Section 2: Fermentation and Cooling

Designed By Anthony Rich

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1. INTRODUCTION

1.1 The Design Problem

Following initial processing described in the previous section the grape juice, and must in the case of red grapes must be fermented chemically change the sugars within the grape juice into ethanol. This process is performed by yeast, a small microorganism. The processes can be performed in a large number of different tanks, vessels and equipment, using a variety of different processes and methods. This section describes our design choices for fermentation areas, both red and white of our winery.

1.2 Process Description

The goal of the overall process is to convert sugar into ethanol in a way which produces minimum undesired by products, with maximum preservation of the natural aroma flavour of the fruit. The basic expression of the fermentation process is given by the overall formulation:

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$

Theoretically:

- 180 grams of sugar will produce 92 grams of ethanol.
- However approximately 5% of the sugar is consumed to produce by products such as glycerol, succinic acid, lactic acid, 2,3-butanediol, acetic acid and other products.
- 2.5% is consumed by the yeast as a carbon source
- 0.5% is left over as unfermented residual sugars.

In total, approximately 8% is not converted into ethanol. From the initial 180 grams we therefore achieve 84.6grams of ethanol. The density of ethanol at 20ºC is 0.789g/ml resulting in a total volume of 107.2ml of ethanol.

If this volume were to be mixed with 1L of water the total volume of the mixed water and ethanol contract by 0.7% (at 10% alcohol). So wine made from 180g/L sugar would contain:

$$107.2 \times 1.007 = \frac{108ml}{L} alcohol$$

Brix units are convenient way to predict the potential alcohol content of juice to be fermented.

$$1.75B^{\text{º}} \rightarrow 1\% \left(\frac{v}{v}\right) alcohol$$

or

$$\%\ potential\ alcohol\left(\frac{v}{v}\right) = 0.57xBrix$$

1.3 White Fermentation

White Wine Yeast Inoculation

Our winery process offers the winemaker the option to inoculate yeast prior to the full introduction of yeast to the fermentation vessel. This is particularly advantageous for white wines due to the low fermenting temperature which can cause a significant increase in the lag phase while yeast numbers slowly build up. By allowing the yeast to build up its population the lag phase can be significantly reduced offering better equipment utilisation.

Inoculation is carried out in an aerobic environment to promote strong yeast growth, at temperatures around 20ºC. During inoculation 100-200 milligrams per litre of diammonium phosphate may be added as a nitrogen source for the yeast. This also inhibits the formation of hydrogen sulphide during fermentation. Inoculation is carried out in a water based solution of approximately 10% grape juice.

White Wine Fermentation Tanks

White wine nowadays is fermented in sealed tanks with cooling which can be provided by several methods. In our process we are providing refrigerated cooling streams to fermentation which will allow the winemaker to control the fermentation temperature to a high degree of accuracy. The mechanism by which cooling is delivered will be a brine solution through either cooling coils inside the tank, or cooling jackets built into the tanks.

Juice is cooled to 10-15ºC using refrigeration. The must is then seeded with yeast between 10-20g/hL of the total juice to be fermented which has been prepared in inoculation. The start of fermentation will be slow and the temperature cannot exceed 20ºC. This method provides a high quality wine.

1.3 Red Fermentation

Red Wine Yeast Inoculation

Separate inoculation is not required for Red Wine manufacture as the higher temperatures and better availability of oxygen promote fast yeast growth. The crushed de-stemmed must is pumped to the fermentation vessel where tartaric acid and SO2 are added. SO_2 is added in the region of 50 milligrams per litre free. Following this the yeast is added using approximately 10-20 g/hL of dry yeast substance. For red wines yeast is added in high quantities.

Red Wine Fermentation Tanks

Red Wine vilification may be conducted in open or closed tanks with the cap floating to the top, held up by evolving CO_2, or with an immersed cap which is held in place by wire mesh or similar holding system to stop it rising. A brief table to the advantages and disadvantages of open and closed tanks is listed below.

Open Tanks

Advantages	***Disadvantages***
Useful in hot regions or for high alcoholic strengths	The surface in contact with air promotes a loss of alcohol ~0.5%. Constitutes a danger of oxidation or acetic scouring, it is necessary to crush or punch down the pomace
Fermentation is made easier by contact with air. It is faster and goes further.	In cold years the tank may not reach temperature and fermentation may become stuck.
Fermentation temperature is not so high due to cooling and surface evaporation	Only suitable for short pomace contact. It must be run off before all the carbon dioxide has been given off.
Control is easier, you can see the tank fermenting and control the state of the pomace	The press wine exhibits rather higher volatile acidity.
Generally produces wine that are made right away, tasting better, sooner.	It is observed that for this kind of pomace, secondary fermentation is retarded

Table 1. Comparison of Open Tank Fermenters

The general consensus is that open fermentation is suited to small institutions, using only short pomace contact for wines and high alcohol strength. In many regions this system has disappeared in favour of closed tanks.

Closed Tanks:

Advantages	***Disadvantages***
Being tight, this tank avoids any contact with air, evaporation and acetic spoilage.	Fermentation takes place without air; however there is a chance of fermentation stoppage due to asphyxia of yeast.
Long pomace contact can be done using this type of tank	Pumping over with aeration is vital to proper multiplication of yeasts (Red Wines)
In cold years is keeps heat well	Heating and cooling closed tanks is important for finishing fermentation completely.
It can be very large capacity	

Secondary fermentation is easier and press wine is higher quality
Dual purpose and can be used for storage

Table 2. Comparison of Closed Tank Fermenters

For our design we have chosen to use open top fermentation tanks with the option to use floating caps or fit a screen to use immersed caps. Due to the very small size of our winery we believe this method will offer the winemaker the most flexibility. It also lends well to the use of smaller fermentation vessels which will allow us to store grapes and juice for a shorter time before fermentation, however at the expense of a higher capital cost in terms of number of tanks required. Mechanical devices can also be considered for punching down the cap to lower the labour cost required.

1.4 Summary of Design Methods Used

All equipment designs have been completed with the use of applicable rules of thumb or the relevant Australian Standards (AS-1210, AS-2129, and AS/NZS-2865) where information is available. Some equipment such as the crusher requires information not readily available or requires a level of detail that well exceeds the scope of this project. In order to facilitate preliminary sizing of these pieces of equipment, the problems have been simplified through the use of suitable assumptions. The design method used for each calculation has been listed in Volume 3 in order to highlight the relevant reasoning. Where assumptions have been made, the basis for the assumption has been stated.

2. Equipment Specification

1.1. Equipment Schedule

Table 1: Equipment Schedule

Alcoholics Anonymous	Equipment Schedule	Project	Winery Design Project
		Sections	Fermentation and Utilities
		Designed By	Anthony Rich
		Date	21/08/2008

Equipment No.	Specification No.	Name	PFD Number	Location	Purpose	T (°C)	P (kPa)	Model No.	Supplier
TNK-05	ES-TNK-05	Inoculation Tank	CHPR4401-A-0102	White Ferment	Introduce yeast to juice to reduce lag time before fermentation	25	101.3		TBA
R-02	ES-R-02	Red Wine Fermenter	CHPR4401-A-0103	Red Ferment	Ferment red wine	25	101.3		TBA
TNK-40	ES-TNK-40	Chilled Coolant Storage	CHPR4401-A-010x	Services	Storage of chilled coolant for winery operations	-4	101.3		TBA
PMP-40	ES-PMP-40	Cooling Circulation Pump	CHPR4401-A-010x	Services	Cycles water through chiller unit	-4	310k Pa		TBA
PMP-41	ES-PMP-41	Plant Circulation Pump	CHPR4401-A-010x	Services	Cycles chilled water to plant	-4	450k Pa		TBA
RFR-01	ES-RFR-01	Refrigeration Unit	CHPR4401-A-010x	Services	Chills the plant cooling liquid	-4	450k Pa		Fluid Chillers Australia

1.2. Red Fermentation Vessel

Tanks R-02-00 to R-02-09 are specially designed single purpose vessels for the fermentation of red grape juice, to red wine. They are open to atmosphere and temperature controlled using helical cooling coils which are submerged under the surface. These coils run a solution of 23.5% methanol with the remainder water by volume. Temperature sensing is done via a sensor and controller attached approximately half way down the vessel. A total of 10 vessels are required for optimal residence time and minimising the time grapes are stored before there is enough of them to begin a ferment campaign.

