FE 467 FOOD PLANT DESIGN

ENERGY MANAGEMENT AND UTILIZATION IN FOOD PLANTS

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Rev: Feb 2015

NOTE:
From FE 366 DON’T FORGET

- This semestry you have to prepare PID drawing

- P&ID Diagram(YOU WILL DRAW THIS FOR YOUR PROJECT (Fe 467 Design II) The details of PID will be learned at FE 403 Food Process Control

ENERGY SOURCES

- Liquids
    - Petrolium (Fuel oil-No:5 «Kalyak» or 6)
    - Waterdam (hydroelectric central→electiricty)
    - Ethly alcohol
- Gas
  - LPG (Liq. petrolium gas: Propane+Butane «butane is heavy/high dense → red/ash fire)»
  - Natural gas
  - Hidrogen gas
  - Biogas (methane)
- Solid
    - Coal
    - Solid waste
    - Wood

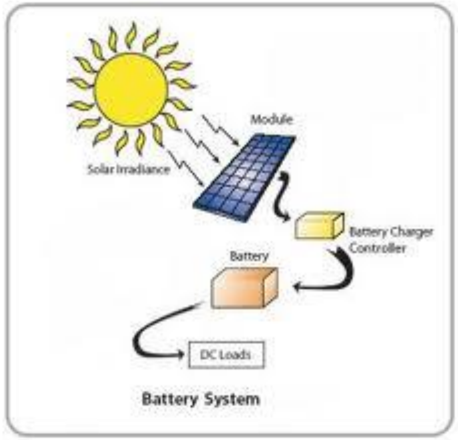
ALTERNATIVE
ENEGRY SOURCES

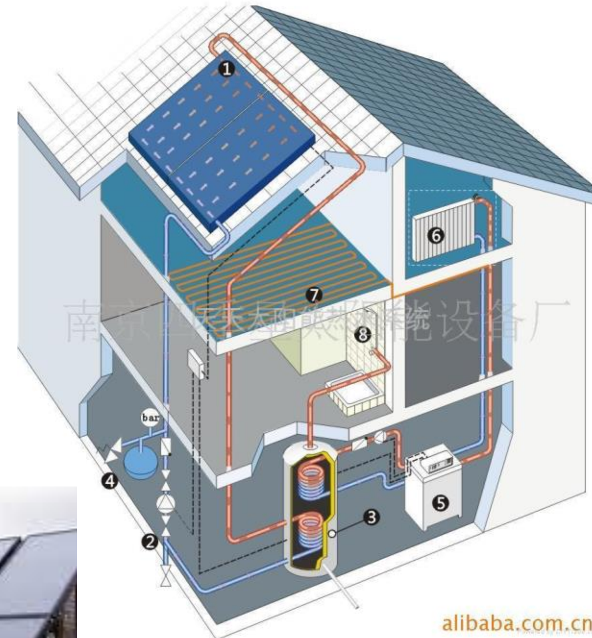
Sun
Wind
Biomass
Hydrogen
Sea wave
etc

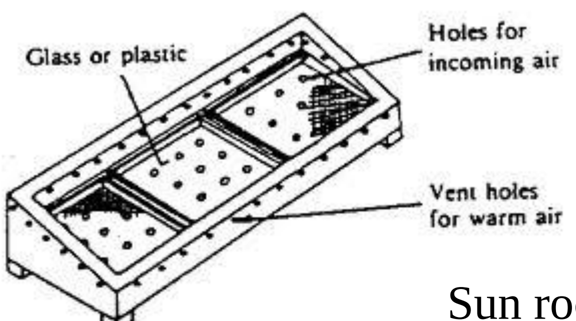
Sun as an energy source

- Sun collectors
- Sun batteries

- To produce;
  - Hot water
  - Steam
  - Electricity
  - Heated air



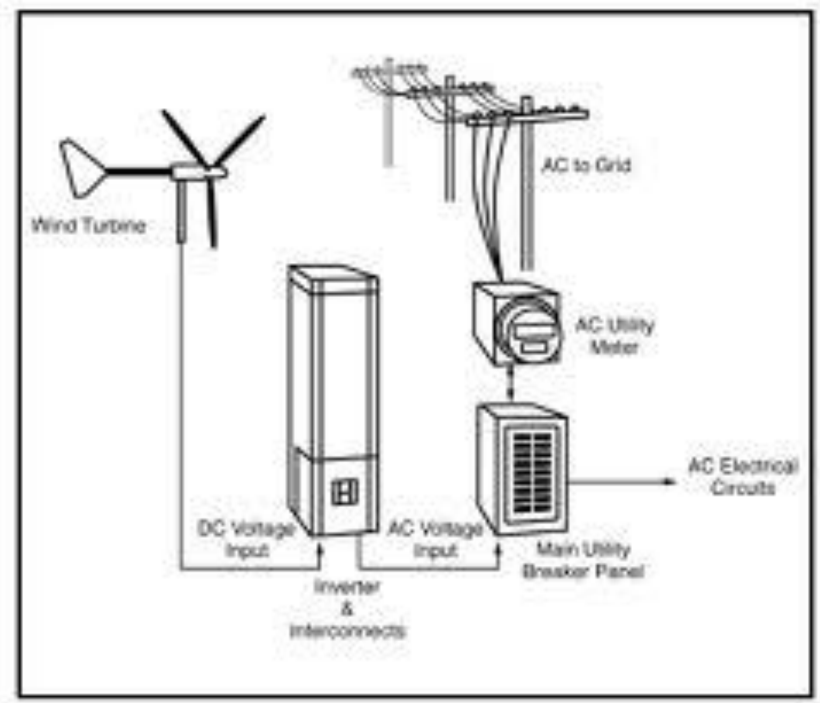




Sun rock dryer (covered black dye or asphalt)

Wind

- To produce electicity
- Using wind turbine



Selection of energy sources

- How can we select energy source?
  - Maintenance (coal needs more laboring, cleaning etc.)
  - Reparing
  - Calori value
  - Service life of heat converter machine
  - Economy (price, inflation etc.)
  - Availability
  - Constant price-constant supply
  - Waste and enviromental issue (coal ?)
  - Goverment policy and laws

Energy usage in the plant

- For lighting (electiricty)
- For motor power /Mechanical drive
- Process Heating
  - Conditioning (indoor) (heating area etc.)
  - Air heating
  - Water heating
  - Steam generation (small scale)
  - Superheated steam
  - Material processing (cooking, pasteurization, sterilization, heatin of material, roasting etc.)
- Cooling
  - Air
  - Water
  - Etc.
- Space heating

Electricity sources

- Energy Converter/Central
  - Natural gas central/converter
  - Coal central/converter
  - Water dam
  - Fuel/motorin central/convert

Electricity usage

- In city
  - 220 V, 50 mHz (in Turkey, Europe etc.)
  - 110 V, 60 mHz (in USA)
  - 1 phase
  - Power (P, Watt): V (voltage) * I (ampere)
  - Energy consumption (E, kWh)= P * t (time)

- In industry
  - 380 V , 50 mHz (in Turkey, Europe etc.)
  - 460 V, 60 mHz (in USA)
  - 3 phases
  - Power (P, Watt): V (voltage) * I (ampere) * √3 * Cos Ø
  - Energy consumption (E, kWh)= P * t (time)

Plug wires – colours

Live – brown

Neutral – blue

Earth – green/yellow

Fuse in live position

AC / DC Electricity

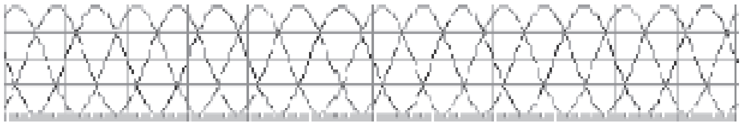
- AC has at least three advantages over DC in a power distribution grid:

1. Large electrical generators happen to generate AC naturally, so conversion to DC would involve an extra step.
2. Transformers must have alternating current to operate, and we will see that the power distribution grid depends on transformers.
3. It is easy to convert AC to DC but expensive to convert DC to AC, so if you were going to pick one or the other AC would be the better choice.

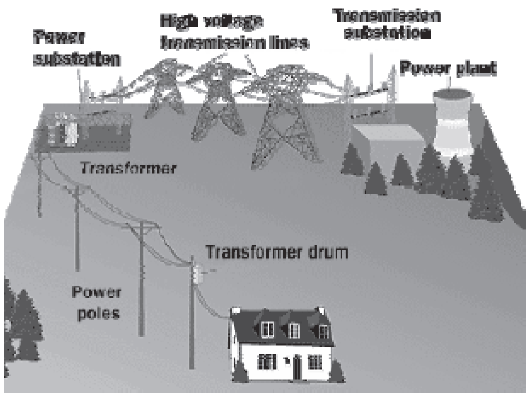
So, in general, in industry, AC motor is used. Why??

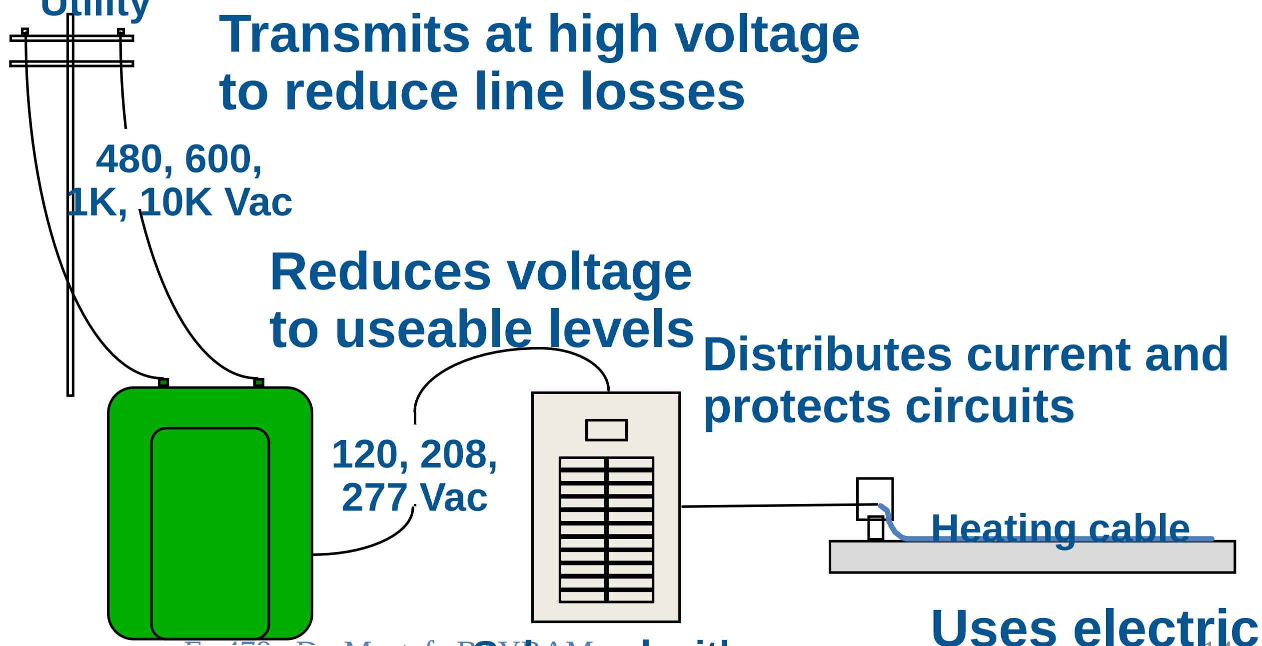
Three phases electricity

- three phases are **offset 120 degrees** from each other
- There are four wires coming out of every power plant: the **three phases** plus a neutral or **ground**



How Power Distribution Grids Work





Decision and calculation (!!!):

Energy/calori examination table: (Source: www.dc ider.org)

PRICE OF 1000 kcal OBTAINED FROM DIFFERENT SOURCE

(Date: Feb. 2012, without VAT (Value added tax))

Energy source	Supplier (Company)	Lowest heat value (Yakıt Alt Isıl Değeri)	Unit price	Average processing yield	Price (TL/1000 kcal)		Index (based on the lowest source)	Unit price one year ago Tarihindeki Birim Fiyatları	For one year period: The change in the price during one year	For one year period: Order for the annual increase in unit price
Doğalgaz Sanayi **Serbest tüketici için**	Kocaeli **İZGAZ GDF SUEZ**	8250 kcal/m³	**0.595727** TL/m³	93%	$\frac{0,595727 \times 1000}{8250 \times 0,93}$	**0.077644**	**106**	0.521070 TL/m³	**14.3%**	**5**
Doğalgaz Sanayi **Serbest tüketici** **300-800 bin m³/yıl**	Ankara **BAŞKENTGAZ**	8250 kcal/m³	**0.668879** TL/m³	93%	$\frac{0,668879 \times 1000}{8250 \times 0,93}$	**0.087179**	**119**	0.506251 TL/m³	**32.1%**	**13**
Doğalgaz Sanayi **Serbest tüketici** **300-800 bin m³/yıl**	İstanbul **İGDAŞ**	8250 kcal/m³	**0.676256** TL/m³	93%	$\frac{0,676256 \times 1000}{8250 \times 0,93}$	**0.088140**	**120**	0.592484 TL/m³	**14.1%**	**4**
Yerli Linyit 10-18 mm Yıkanmış Fındık - Torba	Soma Kısrakdere Manisa - **ELİ**	4904 kcal/kg	**0.335000** TL/kg	65%	$\frac{0,335000 \times 1000}{4.904 \times 0.65}$	**0.105095**	**143**	0.272000 TL/kg	**23.2%**	**11**
İthal Sibirya Kömürü **Ceviz/Fındık tipi**	İstanbul **HAKAN KÖMÜR**	7000 kcal/kg	**0.593220** TL/kg	65%	$\frac{0,593220 \times 1000}{7.000 \times 0.65}$	**0.130378**	**178**	0.474576 TL/kg	**25.0%**	**12**
LNG - Büyük Sanayi Sıvılaştırılmış Doğalgaz	İstanbul **İPRAGAZ**	8250 kcal/m³	**1.244429** TL/m³	93%	$\frac{1,244429 \times 1000}{8250 \times 0,93}$	**0.162193**	**221**	0.811767 TL/m³	**53.3%**	**16**
LNG - Orta Sanayi Sıvılaştırılmış Doğalgaz	İstanbul **İPRAGAZ**	8250 kcal/m³	**1.310927** TL/m³	93%	$\frac{1,310927 \times 1000}{8250 \times 0,93}$	**0.170860**	**233**	0.870450 TL/m³	**50.6%**	**15**
Fuel-oil No: 6 Kalorifer Yakıtı	İstanbul Avrupa Yakası **SHELL TÜRKİYE**	9562 kcal/kg	**1.881356** TL/kg	80%	$\frac{1,881356 \times 1000}{9,562 \times 0,80}$	**0.245942**	**336**	1.406780 TL/kg	**33.7%**	**14**
Elektrik Sanayi	Türkiye **TEDAŞ**	860 kcal/kwh	**0.229023** TL/kWh	99%	$\frac{0,229023 \times 1000}{860 \times 0,99}$	**0.268995**	**367**	0.206957 TL/kWh	**10.7%**	**2**
Dökmegaz LPG - **Miks Büyük** Sanayi	İstanbul **İPRAGAZ - AYGAZ**	11000 kcal/kg	**3.536364** TL/kg	92%	$\frac{3,536364 \times 1000}{11,000 \times 0,92}$	**0.349443**	**477**	3.088636 TL/kg	**14.5%**	**6**
Dökmegaz LPG - **Miks Sanayi**	İstanbul **İPRAGAZ - AYGAZ**	11000 kcal/kg	**3.890000** TL/kg	92%	$\frac{3,890000 \times 1000}{11,000 \times 0,92}$	**0.384387**	**524**	3.397500 TL/kg	**14.5%**	**6**
Dökmegaz LPG - **Propan Sanayi**	İstanbul **İPRAGAZ - AYGAZ**	11100 kcal/kg	**3.981690** TL/kg	92%	$\frac{3,981690 \times 1000}{11,100 \times 0,92}$	**0.389903**	**532**	3.685235 TL/kg	**8.0%**	**1**
Motorin (VP Diesel)	İstanbul Avrupa Yakası **SHELL TÜRKİYE**	10256 kcal/kg	**3.881256** TL/kg	84%	$\frac{3,881256 \times 1000}{10,256 \times 0,84}$	**0.450521**	**615**	3.219336 TL/kg	**20.6%**	**10**
LPG 45 kg	İstanbul	11000			[illegible]					

Natural gas (pipeline in Turkey)

Availabity of Natural gas in Cities

CONVERSION OF ENERGY

- For
  - Air heating
  - Water heating
  - Steam
  - Etc.

