btu/lb	Volume Dry Saturated ft^3/lb
0	212	180	971	1151	26.80
15	250	218	946	1164	13.90
31	275	244	929	1173	9.30
51	299	268	912	1180	6.60
100	338	309	882	1190	3.89
150	366	339	858	1997	2.76
200	388	362	838	1200	2.14

Pressure barg	Temperature °C	Water kJ/kg	Evaporation kJ/kg	Steam kJ/kg	Specific Volume Steam m^3/kg
0	100.00	419.04	2257.00	2676.00	1.673
1	120.42	505.60	2201.10	2706.70	0.881
2	133.69	562.20	2163.30	2725.50	0.603
4	151.96	640.70	2108.10	2748.80	0.374
6	165.04	697.50	2066.00	2763.50	0.272
10	184.13	781.60	2000.10	2781.70	0.177
14	198.35	845.10	1947.10	2792.20	0.132

Steam Production

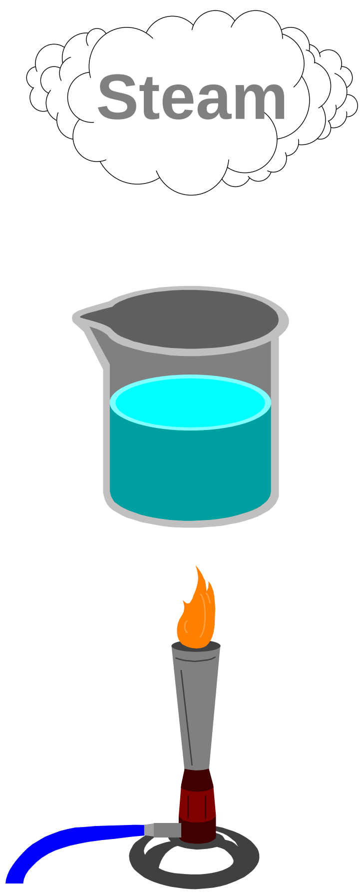


At normal atmospheric pressure, any further addition of heat to water at 100°C will not increase the temperature but will convert some of the water into steam

In order to convert water into steam 2,257 kJ/kg (971Btu/lb) of additional heat must be added

This cannot be detected as a rise in temperature and is called the Latent Heat of Vaporisation (Specific Enthalpy - Evaporation)

Steam Production



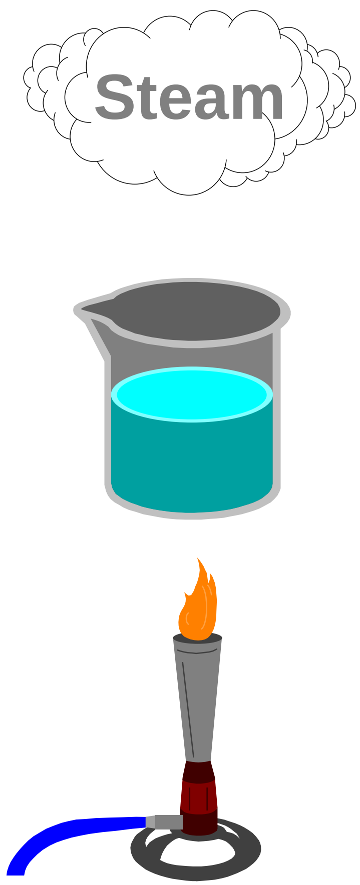
Total Heat of Steam = Sensible Heat + Latent Heat of Vaporisation

Specific Enthalpy :
Steam = Water + Evaporation

Thus the Total Heat of Steam (Specific Enthalpy - Steam) is 2,676 kJ/kg (1151 Btu/lb)

This data is found in Steam Tables

Steam Production



From steam tables we can see that the total heat of steam does not vary a great deal as the boiler pressure increase

The boiling point (b.p.) increases as the pressure increases

Thus the sensible heat increases as the pressure increases, and the latent heat decreases

Boiler pressures are expressed in psia, psig, bar, kg/cm^2, kpa

Steam Uses

Space heating

Drying - paper mill

Process heating

Sterilisation

Humidification

Power generation

Steam Purity
and
Steam Quality

Steam Purity

Steam purity is an expression of the quantity of non water components in the steam

Components can be dissolved in the steam, dissolved in water droplets entrained in the steam or carried as discrete solid particles in the steam

Steam impurities are normally expresses as a quantity in parts per million (ppm) or parts per billion

Steam Quality

Steam quality relates to the quantity of moisture present in the steam

100% quality specifying no moisture content

0% quality specifying all liquid

Liquid droplets entrained in the steam leaving a boiler contain dissolved solids

Types of Boilers

Types of Boilers

- **Fire Tube**
- **Water Tube**
- **Waste Heat**

Types of Boilers

Fire Tube Boilers	Low Pressure Systems
Water Tube Boilers	Medium to High Pressure Systems
Waste Heat Boilers	Process applications HRSG