Specifics of design specification and equations used to develop the red fermentation vessel can be found in Section 2: Fermentation of Volume 3, §1.1

Design Parameter	**Selection**	**Basis for Selection**
Liquids with entrained and suspended solids	Wine, Juice Pommace Must	Process Fluids which will come in contact with the vessel
Construction Material	316 Stainless Steel	Easily cleaned, Corrosion Resistant, Sanitary food grade processing material.
AS1210 Vessel Class	Class 3	Low pressure vessel (tank). Class 3 ensures relaxed weld inspection requirements.
Design Temperature	100ºC	Temperature cleaning fluids may reach.
Operating Temperature	10-30ºC	Temperature controlled to 25º however during filling and other actions may reach these values
Environment Operating Pressure	101.3kPa	Vessel is open to atmospheric pressure
Inerting Gas	CO_2	Produced during fermentation
Pressure Control System	None required	This vessel is open to atmosphere with no possible way of becoming sealed
Process Nozzles	80mm	Large to prevent solids blocking flow
Control Nozzles	50mm	Optimal Sizing, clean fluids
Base	Torispherical	Requires much less materials than flat bottom vessels, still relatively flat to assist solids removal after fermentation.
Top	NA	Vessel is open to atmosphere

Table 2: Basis of design for Red Fermenter

Parameter	Value
Design Capacity	11 m^3
Operating Capacity	10 m^3
Operating Temperature	10-30ºC
Design Temperature	100 ºC
Operating Pressure	0.1886 MPa
Design Pressure	0.1986 MPa
Height	3500mm
Diameter	2000mm
Wall Thickness	4.2mm
Base Thickness	5.9mm
Approximate Dry Mass	800kg
Approximate Operating Mass	11650kg

Table 3: Design Parameters

Feature	Description	No of	Nominal Size	Schedule
A	Temperature Sensor Level	1	NA	NA
B	Juice Drain / Fill	1	82	10
C	Personal Opening	1	450mm	AS 1210
D	Juice Drain / Fill	1	54	10

Table 4: Design Features

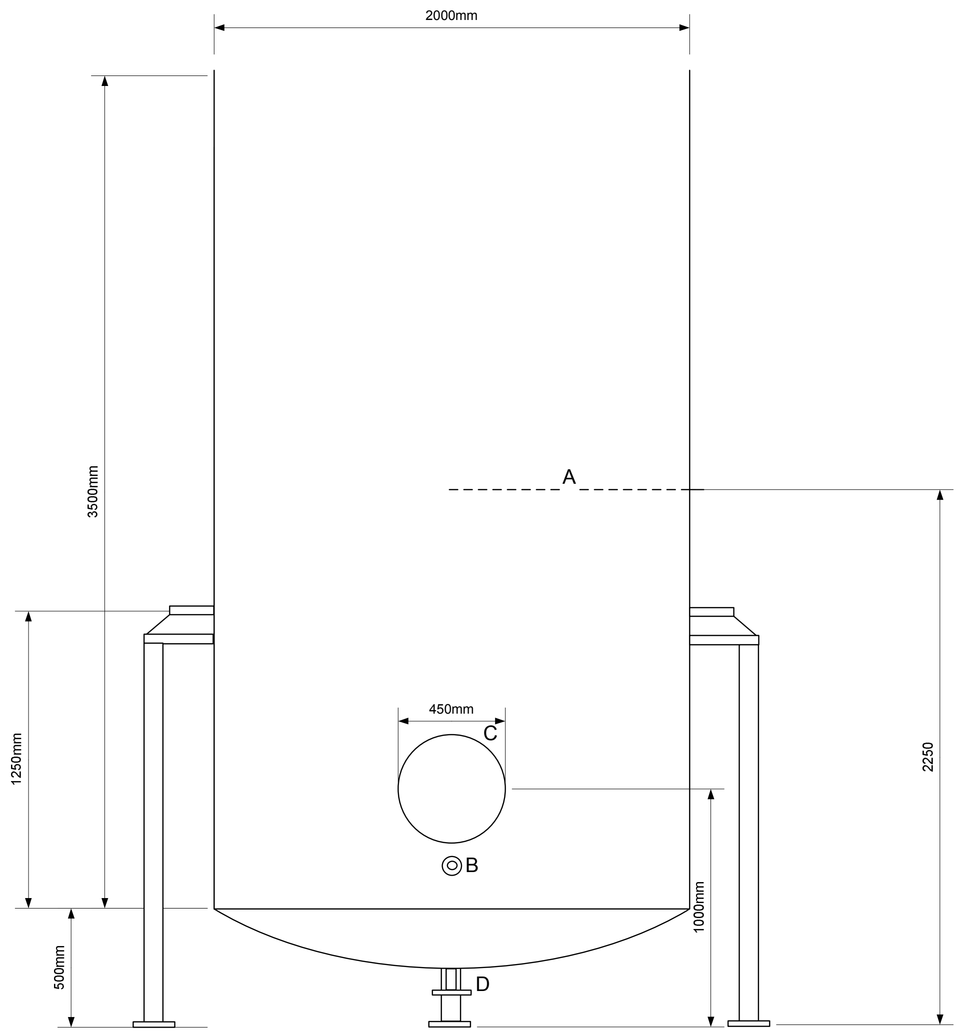

Figure 1: Red Fermenter

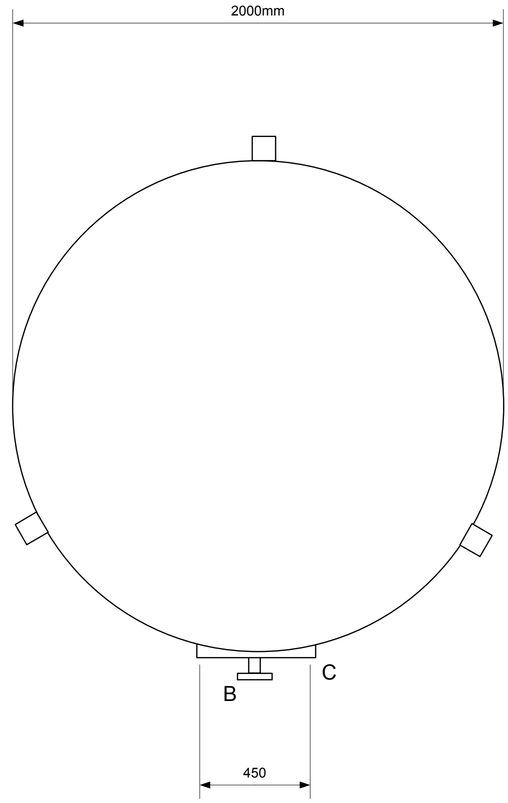

Figure 2: Red Fermenter Top View

1.3 Chilled Cooling Tank

Chilled Cooling Tank

Chilled cooling tank is used to store the brine which has been chilled by the refrigeration unit, in preparation for its circulation around the plant. This method was chosen over direct circulation through the refrigeration unit due to the intermittent nature of the cooling requirements on site. For example, during cold stabilisation the cooling power required will increase significantly for short times.

