Purification of Sulphuric Acid at Wispeca

by

Natalie Joubert
27020119

Submitted in partial fulfillment of the requirements for
the degree of

BACHELORS OF INDUSTRIAL ENGINEERING

in the

FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION
TECHNOLOGY

UNIVERSITY OF
PRETORIA

October 2012

Executive Summary

The anodizing plant at Wispeco Aluminium in Alrode, Alberton, uses various chemicals, but mainly sulphuric acid, in their anodizing process.

During the anodizing process aluminium and other unknown substances dissolve into the sulphuric acid. The concentration levels of the dissolved aluminium within the sulphuric acid are checked and regulated daily to ensure that the aluminium concentration does not exceed a level higher than 14g/ℓ. At the end of each week the sulphuric acid is disposed of and replaced with new sulphuric acid.

An investigation was conducted at the anodizing plant to determine the viability and effectiveness of purifying the sulphuric acid. The main goal of the project is to identify acid purification methods in order to significantly decrease the purchasing and usage of new sulphuric acid in the anodizing process.

The plant was inspected to determine whether there is sufficient space for a purification system. An acid analysis was also done to determine what other unknown substances – apart from aluminium - are found in the sulphuric acid solution which then could also be removed during the purification process.

The current anodizing process at the plant was analysed and discussed with the role players to gain a better understanding of the process and the current problems within the process.

A literature review was conducted of articles, case studies, journals and books about anodizing and the purification of sulphuric acid. From the literature review the best purifying methods were identified and documented.

A cost-analysis was done by comparing (1) the purchase- and installation costs of an acid purification system with (2) the total cost-savings if such a system were implemented. Different suppliers were contacted to obtain quotes for the purchase and installation of an acid purification system and a cost-analysis was done at the effluent plant in order to determine the cost-savings.

Results were documented and recommendations were made.

Table of Contents

List of Tables

List of Figures

Chapter 1 - Project Motivation

1.1 Introduction and Company Background

Wispeco Aluminium is a diverse and innovative Southern African company which leads the way in high quality aluminium extrusion production and supply to various industries. Items that are produced by Wispeco include casement windows, Euralco door and window systems, insect screens, shop fronts, shower doors, sliding doors, windows and garage doors. Wispeco also extrudes specialized engineering profiles such as heat sink profiles, cooling fins, electrical bus bar, ladders, scaffolding, sport and camping equipment, flagpoles and stair treads.

The company has evolved over the years from being the largest manufacturer of steel doors and windows to the largest supplier of aluminium to the architectural market.

Apart from the locally recognized and trusted aluminium windows and doors that Wispeco produces, the company is also involved in large infrastructure developments in the South African region, such as the King Shaka International Airport, Moses Mabhida Stadium and the Coega Container Depot in the Eastern Cape.

Wispeco strives and works towards using the latest and best technology and production methodologies to produce high quality products, but tries to improve production without having to make labour cuts. Job creation is very important to Wispeco.

There are four main operating divisions that exist within the company:

1. Die manufacturing
2. Aluminium extrusions
3. Finishing
4. Aluminium systems

In the third mentioned division the aluminium extrusions are surface-treated and the customer is given the choice of either a powder coated or an anodized surface. The latter is done at an anodizing plant. The anodizing plant consists of two sections: a fully automated section (AAP) and a manual section (MAP). The plant is situated in the industrial area of Alrode in Alberton, Gauteng. This project focuses on the anodizing plant and process.

The anodizing process provides the aluminium beams with a strong, impenetrable coating. The process uses sulphuric acid, water and other chemicals as well as electrical currents.

The process was investigated and analysed to gain insight and an understanding of exactly how it works and also what the current problems with the process are.

1.1.1 The AAP (Automatic anodizing process)

Anodizing is the process by which an oxide film or coating is formed on metals and alloys such as aluminium, titanium, tungsten through electrolysis. This film gives the metal a hard, corrosion resistant and abrasion resistant coating with excellent wear properties.

The automatic anodizing process is fully automated, but chemical levels, pH-balances, concentrations and temperatures are measured manually each day by a chemical expert.

Figure 1, page 4, shows the process flow diagram for the automatic anodizing process (Data from Wispeco, 2012).

1.1.2 The MAP (Manual anodizing process)

The manual anodizing process is performed manually by operators.

The production phases that differ in the MAP from the AAP are indicated in blocks 11-14 in Figure 2, page 5. These phases have the following specifications:

<u>Phase 11: Inspection</u>

Micron test – the aluminium beam is inspected and the coating thickness is measured (in micron) to make sure that the specifications of the customer are met.

The following thicknesses are allowable and the beams pass inspection if the micron measurement falls within the following ranges:

10µ - 8µ or higher

15µ - 13µ or higher

25µ - 22µ or higher

If the coating thickness is found to be below the specified values, the beam is returned to the anodizing tank.

Phase 12: Colouring

Temperature (Temp.): Ambient (Room)

Time: Time differs for every colour. Colours are applied using a code for each colour.

541: 30 seconds
543: 3 minutes

545: 5 minutes
547: 7 minutes

549: 25 minutes

pH: 4 – 4.5

SPECIFICATIONS (SPECS): Stannous sulphate concentration: 14g/ℓ - 22g/ℓ

Sulphuric acid concentration: 14g/ℓ - 22g/ℓ

Tilt and drain well

Phase 13: Colour Rinse (1)

Temperature: Ambient (Room)

Time: 2 – 5 min

pH: 6 – 8

SPECIFICATIONS: Rinse well

Tilt and drain well

Phase 14: Colour Rinse (2)

Temperature: Ambient (Room)

Time: 2 – 5 min

pH: 6 – 8

SPECIFICATIONS: Rinse well

Tilt and drain well

Check pH every 2 hours

The total level of production output of the MAP is lower than that of the AAP, because the process is done manually and more defective products are produced within the MAP.

Figure 2, page 5, shows the process flow diagram for the Manual anodizing process (MAP). (Data from Wispeco, 2012)

Figure 1 - Automatic anodizing process (AAP)

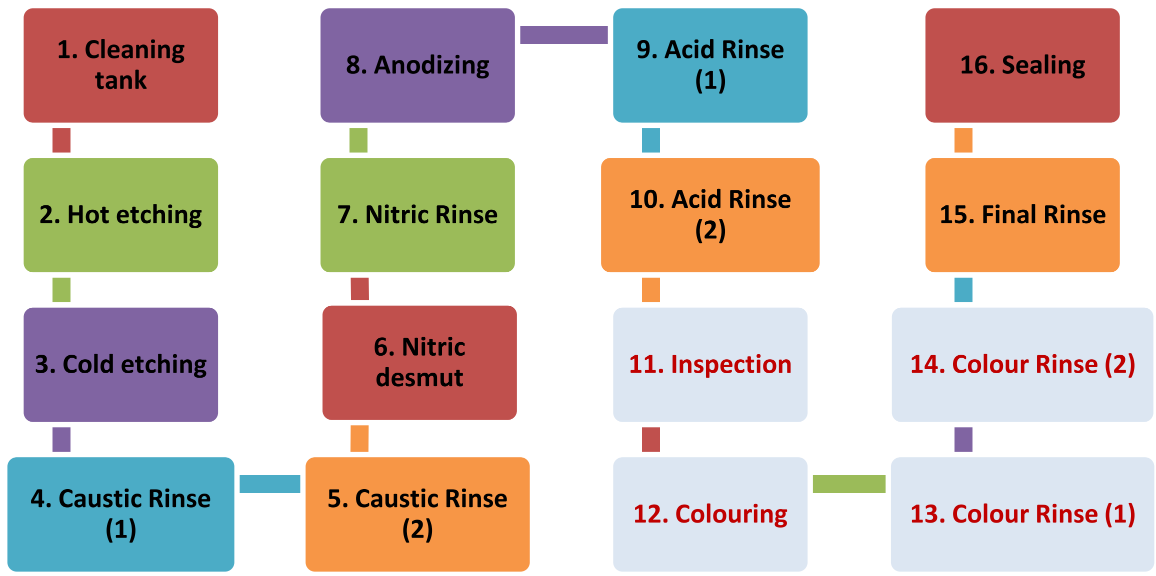


Figure 2 - Manual anodizing process (MAP)

1.2 Project Aim

Sulphuric acid is used in the anodizing process where aluminium extrusions are anodized and an impenetrable layer is formed as a surface finish on the extrusion.

The main aim of this project is to investigate and study the viability and cost effectiveness of purifying the sulphuric acid that is used in the process, so that it can be re-used. This will reduce sulphuric acid purchases and in turn reduce production costs. Currently the sulphuric acid is disposed of once a week and is replaced with new sulphuric acid. The aim of the project is to find a feasible and effective process that recycles the acid and thus reduces the amount of sulphuric acid that is purchased per month, so reducing production costs.

A thorough cost-analysis will have to be done to compare the total cost of implementing a new sulphuric acid recycling system versus the total cost-savings generated if this system were to be implemented. This will give an economic indication of whether it will be cost-efficient and viable to purchase and install the new technology at the anodizing plant.

Different acid purification methods were investigated by means of internet resources, books, journals and articles. During the project investigation cost effectiveness, production time and possible job creation were kept in mind.

Possible objectives towards the project aim:

(i) Investigate possible acid purification systems.
(ii) Investigate whether such systems are being used by companies in South Africa and which systems are used.
(iii) Determine cost and effectiveness of acid purification systems.
(iv) Analyse the sulphuric acid chemically to determine the contents of this post-anodizing solution to determine which impurities in the acid must be removed.
(v) Determine the reduction in the overall production costs (considering the sulphuric acid and concerned production processes) if an acid purification system were implemented.
(vi) Compare the reduction in above mentioned production costs to the cost of purchasing and installing a sulphuric acid purification system.

1.3 Project Scope

The project consists of various stages.

The first stage of the project includes research into current acid purification systems used in the South African production industry. (The international scenario was also investigated as it was found that no suppliers are currently based in South Africa.) This was done through in-depth literature reviews, interviews and visits to companies currently making use of acid purification systems, internet resources, text books and published articles.

The second part of the project includes the investigation into the viability and cost effectiveness of applying above researched methods to the anodizing plant at Wispeco. This was done by contacting and obtaining purchase and implementation quotes from possible suppliers of acid purification systems (via e-mail). A cost analysis was done at the effluent plant to determine cost-savings if an acid purification system were to be purchased and installed.

The remainder of the project time was used to compile a project report including all research, data, findings and recommendations. Engineering methods and best practice methods were used to construct a cost-analysis and appropriate graphs and tables used for data capturing.

This project does not include the implementation and evaluation of purification systems, but includes enough information to help Wispeco choose a viable and cost effective solution.

Possible deliverables of the project:

- ✓ A complete understanding of how the anodizing process works
- ✓ A detailed description of the anodizing process depicted in a process diagram
- ✓ Knowledge of the current production costs and production times, as provided by Wispeco
- ✓ A list of all possible acid purification methodologies
- ✓ A comparison of the cost and effectiveness of each method
- ✓ Discussion of studied methods with Wispeco and elimination of non-viable methods
- ✓ Detailed descriptions and the cost implementations of the best methods
- ✓ Cost-analysis of the purchasing and implementation of an acid purification system
- ✓ Cost-analysis of the total cost-savings in production when an acid purification system is installed
- ✓ Comparison between the purchase and implementation cost of an acid purification system and production cost-savings when such a system is implemented.
- ✓ Final recommendations

Chapter 2 – Literature Review

2.1 Literature Review

2.1.1 Background and Current situation – Anodizing Plant

Wispeco uses sulphuric acid in the anodizing process, as well as for the stripping of non-conforming beams which must then be re-powder coated or anodized. The stripping is done separately and two baths of sulphuric acid are used for this.

The quantities and costs of the historic sulphuric acid usage in the anodizing process are shown in Table 1.

Year	Average sulphuric acid purchases per year	Average cost of sulphuric acid purchases per year
2007	518640*ℓ	R321 576.80*
2008	652200ℓ	R436 973.90
2009	541050ℓ	R362 503.50
2010	535800ℓ	R405 684.74
2011	510320ℓ	R392 436.08
2012	557560ℓ	R524 904.64**
	* 6 months = 259320ℓ	* estimate
	** 6 months = 278780ℓ	** estimate
	Average per year = 559 842.5ℓ	**Average cost per year = R399 399.555**
	Average cost according to litres purchased = R554 244.1 (@R0.99/ℓ current price, 2012)	

Table 1 - Sulphuric acid purchase costs per year

A chemical analysis of the content of the anodizing baths is done each morning to determine the aluminium concentration in the sulphuric acid (this should be lower than 14g/ℓ) and also to determine the sulphuric acid concentration (minimum 175g/ℓ).

The analysis has to be done, since if the aluminium concentration reaches a level higher than 15g/ℓ, the sulphuric acid crystalizes as it passes through the heat exchangers. The heat exchangers block because of these crystals.

When this happens, the heat exchanger must be switched off, opened manually and cleaned. This process can take up to an hour. During this time coolers are used to regulate the temperature of the sulphuric acid.

Since the solution in the anodizing baths is only tested for aluminium and sulphuric acid concentrations, a chemical analysis must be done in order to determine whether there are other substances in the solution and the quantities or concentration of these.

The plant runs daily from Monday to Thursday. On Friday cleaning is done and a third of the sulphuric acid solution in each anodizing bath is drained and new sulphuric acid is added to the bath to increase the sulphuric acid concentration to above 175g/ℓ. At the stripping process the sulphuric acid is disposed of and replaced, on average, every two weeks.

The sulphuric acid, caustic soda (also a product that is used in the anodizing process) and both rinses (acid and caustic) are drained to the effluent plant where the mixing of all the chemicals results in a neutral pH solution.

This solution is then pumped to the flocculent section of the effluent plant where flocculant is added to remove aluminium and other impurities from the water. The water is sent to the municipality for treatment, while the sludge (the solids) is sent through a centrifuge to remove excess water. The semi-dry solids are disposed of into a container. A disposal company removes the sludge at a cost.

2.1.2 Literature study

Various sources were consulted to find different methods of acid purification that have been implemented in anodizing processes and similar situations in order to find a possible solution for the problem at hand. The findings of the research are documented below.

2.1.2.1 Anodizing acid purification using Resin sorption technology at Pioneer Metal Finishing (Pajunen and Harrison, 1997:8)

According to Pajunen and Harrison (1997:1) "a major contributor that leads to quality problems in an anodizing bath is the build-up of dissolved aluminum contamination. Implementing bath purification alleviates this build-up and promotes the generation of a consistent, predictable oxide coating."

This problem is currently faced by Wispeco and could lead to a chain reaction of problems, since Wispeco strives to produce quality products and such a build-up can decrease the quality of their products.

<u>Benefits of acid purification</u>

i) <u>Bath control benefit</u>

A number of potential problems can arise when operating an anodizing bath in a dump/ decant manner.

The following problems can be eliminated by ensuring bath consistency:

- ✓ Variable process times – a fresh and a spent bath scenario means adjustments in the length of time a work-piece remains in the bath for processing and contributes to productivity variation.
- ✓ Periodic line shutdown – when the bath is dumped and made-up with fresh solution, production time is lost.
- ✓ Material rework/ quality problems – poor bath conditions can lead to rework and surface finish problems such as burning and pitting; a more uniform oxide coating leads to better results.
- ✓ Labour costs for bath maintenance – operator safety is a concern.

(Pajunen and Harrison, 1997:2)

ii) <u>Reduced waste benefit</u>

Recycling the sulphuric acid in order to minimize sulphate discharge is attractive for the following reasons:

- ✓ Excess sulphates disposed at the local publically owned treatment works (POTW) are not ecologically desirable due to the damage that can be caused to concrete sewer lines.

  Sulphates attack the concrete, causing expansion/ swelling, loss of strength and hastening metal corrosion.
- ✓ Chemical costs are reduced, which includes the sulphuric acid for anodizing and the caustic soda for neutralization.

Pioneer Metal Finishing chose a purification system that utilizes a well-established method known as resin sorption that is made possible through the technique of reciprocating flow ion exchange.

<u>Acid purification history</u>

A process called acid sorption was introduced in 1963. Ion exchange resins are employed which sorb strong acids from a solution, but exclude metallic salts of those acids.

The acid can be readily desorbed from the resin water, making the process reversible. A chromatographic separation of the free acid from the salt can thus be achieved by alternately passing contaminated acid and water through the bed (Pajunen and Harrison, 1997:3).

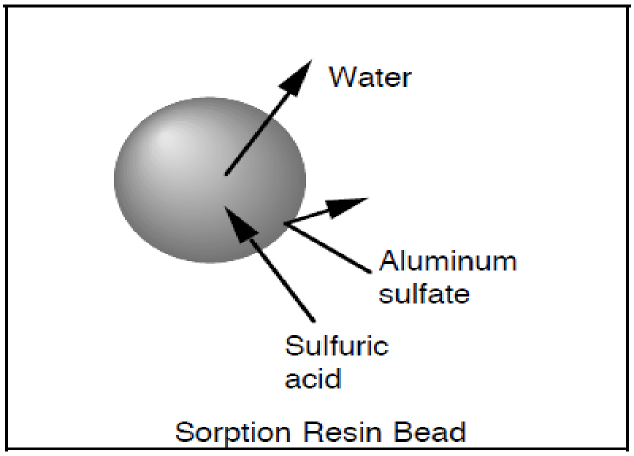


Figure 3 - Acid sorption

For some time this process was not successfully commercialized despite its appeal. According to Pajunen and Harrison (1997:3) this was probably due to “limitations of conventional ion exchange technology which tends to cause excessive dilution of the purified acid upon water elution and the large column size which results from the small bed volume throughputs inherent in the process.”

Reciprocating flow ion exchange, a novel exchange technique, was applied to the acid sorption process in 1975. Known characteristics of this ion exchange method include fine particle size resins, short column heights, fixed, over-packed resin beds and counter-current elution.

When treating small volumes of concentrated solutions with a minimum of dilution or fluid intermixing in the resin column, this process is ideal. The recovery of a wide variety of metals in the metal finishing industry has been achieved by the application of reciprocating flow ion exchange. Due to this method the performance of the acid sorption process was significantly improved (Pajunen and Harrison, 1997:3).

The first successful application of this method was reported in 1976 and since then more than 400 of these systems have been installed in various applications employing sulphuric and other acids all over the world.

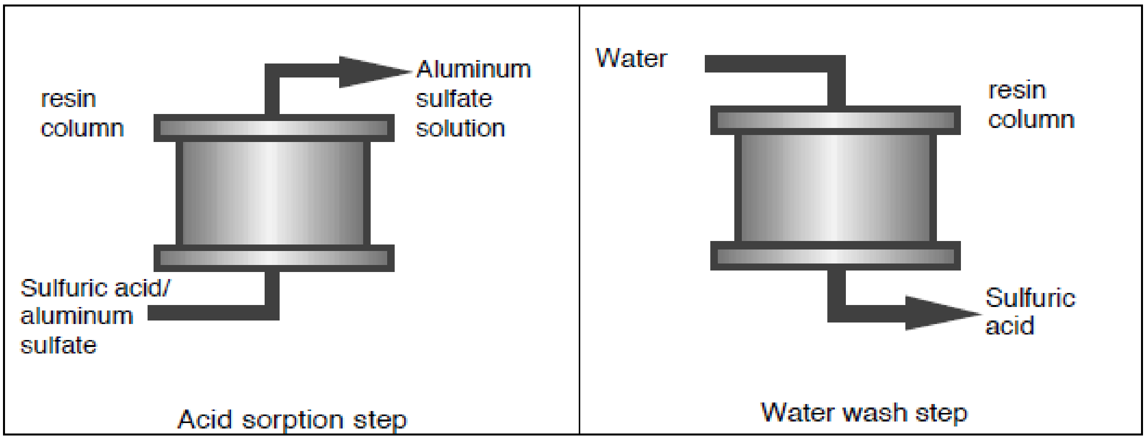


Figure 4 - Basic operation unit of acid sorption

The two main steps in the cycle are:

1. Sorption
2. Washing

During Sorption (step 1), the anodizing solution is pumped upward through the resin column. While aluminum sulphate salt solution passes through, free sulphuric acid is absorbed by the resin.

During Desorption/ water wash (step 2), water passes down through the resin column to extract free sulphuric acid from the resin (Pajunen and Harrison, 1997:4).

The equipment is designed so that it alternates automatically between sorption and desorption every few minutes. The net result is a virtually continuous process for acid purification and metal salt removal.