Fire Tube Boilers

Also referred to as smoke tube boilers, shell boilers, package boilers

Multiple gas paths - 2, 3 and 4 pass

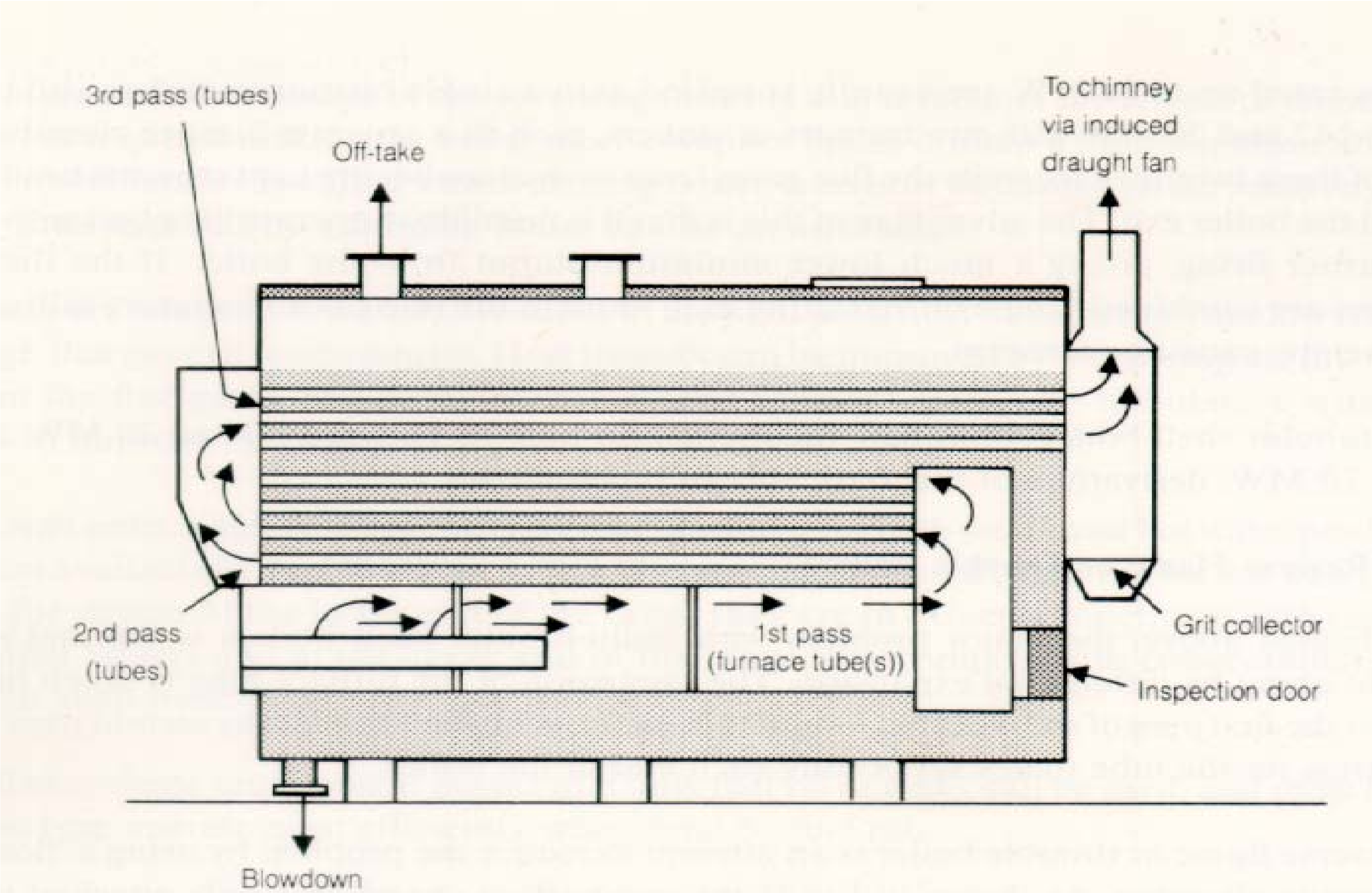
Internal furnace or fire box as the 1st pass

