The

Cyclonic Evaporator

(CycloVap*)

Separating Waste from Water

ACQUA International Group ["ACQUA"]

ACQUA are involved in the extraction of waste from water using proprietary technologies sold under the following brand names:

- *Vertical Gravity Separator (VGS*)*
- *Induced Cyclonic Separator (IC-SEP*)*
- *Cyclonic Falling Film Evaporator (CycloVap*)*
- *Inline Swirl Generator Hydrocyclone Head (ISG*)*
    - *Liquid/Liquid*
    - *Solid/Liquid*
- *Liquid Skimmer (Skimmer*)*

The ACQUA technologies are involved in the following market segments and applications:

- *Oil-water separation*
- *Fat, oil and grease recovery/removal*
- *Marine bilge water treatment and marina oil slicks clean-up*
- *Soil remediation*
- *Tertiary sewage treatment*
- *Recovery of backwash water*
- *Removal of suspended solids*
- *Treatment of wastewater from food and chemical manufacturing, pulp and fines recovery.*

* Indicates International Patents Pending

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1 THE CYCLONIC EVAPORATOR (CYCLOVAP*)

The Cyclonic Evaporator (CycloVap*) is a highly innovative, patented, and environmentally friendly evaporator. Developed and manufactured in Australia, the CycloVap* is set to revolutionise the way evaporators have been perceived.

Whilst traditionally, evaporators have been plagued by high energy consumption, which often has made them financially unviable, they do have relative advantages over other systems designed to allow for water reuse.

Evaporators have the advantage of lower maintenance costs, than membrane systems such as Reverse Osmosis and Nano-Filtration, and they respond much better to fluctuations in the wastewater feed concentration and makeup.

However, despite the relatively higher energy costs of evaporation, they have been used more commonly than membrane systems because of lower overall maintenance costs.

The CycloVap* is a new evaporator, based on traditional rising or falling film evaporators of the plate or tubular type. However, due to greatly enhanced heat transfer coefficients and the ability to handle viscous and scaling materials without the premature loss of performance, the CycloVap* has solved the problem of high energy usage that has plagued evaporators.

1.1 Features and Benefits

- Thin liquid films, generated by the ISG*, give higher heat transfer coefficients.
- Handles viscous and scaling products.
- Energy input may be from many sources - Low grade steam, hot flue gas and an option for vapour recompression systems.
- Multiple effect systems reduce energy input.
- Capital cost is typically 30% less than equivalent evaporators.
- Footprint is reduced by as much as 90% of comparative evaporators.
- Recovery and reuse of demineralised water from process or waste streams.
- Concentration of dilute products or wastes for reuse.

1.2 Applications

- Concentration of juices, pulps, extracts and chemicals.
- Treatment of brine or salt solutions to recover water for reuse and concentrated brine for recovery or reuse.
- Production of demineralised water and concentration/recovery of oil in aqueous based water coolants.
- Aroma recovery.
- Alcohol stripping.
- Recovery of vegetable oils.
- Recovery of Biodiesel.
- Recovery of lanolin.
- Treatment of intractable wastes that have been previously uneconomic to treat.
- Treatment of difficult to treat wastes that have been previously uneconomic to treat

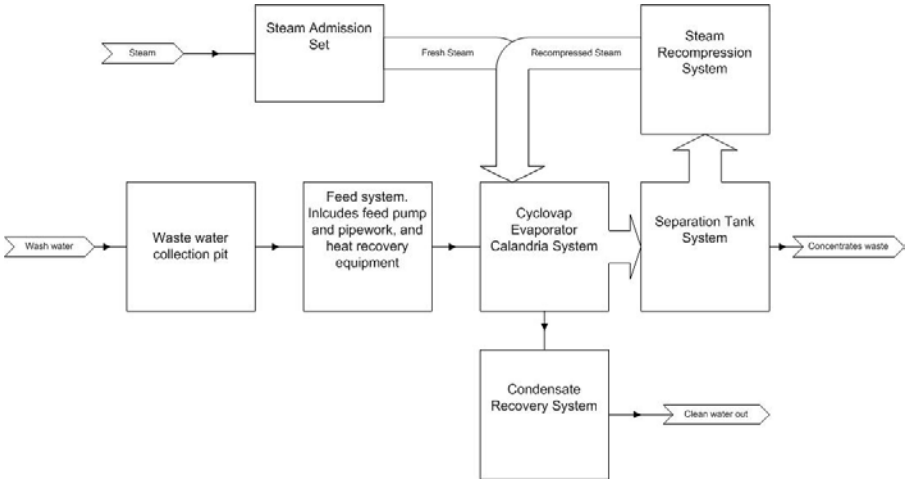
1.3 How does the CycloVap* work?