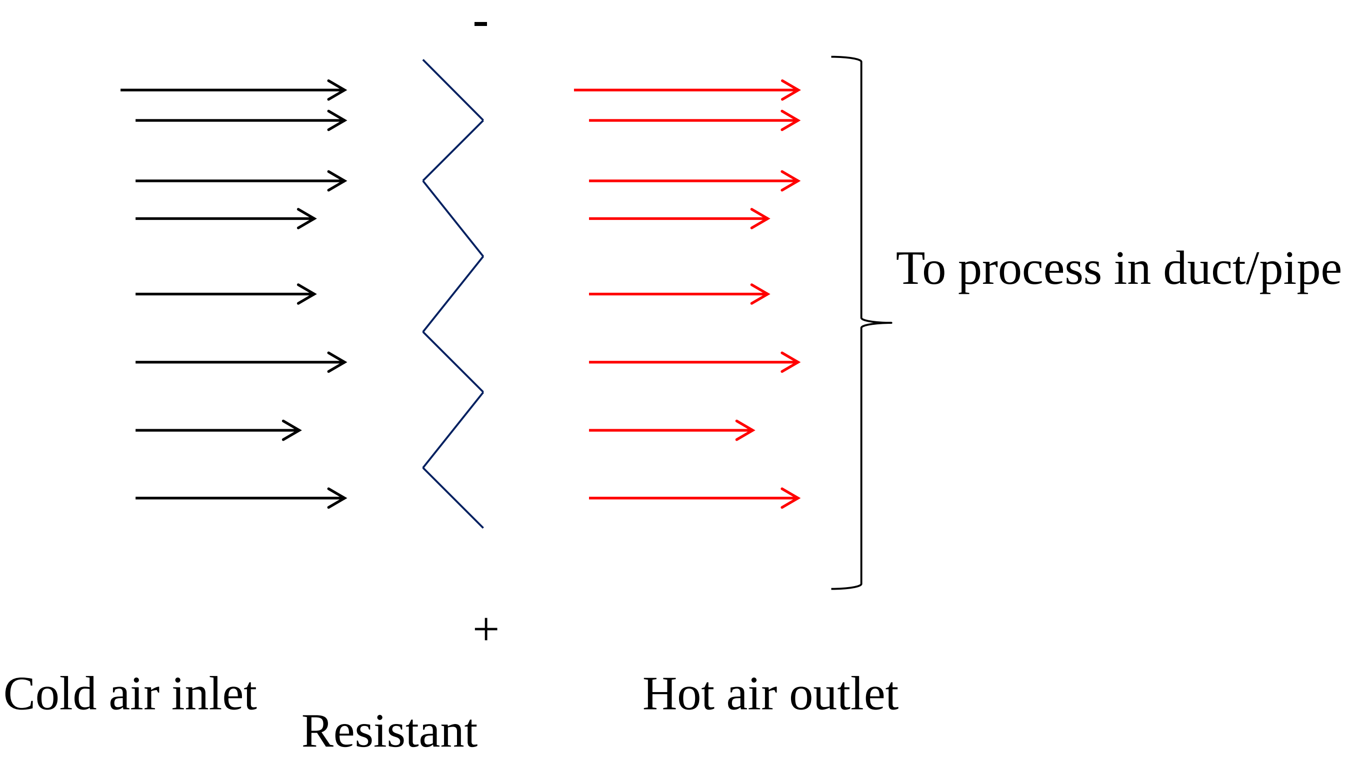
HEATING IN THE PLANT

Direct heating

Indirect heating

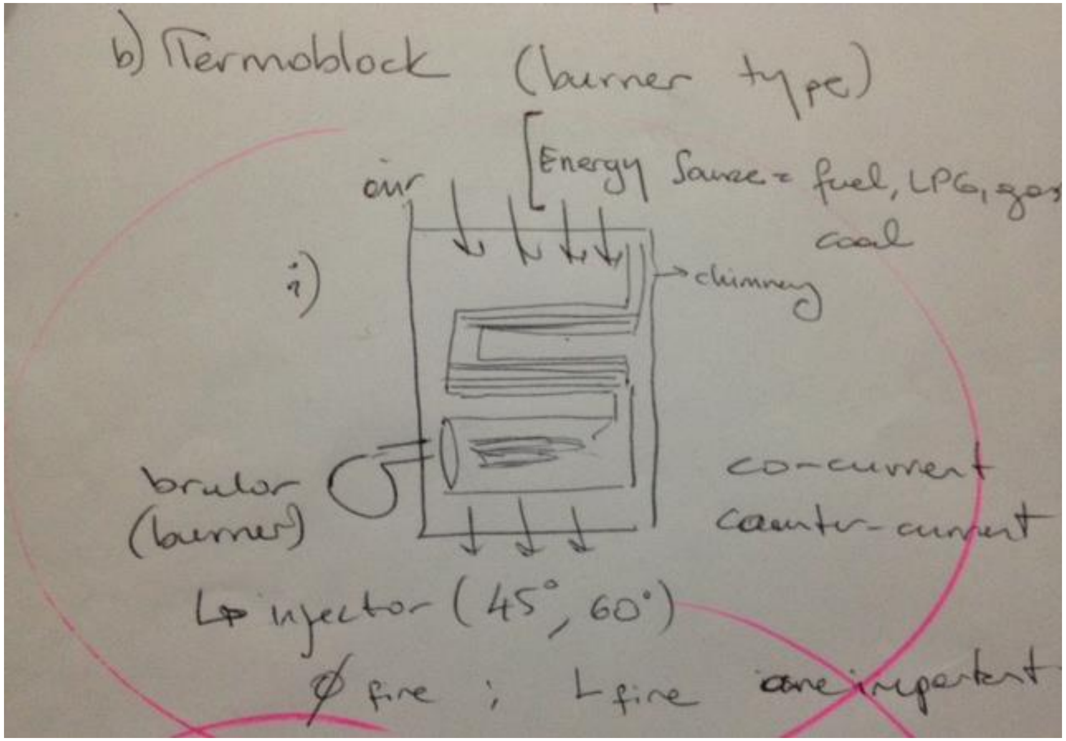
1- Direct air heating

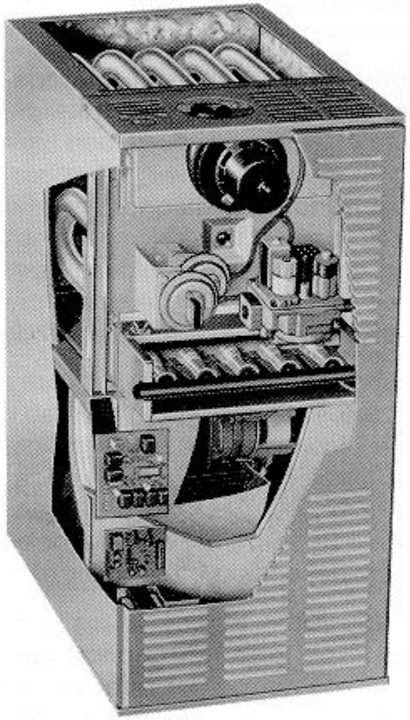
- A) Electricity (by using electrical resistance)



B-Thermoblock (burner type)

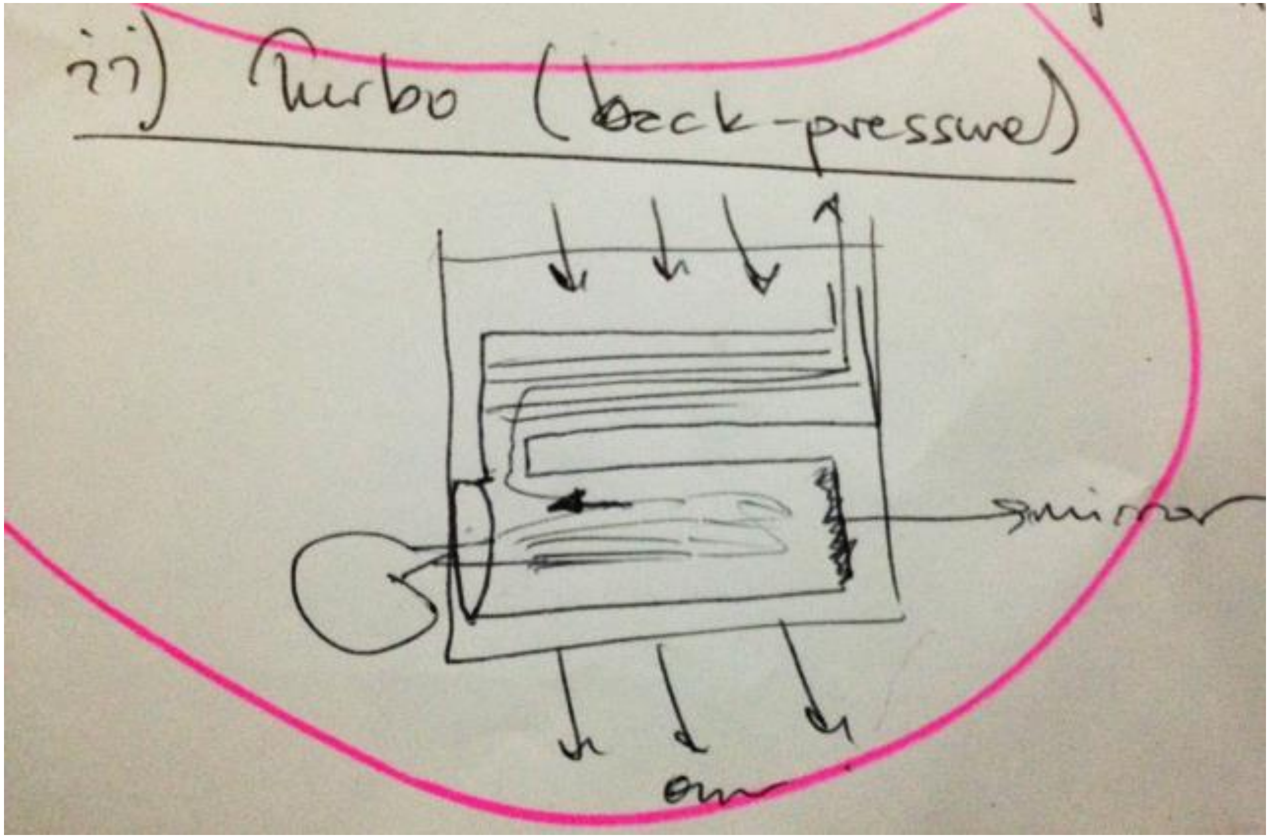
i-Ordinary thermoblock



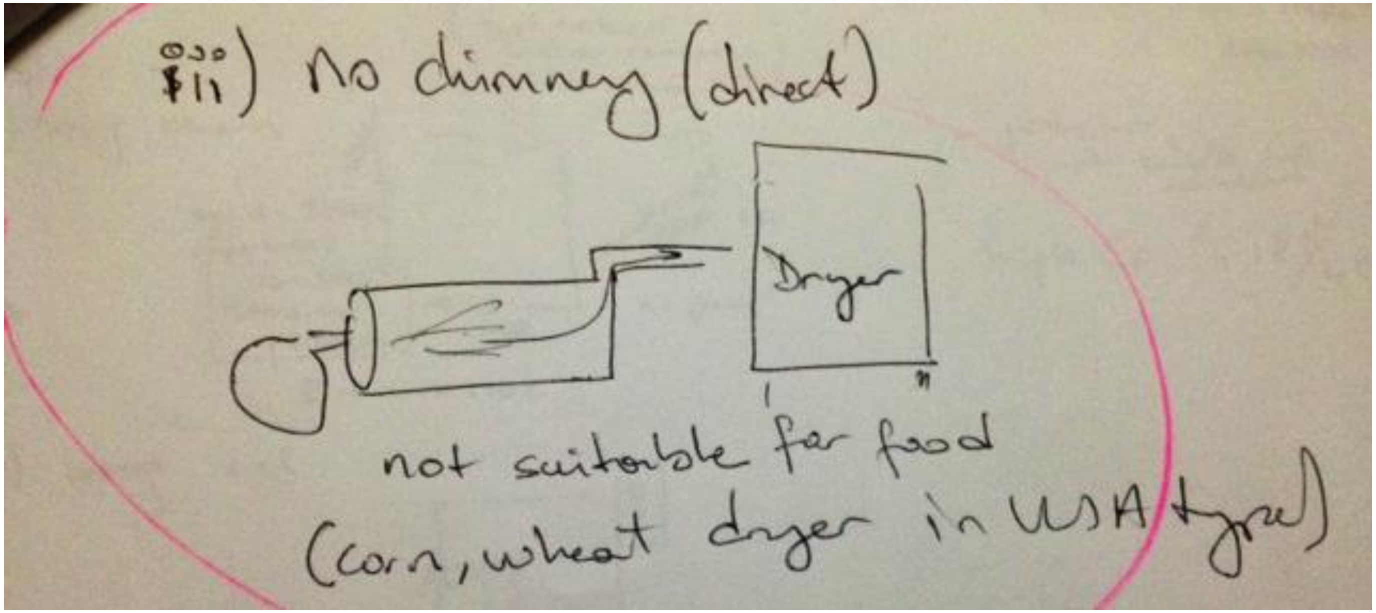


UP-FLO POSITION

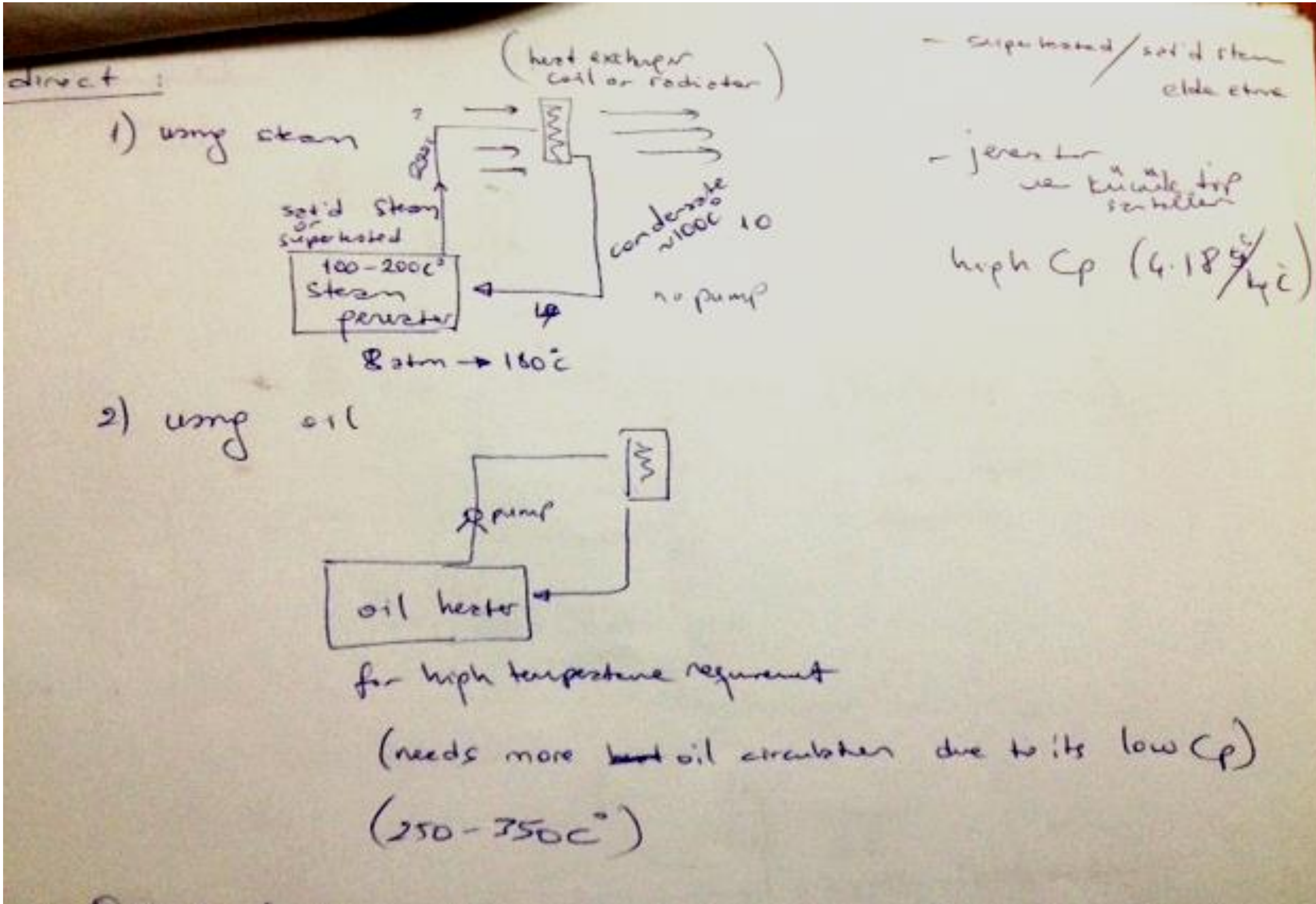
ii-Turbo type thermoblock (back-pressure)



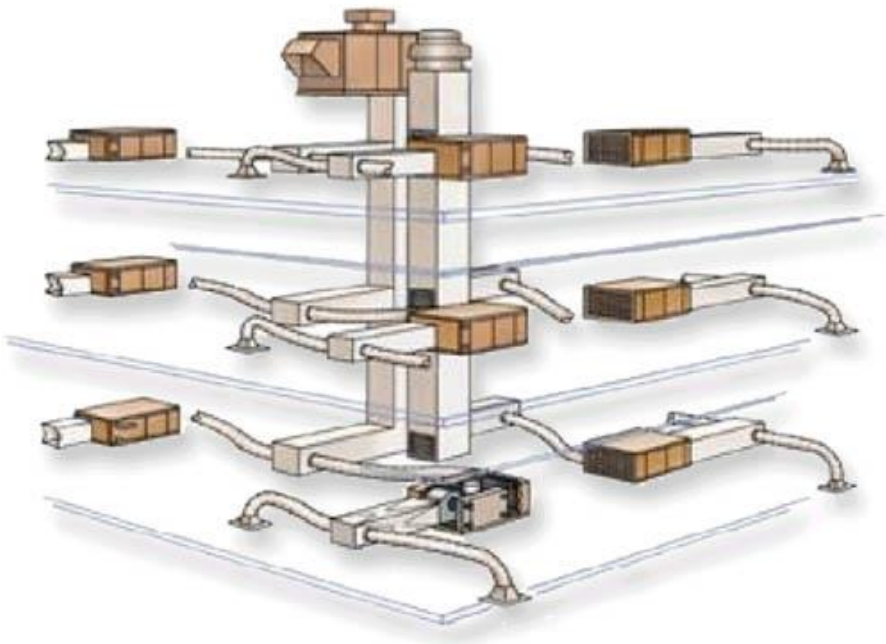
iii-Turbo type thermoblock (back-pressure)/ No Chimney