Dry back or wet back design

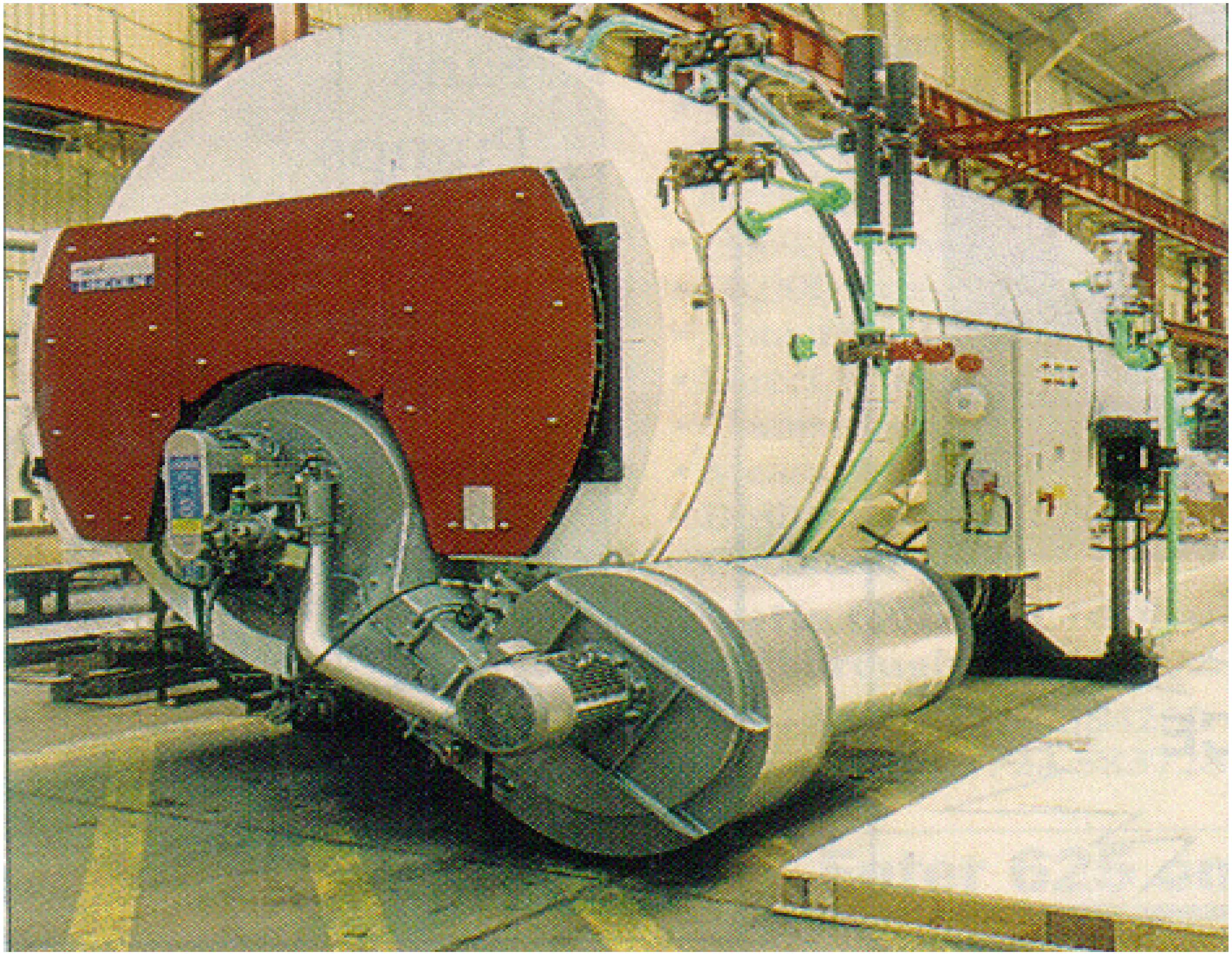
Single fuel or dual fuel design

Little or no steam separation equipment

Fire Tube Boilers



Fire Tube Boilers



Fire Tube Boilers

Typical designs are O, D and A type boilers

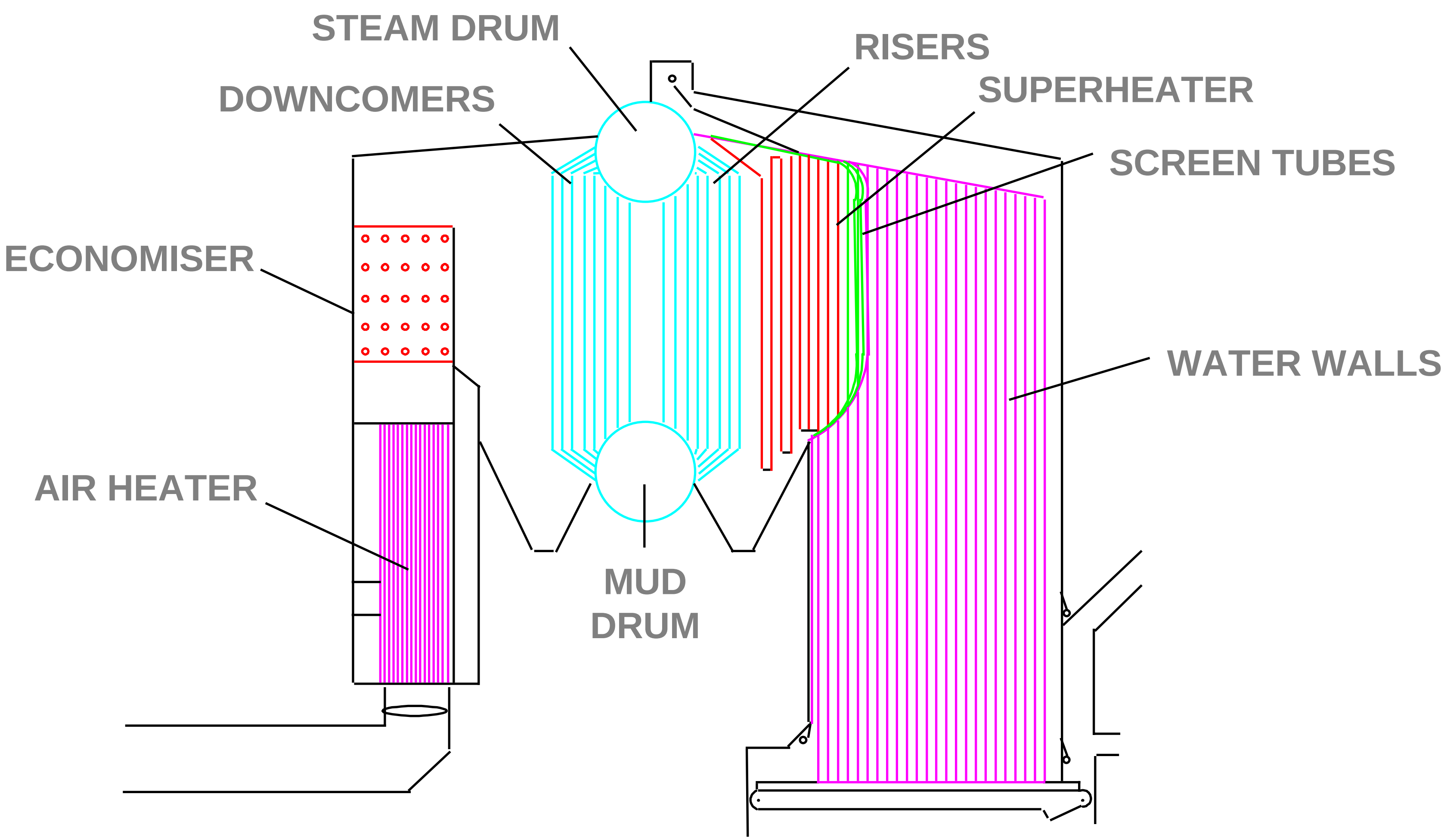
Steam separation equipment - drum furniture