The CycloVap* system works differently to other evaporator systems by introducing the feed wastewater to the heating tubes in a very unique way. The Inline Swirl Generator (ISG*), another patented ACQUA product, imparts a very high tangential swirl on the incoming feed which causes the liquid to be distributed inside the heating tubes as a very thin film.

The film is able to heat very rapidly with minimal temperature difference because of the high heat transfer coefficients caused by very thin film rotating at high velocity. The heat transfer is further aided by the re-circulation of the unvapourised liquid from the bottom of the heating tube.

From the heating chamber, the partially evaporated liquid is fed to the separation chamber where it 'flash' evaporates. An overhead duct allows the vapours to be released while the concentrate is pumped away.

In order to increase system efficiency, the vapour from the first "effect" can be passed to a second "effect" to be used as the steam heating medium. This allows the CycloVap* to develop multiple effects or optionally, employ the use of Mechanical Vapour Recompression.



Mechanical Vapour Recompression allows the CycloVap* to utilise the vapour generated through the evaporation process, and recompress it to form high pressure steam. This allows the CycloVap* to be much more energy efficient, through the makeup of little or no fresh steam, and by using significantly less power in the process.

Finally, the steam vapour is condensed in the heat exchanger shells and to ensure water purity, can be passed through a carbon filter. This allows for the reuse of the water, which again underlines the savings both environmentally and financially to a business. The other output stream is the concentrate, which can be reprocessed or removed depending on the application.

1.4 Comparison of Wastewater Treatment Systems

Relative ability to handle the following issues	Evaporator System	Biological System	Membrane System	Reverse Osmosis System	Dissolved Air Flotation System
Environmental Benefits *(a)*	2	1	1	0	1
Variable contaminants	2	0	1	0	0
Handle volume of at least 2 tonne/hour	2	2	2	1	2
Discharge water quality	2	1	2	2	1
Discharge water reuse	2	1	1	2	0
Reduction in:					
Chemical usage	2	2	1	0	0
Energy consumption	1*(b)*	1	1	1	1*(c)*
Labor usage	2	2	2	2	1
Odor emissions	2	1	2	2	1
Maintenance time	2	1	0	0	1
System downtime	1	2	1	0	2
Total Score	**20**	**14**	**14**	**10**	**10**
System preference	*high*	*medium*	*medium*	*low*	*low*

Performance score legend:

2=High performance
1=Medium performance
0=Low performance

Notes:
(a)The environmental benefit is assessed in terms of reductions in energy consumption, odor and polluted liquid emissions to the environment.

(b)Assumes energy efficient evaporation utilizing mechanical vapor recompression.

(c)Assumes use of surface aeration systems.

