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Industrial Energy Efficiency

Assessment of Energy Savings Potential, Lecture 2 A & B

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Improving university curricula in the areas of

a) energy efficiency in the sectors of energy, industry and buildings, and

b) renewable energy sources (AHEFs AM-54, AM-55, AM-56)

B U I L D I N G   P A R T N E R S H I P S   F O R   E N E R G Y   S E C U R I T Y

Lecture Learning Objectives

- To introduce the student to methodologies to identify the energy savings available from opportunities identified
- To show the student how a balance of theoretical approaches, practical assumption and measured values can be used to put figures to energy savings available
- To show the student that possible energy savings measures are the one that do not negatively impact on the services delivered and in some case can enhance them

Analysis of energy savings potential

- For each potential opportunity we first need to identify HOW we will assess the energy savings potential

- This allows us to identify what information needs to be measured/ gathered to put real numbers on the energy savings potential

- It also needs to clearly identify what ASSUMPTIONS are being made in conjunction with this assessment of energy savings potential

- Assists with later verification

Register of opportunities that we shall examine further

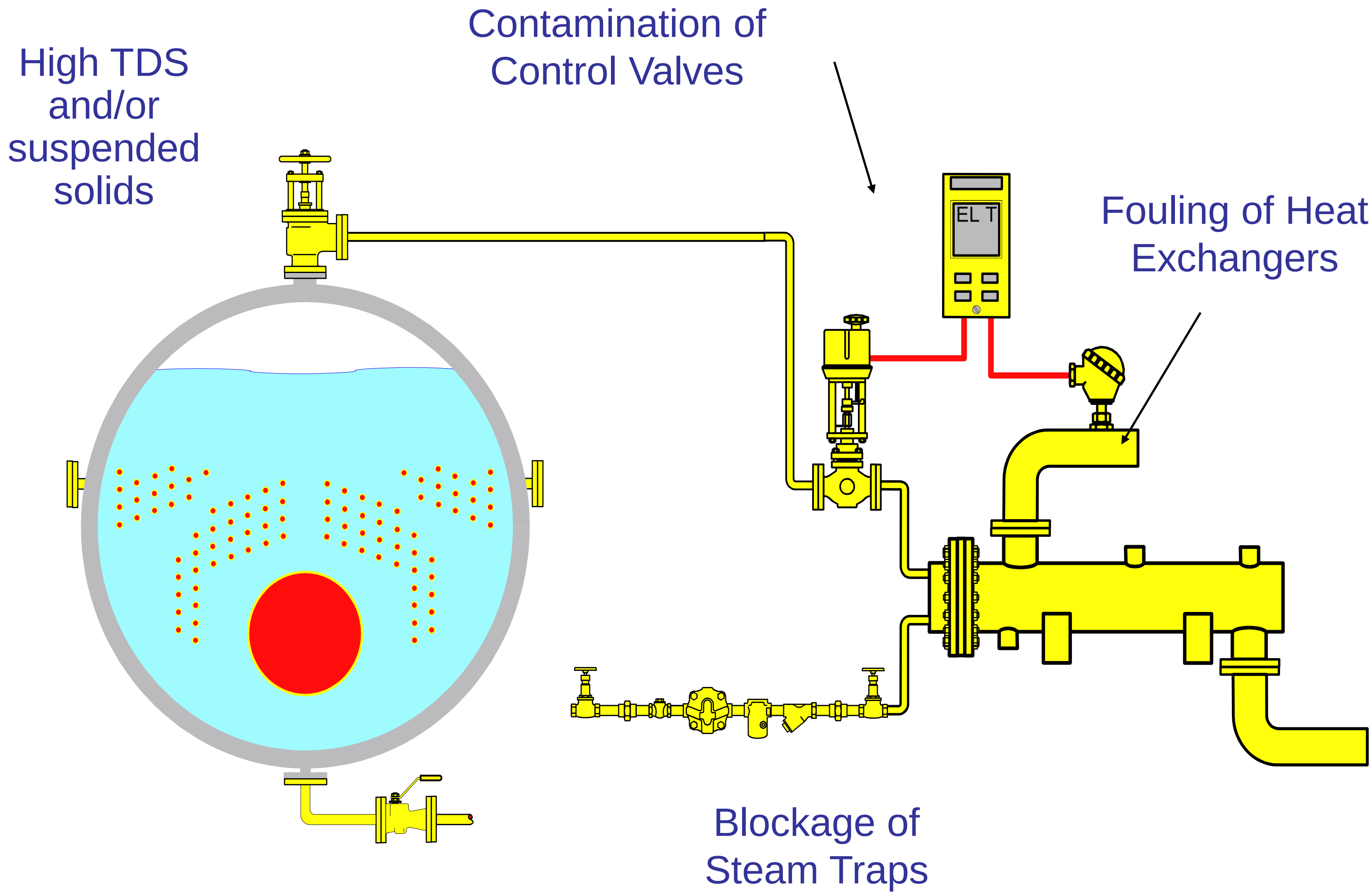
- Flash Steam recovery (Boilers and steam)
- Combined Heat and Power (Thermal and electrical)
- Reducing Air Change per Hour in Ventilation (ventilation)
- Hydraulic flow control on refrigeration systems (refrigeration)
- Increase Pasteurisation plate surface area (pasteurisation)
- Pre-dry incoming air to driers (Driers)

Blow-down Heat Recovery

Assessment of savings potential

Identified Issue / Energy Wastage	Recommended Action	Comment	Assumptions used to identify savings
Blow-down heat loss and various areas throughout the plant that there is visible steam lost that is a waste of energy on site	Recover the heat to a useful place	When high pressure liquid is dropped in pressure it can flash to steam losing a significant amount of energy	Assess the amount of loss of hot condensate (flow measurement or assessment of blow-down %) use steam tables to assess % flashed to steam, and to assess the amount of energy lost as steam

Effect of too High TDS in the Boiler



Calculating Boiler Blow-down

$$\% \, BD = \frac{A}{(B - A)} * 100$$

A = ppm impurities in feed-water

B = ppm allowed in boiler

Assess Blow-down flow

- Calculate the percentage of blow-down for a boiler that has an allowable limit of 3500 ppm of impurities and uses feed-water with 150 ppm of impurities.

A = 150 ppm

B = 3500 ppm

$$\%BD = \frac{150}{3500 - 150} \times 100 = 4.5\%$$

Flash Steam

- When a hot pressurized liquid is placed in a tank with lower pressure, some "flash steam" will form as the enthalpy of the saturated liquid is reduced.
- This phenomenon is sometimes a major loss to the steam system (8 Bar(g) blow-down going to an unpressurized vessel will produce significant atmospheric pressure steam which is worthless and thus is a loss).
- Lets look at the losses

Blow-down Calculation Example

- Calculate the % of flash steam generated by expanding saturated liquid from 8 bar to Atmosphere.