The tank is insulated to reduce loss to the atmosphere and is kept at atmospheric pressure via a pressure vent. The nominal temperature of the tank is -4ºC, however it is expected during times of high load this may increase up to 15ºC Specifics of design specification and equations used to develop the red fermentation vessel can be found in Section 2: Fermentation of Volume 3, §1.6

Design Parameter	**Selection**	**Basis for Selection**
Fluids	Ethanol / Water mixture	This tank stores a 23.5% Ethanol by volume mixture with the remainder water.
Construction Material	316 Stainless Steel	Corrosion Resistant. Anti corrosion additives will be used, however designing for high corrosion resistance is ideal.
AS1210 Vessel Class	Class 3	Low pressure vessel (tank). Class 3 ensures relaxed weld inspection requirements.
Design Temperature	100ºC	This is the lowest AS1210 design temperature for vessels above -50ºC
Operating Temperature	-4 to 15ºC	Temperature controlled to 25º however during filling and other actions may reach these values
Environment Operating Pressure	101.3kPa	Vessel is open to atmospheric pressure
Inerting Gas	Ethanol vapour	This vessel may produce a low amount of ethanol vapour.
Pressure Control System	None required	This vessel is open to atmosphere with no possible way of becoming sealed
Refrigeration Side Nozzles	80mm	This ensures the closest match to the fittings shipped on the refrigeration unit.
Plant Side Nozzles	80mm	80mm has been chosen to minimise pressure drops due to velocity in this section. At the plant the flow size will be reduced for each piece of equipment
Base	Torispherical	Allows for easy implementation of insulation. Much cheaper than flat bottom vessels.

Top	Torispherical	Allows for easy implementation of insulation. Much cheaper than flat bottom vessels.

Table 5: Chilled Holding Tank Basis of Design

Parameter	Value
Design Capacity	2 m^3
Operating Capacity	1.57 m^3
Operating Temperature	-4 to 15ºC
Design Temperature	100 ºC
Operating Pressure	0.1042 MPa
Design Pressure	0.1062 MPa
Height	2500mm
Diameter	1009mm
Wall Thickness	3.2mm
Base Thickness	4.1mm
Approximate Dry Mass	250kg
Approximate Operating Mass	1800kg

Table 6: Design Parameters

Feature	Description	No of	Nominal Size	Schedule
A	Plant return	1	80	10
B	Chiller Return	1	80	10
C	To Plant	1	80	10
D	To Chiller	1	80	10
E	Pressure Equalisation Vent	1	NA	NA

Table 7: Design Features

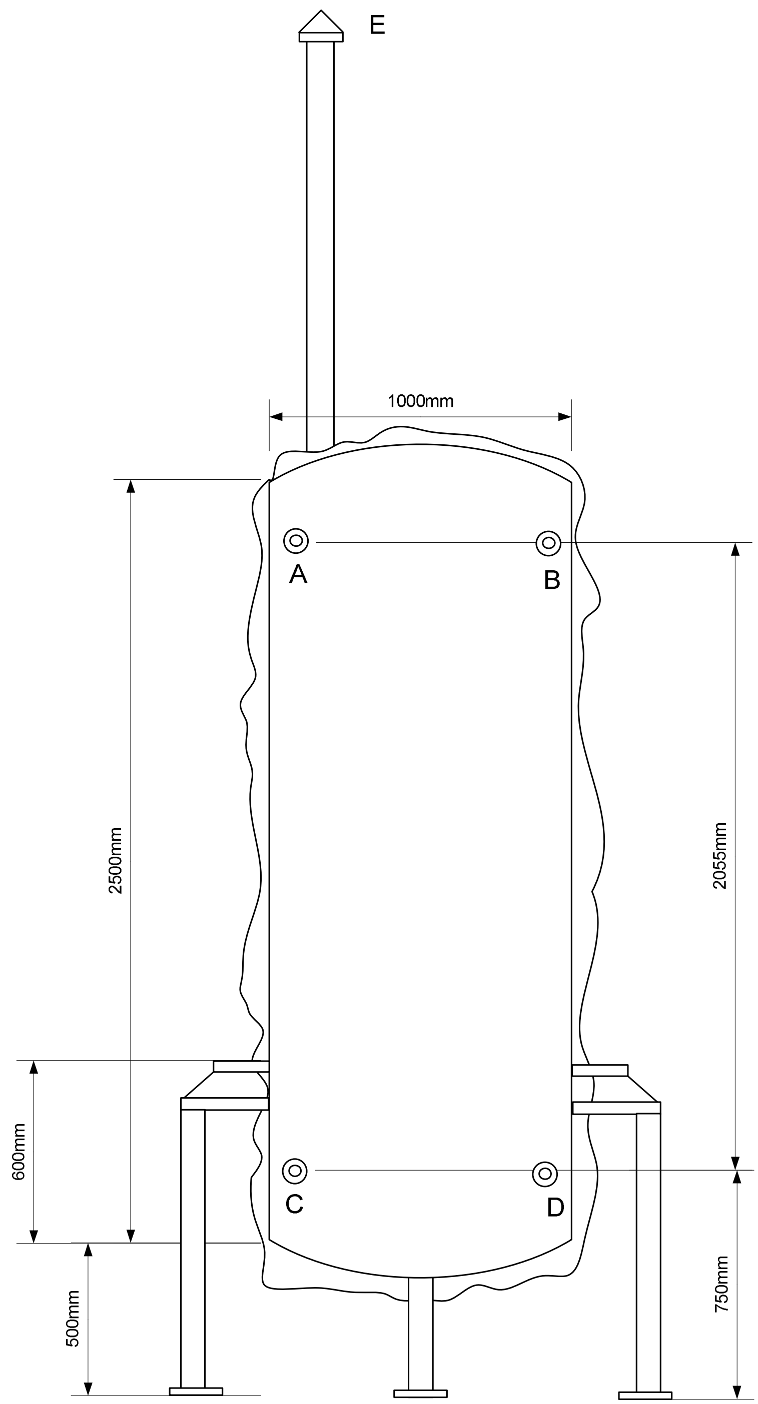

Figure 3: Chilled Storage Tank

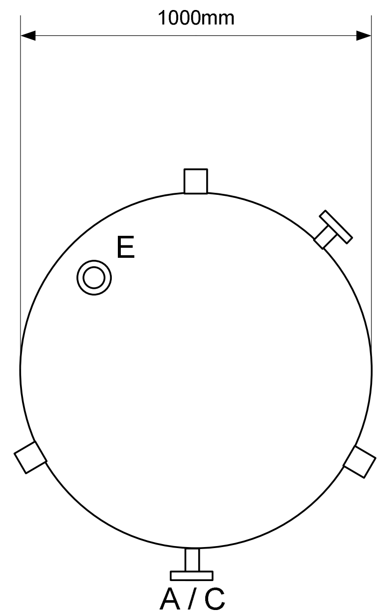

Figure 4: Chilled Storage Top View

1.4 Refrigeration Unit

A chilled 23.5% v/v ethanol water solution with a nominal temperature of -4ºC is provided to the winery for day to day operations and cooling requirements. Refrigeration is carried out by a self contained refrigeration unit. Detailed calculations of the total heat load from the winery are found in the Appendix.

Two units will be used as a pair. This is to account for the spikes in the cooling load of the winery. During low power one unit can be shutoff completely. One unit is capable of running the entire winery however cooling times are extended for some processes on single operation.

