Cold Process & Refrigeration Integration

IBD Midlands Section Engineering Symposium on Engineering Design & Sustainability

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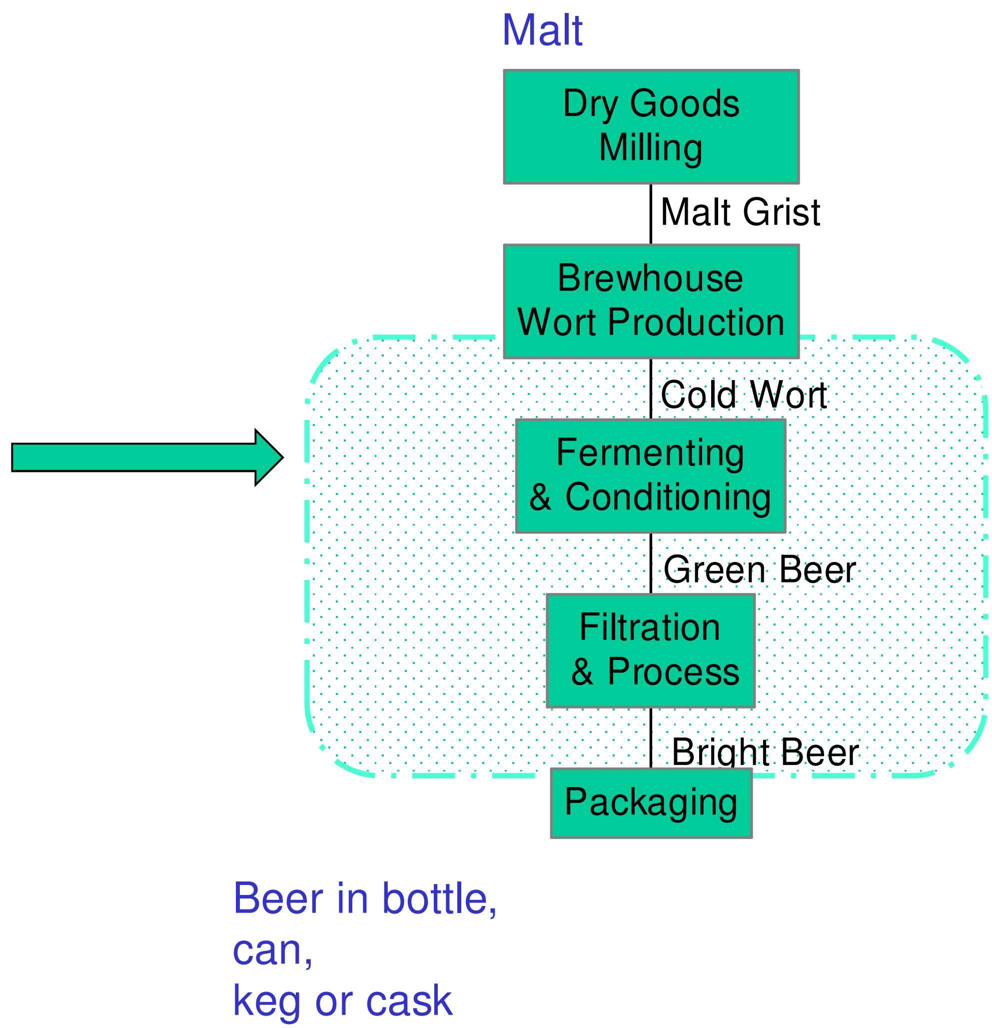
Cold Process & Refrigeration Integration

- Overview of the brewery cold process
- Technology review for key process steps
- Identification of refrigeration duties & reasons to chill
- Refrigerant selection
- Overall refrigeration system design
- Summary

Brewery Cold Process

- Brewery Block Flow Diagram
- Brewery Cold Process
  - Fermenting & Conditioning
  - Filtration & Process



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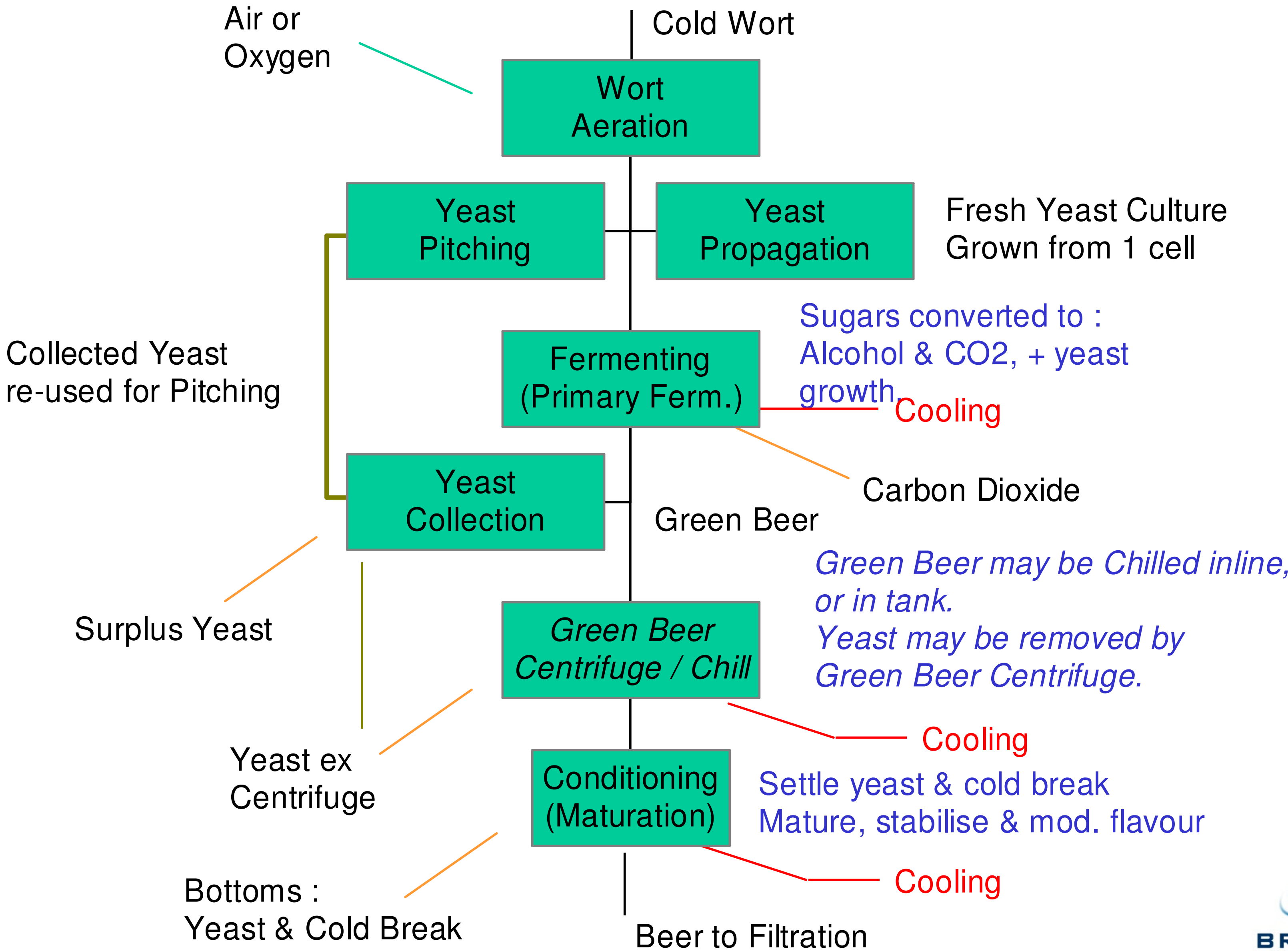
Fermenting & Conditioning - Process Flow