This equipment can easily be installed in the anodizing plant at Wispeco. The only operational costs are that of water usage and energy used for pumping the acid and water through the equipment. The initial capital layout is for the purchasing and installation of the equipment. The quantity of acid that is purified will have to be determined. The cost of purchasing new acid should be weighed against the quantity of sulphuric acid that is purified. This comparison will determine the viability of implementing such a system at Wispeco.

Future costs that will be incurred are replacement and maintenance costs once every 6-12 years, comprising 10-15% of the system cost. These tasks can be executed by regular plant personnel.

System operation and performance

A unit has the potential capability to affect an aluminum removal rate of 1.36kg/hour while holding the aluminum concentration at 7g/ℓ in the anodizing solution.

The mass balance of a unit is shown in Table 2, page 14.

Stream	Sulfuric Acid (g/L)	Aluminum (g/L)	Flow (L/hr)
Feed	200	7.0	432
Product	192	3.9	432
Byproduct	13.7	5.4	253
Water	–	--	253

Table 2 - Acid purifiation unit operating conditions

The following performance standards are reflected in the operating conditions:

- 96% of all free sulphuric acid that passes through the purification unit is recovered for re-use.
- 1.13kg sulphuric acid is lost to waste for every 0.453kg aluminum removed by the unit.
- This reduces the sulphuric acid purchases and caustic soda neutralization costs by up to 70% when comparing this system to holding the sulphuric acid and aluminium concentrations at the above feed levels under a dump/ decant scenario.

<u>System interface</u>

A feed pump is used to transfer anodizing solution from one of the anodizing baths to an acid reservoir located on the skid of the unit. The bath solution is then forced through the resin column by pressurizing the reservoir with air. Once a predetermined volume of bath solution has been processed, a second reservoir is pressurized, forcing water in the opposite direction to displace the free sulphuric acid back to the anodizing bath. The unit cycle operates automatically and continuously in this matter (Pajunen and Harrison, 1997:5).

A schematic of the process is shown in Figure 5, page 15.

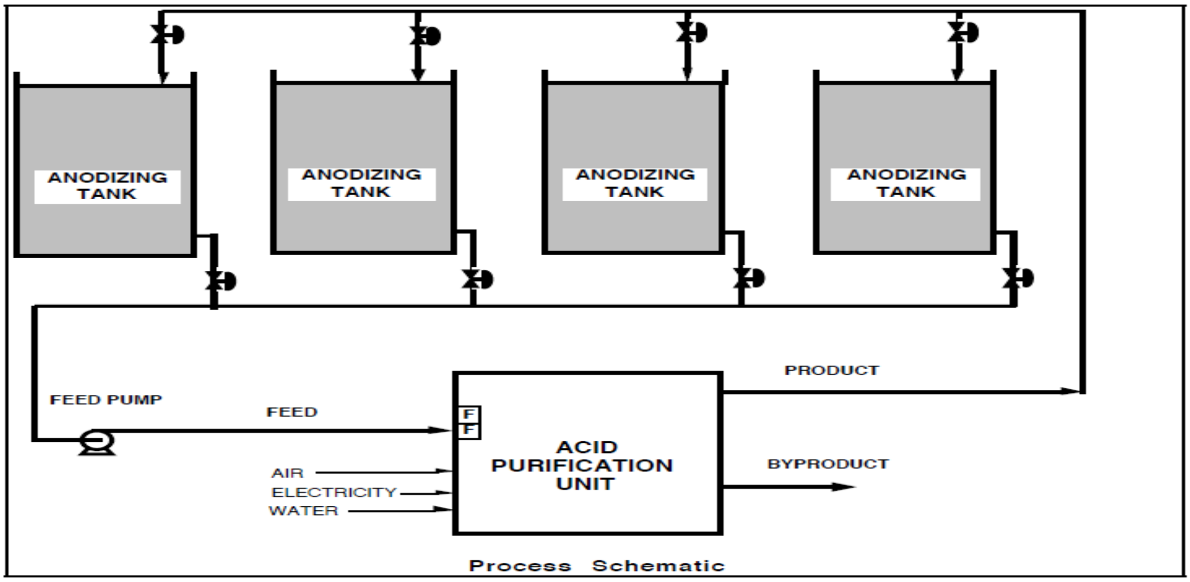


Figure 5 - Schematic of the acid sorption process

If a number of anodizing baths exist, an automatic valve switchover sequence can be used to cycle through the various baths and effectively remove aluminum from all anodizing baths. The operator can program the cycles and shorter or longer times can be specified for each bath.

Results of implementing the acid sorption systems

Sulphuric acid purchases and neutralization costs are reduced and, more importantly, the anodizing operation operates consistently and predictably at all times, even with different requirements.

Figure 6 - An example of a purification system

2.1.2.2 Recycling chemicals on the anodizing line (Pajunen, 2001:5)

"Aluminum is anodized using water-based chemicals that can be treated in a fairly straightforward way. However, many plants now use recycling equipment to extend chemical life and reduce waste treatment costs. This is due, in part, to the large amount of solid waste that etching and anodizing generates. As most methods of recycling involve some degree of purification, anodizers often find that quality improvements go hand in hand with chemical savings.

It is well known that etching and anodizing generates large volumes of aluminum hydroxide sludge. Recycling reduces this waste, lowers chemical costs and frequently improves product quality" (Pajunen, 2001:1).

This article strongly relates to the article discussed in Section 2.1.2.1 (Pajunen and Harrison, 1997:8). It refers to the number of potential problems that can arise from operating an anodizing bath in a dump/ decant manner.

These problems become apparent because a delicate balance exists within an anodizing bath, namely the relationship between the voltage being applied in the anodizing process, the desired current condition and the electrical resistance which is caused by the formed oxide coating and the anodizing solution conductivity.

As the thickness of the oxide coating and the aluminium concentration in the anodizing solution increase, the electrical resistance also increases. The current must remain constant to compensate for this increased resistance and therefor the rectifier voltage must be increased. This and other variables such as the bath temperature, the degree of solution agitation and sulphuric acid concentration can result in upsets and potentially lead to a lower quality product (Pajunen, 2001:3).

In order to minimize these variables that can affect the balance between resistance, voltage and current, it is important to maintain a consistent and low aluminum concentration level.

The solution to maintain a consistent and low aluminium concentration is also done through acid sorption, previously discussed in (Pajunen and Harrison, 1997:8).

Acid sorption technology employs specially treated ion exchange resins that have the ability to sorb free (unused) mineral acids while rejecting the salts (e.g., sodium sulfate) of these acids. The most unique feature of these resins is their ability to release the acid with a simple water wash.

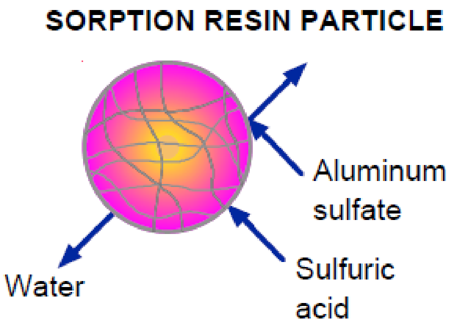


Figure 7 - Another example of acid sorption

As this is the second article on the use of acid sorption to purify acid, it seems that this method is quite popular and recommended by many experts. This method will be investigated further and implementation costs will be determined.

A standard APU offering for aluminum anodizers, known as AnoPur™, is a pre-assembled, skid mounted device that is fully tested, with resin, prior to shipment. The resin column is mounted on a stainless steel frame with process valves, internal piping and a control panel. The panel includes a PLC-based control system.

Figure 8 - Another example of an acid purification system

2.1.2.3 Acid recovery – Acid purification systems (Mech-Chem Ass, Inc.)

Mech-Chem Associates, Inc. claims that their acid purification systems are "simple to operate, dependable and economical" (Mech-Chem Associates, 2012). These systems use an advanced membrane separation technology known as Diffusion Dialysis that separates, recovers and purifies strong acid from spent acid solutions contaminated with dissolved metals, as is the case at the anodizing plant at Wispeco.

Diffusion is the spontaneous movement of a material from an area of high concentration to an area of low concentration. The material will keep on moving between these two concentration levels until no difference in concentration levels exists.

Dialysis is the separation of molecules due to the differences in the rate of movement of the molecules through a semi-permeable barrier. See Figure 9 and Figure 10 below (Mech-Chem Associates, 2012).

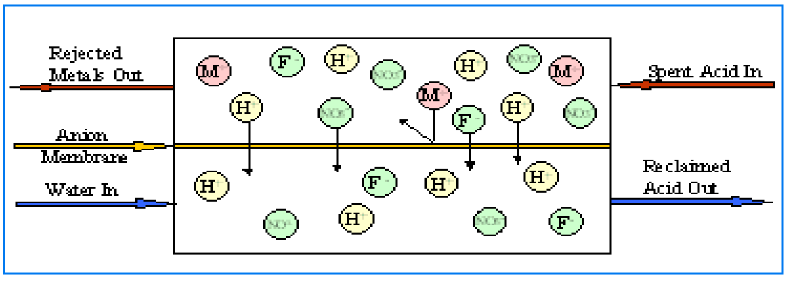


Figure 9 - Diffusion dialysis

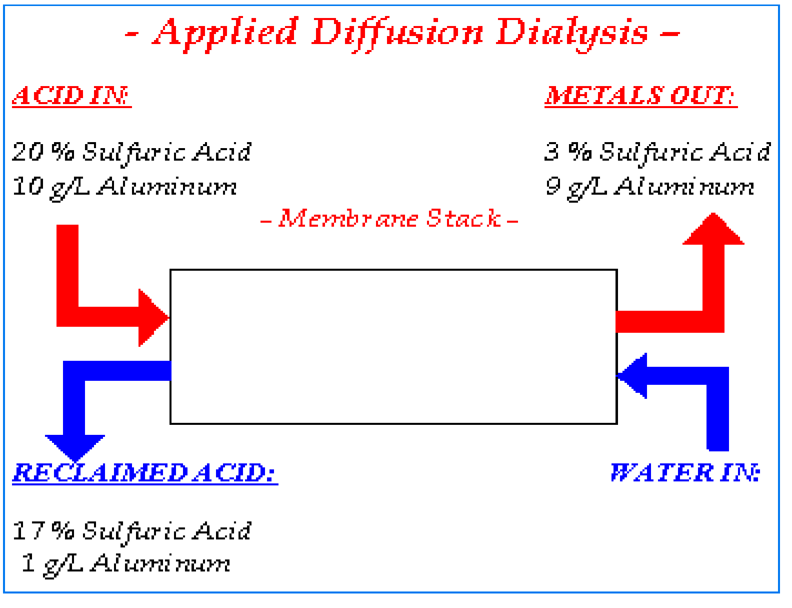


Figure 10 - Diffusion dialysis at an anodizing plant

An ion exchange membrane serves as a semi-permeable barrier between a flowing stream of water and flowing stream of process acid. The process of diffusion dialysis then occurs through this membrane.

The acid purification system is made up of numerous internal channels and this process is carried out hundreds of times through these channels. The predominant anion in sulphuric acid is the sulphate ion SO_4^{-2}. These ions in the sulphuric acid anodizing solution are driven by the concentration difference to diffuse across the membrane to the water side and are attracted by the membrane.

The thermodynamic Law of Electro-neutrality – in solution total charge must balance to zero – requires that for every sulphate ion that is transferred, which carries two negative charges, two positive charges must be transferred as well.

The net effect is that the rate of diffusion of an acid across the membrane is an order of magnitude greater than that of the dissolved metal. The optimal advantage of the necessary concentration ingredients can be realized by causing the flow of the acid solution to be in the opposite direction to the flow of water (counter-current flow). The final results are that the water entering the diffusion dialysis system exits as a metal-depleted recovered acid solution and the acid solution exits as an acid depleted dissolved metal-bearing solution.

The purified acid is returned to the anodizing bath to be re-used and a concentrated metal-containing aqueous solution is removed for waste treatment. The recovery rate of acid is between 80-90% in just one pass through the system and 70-90% of the dissolved metals are removed from the process acid (Mech-Chem Associates, 2012).

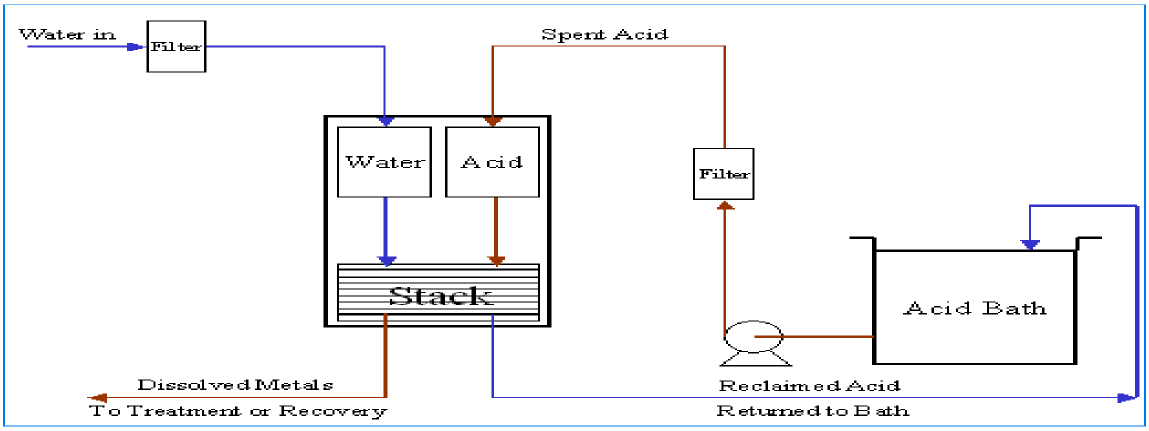


Figure 11 - Diagram of Diffusion dialysis acid recovery

<u>Maintenance of unit</u>

The unit requires little or no maintenance. It is advised that inspection and replacement of the filters as often as necessary is performed. The membrane life is 5-10 years, 10 years for hydrochloric and sulphuric acids.

Direct and indirect benefits of acid purification and recycling through diffusion analysis:

- Acid purchases are reduced by up to 90%
- Acid bath life increases
- Neutralization costs decreases
- Increase in production time/ decrease in down time
- Hazardous waste disposal costs are reduced
- Waste neutralization costs are reduced
- Simple, reliable and economical systems
- Units are self-contained, easy to maintain and require very little floor space (Mech-Chem Associates, 2012)

Referring to the benefits and the success rate of this system, the system would be ideal to use at Wispeco. If multiple production costs can be reduced with the implementation of this system, these savings will add up to cover the initial implementation cost of the system and significant decreases in production costs will follow.

Acid purification Lab unit

Lab units that can be used for testing on small volumes of acid solutions have been designed. This provides users with an introduction to the technology and with initial performance data. Evaluation of the results may lead to further pilot testing or even to full-scale installation at the facility.

These lab units can be rented on a monthly basis or may be purchased. Renting is recommended. Wispeco can determine whether the system will actually work before they implement a full-scale system. The actual cost savings can be calculated to determine whether the system is economically viable (Mech-Chem Associates, 2012).

2.2 Best Methods

The best methods to purify sulphuric acid researched in the literature study are the Resin Sorption method and Diffusion Dialysis.

These methods have the highest acid purification efficiency rates (between 80%-96% of acid purified) and these systems have very low maintenance costs.

Acid purification systems that operate using these methods are relatively expensive and payback periods may easily exceed Wispeco's maximum 2 year payback-period policy. However, large cost-savings can be accomplished by implementing such systems.

These systems were investigated in-depth further to determine whether Wispeco will be able to implement such a system and if the implementation will be cost effective and viable. A cost-analysis was done in order to determine this. These results will be presented to Wispeco.

Chapter 3 - Methodology

Different engineering tools, methods and techniques were used for data capturing and engineering tools and techniques that will be used for problem solving were identified.

These tools, methods and techniques used for data gathering and analysis include:

3.1 Process analysis - Anodizing

The anodizing process and details of the process were analysed to gain a better understanding of the process and to identify problem areas. This was done by reviewing the process and a plant-visit, where the process and step-by-step process details were carefully documented. A process flow diagram was constructed to indicate the flow of the anodizing process (Chapter 1 - Figure 1, page 4 and Figure 2, page 5).

The following questions were raised during the process analysis:

a) Why is this process necessary?

b) Why is this process performed in this manner?

c) What is the maximum allowed aluminium concentration in the sulphuric acid at any given time in the process?

d) When is the sulphuric acid in the process disposed of and replaced by new sulphuric acid?

e) Is there sufficient floor space in the plant to implement an acid purification system?

f) What chemicals or substances are tested for when chemical analysis of the sulphuric acid is done?

g) Are there any other substances or materials other than aluminium in the sulphuric acid?

h) How much sulphuric acid is used in the process per month?

i) How much sulphuric acid is bought per month?

j) What is the average monthly cost of the sulphuric acid?

k) Is the sulphuric acid just disposed of or is it sold to another company?

l) If it is sold, what are the returns?

3.2 Operations process chart

After the process analysis had been done, the data was used to construct an operations process chart. This chart shows the chronological sequence of operations as well as time allowances for each phase of the process and other important specifications such as temperature and pH-balance. See Figures 1 (page 4) and 2 (page 5) for operation process charts of the automatic anodizing (AAP) and manual anodizing processes (MAP).

3.3 Acid analysis

A sample of the saturated acid taken from the anodizing bath was taken to a laboratory for a chemical analysis in order to determine the contents of the saturated solution.

3.4 Cost-analysis – Acid used in Anodizing and Effluent plant

A cost-analysis of the monthly operational costs of the effluent plant was done in order to determine the total cost-savings that would occur if an acid purification system were to be installed. A cost-analysis of the quantity of sulphuric acid used in the anodizing process was also done.

3.4.1 Anodizing

It was necessary to determine the quantity of sulphuric acid that is purchased and used per month and also what the related costs are. These costs will decrease significantly if the acid can be recycled and re-used in the anodizing process.

3.4.2 Effluent plant

As the main purpose of the effluent plant is the disposal of sulphuric acid, this plant will no longer be needed once the sulphuric acid is recycled. A cost-analysis of the monthly operational costs of the effluent plant was therefore done in order to determine the total cost-savings of implementing an acid purification system.

3.5 Fish bone diagram (Cause-and-effect diagram)

This is used to identify an occurrence of a typically undesirable event or problem, which is the ‘effect’, shown as the fish head, and then identifying contributing factors, which are ‘causes’, shown as fish bones attached to a backbone and the head. Refer to Figure 12, page 24.

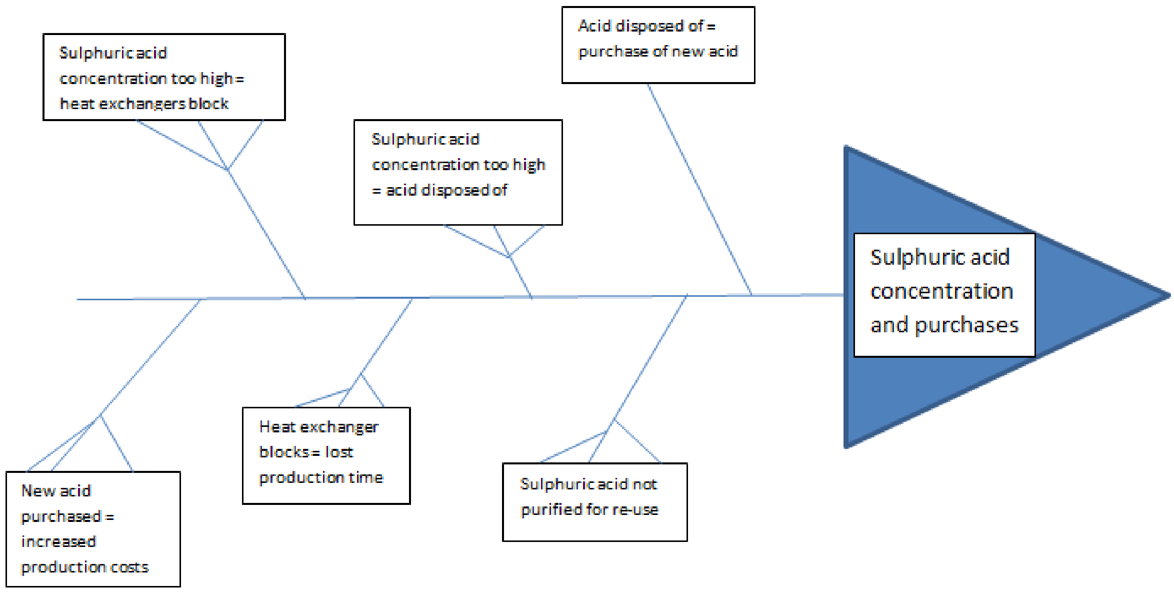


Figure 12 - Fish bone diagram

After all the necessary data has been gathered and analysed, and after literature study and review, different engineering tools and techniques are used to identify possible solutions to the problem. If there are many alternatives, tools and techniques can be used to identify best alternative solutions.