- Cyclone separators
- Demister pads
- Baffle plates

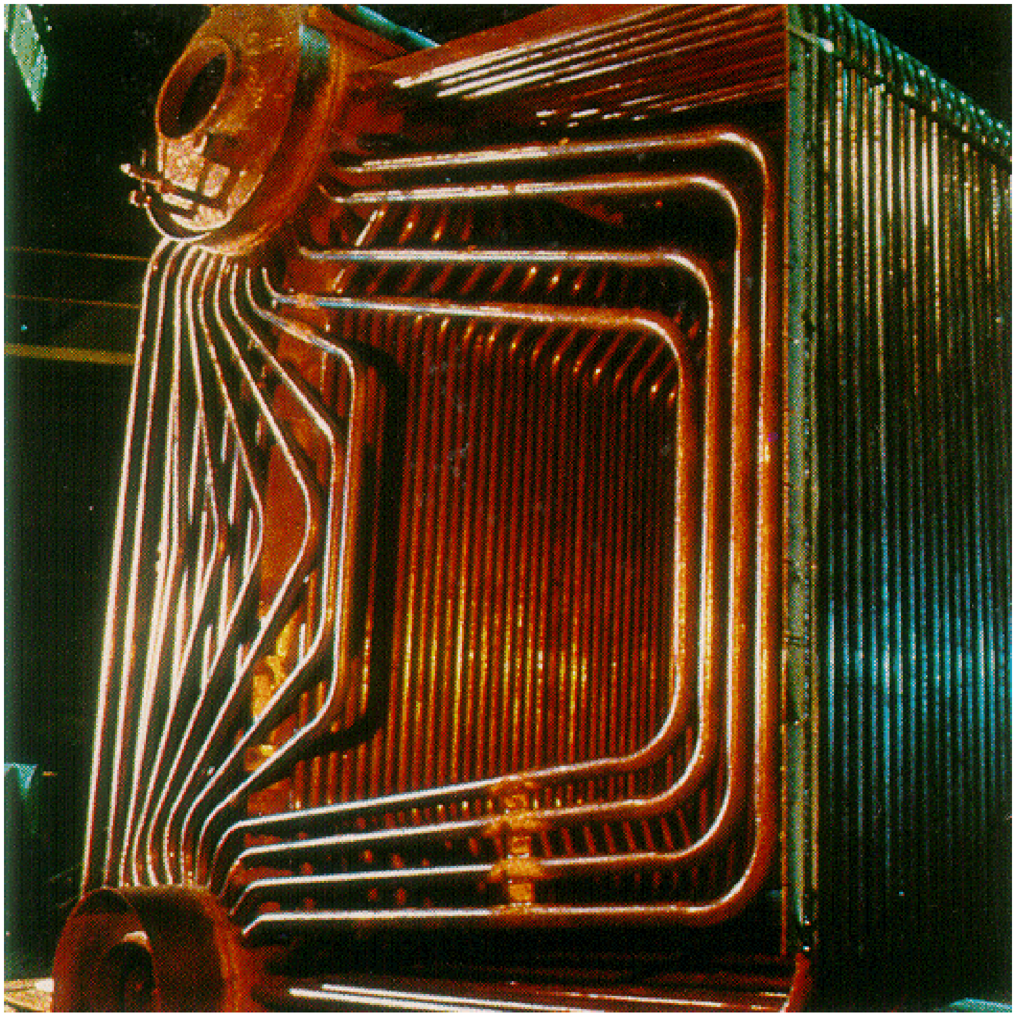
Have economisers and superheaters

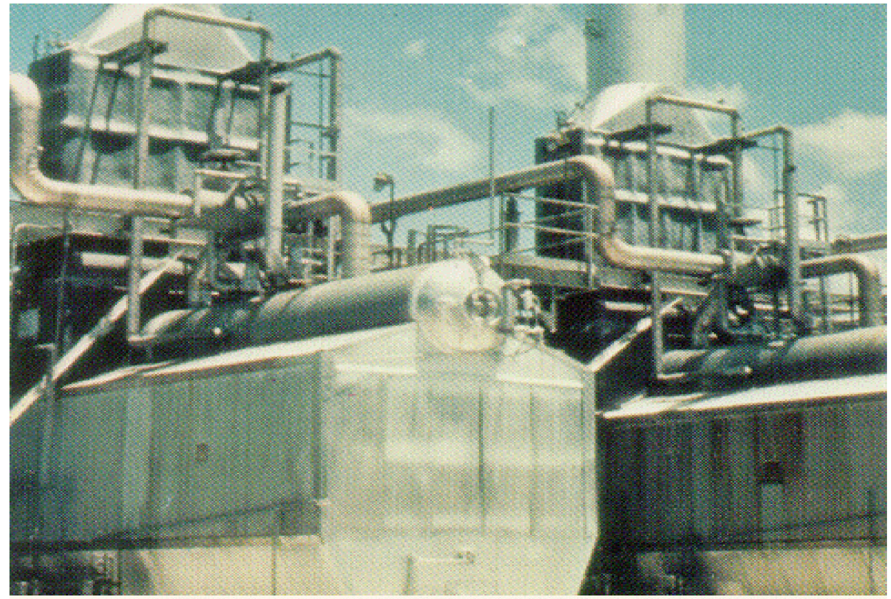
Large water tube boilers are field erected and may be unique design