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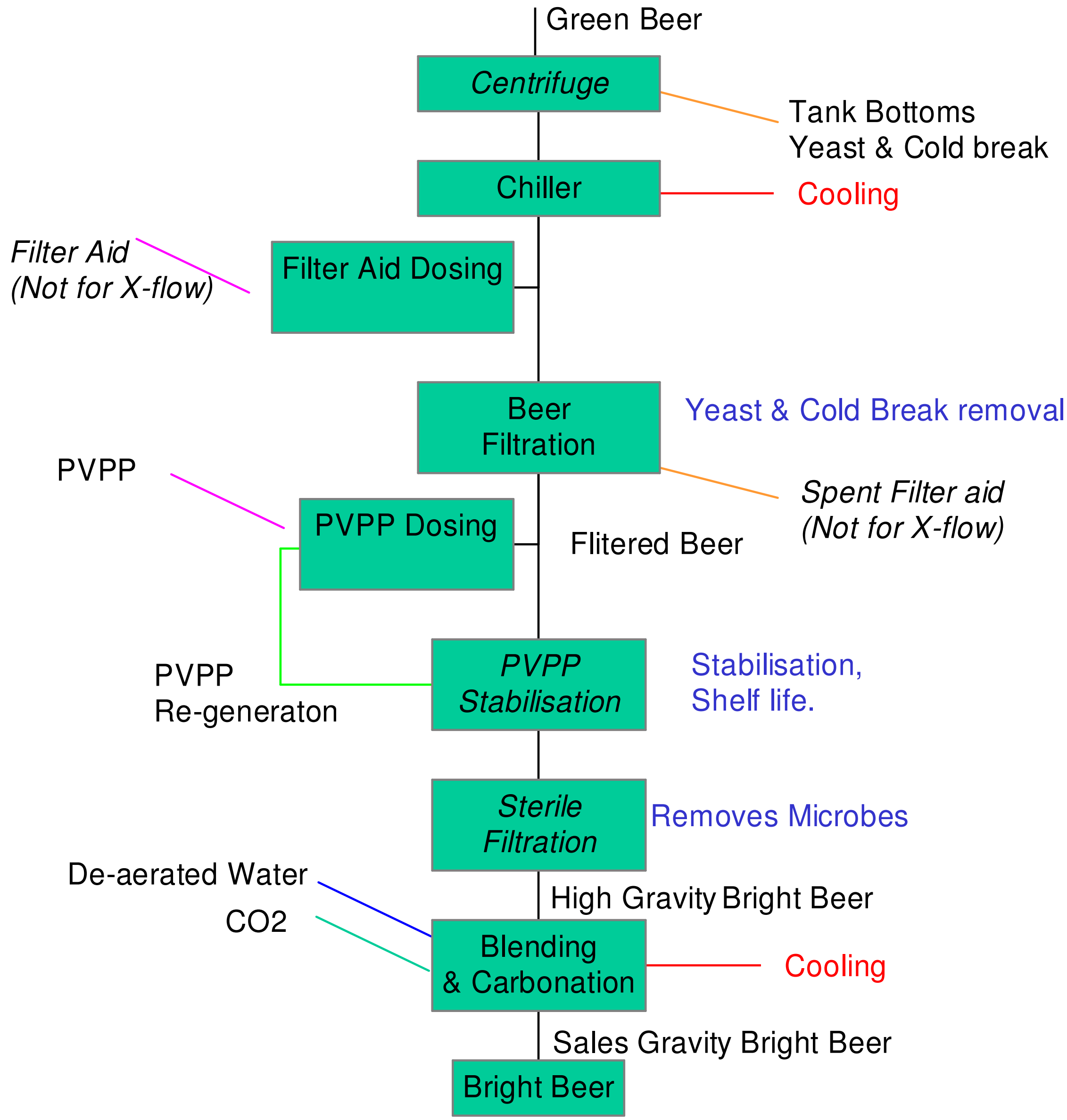
Filtration & Process – Process Flow



Identification of refrigeration duties

- Key locations requiring refrigeration & reasons to chill:
  - Yeast = Maintaining yeast viability & vitality
    - Propagation system – Vessel cooling
    - Collection system – Vessel cooling
  - Fermentation/Storage = Control of fermentation profile
    - Temperature control of fermentation profile – Vessel/HEX
    - Rapid chill back – Vessel/HEX
    - Maturation - Vessel
  - Filtration & Blending = Improved filtration (preventing chill haze) & improving CO2 solubility
    - Chilled de-aerated blending water – HEX
    - Pre-filter – HEX
  - Bright beer Tanks = maintenance of product quality and packaging efficiency
    - Storage – Vessel Cooling