Specifics of design specification and equations used to develop the red fermentation vessel can be found in Section 2: Fermentation of Volume 3, §1.2

Design Parameter	Selection	Basis for Selection
Fluids	Ethanol / Water mixture	Refrigeration unit is expected to chill a 23.5% v/v ethanol water solution to -4ºC
Construction Material	Galvanised and Powder coated steel. Exchangers made from 316 Stainless material.	Unit is completely weather proof and capable of operating indoors or outdoor, all year round.
Design Temperature (Ambient)	50ºC	This chiller operated effectively up to 50ºC ambient temperature. This suits our application fine.
Operating Temperature	35ºC	Chiller has been sized for an average 35ºC operating temperature which corresponds well to ambient temperatures during processing.
Pressure Control System	Valve	This chiller is capable of being isolated from the rest of the system by a manual operated valve.
Refrigeration Side Nozzles	3" TEC	Manufacture supplied fittings
Foundation	Concrete	Concrete foundation will be laid for the unit

Table 8: Basis of Design Chiller Unit

Parameter	**Value**
Manufacture	Fluid Chillers Australia
Supplier	Thermal Engineering WA
Model	CA115
Temperature Out	-4ºC
Temperature In	< 17ºC (excluding start-up)
Maximum Flow Rate	8.5L/s
Cooling Capacity	76.2kW
Pressure Drop at max flow	180.2kPa
Height	2430mm
Width	1684mm
Depth	1320mm
Mass	1100mm

Table 9: Fluid Chiller Design Parameters

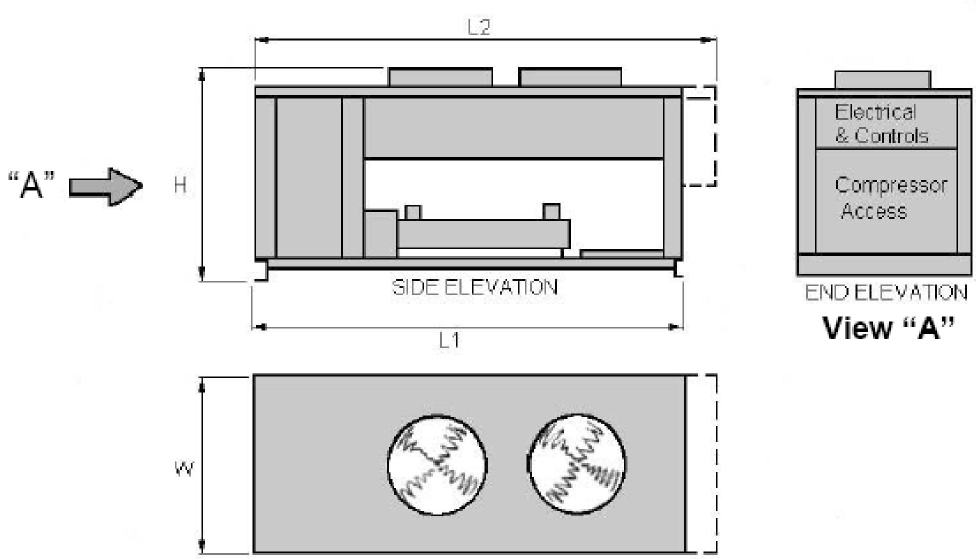

Figure 5: Sketch of Chiller Unit

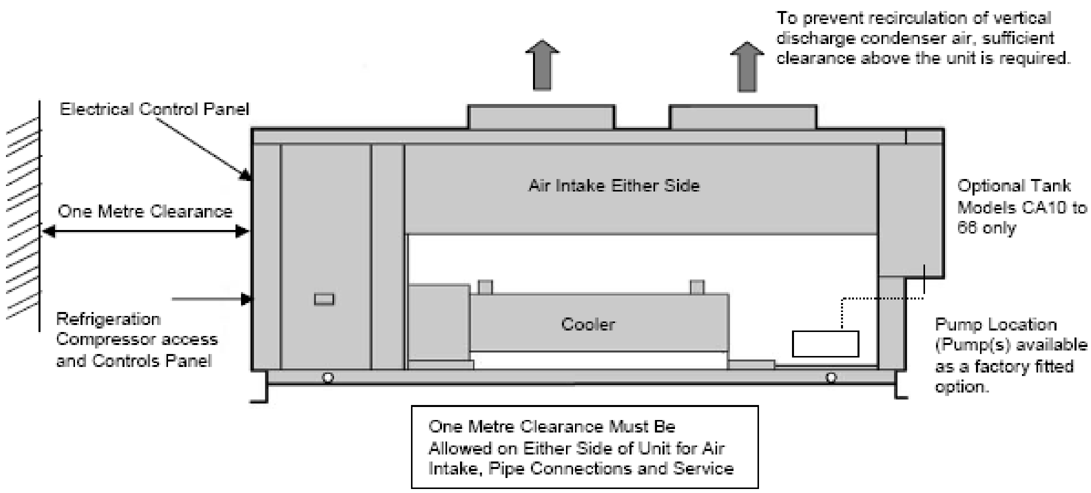

Figure 6: Schematic of Chiller Positioning

Parameter	Value	Source
Ethanol % vol	23.75	Manufacture Spec
Water % vol	76.25	Manufacture Spec
Density kg/m3	980.8	HYSYS at -4ºC
Heat Capacity kJ/kg	4.066	HYSYS at -4ºC
Thermal Conductivity units W/m K	0.4428	HYSYS at -4ºC
Viscosity cP	1.715	HYSYS at -4ºC
Vapour Pressure of Mixture kPa	19.69	Standard Handbook of Engineering Calculations

Table 10: Thermodynamic Properties of Cooling Solution

1.5 Cooling Circulation Pump ES-PMP-40

A fixed pump is required to cycle fluid from the chilled holding tank to the Refrigeration unit and back into holding. Specifics of design specification and equations used to develop the red fermentation vessel can be found in Section 2: Fermentation of Volume 3, §1.4

Design Parameter	Selection	Basis for Selection
Pump Type	Centrifugal	Small size and quite. Reliable operation.
ΔP	3 bar	Mass and Energy Balance Pressure required through refrigeration unit and associated devices.
Volumetric Flow	0.514 m^3/h	Maximum Flow through refrigeration unit.
Operating T	-4 to 15ºC	Contact with fluids
Nozzles	3"	Same as manufacture supplied on chilling unit

Table 11: Basis of Design Cooling Circulation Pump

Parameter	Value
Manufacture	Advanced Pumps
Supplier	Advanced Pumps
Model	SHE Series
Type	32-250/55
Maximum Flow Rate	400 L/min
Motor type IEC	112
η	84.5%
Shaft Power	3.1kW
Height (including pump)	405mm
Width (including pump)	345mm
Length(including pump)	666mm

