Optimization of Tank Cooling

Conor Leahy K00256286

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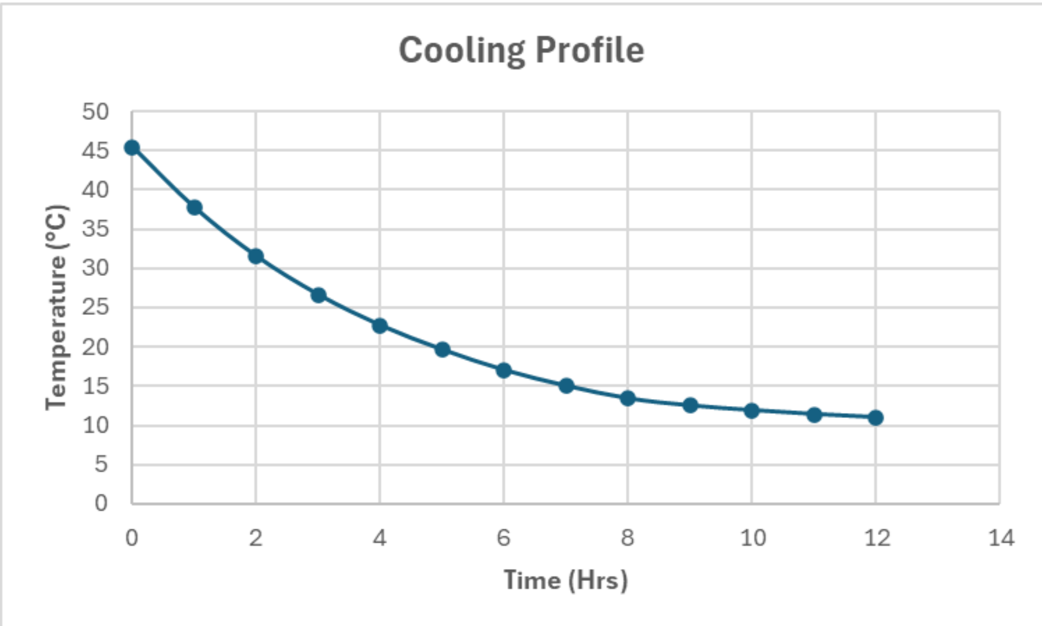
Aim of the Project

The dissertation aims to solve the cooling process of whey using crystallization tanks in the Kerry Group. The whey inside the tank is cooled by Chilled Water and comes in at 45 deg and needs to leave at 11 deg. Currently, there is no effective control process, and it is putting a big demand on the chiller's energy capacity.



Objectives

To solve this problem the following objectives were outlined,

1. Define the existing process and establish all the parameters relating to it.
2. Model the existing process in the form of heat transfer analysis.
3. Refine the model to efficiently achieve the target temperature of 10-12 deg set out.
4. Size a pump that will be suitable for flow rates and pressure losses.
5. Look into how phase-changing materials are used for cooling through case studies.

Background

The main areas investigated were the CHW process, Tank Design & Characteristics, Water tank Cooling, Industrial Automation/ Control of feed rates, Phase Changing Materials, and Kerry Group.

Software such as ANYS, MATLAB, and COMSOL were also investigated before deciding on Excel to model the cooling Process from Kerry Group.