Technology Review - Yeast

- Propagation
  - Wort must be sterile prior to propagation
  - Take off wort from hot side of wort cooler
    - Raise to sterilisation temperature in vessel using external jackets, followed by cooling via jackets – energy intensive
  - Take off wort on cold side of wort cooler
    - Flash pasteurise into sterile vessel
    - Flash pasteurising is described in following slides but 93-95% recovery
- Yeast management
  - Consider temperature shock, refrigerant temperature not too cold
  - If yeast collected from high gravity brewing = high alcohol content which must be blended down with water to maintain yeast viability

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Brewery Yeast Propagation & Storage
NY, USA

- Two-stage 'rapid' yeast propagation - lab. scale to full fermenter pitching scale
- Pure oxygen fed to accurate flow profile for increased biomass & cell viability
- Stage 1 vessel - 7 hl working capacity
- Stage 2 vessel - 94 hl working capacity
- Cropped yeast storage vessels, 1 x 30 hl & 2 x 60 hl
- Dedicated single-use CIP set
- Steam-in-place of vessels & pipework
- Fully automated, repeatable oxygenation, temperature

  & agitation profile

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Brewery Yeast Propagation & Storage VA, USA

- Two-stage ‘rapid’ yeast propagation from laboratory scale to full fermenter pitching scale
- Stage 1 vessel – 16 hl working volume
- Stage 2 vessel – 260 hl working volume
- Designed, installed & commissioned as part of brand new brewery
- Up to 220 million cells/ml within 48 hours from stage one inoculation up to end of stage two growth stage
- Pure oxygen fed to an accurate flow profile leading to increased biomass & cell viability >98%.
- High viability yeast suitable for pitching into production wort volumes, with representative high quality & good yeast growth during production

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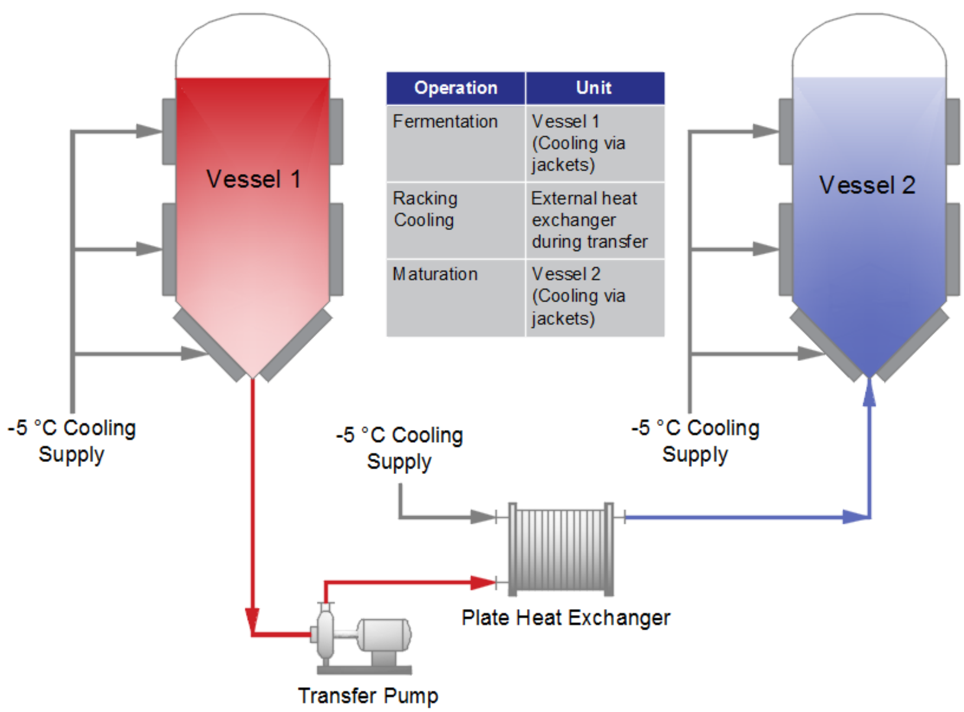
Technology Review - Fermenting and storage methods

- Separate Tanks
  - Separate fermentation and maturation vessels
    - DPVs or dedicated FVs & CTs



Operation	Unit
Fermentation	Vessel 1 (Cooling via jackets)
Racking Cooling	External heat exchanger during transfer
Maturation	Vessel 2 (Cooling via jackets)

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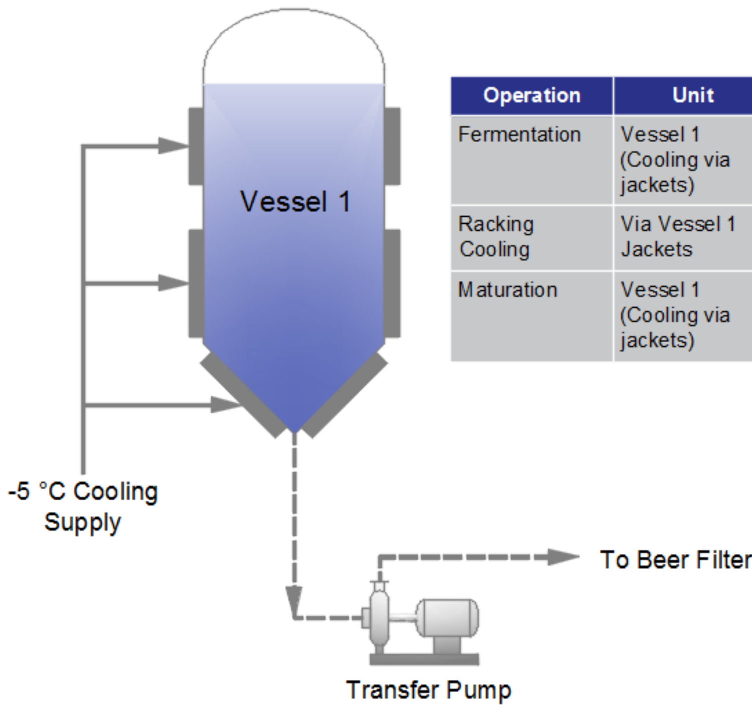
Technology Review - Fermenting and storage methods