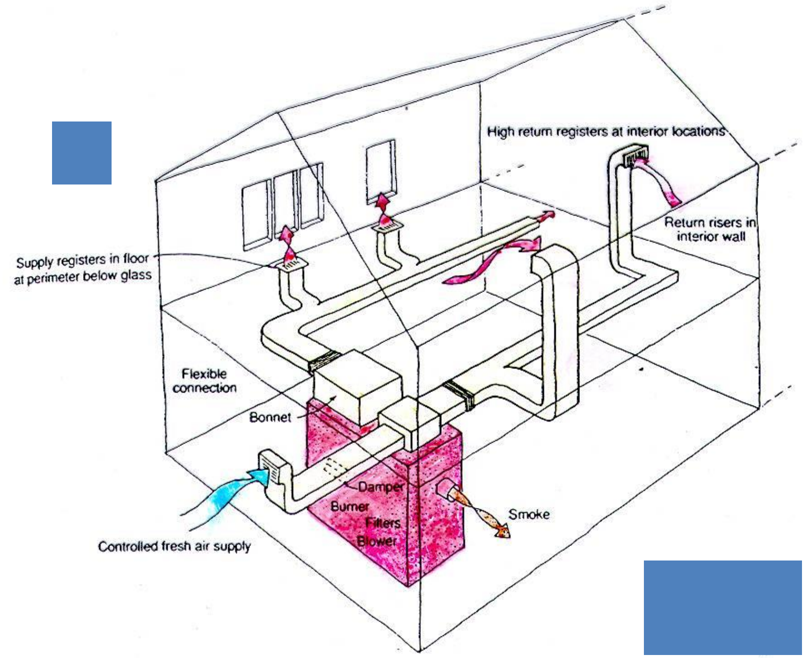


Indirect air heating



Circulating Air Systems



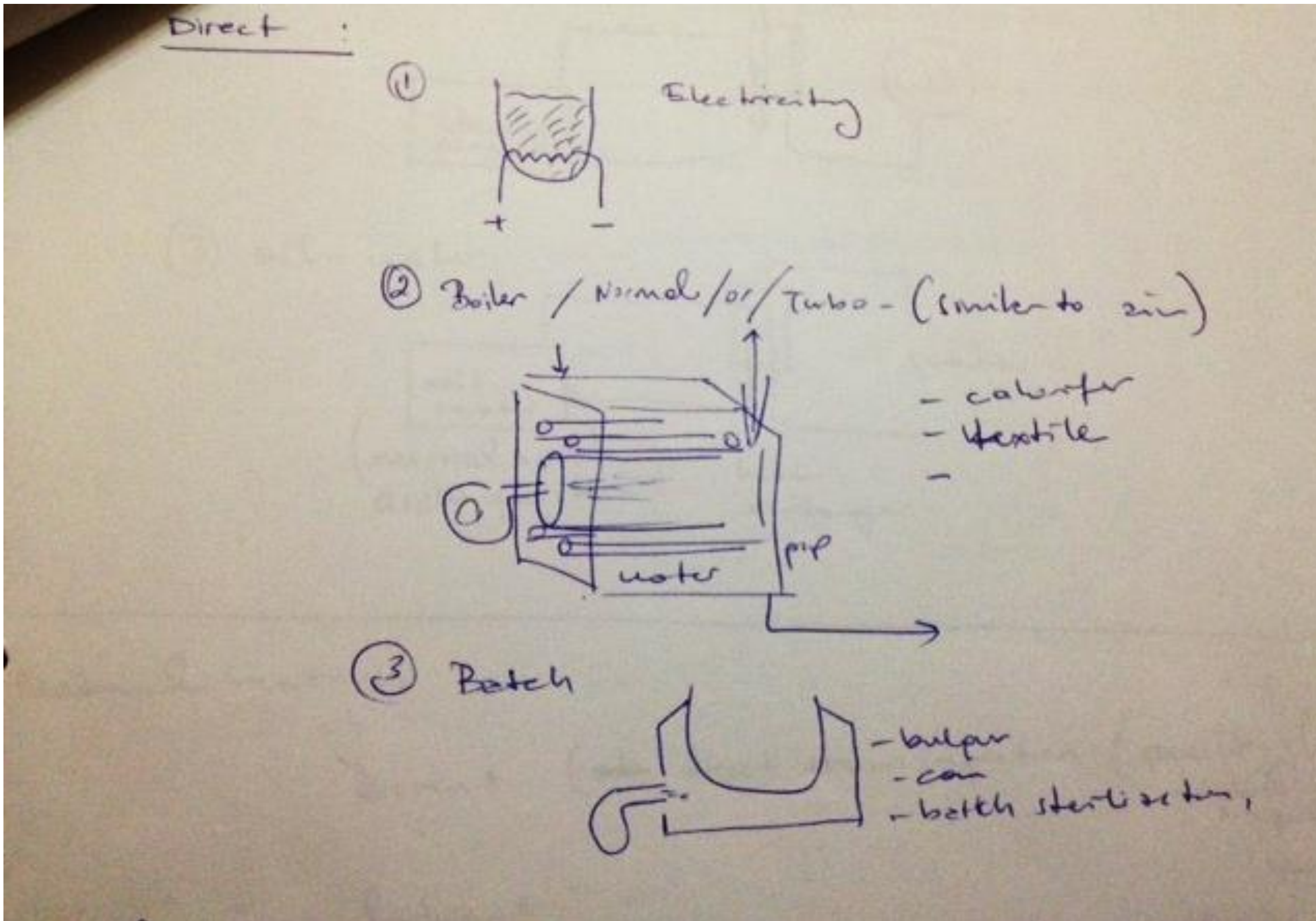


- Heat distributed by an air stream through a heating unit to supply ducts
- duct< 200’

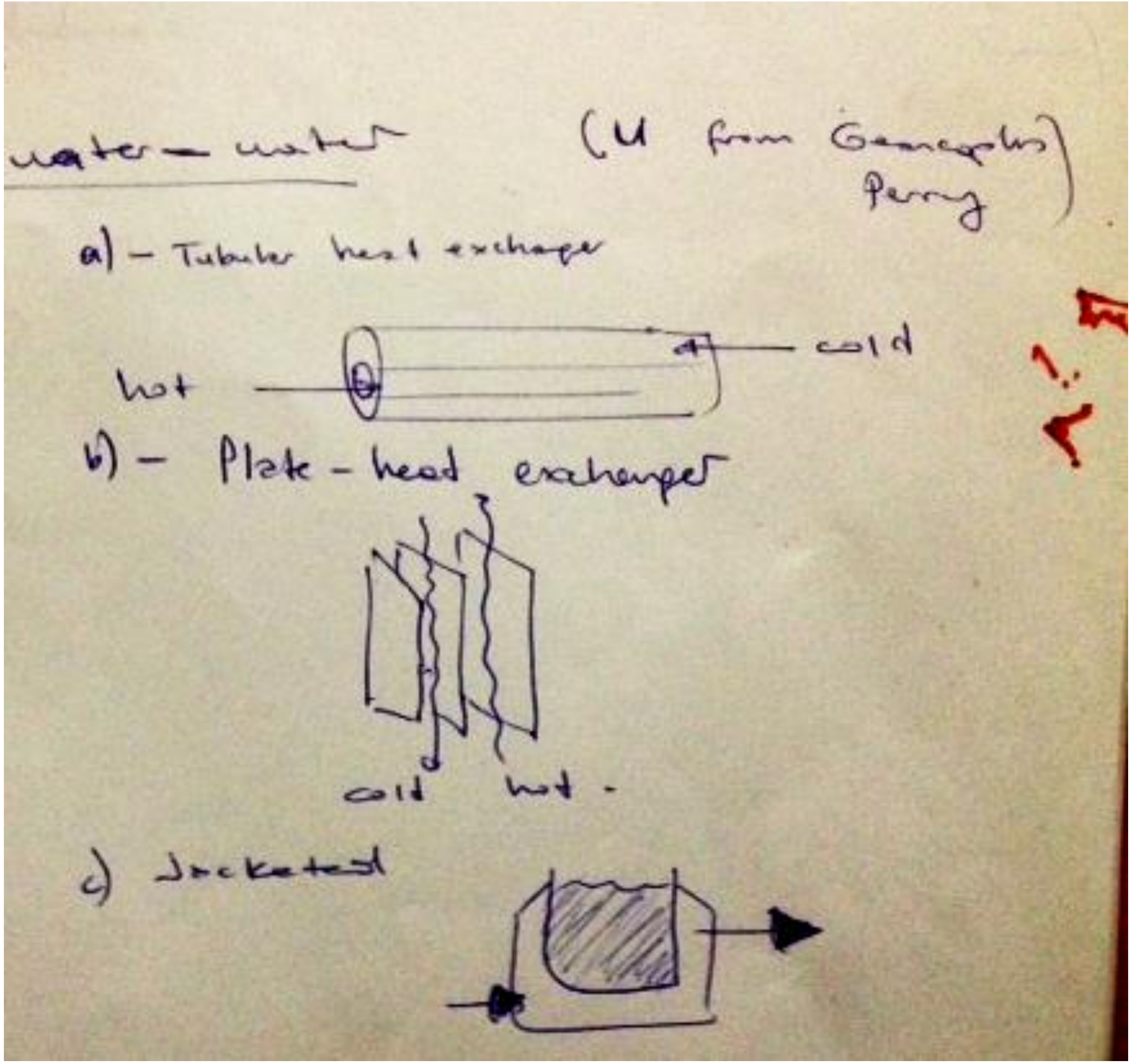
2- WATER HEATING

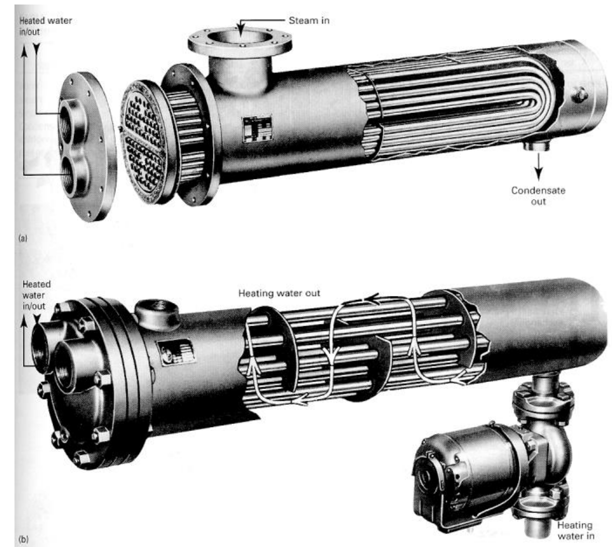
Direct and indirect

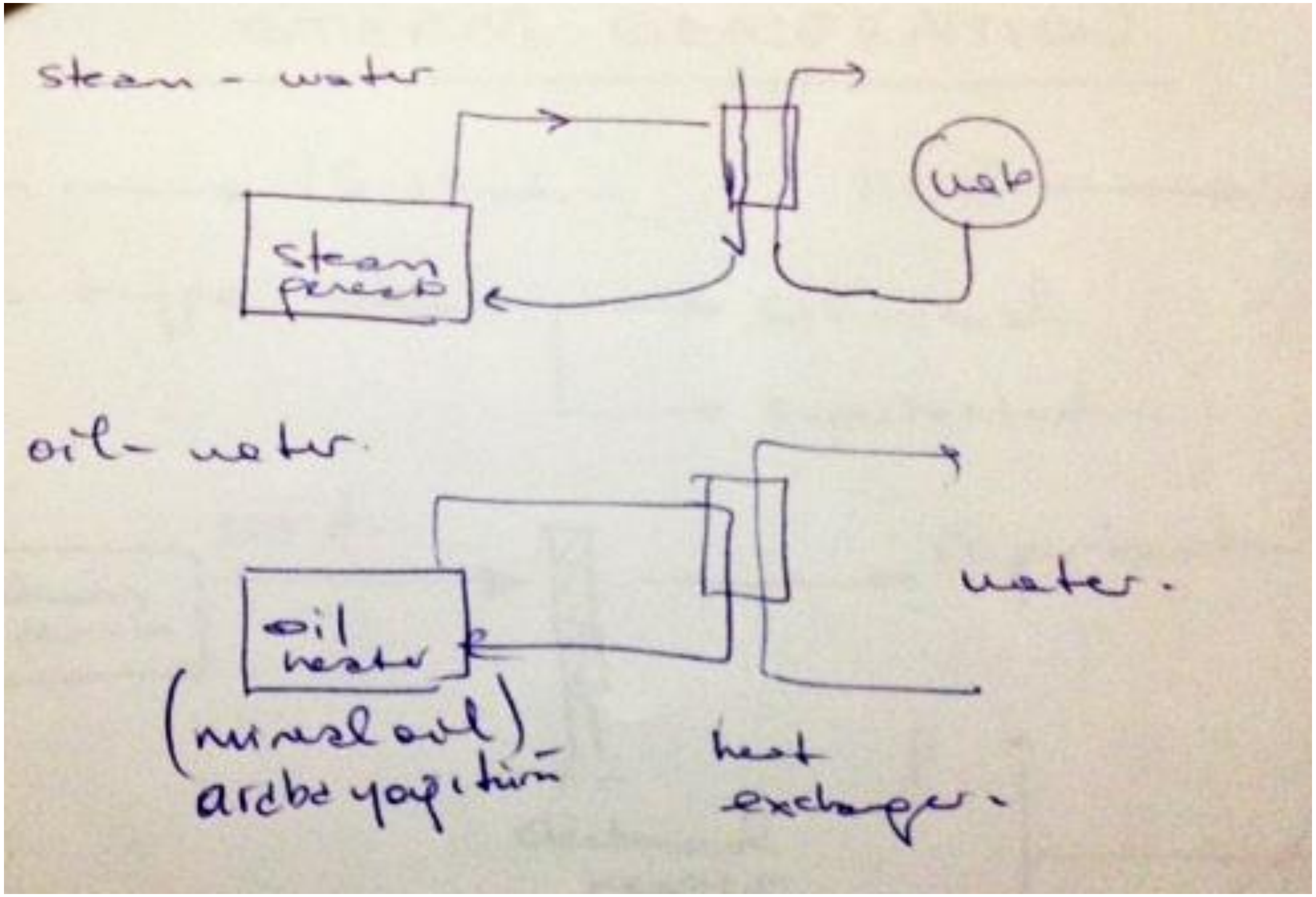
1. Direct

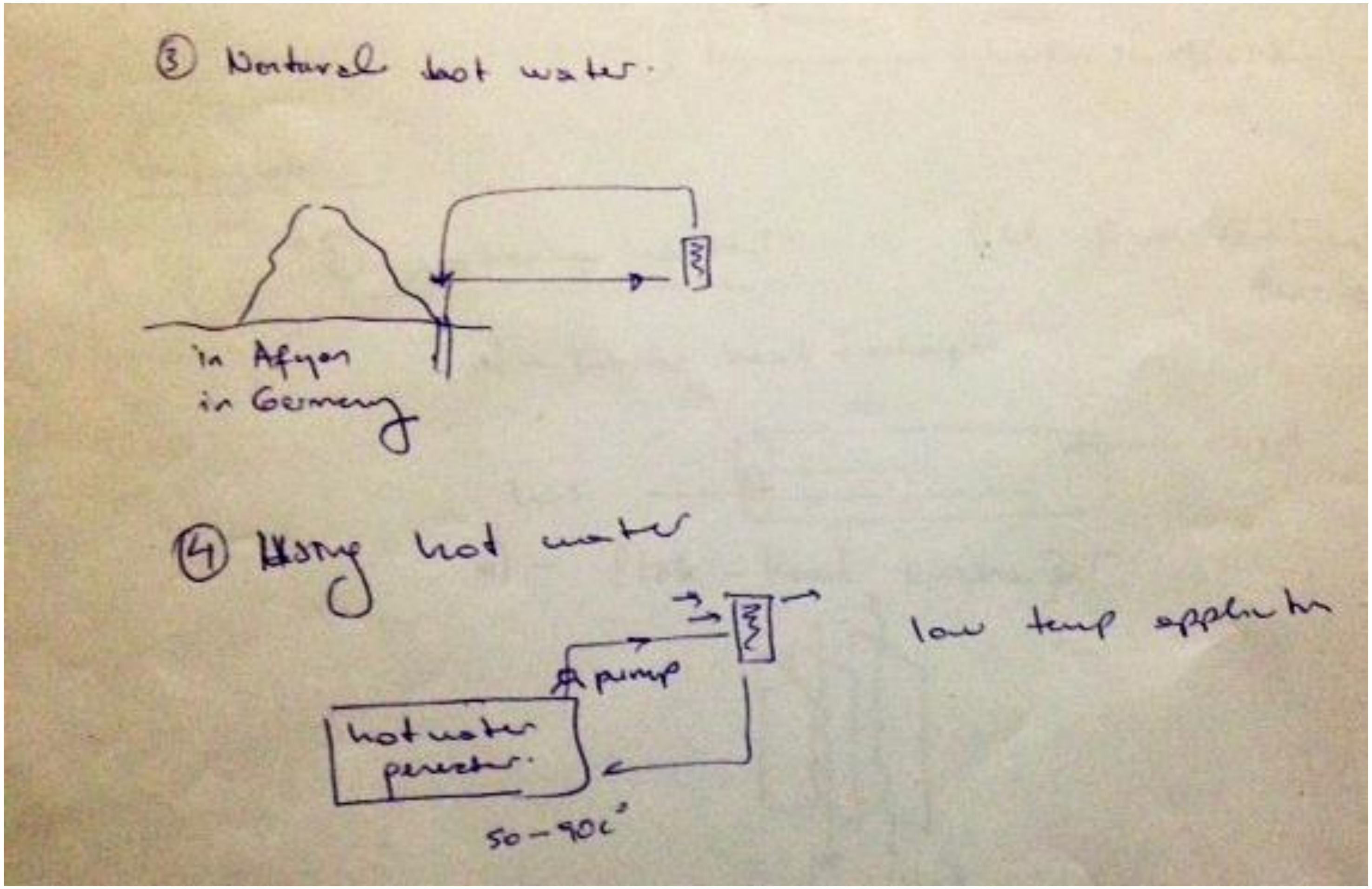


2.Indirect


water – water
(U from Geankoplis
Perry)
a) – Tubular heat exchanger
hot
cold
b) – Plate – head exchanger
cold
hot.
c) Jacketed


Heated water in/out
Steam in
Condensate out
(a)
Heated water in/out
Heating water out
Heating water in
(b)


steam - water
oil- water
oil heater
water.
heat exchanger.


③ Natural hot water.
in Afyon
in Germany
④ Using hot water
pump
hot water generator.
50–90C°
low temp

INDUSTRIAL STEAM GENERATION

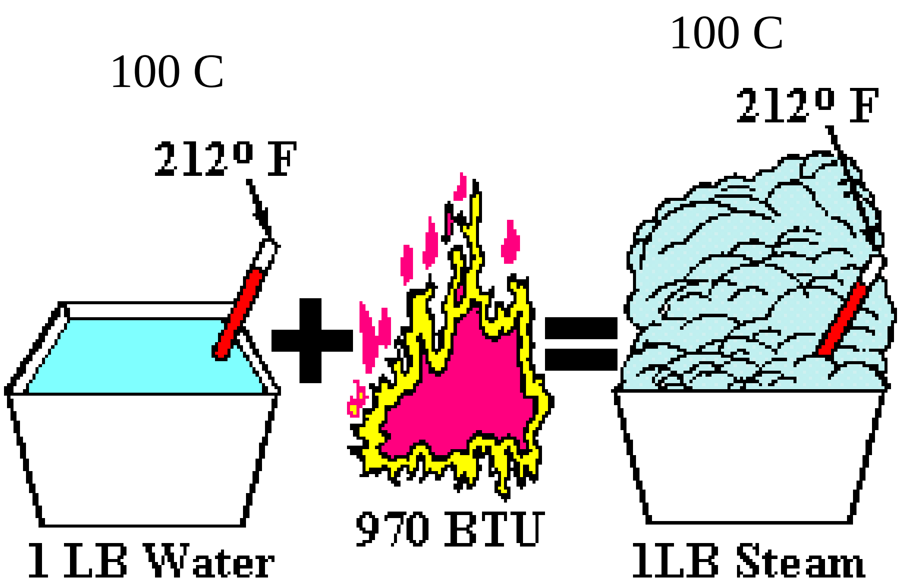
Sensible and Latent Heat

- **Sensible heat** causes a change in temperature
- **Latent heat** causes a change of state but no change in temperature

Calculation hints

- Use Lower Heating Value (LHV) for energy source
  - The quantity known as lower heating value (**LHV**) (*net calorific value* (**NCV**) or *lower calorific value* (**LCV**)) is determined by subtracting the heat of vaporization of the water vapor from the higher heating value. This treats any H_2O formed as a vapor. The energy required to vaporize the water therefore is not released as heat.
  - LHV calculations assume that the water component of a combustion process is in vapor state at the end of combustion, as opposed to the higher heating value (HHV) (a.k.a. *gross calorific value* or *gross CV*) which assumes that all of the water in a combustion process is in a liquid state after a combustion process.
  - The LHV assumes that the latent heat of vaporization of water in the fuel and the reaction products is not recovered. It is useful in comparing fuels where condensation of the combustion products is impractical, or heat at a temperature below 150°C cannot be put to use.
  - Higher heating value (**HHV**) (or *gross energy* or *upper heating value* or *gross calorific value* (**GCV**) or *higher calorific value* (**HCV**)) is determined by bringing all the products of combustion back to the original pre-combustion temperature, and in particular condensing any vapor produced. Such measurements often use a standard temperature of 25°C. This is the same as the thermodynamic heat of combustion since the enthalpy change for the reaction assumes a common temperature of the compounds before and after combustion, in which case the water produced by combustion is liquid.