From steam tables:

Hf1 = 762.5 kJ/kg (10 bar liquid)

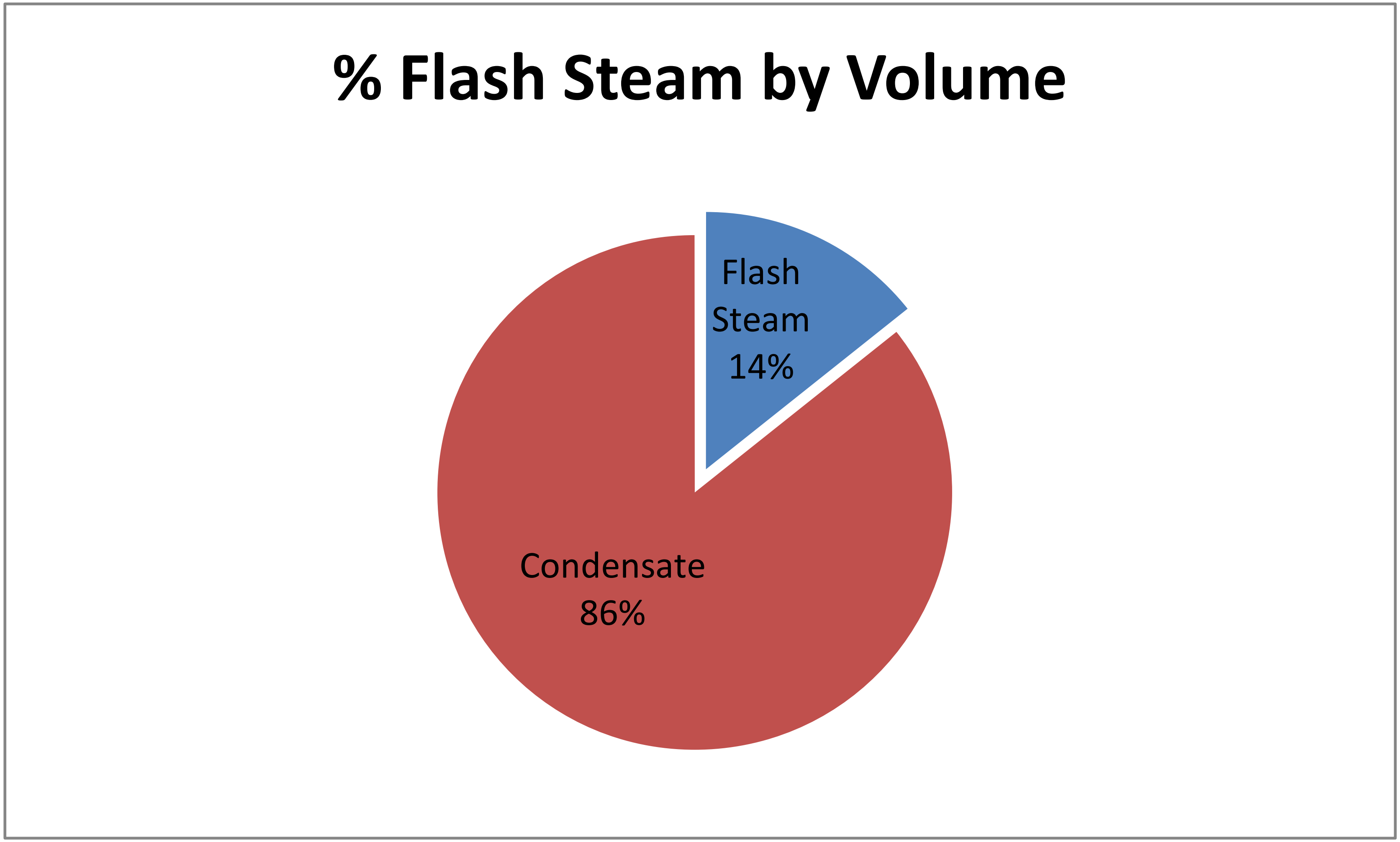
Hf2 = 419.5 kJ/kg (2 bar liquid)

Hfg2 = 2675.6 kJ/kg (bar liquid to vapor)