1.5 Comparison of Evaporators

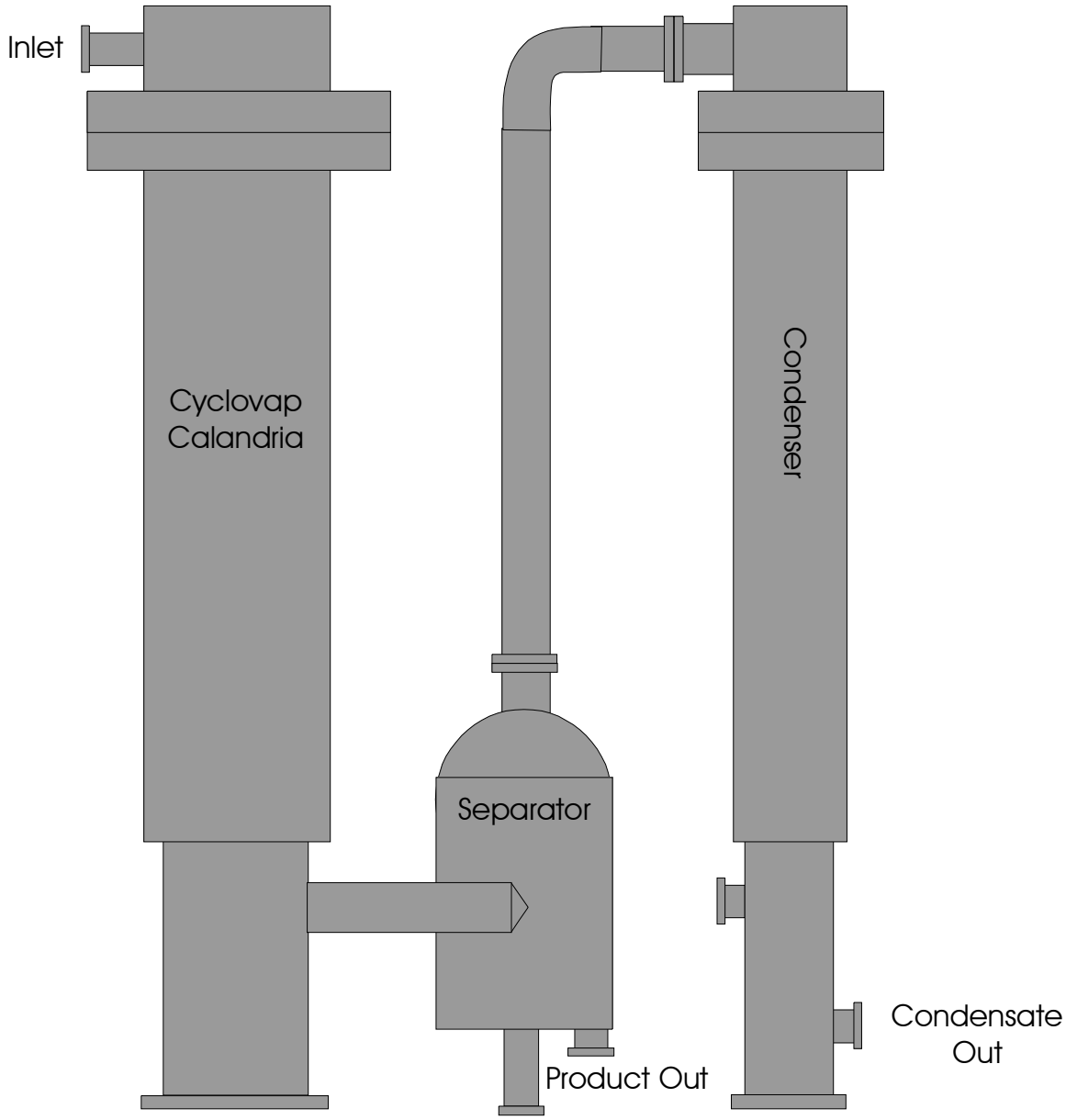
Differentiating characteristics	Cyclonic	Plate	Flash	Falling Film	Rising Film	Spinning Disk
Ease of cleaning	2	2	2	1	1	0
Reduction in fouling	2	1	1	1	1	2
Reduction in cleaning downtime	2	1	1	1	1	1
Reduction in maintenance costs	2	1	1	1	1	0
Reduction in capital cost	2	1	2	1	1	0
Reduction in footprint	1	2	1	1	1	2
Increase in life expectancy	2	1	2	1	1	0
Handling viscous contaminants	2	1	0	0	0	2
Modular expansion capacity	2	2	1	2	1	0
Total Score	**17**	**12**	**11**	**9**	**8**	**7**
System preference	*high*	*medium*	*medium*	*low*	*low*	*low*

Performance score legend:

2=High performance
1=Medium performance
0=Low performance

2 DIAGRAMS

2.1 CycloVap*



3 TECHNICAL PAPER

"CYCLOVAP* TECHNOLOGY FOR COST EFFECTIVE WASTE WATER TREATMENT AND RECYCLING IN THE STEEL INDUSTRY"

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Synopsis

With the global trend towards reducing discharge to waterways, even after pre-treatment, a new generation of evaporator has the capability to economically recover water to a standard for re-use and to separate the "waste" contaminant without the addition of costly chemicals.