Table 12: Design Parameters

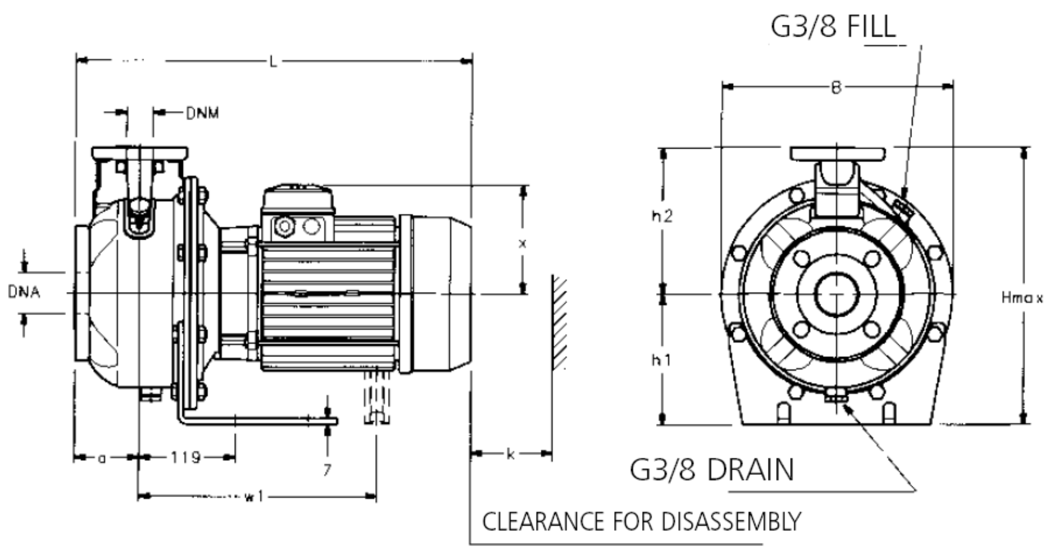

Figure 7: Schematic of Pump

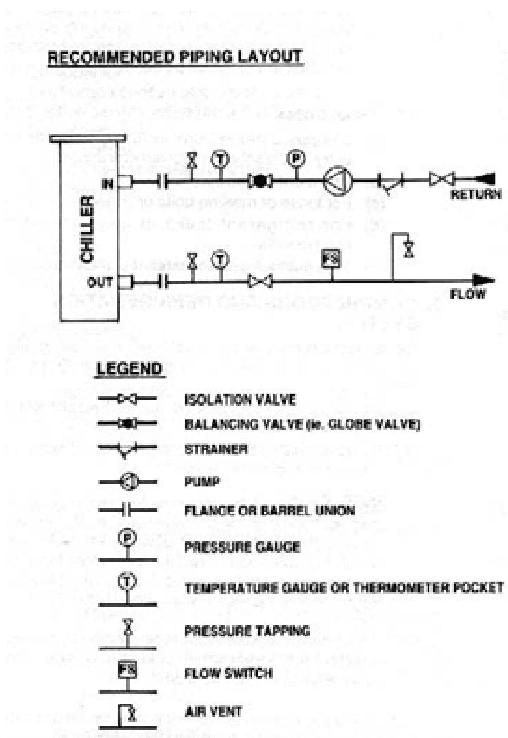

Figure 8: Piping and Instrument Layout

1.6 Plant Circulation Pump ES-PMP-40

A fixed pump is required to cycle fluid from the chilled holding tank winery as required. Specifics of design specification and equations used to develop the red fermentation vessel can be found in Section 2: Fermentation of Volume 3, §1.5

Design Parameter	Selection	Basis for Selection
Pump Type	Centrifugal	Small size and quite. Reliable operation.
ΔP	4.25 bar	Mass and Energy Balance Pressure required through plant and devices
Volumetric Flow	1 m^3/h	Maximum flow through. During short periods only. Average flow much lower.
Operating T	-4 to 15ºC	Contact with fluids
Nozzles	80mm	Matches other equipment

Table 13: Basis of Selection Plant Side Circulation Pump

Parameter	Value
Manufacture	Advanced Pumps
Supplier	Advanced Pumps
Model	SHE Series
Type	32-250/55
Maximum Flow Rate	400 L/min
Motor type IEC	112
η	84.5%
Shaft Power	4.3kW
Height (including pump)	405mm
Width (including pump)	345mm
Length(including pump)	666mm

Table 14: Design Parameters

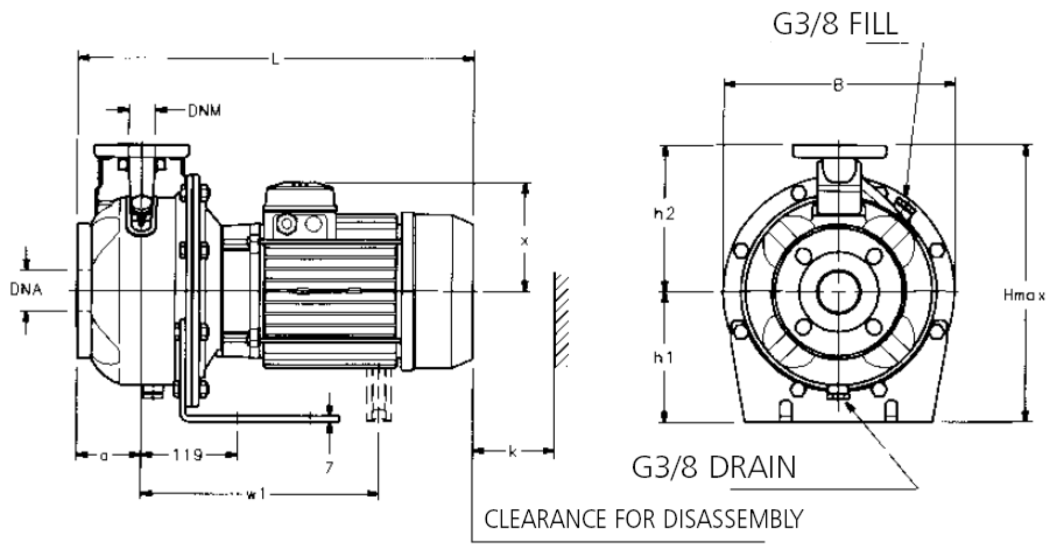

Figure 9: Schematic of Pump

1.7 Yeast Inoculation Tank

Yeast inoculation tank is a small, movable vessel for introducing yeast with a mixture of water and grape juice, so as to minimise the lag period before fermentation gets started. The AS 1210 specification struggle to size this vessel as it is so small and under such small load, however they have still been used as guidelines.

Specifics of design specification and equations used to develop the red fermentation vessel can be found in Section 2: Fermentation of Volume 3, §1.7

Design Parameter	Selection	Basis for Selection
Liquids and solids	Juice, water and solid yeast powder	Process Fluids which will come in contact with the vessel
Construction Material	316 Stainless Steel	Easily cleaned, Corrosion Resistant, Sanitary food grade processing material.
AS1210 Vessel Class	Class 3	Low pressure vessel (tank). Class 3 ensures relaxed weld inspection requirements.
Design Temperature	100ºC	Temperature cleaning fluids may reach.
Operating T	10-30ºC	Vessel is not temperature controlled however will never exceed design temperature.
Design Parameter	**Selection**	**Basis for Selection**
Environment Operating Pressure	101.3kPa	Vessel is open to atmospheric pressure
Inerting Gas	CO_2	Produced during fermentation
Pressure Control System	None required	This vessel is open to atmosphere with no possible way of becoming sealed
Process Nozzles	80mm	Large to prevent solids blocking flow
Base	Conical	Requires much less materials than flat bottom vessels, allows for fast removal of liquid from the vessel.
Top	NA	Vessel is open to atmosphere

Table 15: Basis of design Yeast Inoculation Tank

Parameter	Value
Design Capacity	0.5 m^3

Operating Capacity	0.3 m^3
Operating Temperature	10-30ºC
Design Temperature	100 ºC
Operating Pressure	0.1018 MPa
Design Pressure	0.1027 MPa
Height	1000mm
Diameter	800mm
Wall Thickness	2.45mm
Base Thickness	2.8mm
Approximate Dry Mass	50kg
Approximate Operating Mass	450kg