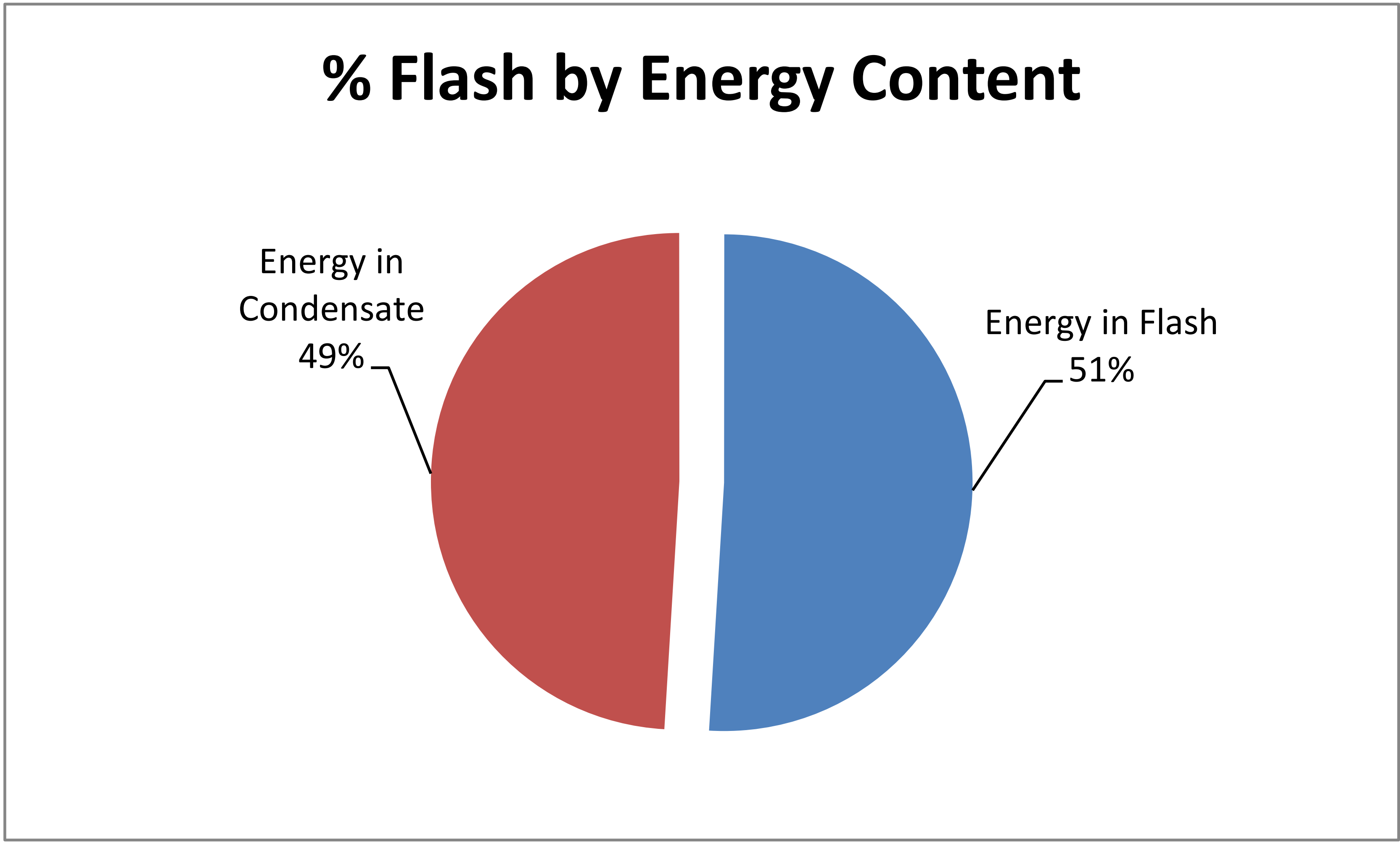
Hg2 = 3095.1

$$\% \text{ FLASH} = \frac{(762.5 - 419.5)}{2675.6} * 100 = 14.3\%$$

Approximate Amount of Flash Steam in Condensate



Approximate Amount of Energy in Condensate

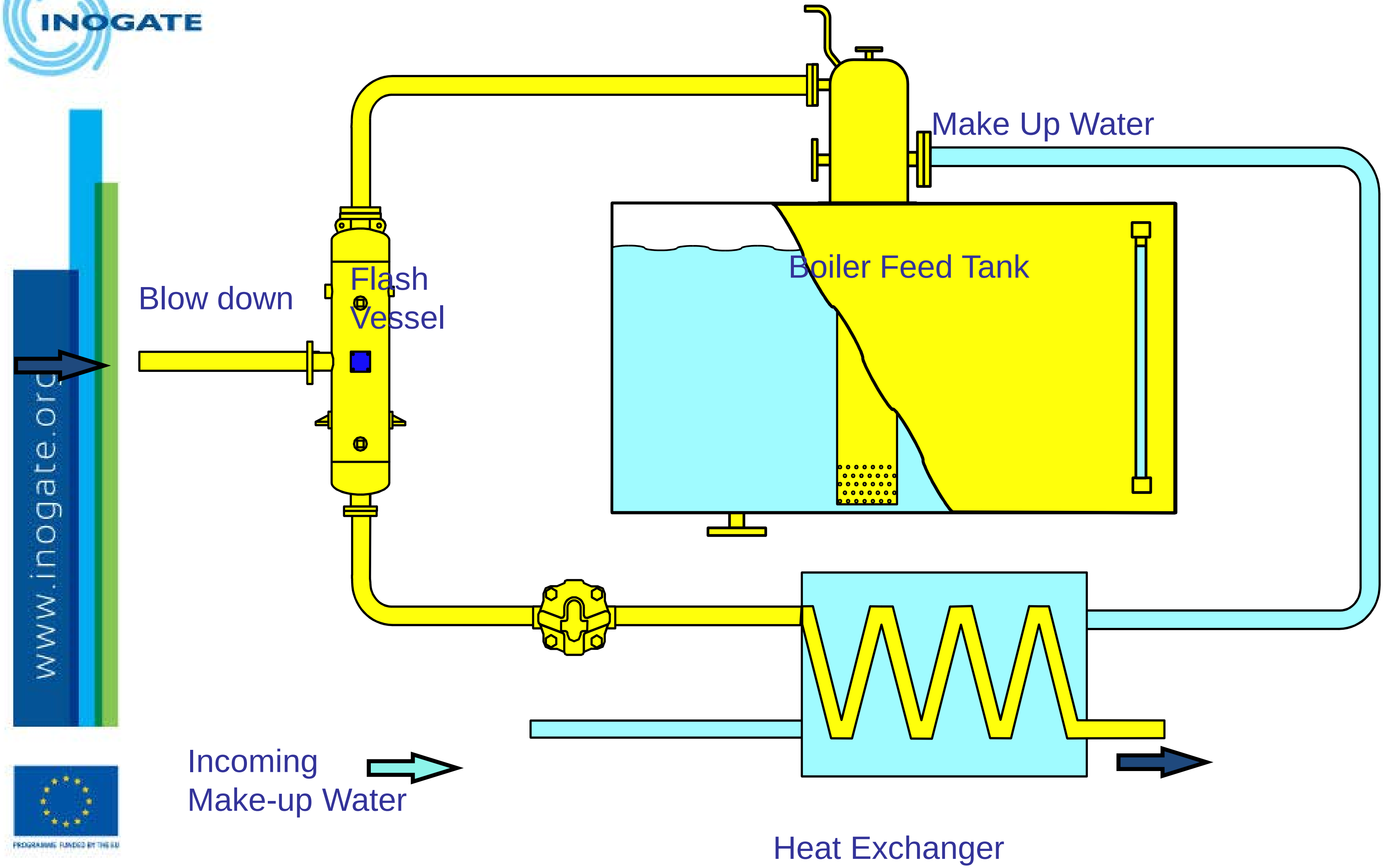


Flash Steam

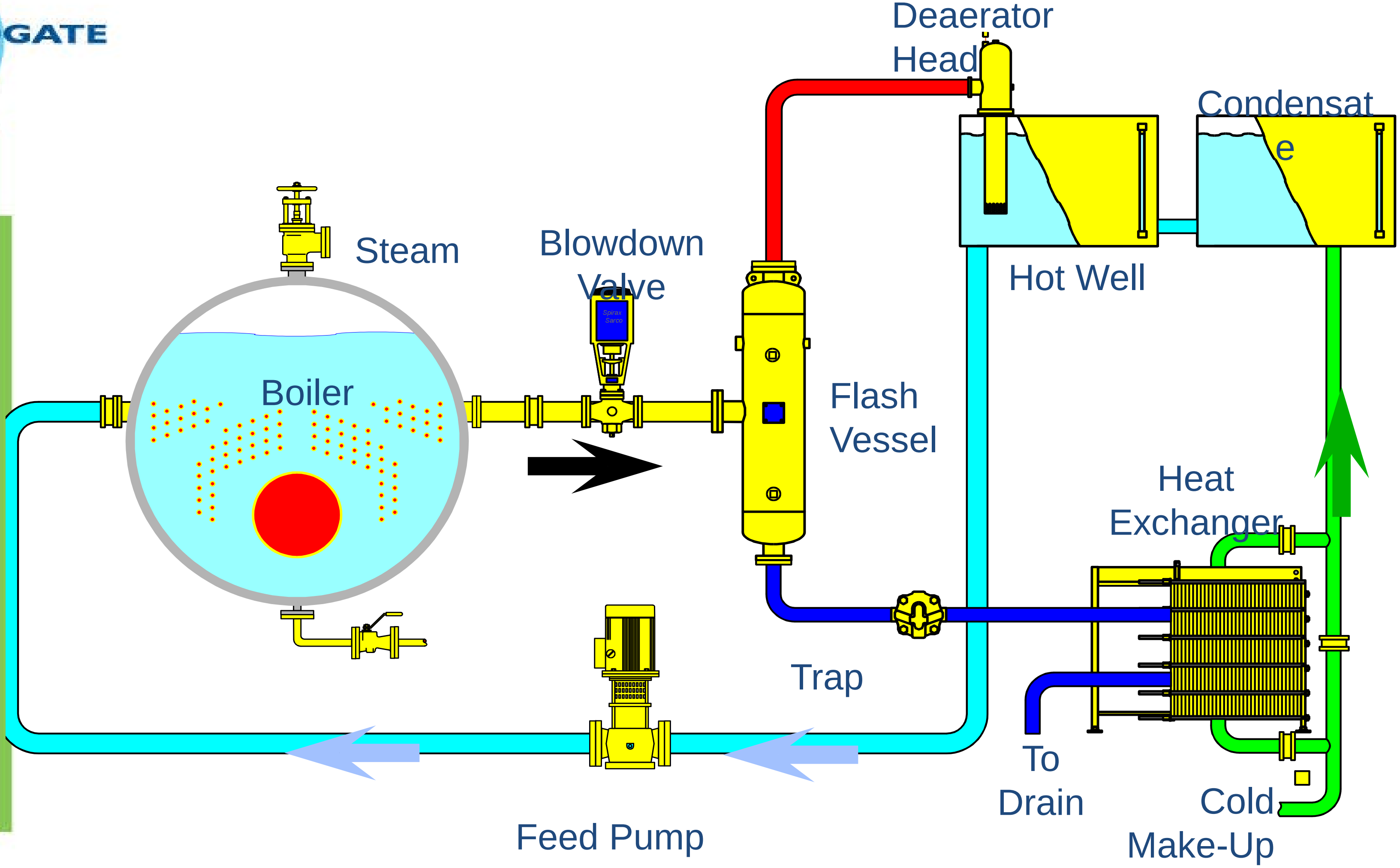
- Alternatively, the high-pressure liquid can be taken to a low pressure tank. The flash steam now has enough pressure to use, and inexpensive low-pressure steam is the result.