Chapter 4 – Data and data capturing

4.1 Data capturing

Extensive data capturing was necessary in order to conduct a cost-analysis of:

- the purchase and installation of an acid purification system
- the total monthly operational costs of the effluent plant
- the total monthly costs of sulphuric acid purchases.

4.1.1 Purchase and installation of an acid purification system

Various international suppliers were contacted via e-mail in order to obtain purchase - and installation quotes for different types of acid purification systems. These suppliers include

✓ **Prosep Technologies Limited**
Salesperson: WS (Bill) Anderson
Address: Unit 6A Zone 4
Burntwood Bussiness Park
Burntwood
Staffordshire
WS73XD
ENGLAND
Tel: (+44) 01543 675731
Fax: (+44) 01543 679484
E-mail: ptl@eco-tec.com

✓ **Mech Chem**
Salesperson: Dan Bailey
Address: P.O. Box 473
144 Main Street
Norfolk, MA
02056
Tel: (+508) 528 5990
Fax: (+508) 528 8972
E-mail: DBailey@mech-chem.com

✓ **De Dietrich Process Systems Ltd.**

Salesperson: Paul Finney

Proposals Manager

Tel: (+44) 01785 609823

Mobile: (+44) 079 680 14421

E-mail: pfinney@ddpsltd.co.uk

These systems do not only have once-off costs (called sunk costs), but also have monthly operating and maintenance costs (net annual costs). A list of questions was e-mailed to the suppliers in order to determine the sunk- and annual costs of their particular purification systems.

This list included:

- electricity consumption of the system (kW/hour)
- water consumption rate of the system (kℓ/hour)
- air pressure requirements (bar)
- maintenance requirements and maintenance costs of the system
- whether the system is manually operated (to include operator's salary in total operational costs)
- number of times that the sulphuric acid can be recycled within the recycling system before it has to be replaced
- efficiently of the sulphuric acid recycling
- frequency of servicing of the system and the related costs

The suppliers replied via e-mail. Some required more detailed process descriptions and specifications before committing to quoting on the acid purification system. See Appendix A for e-mail copies.

Brochures and other informative documents about the different acid purification systems were received from the suppliers. These documents can be viewed in Appendix B.

4.1.2 Total monthly operational costs of the effluent plant

The following data was needed in order to do a cost-analysis of the effluent plant:

Water usage:

- How much water (kℓ) is discharged from the anodizing process to the effluent plant?
- How much water (kℓ) is discharged to the Ekurhuleni Municipality?
- What are the costs (R/ℓ) that the municipality charges for the discharged water?

Plant costs:

- Electricity usage (in kW/month)
- Operator's salaries
- Maintenance
- Sludge removal – how much sludge is produced per month?
- How much does a company charge to remove the sludge from the effluent plant (R/kg)?
- Any other related costs

Refer to Appendix C for all the documents used to determine the costs of the effluent plant.

4.1.3 Economic factors that need to be considered during cost-analysis

- Inflation
- Rand/Dollar, Rand/Euro or Rand/Pound exchange rates (if the acid purification system is purchased from international suppliers)
- Interest on loans (if a loan is used to fund the purchase of the acid purification system)
- Payback period (Wispeco requires a maximum payback period of 2 years)

Other factors to keep in mind:

Caustic soda:

- What will happen to the caustic soda of the sulphuric acid is recycled?

This is a very important aspect to keep in mind since the caustic soda and the sulphuric acid neutralize each other in the effluent plant. If the sulphuric acid is no longer used as a "neutralizing agent" for the caustic soda, it must then be dealt with as a separate issue.

4.1.4 Total monthly sulphuric acid purchase costs

The quantity of sulphuric acid that is used monthly in the anodizing process must be determined. This will indicate the cost-savings that will be achieved if an acid purification system were to be implemented and the acid is recycled and re-used. This is also an important factor to consider when determining what the capacity of the acid purification system should be, in other words, how much sulphuric acid must be recycled by the purification unit per day/week/month. Records of the quantity of sulphuric acid used per month were used for the cost-analysis. These records can be viewed in Appendix D.

Chapter 5 – Results and Recommendations

Results of data capturing and possible solutions are discussed according to project aims and objectives.

5.1 Project aim 1: Investigate possible acid purification systems

This was done in the literature study in Chapter 2 under section 2.1.2. Two main acid purification methods were identified, namely Resin sorption technology and Diffusion dialysis.

Further investigation into these systems was done by conducting internet research and by contacting possible suppliers of these systems via e-mail.

Companies replied with Engineering Survey forms that had to be completed before purchase and installation quotes could be issued. These forms were taken to Wispeco and filled out by experts. After the forms had been completed, they were returned to the suppliers so that their quotes could be generated. The forms are attached as Appendix E.

5.2 Project aim 2: Investigate whether such systems are being used by companies in South Africa and which systems are being used.

Companies that are currently making use of acid purification units were unwilling to share this information and indeed any other information regarding their acid purification units. This can be attributed to their fears that competitors might obtain this information and that respondents might then lose their (perceived) advantage in the market.

Although no confirmation from South African based companies could be obtained, the suppliers of the acid purification units confirmed that they have installed acid purification systems for companies in South Africa until very recently. These companies include Rheinmetal Denel Munitions in Wellington, near Cape Town and Chemapan.

Thus it can be reasoned that the installation of an acid purification system at Wispeco is possible, even though the suppliers are internationally based.

5.3 Project aim 3: Determine cost and effectiveness of acid purification systems

Different suppliers were contacted for quotes. After quotes had been received, they were evaluated and compared to determine the best quote. The respective quotes from the different suppliers are based on design and process requirements as specified and furnished by Wispeco. The cost of the purification unit (lowest cost), the currency and current exchange rate and acid purification efficiency rate were taken into consideration. (The currencies used are GB Pound and US Dollar.)

(i) Purchase cost of system

(A) De Dietrich Process Systems Ltd.

BALLPARK price: **£1 300 000 - £1 500 000 (GBP)**. This excludes the cleaning system for removal of aluminium (to be designed).

(B) Mech-Chem Ass. Inc.

For an application at Wispeco the AP-300 Model which sells for $88 200 (USD) is recommended by the supplier. The supplier also recommends the optional filtration module which sells for $9 600. The AP-300 may be too small for this application, but it can be doubled in size by adding a second membrane module at a cost of $56 800.

This amounts to a total cost of **$154 600**.

(C) Prosep Technologies Ltd.

Based on the information provided by Wispeco to Prosep, the supplier believes that it will be necessary for Wispeco to consider the installation of an AnuPur, Model D13 Purification System. The quotation that was received by Prosep indicates that such a system will cost approximately **$95 717**.

(ii) Exchange rate (as on 06/10/2012)

USD 1 = ZAR 8.82

GBP 1 = ZAR 14.25

(iii) Purchase cost of system in South African Rand

(A) De Dietrich Process Systems Ltd.

£1 500 000 x R14.25/£ = **R21 375 000 (sunk cost)**

(B) Mech-Chem Ass. Inc.

$154 600 x R8.82/$ = **R1 363 572 (sunk cost)**

(C) Prosep Technologies Ltd.

$95 717 x R8.82/$ = **R844 223.94 (sunk cost)**

(iv) Freight cost from manufacturer to South Africa

(A) De Dietrich Process Systems Ltd.

The BALLPARK purchase cost of the system allows for this, but the actual cost will be £5 000 – £10 000. This price excludes import duties, customs clearance etc. and local taxes.

(B) Mech-Chem Ass. Inc.

The supplier makes use of air freight to ship the equipment and the approximate cost is $940 x R8.82 = R8 290.80.

(C) Prosep Technologies Ltd.

The supplier advised that between $10 000 and $12 000 be added to the budget for freight cost. (CIF to Durban)

Freight costs are always subject to review at the time a contract is placed.

$12 000 x R8.82/$ = **R105 840 (sunk cost)**

(v) Efficiency of the system (the percentage of sulphuric acid that is recycled by the system)

(A) De Dietrich Process Systems Ltd.

The purification process is carried out through two stages and at the end of the second stage up to 96% of the acid is recovered.

(B) Mech-Chem Ass. Inc.

The sulphuric acid can be reused indefinitely, but each time a litre is dialyzed about 15% of the acid is lost and ends up with the 90+% aluminium that is removed. Thus 85% sulphuric acid is recovered and 15% will need to be replaced as needed.

(C) Prosep Technologies Ltd.

If a feed of 160g/ℓ sulphuric acid solution is sent through the AnoPur system, 157g/ℓ sulphuric acid is recovered. This amounts to an efficiency rate of 98%. If a feed of 240g/ℓ sulphuric acid solution is sent through the system, 235g/ℓ sulphuric acid is recovered. This amounts to an efficiency rate of 97.9%. Thus the average efficiency rate of the system is 98%.

(vi) Electricity consumption cost

(A) De Dietrich Process Systems Ltd.

The acid purification system uses approximately 25 kW/hour (excluding steam generator and chillers if required). According to the calculations done in Table 3, the total electricity cost is **R101 346 per year**.

Hours	Rate (R/kW)	Electricity consumption in kW	No of months rate applicable	No of operating days per week	No of operating weeks per month	TOTAL cost (R/year)
5	0.71	25	5	6	4	10 650
5	1.91	25	1	6	4	5 730
5	2.32	25	2	6	4	13 920
5	0.86	25	4	6	4	10 320
10	0.47	25	5	6	4	14 100
10	0.67	25	1	6	4	4 020
10	0.81	25	2	6	4	9 720
10	0.49	25	4	6	4	11 760
7	0.37	25	5	6	4	7 770
7	0.4	25	1	6	4	1 680
7	0.49	25	2	6	4	4 116
7	0.45	25	4	6	4	7 560
					TOTAL	**101 346**

Table 3 - Annual electricity cost of a De Dietrich acid purification unit

(B) Mech-Chem Ass. Inc.

Since the system uses gravity to do most of the work in the process, the metering pumps on the membrane modules are the only normally moving parts in the system (except when the system is refilling itself). These draw a maximum of 1.8 amps each. Thus the approximate electricity usage is 0.5 kW/hour.

According to the calculations done in Table 4, the total electricity cost is **R2 026.92 per year**.

Hours	Rate (R/kW)	Electricity consumption in kW	No of months rate applicable	No of operating days per week	No of operating weeks per month	TOTAL cost (R/year)
5	0.71	0.5	5	6	4	213
5	1.91	0.5	1	6	4	114.60
5	2.32	0.5	2	6	4	278.40
5	0.86	0.5	4	6	4	206.40
10	0.47	0.5	5	6	4	282
10	0.67	0.5	1	6	4	80.40
10	0.81	0.5	2	6	4	194.40
10	0.49	0.5	4	6	4	235.20
7	0.37	0.5	5	6	4	155.40
7	0.4	0.5	1	6	4	33.60
7	0.49	0.5	2	6	4	82.32
7	0.45	0.5	4	6	4	151.20
					TOTAL	**2 026.92**

Table 4 - Annual electricity costs of a Mech-Chem acid purification unit

(C) Prosep Technologies Ltd.

According to the brochure the system uses 5 amps per hour and 24V. The power *P* in kilowatts (kW) is equal to the current in amps (A), times the voltage *V* in volts (V) divided by 1000: $P_{(kW)} = I_{(A)} \times V_{(V)} / 1000$

Thus the system uses 0.12 kW/hour

According to the calculations in Table 5, page 34, the electricity cost is **R486.48 per year**.

Hours	Rate (R/kW)	Electricity consumption in kW	No of months rate applicable	No of operating days per week	No of operating weeks per month	TOTAL cost (R/year)
5	0.71	0.12	5	6	4	51.12
5	1.91	0.12	1	6	4	27.50
5	2.32	0.12	2	6	4	66.82
5	0.86	0.12	4	6	4	49.54
10	0.47	0.12	5	6	4	67.68
10	0.67	0.12	1	6	4	19.30
10	0.81	0.12	2	6	4	46.66
10	0.49	0.12	4	6	4	56.45
7	0.37	0.12	5	6	4	37.30
7	0.4	0.12	1	6	4	8.06
7	0.49	0.12	2	6	4	19.76
7	0.45	0.12	4	6	4	36.29
					TOTAL	**486.48**

Table 5 - Annual electricity costs of a Prosep acid purification unit

(vii) Water consumption cost

(A) De Dietrich Process Systems Ltd.

According to the information received from the supplier, this purification unit uses 55m^3/hour cooling water and 3m^3/hour chilled cooling water.

As 1m^3/hour = 1 kℓ/hour, it is appropriate to assume the purification unit uses a total of 58 kℓ/hour. Thus:

58 kℓ/hour x 21 hours/day x 6 days/week x 4 weeks/month = 29 232 kℓ/month

29 232 kℓ/month x 12 months/year = 350 784 kℓ/year

350 784 kℓ x R13.18/kℓ = **R4 623 333.12 per year**

(B) Mech-Chem Ass. Inc.

The water consumption is equal to, or slightly greater than the acid solution processing rate. For the system requirements at Wispeco the water consumption will be approximately 1 600 ℓ/day.

Thus 1 600 ℓ/day x 6 days/week x 4 weeks/month = 38 400 ℓ/month

38 400 ℓ/month x 12 months/year = 460 800 ℓ/year = 460.8 kℓ/year

460.8 kℓ/year x R13.18/kℓ = **R6 073.34 per year**

(C) Prosep Technologies Ltd.

2 540 ℓ/hour x 21 hours/day = 53 340 ℓ/day

Thus 53 340 ℓ/day x 6 days/week x 4 weeks/month = 1 280 160 ℓ/month

1 280 160 ℓ/month x 12 months = 15 361 920 ℓ/year = 15 361.92kℓ/year

15 361.92 kℓ/year x R13.18/kℓ = **R202 470.11 per year**

(viii) Air pressure requirement

(A) De Dietrich Process Systems Ltd.

16 bar; 515 kg/hour

(B) Mech-Chem Ass. Inc.

None

(C) Prosep Technologies Ltd.

5.5 bar

(ix) Operator salary (if required)

(A) De Dietrich Process Systems Ltd.

The equipment will be controlled by a programmable logic controller (PLC) type control system. The operation is automatic but needs some supervisory control. The supervision of the system can be carried out by the lab technician.

(B) Mech-Chem Ass. Inc.

The Diffusion Dialysis systems are designed to run unattended, 24 hours per day/seven days per week. The system is designed to go into automatic shut-down if there is a problem. It is recommended that someone inspect the system at least once per day during the week. Thus it is not necessary to appoint an operator at all times. The lab technician can inspect the system daily.

(C) Prosep Technologies Ltd.

As to the requirements for operation and maintenance it is advised that it is only normally necessary for an operator to spend between 15-20 minutes each day carrying out basic checks such as pressure readings etc. This can be done by the lab technician.

(x) Maintenance costs

(A) De Dietrich Process Systems Ltd.

The acid purification plant requires little maintenance other than a yearly check for integrity of joints and seals etc. The supplier recommends that one of their local engineers carry out this check. This check will take approximately 3-5 days and cost £800 x R13.18/£ = R10 544.

(B) Mech-Chem Ass. Inc.

The membranes will last 7-10 years or more before requiring changing. The metering pumps and double-diaphragm pump should be rebuilt every one to two years at a total cost of about $800. If the acid solution is properly filtered, and there is no algae growth (which can be counter-acted by acidifying the water feed solution), then the membrane stack will not need servicing and maintenance costs will be minimal.

This amounts to an estimated total of $800 x R8.23/$ = R6 584 per year.

(C) **Prosep Technologies Ltd.**

Maintenance costs for the system are low and generally consist of periodic changing of the cartridge filters. Some replacement cartridge filters have been included in the base price.

(xi) Sulphuric acid cost savings

(A) De Dietrich Process Systems Ltd.

Using data that was received from Wispeco it was estimated that approximately 559 842.5ℓ of sulphuric acid is used per year (see Table 1).

The efficiency of the De Dietrich acid purification system is estimated to be 96%. Thus 559 842.5ℓ x 96% = 537 448.8ℓ of sulphuric acid should be recovered by the purification system per year.

This amounts to a total cost-saving of 537 448.8ℓ x R0.99/ℓ

= **R532 074.31 per year**.

(B) Mech-Chem Ass. Inc.

The efficiency of the Mech-Chem purification unit is 85%.

Thus 559 842.5ℓ x 85% = 475 866.13ℓ of sulphuric acid should be recovered by the purification system per year.

This amounts to a total cost-saving of 475 866.13ℓ x R0.99/ℓ
= **R471 107.46 per year**.

(C) Prosep Technologies Ltd.

The efficiency of the Prosep purification unit is 98%.
Thus 559 842.5ℓ x 98% = 548 645.65ℓ of sulphuric acid should be recovered by the purification system per year.
This amounts to a total cost-saving of 548 645.65ℓ x R0.99/ℓ
= **R543 159.19 per year**.

(xii) Does the supplier have an office in South Africa?

(A) De Dietrich Process Systems Ltd.

Yes.

222 Steventon Road
Anderbolt, Boksburg
P.O. Box 6245
Dunswart
1508, South Africa

Phone: (+27) 11 918 4131
Fax: (+27) 11 918 4133
E-mail: info.za@dedietrich.com

(B) Mech-Chem Ass. Inc.

No.

(C) Prosep Technologies Ltd.

No.

(xiii) Will it be possible for the supplier to supply and install the system to Wispeco in South Africa?

(A) De Dietrich Process Systems Ltd.

Yes.

(B) Mech-Chem Ass. Inc.

Yes.

(C) Prosep Technologies Ltd.

Yes.

Supplier	**(A) De Dietrich**	**(B) Mech-Chem Ass. Inc.**	**(C) Prosep Techn. Ltd**
(i) Purchase cost of system (current)	£1 500 000	$154 600	$95 717
(ii) Exchange rate (as on 06/10/2012)	R14.25	R8.82	R8.82
(iii) Cost in Rand	R21 375 000	R1 363 572	R844 223.94
(iv) Freight cost	None (included in cost)	R8 290.80	R105 840
(v) Efficiency	96%	85%	98%
(vi) Electricity consumption cost	R101 346/year	R2 026.92/year	R486.48/year
(vii) Water consumption cost	R4 623 333.12/year	R6 073.34year	R202 470.11/year
(viii) Air pressure requirement	16 bar	None	5.5 bar
(ix) Operator salary (if required)	None	None	None
(x) Maintenance costs	R10 544/year	R6 584/year	None (Included in cost)
(xi) Sulphuric acid cost savings	R532 074.31/year	R471 107.46/year	R543 159.19/year

Table 6 - Comparison of acid purification systems costs

Supplier	**(A) De Dietrich**	**(B) Mech-Chem Ass. Inc.**	**(C) Prosep Technologies Ltd**
Total costs per year	R4 735 233.12	R14 684.26	R202 956.59
Total savings per year (costs deducted)	-R 4 203 148.81	R456 423.2	R340 202.6

Table 7 - Costs VS savings of implementing an acid purification system

As indicated in Table 7, acid purification systems from supplier B and C will contribute to a cost-saving of between R340 000 and R460 000 per year. The acid purification system from supplier A will cost Wispeco substantially more than the total cost-savings made per year. Thus only the quotes of supplier B and C will be taken into consideration in the cost analysis, but the costs of the system of supplier A will also be calculated to prove that the system is too expensive.

5.4 Project aim 4: Conduct a sulphuric acid chemical analysis to determine the contents of post-anodizing sulphuric acid to determine which impurities in the acid must be removed.

This is necessary to determine whether the acid purification unit will be effective in recycling acid. This was one of the requirements of the suppliers in order to furnish a purchase quote for an acid recycling system.