- Unitank
  - Single vessel only



Operation	Unit
Fermentation	Vessel 1 (Cooling via jackets)
Racking Cooling	Via Vessel 1 Jackets
Maturation	Vessel 1 (Cooling via jackets)

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FVs / DPVs - Limpet Coil Jackets

- Continuous spiral
- Defined flow path
- Ideal for secondary refrigerant – e.g. Glycol
- Also used for Primary refrigerant – e.g. NH_3

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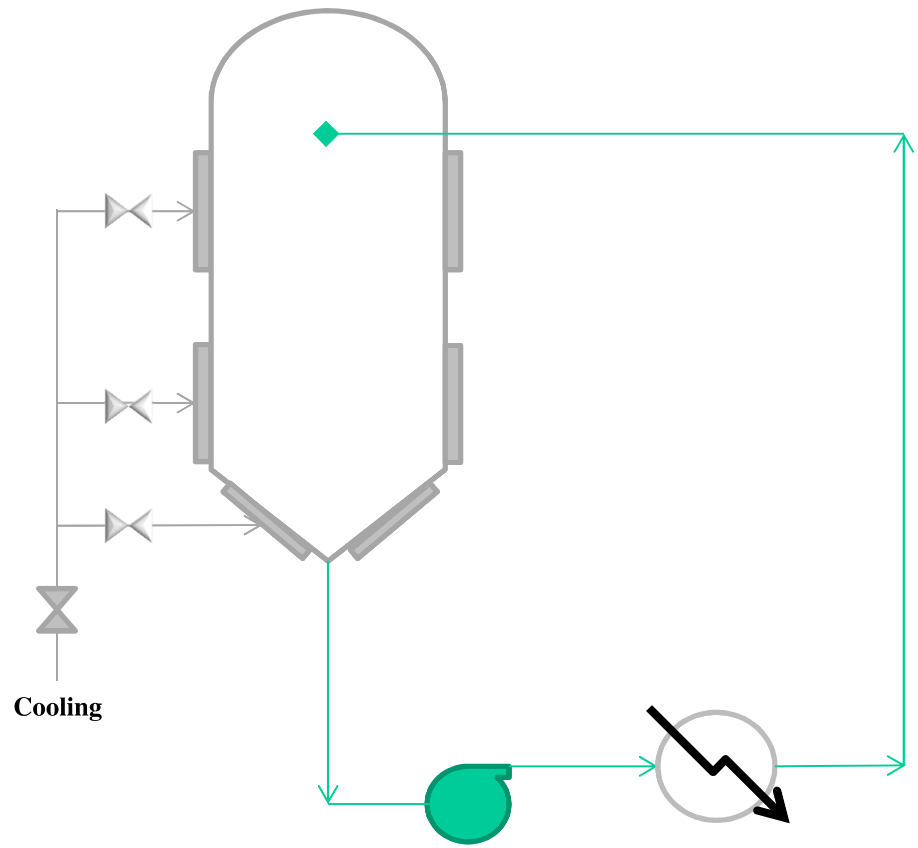
External Chilling & Dynamic Mixing

- Advantages
  - Removes limitation of jacket surface area, especially important on large vessels
  - Increased surface area and so decreased chill back time
  - Enables vessel agitation so decreased fermentation time
  - Reduced jacket area which can save costs



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Technology Review – Beer Filters

- Filtration options
  - DE vs membrane
  - Types of membrane system
    - Pre-Filter Centrifuge?
    - Batch
    - Continuous
- Stabilisation options
  - Single use / total loss - Silica gel or PVPP
  - Conventional Regen PVPP
  - Modular / continuous PVPP

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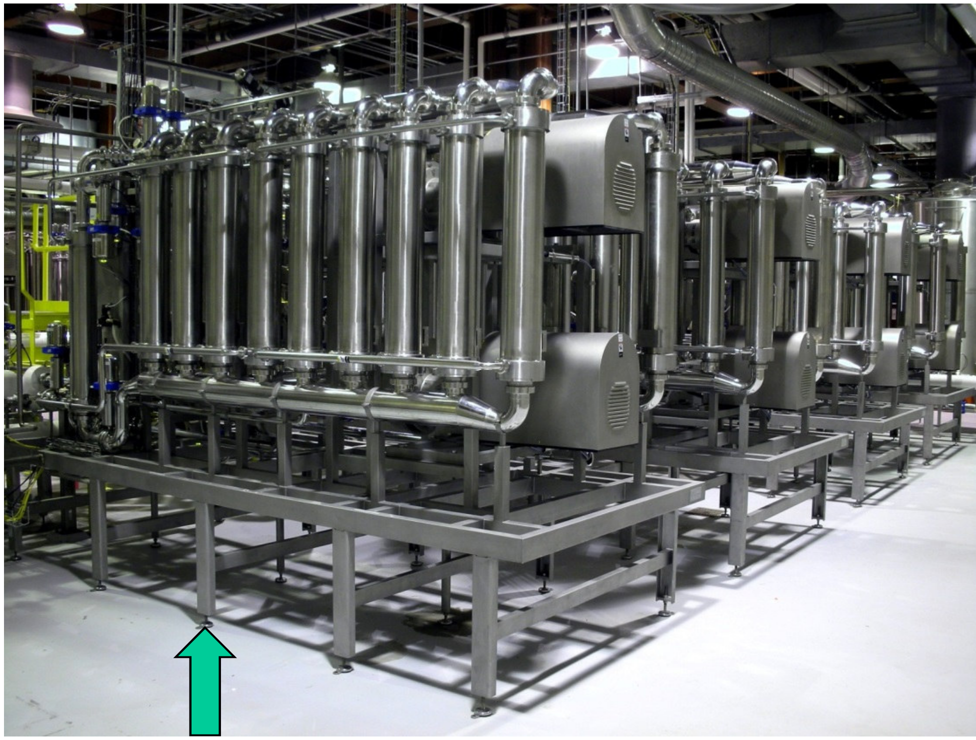
Membrane Filtration



- 470 hl/h Membrane Filter Stream
- One of 2 streams installed in 2007
- Pall Membrane technology
- Continuous system

- 400 hl/h Membrane Filter Stream
- One of 2 streams installed in 2015
- Pentair Membrane technology
- Batch system