Latent Heat of Evaporation



- **Evaporator**: liquid changing to gas
- **Condenser**: gas changing to liquid

- It takes 180 Btu's to raise the temperature of 1 lb. of water from 32 deg. to 212 deg. (100 C).
- It takes 970 Btu's to boil or vaporize 1 lb. of water at 212 deg. (100 C).

Training Agenda: Steam

Introduction

Steam distribution system

Assessment of steam distribution system

Energy efficiency opportunities

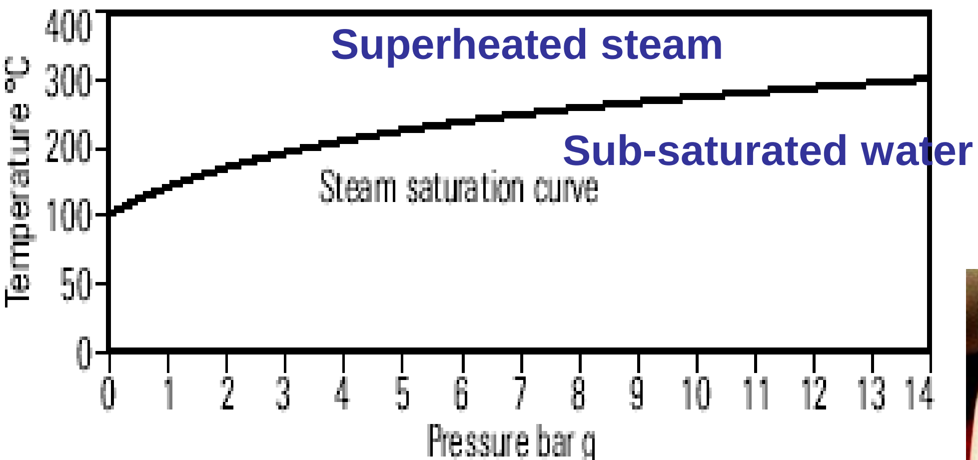
Introduction

What is steam – Dryness fraction

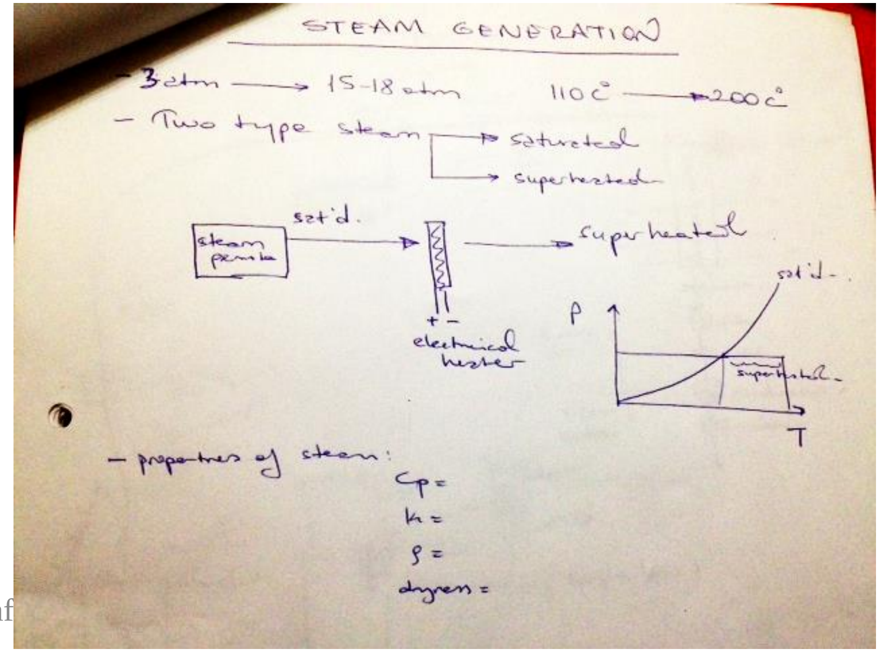
- Dry saturated steam: T = boiling point
- Steam: mixture of water droplets and steam
- Dryness fraction (*x*) is 0.95 if water content of steam = 5%
- Actual enthalpy of evaporation = dryness fraction X specific enthalpy h_{fg}

Introduction

Saturated and super heated steam



- After obtaining saturated steam (in general it is used in all heating operation in food industry), saturated steam is heated with electirical resistant or hot oil or hot surface to obtain superheated steam (it is used for deodorization etc.)



Introduction

Steam quality

Steam should be available

- In correct quantity
- At correct temperature
- Free from air and incondensable gases
- Clean (no scale / dirt)
- Dry

Classes of Steam

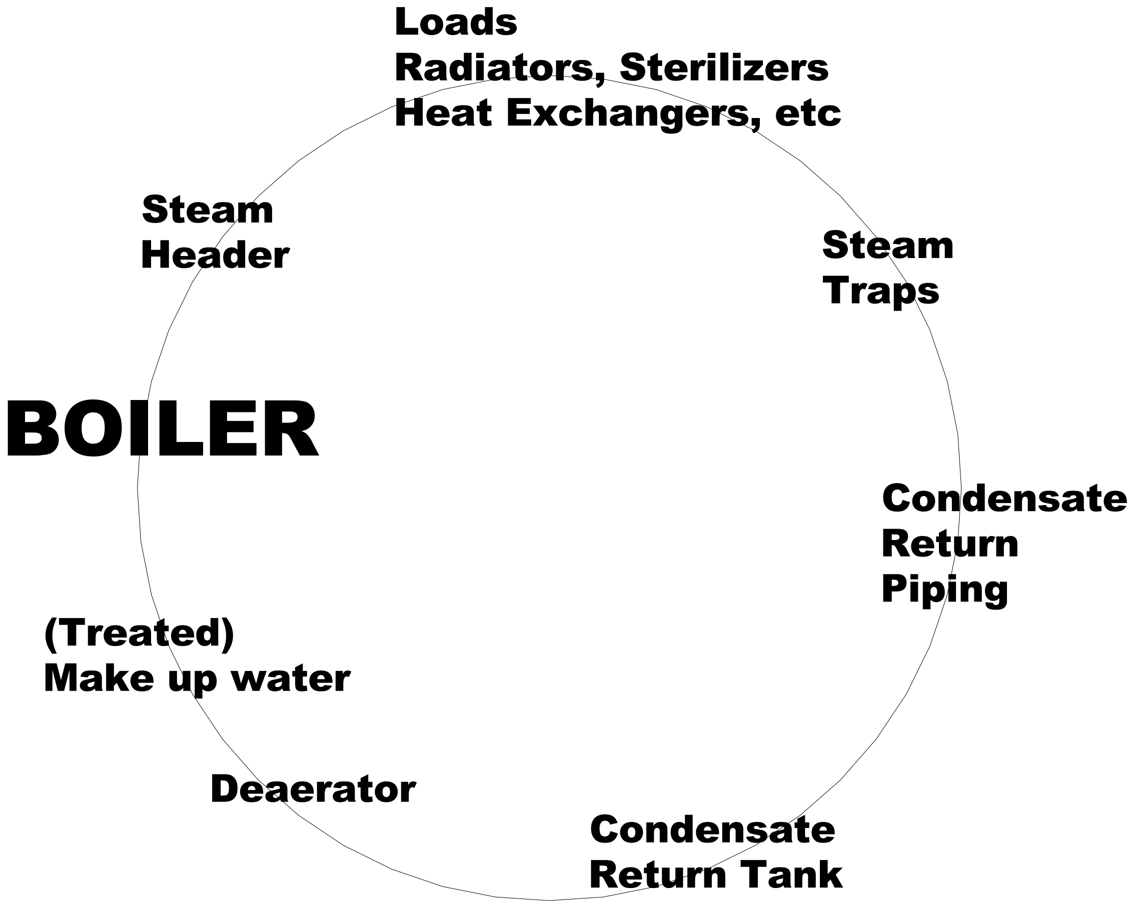
- Low Pressure Heating Steam – 15 psig
  - Used Mainly for Space Heating Systems and Single Effect Absorption Chillers
  - Actual Code is More Restrictive
- Medium Pressure Steam: 15-150 psig
  - Used in Hospitals, District Steam Systems, Some Industrial Heating
- High Pressure: Above 150 psig
  - Strictly Industrial and Power Generating Applications

- Each Class has Piping and Valve Requirements
  - Increase in Expense with Each Higher Class

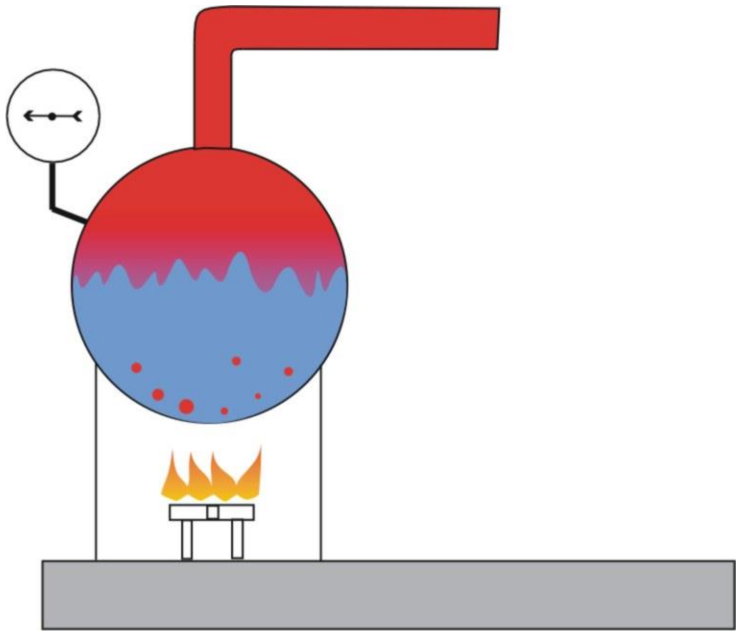
Steam System Operation

- Generation
- Distribution
- End Use (equipment)
- Condensate Recovery & Feed Water Systems

Steam Circle System



Generation

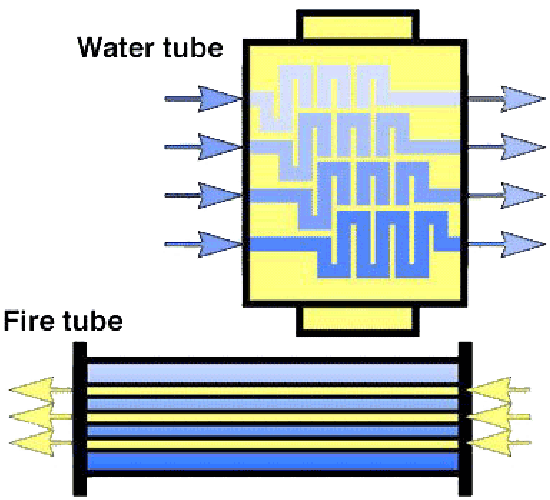


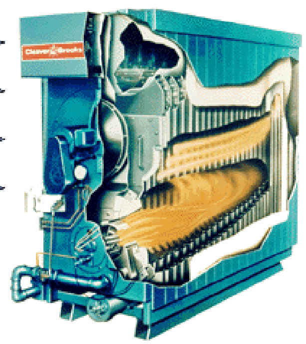
Typical Boiler

- Boilers
  - Fire-tube or water-tube

- Heat recovery generators
  - Turbine exhaust
  - Furnace exhaust

Generation (2 types)

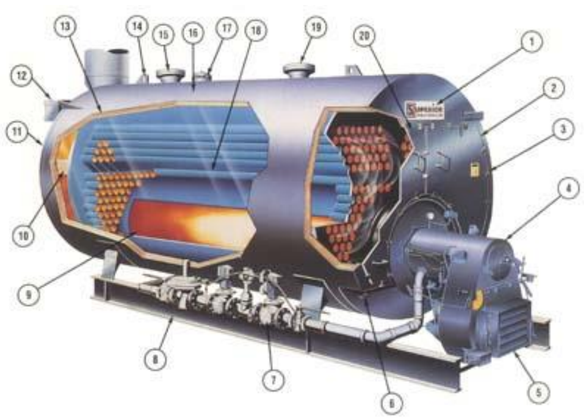




- Water tube
  - fuel burned within combustion chamber
  - combustion gas surrounds water tubes within vessel

- Fire tube
  - fuel burned in combustion chamber
  - combustion gases flow through tubes
  - water surrounds tubes

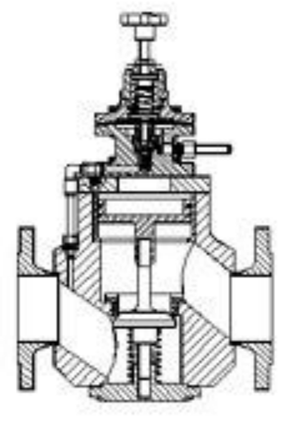
  - Scotch Marine – most popular

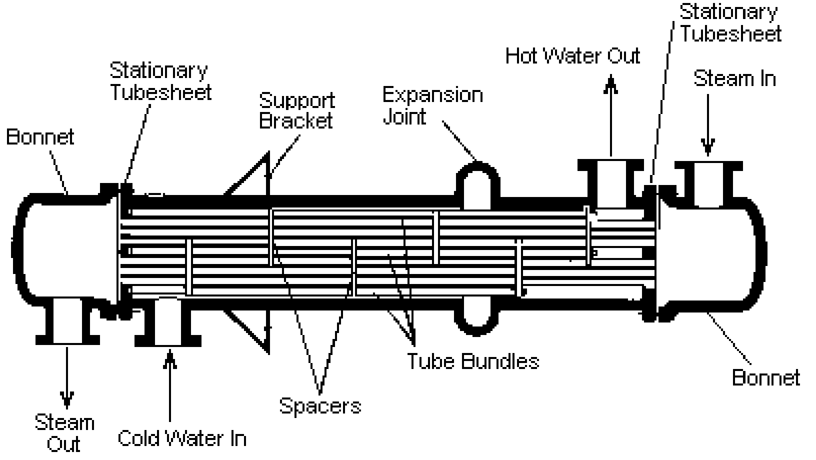


Fire tube

Distribution & End Users

- Distribution Systems
  - Distribution lines
  - Pressure reduction
    - Pressure reduction valve
    - Backpressure turbine





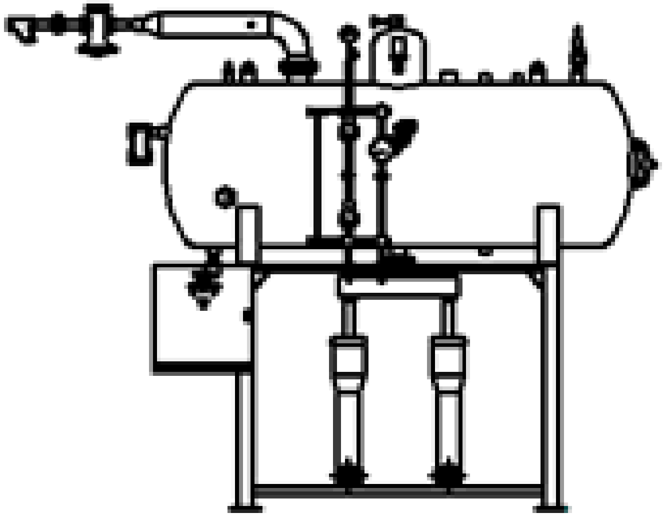
End Use Components

- Heat exchangers
- Mechanical drives
- Steam sparging/injection equipment

Recovery & Feed Water

- Condensate Recovery System
  - Steam traps
  - Collection tanks
  - Flash steam recovery
  - Pumps

- Feed Water System
  - Deaerator
  - Economizer



BOILER EFFICIENCY

HEAT LOSS METHOD

BOILER EFFICIENCY = 100 - % AGE LOSSES

1. **Heat Loss in Dry flue gas**
   a. $H_g = \frac{0.24\, w_g\, (T_g - T_a)}{G.C.V}$ as percentage of heat input

   a. $H_g = \frac{K\,(T_g - T_a)\,/1.8}{\%\, CO_2 \text{ in flue gas}}$ K=0.32 for fuel oil, K=0.35 for Bituminous coal

2. **Heat loss due to evaporation of moisture & H_2 in fuel**

   $H_m = \frac{W_m + 9H\,(100 - T_f) + 540 - 4.6\,(T_g - 100)}{G.C.V}$ %of heat input

3. **Heat loss due to moisture in air**

   $H_a = \frac{0.26\, W_{ma}\,(T_g - T_a)}{G.C.V}$ % of heat input

4. **Heat loss due to Incomplete combustion to Co**

   $H_{co} = 2414\, C \times \frac{CO}{CO + CO_2} \times \frac{1}{G.C.V}$ as % of heat input

5. **Heat loss due to unburnt carbon "C"**

   $H_c = \frac{W_c \times 7831}{G.C.V}$ as % of heat input

6. Heat loss due to Blow Down

$$H_{bd} = \frac{W_b\,(h_{bw} - h_w)}{G.C.V} \quad \text{as \% of heat input}$$

7. Heat loss due to Radiation

HR = Difficult to evaluate & thus take design values only

<u>In above</u>

W_g =Wt of dry flue gas

W..G = $\frac{[44.01 * CO2 + 32*O2\ 28.02 * N2 + 28.01*CO]*[Cb + 12.01 * S/32.07]}{12.01 * (CO2 + CO)}$

T_g = Tempt. Of flue gas at exit of Boiler

T_a = Tempt. Of air at inlet (ambient)

T_f = Tempt. Of fuel inlet

h_{bw}-h_w = Heat in blow down

W_m = Weight of moisture

W_{ma} = Wt of waterin Kg/Kg of air X Wt of air in Kg supplied / Kg of fuel

W_c = Weight of unburnt "C"

W_b = Wt of water blow down

All wts are / kg of fuel

Training Agenda: Steam

Introduction

Steam distribution system

Assessment of steam distribution system

Energy efficiency opportunities

Steam Distribution System

Most important components

1. Pipes
2. Drain points
3. Branch lines
4. Strainers
5. Filters
6. Separators
7. **Steam traps**
8. **Air vents**
9. **Condensate recovery system**
10. **Insulation**

Steam Distribution System

1. Pipes

- Pipe material: carbon steel or copper
- Correct pipeline sizing is important
- Oversized pipework:
  - Higher material and installation costs
  - Increased condensate formation
- Undersized pipework:
  - Lower pressure at point of use
  - Risk of steam starvation
  - Risk of erosion, water hammer and noise
- Size calculation: pressure drop or velocity