Table 16: Design Parameters

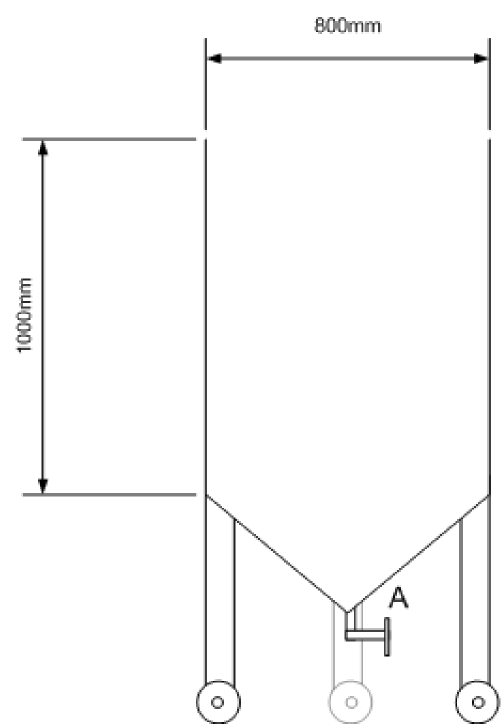

Figure 10: Front view Yeast Inoculation

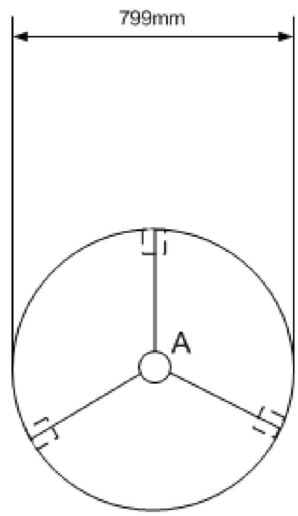

Figure 11: Top view Yeast Inoculation

Feature	Description	No of	Nominal Size	Schedule
A	Outlet	1	80	10

Table 17: Design Features

1.8 Helical Cooling Coil

The helical coil pipe heat exchanger is used to regulate the temperature in the red fermenters. It is not a permanent fixing and can be removed when not required. Since the heat flow is so small in the red fermenters the velocity of fluid flowing through the coil is extremely low. and they will not be required to even flow fluid all the time, however the option is needed in case the temperature begins to rise too much.

Specifics of design specification and equations used to develop the helical cooling cool can be found in Section 2: Fermentation of Volume 3, §1.3

Design Parameter	Selection	Basis for Selection
Type of exchange	Helical Coil	The heat flow is far too low for jacketed vessels.
Construction Material	316 Stainless Steel	Easily cleaned, Corrosion Resistant, Sanitary food grade processing material.
Design Temperature	100ºC	Temperature cleaning fluids may reach.
Operating Temperature	-4 - 30ºC	
Operating Pressure Difference	1.15kPa	Very small flow needed.
Pressure Control System	None required	NA
Flow Control	Control Valve	Flow through the coil will be controlled via control loop and a control value related to the vessel temperature
Control Nozzles	30mm	Low Flow

Table 18: Basis of Design Cooling Coil

Table 19: Design Parameters Cooling

Parameter	Value
Design Capacity	7kW
Operating Capacity	4kW
Operating Temperature	-4 - 30ºC
Design Temperature	100 ºC
Operating Pressure	105kPa
Height	1150m
Diameter	336mm
Wall Thickness	1.5mm

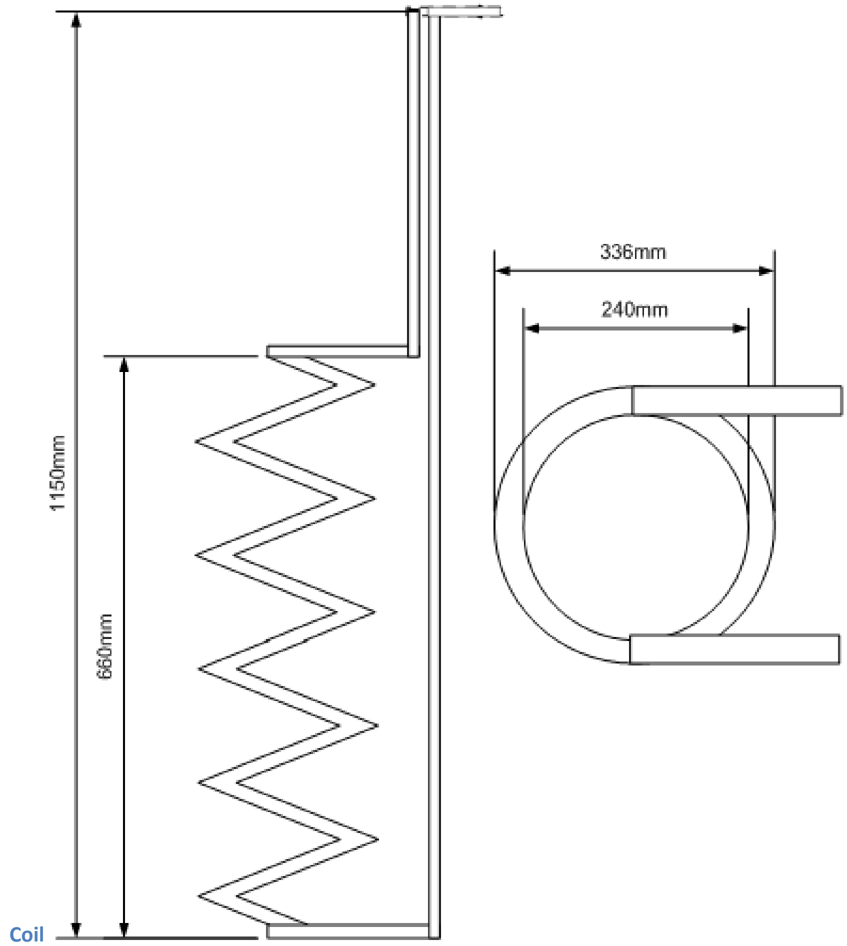

Figure 12: Cooling Coil Schematic)

3. Detailed Design: R-00 to R-09

1.3. Vessel Description:

Tanks R-02-00 to R-02-09 are specially designed single purpose vessels for the fermentation of red grape juice, to red wine. They are open to atmosphere and temperature controlled using helical cooling coils which are submerged under the surface. These coils run a solution of 23.5% methanol with the remainder water by volume. Temperature sensing is done via a sensor and controller attached approximately half way down the vessel. A total of 10 vessels are required for optimal residence time and minimising the time grapes are stored before there is enough of them to begin a ferment campaign.

1.4. Design Basis:

Table 20: Design Basis for Red Fermenter

Design Parameter	Selection	Basis for Selection
Liquids with entrained and suspended solids	Wine, Juice Pommace Must	Process Fluids which will come in contact with the vessel
Construction Material	316 Stainless Steel	Easily cleaned, Corrosion Resistant, Sanitary food grade processing material.
AS1210 Vessel Class	Class 3	Low pressure vessel (tank). Class 3 ensures relaxed weld inspection requirements.
Design Temperature	100ºC	Temperature cleaning fluids may reach.
Operating Temperature	10-30ºC	Temperature controlled to 25º however during filling and other actions may reach these values

Design Parameter	Selection	Basis for Selection
Environment Operating Pressure	101.3kPa	Vessel is open to atmospheric pressure
Inerting Gas	CO_2	Produced during fermentation
Pressure Control System	None required	This vessel is open to atmosphere with no possible way of becoming sealed
Process Nozzles	80mm	Large to prevent solids blocking flow
Control Nozzles	50mm	Optimal Sizing, clean fluids
Base	Torispherical	Requires much less materials than flat bottom vessels, still relatively flat to assist solids removal.
Top	NA	Vessel is open to atmosphere
Additional Height	10 mm	Head space allowance
Vessel Outer Diameter	2008.4 mm	Optimised value
Vessel Height	4005.9 mm	Optimised value
Weld Type	Double welded butt joint as per figure 3.5.1.7b of AS1210	Sufficient strength in weld for requirements of vessel.
Weld Efficiency	0.7	Suitable based on weld type and vessel class
Corrosion Allowance	2 mm	Fluid has low pH and contains hard solids
Wall Thickness	4.2 mm (Gauge 30)	Available gauge Meets minimum wall thickness requirement from AS1210
End Thickness	5.9 mm (Gauge 25)	Available gauge Meets minimum end thickness requirement from AS1210
Supports	3 Columns	Vessel weight when loaded
Access Points	1 450mm manway, inwards opening	Access to vessel when empty to allow for cleaning. Pressure seals opening when full