- Continuous top blow-down is an excellent source for this purpose and sometimes enough pressure is left in the condensate return to accomplish the same thing.

Using the Heat in the Water



Heat Recovery from Continuous Blow-down



Flash Steam

- Therefore we can save 51% of the blow-down lost by flash steam recovery, and then additionally we could save 70% of the heat in the condensate.

- 51% of 4.3% of the oil bill saved from flash steam

- 70% of 49% of 4.3% of the oil bill saved in condensate

Combined Heat and Power

Assessment of savings potential

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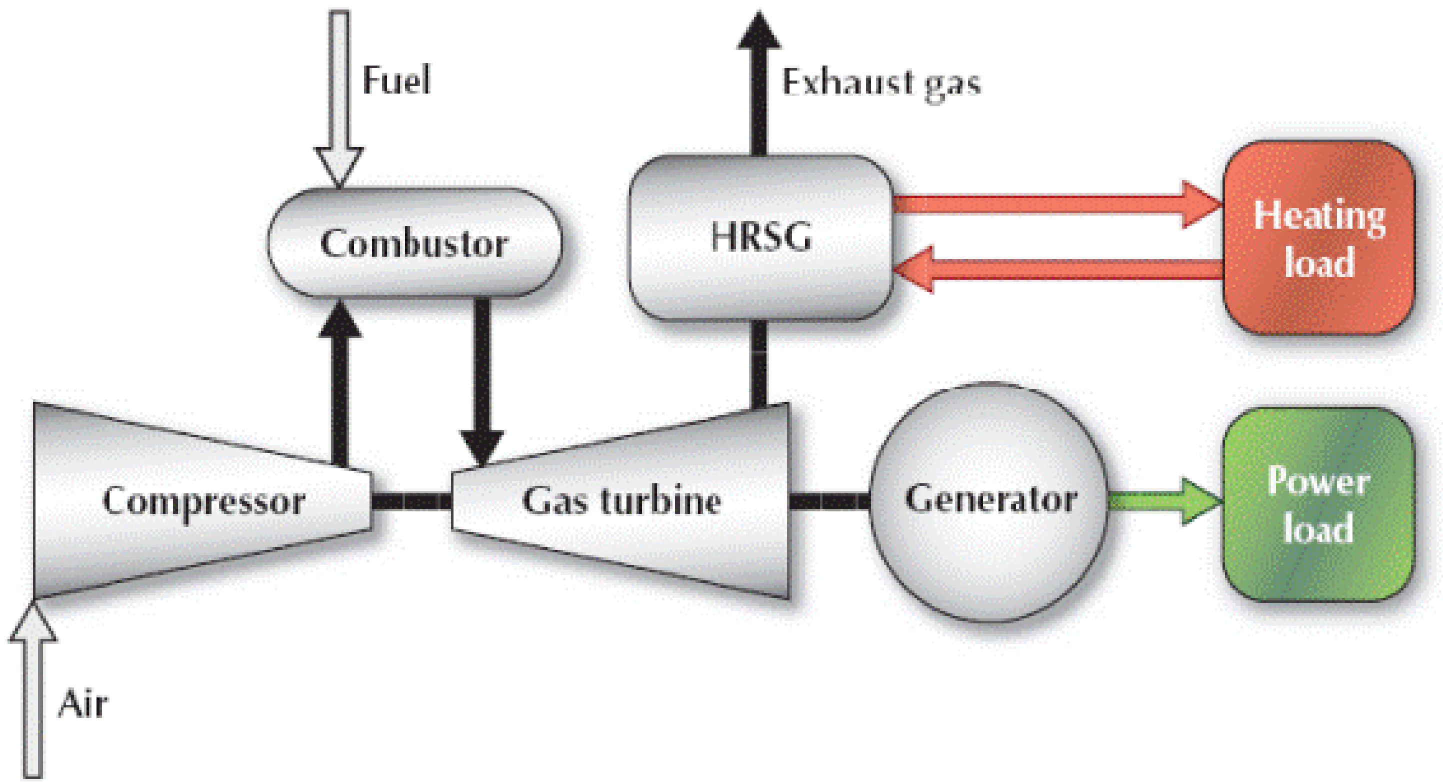
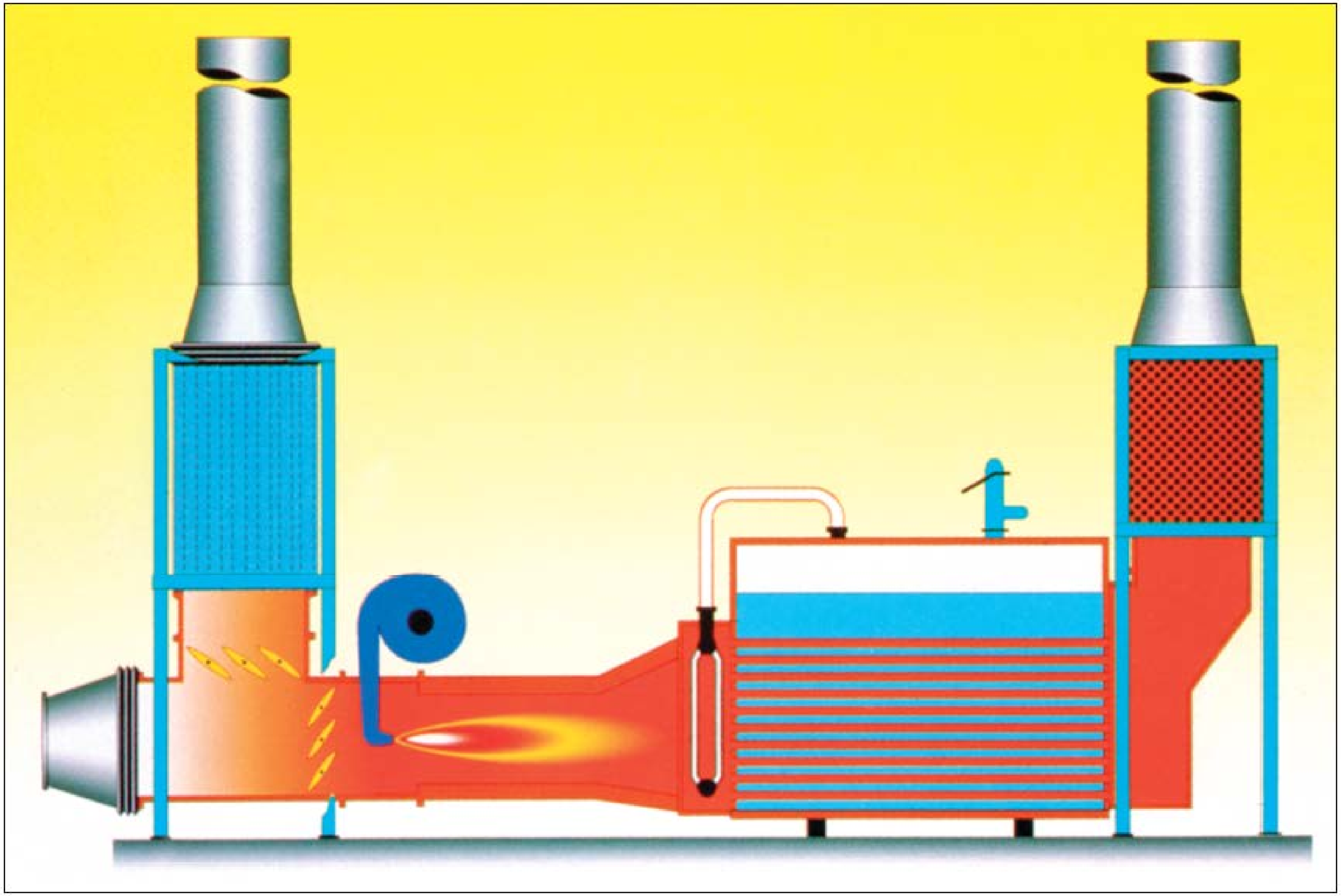
Identified Issue / Energy Wastage	Recommended Action	Comment	Assumptions used to identify savings
The ratio of thermal energy demand to electricity demand suggests that co-generation would reduce the cost of operation of the plant as the thermal and electrical demands may be delivered at lower cost and with the use of less primary energy	Consider installation of combined cycle CHP system	To be effective this requires that the vast majority of heat generated by CHP is used for a useful purpose, and that the cost of operating this system is less than what it would cause to burn oil in the boiler and take in electricity	Use a model for CHP that allows us to vary the cost of fuels and amount of heat used to calculate savings. Ensure we know the amount of actual steam required and electricity required on site to use as inputs to the model