Velocity of steam in pipe

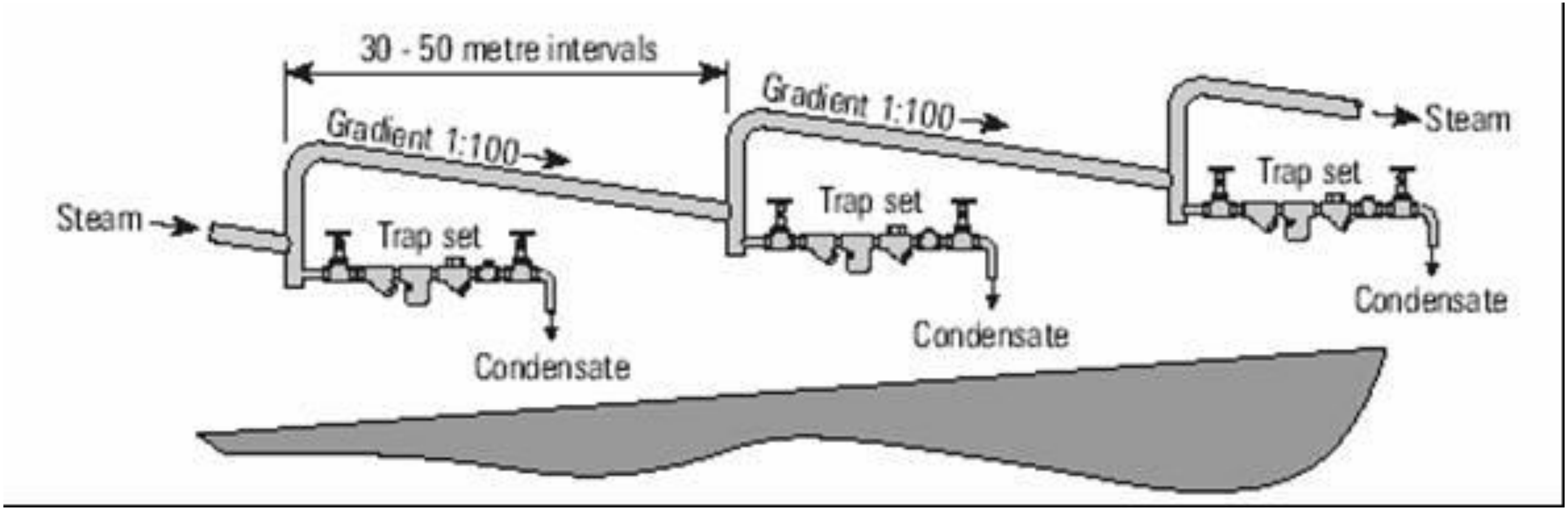
TABLE 2.10-3. *Representative Ranges of Velocities in Steel Pipes*

Type of Fluid	*Type of Flow*	*Velocity*	
		ft/s	*m/s*
Nonviscous liquid	Inlet to pump	2–3	0.6–0.9
	Process line or pump discharge	5–8	1.5–2.5
Viscous liquid	Inlet to pump	0.2–0.8	0.06–0.25
	Process line or pump discharge	0.5–2	0.15–0.6
Gas		30–120	9–36
Steam		30–75	9–23

Steam Distribution System

1. Pipes

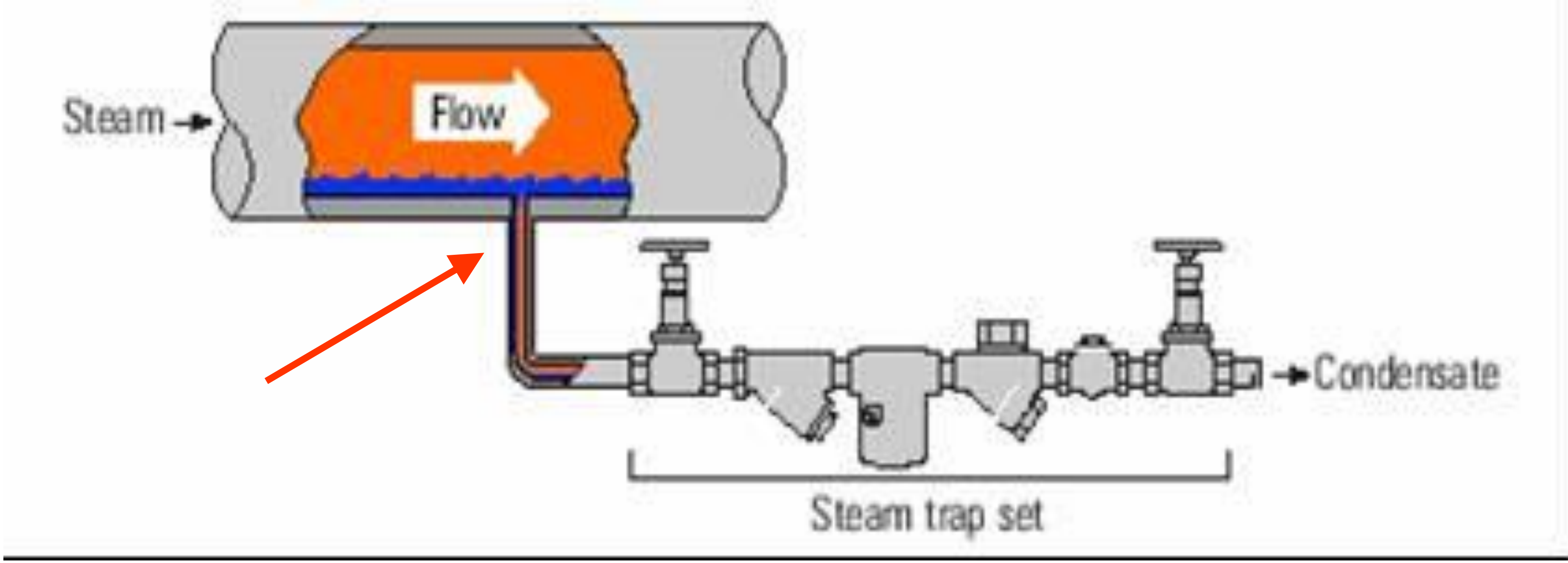
- Pipeline layout: 1 m fall for every 100 m
- Apply 5 degree angle for piping to remove/sliding condense



(Spirax Sarco)

Steam Distribution System

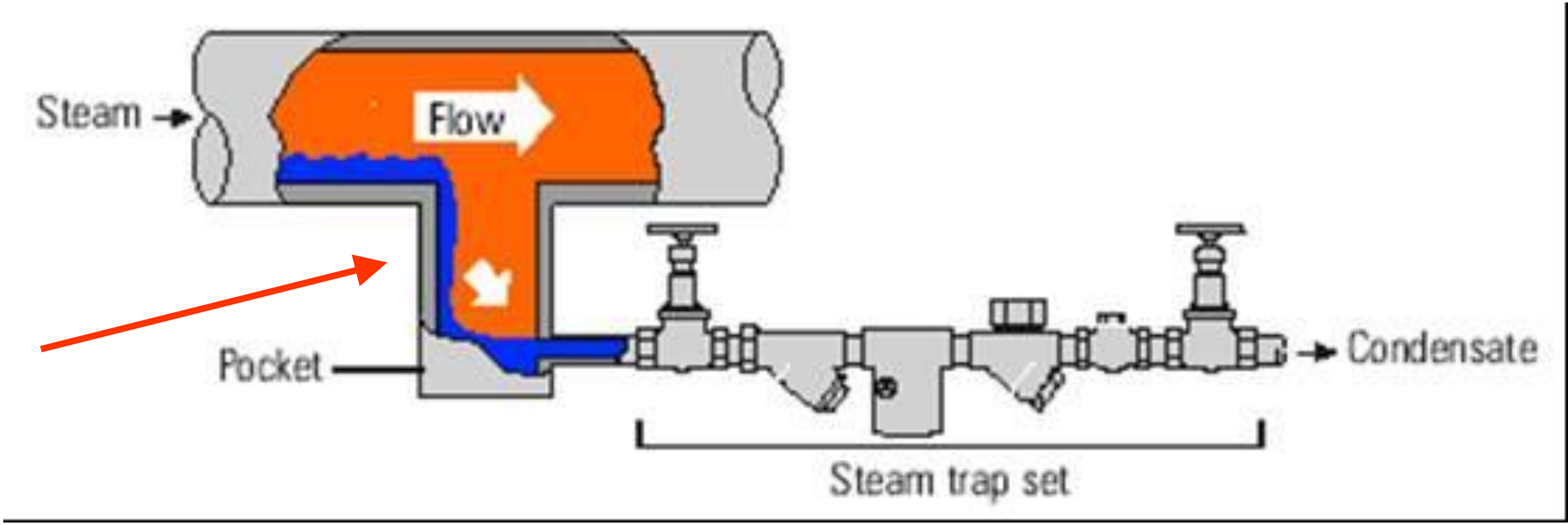
2. Drain points



Trap Pocket too small (Spirax Sarco)

Steam Distribution System

2. Drain points

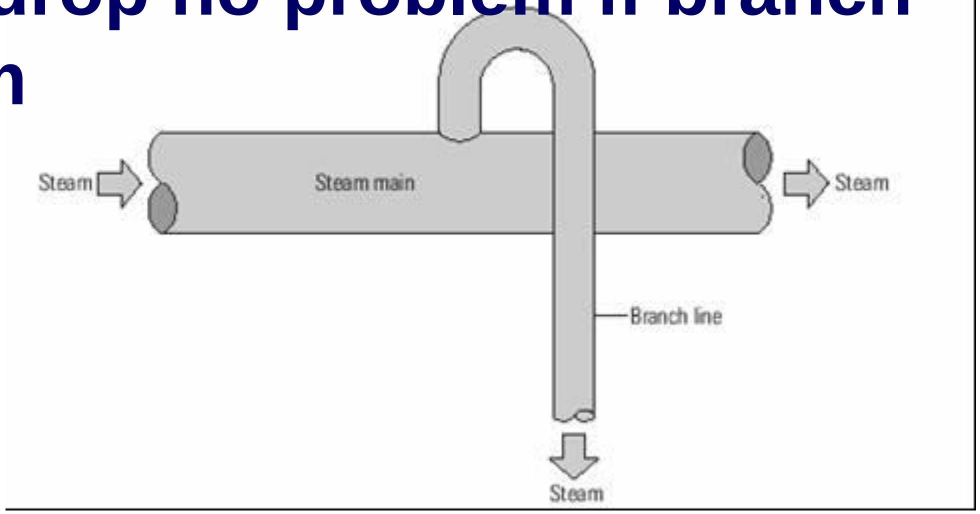


Properly Sized Trap Pocket (Spirax Sarco)

Steam Distribution System

3. Branch lines

- **Take steam away from steam main**
- **Shorter than steam mains**
- **Pressure drop no problem if branch line < 10 m**



A Branch Line
(Spirax Sarco)

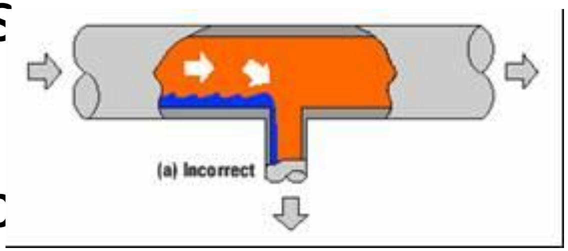
Steam Distribution System

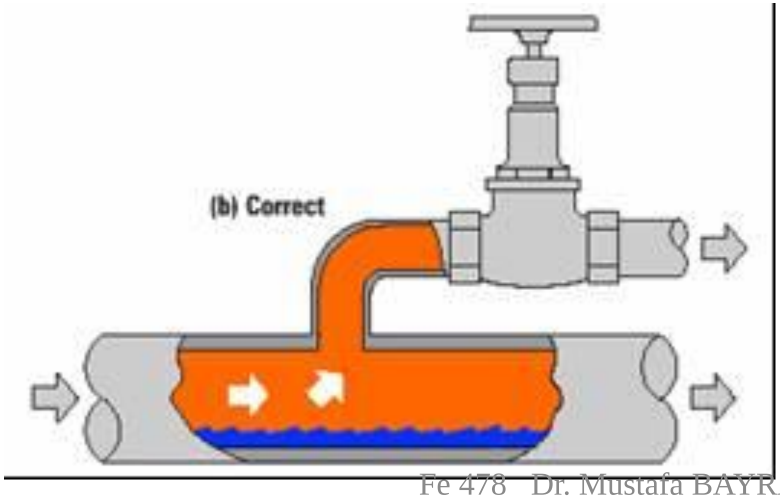
3. Branch lines

Branch line connections

– Top: driest steam

– Side or bottom: accep debris



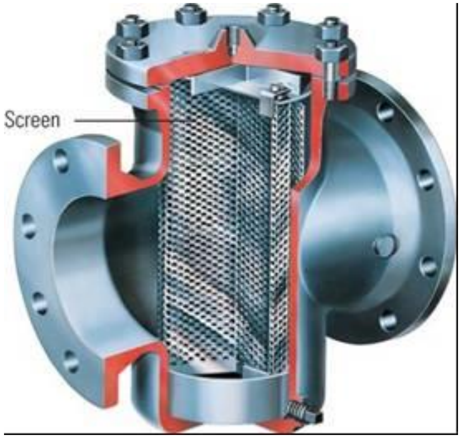


(Spirax Sarco)

Steam Distribution System

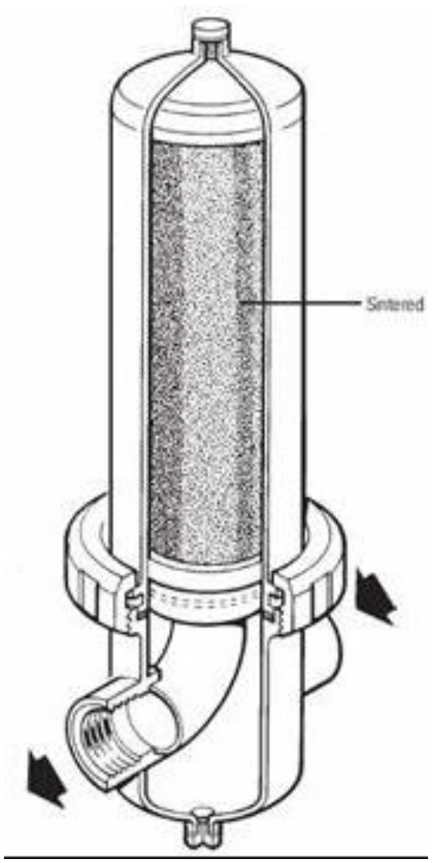
4. Strainers

- Purpose
  - Stop scale, dirt and other solids
  - Protect equipment
  - Reduce downtime and maintenance
- Fitted upstream of steam trap, flow meter, control valve
- Two types: Y-type and basket type



Steam Distribution System

5. Filters

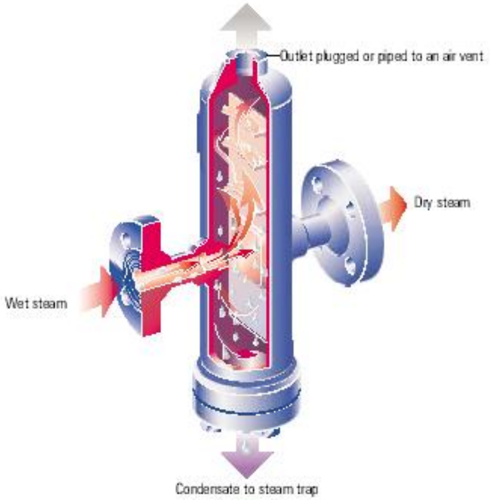


- Consists of sintered stainless steel filter element
- Remove smallest particles
  - Direct steam injection – e.g. food industry
  - Dirty stream may cause product rejection – e.g. paper machines
  - Minimal particle emission required from steam humidifiers
  - Reduction of steam water content

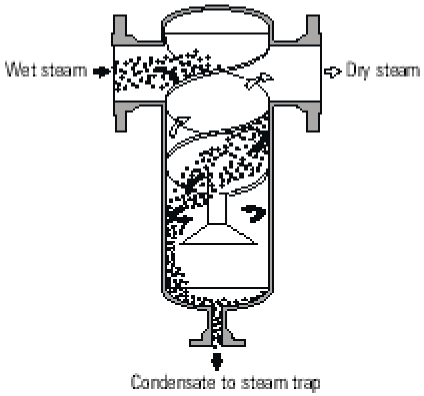
Steam Distribution System

6. Separators

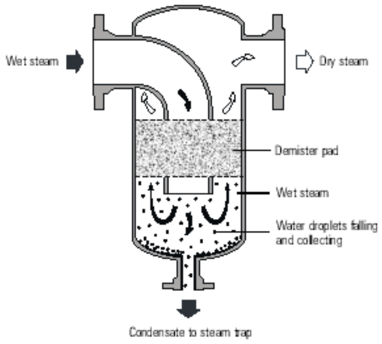
- Separators remove suspended water droplets from steam
- Three types of separators



Baffle type



Cyclonic type



Coalescence type

Steam Distribution System

7. Steam traps

- What is a steam trap?
  - "Purges" condensate out of the steam system
  - Allows steam to reach destination as dry as possible

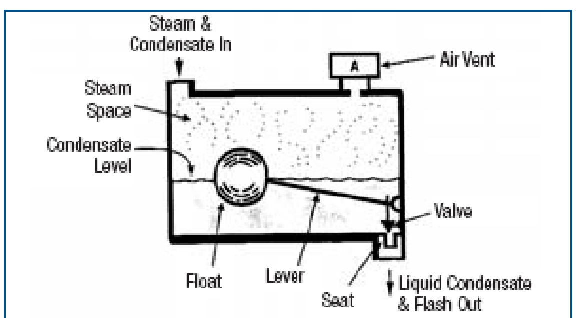
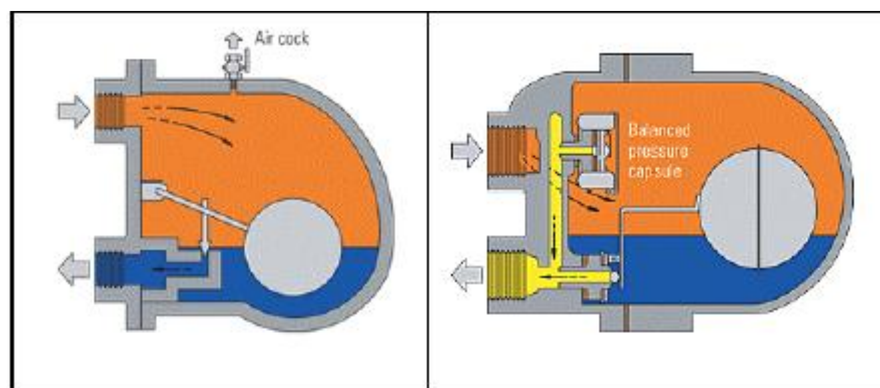


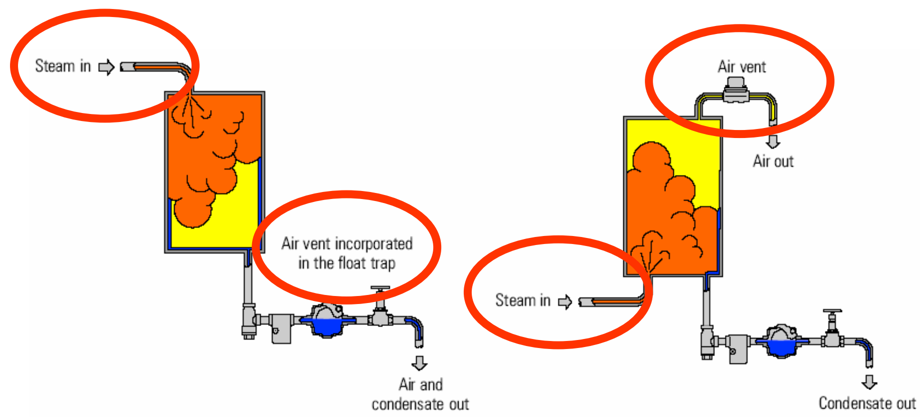
Figure 7. Float and Thermostatic Steam Trap