The CycloVap* technology was developed by the ACQUA International Group and is sold into the global Steel Industry, under license from ACQUA, by WasteCycle Pty Ltd. This innovative equipment has made evaporative treatment of waste streams, within the steel industry, an economical alternative to currently used technologies.

The CycloVap* technology has many advantages over traditional evaporators. The fundamental advantage is a patented injection system that enables excellent heat transfer efficiency. This feature in turn enables a significantly smaller design that reduces both capital costs and ongoing running costs.

The first Steel mill application of CycloVap* technology has been successfully developed at BHP Western Port (Victoria, Australia) in conjunction with Quaker Chemical (A/Asia) P/L. This installation processes all the Cold Mill effluent (~20 Million litres per year) and returns distilled quality water back to the mill for use in the coolant emulsion, in place of the demineralisation water plant.

Introduction

In industry the objective of wastewater treatment fit into two broad categories. To treat effluent streams as cheaply and efficiently as possible and to create a minimum volume for discharge or to process the effluent stream to a point where one or all of its components, particularly the water, can be reused. The first objective is usually to meet an imposed requirement set by government. It is a cost of doing business. The second objective then becomes an *opportunity* in cases where it is cost effective to recover the component at a cost less than to obtain it in the first instance. Often this may be driven by shear availability of the resource, particularly in the case of water.

Many different treatment techniques have been devised to treat the many types of wastewater that are generated by modern industrial practices. Most wastewater problems using traditional waste treatment solutions end up with the water passing once through the factory or down graded to be used in another process before it is disposed. Disposal in its simplest form may be to the environment in some manner at an intangible cost or to a designated system with either direct costs for further treatment or more indirect intangible costs.

Generally the first objective (wastewater minimisation) is partially met, because it has to be but the second (water reuse) is usually ignored because of cost. The cost of additional energy, invested capital or requirement of process chemicals outweighs the cost recovered. Often not factored into the review is the benefit that an organisation may be able to claim through being good environmental stewards. It becomes very difficult to translate this to a monetary figure.

For intractable wastewater problems, and / or where pure water is required as a feedstock, the more traditional forms of treatment do not adequately fulfil the dual objectives of wastewater minimisation and water reuse. New, more cost-effective methods of wastewater treatment are required.

Any alternative system should fulfil the following:

- Waste discharge costs are to be minimised.
- Water reuse has to be maximised.
- Maintenance costs should be low.
- The system has to be easy to operate.
- Capital costs should be as low as possible.

Ultimately the cost and practicality of recovering the resource must win out.

Technically, the treatment requirement for total water reuse is a particularly onerous one. Few technologies are capable of treating the really difficult wastes, whilst still recovering a water stream suitable for re-use. Those technologies capable must work on complete separation based on molecular size or physical phase.

Those proposed and used commercially are Reverse Osmosis, Nano-Filtration and Evaporation. Traditionally each has had their advantages and disadvantages but for truly large and highly contaminated waste streams neither have been seen as a cost effective solution.

Membrane systems such as Reverse Osmosis and Nano-Filtration have the advantage of lower energy use, but tend to have higher operating costs due to the constant replacement of membranes over the life of the plant. They also have a more limited operating range, and do not respond well to changes in the feed concentration and makeup. The concentrated phase needs to be treated further for complete recovery and reduction of disposal costs.

Evaporators have the advantage of lower maintenance costs and respond much better to fluctuations in feed concentration and makeup, but energy use is usually greater than membranes. The evaporator is used more frequently for these difficult wastewater problems because of its relative advantages over membranes, but sometimes when energy is very expensive, evaporators are not always economic.