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Membrane Filtration vs DE

Filter Media	• Lower cost than DE	10 – 30%
Electrical Energy Cost	• Comparable to DE • 0.3 –0.6 kWh	
Thermal Energy Cost	• Lower than DE	60 – 75%
Water Consumption	• Lower than DE • Water consumption < 0.15 hl/hl beer	25-40%
Manpower	• Lower than DE	80%
Disposal Cost	• Lower than DE	>95%
Service Cost	• Lower than DE	30 –50%

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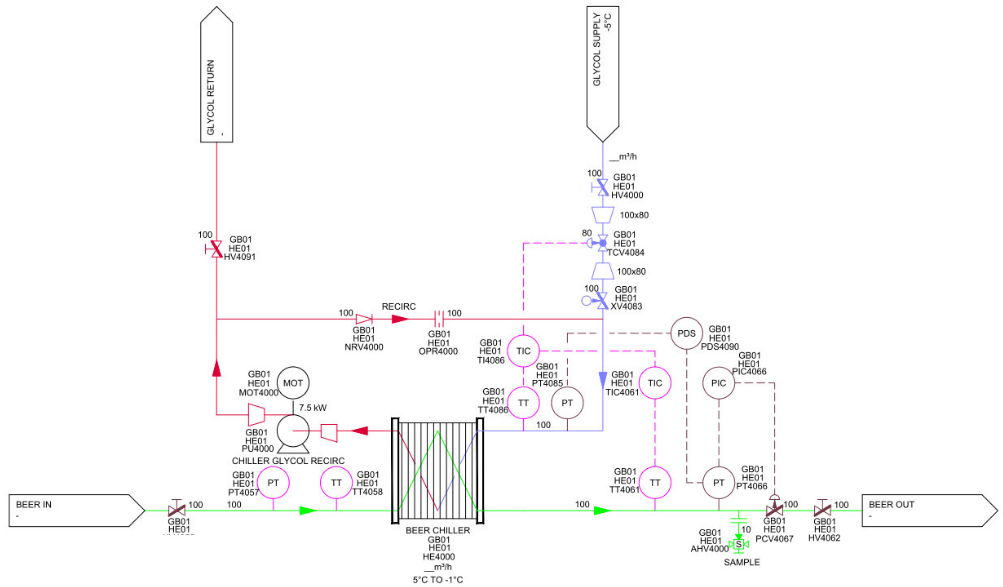
Heat Exchange – Beer Chiller

- Plate Heat Exchanger
  - Single stage
- Secondary refrigerant
  - Beer pressure > coolant
  - Coolant Recirculation
    - Minimises freezing risk
    - Stabilises temperature control



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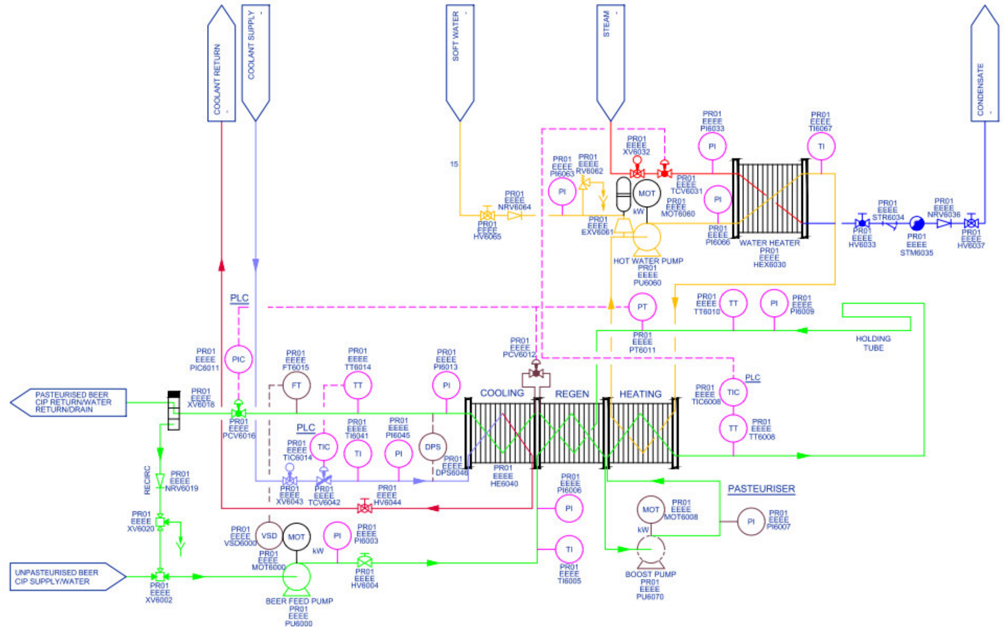
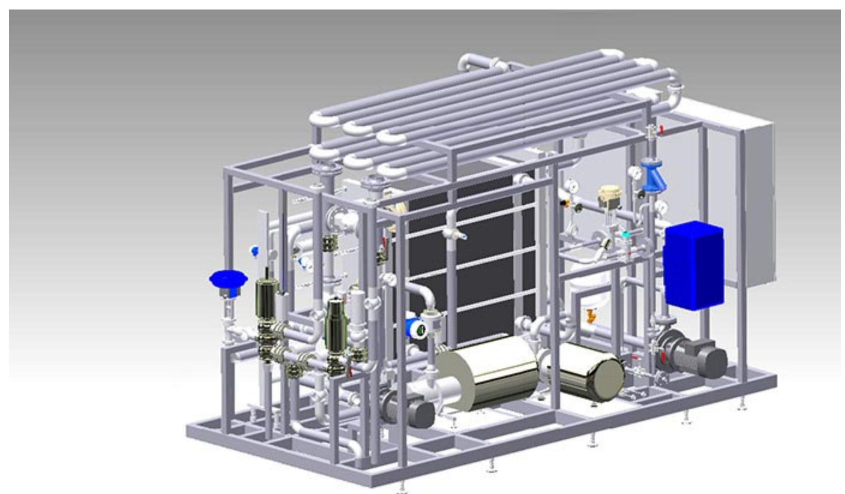
Heat Exchange – Flash Pasteuriser