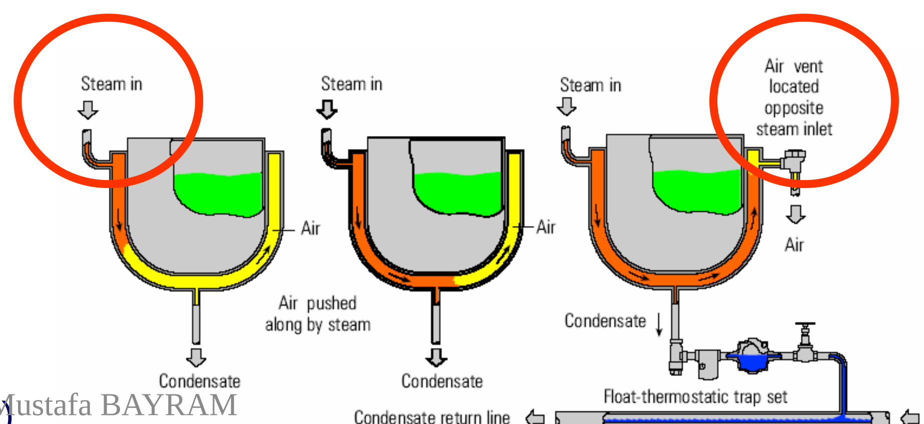


Steam Distribution System

8. Air vent - location

- Within low lying steam trap opposite high level steam inlet
- Opposite low level steam inlet
- Opposite end of steam inlet



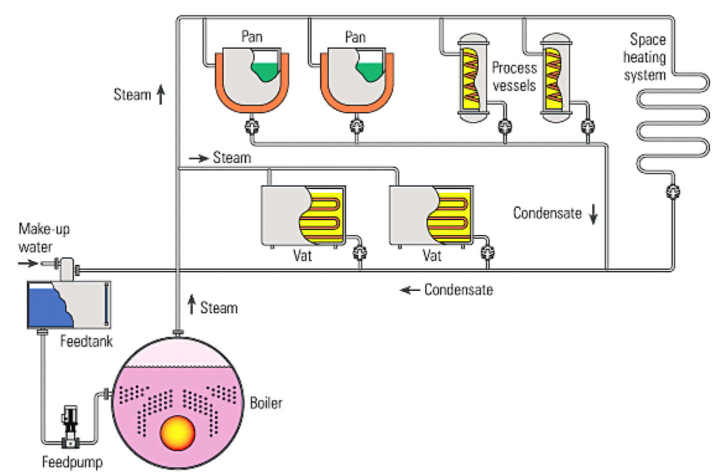


(Spirax Sarco)

Steam Distribution System

9. Condensate recovery system

- What is condensate
  - Distilled water with heat content
  - Discharged from steam plant and equipment through steam traps
- Condensate recovery for
  - Reuse in boiler feed tank, deaerator or as hot process water
  - Heat recovery through heat exchanger



Steam Distribution System

10. Insulation

- Insulator: low thermal conductor that keeps heat confined within or outside a system
- Benefits
  - Reduced fuel consumption
  - Better process control
  - Corrosion prevention
  - Fire protection of equipment
  - Absorbing of vibration
  - Protects staff: hot surfaces, radiant heat

Steam Distribution System

10. Insulation

Classification of insulators

Temperature	Application	Materials
Low (<90 ^{o}C)	Refrigerators, cold / hot water systems, storage tanks	Cork, wood, 85% magnesia, mineral fibers, polyurethane, expanded polystyrene
Medium (90 – 325 ^{o}C)	Low-temperature heating and steam generating equipment, steam lines, flue ducts,	85% magnesia, asbestos, calcium silicate, mineral fibers
High (>325 ^{o}C)	Boilers, super-heated steam systems, oven, driers and furnaces	Asbestos, calcium silicate, mineral fibre, mica, vermiculite, fireclay, silica, ceramic fibre

Velocity of Steam in piping system

TABLE 2.10-3. *Representative Ranges of Velocities in Steel Pipes*

Type of Fluid	*Type of Flow*	*Velocity*	
		ft/s	*m/s*
Nonviscous liquid	Inlet to pump	2–3	0.6–0.9
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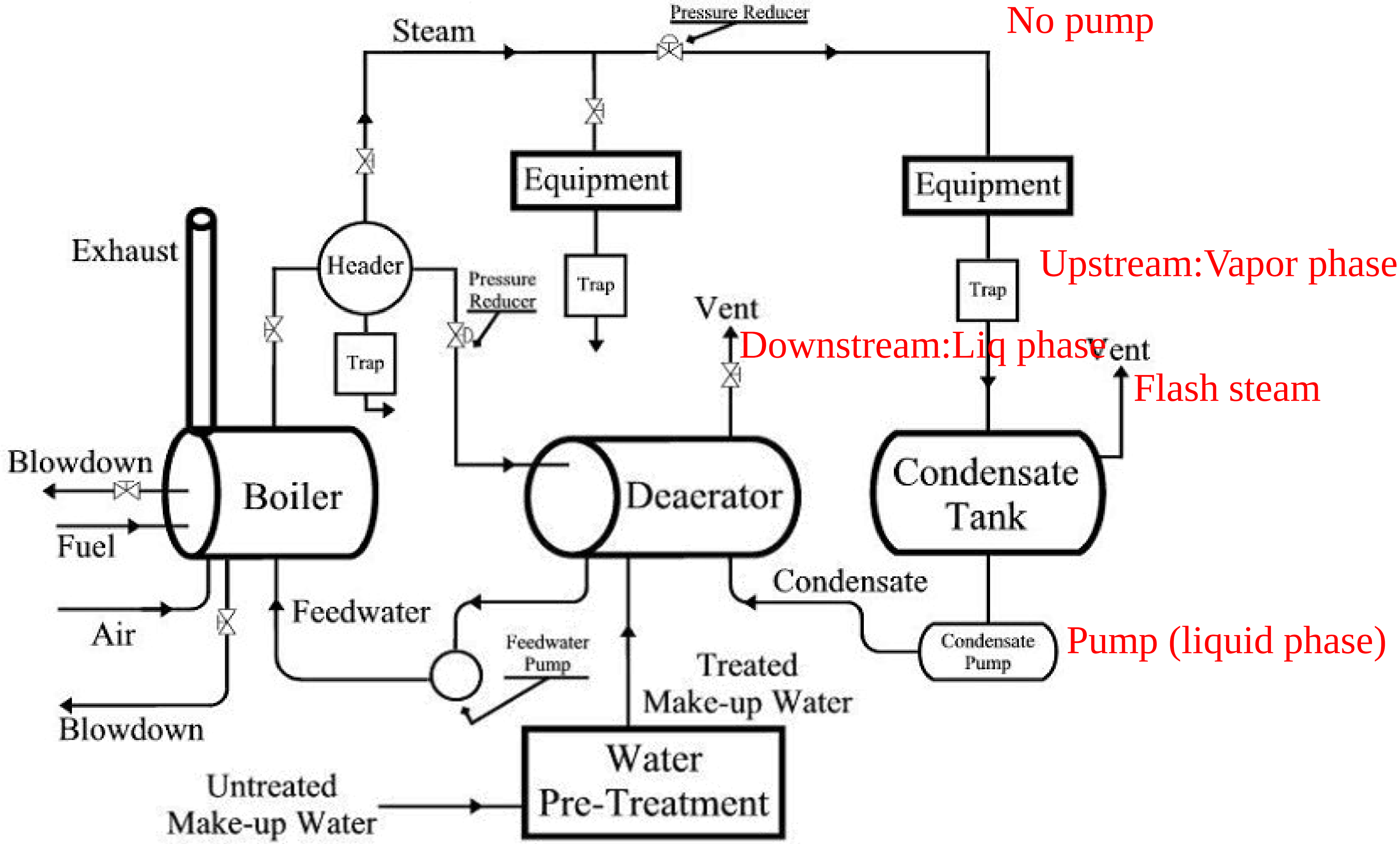
	Process line or pump discharge	0.5–2	0.15–0.6
Gas		30–120	9–36
Steam		30–75	9–23

(-)no pump at steam section)

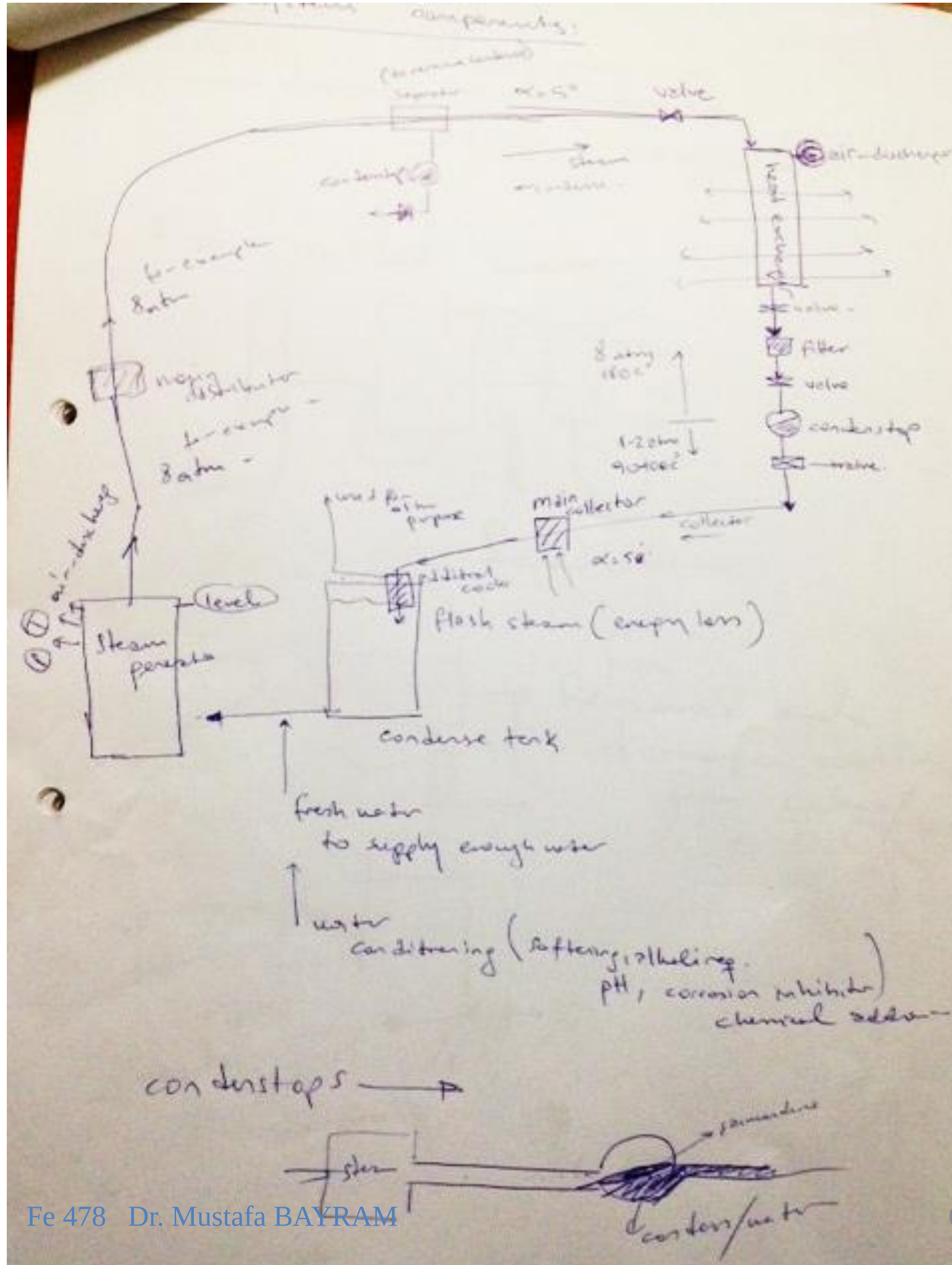
(+) pump at condensed section

Steam Distribution System

Steam System Schematic



Example



valve
filter
valve
main collector
level
flash steam (energy loss)
condense tank
fresh water
to supply enough water
condenstops

Training Agenda: Steam

Introduction

Steam distribution system

Assessment of steam distribution system

Energy efficiency opportunities

Assessment of Steam Distribution System

Three main areas of assessment

- Stream traps
- Heat loss from uninsulated surfaces
- Condensate recovery

Training Agenda: Steam

Introduction

Steam distribution system

Assessment of steam distribution system

Energy efficiency opportunities

Efficient Steam Systems

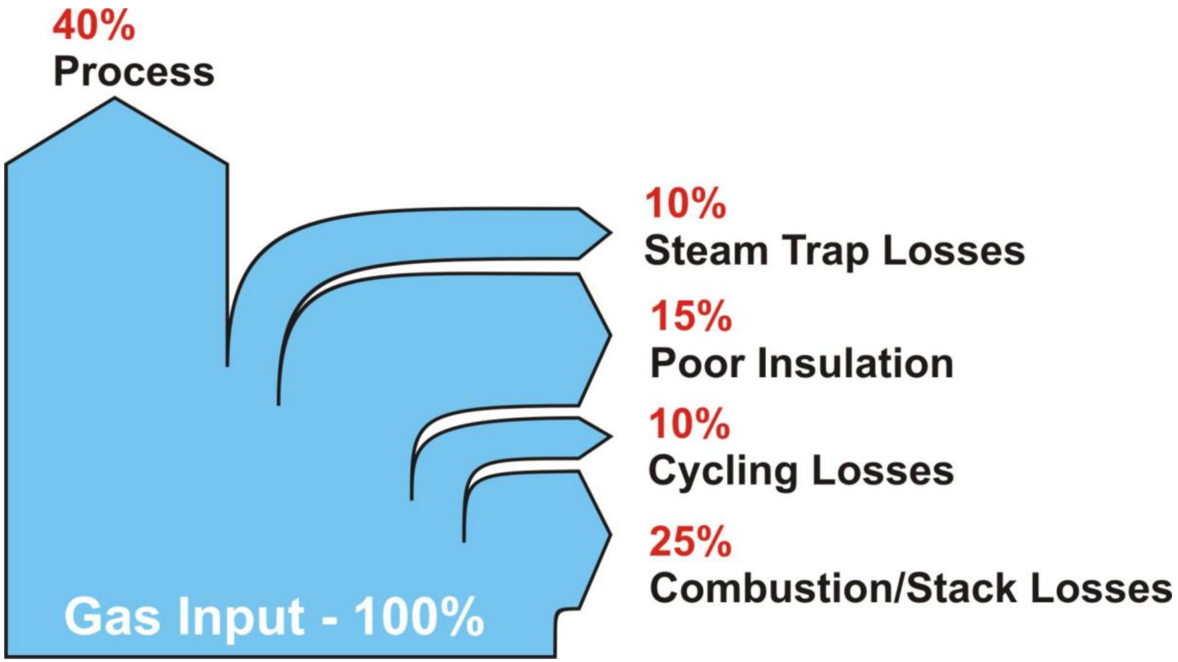
- Proper performance yields
  - Low operating costs
  - Minimal downtime
  - Reduced emissions
  - Effective process control
- Effective maintenance is the best strategy!!

Energy Efficiency Opportunities

1. Manage steam traps
2. Avoid steam leaks
3. Provide dry steam for process
4. Utilize steam at lowest acceptable pressure
5. Proper utilization of directly injected steam
6. Minimize heat transfer barriers
7. Proper air venting
8. Minimize waterhammer (Koç darbesi due to condensed water in pipe)
9. Insulate pipelines and equipment
10. Improve condensate recovery
11. Recover flash steam
12. Reuse low pressure steam

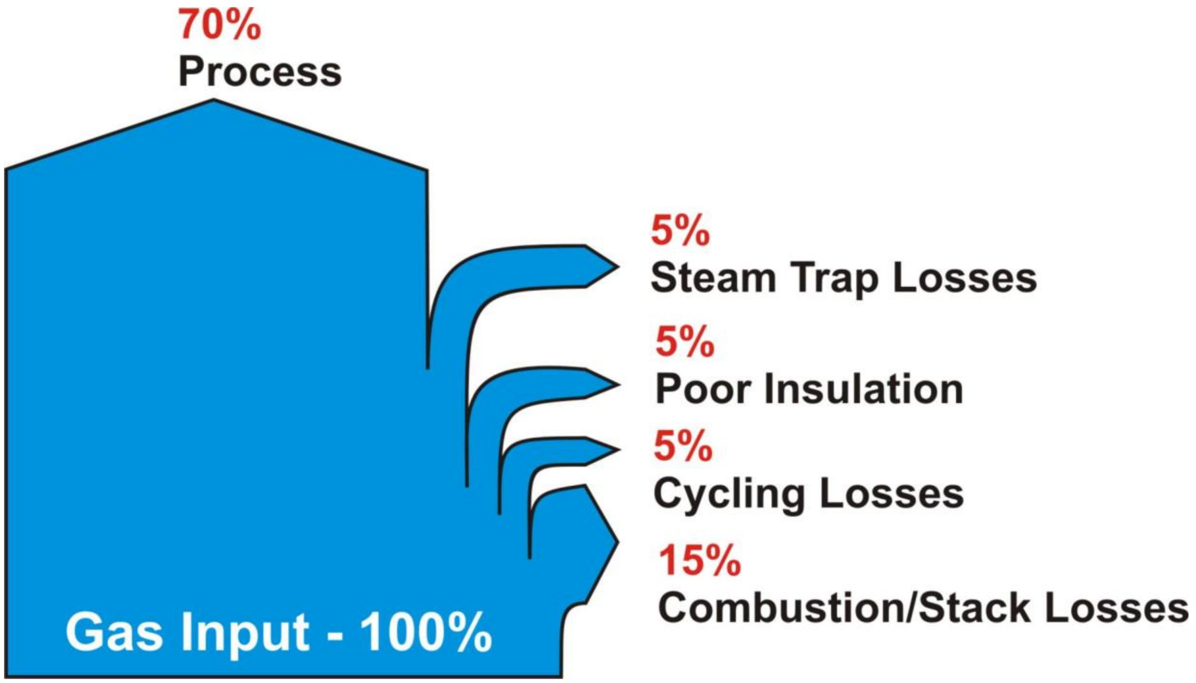
Why make a change?

INEFFICIENT STEAM SYSTEM



Why make a change?