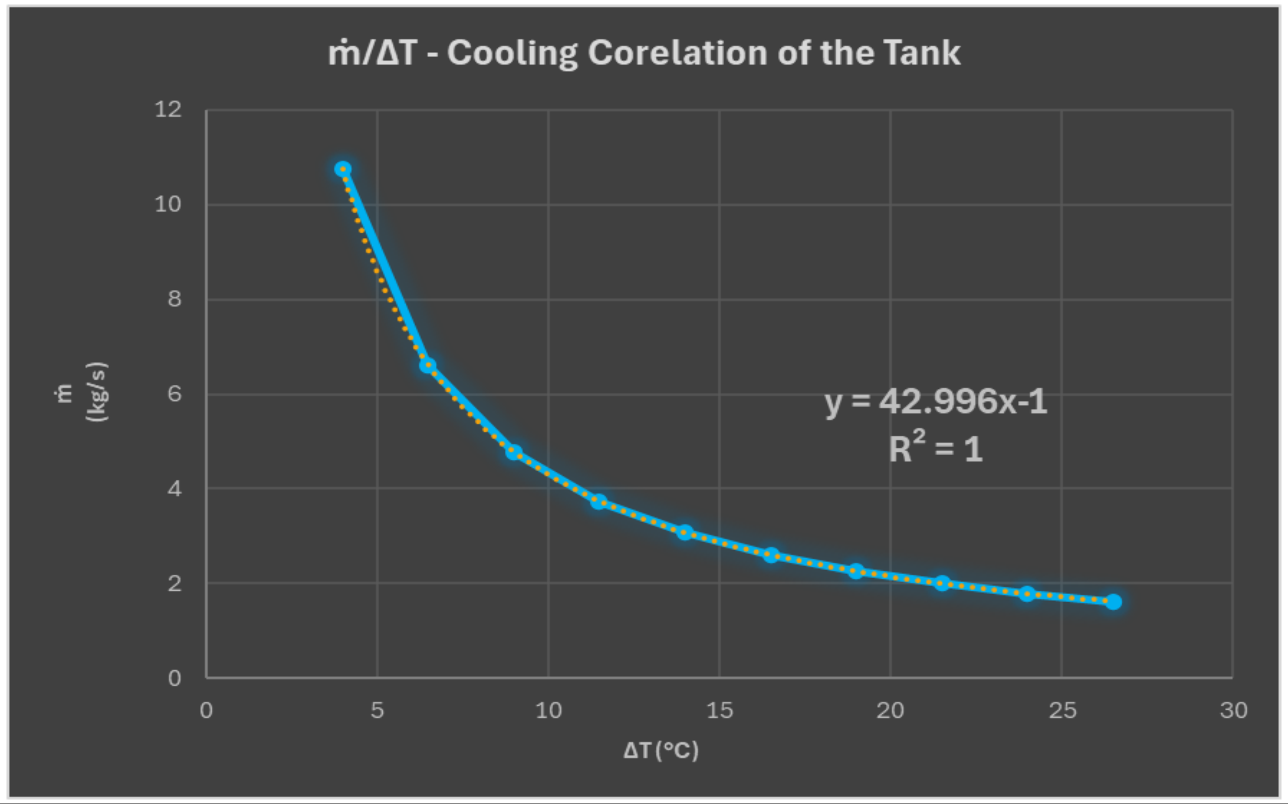
Process Modelling

The below tables act as the mass flow rate of the CHW required calculator. This was formed by the thermodynamic law Energy to cool the whey must equal the energy added to the CHW this was broken down to the heat transfer equation Q=m.cp.ΔT

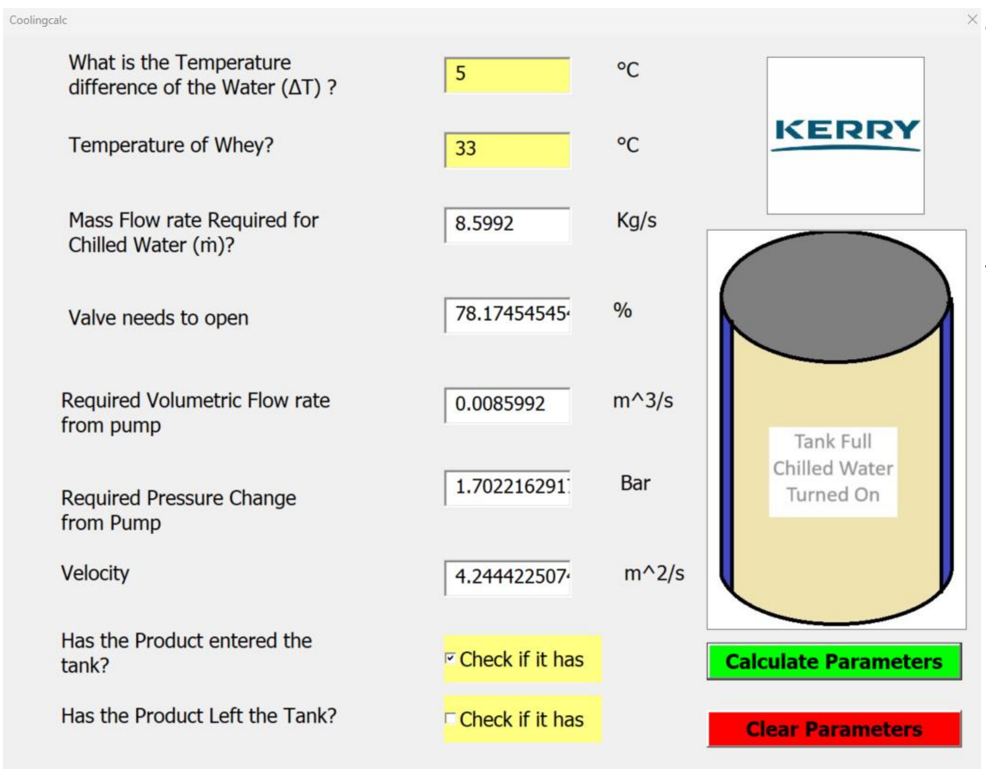
Product (Whey)		
T1	45	°C
T2	11	°C
ΔT	34	°C
Cp	2495.8	J/Kg.K
ṁ	2.128085	kg/s
Q̇	180583.33	W

Chilled Water		
T1	5	°C
T2	9	°C
ΔT	4	°C
Cp	4200	J/Kg.K
ṁ	10.749008	kg/s
Q̇	180583.33	W

From using the above calculator points were taken at different ΔTchw and mass flow rates CHW. From this, a graph was plotted to show the difference in mass flow of CHW vs the temperature difference of it. This allowed for correlation to be created.