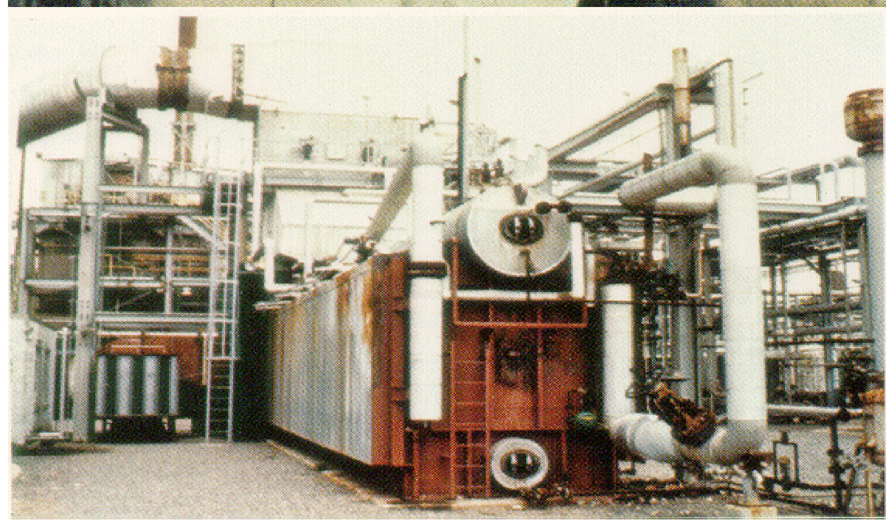
Fire Tube Boilers



Fire Tube Boilers







Waste Heat Boilers

Various types and designs

Shell and tube exchanger

Linked to process

Ammonia plant

Waste Heat Boiler

Ammonia Plant

Heat Recovery Steam Generators (HRSG)

Various types and designs

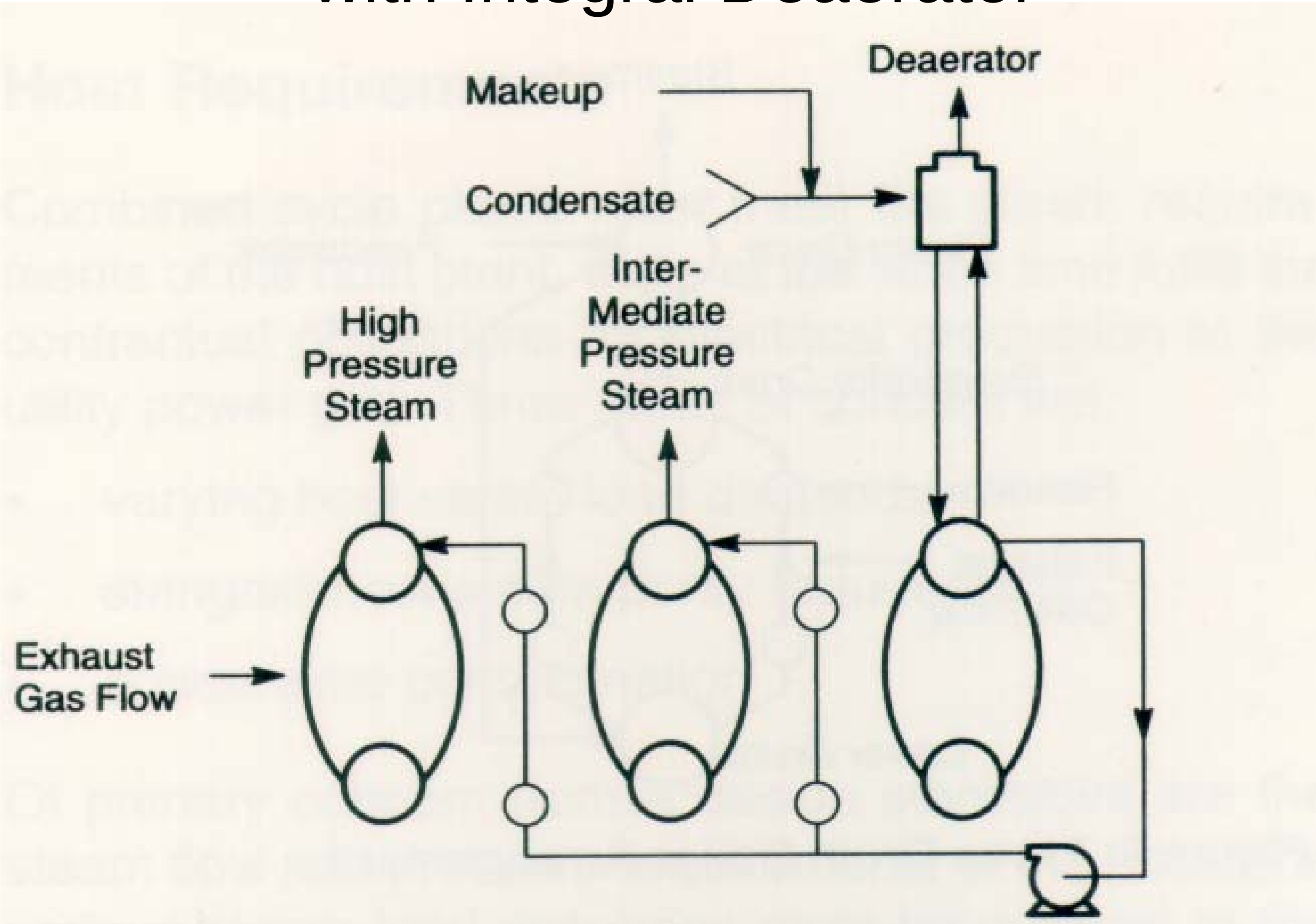
Shell and tube exchanger

Water tube boiler

Multiple drum system

- low pressure (LP)
- medium pressure (MP)
- high pressure (HP)