1.5. Operating Conditions:

Table 21: Operating Conditions for Red Fermenter

Parameter	Value
Design Capacity	11 m^3
Operating Capacity	10 m^3
Operating Temperature	10-30ºC
Design Temperature	100 ºC
Operating Pressure	0.1886 MPa
Design Pressure	0.1986 MPa
Height	3500mm
Diameter	2000mm
Wall Thickness	4.2mm
Base Thickness	5.9mm
Approximate Dry Mass	800kg
Approximate Operating Mass	11650kg

1.6. Design Method

Capacity Calculation: Red Fermenter

Cab Sauv which delivers the most grapes out of any variety is the determining size for red fermenter. Design goals included:

- Even number of tanks for ease of arrangement
- Minimise the time grapes are waiting to be fermented

General Details
1. Shriaz total volume to be fermented 60 000L
2. Cab Sauv total volume to be fermented 101 000L
3. Average Shiraz brix: 22º
4. Average Sab Sauv brix: 21.5º
5. Average reaction rate: 3º Brix /day
6. End Point 2º Brix
Residence Time (days)
Shiraz: 6.67
Cab Sauv:6.50

Table 22: General Details relating to Red Fermentatino

Residence time was developed from the ideal reaction rate of ºBrix per day for each variety and a standard end point of 2º Brix.

Following this information capacity calculations were done by trail and error in excel using various reactor volumes to achieve the minimal number of tanks and waiting days. The following table outlines what was found to be a good balance between grape storage on arrival and number of fermenters.

Constants	
Volume (capacity): m^3	11
Volume (fill): m^3	10
Number of Fermenters:	10
Density (red must) kg/m3	1085

Table 23: Volume Developed for Red Fermenter

- Knowing the desired volume of 11m3 (fill level of 10m3) tank diameter was solved in excel.

$$Diameter(mm) = \sqrt{\frac{Volume}{Height \times \pi}} \times 2000$$

- Using the following constants the pressure incident on the bottom of the vessel was solved:

Constants	
Density (red must) kg/m3	1085
Atmo Pressure (kPa)	101.3
Gravity (ms-2)	9.81

$$Pressure(MPa) = \frac{\rho_{must} \cdot 9.81 \cdot Height}{1000000} + \frac{101.3}{1000}$$

- ASTM A240 316 K Stainless steel has been chosen for the manufacture type. It has a design tensile stress of 129 MPa at 100ºC.

- Australian Standard 1210 has been used to size the vessel as pressure vessel. Wall size is determined by the larger of either the Longitudinal or Circumferential functions. Since the Longitudinal is always larger for vessels of this size this is the only equation repeated.

1.7. Flanges (AS 2129):

Table 24: Flange Sizing Information for Red Fermenter

Flange	Description	DN (mm)	Sched.	OD (mm)	Bolts	Hole Diameter (mm)	Bolt Type	Pitch Circle (mm)
B	Liquid Drain/Fill	80	10S	185	4	18	M16	146
D	Liquid Drain/Fill	80	10S	185	4	18	M16	146

All flanges will be connected to piping via valves, hence will need to be constructed as per figure v, table D of AS2129. Flanges will have radius of their fillet (R_2) equal to 6.5mm.

2. CONTROL SCHEME DESIGN

2.1. White Wine Fermenters

White Wine Fermenters are of a common design used throughout the winery. The control scheme for each has been modified to suit the particular application.

Table 25: White Wine Fermenter Temperature Control

CONTROL LOOP/MEASUREMENT		TI-300
PROCESS UNIT		WHITE WINE FERMENTERS
P&ID DRAWING		CHPR4401-A-PID03
Item	**Description**	**Justification**
Controlled Variable	Tank Temperature	Tank needs to be maintained stable fermentation conditions and maximise wine quality.
Measured Variable	Tank Temperature	Direct measurement of vessel temperature via thermocouple attached to internal wall.
Manipulated Variable	Coolant Flow Rate	Adjustment of coolant flow through the cooling jacket. During normal operation and once tank temperature is stable; this should only be to remove heat absorbed from the surroundings and heats of reaction. It is expected the flow rate will be overall low. The manipulated variable may be placed in manual in the off position should the winemaker decide ambient conditions do not require active cooling.
Alarms	High : 18ºC Low : 10ºC	Of main importance during fermentation is maintaining stable temperature. High and low alarm values for fermentation are suitable for storage.
Trips	Nil	No trips required
Indicators	TI-300	Display vessel temperature in control room.
Interlocks	Nil	No interlocks required.
Set Point	15ºC	Temperature selected to be optimal for the individual processes at hand.
Control Type	D.C.S.	Loop is part of the plant distributed control system

Table 26: White Wine Fermenter Pressure Control

CONTROL LOOP/MEASUREMENT		PI-301
PROCESS UNIT		WHITE WINE FERMENTERS
P&ID DRAWING		CHPR4401-A-PID03
Item	**Description**	**Justification**
Controlled Variable	Tank Pressure	Tank needs to be maintained stable fermentation conditions and maximise wine quality.
Measured Variable	Tank Pressure	Direct measurement of vessel pressure via transducer attached to internal roof.

Manipulated Variable	Pressure Relief Valve	Adjustment of internal pressure through pressure relief valves.
Alarms	High: 150kPa Low : 98kPa	Of main importance during fermentation is maintaining stable pressure so as not to starve the yeast and prevent atmosphere entering the tank and spoiling the wine. High and low alarm values for fermentation are suitable for storage.
Trips	Nil	No trips required
Indicators	TI-300	Display vessel temperature in control room.
Interlocks	Nil	No interlocks required.
Set Point	10kPag	Temperature selected to be optimal for the individual processes at hand.
Control Type	D.C.S.	Loop is part of the plant distributed control system

2.2. Red Wine Fermenters

Table 27: Red Wine Fermenter Temperature Control

CONTROL LOOP/MEASUREMENT		T-302
PROCESS UNIT		RED WINE FERMENTER
P&ID DRAWING		CHPR4401-A-PID03
Item	**Description**	**Justification**
Controlled Variable	Tank Temperature	Tank needs to be maintained stable fermentation conditions and maximise wine quality.
Measured Variable	Tank Temperature	Direct measurement of vessel temperature via thermocouple attached to internal wall.
Manipulated Variable	Coolant Flow Rate	Adjustment of coolant flow through the cooling coil. During normal operation and once tank temperature is stable, this should only be to remove heat absorbed from the surroundings and the heat of reaction hence flow rate should be minimal. The manipulated variable may be placed in manual in the off position should the winemaker decide ambient conditions do not require active cooling.
Alarms	High: 30ºC Low: 20ºC	Of main importance during fermentation is maintaining stable temperature. High and low alarm values for fermentation are suitable for storage.
Trips	Nil	No trips required
Indicators	TI-300	Display vessel temperature in control room.
Interlocks	Nil	No interlocks required.
Set Point	25ºC	Temperature selected to be optimal for the individual processes at hand.
Control Type	D.C.S.	Loop is part of the plant distributed control system

2.3. Racking

Racking occurs after fermentation. It can either be conducted in the sealed fermentation vessel that the juice was fermented in, or transferred to a new vessel. All red wine in transferred to racking after fermentation in open tanks.

All the tanks in this section are of two comparable designs and subsequently have almost identical control loops. Automated pressure control should be implemented as a small amount of fermentation may continue for some time. Atmosphere must be kept out of the tank to prevent spoilage of the wine.

On draining these vessels, 19.5% oxygen content is required before personnel can enter to undertake cleaning operations (AS/NZS 2865). In order to achieve this, the check valve fitted to the top of the vessel must be connected to a line open to atmosphere. As the tank is drained, air will flow into the tank, leading to a situation in which minimal additional ventilation is required.