The following information was obtained from the acid analysis:

PROCESS	CUSTOMER	FAX / E-MAIL
Anodising	Wispeco Anodising	lindie@wispeco.co.za
TANK CAPACITY (Litres)	**ATTENTION**	**TEL**
18 000	Lindie Pienaar	0113890007

DATE	ANALYSIS						ADDITIONS		
[Optimum Conc.]	Free Sulphuric Acid	Total Sulphuric Acid	Aluminium				Sulphuric Acid		
	g/ℓ	g/ℓ	g/ℓ				kg		
	180	340	15						
Allowed	160 - 200		8 - 28						
28.08.12	182	248	12.1				0.0		

Table 8 - Acid analysis

According to the analysis no other impurities are present in the sulphuric acid solution.

5.5 Project aim 5: Determine the reduction in the overall production costs (considering the sulphuric acid and concerning production processes) should an acid purification system be implemented.

Should an acid purification system be installed at the anodizing plant at Wispeco (and the caustic soda is removed by another company), the effluent plant would no longer be needed. Thus the total operational costs of the effluent plant will result in cost-savings.

The total operational costs of the effluent plant were determined by doing a cost-analysis.

(a) Labour costs: Two students @ R4 780/month
+ Operator (permanent employee) @ R6 191/month
+ R2 303 / month overtime pay (for the permanent employee)
= (R4 780 x 2) + R6 191 + R2 303 = **R18 054/month**
R18 054/month x 12 months/year = **R216 648/year**

(b) Chemical costs: Flocculant is added to the acid-caustic-solution to remove the solid particles from the water. 50 kg is used/day @ R58/kg = R2 900/day
R2 900/day x 6 days/week = R17 400/week
R17 400/week x 4 weeks/month = **R69 600 /month**
R69 600/month x 12 months = **R835 200/year**

(c) Maintenance: As maintenance changes each month, an average maintenance cost is estimated per year @ **R50 000/year**. This includes replacement of machine parts and also the servicing of the decanter every 3-6 months.
R50 000/year ÷ 12 months/year = **R4 167/month**

(d) "Interwaste" fee (sludge removal): A contractor company removes the sludge from the effluent almost daily at a cost/ton. According to records an average of 200ton of sludge is removed per month. The removal cost/ton increases yearly. The current (2012) sludge removal cost is R928.22/ton (including vat).
Thus 200ton x R928.22/ton = **R185 644/month**
Thus 12 months x R185 644/month = **R2 227 728/year**

(e) Water treatment costs: The water that is sent to the municipality from the effluent plant contains chemicals and the municipality charges a fee accordingly to treat the water. As it is difficult to obtain records of the water treatment costs per month, available records were taken and costs were estimated. The estimated cost is approximately **R25 000/month**. This differs every month, because the treatment cost per kℓ of water differs each month according to the amount of chemicals contained in the water. This amounts to an estimated total of **R300 000/year**.

(f) Municipality fees: When the concentration of chemicals in the waste water reaches a certain level, the municipality fines Wispeco as there are certain standards that must be adhered to. The fines that are issued are issued together with the water treatment costs and as stated above, the records are difficult to obtain. Thus an estimate was made according to the available data. The estimated amount is **R10 500/month** and thus **R126 00/year**.

(g) Electricity usage costs: Electrically driven pumps are the main energy users at the effluent plant. There are 12 pumps of different sizes that are used in the effluent plant. Table 9 specifies the different pump sizes and the electricity usage of each pump.

Pump power output	Nr. of pumps	Operating hours per day	Operating hours during Peak-rates*	Operating hours during Standard-rates*	Operating hours during Off-peak-rates*	Total electricity usage (per day)	Total electricity usage cost (per year)
1.5 kW	7	21	5	10	7	31.5 kW	R42 598.92
0.75 kW	2	21	5	10	7	15.75kW	R6 181.56
7.5 kW	1	21	5	10	7	157.5 kW	R30 907.80
0.55 kW	1	21	5	10	7	11.55 kW	R2 266.57
5.852 kW	1	21	5	10	7	122.892 kW	R22 471.90
TOTAL	12	21	5	10	7	339.192 kW	R104 426.75

Table 9 - Electricity usage costs

*Refer to Appendix C for electricity tariffs for each time-zone

Thus the electricity usage at the Effluent plant for the pumps alone (not considering any other electricity usage like lights etc.) is **R104 426.75/year**. This amounts to an average of **R8 702.23/month**.

Cost factor	Cost per month	Cost per year
(a) Labour costs	R18 054	R216 648
(b) Chemical costs	R69 600	R835 200
(c) Maintenance	R4 167	R50 000
(d) "Interwaste" fee	R185 644	R2 227 728
(e) Water treatment costs	R25 000	R300 000
(f) Municipality fees	R10 500	R126 000
(g) Electricity usage costs	R8 702.23	R104 426.75
TOTAL	**R321 667.23**	**R3 860 002.75**

Table 10 - Operating costs of the effluent plant

An important question that was raised was: "What happens to the caustic soda of the acid should be recycled?" At the moment there is a company that is interested in removing the caustic soda from the anodizing plant at no cost. If the company decides not to do so, other alternative methods of disposal will have to be researched.

5.6 Project aim 6: Compare the reduction in above mentioned production costs to the cost of purchasing and installing a sulphuric acid purification system.

5.6.1 Sunk costs

This includes the purchase cost of each system (in SA Rand) and the freight cost.

(A) De Dietrich: R21 375 000 (purchase cost)+ R0(freight cost) (incl. in purchase cost)
= R21 375 000

(B) Mech-Chem: R1 363 572 (purchase cost) + R8 290.80 (freight cost)
= R1 371 862.8

(C) Prosep Technologies Ltd.: R844 223.94 (purchase cost) + R105 840 (freight cost)
= R950 063.94

5.6.2 Annual costs

The annual costs are the total yearly operational cost of each purification system. These costs include electricity consumption, water consumption, operator's salary and maintenance costs.

(A) De Dietrich: R4 735 233.12/year

(B) Mech-Chem: R14 684.26/year

(C) Prosep Technologies Ltd.: R202 956.59/year

5.6.3 Current production cost-savings

This includes all the cost-savings the company will make if an acid purification system is implemented. Possible cost-savings will be made by reduction in sulphuric acid purchases. If a company can be found that is willing to take the caustic soda, the elimination of the current operational costs of the Effluent plant will also result in cost-savings.

2012:

(A) De Dietrich: R532 074.31/year

(B) Mech-Chem: R471 107.46/year

(C) Prosep Technologies Ltd.: R543 159.19/year

(D) Effluent plant: R3 860 002.75/year

5.6.4 Inflation

The total cost-savings per year and total operational cost of an acid purification system will increase annually. A calculation considering inflation is used to determine the total increase of these costs and cost-savings. The current inflation rate according to the South African Reserve bank, dated 07/10/2012 is 5%. The inflation rate changes each year, but an inflation rate of 5% will be used in calculations to estimate costs.

2013:

1. Sulphuric acid purchase cost-savings

   (A) De Dietrich: R532 074.31 x 1.05 = R558 678.03/year

   (B) Mech-Chem: R471 107.46 x 1.05 = R494 662.83/year

   (C) Prosep Techn. Ltd.: R543 159.19 x 1.05 = R570 317.15/year

2. Operational costs

(A) De Dietrich: R4 735 233.12 x 1.05 = R4 971 994.78/year

(B) Mech-Chem: R14 684.26 x 1.05 = R15 418.47/year

(C) Prosep Techn. Ltd.: R202 956.59 x 1.05 = R213 104.42/year

3. Effluent plant operational costs

R3 860 002.75 x 1.05 = R4 053 002.89/year

2014:

1. Sulphuric acid purchase cost-savings

(A)De Dietrich: R558 678.03 x 1.05 = R586 611.93/year

(B) Mech-Chem: R494 662.83 x 1.05 = R519 395.97/year

(C) Prosep Techn. Ltd.: R570 317.15 x 1.05 = R598 833.01/year

2. Operational costs

(A) De Dietrich: R4 971 994.78 x 1.05 = R5 220 594.52/year

(B) Mech-Chem: R15 418.47 x 1.05 = R16 189.39/year

(C) Prosep Techn. Ltd.: R213 104.42 x 1.05 = R223 759.64/year

3. Effluent plant operational costs

R4 053 002.89 x 1.05 = R4 255 653.04/year

2015:

1. Sulphuric acid purchase cost-savings

(A)De Dietrich: R586 611.93 x 1.05 = R615 942.53/year

(B) Mech-Chem: R519 395.97 x 1.05 = R545 365.77/year

(C) Prosep Techn. Ltd.: R598 833.01 x 1.05 = R628 774.66/year

2. Operational costs

(A) De Dietrich: R5 220 594.52 x 1.05 = R5 481 624.24/year

(B) Mech-Chem: R16 189.39 x 1.05 = R16 998.86/year

(C) Prosep Techn. Ltd.: R223 759.64 x 1.05 = R234 947.62/year

3. Effluent plant operational costs

R4 255 653.04 x 1.05 = R4 468 435.69/year

<u>2016</u>:

1. <u>Sulphuric acid purchase cost-savings</u>

   (A)De Dietrich: R615 942.53 x 1.05 = R646 739.66/year

   (B) Mech-Chem: R545 365.77 x 1.05 = R572 634.06/year

   (C) Prosep Techn. Ltd.: R628 774.66 x 1.05 = R660 213.39/year

2. <u>Operational costs</u>

   (A) De Dietrich: R5 481 624.24 x 1.05 = R5 755 705.45/year

   (B) Mech-Chem: R16 998.86 x 1.05 = R17 848.80/year

   (C) Prosep Techn. Ltd.: R234 947.62 x 1.05 = R246 695.00/year

3. <u>Effluent plant operational costs</u>

   R4 468 435.69 x 1.05 = R4 691 857.48/year

<u>2017</u>:

1. <u>Sulphuric acid purchase cost-savings</u>

   (A)De Dietrich: R646 739.66 x 1.05 = R679 076.64/year

   (B) Mech-Chem: R572 634.06 x 1.05 = R601 265.76/year

   (C) Prosep Techn. Ltd. R660 213.39 x 1.05 = R693 224.06/year

2. <u>Operational costs</u>

   (A) De Dietrich: R5 755 705.45 x 1.05 = R6 043 490.72/year

   (B) Mech-Chem: R17 848.80 x 1.05 = R18 741.24/year

   (C) Prosep Techn. Ltd.: R246 695.00 x 1.05 = R259 029.75/year

3. <u>Effluent plant operational costs</u>

   R4 691 857.48 x 1.05 = R4 926 450.35/year

	(A) De Dietrich		(B) Mech-Chem		(C) Prosep Techn. Ltd.	
Year	Sulphuric acid savings	Operational costs	Sulphuric acid savings	Operational costs	Sulphuric acid savings	Operational costs
2012	R532 074.31	R4 735 233.12	R471 107.46	R14 684.26	R543 159.19	R202 956.59
2013	R558 678.03	R4 971 994.78	R494 662.83	R15 418.47	R570 317.15	R213 104.42
2014	R586 611.93	R5 220 594.52	R519 395.97	R16 189.39	R598 833.01	R223 759.64
2015	R615 942.53	R5 481 624.24	R545 365.97	R16 998.86	R628 774.66	R234 947.62
2016	R646 739.66	R5 755 705.45	R572 634.06	R17 848.80	R660 213.39	R246 695.00
2017	R679 076.64	R6 043 490.72	R601 265.76	R18 741.24	R693 224.06	R259 029.75

Table 11 - Cost-savings VS operational costs over a period of 5 years

Year	Effluent plant operational costs per year
2012	R3 860 002.75
2013	R4 053 002.89
2014	R4 255 653.04
2015	R4 468 435.69
2016	R4 491 857.48
2017	R4 926 450.35

Table 12 - Effluent plant annual operational costs over a period of 5 years

According to the calculations in Table 12, an acid purification system can be purchased and paid back within a year from supplier B – Mech-Chem and supplier C – Prosep Techn. Ltd. if the effluent plant is not used at all.

If the effluent plant is still used by Wispeco and only the cost-savings of sulphuric acid purchases are taken into consideration, the following payback periods are obtained:

(A) De Dietrich Process Systems Ltd.

Total cost savings – Operational cost per year=

2013: -R4 413 316.75/year

2014: -R4 633 982.59/year

2015: -R4 865 681.71/year

2016: -R5 108 965.79/year

2017: -R5 364 414.08/year

Amount saved after 1 year = -R4 413 316.75

Amount saved after 2 years = -R9 047 299.34

Amount saved after 3 years = -R13 912 981.05

Amount saved after 4 years = -R19 021 946.84

Amount saved after 5 years = -R24 386 260.92

Thus the acid purification system will never be paid back and Wispeco will lose money each year when this system is installed due to very high operational costs. This is clearly shown in figures 13 and 14.

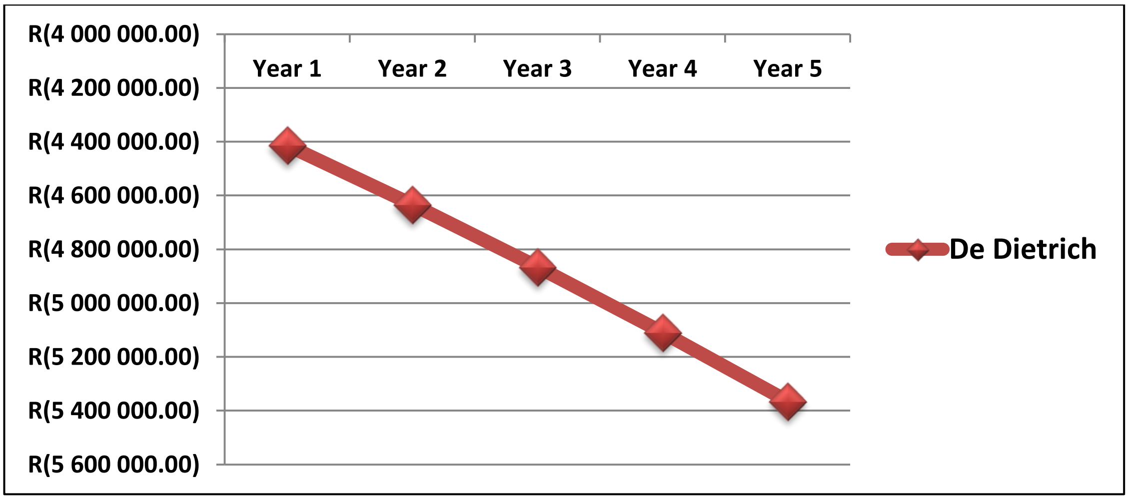


Figure 13 - Cost-savings generated annually by De Dietrich acid purification system

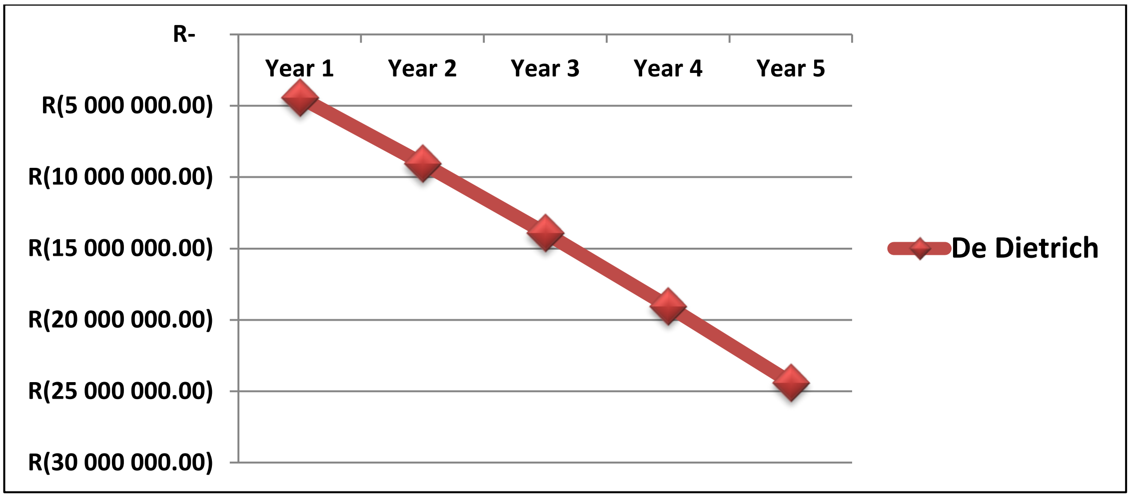


Figure 14 - Accumulated cost savings generated annually by De Dietrich acid purification system

(B) Mech-Chem

Total cost-savings – Operational cost per year=

2013: R479 244.36/year

2014: R503 206.58/year

2015: R528 367.11/year

2016: R554 785.26/year

2017: R582 524.52/year

Amount saved after 1 year = R479 244.36

Amount saved after 2 years = R982 450.94

Amount saved after 3 years = R1 510 818.05 (end of payback period)

Amount saved after 4 years = R2 065 603.31

Amount saved after 5 years = R2 648 127.83

Thus the acid purification system has a maximum **payback period of 3 years.**

(C) Prosep Techn. Ltd.

Total cost savings – Operational cost per year=

2013: R357 212.73/year

2014: R375 073.37/year

2015: R393 827.04/year

2016: R413 518.39/year

2017: R434 194.31/year

Amount saved after 1 year = R357 212.73

Amount saved after 2 years = R732 286.10

Amount saved after 3 years = R1 126 113.14 (end of payback period)

Amount saved after 4 years = R1 539 631.53

Amount saved after 5 years = R1 973 825.84

Thus the acid purification system has a maximum **payback period of 3 years**.

Figure 15 indicates the annual cost-savings that will be generated considering a 5% inflation rate if either a Mech-Chem or a Prosep Techn. Ltd. acid purification system is to be purchased by Wispeco and installed at the anodizing plant.

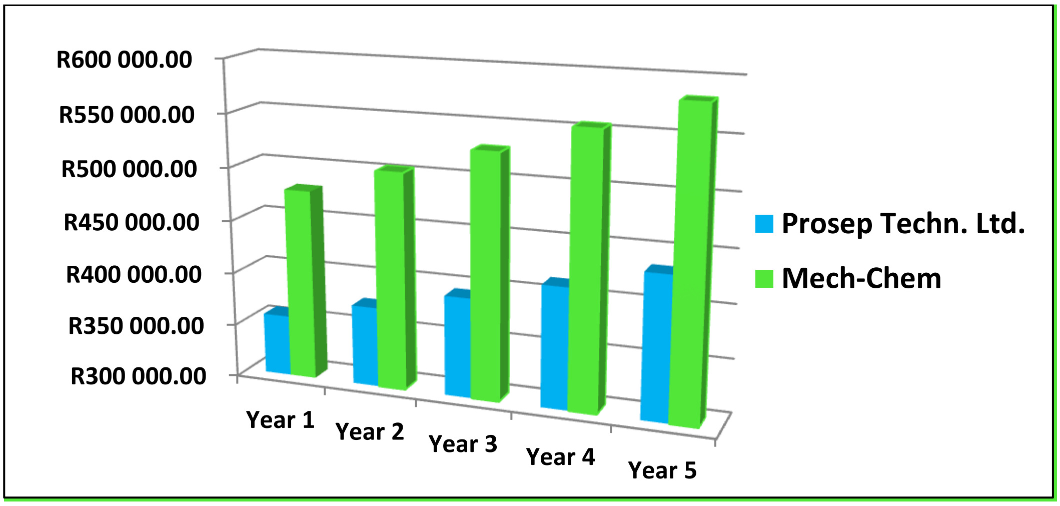


Figure 15 - Cost savings generated annually be acid purification systems

It is evident from Figure 15 that an acid purification system purchased from Mech-Chem will result in greater annual cost-savings than a system purchased from Prosep Techn. Ltd.

Figure 16 indicates the payback period of each acid purification system purchased from Mech-Chem and Prosep Techn. Ltd. respectively. Here it is evident that the estimated accumulated cost savings generated from each acid purification system will result in an estimated payback period of maximum 3 years considering an inflation rate of 5% per year.