EFFICIENT STEAM SYSTEM



Çeşitli Sektörlerde Kullanılan Makinaların Buhar Tüketim Miktarı

	Çalışma basıncı (bar)	Kg / h	
		Kullanımda	Maksimum
EKMEK FABRİKALARI	0.7		
2.5 metre uzunluğundaki hamur teknesi		1.8	
14 m^3 kapasiteli, muhafaza kutuları		3	
Fırınlar peel veya kanal tipi	0.7		
Beyaz ekmek 11 m^2 yüzeyi		13	
Çavdar ekmeği 1 m^2 yüzeyli		26	
Master baker fırınları		13	
Döner fırınlar, her tambur için		13	
Bennett 400, tek tamburlu		20	
Hubbard (her ölçüde)		26	
Baker - Perkins hareketli fırın, uzun (her 45 kg için)		6	
Baker - Perkins hareketli fırın, kısa (her 45 kg için)		13	
ŞİŞE YIKAMA	0.35		
Hafif içecekler (bira vs.) dakikada 100 şişe için		140	
Süt mamülleri, saatte 100 kasa için		26	
ŞEKER ve ÇİKOLATA	5		
Şeker pişirme, saatte 130 litre		21	
Ceketli çikolata eritici, 610 mm çaplı		13	
Çikolata daldırma kazanı, her 6451 mm^2 yüzey alanı için		13	
Çikolata serleştirme, karıştırma, her 1.9 m^2 aktif yüzey için		13	
Ceketli şeker pişirme kazanı, her 0.1 m^2 ceket yüzeyi için	2		27
Ceketli şeker pişirme kazanı, her 0.1 m^2 ceket yüzeyi için	5		45
KREMA ve SÜT ÜRETİCİLERİ			
Krema kutuları, dakikada 3 adet			140
Pastörizasyon, 455 litrenin 20 dakika ısıtılması için			106
BULAŞIK MAKİNALARI	0.6 - 2		
2 bölmeli, tene tipi			26
Büyük konveyör veya silindirik tipler			26
Autosan, ebatlara bağlı		13	52
Champion, ebatlara bağlı		26	140
HobartCrescent, ebatlara bağlı		13	84
Fan spray, ebatlara bağlı		26	113
Cresscent, manual buhar kontrollü	2		
Hobart AM-5 modeli	0.7		
Bulaşık makinası	1 - 1.4	27 - 31	

Co-generator

- To produce
  - Electricity
  - Hot water or steam

From the engine

From the engine

- Hot water or steam from engine cooling water line
- Hot water or steam from engine oil/lubrication part
- Hot water or steam from engine exhaust part
- Electricity from engine

Technical data 50 Hz

$NO_x <= 500\ mg/m_n^3$ [1)]

Natural gas applications

Minimum methane number MN: 80
dry exhaust manifold

Engine type		TCG 2016 V12	TCG 2016 V16
Engine power [2)]	kW	600	800
Speed	min^{-1}	1500	1500
Mean effective pressure	bar	18.3	18.3
Exhaust temperature	approx. °C	468	470
Exhaust mass flow wet	approx. kg/h	3239	4294
Combustion air mass flow [2)]	approx. kg/h	3134	4155
Combustion air temperature minimum/design	°C	20/25	20/25
Ventilation air flow [3)]	approx. kg/h	13164	17289
Generator			
Efficiency [4)]	%	96.6	96.9
Energy balance			
Electrical power [4)]	kW	580	775
Jacket water heat	±8 % kW	208	286
Intercooler LT heat [5)]	±8 % kW	118	141
Exhaust cooled to 120°C	±8 % kW	348	466
Exhaust cooled to 150°C	±8 % kW	318	426
Engine radiation heat	kW	22	30
Generator radiation heat	kW	20	25

7,86 x 10,63 in

Generator			
Efficiency [4)]	%	96.6	96.9
Energy balance			
Electrical power [4)]	kW	580	775
Jacket water heat	±8 % kW	208	286
Intercooler LT heat [5)]	±8 % kW	118	141
Exhaust cooled to 120°C	±8 % kW	348	466
Exhaust cooled to 150°C	±8 % kW	318	426
Engine radiation heat	kW	22	30
Generator radiation heat	kW	20	25
Fuel consumption [6)]	+5 % kW	1422	1882
Specific fuel consumption [6)]	+5 % kWh/kWh	2.37	2.35
Electrical efficiency	%	40.8	41.2
Thermal efficiency	%	39.1	40.0
Total efficiency	%	79.9	81.2
System parameters			
Engine jacket water flow rate min./max.	m^3/h	22/36	30/45
Engine K_{VS}-value [7)]	m^3/h	40	42

FOR PRESENTATION AND REPORTS

- Show steam/hot water pipeline and ALL components
- Calculate required steam/hot water for each machine separately
- Calculate total steam/hot water quantity
- Calculate total steam/hot water calories
- Calculate total natural gas/electiricty/coal etc. «as energy source» quantity per hour,
  day, year and use them in feasibilty survey
- Calculate boiler efficiency
- Show in a **table** for;
  - Electricity
  - Energy

SOME IMPORTANT POWER CALCULATIONS FOR MOTOR/EQUIPMENT

Hesaplama Temelleri:

1. Motorun harcadığı güç:

$$P = \sqrt{3} \cdot U \cdot I \cdot \cos\varphi \div 1000$$

P : Güç (kW)
U : Gerilim (volt)
I : Akım (amper)
cosφ : Güç faktörü

2. Motorun verdiği mekanik güç:

$$P = \sqrt{3} \cdot U \cdot I \cdot \cos\varphi \cdot \eta \div 1000$$

P : Güç (kW)
U : Gerilim (volt)
I : Akım (amper)
cosφ : Güç faktörü
η : Verim

3. Harcanan güç:

a) Doğrusal hareket:

$$P = \frac{F \cdot v}{1000 \cdot \eta} (kW)$$

$$F = m \cdot g \cdot \mu \quad (N)$$

$$P = \frac{m \cdot g \cdot \mu \cdot v}{1000 \cdot \eta} (kW)$$

b) Dönme hareketi:

$$P_2 = \frac{M \cdot v}{9550 \cdot \eta} (kW)$$

c) Vantilatör gücü:

$$P_2 = \frac{V \cdot n}{1000 \cdot \eta} (kW)$$

d) Kaldırma hareketi:

$$P = \frac{m \cdot g \cdot v}{1000 \cdot \eta} (kW)$$

e) Pompa gücü:

$$P = \frac{V \cdot p}{1000 \cdot \eta} (kW)$$

P : Güç (kW)
F : Kuvvet (N)
v : Hız (m/s)
η : Verim
M : Moment (Nm)
n : Devir (d/d)
V : Debi (m^3/s)
p : Toplam basınç (Pa)
m : Kütle (kg)
g : Yer çekimi ivmesi (m/s^2)
μ : Sürtünme katsayısı

Principles of Calculations:

1. Consumed capacity of the motor:

$$P = \sqrt{3} \cdot U \cdot I \cdot \cos\varphi \div 1000$$

P : *Power (kW)*
U : *Voltage (volt)*
I : *Current (ampere)*
cosφ : *Power factor*

2. Mechanical output power:

$$P = \sqrt{3} \cdot U \cdot I \cdot \cos\varphi \cdot \eta \div 1000$$

P : *Power (kW)*
U : *Voltage (volt)*
I : *Current (ampere)*
cosφ : *Power factor*
η : *efficiency*

3. Consumed capacity:

a) Linear movement:

$$P = \frac{F \cdot v}{1000 \cdot \eta} (kW)$$

$$F = m \cdot g \cdot \mu \quad (N)$$

$$P = \frac{m \cdot g \cdot \mu \cdot v}{1000 \cdot \eta} (kW)$$

b) Rotating movement:

$$P_2 = \frac{M \cdot v}{9550 \cdot \eta} (kW)$$

c) Ventilator drive:

$$P_2 = \frac{V \cdot n}{1000 \cdot \eta} (kW)$$

d) Stroke movement:

$$P = \frac{m \cdot g \cdot v}{1000 \cdot \eta} (kW)$$

e) Pump drive:

$$P = \frac{V \cdot p}{1000 \cdot \eta} (kW)$$

P : *Rated Power (kW)*
F : *Force (N)*
v : *Velocity (m/s)*
η : *Efficiency*
M : *Torque (Nm)*
n : *Speed (d/d)*
V : *Flow Rate (m^3/s)*
p : *Total pressure (Pa)*
m : *Mass (kg)*
g : *Gravity (m/s^2)*
μ : *Friction cofficient*

4. Döndürme Momenti:

$$M = 9550 \cdot \frac{P}{n} (Nm)$$

P : Güç (kW)
n : Devir (d/d)

5:Atalet momenti:

a) Silindir için:

$$J = 98 \cdot \rho \cdot L \cdot D^4 \ (\mathrm{kg \cdot m^2})$$

b)Delik mil için:

$$J = 98 \cdot \rho \cdot L \cdot (D^4 - \mathrm{d}^2) \ (\mathrm{kg \cdot m^2})$$

ρ :Özgül kütle (kg/dm³)
L :Uzunluk (m)
D :Dış çap (m)
d :İç çap (m)

6:Lineer hareketin motor atalet momenti etkisine çevrilmesi:

$$J = 91.2 \cdot m \cdot \frac{v2}{n_1} (kg \cdot m^2)$$

m :Hareket eden kütle (kg)
v :Hız (m/s)
n_1 :Motor devri (d/d)

7: Farklı devirlerde oluşan atalet momentlerinin motor miline indirgenmesi:

$$J_{ind} = \frac{J_2 \cdot n_2^2 + J_3 \cdot n_3^2}{n_1^2} (kg \cdot m^2)$$

n_1 = Motor devri (d/d)
J_{ind} = İndirgenmiş atalet momenti

8:Atalet momenti:

$$FI = \frac{J_E + J_{ind}}{J_E}$$

J_E=Tahrik atalet momenti
J_{ind}=İndirgenmiş atalet

9:Motor Hızlanma Zamanı:

a) Frensiz motorlar:

$$t_a = \frac{J_{top} \cdot n_1}{9.55 \cdot (M_A - M_L)} (sn)$$

$$J_{top} = J_E + J_{ind} \ (\mathrm{kg \cdot m^2})$$

(Motor atalet momenti ve ek atalet momenti)
n_1=Motor devri (d/d)
M_A=Motor start momenti (Nm)
M_L=Gerekli tahrik momenti (Nm)

4.Torque:

$$M = 9550 \cdot \frac{P}{n} (Nm)$$

P *:Power (kW)*
n *:Speed (rpm)*

5.Moment of inertia:

a) For a cylinder:

$$J = 98 \cdot \rho \cdot L \cdot D^4 \ (\mathrm{kg \cdot m^2})$$

e) For hollow shaft:

$$J = 98 \cdot \rho \cdot L \cdot (D^4 - \mathrm{d}^2) \ (\mathrm{kg \cdot m^2})$$

ρ *:Density (kg/dm³)*
L *:Length (m)*
D *:Outer diameter (m)*
d *:İnner diameter (m)*

6.Convertion of linear inertia to a flywheel effect at the motor shaft:

$$J = 91.2 \cdot m \cdot \frac{v2}{n_1} (kg \cdot m^2)$$

m *:Mass in motion (kg)*
v *:Velocity (m/s)*
n_1 *:Motor speed (rpm)*

7.Converting moment of intertia of different speeds to a common moment of intertia at the motor speed:

$$J_{ind} = \frac{J_2 \cdot n_2^2 + J_3 \cdot n_3^2}{n_1^2} (kg \cdot m^2)$$

n_1*=Motor speed (rpm)*
J_{ind}*=Reduced moment intertia*

8.Factor of intertia:

$$FI = \frac{J_E + J_{ind}}{J_E}$$

J_E*=Moment of Intertia of excitation*
J_{ind}*=Reduced inertion*

9.Starting Period:

a) For motors without brake:

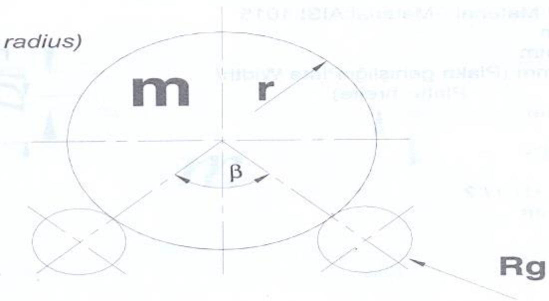
$$t_a = \frac{J_{top} \cdot n_1}{9.55 \cdot (M_A - M_L)} (\mathrm{sec})$$

$$J_{top} = J_E + J_{ind} \ (\mathrm{kg \cdot m^2})$$

(Moment of Intertia of geared motor and additional intertia)
n_1*=Motor speed (rpm)*
M_A*=Starting torque of motor (Nm)*
M_L*=Required excitation torgue (Nm)*

Silindirik Karıştırıcı *Cylindrical Mixer* Drehtisch

$m = 400$ kg **(Yük)** *(muss)*
$r = 1.2$ m **(Silindir çapı)** *(Cylinder diameter)*
$r_g = 0.1$ m **(Tahrik makarası yarıçapı)** *(excitation roller radius)*
$v = 1$ m/s
$\beta^o = 60^o$
$k_f = 0.25$
$\eta_{red.} = 0.98$ **(Redüktör verimi/** *Gearbox efficiency/* Getriebe Wirkungsgrad)
$n = ?$
$P = ?$



Örnek 9: 1000 kg ağırlığındaki silindir 0.1 m yarıçaplı tahrik makaraları üstünde1 m/s hızla taşınmaktadır. Makara devrini ve gerekli motor gücünü bulunuz.

B = Açı faktörü (Aşağıdaki tabloda verilmiştir)

B = 1.15 (60^o için tablodaki değer)
Makara devri:

$$n_{silindir} = 9.55 \cdot v \div r = \frac{9.55}{1.2}$$

$\Rightarrow n_{silindir} = 7.95$ d/d

Makara devri:

$$n_g = \frac{n \cdot r}{r_g} = \frac{7.95 \cdot 1.2}{0.1} = 95.4\ d/d$$

Makara eksenine göre moment:

$M = m \times r_g \times k_f \times B$
$M = 1000 \times 0.1 \times 0.25 \times 1.15$
$\Rightarrow M = 28.75$ Nm

Motor gücü:

$$P = \frac{M \cdot ng}{9550 \cdot \eta} = \frac{28.75 \cdot 95.4}{9550 \cdot 0.98}$$

$\Rightarrow P = 0.3$ kW

Example 9: A 1000 kg cylinder moves on the horizontal axis supported cylinders with a velocity of 1 m/s. System efficiency is 0.98. Find the required power.

B = Angle factor (it is given in the table below)

B = 1.15 (value for 60^o in the table)
Speed of roller:

$$n_{cylinder} = 9.55 \cdot v \div r = \frac{9.55}{1.2}$$

$\Rightarrow n_{cylinder} = 7.95$ *rpm*

Drive roller speed:

$$n_g = \frac{n \cdot r}{r_g} = \frac{7.95 \cdot 1.2}{0.1} = 95.4\ rpm$$

Torque at axis of the roller:

$M = m \times r_g \times k_f \times B$
$M = 1000 \times 0.1 \times 0.25 \times 1.15$
$\Rightarrow M = 28.75$ *Nm*

Motor power:

$$P = \frac{M \cdot ng}{9550 \cdot \eta} = \frac{28.75 \cdot 95.4}{9550 \cdot 0.98}$$

$\Rightarrow P = 0.3$ *kW*

Beispiel 9: Ein Zylinder mit 1000 kg Gewicht wird auf einem Horizontalern Achse läufende Stütztrommeln gedreht. Zylinder Umfangsgeschwindigkeit ist 1 m/s. Gesamt Wirkungsgrad ist 0,98. Gesucht ist Motor Leistung.

B = Winkel Faktor (Unten auf der Tabelle angegeben)

B = 1.15 (von der Tabelle für 60^o)
Zylinder Drehzahl:

$$n_{zylinder} = 9.55 \cdot v \div r = \frac{9.55}{1.2}$$

$\Rightarrow n_{zylinder} = 7.95$ rpm

Trommel Drehzahl:

$$n_g = \frac{n \cdot r}{r_g} = \frac{7.95 \cdot 1.2}{0.1} = 95.4\ upm$$

Stütztrommel Drehmoment:

$M = m \times r_g \times k_f \times B$
$M = 1000 \times 0.1 \times 0.25 \times 1.15$
$\Rightarrow M = 28.75$ Nm

Motor Leistung:

$$P = \frac{M \cdot ng}{9550 \cdot \eta} = \frac{28.75 \cdot 95.4}{9550 \cdot 0.98}$$

$\Rightarrow P = 0.3$ kW

Tablo 6 */Table 6* / Tabelle 6

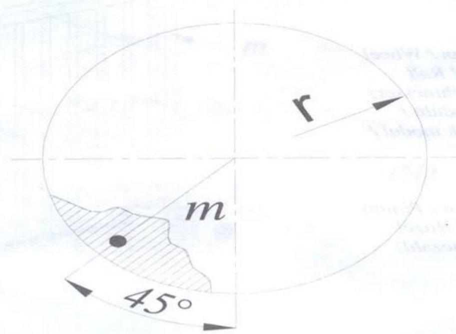
b^0	0^0	20^0	40^0	50^0	60^0	70^0	80^0	90^0
B	1	1.02	1.06	1.1	1.15	1.22	1.31	1.41

Ekseni Etrafında Dönen Silindirler

Cylinder Rotating around its axis

Zylinder Dreht Sich Um Seine Eigenen Achse

m = 400 kg (Ağırlık/Weight/Gewicht)
r = 0,6 m (Yarıçap/Radius/Radius)
n = 20 rpm (Devir/Speed/Drehzahl)
i = 5 (Zincir Dişli Tahvili/Chain Drive Ratio/ Kettentrieb Überzetzung)
ηk = 0.9 (Zincir Vrimi/Efficiency of Chain Drive/ Ketentrieb Virkungsgrad)
ηr = 0.98 (Redüktör Verimi/Efficiency of Gearbox /Getriebe Virkungsgrad)
C Doldurma faktörü / Filling Factor / Füllungszahl
P = ?