- Plate Heat Exchanger
  - Multi stage unit
  - Regeneration > 93%
  - Hot water heating
- Holding tubes
  - Thermal stabilisation
  - PUs related to temperature and time
- Boost pump
  - pasteurised beer at higher pressure than unpasteurised





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Technology Review – DAW Systems

- DAW generation technology
  - N2 vs CO2
  - Hot or cold
  - Gas stripping vs cross flow
- Choosing a DAW storage temperature
  - Blending largest user
  - Hold at max temperature possible to achieve blended beer temperature to reduce energy loss
- Do you need to DAW flush?
  - If DAW not required used chilled water (e.g. yeast flushes)

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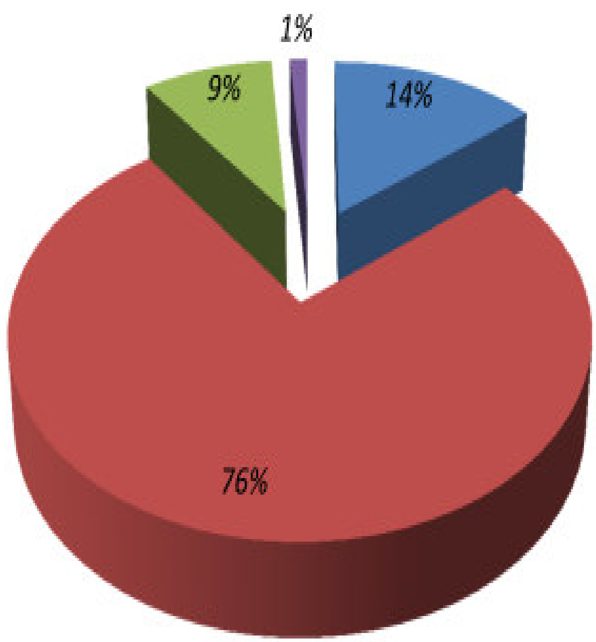
DAW Generation

- Cross flow DAW plant
- 950 hl/h capacity
- Centec Technology
- Installed 2015, UK

- CO2 Stripping DAW plant
- 300 hl/h capacity
- Alfa Laval, Aldox Technology
- Installed 2012 Uganda

Brewery Refrigeration Load

Mean Refrigeration Load Split



DESIGN BASIS FOR UNITANK COOLING (ENERGY BALANCE SPREADSHEET ("UNITANKS BS1 TAB")

		kW cooling required per step				
					2	Number of streams
						Vessels (per stream)
0	kW R	0	kW	2	1	Number of vessels filling
3728	kW R	117	kW	32	16	Number of vessels fermenting
1664	kW R	832	kW	2	1	Number of vessels Chilling Back
216	kW R	9	kW	24	12	Number of vessels Maturation
0	kW R	0	kW	2	1	Number of vessels Empty/CIP
5608	kW R			62	31	Total (@4200 HL unitank size)
4	CoP			1402.0	701	kW of electricity

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Refrigerant Selection

- Refrigerant options:
  - Primary
    - R717 - Ammonia
    - R134a – 1,1,1,2 Tetrafluoroethane
  - Secondary
    - Water
    - IMS
    - Glycol
    - Brine
- Refrigeration choice depends on:
  - Process requirements
  - Temperature required
  - Safety
  - Existing site capability

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Refrigerant Selection

- Water
  - Pro's
    - Safe
    - Energy can be transferred into the product (e.g. wort cooler used to heat process water for sparging)
    - Environmentally friendly
    - Can be buffered
  - Con's
    - Possible to freeze
    - Unable to be used at low temperatures
- Glycol
  - Pro's
    - Safe
    - Can be buffered
    - Can be used at lower temps to water
  - Con's
    - Increased pumping energy
    - If released into the environment can lead to high COD/BOD
    - Requires primary refrigerant (e.g. ammonia) to cool

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Refrigerant selection

- Brine
  - Pro's
    - Safe
    - Environmentally friendly
    - Easy to detect
    - Can be buffered
  - Con's
    - Corrosive (increased pipework spec required)
    - Requires primary refrigerant (e.g. ammonia) to cool
- Ammonia
  - Pro's
    - Efficient
      - Minimal pumping
      - Change of state
    - Single supply can offer multiple temperatures
  - Con's
    - Toxic but detectable at low levels
    - Difficult to buffer
    - High Pressure Storage, highly regulated
    - Widely used outside UK

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Typical Operating Temperatures

Operation	Ale	Lager	Stout
Ferment	18-22°C	10-12°C	20-24°C
Yeast Crop	10-12°C	4-6°C	N/A
Green Beer	10-12°C	1-3°C	3-4°C
Condition	N/A	-1.5°C +/- 1ºC	0ºC

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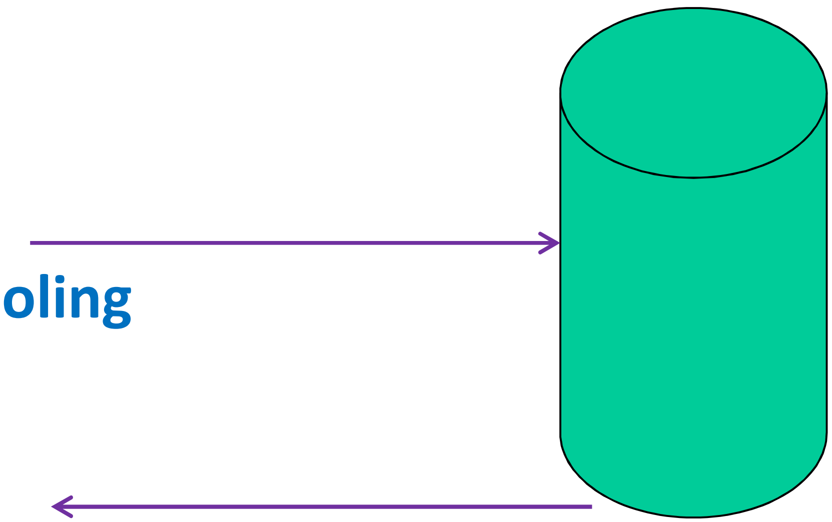
Overall Refrigeration system design