The CycloVap*

The CycloVap* evaporator is a newly patented evaporator that performs the same basic treatment functions, but in a much more efficient way. It can process the wastewater from a Cold Mill, or other source, into two discrete streams.

- A distilled clean water stream and,
- A concentrated waste stream containing all the oily / non-volatile & dissolved salts.

The CycloVap* system starts with a preheating exchanger that raises the temperature of the wastewater to approximately 95º C. This temperature is very close to the boiling point of the fluid at the vapour pressure inside the cyclone chamber in the Cyclovap. When the fluid enters the Cyclovap cyclone chamber, it is rapidly accelerated to several thousand rpm, and then introduced to a steam-heated surface where the water starts to boil. The rapid spinning of the fluid inside the heating surface (tube) minimises the possibility of boil-on scaling whilst promoting a very thin fluid film creating an extremely high heat transfer coefficient (HTC) that increases efficiency and reduces the required surface area of the evaporator. Unvapourised liquid from the bottom of the tubes is circulated back to the top of the Cyclovap to maintain the turbulence and therefore the high heat-transfer coefficient in the unit.

The heart of the CycloVap* is the In-Line Swirl Generator (ISG*), a patented device that can rapidly accelerate the liquid inside the tubes of a shell and tube heat exchanger. The rapid swirling helps the CycloVap* behave with the performance characteristics (low scaling & high HTC) of a wiped surface evaporator, whilst obtaining the high throughput and low maintenance of a traditional falling film evaporator. The key difference between this unit and ordinary falling film evaporators is the high Reynolds number generated by the ISG*. This high turbulence leads to high heat transfer coefficients. For wastewater applications, overall heat transfer coefficients of over 4500 $W/m^2/°C$ have been observed. The high turbulence also reduces the size of the critical evaporation zone where scaling is likely to occur, leading to reduced scaling tendency in the Cyclovap, and increased time between cleaning operations.

After heating to the boiling point in the tubes, the vapourised water and the concentrated solution flow into a separation vessel where the vapour is removed via an overhead duct, and the concentrate is pumped away from underneath.

In order to increase the energy efficiency of the total system, the vapours from this first “effect” can be passed to a second “effect” to be used as the steam heating medium. The concentrate-water can be fed into the second “effect” just as with the first “effect” and evaporated. As the steam for the second “effect” was really just waste vapour from the first effect, the overall energy efficiency of the system is almost doubled.

To further increase the energy efficiency of the system, the evaporated vapours coming from the second "effect" can be recompressed in a Centrifugal Mechanical Vapour Recompression system, and used as the steam source in the first "effect". In this way, all the evaporation of wastewater can be achieved with little or no fresh makeup steam. The steam vapour from the process was the water from the wastewater feed and is condensed in the heat exchanger shells (i.e. on the outside of the tubes).

To ensure water purity, the condensate can be passed through a carbon filter or ion exchange filter to ensure that no dissolved volatile organics remain. This use of these types of *post filters* is now possible in these systems because the total organic load is now very low and they now become economic as *polishers* in comparison to not being economic in the first instance. The recovered water can be stored and used again in the mill.
The concentrate *or oily* phase collected after the second "effect" can be reprocessed or removed for disposal. Because no emulsion breaking chemicals or polymers have been used, there is no additional contamination of the concentrate phase, thereby significantly increasing the probability for recycling.

BHP Western Port Cyclovap*

The following diagram "EXISTING SYSTEM" shows the process that operated historically for the treatment of the Cold Mill's oily wastewater.

- To address the waste costs incurred by the mill, a 6000 litre per hour CycloVap* was installed by Quaker Chemical (A/Asia) as part of their on site coolant & cellar management service.