Örnek 6: Silindirik bir karıştırıcı 1.2 m çapındadır. İki devirli bir redüktör ve 1/5 oranında zincir dişlilerle (verim = 0.9) tahrik edilmektedir. Silindir devri 20 dır. Silindir 1/4 doludur. Yük ağırlığı 400 kg dır. Redüktör devrini ve gücünü hesaplayınız. (Redüktör verimi = 0.98)

Silindir eksenine göre M momenti:

$$M = m \cdot r \cdot C \ (Nm)$$

Doldurma faktörü:
C = 4.5 (N/kg) (Tablo 4 den)

$$M = 400 \cdot 0.6 \cdot 4.5$$
$$\Rightarrow \mathrm{M} = 1080 \ \mathrm{Nm}$$

Redüktör çıkış milindeki moment:

$$\mathrm{M_S} = \frac{1080}{5 \cdot 9} \Rightarrow M_S = 240 \ Nm$$

Redüktörün devri:

$$\mathrm{n} = 20 \cdot 5 = 100 \ \mathrm{d/d}$$

Motor gücü:

$$\mathrm{P} = \mathrm{M} \cdot \mathrm{n} \div (9550 \cdot \eta)$$

$$\mathrm{P} = \frac{240 \cdot 100}{9550 \cdot 0.98} \Rightarrow P = 2.6 \ kW$$

Example 6: A cylinder blender 1.2m in dianeter is driven at 20 rpm in rotation around its axis through chain and sprockets, ratio 5 to1, efficiency 0.9. It is quarter full and the weight of the product is 400 kg. Calculate the output gearbox speed and motor power.(efficiency of the drive 0.98)

Torque at the axis of the cylinder:

$$M = m \cdot r \cdot C \ (Nm)$$

Filling factor :
C=4.5 (N/kg) (from table 4)

$$M = 400 \cdot 0.6 \cdot 4.5$$
$$\Rightarrow \mathrm{M} = 1080 \ \mathrm{Nm}$$

Gearbox output shaft Torque:

$$\mathrm{M_S} = \frac{1080}{5 \cdot 9} \Rightarrow M_S = 240 \ Nm$$

Gearbox output speed:

$$\mathrm{n} = 20 \cdot 5 = 100 \ \mathrm{rpm}$$

Motor power:

$$\mathrm{P} = \mathrm{M} \cdot \mathrm{n} \div (9550 \cdot \eta)$$

$$\mathrm{P} = \frac{240 \cdot 100}{9550 \cdot 0.98} \Rightarrow P = 2.6 \ kW$$

Beispiel 6: Ein Zylinder Mixer mit 1.2m Durchmesser wird bei 20upm mit Kettentrieb (Übersetzung 5, Wirkungsgrad 0.9) Angetrieben. Zylinder ist 1/4 voll mit 400 kg Last. Gesucht ist Getriebe Drehzahl und Leistung (Getriebe Wirkungsgrad 0.98)

Drehmoment an der Zylinder Shaft :

$$M = m \cdot r \cdot C \ (Nm)$$

Füllungszahl :
C=4.5 (N/kg) (von Tabelle 4)

$$M = 400 \cdot 0.6 \cdot 4.5$$
$$\Rightarrow \mathrm{M} = 1080 \ \mathrm{Nm}$$

Getriebe Drehmoment:

$$\mathrm{M_S} = \frac{1080}{5 \cdot 9} \Rightarrow M_S = 240 \ Nm$$

Reducer's maximum output speed:

$$\mathrm{n} = 20 \cdot 5 = 100 \ \mathrm{upm}$$

Motor Leistung:

$$\mathrm{P} = \mathrm{M} \cdot \mathrm{n} \div (9550 \cdot \eta)$$

$$\mathrm{P} = \frac{240 \cdot 100}{9550 \cdot 0.98} \Rightarrow P = 2.6 \ kW$$

Tablo 4 / Table 4 / Tabelle 4

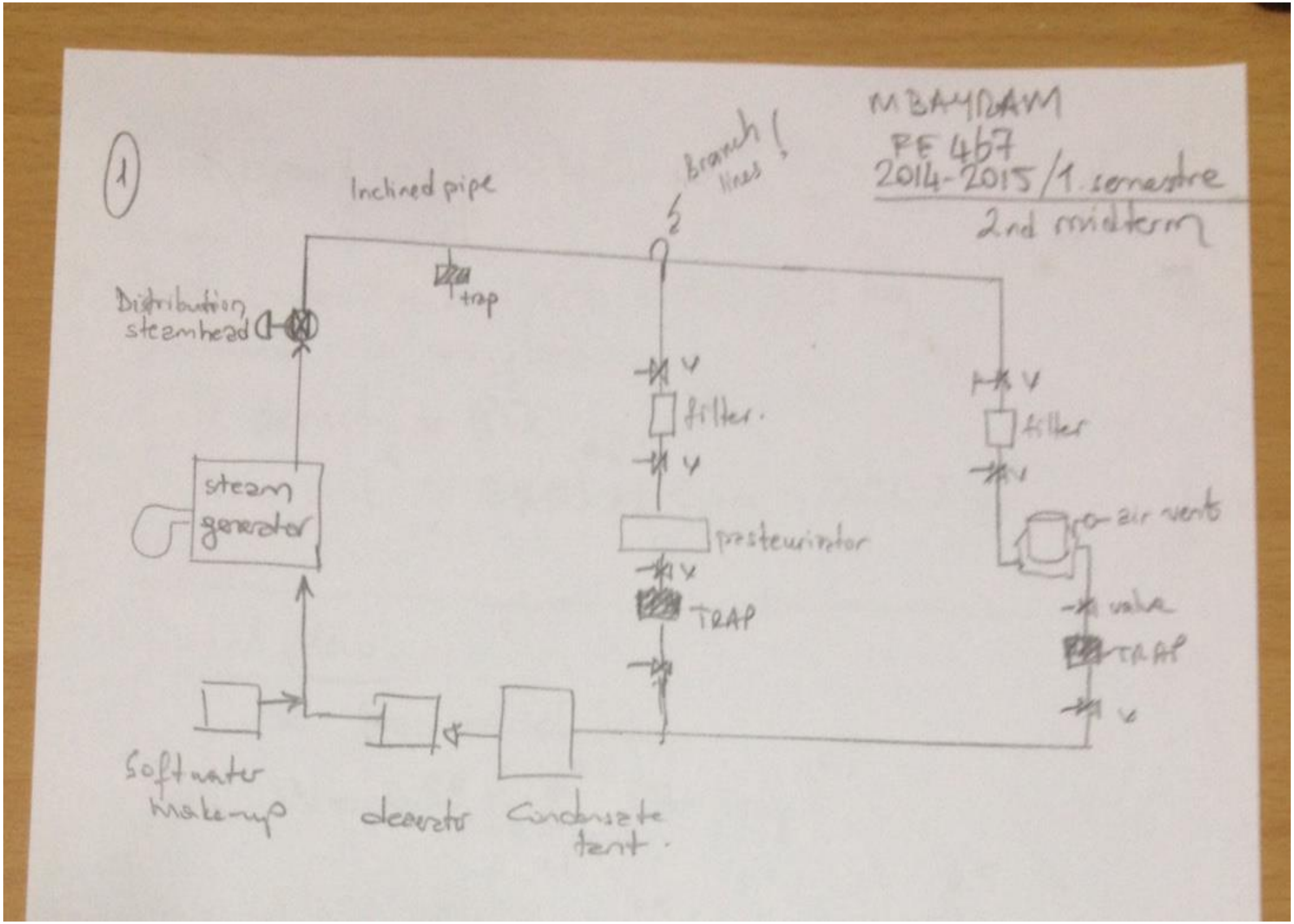
Silindir /Cylinder /Zylinder	C
1/4 dolu / full / voll	4.5
1/3 dolu / full / voll	3
1/2 dolu / full / voll	1.6

EXAMPLES
HOME STUDIES (SOME EXAM QUESTIONS)

1-Draw flow-diagram of a steam system, which includes the following components (use full page of your answer book, drawing is important, no partial grade will be given in this question)

Pasteurizator (in parallel process)	Jacketed tank (in parallel process)	Steam distributor/head
Steam traps	Steam filters	Condense tank
Deaerator	Water make-up/soft water system	Pipes + Inclined pipes
Air vents	Valves	Branch lines

FLOW DIAGRAM !!!!!


M BAYRAM
FE 467
2014-2015/1. semestre
2nd midterm
1
Inclined pipe
Branch lines!
trap
Distribution steamhead
V
filter.
V
steam generator
pasteurizator
V
TRAP
V
filter
V
air vents
valve
TRAP
v
Softwater makeup
deaerator
Condensate tank.

2-In a food plant, overall steam requirement of the system is 5000 kg steam/hr at 120 C saturated steam. The efficiency of steam generator found in the plant is 85%. Condensed steam return at saturation temperature to the steam generator. According to following table, what quantity of the cheapest energy source is required (show all calculations)?

Energy Source	**Heat value**	**Unit cost**	**Burning Efficiency**
Coal (C)	6500 kcal/kg	0.220 (TL/kg)	69%
Natural Gas (N)	8250 kcal/m^3	0.297 (TL/ m^3)	93%
Fuel-oil (No: 6) (F)	9200 kcal/kg	0.508 (TL/kg)	83%

A.2-9 Properties of Saturated Steam and Water (Steam Table), SI Units

Temperature (°C)	Vapor Pressure (kPa)	Specific Volume (m^3/kg)		Enthalpy (kJ/kg)		Entropy (kJ/kg · K)	
		Liquid	Sat'd Vapor	Liquid	Sat'd Vapor	Liquid	Sat'd Vapor
0.01	0.6113	0.0010002	206.136	0.00	2501.4	0.0000	9.1562
3	0.7577	0.0010001	168.132	12.57	2506.9	0.0457	9.0773
6	0.9349	0.0010001	137.734	25.20	2512.4	0.0912	9.0003
9	1.1477	0.0010003	113.386	37.80	2517.9	0.1362	8.9253
12	1.4022	0.0010005	93.784	50.41	2523.4	0.1806	8.8524
15	1.7051	0.0010009	77.926	62.99	2528.9	0.2245	8.7814
18	2.0640	0.0010014	65.038	75.58	2534.4	0.2679	8.7123
21	2.487	0.0010020	54.514	88.14	2539.9	0.3109	8.6450
24	2.985	0.0010027	45.883	100.70	2545.4	0.3534	8.5794
25	3.169	0.0010029	43.360	104.89	2547.2	0.3674	8.5580
27	3.567	0.0010035	38.774	113.25	2550.8	0.3954	8.5156
30	4.246	0.0010043	32.894	125.79	2556.3	0.4369	8.4533
33	5.034	0.0010053	28.011	138.33	2561.7	0.4781	8.3927
36	5.947	0.0010063	23.940	150.86	2567.1	0.5188	8.3336
40	7.384	0.0010078	19.523	167.57	2574.3	0.5725	8.2570
45	9.593	0.0010099	15.258	188.45	2583.2	0.6387	8.1648
50	12.349	0.0010121	12.032	209.33	2592.1	0.7038	8.0763
55	15.758	0.0010146	9.568	230.23	2600.9	0.7679	7.9913
60	19.940	0.0010172	7.671	251.13	2609.6	0.8312	7.9096
65	25.03	0.0010199	6.197	272.06	2618.3	0.8935	7.8310
70	31.19	0.0010228	5.042	292.98	2626.8	0.9549	7.7553
75	38.58	0.0010259	4.131	313.93	2635.3	1.0155	7.6824
80	47.39	0.0010291	3.407	334.91	2643.7	1.0753	7.6122
85	57.83	0.0010325	2.828	355.90	2651.9	1.1343	7.5445
90	70.14	0.0010360	2.361	376.92	2660.1	1.1925	7.4791
95	84.55	0.0010397	1.9819	397.96	2668.1	1.2500	7.4159
100	101.35	0.0010435	1.6729	419.04	2676.1	1.3069	7.3549
105	120.82	0.0010475	1.4194	440.15	2683.8	1.3630	7.2958
110	143.27	0.0010516	1.2102	461.30	2691.5	1.4185	7.2387
115	169.06	0.0010559	1.0366	482.48	2699.0	1.4734	7.1833
120	198.53	0.0010603	0.8919	503.71	2706.3	1.5276	7.1296
125	232.1	0.0010649	0.7706	524.99	2713.5	1.5813	7.0775
130	270.1	0.0010697	0.6685	546.31	2720.5	1.6344	7.0269
135	313.0	0.0010746	0.5822	567.69	2727.3	1.6870	6.9777
140	316.3	0.0010797	0.5089	589.13	2733.9	1.7391	6.9299
145	415.4	0.0010850	0.4463	610.63	2740.3	1.7907	6.8833
150	475.8	0.0010905	0.3928	632.20	2746.5	1.8418	6.8379
155	543.1	0.0010961	0.3468	653.84	2752.4	1.8925	6.7935
160	617.8	0.0011020	0.3071	675.55	2758.1	1.9427	6.7502
165	700.5	0.0011080	0.2727	697.34	2763.5	1.9925	6.7078
170	791.7	0.0011143	0.2428	719.21	2768.7	2.0419	6.6663
175	892.0	0.0011207	0.2168	741.17	2773.6	2.0909	6.6256

(2) Required steam = 5000 kg/h at 120°C . sat'd steam
↓
cond. sat'd.

Efficiency of steam gen ⇒ 85%

* At 120°C from sat'd steam table ⇒ ΔH =

$$\left.\begin{aligned} H_L &= 503,71 \text{ kJ/kg} \\ H_V &= 2706,3 \text{ kJ/kg} \end{aligned}\right\} \underset{\text{at } 120°C}{\Delta H} = 2202.59 \text{ kJ/kg}$$

$$\Rightarrow \underline{526,94 \text{ kcal/kg steam}}$$

$$5000 \frac{\text{kg st}}{\text{h}} \times \frac{526.94 \text{ kcal}}{\text{kg}} = 2634677.03 \frac{\text{kcal}}{\text{h}}$$

$$\eta_{0,85} \Rightarrow \frac{2634677.03}{0,85} = \boxed{3099620,04 \frac{\text{kcal}}{\text{h}}} \text{ (actual energy in plant)}$$

Energy Source	Heat value	Unit cost	Burning Efficiency		TL/1000 kcal
C	6500	0.220	0.69		0.0491
N	8250	0.297	0.93	CHEAPEST	0.0387
F	9200	0.508	0.83		0.0665

Natural gas is the cheapest:
Required amount of natural gas:
Real energy: 8250*0,93 = 7672,5 kcal/m3

3099620,04 kcal/h / 7672,5 kcal/m3 = 403,99 m3/h natural gas required.

AS an example

Calculating your electric bill

- Now all you need to know is how much your electric utility or company charges you for energy. This will usually be in the units of $ per kw hr. Then you just multiply the kw hrs by the $ per kw hr, and you end up with the cost for that appliance for the amount of time that you have used it.

Sample Calculations

- Let's say that you found that your microwave oven has a power rating of 120 watts. To convert that into kilowatts you must divide by 1000 as follows. Place this number in the table.

$$120\text{w}\left(\frac{1\text{kw}}{1000\text{w}}\right)=0.12\text{kw}$$

- You estimate that your microwave oven is used 3 hours per day. Multiply by 365 days per year to get the hours used per year as follows:

$$\frac{3\text{hr}}{\text{day}}\left(\frac{365\ \text{hr}}{1\ \text{yr}}\right)= 1095\ \text{hr/year}$$

- Now you can calculate your energy consumption by multiplying the power in kw times the time used in hr/yr as follows:

$$\text{Energy} = \mathbf{P}\ t$$

$$E = (0.12\ \text{kw})(1095\ \text{hr/yr}) = 131.4\ \text{kw hr/yr}$$

$$\text{Cost} = (131.4\ \text{kw hr/yr})(0.077\ \$/\text{kw hr}) = \$10.12\ /\ \text{yr}$$

Example 3

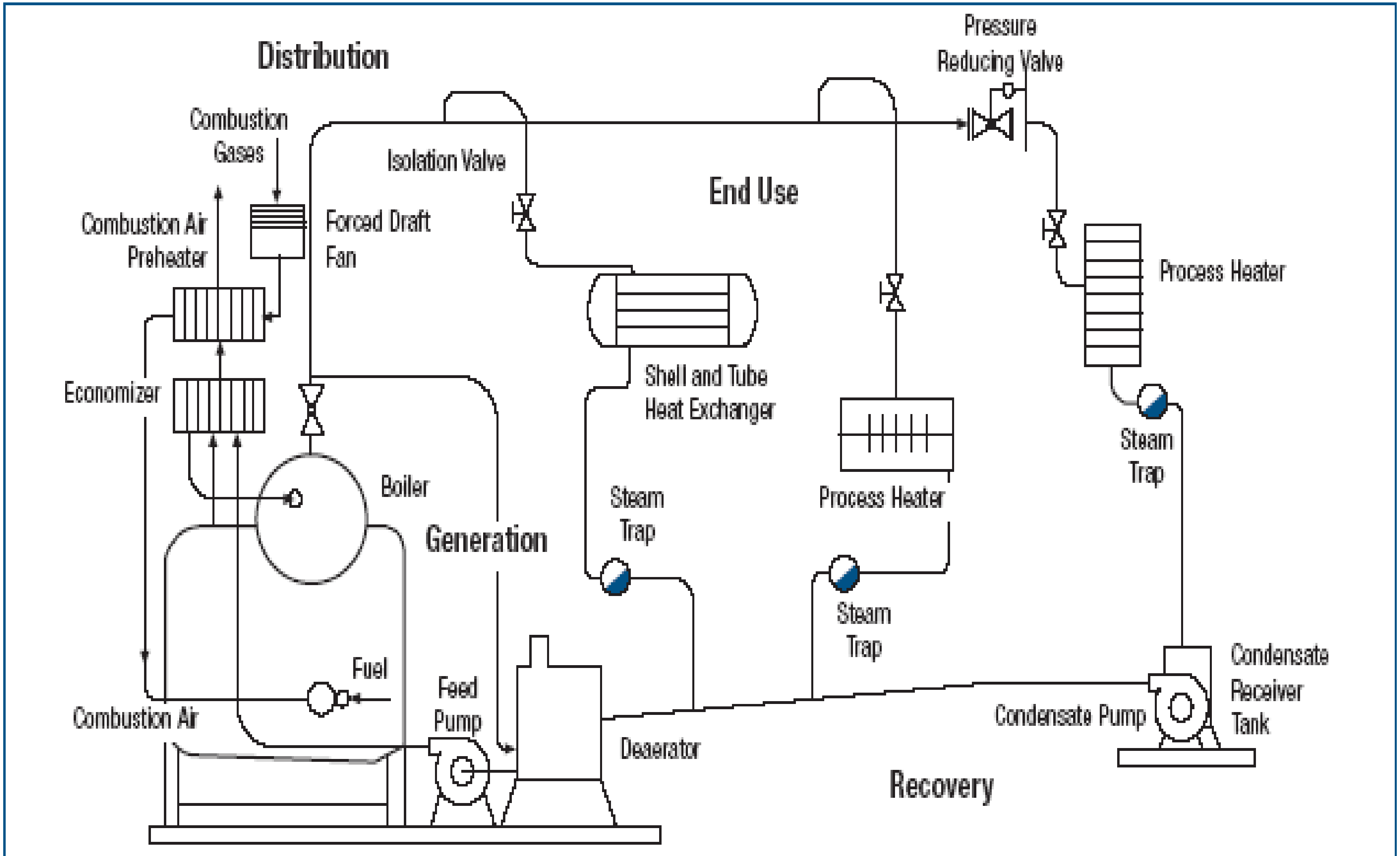


Figure 1. Steam System Schematic

(10 pts) Draw a steam generation and utilization system (in your drawing, show burner, steam generator, valves, termocouple, filters, piping, steam traps, one heating equipment/heat exchanger, condense tank, water treatment, flash etc),

1. (5 pts) Which energy source is the best according to following table?

Energy source	**Energy value**	**Unit price**	**Burning yield (%)**
Diesel (Motorin)	10256 kcal/kg	2.805 TL/kg	84
Electricity	860 kcal/kWh	0.183 TL/kWh	99
Fuel oil (No:6)	9562 kcal/kg	0.95 TL/kg	80
Local Soma coal	4640 kcal/kg	0.348 TL/kg	65
LPG	11000 kcal/kg	3.100 TL/kg	92
Natural gas	8250 kcal/m^3	0.820 TL/m^3	93