Primary



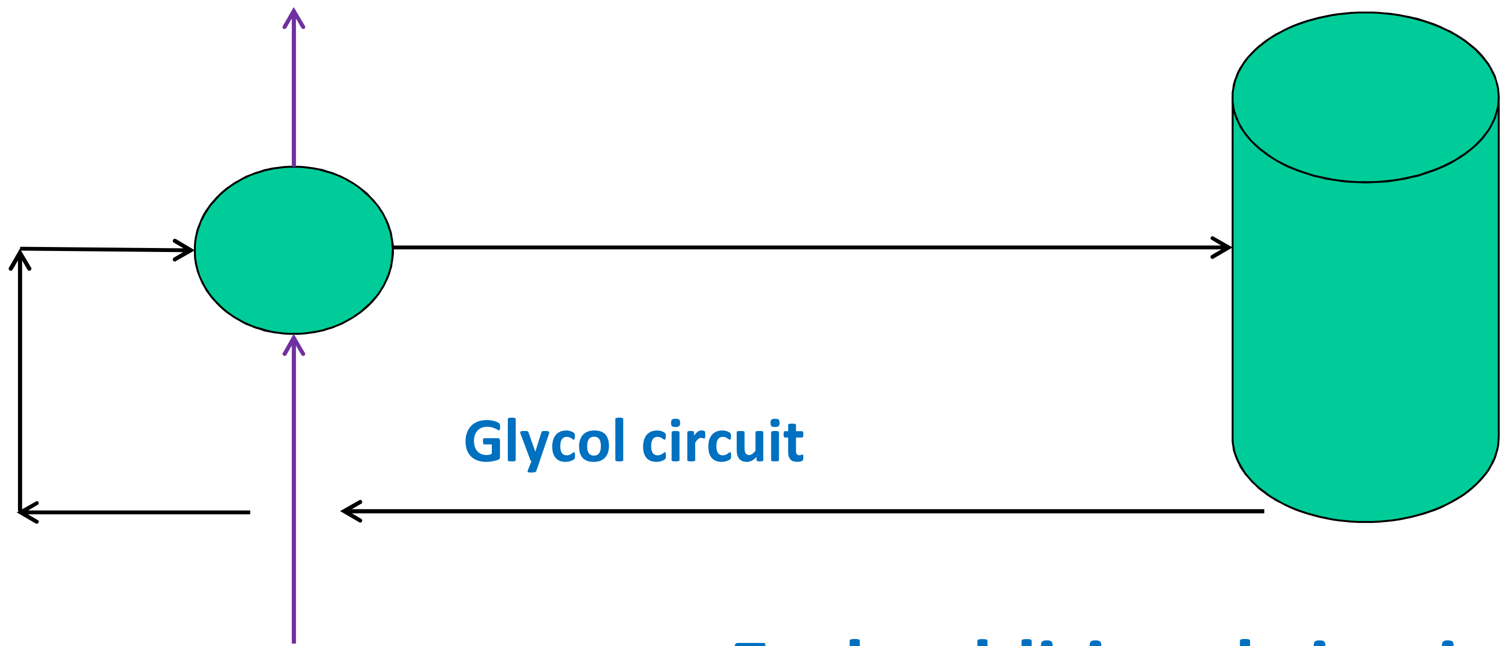
Direct expansion cooling on to vessel e.g. Ammonia

<u>Each additional circuit = loss in efficiency</u>

Overall Refrigeration system design

Primary

Secondary



Primary coolant
e.g. Ammonia

<u>Each additional circuit</u>
<u>= loss in efficiency</u>

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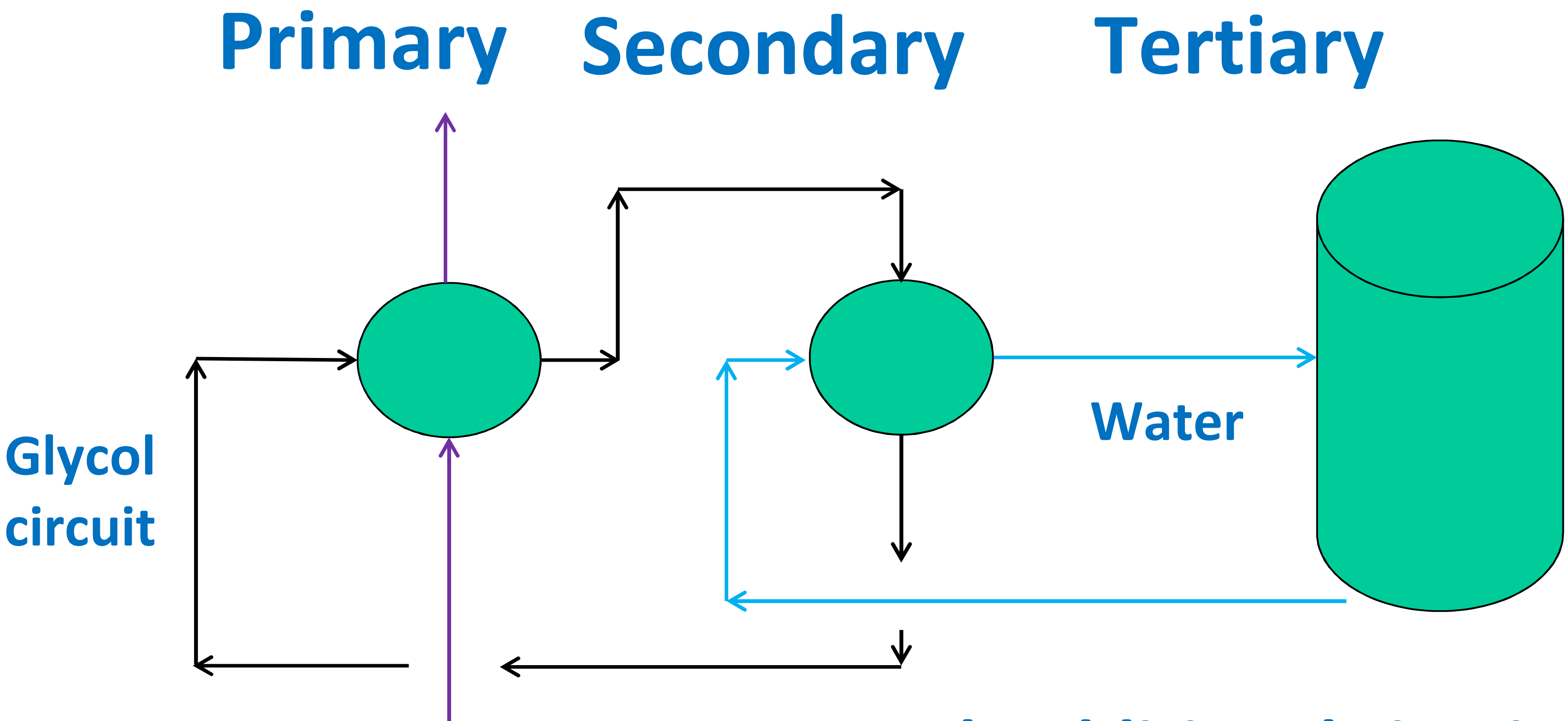
Overall Refrigeration system design