CHP Arrangement

- Typical configuration for CHP turbine



Supplementary Firing



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Cost savings model

- Simple model that allows assessment of savings potential
- Note that supplementary firing makes the unit much more financially viable.
- Gas Turbine Model.xls

Ventilation – Reduce Air Change Per Hour

Assessment of savings potential

Identified Issue / Energy Wastage	Recommended Action	Comment	Assumptions used to identify savings
It has been identified that the flow of ventilation air in the facility is excessive and could be reduced for a portion of the time of the year	Select an appropriate mechanism to reduce the air flow (install variable speed drive)	Ensure that air flow is sufficient to meet the ventilation requirements of the facility. There may be legal constraints as to what is possible	Measure existing air flows and existing electrical consumption, Estimate savings based on a lower air flow that we think will be acceptable. Undertake a risk analysis to assess potential risk.

Cost of Ventilation

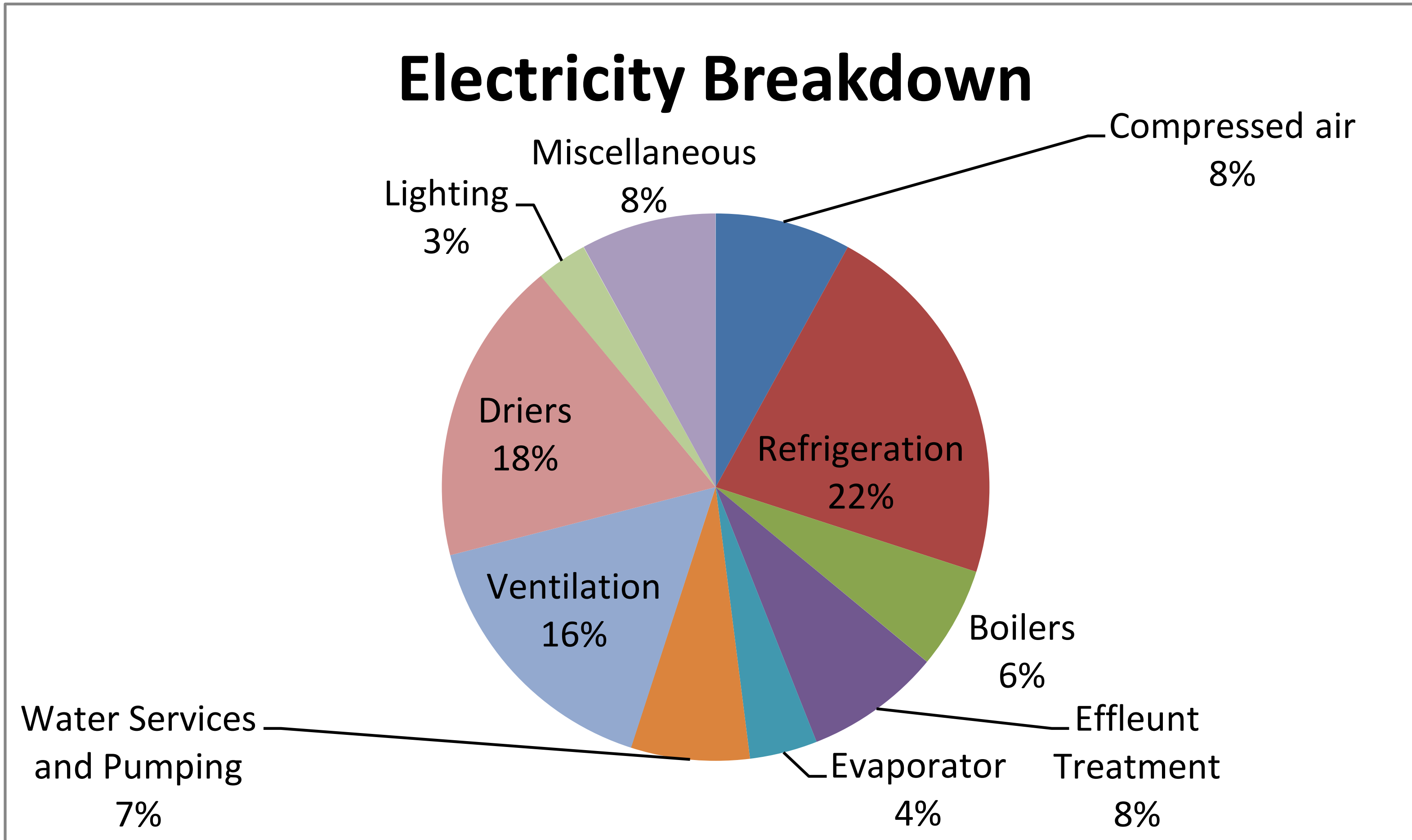
- We have already at an early stage identified the cost of ventilation to the organisation. (16% of electricity bill – excluding standing charges)

- The vast amount of ventilation is delivered using centrifugal type fans – therefore the affinity laws apply.