Multi Pressure Boiler System with Integral Deaerator



Steam Generators

Coil designs, vertical or horizontal

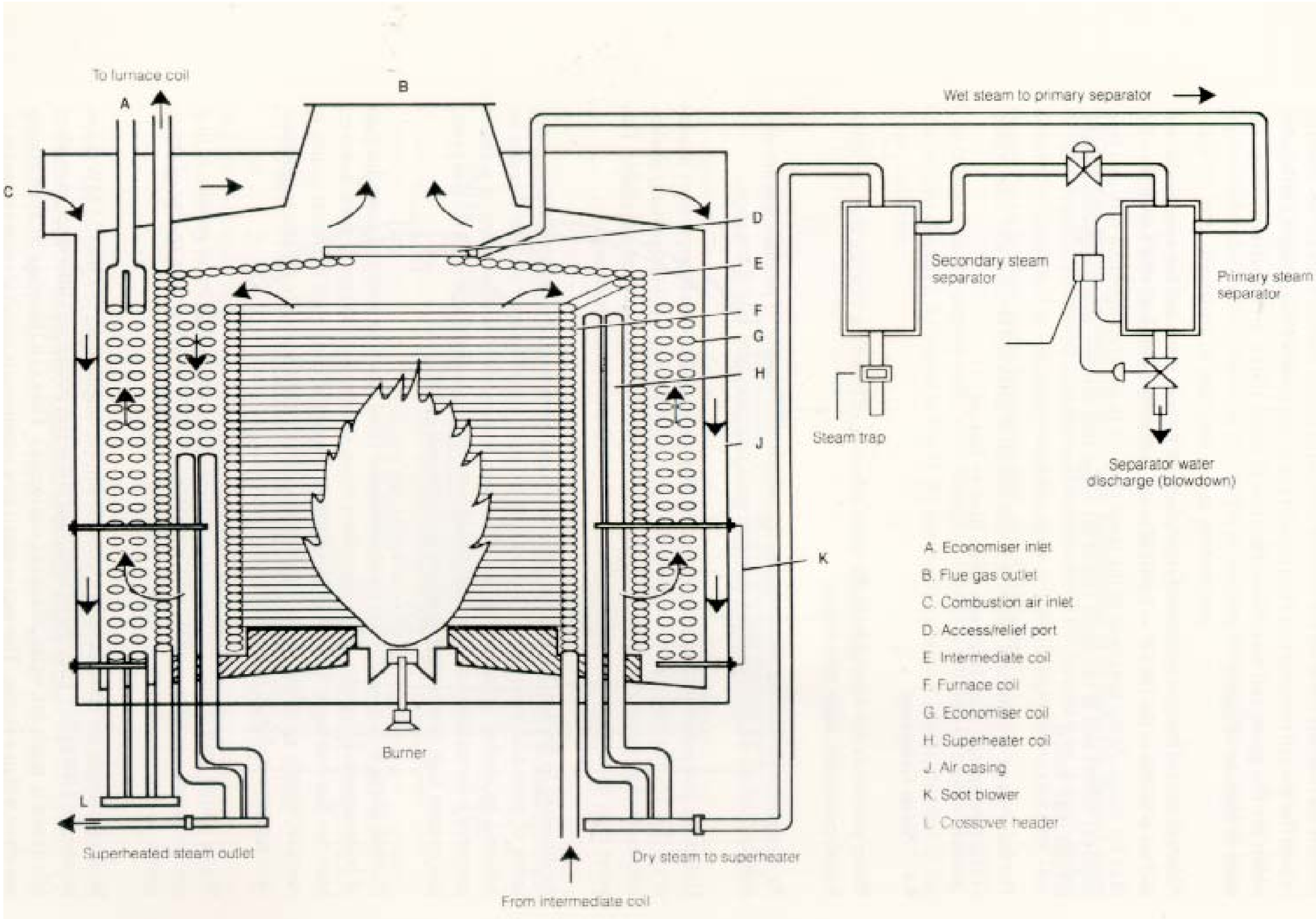
Bucket types

Steam water separator

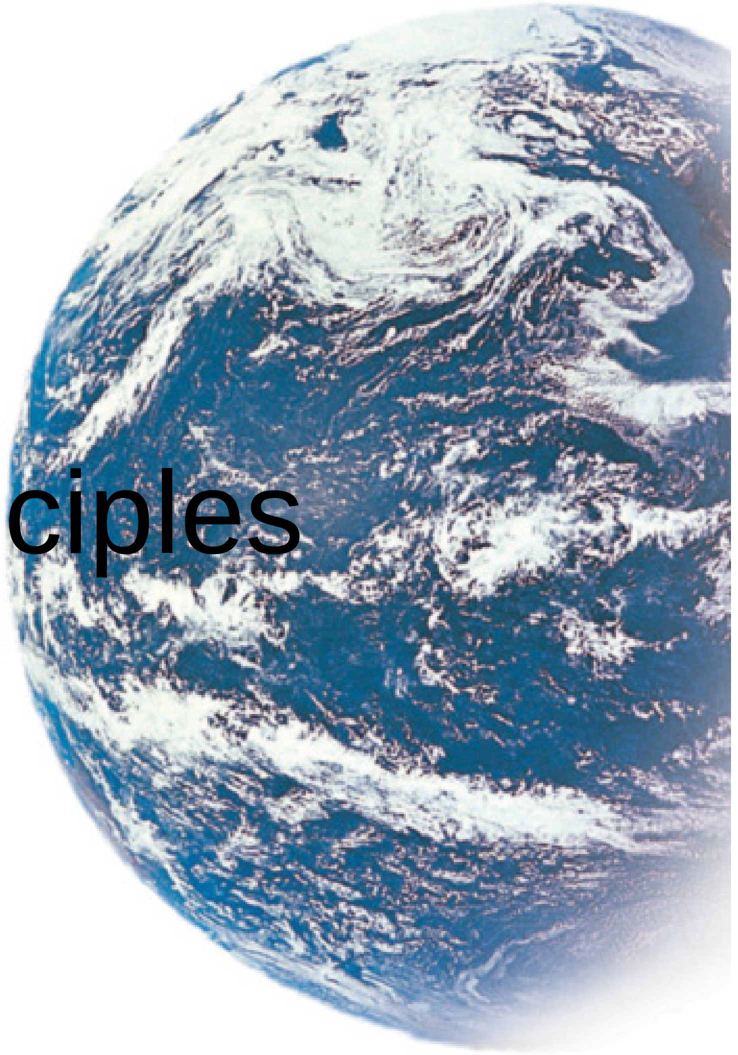
Boiler water returned to feed tank

May include economiser and superheater

Steam Generator - Coil



Basic Boiler Principles



Basic Boiler Principles

EXTERNAL TREATMENT

MAKE UP

WATER AND SOLIDS

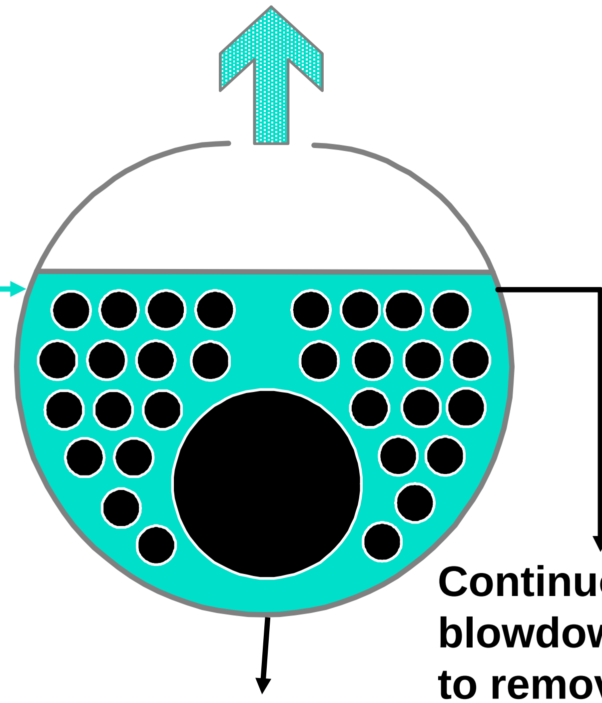
HOT WELL DEAERATOR

FEEDWATER

WATER AND SOLIDS

RETURNED CONDENSATE

WATER AND HEAT



Blowdown - Removes boiler water with a high concentration of solids which is replaced by feedwater containing a low concentration of solids

Basic Boiler Principles

Water and solids enter the boiler