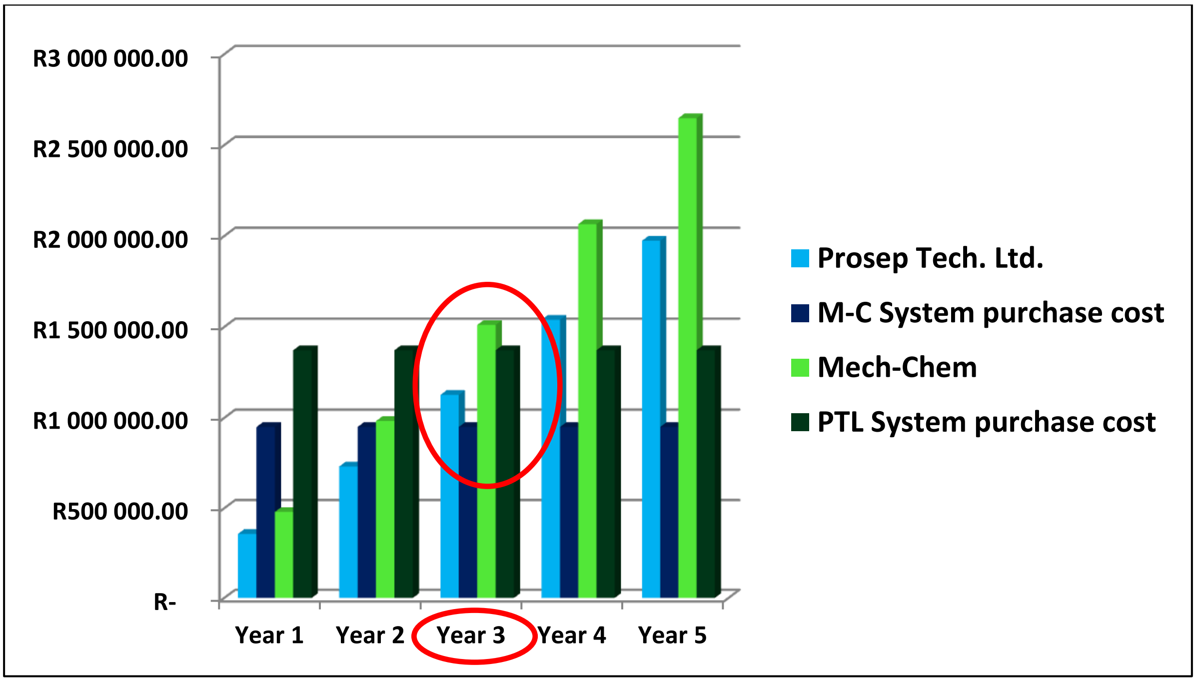


Figure 16 - Accumulated cost savings generated annually from individual acid purification systems

The two acid purification systems from Mech-Chem and Prosep Techn. Ltd. have similar estimated payback periods and therefore a further cost analysis is necessary in order to determine which acid purification system will generate the greatest return for Wispeco.

5.6.4 Net Present Value

Calculating the net present value (NPV) is a standard method for using the time value of money to appraise long-term projects. Before a project is undertaken, it must first be subjected to a preliminary analysis in order to determine the NPV, using the MARR as the discount rate. The MARR is the minimum rate of return on a project that a company is willing to accept and it is also the target rate for evaluation of the project investment.

The NPV of a project compares the current value of a SA rand to the value of the currency in the future, taking inflation and returns into account. If the NPV of a prospective project is positive, the project can be accepted. However, if the NPV of the prospective project is negative, the project should be rejected because cash flows will also be negative.

- When the NPV>0 (positive), the discounted value of future cash flows is greater than the initial investment and a higher return than initially desired, is expected.

- When the NPV=0, the discounted value of future cash flows equals the initial investment made and a return equal to the desired return is expected.

- When the NPV<0, the discounted value of future cash flows is less than the initial investment and a lower return than desired is expected.

The calculation of the NPV of each acid purification system is done in order to determine which investment has the highest NPV.

Different MARR values were used to estimate net present values for both Mech-Chem and Prosep Techn. Ltd. acid purification systems.

The following formula is used to calculate the NPV =

$$NPV = \sum_{t-1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

<u>Where</u>:

C_t = cash flow at year t (in this case annual cost savings)

T = period (total number of years used to calculate NPV)

C_o = initial investment (in this case purchase cost of acid purification system)

r = MARR value

t = year

Cash flow diagrams in Figures 17 and 18 indicate all relative transactions – purchase costs of acid purification systems and annual cost savings.

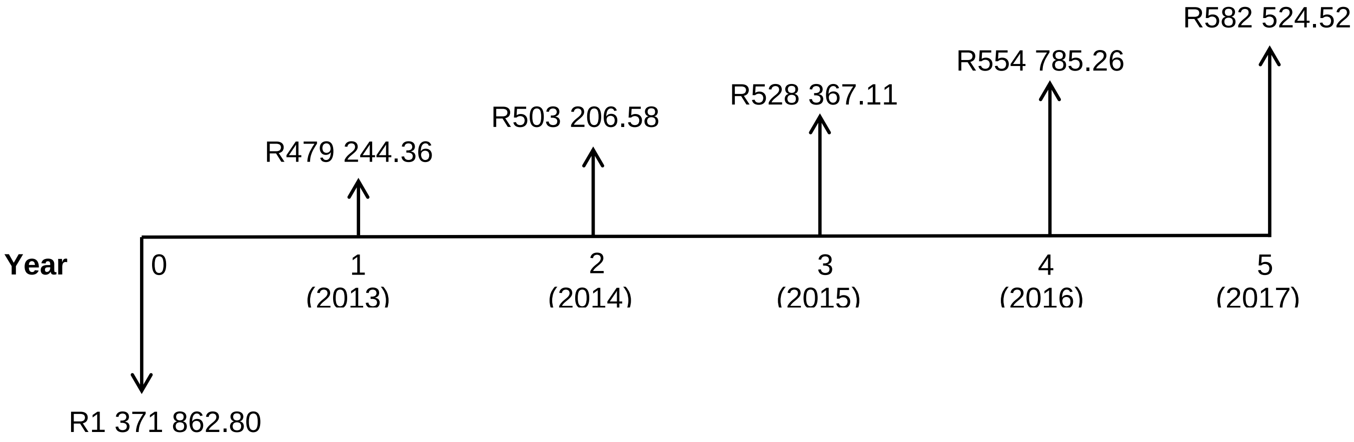


Figure 17 - Cash flow diagram for Mech-Chem acid purification system

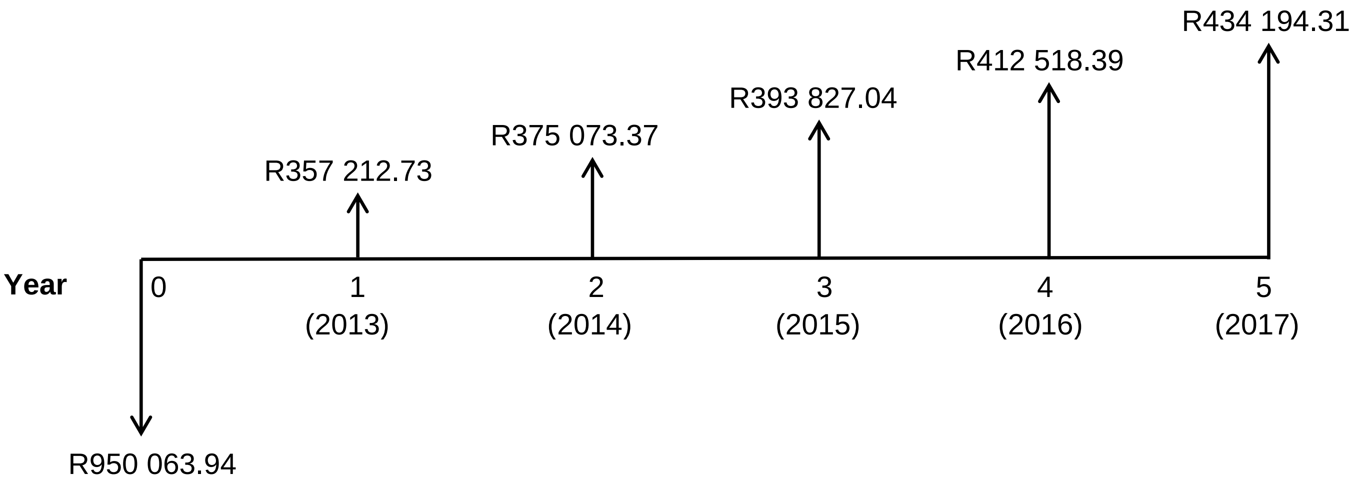


Figure 18 - Cash flow diagram for Prosep Techn. Ltd. acid purification system

1. **MARR: 15%**

$$\text{(B) Mech-Chem: NPV} = \left(\frac{479\,244.36}{(1.15)^1}\right) + \left(\frac{503\,206.58}{(1.15)^2}\right) + \left(\frac{528\,367.11}{(1.15)^3}\right) + \left(\frac{554\,784.26}{(1.15)^4}\right) + \left(\frac{582\,524.52}{(1.15)^5}\right) - 1\,371\,862.80 = \mathbf{R379\,595.76}$$

$$\text{(C) Prosep Techn. Ltd.: NPV} = \left(\frac{357\,212.73}{(1.15)^1}\right) + \left(\frac{375\,073.37}{(1.15)^2}\right) + \left(\frac{393\,827.04}{(1.15)^3}\right) + \left(\frac{413\,518.39}{(1.15)^4}\right) + \left(\frac{434\,194.31}{(1.15)^5}\right) - 950\,063.94 = \mathbf{R355\,414.64}$$

2. MARR = **20%**

$$\text{(B) Mech-Chem: NPV} = \left(\frac{479\,244.36}{(1.2)^1}\right) + \left(\frac{503\,206.58}{(1.2)^2}\right) + \left(\frac{528\,367.11}{(1.2)^3}\right) + \left(\frac{554\,784.26}{(1.2)^4}\right) + \left(\frac{582\,524.52}{(1.2)^5}\right) - 1\,371\,862.80 = \mathbf{R184\,424.95}$$

$$\text{(C) Prosep Techn. Ltd.: NPV} = \left(\frac{357\,212.73}{(1.2)^1}\right) + \left(\frac{375\,073.37}{(1.2)^2}\right) + \left(\frac{393\,827.04}{(1.2)^3}\right) + \left(\frac{413\,518.39}{(1.2)^4}\right) + \left(\frac{434\,194.31}{(1.2)^5}\right) - 950\,063.94 = \mathbf{R209\,903.61}$$

3. MARR = **25%**

$$\text{(B) Mech-Chem: NPV} = \left(\frac{479\,244.36}{(1.25)^1}\right)+\left(\frac{503\,206.58}{(1.25)^2}\right)+\left(\frac{528\,367.11}{(1.25)^3}\right)+\left(\frac{554\,784.26}{(1.25)^4}\right)+\left(\frac{582\,524.52}{(1.25)^5}\right) - 1\,371\,862.80 = \mathbf{R22\,230.53}$$

$$\text{(C) Prosep Techn. Ltd.: NPV} = \left(\frac{357\,212.73}{(1.25)^1}\right)+\left(\frac{375\,073.37}{(1.25)^2}\right)+\left(\frac{393\,827.04}{(1.25)^3}\right)+\left(\frac{413\,518.39}{(1.25)^4}\right)+\left(\frac{434\,194.31}{(1.25)^5}\right) - 950\,063.94 = \mathbf{R89\,046.56}$$

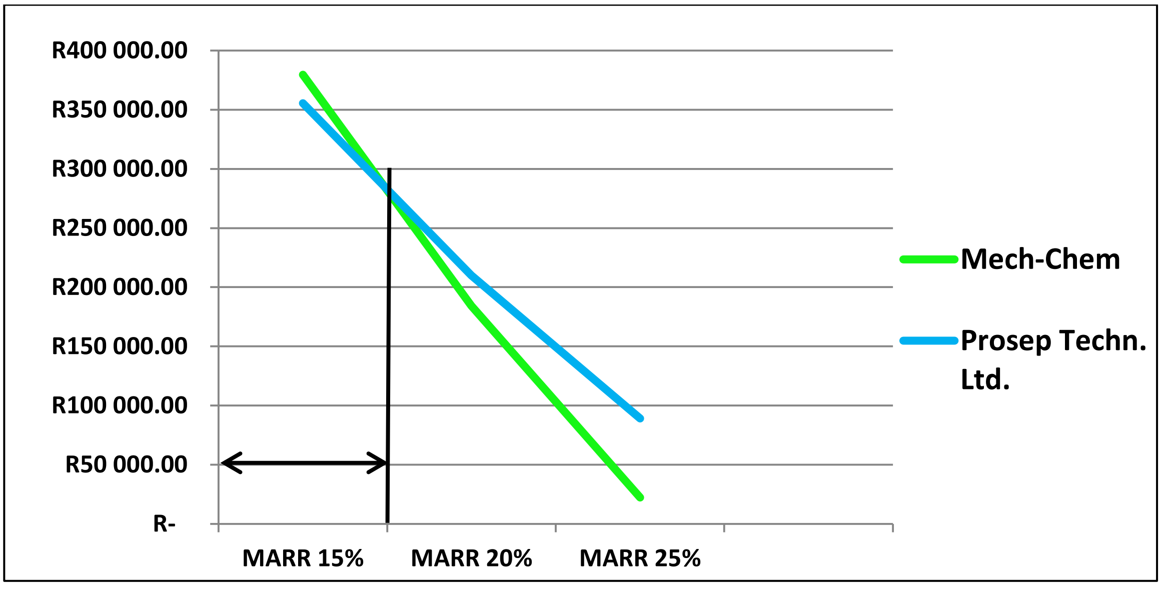


Figure 19 - Net Present Value (NPV) VS Minimum Annual Return Rate (MARR)

Figure 19 indicates the net present values that are generated for MARR values of 15%, 20% and 25%. For a MARR of 15%, the net present value generated for a Mech-Chem acid purification system is higher compared to the net present value of a Prosep Techn. Ltd. system. If a MARR of 20% or higher is desired, the net present value of a Prosep Techn. Ltd. purification system exceeds that of a Mech-Chem purification system.

5.7 Recommendations

The cost analysis in section 5.6 clearly indicates that the acquisition of an acid purification system from De Dietrich Process Systems Ltd. results in an immense loss each year, as operational costs exceed total cost-savings by far. This study advises against the purchase of an acid purification system from De Dietrich Process Systems Ltd. by Wispeco.

Furthermore, the cost analysis indicates that the acid purification systems available from Mech-Chem and Prosep Technologies Limited have maximum payback periods of 3 years. Although this payback period exceeds the two year payback policy of Wispeco, it is recommended that one of these systems is purchased from the supplier and installed at the anodizing plant, as this system can save Wispeco a substantial amount of money over a relatively short period.

If a minimum return rate of either 20% or 25% and higher is desired, it is evident from the net present value calculations that the purchase and installation of an acid purification system from Prosep Technologies should be considered. However, the purchase and installation of an acid purification system from Mech-Chem is recommended if a minimum return of 15% or less is desired.

References

ACID RECOVERY. 2012. Consumer Products Manufacturer Case Study. North East United States.
http://acidrecovery.com/misc-content/case-studies/consumer-products-manufacturer-case-study.html
Date of Access: 1 April 2012

ACID RECYCLING TECHNOLOGY, 2012. WMRC Technology update. Management and Research Center.
http://www.istc.illinois.edu/info/library_docs/TN/00-070.pdf
Date of Access: 22 February 2012

BAILEY,DE. 1998. *Optimizing Anodizing baths with Diffusion Dialysis.*
http://www.sciencedirect.com/science/article/pii/S0026057698812506
Date of Access: 16 August 2012

BAILEY, D.E. n.d. *Recycling of nitric-hydrofluoric acid with diffusion dialysis.*
http://www.mech-chem.com/images/stories/Acid-Brochure/Nitric-HF.pdf
Date of Access: 16 August 2012

Data from Wispeco. 2012.

ELECTRICITY SUPPLY, 2012. Ekurhuleni Metropolitan Municipality.
http://www.ekurhuleni.gov.za/residents/customer-information/tariffs
Date of Access: 10 August 2012

IMPORTANT RATES, 2012. South African Reserve Bank.
http://www.resbank.co.za/Pages/default.aspx
Date of Access: 7 October 2012

KLEYNHANS, B. 2012. Personal interviews. 20 March 2012, 17 April 2012, 31 July 2012, 7 August 2012.

MECH-CHEM ASSOCIATES, 2012. *Acid recovery – Acid purification systems.* http://www.mech-chem.com/products-and-services/acid-recovery-and-reclamation-systems/how-our-dd-systems-work.html
Date of Access: 23 March 2012

MPINGA, CN. 2009. *Removal and recovery of aluminium and sulphate ions from an alkaline medium using solvent extraction*. Unpublished MTech dissertation Cape Town: Cape Peninsula University of Technology.
http://dk.cput.ac.za/cgi/viewcontent.cgi?article=1126&context=td_cput
Date of Access: 1 April 2012

OLIVETTI, N. 2012. Personal interviews. 20 March 2012, 17 April 2012, 31 July 2012, 7 August 2012.

PAJUNEN, P. 2001. *Recycling chemicals on the Anodizing line*.
http://www.eco-tec.com/techpapers/TP%20154%20Anodizing%20AEC.pdf
Date of Access: 20 Feb. 2012

PAJUNEN, P and HARRISON, J. 1997. *Anodizing acid purification using Resin sorption technology at Pioneer Metal Finishing.*
http://www.eco-tec.com/pdf/TP-%20124%20Anodizing%20Acid.pdf
Date of Access: 21 February 2012

PIENAAR, L. 2012. Personal interviews. 20 March 2012, 17 April 2012, 31 July 2012, 7 August 2012.

SCHULTZ, C. n.d. *How to realize Significant Cost Savings with Filtration and Purification*
http://www.pro-phx.com/docs/AAC%20Conf%20SERFIL%20Talk.pdf
Date of Access: 25 March 2012

SEWAGE DISPOSAL SERVICES, 2012. Ekurhuleni Metropolitan Municipality.
http://www.ekurhuleni.gov.za/residents/customer-information/tariffs
Date of Access: 10 August 2012

SHREVE, RN and AUSTIN, GT. 1984. *Shreves Chemical Process Industries Handbook, 5th EDITION,* New York: McGraw Hill.

SKEEN, JB and SUMNER, ME 1965. *Proceedings of the South African Sugar Technologists' Association – March 1965.* A new method for the determination of exchangeable Aluminium in acid solids. (1):209-213. http://www.sasta.co.za/wp-content/uploads/Proceedings/1960s/1965_Skeen_A%20New%20Method%20For.pdf
Date of Access: 21 Feb. 2012

WATER SUPPLY SERVICES, 2012. Ekurhuleni Metropolitan Municipality.
http://www.ekurhuleni.gov.za/residents/customer-information/tariffs
Date of Access: 10 August 2012

Appendix A – Emails

De Dietrich

From: noreply@www.dedietrich.com [mailto:noreply@www.dedietrich.com]
Sent: Saturday, August 04, 2012 4:13 PM
To: Jennifer Mayo; Tom Adams
Subject: Generic request quote

Description of Equipment: Sulphuric acid recycling/purification system

Do you have suppliers in South Africa and if not, would you be able to supply us here in South Africa?

Are you interested in additional services and/or components? No

I am looking to: Get more information

Please: Send me a quote

Additional Comments: I would like to know more about the purification systems. Electricity consumption per hour, water consumption (if any) per hour and annual maintenance costs as well as number of operators needed per system (if any).

Name: Natali Joubert
E-mail: natali.skrps@gmail.com
Phone: +27723682474
Company: Private
City: Pretoria, Gauteng
State: South Africa

This e-mail may contain confidential and/or privileged information. If you are not the intended recipient (or have received this e-mail in error) please notify the sender immediately and destroy this e-mail. Any unauthorised copying, disclosure or distribution of the material in this e-mail is strictly forbidden

---

Dear Natali,

We have received your enquiry via our US website.
There is a De Dietrich office in Johannesburg (DDSA) who we work closely with, however, the design and supply of this type of equipment is done from here in the UK.
Do you have a specific requirement or is this a general enquiry?

Can you please advise your company name etc. and I will forward some general information.

Best regards
Paul Finney
Proposals Manager
De Dietrich Process Systems Ltd.
Direct: 01785 609823
Mobile:07968014421
e-mail: pfinney@ddpsltd.co.uk

Mr. Finney

I am doing a cost benefit analysis for Wispeco Aluminium to determine whether it will benefit the company by implementing an acid purification system. This system is needed to purify sulphuric acid that is used in an anodizing process. According to your website, your company can provide us with such a system.

What i need is a quote stating the overall cost of the system and the following information about the system:
--The electricity consumption rate per hour
--The water consumption rate per hour
-- Maintenance costs (monthly or yearly)
-- Does the system need to be operated by an operator?
-- How many times can the acid be purified with this system?
-- How often does the system need to be serviced and what are the costs regarding this?

Would the supply of such a system be possible in South Africa?