- Savings delivered can be large

$$Power \propto Flow^3$$

Electricity breakdown



Focus on savings that you can deliver

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- There is always a temptation to attempt to make large reductions but small reductions may be less likely to get traction with environmental and quality agents in the business

- 20% flow reduction delivers approximately 50% energy savings.

- If Motive power associated with 30 m^3/ hr is 50 kW, then what is motive power associated with 24 m^3/hr

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Pasteurisation – increasing plate surface area

Assessment of savings potential

Identified Issue / Energy Wastage	Recommended Action	Comment	Assumptions used to identify savings
Liquid milk from the heat recovery section in the pasteurisation could be brought closer to the required hot and cooled temperature by improving the heat exchanger effectiveness. Current situation leads to increased heat load and increased refrigeration load that could be eliminated	Increase heat exchanger surface area	Need to ensure that increased back pressure on the heat exchanger will not lead to reduced liquid flow or excessive pressure in heat exchanger causing seals to leak and cross contamination	Assess efficiency of heat recovery exchanger with different approach temperature

Improve approach temperature

- Liquid from storage at 4 degrees, needs to be heated to 72 degrees, then cooled to 4 degrees.
- Ideally the incoming liquid will be pre-heated by the exiting hot fluid, thereby pre-cooling the hot fluid and minimising the cooling load on the refrigeration plant.
- It was noted during the assessment that the cold liquid from the tank (4 deg) was being pre-heated to 60 degree by the pasteurised milk with a consistent reduction in temperature for the pre-cooled liquid load on the refrigeration section

Consider efficiency of the heat exchanger

- Milk start temperature 4 degrees
- Ideal temp leaving heat exchanger before added heat 72 degrees
- Actual temperature leaving 60 degrees
- Required temperature increase = 68 deg (A)
- Actual temp increase = 56 deg (B)
- Heat exchanger effectiveness

= (A-B)/A = 82.3% efficient

- Typically 94% achievable

Potential savings

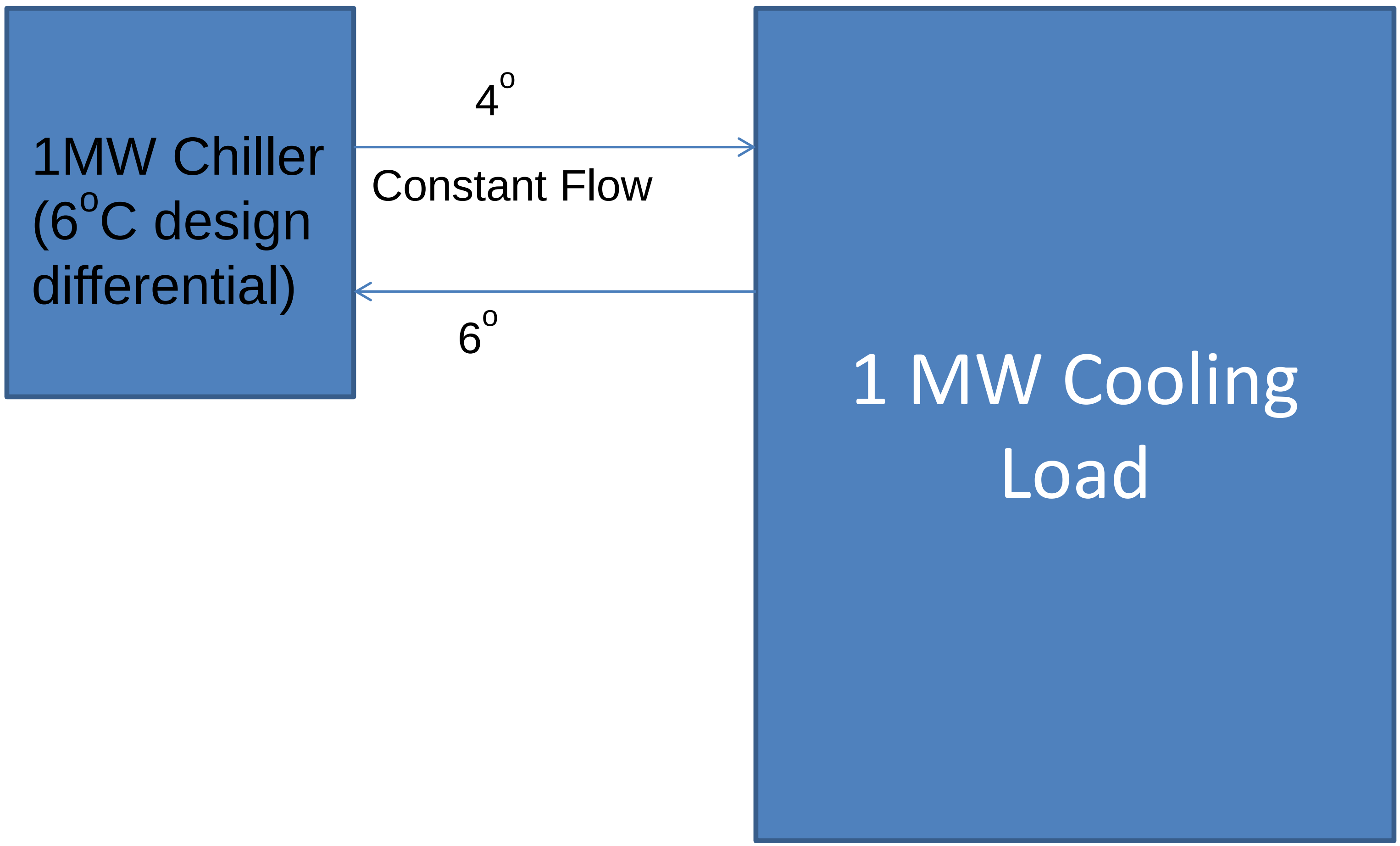
- By reducing the approach temperature (difference between heated fluid leaving and heating fluid entering) we improve the energy regenerated.
- % savings given by
- (New efficiency-old efficiency)/ new efficiency
- So savings here of (94-82.3)/94
- Or 12.4%   (of heating energy and cooling energy for pasteurisation

Driers – Flow control on refrigeration Hydraulics

Assessment of savings potential

Identified Issue / Energy Wastage	Recommended Action	Comment	Assumptions used to identify savings
It has been found that more refrigeration plants are in operation than would appear to be required due to thermal demands of the site. The reason is due to excessive hydraulic flow on the chilled water, meaning lower ΔT on the chillers causing reduced cooling capacity	Balance primary and secondary flow loops by either reducing secondary flow or optimising primary flow to this requirement.	This can lead to significant energy savings by shutting down existing chiller plant leading to energy savings, operational savings and maintenance savings. With modifying the flow driver (pumps) there may be pressure changes in the system and this may lead to the requirement to install pressure independent control valves	Assess savings based on existing cooling loads, existing electrical loads on chillers and using the chiller manufacturers data to assess the savings potential with an increased load on less chiller plant and chiller plant shut down

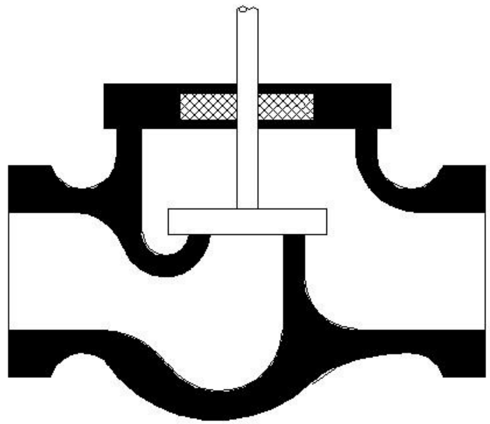
How many Chillers Required?