Water leaves the boiler as steam

Solids concentrate in the boiler

Therefore the boiler water will contain more solids than the feedwater

This Concentrating effect is called

The Cycles of Concentration or The Cycles

Basic Boiler Principles

A boiler can only tolerate a specific number of cycles of concentration

This will vary depending on

Type and pressure of the boiler

Type of external treatment

Percentage condensate return

Basic Boiler Principles

The chemical factors which limit the boiler water cycles of concentration are

Suspended solids (Total Hardness)

Dissolved solids

Total alkalinity (M Alkalinity)

Silica

Basic Boiler Principles

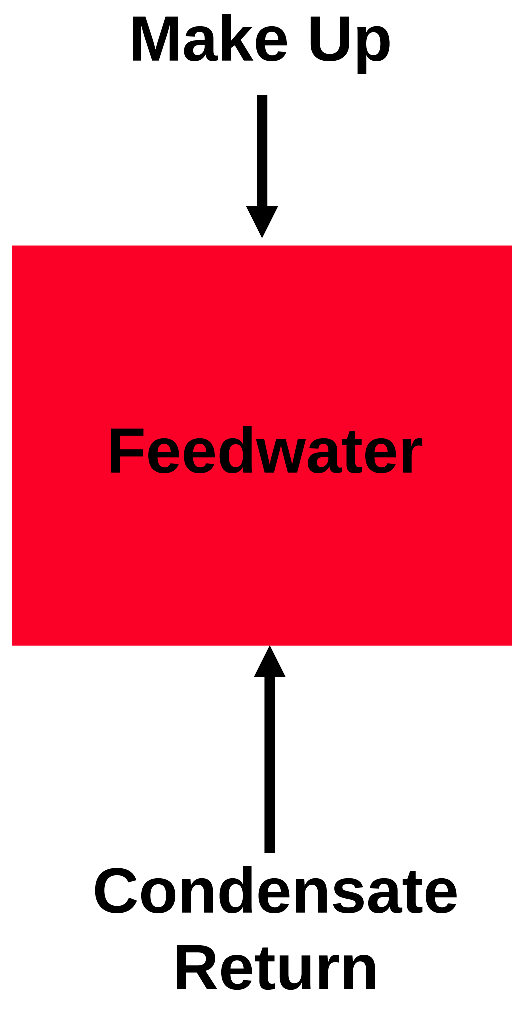
How do we determine the chemical control limits that we apply to an operating boiler ?