Kind regards
Natali Joubert

Hi Natali,

We can certainly supply such a system and have recently completed a large waste acid recovery plant in South Africa.

To provide you with indicative costs we will need some details of the acid flow rate, concentration of the feed, purity and concentration required and details of any impurities in the feed acid.

For information, there is a De Dietrich sales office in Johannesburg who can also assist if required.

Best regards
Paul

I have requested that an acid analysis be done in order to determine the contents of the acid.

Regarding the other information I will have to speak to the lab technician at the anodizing plant and get back to you as soon as possible.

Regards
Natali

Thank Natali.

If you can advise a typical flow rate and concentration I can give a BALLPARK cost for a typical plant and possible concentrations/purities.

Paul

Good day Paul

The anodizing plant generates and dumps approximately 11 000 litres of sulfuric acid waste weekly. The aluminium concentration is 14grams/litre at the time of dumping. According to the acid analysis no other impurities except the aluminium is found in the acid. The grade of sulfuric acid that is used in the process is 98%.

The plant runs 24hours a day and 5 days a week, 45 weeks per year. There are two anodizing lines, an automatic- and a manual operated line each with 3 anodizing baths each with a capacity of 6 300 kg sulfuric acid. The total volume of one anodizing bath is 33 000 litre and water (26 500kg) is the only addition to the bath.

The anodizing acid is pumped through a chiller for cooling.
Caustic soda etching is also carried out at the plant.

Deionized water and compressed, filtered air is available at the plant.

If you need any other information in order to generate a quote, please do not hesitate to contact me.

Kind regards
Natali

Hi Nats,

What is the approximate concentration of the used acid to be re-concentrated?

Our typical plants work on a 2-stage basis, the first stage concentrating a weak waste stream up to 68% and then a second stage to concentate to 96%.
98% is not economical/practical.

Paul

Hi Paul

A fresh bath is reformulated (after dumping of acid) to have between 2 - 4 g/litre of aluminium present. At all times the aluminium strength should be less than 14g/litre and the ideal is between 5-10g/litre.

There are 3 anodizing tanks per line and each tank has a volume of 33 000 litres.

Hope you have sufficient information to generate a quote. Please do not hesitate to contact me regarding any other information.

Kind regards

The information contained in this electronic mail transmission is intended by the sender for the use of the named individual or entity to which it is directed and may contain information that is confidential or privileged. Said information is to be regarded as privileged and the intellectual property of the sender and may not be forwarded, copied or retained in any form except with the written permission of the sender. If you have received this electronic mail transmission in error, please delete it from your system without copying or forwarding it, and notify the sender of the error by reply email so that the sender's address records can be corrected.

Hi Natali,

Our engineer is asking what the concentration of the used acid is (after dumping).

Generally, it will be no problem to re-concentrate the acid but we may need to carry out some trials work to understand how the aluminium affects the process.

Paul

Hi Paul

The acid contains 14-15g/l of aluminium at the time of dumping. No other impurities were found in the acid according to the acid analysis.

Natali

Referring to one of your previous e-mails 96% concentration is correct.

Natali,

According to your figures, the baths are filled with 6,300kg of acid (98%?) and 26,500kg of water.
The waste stream will contain acid; water and aluminium sulphate. What is this concentration?
This waste stream needs to be re-concentrated (i.e remove the water) to re-cycle back into the tank.
During the re-concentration we will also need to remove some of the aluminium (aluminium sulphate).

To give an indicative cost we need to know the concentration of the waste stream and also the quantity of waste acid used per day i.e how many batches per day?

Plant can be sized to suit.

Paul

Paul

The 98% is the GRADE of acid that is used. One anodizing bath is made up with 6 300kg acid and 26 500kg water.
At the end of each week 11 000 litres is dumped out of the anodizing bath and the bath is made up again with new acid.
I do not know what the percentage of water in the waste stream is, nor the concentration of aluminium sulphate.

We test the concentration of aluminium in the acid before dumping. The acid contains 14-15g/l aluminium at the time of dumping. A fresh bath contains 2-4g/l aluminium.

There are 2 anodizing lines which have 3 anodizing baths each. That means there are 6 anodizing baths at the factory and each bath has a
volume of 33 000 litres. 11 000 litres is dumped at the end of the week out of EACH bath.

Natali

Thanks Natali,

Based on this I will get some indicative sise and price for the plant to you.

Paul

Hi Natali,

Our engineers think that we can design a small palnt to meet your requirements which will be cost effective.
They have asked again if you can check the concentration of the waste stream.

Based on the bath contents this should be around 20% but may be higher if some of the water evaporates during processing etc.

Paul

Hi Paul

I have asked the anodizing manager, but the concentration is not measured, so I do not know the exact concentration.

I think it is safe to work with between 20 and 30%.

Natali

Hi Natali,

We have done a similar project in Australia concentrating from 20%.

We are getting some BUDGET figures based on this plant.

Paul

Hi Paul

Can you please provide the following information together with the purchase price:
»Efficiency of the system (the % of sulphuric acid that is recovered by the system)
»Electricity consumption rate (per hour)
»Water consumption rate (in kl per hour)
»Air pressure requirements
»If an operator is needed to operate the system
»And what the estimated maintenance costs are (per year)

Kind regards
Natali

Hi Paul

My manager advised me that I need to submit all quotes for the purification systems no later than Friday morning.

I would highly appreciate it if you could send me the quote and also answer the questions I sent you so that I can calculate the operational costs of the system per year BEFORE Friday.

I would really like to include your quote, as I believe the company can greatly benefit form such a system.

Kind regards
Natali

Hi Natali,
I will get something to you tomorrow

Paul

I appreciate it very much!

Natali

Hi Natali,

Outline info and pricing are as follows:

DESIGN BASIS

20%/ 66000L (approx 75200 Kg/ 6-day week)

Say 522 kg/ hour feed

96% product= 109 approx kg/hr

UTILITY REQUIREMENTS

16 barg Steam: 515 kg/hr

Cooling Water: 55m3/hr

Chilled Cooling Water: 3m3/hr

Electricity: 25 kw (excluding steam generator and chilers if required).

BALLPARK Price: GBP1,300,000.00 - GBP1,500,000.00

This excludes cleaning system for removal of aluminium (to be designed)

Installation and Commissioning extra at day rate of GBP600.00 plus accomodation and subsistence at cost

To move this forward we would suggest we carry out a Front End Study including some trials/ASPEN modelling.
Cost for this would be around GBP20K

We have just installed and commisioned a Waste Acid Plant at Rheinmetal Denel Munitions in Wellington nr.Cape Town.
The plant concentates bot Nitric and Sulphuric Acid from a waste stream.Sulphuric Acid up to 96%.

We may be able to arrange for you to visit site if this would be of interest?

Hope this is OK for now.

Paul

Hi Paul

Thank you very much. I will contact you if I need any other information.

Kind regards
Natali

Good morning Paul

I just have 3 more queries and would appreciate it very much if you can help me in this matter.

1. Is it possible that you can get me an approximate freight cost of the system to South Africa as it is necessary to include this in the purchase price.
2. You did not specify whether an operator needs to operate the purification system?

3. What are the related maintenance costs yearly?

I need this information quite urgently to complete the cost-analysis.
Thank you in advance!

Kind regards
Natali

Hi Natali,

1. We would ship the equipment by sea-freight to the nearest part and deliver to site on trailer. BALLPARK cost includes for this but actual cost will be c. GBP5-10000. Price excludes import duties; customs clearance etc. and local taxes.

2. Equipment will be controlled by a PLC type control system. Operation is automatic but needs some supervisory control.

3. Plant requires little maintenance other than a yearly check for integrity of joints and seals etc. We would recommend that one of our local engineers carries out this check .
Allow 3-5 days @ GBP800.00

Paul

Thank you kindly!

Regards
Natali

Mech-Chem

----Original Message-----
From: Natali Joubert [mailto:natali.skrps@gmail.com]
Sent: Saturday, August 04, 2012 4:35 PM
To: Inquiry
Subject: AcidRecovery.com Website: Sulphuric acid purification/recycling systems

This is an enquiry e-mail via http://AcidRecovery.com from:
Natali Joubert <natali.skrps@gmail.com>

I am interested in an sulphuric acid purification/recycling system. Our company is situated in South Africa. Do you have suppliers in South Africa and if not, would you be able to supply us?

I have a few questions regarding the purification systems:
What is the electricity consumption rate per hour of the system?
What is the water consumption rate (if any) of the system?
What are the annual maintenance costs of such a system?
Does the system need an operator present at all times?
How many times can the acid be recycled before the acid has to be replaced?
After how many hours does the system need servicing?

Looking forward to hear from you soon

Please see previous reply.

Thanks,
Dan
Mech-Chem Associates, Inc.
P.O. Box 473
144 Main Street
Norfolk, MA 02056

(508)528-5990 P
(508)528-8972 F

Mr Bailey

It seems as though I only received this one e-mail referring to a previous reply, but I did not receive the reply.

Would it be possible to send the reply again?

I am doing a cost benefit analysis for Wispeco Aluminium to determine whether it will benefit the company by implementing an acid purification system. This system is needed to purify sulphuric acid that is used in an anodizing process. According to your website, your company can provide us with such a system.

What i need is a quote stating the overall cost of the system and the following information about the system:
--The electricity consumption rate per hour
--The water consumption rate per hour
-- Maintenance costs (monthly or yearly)
-- Does the system need to be operated by an operator?
-- How many times can the acid be purified with this system?
-- How often does the system need to be serviced and what are the costs regarding this?

Would the supply of such a system be possible in South Africa?

Kind regards
Natali Joubert

Hello Natali:

Here is the previous email that was sent.

If you could provide me with the amount of waste sulfuric acid that is being generated, and how frequently, I can give you detailed answers to your questions.

Thanks very much!

Sincerely,
Dan Bailey

Dear Natali Joubert:

Thank you for your inquiry. I have attached some more information for your review.

Here are the answers to your questions:
We have worked with a Company in South Africa called Chemapan, but have not heard from them in a while. Would you like their contact information?

The answer to most of your questions depends upon the size of the system needed. Could you tell us more about the application? Then I would be able to assist further.
Sincerely,
Dan Bailey

Good day Dan

The amount of waste of sulfuric acid that is generated weekly and decanted (dumped) is 11 000 litres.

Attached is the completed customer questionnaire. Please let me know if you need any other information in order to generate a quote.

Kind regards
Natali

Good Day Natali:

Thank you for this additional information. It is very helpful. Here are some answers to your questions:

1) Since we use gravity to do most of the work in the process, the metering pumps on the membrane modules are the only normally moving part on the system (except when the system is refilling itself). These draw a maximum of 1.8 amps each. So, figure 0.5 kw-hr. Typically, less than $0.01 power cost per gallon processed.

2) The water consumption is equal to, or slightly greater than the acid solution processing rate. For your requirements it will be about 1,600 liters per day.

3) The membranes will last 7-10 years or more before requiring changing. The metering pumps and double-diaphragm pump should be rebuilt every one to two years at a total cost of about $800 USD. If the acid solution is properly filtered, and there is no algae growth (which can be counter-acted by acidifying the water feed solution), than the membrane stack will not need servicing and maintenance costs will be minimal.

4) The sulfuric acid can be reused indefinitely, but each time a liter is dialyzed about 15% of the acid is lost and ends up with the 90+% Aluminum that is removed. This sulfuric acid needs to be replaced.

For your application I recommend our Model AP-300 which sells for $88,200 USD. I also recommend the optional filtration module which sells for $9,600 USD. The AP-300 might be slightly too small for this application, but it can be doubled in size by adding a second membrane module at a cost of $56,800 USD.

We do have Lab units available for purchase or rent so that you can verify the process at your facility.

Looking forward to your additional questions.

Kind Regards,
Dan

Good day Dan

Thank you very much for the purchase costs and other relevant information.

I just want to know whether the system requires an operator present at all times?

Kind regards
Natali

Hello Natali:

Our Diffusion Dialysis systems are designed to run unattended, 24 hours per day/seven days per week. The system is designed to go into automatic shut-down if there is a problem. We recommend that someone inspect the system at least once per day during the week.

Kind Regards,
Dan

Good morning Dan

I just have one more query about the acid purification system and would appreciate it very much if you could assist me in this matter.

Can you please find out what the approximate freight costs of the system to South Africa would be? I need to include this in the purchase cost in order to complete the cost-analysis.

Thank you in advance!

Kind regards
Natali

Hello Natali:

We have shipped a Lab unit to South Africa in the past couple of years. The cost, by Air Freight was about $940 USD.

I hope that this is useful.

Best Regards,
Dan

Prosep Technologies Limited

Good Afternoon Natali

Your e-mail addressed to Eco-Tec Inc in Canada has been forwarded on to Mr Anderson of Prosep Technologies Limited.

My colleague Mr Anderson is out of the office on business and will return on Thursday 9 August when he will reply to your e-mail.

Best regards

Julie Geraghty
Administrator-Finance
Prosep Technologies Limited

Tel: (44) 01543 675731
Fax: (44) 01543 679484
E-mail: ptl@eco-tec.com

Good Day Natali

Your e-mail addressed to George Di Falco at Eco-Tec has been passed to the undersigned as Prosep Technologies Limited is the part of the Eco-Tec group which has responsibility for Sales and Marketing to clients based in South Africa.

We do not have an agent who is based Johannesburg, however in the first instance you should forward specific data to us as we will be responsible for the technical evaluation.

I am attaching herewith a copy of our Information Package for the AnoPur range of equipment as this will answer most, if not all of your questions.

Annual maintenance costs are low, as long as you follow the maintenance program described within the operator instructions ie. changing the filter cartridges, periodically checking diaphragm valves.

The AnoPur Unit is designed to run without the presence of an operator, normally the operator would spend 20-30 minutes per day carrying out routine checks to maintain and monitor the efficiency.

For this application the resin has a life expectancy of between 5 and 7 years.

In order to provide you with a suitable quotation we need to understand your current production. Please refer to the attached engineering survey form. If you would complete this form and return it to me we would be happy to prepare a suitable offer.

Best regards
WS Anderson

Prosep Technologies Limited
Unit 6A Zone 4
Burntwood Business Park
Burntwood
Staffordshire
WS7 3XD
ENGLAND
Tel: (44) 01543 675731
Fax: (44) 01543 679484
E-mail: ptl@eco-tec.com

2 attachments — Download all attachments

AnoPur Brochure.pdf
446K View Download

AF91 - ES 2-2-1 APU Anodizing.dot
372K View Download

Good day

Attached is the completed engineering survey form. Please let me know if you need any other relevant information in order to generate a quote.

Kind regards
Natali

Please refer to page 4 of the survey form. The amount of H_2SO_4 in a bath is 6 300kg and NOT 63 000kg.

Kind regards
Natali

Good day Natali,

Thank you for sending us the completed engineering survey form.

We are happy to prepare a technical proposal and sales quotation for a suitable system. I am familiar with the operation at Wispeco Aluminium as in the past I have visited their facility in Johannesburg. I note from your original enquiry that you are based in Pretoria. Do you actually work for Wispeco, are you a consultant or have a similar role?

I have made an initial review of the information contained within the completed engineering survey form and need you to clarify a few areas.

1. Fresh Bath.
a) In all cases you show the concentration of aluminium at zero. My experience is that most anodising baths, when they are re-formulated, are done so in such a way as there is a low level of aluminium present. Depending on the nature of the operation this can be in the range of 2-4 g/l. Can you recheck to see how the baths are reformulated?

b) Concentration of sulphuric acid is reported as 6300 Kg. In practice most anodising companies report this value in terms of grams per litre. The normal range is between 180 and 250 g/l. Can you confirm how Wispeco are operating each bath?

2. Bath Value.
You state that each line has 3 anodising tanks and show a volume per line of 33,000 litres. Please confirm that 33000 litres is the total volume for the 3 tanks.

3. Dump Volumes.
You state 11,000 litres per week. Please confirm, is the 11,000 litres per tank per week or per line?

4. Preferred Bath.
You state that this is the same as for the fresh bath. Please refer to 1 a) above where I have requested clarification on this point. In practice most anodising organisations prefer to run their baths at between 7-10 g/l. Please confirm if this is the case at Wispeco.

If you can confirm that above, it will help us to ensure that we offer the correct size of equipment.

We look forward to hearing from you.

Bill Anderson

Good day Bill

As requested:

1 (a) Fresh bath
A bath is reformulated that there is between 2-4g/litre aluminium present.
(b) Each sulphuric acid bath is operated between 175 - 195g/litre.

2. Bath volume
The volume of EACH bath is 33 000 litres

3.Dump volumes
11 000 litres per tank per week

4. Preferred bath
Aluminium strength should be less than 14g/litre. Ideally it must be 5-10g/litre.

I hope that this provides you with sufficient information in order to generate a quote.

Please do not hesitate to contact me regarding any other information.

Kind regards
Natali

Good Afternoon Natali

Thank you for your e-mail dated 24 September 2012.

Mr Anderson is currently on holiday.

We will request a preliminary proposal and quotation to be provided and once completed
will send on to you.

Best regards
Julie Geraghty
Administrator-Finance
Prosep Technologies Limited
Tel: (44) 01543 675731
Fax: (44) 01543 679484
E-mail: ptl@eco-tec.com

Thank you very much Julie.

Natali

Good Morning Natali

Please accept my apologies in the delay in responding to your e-mails.

Firstly I am currently working on the finalisation of the sales quotation which I hope to be able to send to you later today.

Based on the information previously supplied we believe that it will be necessary for Wispeco to consider the installation of an AnoPur, Model D13 Purification System.
Please find attached a copy of the Technical Brochure for this range of equipment.

Please refer to the Sections marked Performance Specification and Equipment Specification which I believe provides you with the necessary answers to your questions.

As to the requirements for operation and maintenance we would advise that it is only normally necessary for the Operator to spend between 15 and 20 minutes each day carrying out basic checks such as pressure readings etc. Maintenance costs for the system are low and generally consist of periodic changing of the cartridge filters (within the base price we have included for some replacement cartridge filters).

As to the life expectancy of the resin for this application we normally expect to achieve between five and seven years.

I trust the above is of assistance and will provide the formal quotation to you shortly.

Best regards

Bill Anderson
Prosep Technologies Limited
Tel: (44) 01543 675731
Fax: (44) 01543 679484
E-mail: ptl@eco-tec.com

BRMC400_AnoPur.pdf
1460K View Download

Good morning Bill

Thank you very much!

Regards
Natali

Good Afternoon Natali

Further to our earlier communication we have pleasure in providing you with our Equipment Sales Quotation.

Unfortunately our Freight Agent has not been able to provide us with a detailed costing for freight from our Canadian manufacturing plant to South Africa.

In order to allow you to submit your application for Capital Funds I would suggest that you allow for a budget cost of 10,000 to 12,000 US$ for CIF to Durban.

Freight costs are always subject to review at the time a contract is placed. We will provide you with a more accurate cost at that time.

I hope this is of assistance.

Regards
Bill Anderson
Prosep Technologies Limited
Tel: (44) 01543 675731
Fax: (44) 01543 679484
E-mail: ptl@eco-tec.com

Appendix B – Acid purification systems brochures from suppliers

De Dietrich

QVF Process Systems Ltd — Technical Information

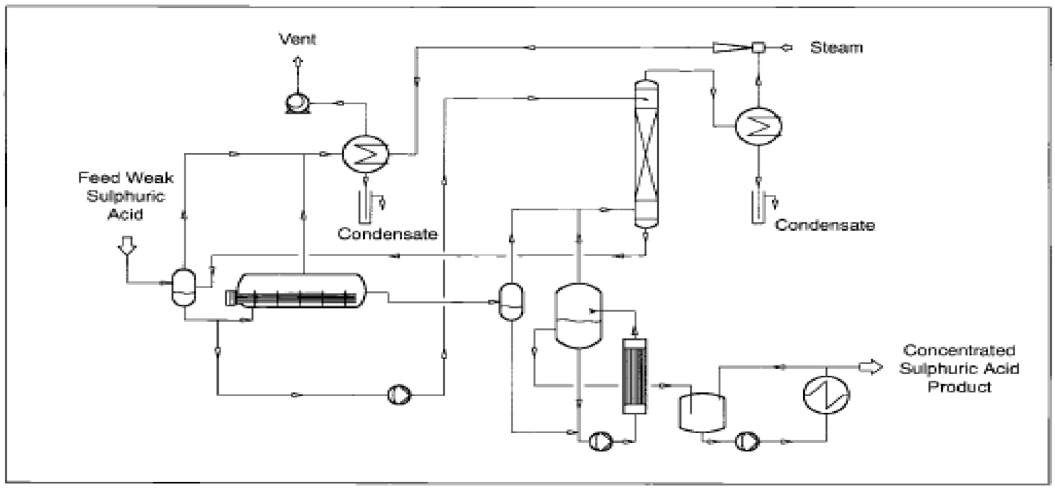
Sulphuric Acid Concentration by QVF

Introduction

Many processes within the chemical industry generate a waste dilute sulphuric acid. Disposal of such waste streams is becoming increasingly difficult and expensive. If the waste acid is relatively uncontaminated, it can be concentrated and recycled to the process. Also, contaminated acid can often be recovered by using a suitable pretreatment before concentration. This produces savings in raw materials and effluent disposal costs.