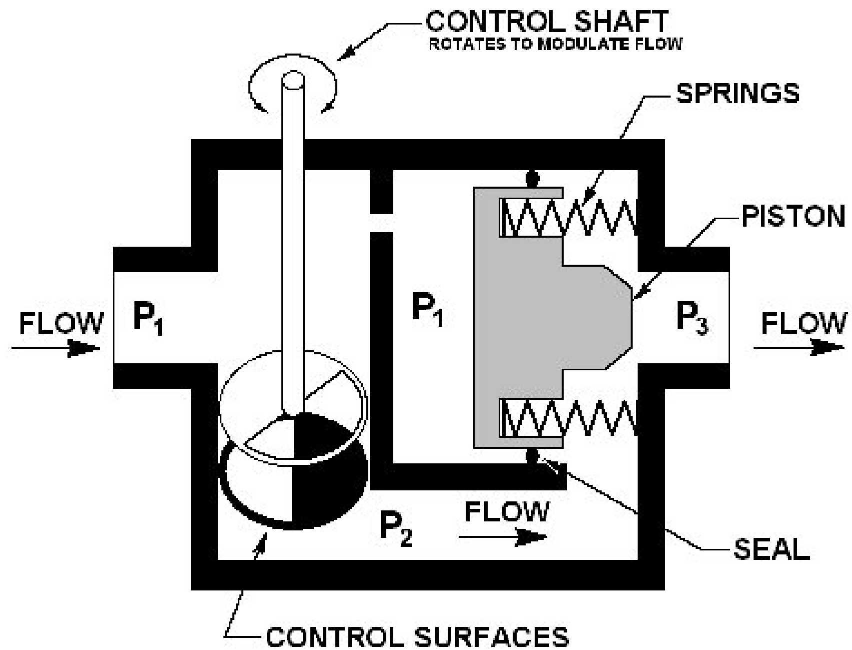


Always look at hydraulic flow

- Before attempting to improve chiller plant performance always look at hydraulic flow.
- Improvement in this will allow large additional chillers to be shut down.
- Approach
  - Shut down multiple bypass lines
  - Install valves to shut off areas when cooling load disconnected
  - Reduce pressure set point on distribution circuits
  - Cooling Requirement kW = 4.2 * LPS * ΔT

New Technology Approach





Coil and valve flow varies with pressure

$$Q = Kvs\sqrt{\Delta P}$$

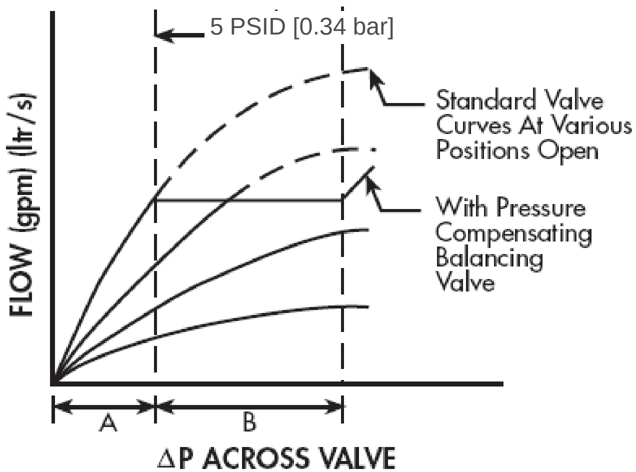
(ΔP Varies)

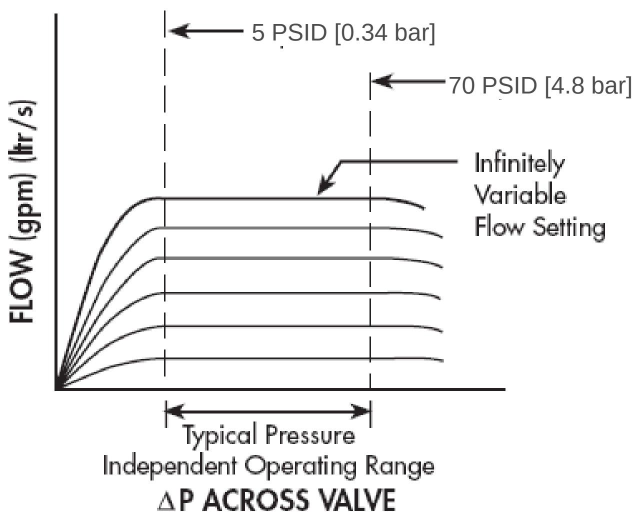
Coil and valve flow does not vary with pressure because P1-P2 is held constant

$$Q = Kvs\sqrt{\Delta P}$$

(ΔP Constant)