Control Process



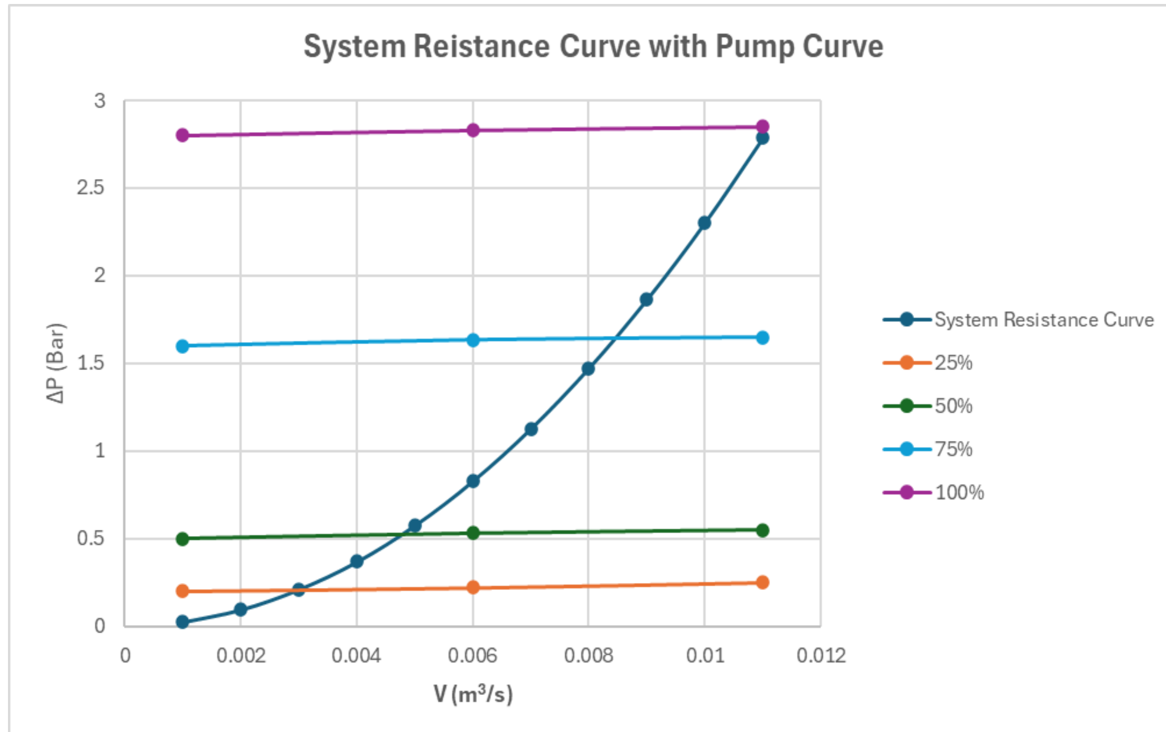
The control process was created on an Excel macro, it controls the CHW valve adjusting the flow rate from the calculators above. It also prevents the valve from opening when the product has left the tank or when the product drops below 11 degrees. It also shows the head pressure, and the image adjusts per the parameters.

Pump for Flow rates

The following table was used to calculate the system resistance curve. It does this through the Darcys equation the parameters adjust per the mass flow rate and friction factor.

ṁ	11	kg/s
Pipe Diameter	0.0508	m
friction factor	0.064	(from moody diagram)
density	1000	kg/m3
Viscosity	0.001519	kg/m.s
Length	15	m
Re	181594.02	Turbulent Flow
ξ - Roughness	0.002	mm
ed	0.03937008	Unit less
ΔP	278592.059	Pa
ΔP	2.786	Bar
CSA	0.0020258	m^2
v	5.430	m/s
V	0.011	m^3/s

The pump selected was a centrifugal pump from Grundfos with an efficiency of 96%. As seen from the graph the pump can handle the desired flow rates.



Conclusion

In Conclusion, from the modeled process the optimal mass flow rate is calculated from the temperature difference. From this, it will tell the automatic valve how much it needs to open. The pump size from Grundfos is good as the specification of the pump is suitable for CHW and it can handle the required flow rates. A control process was made that incorporates these calculators into a user-friendly and foolproof algorithm.

To continue this dissertation, I would recommend getting a PCM specialist into Kerry Group to utilize the prosperous energy savings it demonstrates. The control algorithm needs to be installed and automated into the siemens s7 software.

References

Cervera-Vázquez, J., 2016. Sizing of the buffer tank in chilled water distribution air-conditioning systems. Science and Technology for the Built Environment, 22(3), pp. 290-298.

Coorey, R., 2018. The Impact of Cooling Rate on the Safety of Food Products as Affected by Food Containers. Comprehensive Reviews in Food Science and Food Safety, 17(4), pp. 827-840.

Phase Changing Materials

After researching case studies phase changing materials was a significant tool in improving heat transfer. To allocate PCMs into the tank in Kerry Group it would need to be FDA-approved (sodium hydrates). The idea would be to have the PCM melting point at 45 deg so it absorbs heat from the whey and by the time it reaches its freezing point the whey would have left the tank.

Acknowledgments

Alan O Donovan – supervisor
Maurice Cuddigan – Engineer
Clodagh Moore - Lecturer