A further advantage of the QVF Horizontal Boiler is reduced vapour acidity, which gives lower acid losses and reduced effluent treatment cost. Since the acidity of the vapour rises virtually exponentially with the acid concentration, the vapours generated at the front end have an acidity in the region of 1 ppm, compared to almost 3% at the discharge for the above concentrations. For this reason it is not normally necessary to scrub the vapours.

For discharge concentrations above 90%, where the acid to be treated contains dissolved iron, this is precipitated as the acid is concentrated. With the QVF Horizontal Boiler this precipitated iron is deposited on the tubes, which then requires regular shutdown for cleaning. This regular shutdown can be an advantage as it provides a method of removal of iron from the system.



Process Description

QVF sulphuric acid concentration plants are designed for maximum efficiency at minimum cost. The acid is concentrated by evaporation under vacuum, using steam (typically at 13-17bar) with tantalum tubed heat exchangers.

All equipment in contact with the acid is manufactured from borosilicate glass, glass-lined steel, PTFE or tantalum for long life.

For concentrations up to 90% sulphuric acid the QVF Horizontal Boiler is employed. This boiler outperforms the circulatory boiler which is usually employed by others. The boiler is divided into many segments, and the acid is progressively concentrated as it flows along the length. This means that for a boiler concentrating acid from say 66% to 88%, the temperature at the inlet would be about 90°C and rise progressively to over 170°C at the discharge point. This results in a vastly improved mean temperature difference between the acid and steam compared to the circulatory types, where all of the acid is at the discharge concentration and therefore the discharge temperature. In addition since everything is internal, there are no circulation lines or circulation pumps, reducing maintenance.

However for high strength acid 90%-96%, QVF would generally install a forced circulation boiler using a silicon iron circulation pump. In this case the circulating acid is pumped from a vessel through a heat exchanger, but due to the elevated boiling point because of the liquid head, there is no boiling at the heat exchanger, only a temperature rise. After the heat exchanger, the acid is returned to the vessel, where the vapour flashes off, and the temperature drops to the boiling point of the acid at the operating vacuum. It is at this point that the dissolved iron is precipitated, well clear of the heat exchange surface.

Because of the acidity of the vapour at high concentrations, it is necessary to scrub the vapours. It is normal to use the feed weak sulphuric acid for this purpose so that the acid in the vapour is recovered.

To concentrate from say 66% to 96% the process would be carried out in two stages, the first stage up to 88/90% using the QVF Horizontal Boiler, and a final stage at a greater vacuum with a forced circulation system.

It is normal to employ energy recovery by interchange between feed and product for minimum operating cost.

PPAE 16

member of De Dietrich PROCESS SYSTEMS

Process Description Continued

Acid Concentration Range	Number of Stages	Vacuum (Torr)	Temperature C
65% to 85%	1	70	170
85% to 96%	1	10	175
65% to 96%	2	Stage 1- 70 Stage 2 - 10	170 175

Plants can be designed for throughputs of up to 10,000 kg/hr in a single stream. For higher capacities, the use of multiple streams is recommended.

Associated Processes

The sulphuric acid concentration process can be used in conjunction with nitric acid concentration and denitration processes to produce a fully integrated system with minimum energy consumption and minimum effluent.

Tollgate Industrial Estate
Stafford ST16 3HS England
Tel +44 1785 609900 Fax +44 1785 609899
E-mail qvf@qvf.co.uk

Mech-Chem

Engineering a GREENER Tomorrow

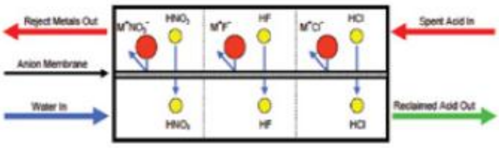
Mech-Chem Associates, Inc.

ACID PURIFICATION SYSTEMS

Acid Purification System Lab Unit

This Acid Purification Lab unit is designed for testing on small volumes of acid solutions, to provide users with an introduction to the technology, and with initial performance data. Evaluation of the results may lead to further pilot scale testing, or to full-scale installation at the facility.

Lab units are available for monthly rental, or may be purchased. The Lab units are designed to process between ½ to one gallons of acid solution, per 24 hours of operation, depending upon the type and concentrations of acids and dissolved metals in solution.



Acid Purification Systems: An Overview

Mech-Chem Associates, Inc.'s Acid Purification Systems are simple to operate, dependable, and economical. Our purification systems use an advanced membrane separation technology known as Diffusion Dialysis to separate, recover, and purify strong acids from spent acid solutions contaminated with dissolved metals. An anion exchange membrane serves as a semi-permeable barrier between a flowing stream of water and a flowing stream of process acid. Through this membrane, the processes of both Diffusion and Dialysis occur. These processes are carried out hundreds of times through the numerous internal channels that are contained in the many layers that make up the centrally-located stack of the Acid Purification System.

This technology is capable of recovering acids from concentrated baths that would have been discarded in the past. The purified acid is returned to the process tank for continued use, while a concentrated metal-containing aqueous solution is removed for waste treatment. Typically, 80-90% of the initial process acid is recovered in one pass through the system with 70-90% removal of the dissolved metals from the process acid.

The Acid Purification Systems manufactured by Mech-Chem Associates, Inc. are tailored to the client's needs with respect to materials of construction and operating capacity required. The systems range in size from the AP-15, which processes 15 gallons of acid per day, to the AP-1200, which processes up to 1,200 gallons of acid per day.

- **Up to 90% reduction in new acid purchases**
- **Increase acid bath life / Decrease neutralization costs**
- **Maintain bath uniformity for optimum performance**
- **Increase production / reduce downtime**
- **Reduce hazardous waste disposal costs**

Mech-Chem Associates, Inc.
144 Main Street, P.O. Box 473, Norfolk, Massachusetts 02056 Telephone 508-528-5990 Fax 508-528-8972
www.mech-chem.com info@mech-chem.com

RECYCLING OF NITRIC-HYDROFLUORIC ACID WITH DIFFUSION DIALYSIS

By Daniel E. Bailey

Stainless steels can be pickled in a variety of acid solutions to remove scale and to eliminate weld and machining marks, in order to blend the final finish into the original mill finish. A common choice among stainless steel fabricators is a mixture of Nitric and Hydrofluoric acid. Varying formulations of this chemistry are used to adjust etch rates and temperature requirements, dependent upon the type and condition of the stainless steel parts that are being pickled.

As the stainless steel is pickled, metallic components of the alloy are oxidized from the surface of the part into the acid pickling solution, producing metal salts in solution, and liberating hydrogen gas in the reduction reaction. As the concentration of metal salts increase in the pickling solution, the rate of oxidation of the metallic substrate will be affected. Although a small amount of metal salts dissolved in the pickling solution will initially enhance the dissolution rate of metal oxides at the surface of the part, -catalyzing the electron transfer step from the metal to the hydrogen ion at the solution-substrate interface, - generally the rate of pickling will decrease as the metal salt concentration in the pickling solution increases. At some point, dependent upon the operational parameters of the particular pickling bath, the pickling rate will become unacceptably slow or incomplete, decreasing both the quality and the throughput of the pickling operation. At this point, the pickling bath is either discarded and made up with a fresh acid mixture, or partially discarded and refreshed with the appropriate acid mixture. The spent pickling acid is either treated in-house or contracted for disposal off-site. Hauling away spent pickling acid is typically an expensive proposition, which requires a significant amount of paperwork. Disposal also subjects a company to long-term liability for its hazardous waste by-product. Treating the spent acid in-house requires added capital investment, labor and operational cost, and exposes plant personnel to increased health and safety risks.

Diffusion Dialysis is ideally suited for the recycling of Nitric-Hydrofluoric acid, stainless steel pickling solutions. Diffusion dialysis provides improved pickling quality, consistent pickling rates, and less energy demanding pickling baths. It also eliminates production down-time associated with the dumping and remaking of the pickling bath. The passive, continuous Diffusion Dialysis process enables the stainless steel pickler to efficiently remove and control the dissolved metal content in the bath while recovering and returning a high percentage of the acid mixture back into the process bath. The Diffusion Dialysis process also removes and controls other contaminant build-up in the bath, while producing a minimum of rejected waste by-product for subsequent treatment and disposal.

This paper reviews Diffusion Dialysis technology and relates its benefits for the recycling of Nitric-Hydrofluoric acid solution used for the pickling of stainless steel.

What is Diffusion Dialysis?

Diffusion Dialysis is a membrane separation process. It has been successfully used for many years for the separation and recovery of acids from dissolved metal bearing solutions. Diffusion is the spontaneous movement of a material from an area of high concentration to an area of lower concentration. Driven by the concentration difference, the movement of material will continue on its own until the concentration difference no longer exists. Dialysis is the separation of molecules due to the differences in the rate of movement of the molecules through a semi-permeable barrier.

In the recovery of acids with Diffusion Dialysis, an anion exchange membrane acts as a semi-permeable barrier placed between a flowing water stream and a flowing acid solution with dissolved metal. The anion exchange membrane has fixed positive charges located on its surface. These positive charge locations attract the negatively charged anions in solution that come in close contact with the anion exchange membrane surface.

In the case of nitric-hydrofluoric acid pickling solution, the overwhelmingly predominant anions are the nitrate ion, NO_3^{-1} and the fluoride ion, F^{-1}. As these nitrate and fluoride anions in the acid solution come in contact and are attracted to the positively charged membrane, they diffuse across the membrane into the less concentrated water solution on the other side of the membrane. This is due to the concentration difference across the membrane. Simultaneously, the thermodynamic Law of Electroneutrality (in solution total charge must balance to zero) requires that the transference of every nitrate or fluoride anion across the membrane be accompanied by the transference of a positive charge. Positively charged ions such as the ferrous cation, Fe^{+2}, or the nickel cation, Ni^{+2} or other metal cations, are strongly inhibited from crossing the positively charged membrane because of the repulsion between like charges. The hydrogen ion, present in the acid solution as H_3O^+ ions, or protonated water, is also positively charged, but is able to cross the membrane with very little hindrance. This occurs for two reasons: the highly associated nature of water allows the hydrogen ion to effectively delocalize its charge, and because of the high concentration of hydrogen ions in the acid solution.

Diffusion Dialysis Separation Process

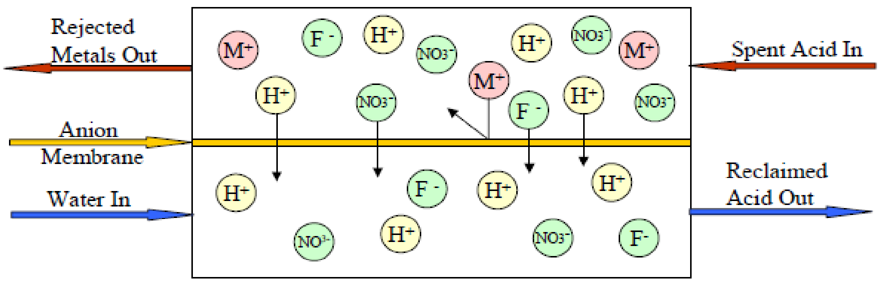


Figure #1

2

The net effect is that the rate of diffusion of nitric or hydrofluoric acid across the membrane is an order of magnitude greater than that of the dissolved metal cations. Finally, by causing the flow of the acid solution to be in the opposite direction to the flow of water (counter-current flow), optimal advantage of the necessary concentration gradients can be realized. The results are that the water entering the Diffusion Dialysis system exits as a metal-depleted recovered acid solution (diffusate) and that the acid solution entering the Diffusion Dialysis system exits as an acid-depleted dissolved metal-bearing solution (dialysate). See figure #1.

Applied Diffusion Dialysis.

The standard processing rate for Diffusion Dialysis systems is: a liter per hour per square meter (approximately 0.025 gallons/hour/square foot) of available anion exchange membrane surface area. To obtain the necessary membrane area that is required to process large volumes, the membranes are stacked between gasketed hydraulic flow spacers. These membrane stacks are usually standardized over a range of differing processing capacities.

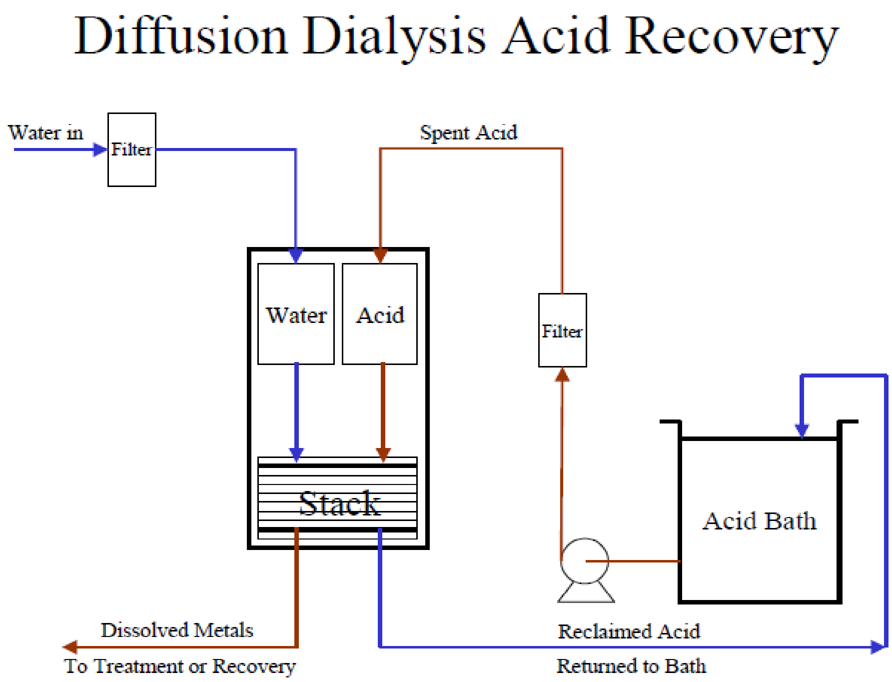


Figure #2.

Figure #2 depicts a typical, automatically operated acid recycling configuration. The acid recycling system has two liquid chambers at the top of the unit: one chamber is for water, and the other is for the acid to be processed. A dual set of level controls is located in each chamber. As the acid level drops in the chamber, the primary level controller will energize a self-priming air diaphragm pump located on the system. Acid solution will be drawn into this pump and then sent through a filter and into the acid holding chamber on top of the module.

Once the acid holding chamber has been refilled, the primary level controller will shut off the pump. Should the primary level controller fail for some reason, a secondary level controller will shut off power to the system at emergency-high, or emergency-low level, and an audible alarm will sound.

A similar dual arrangement is present in the water holding chamber. Instead of a pump, the primary level controller is tied into a solenoid valve which is plumbed to the water feed line.

Once the water and acid solutions are in the holding chambers on the unit, they flow independently, by gravity, into the membrane stack(s) on the base of the unit (see Figure #2). The acid and water solutions flow counter-currently through the membrane stack, thus maximizing usage of the concentration gradients. Using the principles of Diffusion Dialysis, anion exchange membranes segregate acid molecules into a purified zone. Typically, 80-95% of the acid is recovered with 70-95% of the metals removed.

The exit ports of the membrane stack are plumbed to a set of metering pumps. Except during the automatic refilling of the system, these metering pumps are the only moving components on the entire system. The metering pumps are used to control the solution flow rates. The exit ports of the recovered acid metering pump(s) are plumbed into the acid pickling tank, and in the case of the metal-rich, acid-depleted waste solution, the metering pump(s) are plumbed to final treatment.

The acid recycling system is a fully modularized unit. For installation, the pump on the acid recycling unit is plumbed to the working pickling tank(s) and a solenoid valve on the unit is plumbed to a pressurized water source. The system uses 115 VAC/ 20 AMP service and, upon delivery, can be plugged in and immediately utilized.

Implementing Acid Recycling -

A stainless steel pipe manufacturer began to investigate Diffusion Dialysis for the recovery of their Nitric-Hydrofluoric acid pickling solution and for control of metal and contaminant build-up in their pickling bath. Immediate motivation was for the replacement of a resin-sorption recovery system that had been marginally successful at recovering their pickling acid and controlling the metals in their bath. Adverse maintenance and reliability issues associated with the resin-sorption recovery system were key motivators for investigating alternative technologies.

Resin Sorption technologies have occasionally been utilized for the recycling of stainless steel pickling baths. This technology relies on the sorption of acid molecules on an ion exchange resin bed. The process works by pumping contaminated acid into the bottom of the resin bed. Acid is sorbed by the resin particles and the partially de-acidified salt solution is collected from the top of the bed. Water is then pumped into the top of the bed, desorbing the acid from the resin and the recovered acid product is collected from the bottom of the bed. The above cycle is continuously repeated by alternately opening and closing a series of valves.

Acid recovery efficiency via resin sorption can vary between 40% to 90% per pass. Metal removal rates per pass can be as low as 25%. One reason for this low metal removal efficiency is due to the entrapment of process solution in the resin bed column. This entrapment hinders overall recycling efficiency because it requires multiple passes to achieve sufficient metal removal. With Diffusion Dialysis technology, significantly less waste by-product is produced- typically one-half to one-fifth as much as with resin sorption systems.

With the advent of significantly more durable ion exchange membranes in recent years, the life expectancy of the majority of the ion exchange membranes utilized in Diffusion Dialysis acid recovery can be up to 10-20 years, dependent upon the application. Typical ion exchange resin life in acid sorption systems varies between 2-5 years. Both technologies require very good pre-filtration of the process solution prior to introduction into the recovery units.

To prove the effectiveness of the Diffusion Dialysis technology in removing metallic contaminants and in producing workable concentrations of recovered acid, a pilot study was performed at the customer's facility, by in-plant personnel, on their working pickling solution. The pilot studies showed excellent results in removing metallic contaminants and generated a recovered acid permeate of high concentration for reuse. The acid depleted fraction following dialysis produced a solution which was rich in metal and weak in acid concentration.

The sizing of the Diffusion Dialysis system was based upon the volume of spent pickling solution previously produced, the rate of this production, and the efficiency of the Diffusion Dialysis process. A useful "rule of thumb" requires that, at a minimum, the volume of spent acid that was previously discarded be recycled once through the Diffusion Dialysis unit over the same period of time that it took to generate the spent acid.

A 600 GPD acid recycling system was installed directly on to the working pickling tank, as illustrated in Figure #1. Additions of virgin acid are made to replenish depleted volumes due to: consumption, drag-out, exhaust escape, and the minor amounts lost in the dialysis process.

Table #1 relates the Diffusion Dialysis performance results of this installation. Sixteen sample sets were taken over a three month period and averaged. Recycling efficiencies (in parentheses) were calculated by comparing the recycled acid and rejected metal concentrations to the initial pickling bath concentrations. The system is dialyzing about 500-600 gallons per day. A flow imbalance between the reclaim stream and reject stream can produce concentration increases, as seen in the increased nitric acid concentration in the reclaimed acid solution as compared to the initial nitric acid concentration.

TABLE #1	**INITIAL ACID**	**RECLAIMED ACID**	**REJECTED METAL**
NITRIC ACID	**10.0%**	**11.4%** (114%)	**1.8%** (18%)
HYDROFLUORIC ACID	**2.5%**	**1.7%** (68%)	**0.8%** (32%)
IRON	**2.4%**	**<0.5%** (<20%)	**1.7%** (71%)

For this stainless steel fabricator the major benefit was cost savings. Capital investment for a 600 GPD Diffusion Dialysis acid recycling system is $144,500. After start-up of the system at this facility, monthly savings from reduced chemical purchases and elimination of off-site disposal are $8,000 per month. With an operational cost of less then $0.01 per gallon processed (less then $5.00 per day), payback for this system was reached in about a year and a half. There were also quality improvements and a decrease in production down-time. The environmental benefits are also significant with the elimination of hundreds of thousands of pounds of hazardous waste generation and the associated off-site disposal.