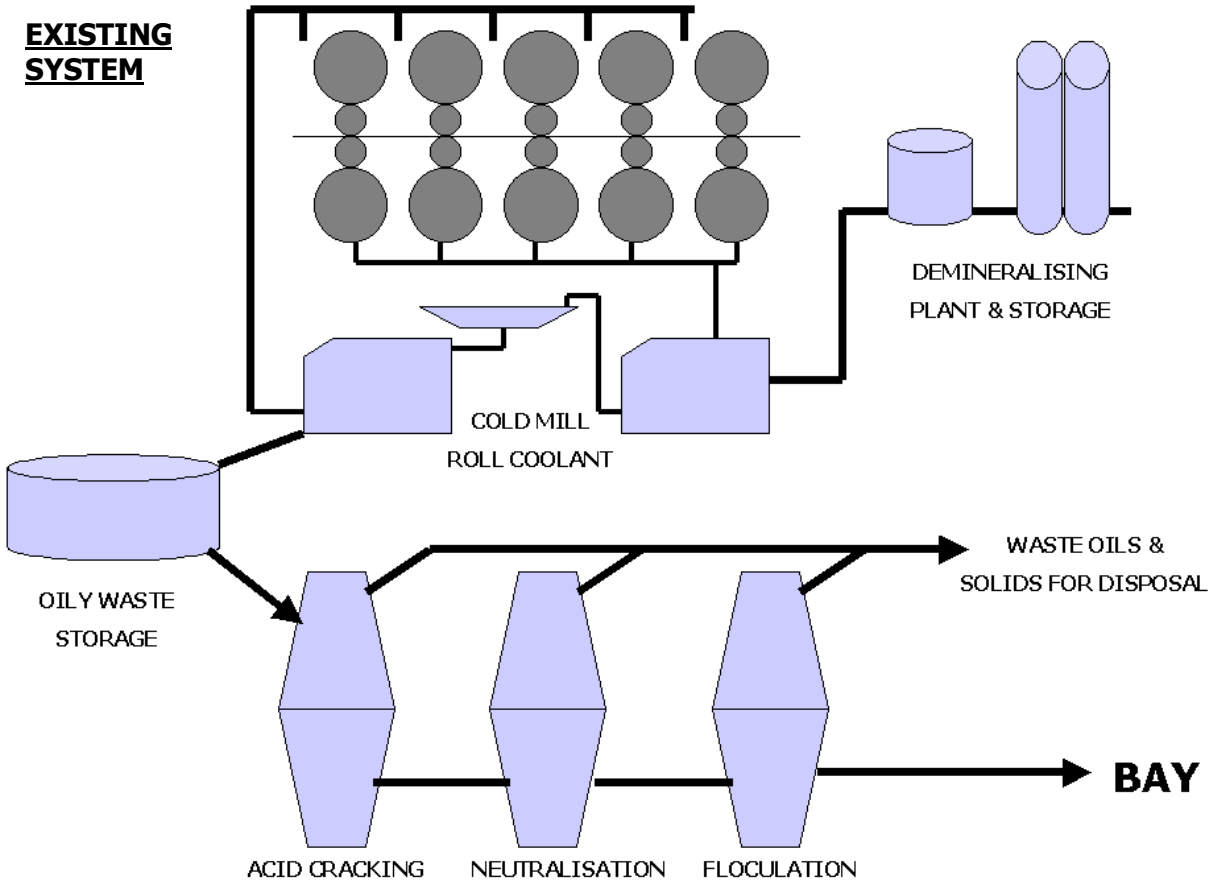
- Typically 20 M Litres per year was discharged from the mill cellar and processed though the existing water treatment plant. In addition, 50 M litres of fresh water was processed through an aging demineralisation plant (at the mill) to provide suitable water for coolant operations.