Pressure Independent Operation





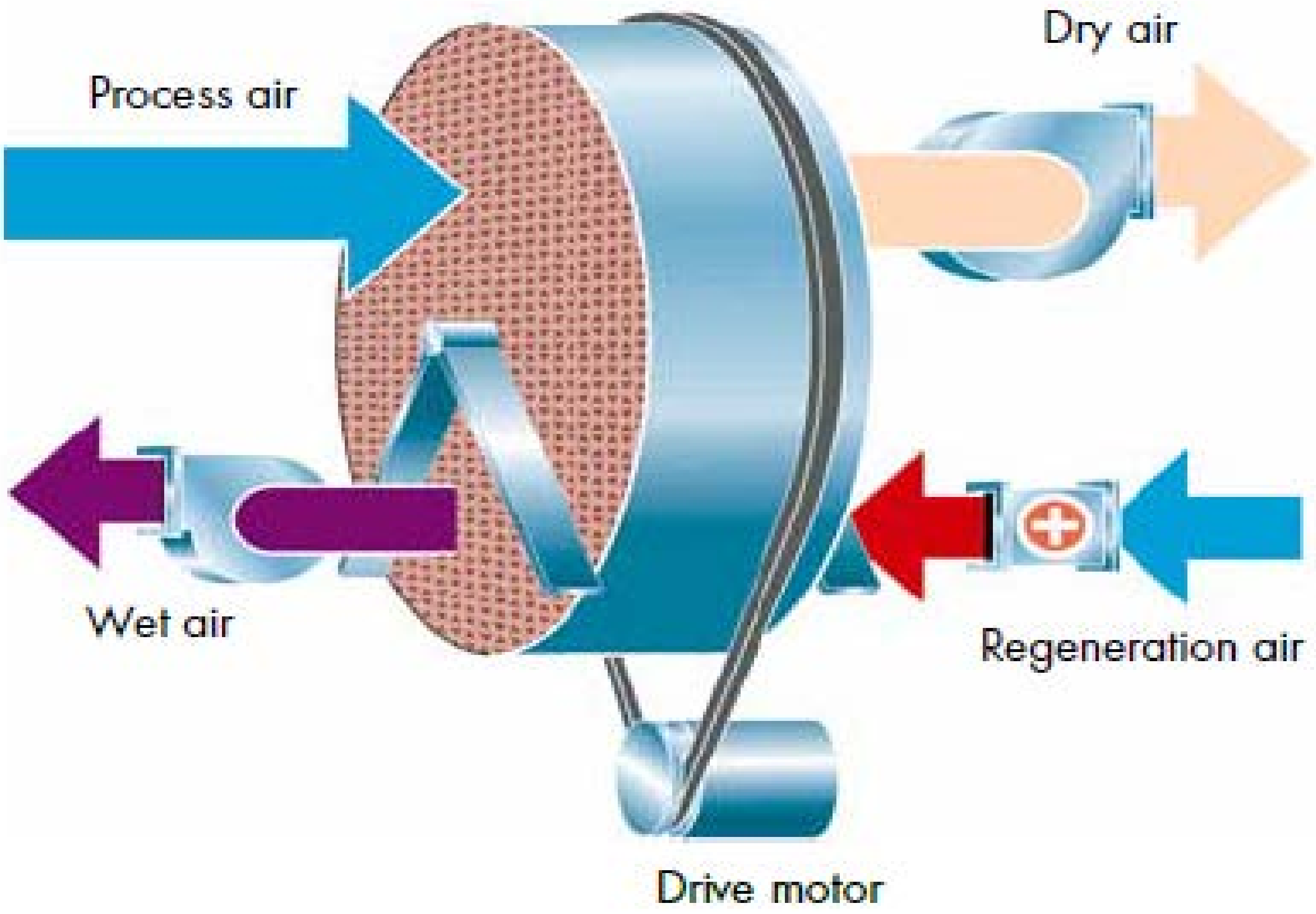
- Conventional Control
  - Flow will vary as system pressure changes
  - Typical sizing results in oversized valves
  - Balancing valves limit flow and add pressure drop
- Pressure Independent
  - Flow remains constant despite pressure changes
  - Sized by flow only
  - No balancing required, even with expansions or changes

Driers – Pre-Drying incoming Air

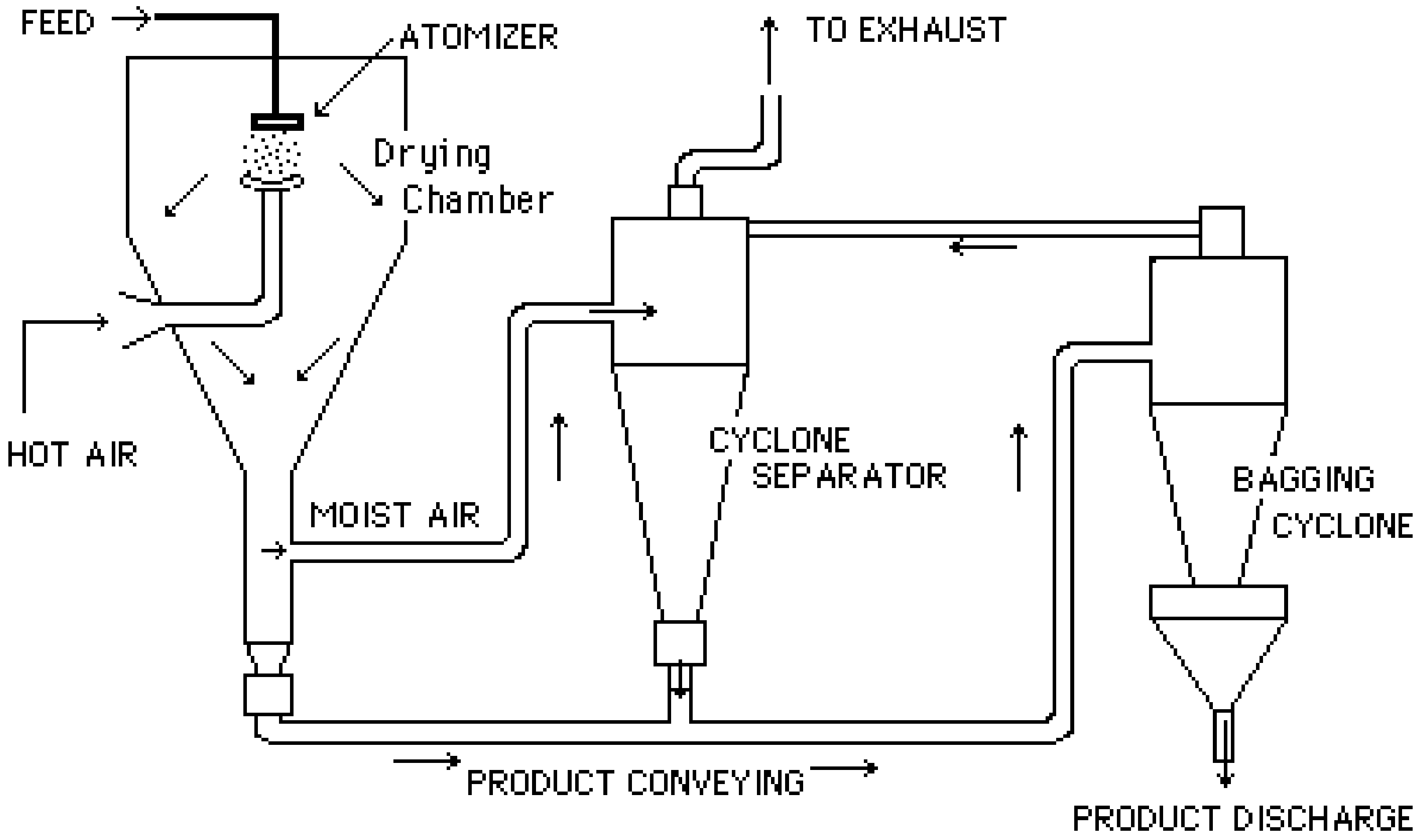
Assessment of savings potential

Identified Issue / Energy Wastage	Recommended Action	Comment	Assumptions used to identify savings
There is an opportunity to remove the humidity from the incoming air to the drier using an desiccant de-humidification wheel, this would give more moisture pick up in the drier allowing either reduced air flow or increased product through-put and therefore improved drier efficiency	Install desiccant wheel	This is actually a counter-intuitive approach that leads to increased energy use normally but increased production throughput	Savings based on shutting down additional driers by increasing production capacity on a single drier.

How a desiccant wheel works



Spray Dryer


FEED
ATOMIZER
TO EXHAUST
Drying
Chamber
HOT AIR
MOIST AIR
CYCLONE
SEPARATOR
BAGGING
CYCLONE
PRODUCT CONVEYING
PRODUCT DISCHARGE

Spray Drier action

- The trick here is to use the desiccant wheel to pre-dry the incoming air to the spray drier.
- It means that the drier will use a slightly higher amount of energy (to operate the desiccant regeneration wheel)
- The cost of operation of this is the cost of evaporation of the water that is collected from the drying of the air.
- 40% reduction in drying energy per Tonne of product dried

Questions/ comments?

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