<u>Each additional circuit = loss in efficiency</u>

COP & Relative Refrigerant temperature

- **COP = Q/P**

Where:

Q = Refrigeration energy (kWr)

P = Power Input (kW)

<u>The Higher The Better</u>

Can be estimated typically:

$$C_f = \frac{T_e}{T_e - T_c}$$

Where:

$$C_f = Carnot\ Factor$$
$$T_e = \text{Evap Temp (K)}$$
$$T_c = Cond\ Temp\ (K)$$

COP = (0.5-0.7) C_f

Primary Fridge Circuit	Evap Temp °C	COP (Est)
1	10	6.2
2	5	5.0
3	0	4.1
4	-5	3.5

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Direct Expansion Refrigeration

- Indirect –
  - Glycol -5°C in
  - NH_3 – 10°C
- Direct –
  - NH_3 – 3°C in & out
- 20% reduction in refrigeration electrical power

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Heat Exchange - Close Approach

- $Q = U \times A \times \Delta T$
- Close approach = minimise ΔT
  - Higher Coolant Temp
  - Less refrigeration energy
  - Lower operational cost
- Higher UA needed
  - Greater surface area A
  - Greater capital cost

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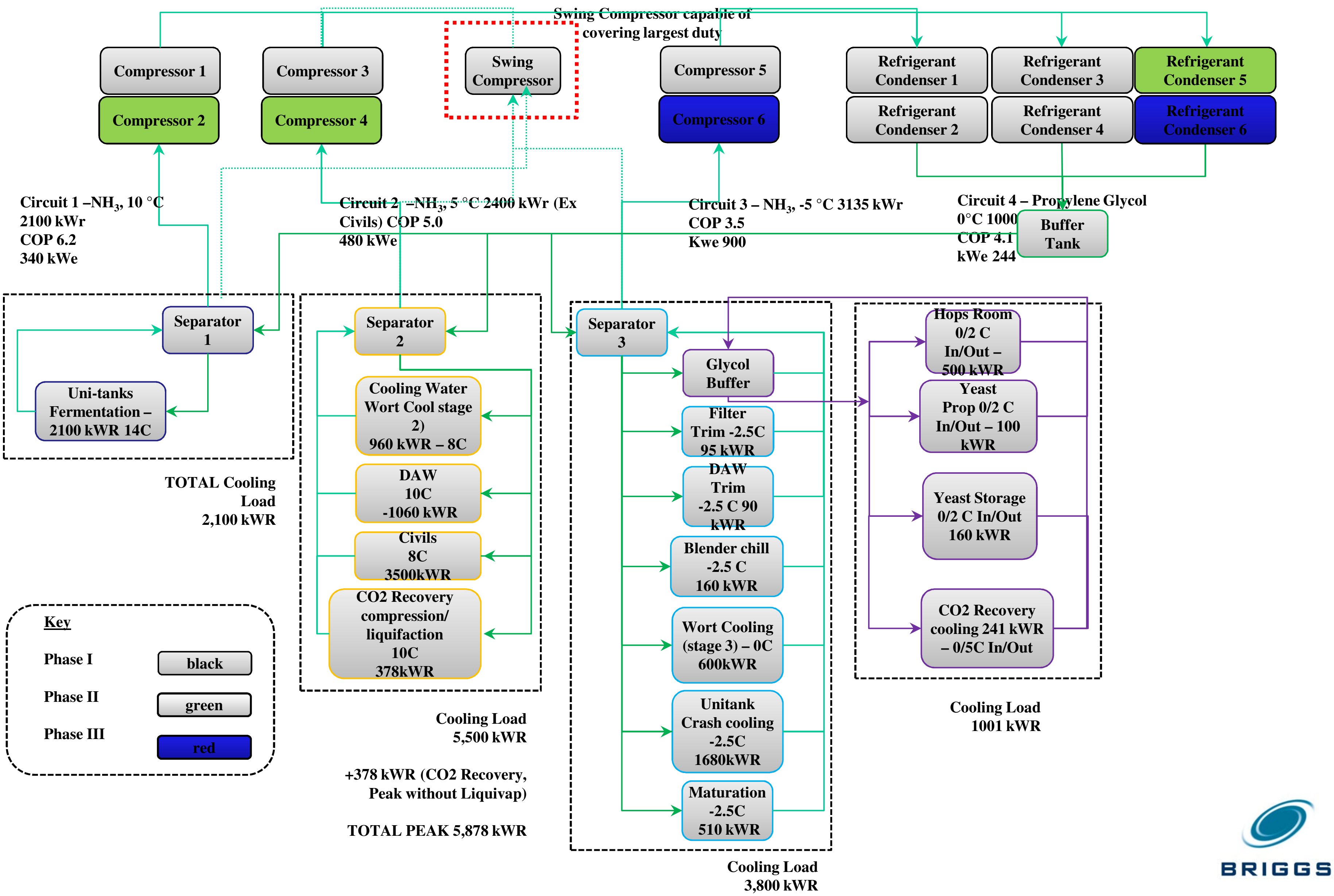
Refrigeration



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Summary

- Largest Energy Saving Opportunities in Tank Farm Operations
- Good Integration allows matching of Utilities with Process to maximise efficiency
- The search goes on for an efficient Non Toxic Primary Refrigerant

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