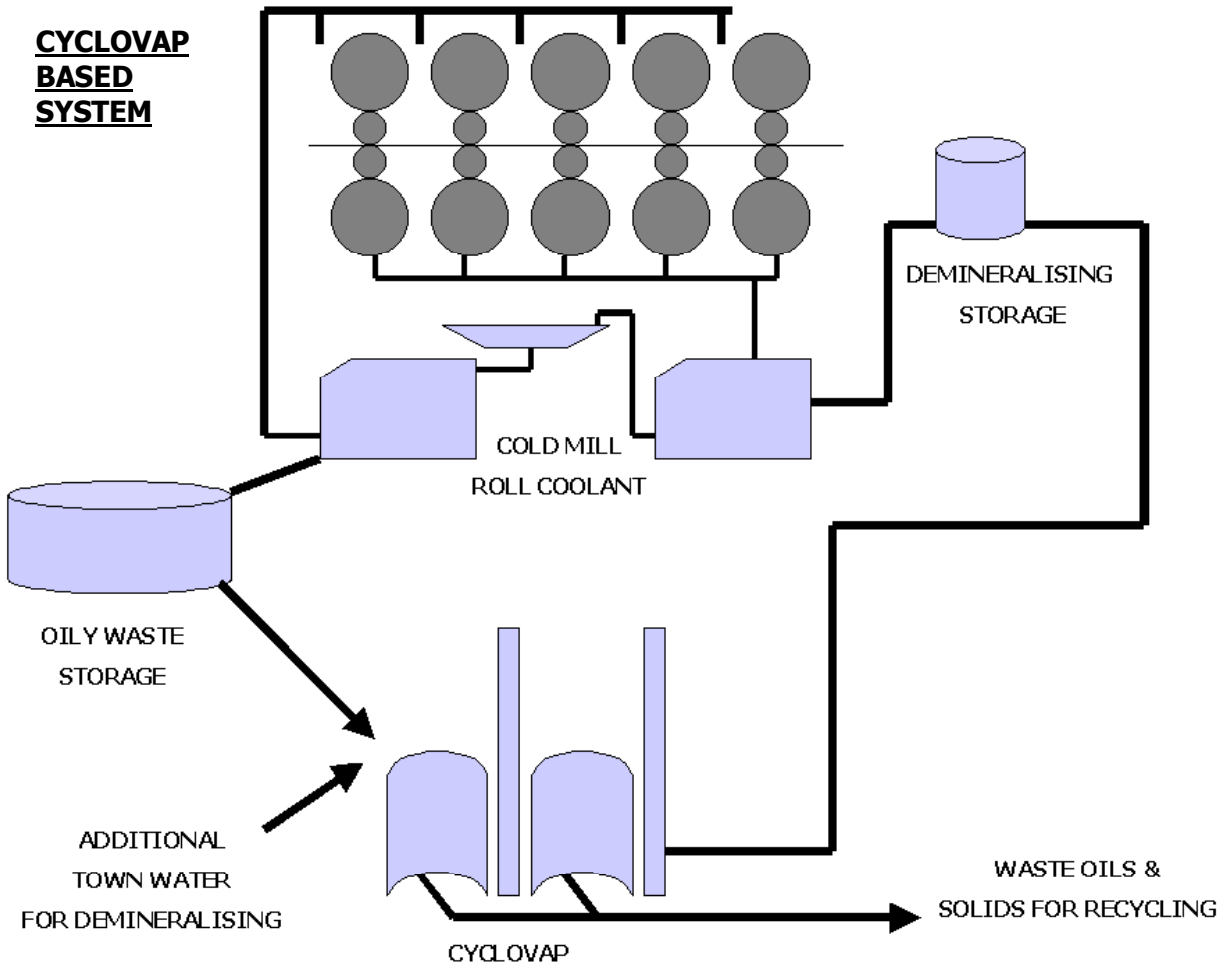
The "CYCLOVAP* BASED SYSTEM" diagram shows the process path following the installation of the CycloVap* system.

This new treatment process takes all the oily waste and returns the water phase to the mill, in place of the existing demineralisation plant. Any water short fall (to the cold mill's needs) is supplemented by either additional oily waste from other parts of the steel works or by fresh water into the CycloVap*.

It is located in the Cold Mill cellar and occupies a foot print area 5 meters by 2 metres, with a height of 7 metres.

Note: The primary water quality requirement from the Western Port demineralisation plant is to remove chloride from the incoming municipal water supply.





Energy Efficiency

The CycloVap* configuration installation at BHP Western Port (see diagram) optimises the use of site available energy sources. The unit uses both site steam and electricity, however double effect and a steam recompression system was also incorporated which significantly reduced the amount of steam required and hence reduced the operation costs.