- British Standard BS2486:1997
- ASME Guidelines* 1994

★ Consensus on operating practices for the control of feedwater and boiler water chemistry in modern industrial boilers

Basic Boiler Calculations

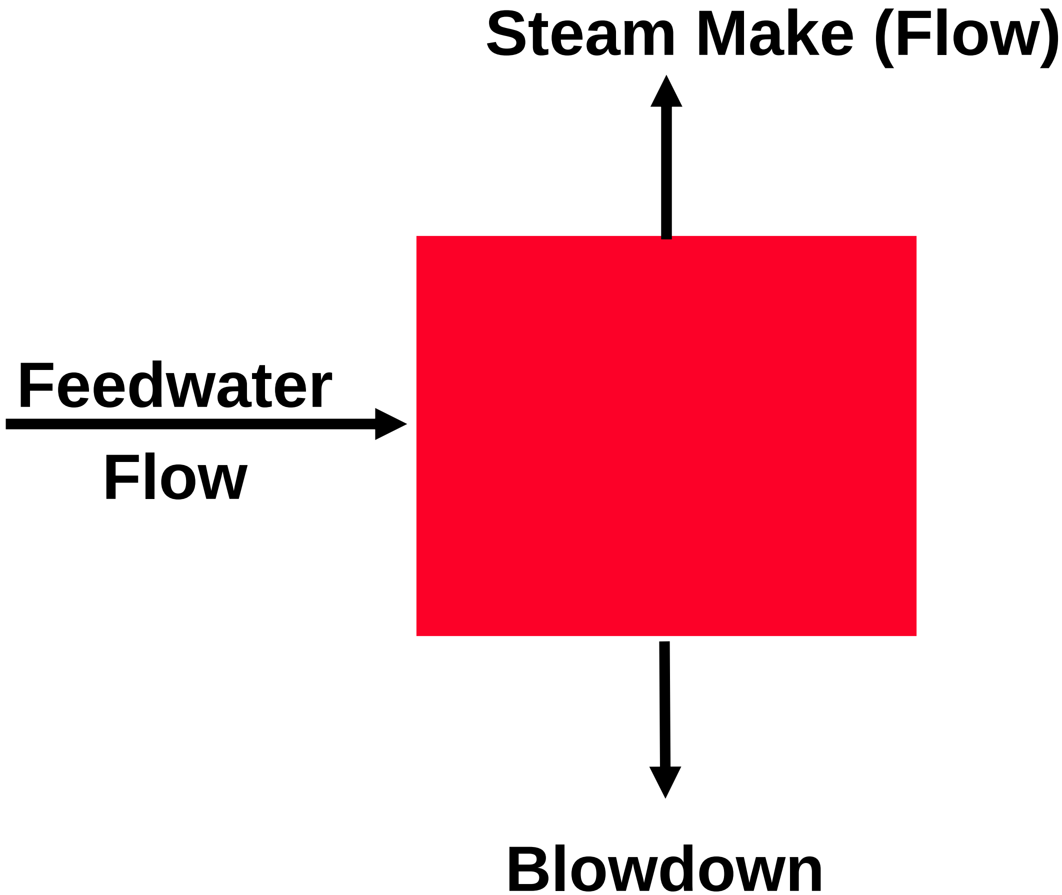
Basic Boiler Calculations



Basic Boiler Calculations

- Feedwater = Make up + Condensate Return

Basic Boiler Calculations



Basic Boiler Calculations

- Feedwater = Make up + Condensate Return
- Feedwater Flow (FWF) = Steam Make + Blowdown

Basic Boiler Calculations

- Feedwater = Make up + Condensate Return
- Feedwater Flow (FWF) = Steam Make + Blowdown(BD)
- Feedwater Flow (FWF) = Steam Make + Steam Make
- Cycles - 1

Basic Boiler Calculations

- Feedwater = Make up + Condensate Return
- Feedwater Flow (FWF) = Steam Make + Blowdown(BD)
- $\text{Feedwater Flow (FWF)} = \text{Steam Make} + \dfrac{\text{Steam Make}}{\text{Cycles} - 1}$
- $\text{Blowdown} = \dfrac{\text{Steam make}}{\text{Cycles} - 1}$ or $= \dfrac{\text{FWF}}{\text{Cycles}}$
- $\%\ \text{Blowdown} = \dfrac{1}{\text{Cycles}}$ as a % of FWF

Basic Boiler Calculations

Condensate Return is also expressed as % of FWF

If Condensate Return = 60% Make up = 40%

% Condensate + % Make up = 100% = FWF

As the boiler water cycles of concentration increase then the feedwater flow and the steam make approach the same number

Basic Boiler Calculations

Calculate the feedwater composition (impurities) from make up and condensate analysis below

	Make-Up	Condensate	Feedwater
Total Hardness	2	0	
M Alkalinity	200	10	
TDS	350	15	
Silica	6	0	
% Condensate		50	

Basic Boiler Calculations

Calculate the feedwater composition (impurities) from make up and condensate analysis below

	Make up	Condensate	Feed water
Total Hardness	**2**	**0**	**1**
M Alkalinity	**200**	**10**	**105**
TDS	**350**	**15**	**182.5**
Silica	**6**	**0**	**3**
% Condensate		**50**	