Before filling can be undertaken, the tanks must have their O_2 content reduced. To achieve this, a small quantity of CO_2 is manually added to the bottom of the tank from a high-pressure line. In this arrangement, the denser CO_2 (Haywood, 1990) should displace the air in the lower part of the vessel and form somewhat of a buffer layer between the process liquid and the air until the vessel is full.

Table 28: Racking Temperature Control

CONTROL LOOP/MEASUREMENT		TI-305
PROCESS UNIT		RACKING TANKS
P&ID DRAWING		CHPR4401-A-PID03
Item	**Description**	**Justification**
Controlled Variable	Tank Temperature	Tanks are kept cool to maintain the quality of wine produced.
Measured Variable	Tank Temperature	Direct measurement of vessel temperature via thermocouple attached to internal wall.
Manipulated Variable	Coolant Flow Rate	Adjustment of coolant flow through the cooling jacket. During normal operation and once tank temperature is stable, this should only be to remove heat absorbed from the surroundings and hence flow rate should be minimal. The manipulated variable may be placed in manual in the off position should the winemaker decide ambient conditions do not require active cooling.
Alarms	High : 18ºC Low : 10ºC	To ensure the quality of the product the temperature should be monitored and alarmed before exceeding safe limits.
Trips	Nil	No trips required
Indicators	TI-300	Display vessel temperature in control room.
Interlocks	Nil	No interlocks required.
Set Point	15ºC	Temperature selected to be optimal for the individual processes at hand.
Control Type	D.C.S.	Loop is part of the plant distributed control system

Table 29: Racking Pressure Control

CONTROL LOOP/MEASUREMENT		TI-305
PROCESS UNIT		Racking Pressure Control
P&ID DRAWING		CHPR4401-A-PID03
Item	**Description**	**Justification**
Controlled Variable	Tank Pressure	Temp
Measured Variable	Tank Pressure	Direct measurement of vessel temperature via thermocouple attached to internal wall.
Manipulated Variable	Pressure Relief Valve	Adjustment of coolant flow through the cooling coil. During normal operation and once tank temperature is stable, this should only be to remove heat absorbed from the surroundings and hence flow rate should be minimal. The manipulated variable may be placed in manual in the off position should the winemaker decide ambient conditions do not require active cooling.
Alarms	High: 150kPa Low: 98kPa	Of main importance during fermentation is maintaining stable temperature. High and low alarm values for fermentation are suitable for storage.
Trips	Nil	No trips required
Indicators	TI-300	Display vessel temperature in control room.
Interlocks	Nil	No interlocks required.
Set Point	10kPag	Temperature selected to be optimal for the individual processes at hand.
Control Type	D.C.S.	Loop is part of the plant distributed control system

2.4. P&ID Notes

Valves

Unless otherwise noted, all valves shown on P&IDs 1 and 2 are constructed from 316 stainless steel.

Isolation Valves

All equipment is flanged and control valves can be isolated and removed from pipelines without loss of fluid. For the pressure control valves fitted to the tanks, no additional isolation is supplied. In this case, the tank is to be reduced to atmospheric pressure rather than shut-in in order to prevent damage due to potential over pressurisation. Oxygen transfer into the tank is minimised by the narrow bore of the piping and CO_2 produced during fermentation should provide a net outflow from the tank.

3. START-UP AND SHUTDOWN PROCEDURES

3.1. Overview

As a winery consists largely of batch processes, traditional documentation of start-up shutdown procedures is not strictly relevant. The following section outlines the key aspects of each of the major pieces of equipment in Initial Processing and their correct handling before and after usage.

For all equipment contacting the process fluids, ensuring hygiene is essential. All shutdown procedures therefore, include a cleaning step. Cleaning is essentially a four-step process that comprises the removal of any solid debris, a rinse with clean water, thorough wash with hot caustic and finally finished with a second rinse.

3.2. White Wine Fermenter

At start-up the correct operation of the cooling loop should be verified in order to minimise the risk of having to drain the vessels immediately after filling. Every fill/drain of a tank increases the chances that the process fluids will come into contact with oxygen. Before juice or wine can be stored in the chilled holding tanks, the vessels first need to be prepared in order to minimise the contact between the process liquids and air. The vessel should be sealed to all lines other than the CO_2 inlet and the pressure regulation line. The CO_2 line should then be opened for 10-30 seconds to provide a layer of gas in the lower section of the tank. Incoming liquid fills beneath this layer and is buffered from the air in the top half of the vessel. Once the tank has been filled to the correct level the inoculated yeast may be added and fermentation will begin shortly after

At drainage, in order to prevent collapse, the vessel is allowed to ingest air by way of the check valve fitted to the vent line. The line should be checked for blockages and the correct operation of the check valve before liquid is pumped from the vessel. The ingested air does not contact the wine inside the vessel due to the CO_2 present at the top of the vessel from the filling stage. The air also serves to increase the oxygen concentration inside the vessel in order to provide a safe atmosphere for entry (AS2865). Once drained the vessels require thorough cleaning, inspection and if appropriate maintenance before being sealed. When not in use the vessels are to be filled with air rather than CO_2 to facilitate easy entry at a later date.

3.3. Red Wine Fermenter

As with the white wine fermenter the cooling control loop operation should be verified before beginning the fermentation process to minimise the potential risk of losing a batch of wine. Unlike the white fermenter however the red tanks do not required flushing with CO2 in order to prevent contact with air. Air contact with red wine fermentation assist in producing the distinctive flavour of red wine.

When drained there is no chance of applying a negative pressure differential to the tank as it is open to atmosphere by design. However the red fermentation processes has a high amount of solids and only the peristaltic pump should be used to prevent blockages in other types of pumps. Once drained the vessels require thorough cleaning, inspection and if appropriate maintenance before being sealed. When not in use the vessels are to be filled with air rather than CO_2 to facilitate easy entry at a later date.

3.4. Refrigeration Unit and Process

The refrigeration unit side pump should be turned on before all other equipment. Having no flow through the refrigeration unit can cause damage if it operates for extended time in this manner. Following confirmation of flow the refrigeration unit itself can be switched on. It has an automated start-up procedure built into the on board PID controller. Once correct operation has been established the plant side operating pump may be turned on and regular operation of cooled devices may begin.

4. Critical Review and Conclusions

4.1. Critical Review of Design

Overall this design is solid, proven and operable grape fermentation process. By choosing to allow the winemaker a certain degree of freedom in the choices they make we have developed a strong technical solution to the design problem. Due to our grape arrival distribution we use many more fermentation tanks than would have been economical. A trade off was required in the length of time grapes were stored, compared with the number and size of each fermentation vessel. In reality we suspect this number of fermentation vessels may be difficult to manage.

Our cooling design solution offers on demand, high capacity cooling which is highly suited to the types of cooling demand present at the winery, such as cold stabilisation. However it is a relatively energy expensive processes, requiring the refrigeration unit to run extremely frequently. More time and expertise may have resulted in a more efficient cooling solution capable of the same requirements as the one presented here.

The yeast inoculation tank is good for fermentation control. We are able to store juice, then raise its temperature slightly and introduce strong, well formed yeast to the tank to start fermentation when it is needed by the winemaker. This process may get tiring though, alternatives to this solutions should be investigated in due time.

4.2. Conclusions

The goal of the process has been to convert sugar into ethanol in a way which produces minimum undesired by products, with maximum preservation of the natural aroma flavour of the fruit. We believe this has been achieved with a realistic design presented within. It accommodates the production of high quality wine, with relatively good productivity and utilisation of equipment, safety and control.

On the whole, the assumptions and simplifications have resulted in equipment that if anything has been overdesigned in most cases. If built the process would most likely work, although considerable work would then be required in order to maximise efficiency. This initial design would require additional review and where appropriate, redesign, in order to reach its full potential.

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