The unit will typically use 50kg of steam and 12Kw of electricity per 1000 litres of oily wastewater. This translated into less than US$0.001 per litre running costs (less than US$1 per KL)

Water Quality

The following table shows the results that can be achieved by the CycloVap* process in treating Cold Mill oily wastewater.

TEST	Units	INPUT Oily Wastewater (ex Steel Works)	OUTPUT CycloVap* Water
pH		6.1	6.6
Conductivity	uS/cm	190	20
Chlorides	mg/l	42	7
Sodium	mg/l	38	<1
Total Dissolved Solids	mg/l	4420	5
Suspended Solids	mg/l	366	5
Sulphate	mg/l	14	<1
Total Alkalinity	mg/l	45	4
Hardness	mg/l CaCO3	33	<1
Iron	mg/l	16	<0.1
Zinc	mg/l	0.6	<0.1
Chrome	mg/l	0.5	0.1
Chemical Oxygen Demand (COD)	mg/l	3200	25
Total Oil & Grease	mg/l	372	3

Process benefits & Summary

The use of the unique ISG* means extremely high heat transfer coefficients, and the use of multiple effects and vapour recompression means utilising all the heat available. These innovations have removed the two negatives of evaporative wastewater treatment – namely the high-energy use and the high capital cost. The CycloVap* is able to handle a wide range of incoming wastewater with minimal operator intervention and with maximum energy-efficiency. It solves the dual objectives, waste minimization and water reuse, in the most practical and cost effective way.

The economic and environmental benefits achieved by the CycloVap* in this application are:

- No chemical usage to treat the mill oily wastewater.
- No requirement to produce demineralised water from the existing demineralisation plant.
- No discharge to the bay.
- No cost to dispose of recovered oil.
- Town water usage reduced.
- Significantly lower cost to manage the Mills water and coolant lifecycle.

The savings impact at the Cold Mill has been a cost reduction in the order of 70% on their previous water and waste treatment operation. The environmental benefits are in additional to the “hard dollar” savings generated and whist they carry no financial evaluation at this stage, the stewardship benefits for all parties are well acknowledged.

4 PROJECT SUMMARY

Tarac

4.1 Tarac

Client	Tarac
Location	Nurioopta, South Australia, Australia
Product	Cyclonic Evaporator (CycloVap*)

Objective

To concentrate heat sensitive wine extract from 1000 litres per hour to a concentrate of 100 litres per hour (10:1 concentration) without loss of colour or aroma and without caramelisation of the product.

Background

The client produces a wine extract to enhance the quality of lower grade red wines with a material that is derived from natural grape.

There were space and height limitations in the existing factory so a compact plant was a major requirement.

Wine extract also has a substantial amount of tartrate present and this has previously been a problem with heavy deposits in the plate evaporator that was used to 2:1 concentrate the product, the CycloVap* had to overcome all of these problems.

Solution

To provide the client with a compact CycloVap* plant to process 1000kg/hr of wine extract, to produce 100kg/hr of concentrate without loss of colour or aroma and not caramelised.

The CycloVap* uses a patented ISG* inlet nozzle to provide equal distribution to all of the calandria tubes as well as very high cyclonic liquid inlet velocities to highly improve film and heat transfer coefficients. This results in the ability of the CycloVap* to evaporate liquids in a 3 metre calandria tube length compared to 9 – 12 metre long calandria lengths. This results in lower capital cost per kilogram of water evaporated as well as reduced building costs due to lower headroom requirements.

5 LIST OF CYCLOVAP* PROJECTS

Detailed below is a complete list of CycloVap* systems that have been installed by ACQUA.

Client	Country	Industry	Throughput (L/hr)	Application
Tarac	Australia	Wine	1,000	Product Recovery
BHP Billiton	Australia	Steel	5,000	Wastewater

6 INDUSTRY INTEGRATION FLOWCHART

This industry integration flowchart illustrates the applications for the ISG* and other ACQUA proprietary technologies.

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