Justification and Benefits.

Cost savings are a major justification for using Diffusion Dialysis for the recycling of pickling acids. Diffusion Dialysis acid recycling users obtain improved quality and reduced rework, often with reduced processing times. The following is a summary of benefits being derived from the implementation of acid recycling utilizing Diffusion Dialysis:

- Savings from reduced or eliminated disposal costs and reduced acid purchases.
- Elimination of production down-time associated with the dumping and recharging of acid baths.
- Minimization of direct operator contact with dangerous chemicals - reduced operator exposure.
- Fully automatic operation, 24 hours per day, seven days per week, with very minimal operating costs.
- Improved process control with consistent pickling rates, improved quality and minimized waste.
- Improved environmental impact.

Summary.

Diffusion Dialysis for acid recycling reduces acid purchases and eliminates or lowers neutralization or hazardous waste hauling costs and the related liability. Toxic chemical use is reduced as is the required reporting and handling of hazardous materials and associated labor. Consistent bath strength yields greater product uniformity and better quality with lower operating costs. Diffusion Dialysis can dramatically improve a facility's quality, environmental, and economic performance.

Mech-Chem Associates, Inc.

Design ▪ Engineering ▪ Construction
Installation ▪ Start-Up

Acid Purification System

The Answer to Your Acid Concerns

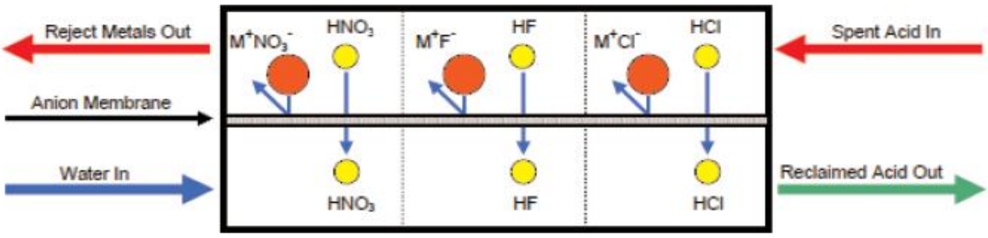
If your facility is currently relying on the use of acids for production purposes, you are undoubtedly concerned with acid bath quality as well as the costs and liability associated with the disposal of spent acids each month. Not only are these issues related to production reliability, they are also of concern when it comes to production downtime and cost.

As a means to remedy these problems, Mech-Chem Associates, Inc. manufactures a line of built-to-order **Acid Purification Systems** that utilize the process of diffusion dialysis to remove dissolved metal impurities from acid solutions and produce clean, useable acid from what would have otherwise been waste.

Diffusion Dialysis for acid recycling has many benefits. It reduces acid purchases and eliminates or lowers neutralization or hazardous waste hauling costs and the related liability. Toxic chemical use is reduced and the required reporting and handling of hazardous materials and associated labor is greatly reduced. Consistent bath strength yields greater product uniformity and better quality with lower operating costs. Diffusion dialysis can dramatically improve a facility's quality and economic performance.

Advantages of Acid Recycling

- Up to 90% reduction in new acid purchases
- Increase acid bath life
- Maintain bath uniformity for optimum performance
- Increase production/reduce downtime
- Reduce hazardous waste disposal costs
- Reduce waste neutralization costs
- Reduce long-term liability
- Simple, Reliable, Economical
- Units are self-contained, easily maintained, and require very little floor space



Acid Purification Systems: An Overview

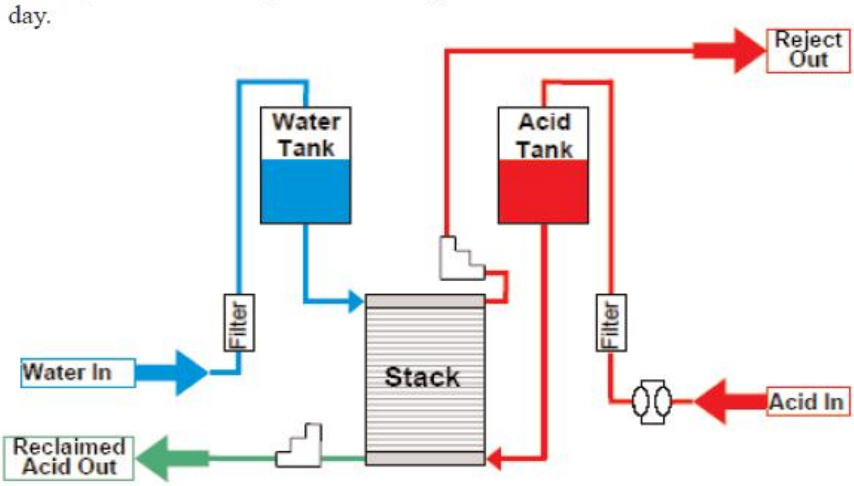
Mech-Chem Associates, Inc.'s Acid Purification Systems are simple to operate, dependable, and economical. Our purification systems use an advanced membrane separation technology known as Diffusion Dialysis to separate, recover, and purify strong acids from spent acid solutions contaminated with dissolved metals. An anion exchange membrane serves as a semi-permeable barrier between a flowing stream of water and a flowing stream of process acid. Through this membrane, the processes of both Diffusion and Dialysis occur. These processes are carried out hundreds of times through the numerous internal channels that are contained in the many layers that make up the centrally-located stack of the Acid Purification System.

This technology is capable of recovering acids from concentrated baths that would have been discarded of in the past. The purified acid is returned to the process tank for continued use, while a concentrated metal-containing aqueous solution is removed for waste treatment.

Typically, 80-90% of the initial process acid is recovered in one pass through the system with 70-90% removal of the dissolved metals from the process acid.

The Acid Purification Systems manufactured by Mech-Chem Associates, Inc. are tailored to the client's needs with respect to materials of construction and operating capacity required. The systems range in size from the AP-15, which processes 15 gallons of acid per day, to the AP-1000, which processes 1,000 gallons of acid per day.

AP-30 Membrane Stack



For a more in-depth description of the technology and benefits of the Acid Purification Systems produced by Mech-Chem Associates, Inc., simply contact us. We will be more than happy to help you meet your acid purification needs.

Mech-Chem Associates, Inc.
144 Main Street, P.O. Box 473 Norfolk, Massachusetts 02056
Telephone: 508-528-5990 Fax: 508-528-8972 info@mech-chem.com http://www.mech-chem.com

Engineering a GREENER Tomorrow

Mech-Chem Associates, Inc.

ACID RECYCLING SYSTEM
MODEL AP-45

Specifications

CAPACITY:	Up to 45 GPD (170.34 LPD)
LENGTH:	41in (104.1 cm)
WIDTH:	30in (76.2 cm)
HEIGHT:	80.5in (204.5 cm)
WEIGHT:	790lbs (358.34 kilos)
TEMP.:	110 F. (43 C.) cooling required above this.
POWER:	115 VAC/15 Amp
UTILITIES:	Water: Up to 60 GPD
	Air: 30-60 psi
FILTERS:	1.0 micron by 10 inch
ACID INLET:	0.5in NPT
WATER INLET:	0.5in NPT
RECLAIM OUTLET:	0.5in NPT
METALS OUTLET:	0.5in NPT

SIZING:

Divide the volume of spent acid solution generated by the number of calendar days between make-up and waste generation. e.g., 1350 gallons being discarded once per month equals 45 GPD, equals Model AP-45.

•Design •Engineering •Construction •Installation •Start-Up

Acid Purification Systems

Acid Purification Systems utilize an easy-to-use, dependable, and economical purification membrane technology known as Diffusion Dialysis.

Mech-Chem manufactures a line of Acid Purifications Systems that utilize the process of diffusion dialysis to remove dissolved metal impurities from used or spent acid solutions and produce a clean, useable acid from what would have otherwise been waste.

Diffusion Dialysis is a very effective technology for the recovery and purification of used, spent, or waste acid solutions that contain low levels of dissolved metals and still contain a large fraction of the acids.

Advantages of Acid Recycling

- **Reduced acid purchases**
- **Reduced waste neutralization costs**
- **Increase acid bath life**
- **Maintain optimum bath uniformity**
- **Increase production/reduce downtime**
- **Reduced hazardous waste disposal costs**
- **Reduce long-term liability**
- **Simple, reliable, economical**
- **Units are self-contained, easily maintained, and require very little floor space**

Acid Purification System Overview

In the recovery of acids with diffusion dialysis, an anion exchange membrane acts as a semi-permeable barrier between a flowing water stream and a flowing acid solution that contains the dissolved metals. The anion exchange membrane has fixed positive charges located on its surface. These positive charge locations attract the negatively charged anions in the solution that come in close contact with the anion exchange membrane surface. As a result, the acids in the spent or waste acid solution are attracted to the membrane.

The metal ions which are larger molecules and positively charged are repelled by the positively charged membrane. This allows the acid molecules to diffuse through the membrane at a much faster rate than the dissolved metals. The result is that the water entering a diffusion dialysis system exits as the recovered acid solution containing most of the acid. The spent or waste acid solution entering the diffusion dialysis exits as an acid depleted solution containing most of the dissolved metals. Normal acid recovery is 80% to 90% with removal of 70% to 90% of the dissolved metals .

Mech-Chem Associates, Inc
144 Main Street, P.O. Box 473, Norfolk, MA 02056 Telephone: 508-528-5990 Fax: 508-528-8972
WWW.Mech-Chem.Com Inquiry@Mech-Chem.Com

Optimizing Anodizing Baths with Diffusion Dialysis

by Daniel E. Bailey,

Diffusion dialysis is ideally suited for the recycling of sulfuric acid anodize solutions. Diffusion dialysis provides improved anodize quality, consistent anodic thicknesses, cooler and less energy-demanding baths, while eliminating production downtime associated with the dumping and remaking of the anodize bath. The passive, continuous diffusion dialysis process enables the anodizer to efficiently remove and control the dissolved aluminum content in the bath while recovering and returning a high percentage of the sulfuric acid back into the process bath. The diffusion dialysis process also removes and controls other contaminant build-up in the anodize bath, such as copper, iron, lead, magnesium, manganese, silicon, and zinc, while producing a minimum of rejected waste byproduct for subsequent treatment and disposal.

This article reviews diffusion dialysis technology and relates its benefits to anodizers.

WHAT IS DIFFUSION DIALYSIS?

Diffusion dialysis is a membrane separation process. It has been successfully used for many years for the separation and recovery of acids from dissolved metal-bearing solutions. Diffusion is the spontaneous movement of a material from an area of high concentration to an area of lower concentration. Driven by the concentration difference, the movement of material will continue on its own until the concentration difference no longer exists. Dialysis is the separation of molecules due to the differences in the rate of movement of the molecules through a semi-permeable barrier.

In the recovery of acids with diffusion dialysis an anion exchange membrane acts as a semi-permeable barrier placed between a flowing water stream and a flowing acid with dissolved metal solution. The anion exchange membrane has fixed positive charges located on its surface. These positive charge locations attract the negatively charged anions in solution that come in close contact with the anion exchange membrane surface.

In the case of sulfuric acid anodize baths the overwhelmingly predominant anion is the sulfate ion, SO_4. As these sulfate ions in the sulfuric acid anodize solution are attracted to the membrane they are also driven by the concentration difference to diffuse across the membrane to the water side. Simultaneously, the thermodynamic Law of Electroneutrality (in solution total charge must balance to zero) requires that the transference of every sulfate ion, which carries two negative charges, be accompanied by the transference of two positive charges. Positively charged ions, such as Al^{+3} or other metal ions, are strongly inhibited from crossing the positively charged membrane because of the repulsion between like charges. The hydrogen ion, present in the acid solution as H_3O^{+1} ions, or protonated water, is also positively charged, but is able to cross the membrane with very little hindrance. This is due, in part, to the high concentration of hydrogen ion in the acid solution and also, in part, because of the highly associated nature of water, which allows the hydrogen ion to effectively delocalize its charge. The net effect is that the rate of diffusion of sulfuric acid across the membrane is an order of magnitude greater than that of the dissolved aluminum. Finally, by causing the flow of the acid solution to be in the opposite direction to the flow of water (counter-current flow), optimal advantage of the necessary concentration gradients can be realized. The results are that the water entering the diffusion dialysis system exists as a metal-depleted recovered acid solution and that the acid solution entering the diffusion dialysis system exists as an acid-depleted dissolved metal-bearing solution.

APPLIED DIFFUSION DIALYSIS

The standard processing rate for diffusion dialysis systems is a liter per hour per square meter (approximately 0.025 $gal/hr/ft^2$) of available anion exchange membrane surface area. To obtain the necessary membrane area that is required to process large volumes, the membranes are stacked between gasketed hydraulic flow spacers. These membrane stacks are usually standardized over a range of differing processing capacities.

Figure 1 depicts a typical, automatically operated acid-recycling configuration. The acid-recycling system has two liquid chambers at the top of the unit: one chamber is for water and the other is for the acid to be processed. A dual set of level controls is located in each chamber. As the acid level drops in the chamber the primary level controller will energize a pump located on the base of the system. Acid solution will be drawn into this pump and then sent through a filter and into the acid-holding chamber on top of the module.

Once the acid-holding chamber has been refilled the primary level controller will shut off the pump. Should the primary level controller fail for some reason a secondary level controller will shut off power to the system at emergency-high or emergency-low level and an audible alarm will sound.

A similar dual arrangement is present in the water-holding chamber. Instead of a pump the primary level controller is tied into a solenoid valve,

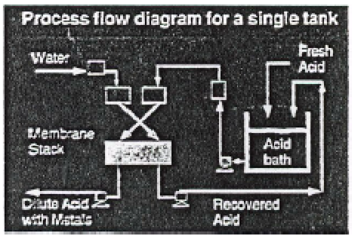


Figure 1. Acid-recycling flow schematic.

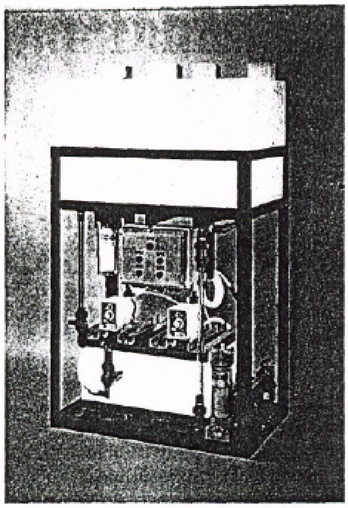


Figure 2. Typical diffusion dialysis acid-recycling system.

which is plumbed to the water feed line.

Once the water and acid solutions are in the holding chambers on the unit they flow independently by gravity into the membrane stack on the base of the unit (see Fig. 2). The acid and water solutions flow counter-currently through the membrane stack, thus maximizing usage of the concentration gradients. Using the principles of diffusion dialysis, anion exchange membranes segregate acid molecules into a purified zone. Typically, 80 to 95% of the acid is recovered with 80 to 95% of the metals removed.

The exit ports of the membrane stack are plumbed to a set of metering pumps. Except during the automatic refilling of the system these metering pumps are the only moving components on the entire system. The metering pumps are used to control the solution flow rates. The exit ports of these metering pumps are plumbed either back into the acid process tank, for the recovered acid stream, or in the case of the metal-rich, acid-depleted waste, plumbed to final treatment.

The acid-recycling system is a fully modularized unit. For installation the pump on the acid-recycling unit is plumbed to the working anodize tank(s) and a solenoid valve on the unit is plumbed to a pressurized water source. The system uses 115 V AC/20 Amp service and upon delivery can be plugged in and immediately utilized.

IMPLEMENTING ACID RECYCLING

In 1995 three 10 gpd diffusion dialysis systems were installed onto three 1,000-gal sulfuric acid anodize tanks at an anodizing job shop located in Santa Clara, Calif., for control of aluminum and contaminant build-up and recovery of sulfuric acid. Quality control through consistent anodize bath purity was a major motivating force in the implementation of these units.

To prove its effectiveness in removing metallic contaminants and in producing workable concentrations of acid, pilot studies were performed on the anodizing solutions. The pilot studies showed excellent results in removing metallic contaminants as well as generating a recovered acid permeate of sufficient concentration for reuse. The acid-depleted fraction following dialysis produced a solution, which was rich in metal and weak in acid concentration.

The sizing of the diffusion dialysis system was based upon the volume of spent anodizing solution that was previously produced, the rate of this production, and the efficiency of the diffusion dialysis process. A useful "rule of thumb" requires that, at a minimum, the volume of spent acid that was previously discarded be recycled once through the diffusion dialysis unit over the same period of time that it took to generate the spent acid.

The three 10-gpd acid-recycling systems were installed directly onto the anodizing process tanks. Additions of virgin acid are made to replenish depleted volumes due to consumption, dragout, exhaust escape, and (he minor amounts lost in the dialysis process.

Table I is representative of the diffusion dialysis performance results of this installation. Recycling efficiencies were calculated by comparing the recycled acid concentrations to the initial anodize bath concentrations.

In 1995 an anodizing job shop located in Pawtuckct, R.I., installed a 20-gpd diffusion dialysis system onto a 1,000-gal sulfuric acid anodize tank for control of aluminum and improved quality control. In 1996 another 20-gpd diffusion dialysis system was installed onto a 1,000-gal sulfuric acid hardcoat tank that contained glycerin as an additive. It was found that about two-thirds of the glycerin was also recovered with the reclaimed sulfuric acid. These anodizing baths have not been dumped since.

COMPARISON OF DIFFUSION DIALYSIS TO RESIN SORPTION TECHNOLOGY

Resin sorption technologies have often been successfully utilized for the recycling of aluminum anodizing baths. This technology relies on the sorption of acid molecules on an ion exchange resin bed. The process works by pumping contaminated acid into the bottom of the resin bed. Acid is sorbed by the resin particles and the partially deacidified salt solution is collected from the top of the bed. Water is then pumped into the top of the bed, desorbing the acid from the resin and the recovered acid product is collected from the bottom of the bed. The above cycle is continuously repeated by alternately opening and closing a series of valves.

Acid recovery efficiency via resin sorption can vary from 70 to 95% per

Table I. Anodize Recycling Performance

	Anodize Acid	*Recycled Acid*	*Depleted Acid with Metal*
H_2SO_4, g/L	188	170	39
Aluminum, ppm	6,600	<100	6,300
Copper, ppm	83	5.4	127
Iron, ppm	123	8.7	118
Magnesium.ppm	205	1.3	220
Zinc, ppm	280	13	310
Acid-recycling efficiency:		90.4%	
Aluminum elimination efficiency:		95.4%	
Copper elimination efficiency:		93.5%	
Iron elimination efficiency:		93.0%	
Magnesium elimination efficiency:		99.3%	
Zinc elimination efficiency:		95.4%	

pass; however, metal removal rates per pass can be as low as 25%. One reason for this low aluminum removal efficiency is due to the entrapment of process solution that is still contaminated with aluminum in the resin bed column. This entrapment hinders overall recycling efficiency because it requires multiple passes to achieve sufficient metal removal. For example if a bath is maintained at 6 g/L aluminum and the bath normally builds up to a tolerable limit of 12 g/L in 10 days then the system must remove a mass of aluminum equivalent to 6 g/L times the entire volume of the bath in the same 10 days. If the system has an aluminum removal efficiency of 25% per pass it must process the entire volume of the bath 4 times in 10 days. Assuming that 90% of the acid is recovered in each pass and that the acid concentration in the bath is maintained at 15% by weight, 1.5% by weight of the acid is lost in each pass. After 4 passes a total of 6% by weight of the acid is lost.

By contrast, diffusion dialysis systems will typically remove 90% or greater of the aluminum per single pass while recovering 90% of the acid. In the hypothetical case described above -a diffusion dialysis system will require 1.1 passes (6 g/L H- [0.9 X 6 g/L]) to remove 6 g/L of aluminum. After 1.1 passes at 90% acid recovery a total of 1.7% by weight of acid will be lost. The effective net efficiency of acid recovery is, therefore, only 89%. Thus, significantly less waste by-product is produced, typically one-half to one-fifth as much. When assessing the benefits of any recycling technology it is important to closely look at the volume and content of the waste by-products produced and balance this with the volume and content of the products recovered.

With the advent of significantly more durable ion exchange membranes in recent years, the life expectancy of the ion exchange membranes utilized in sulfuric acid recovery is between 10 to 20 years. Typical ion exchange resin life in acid sorption systems varies between 2 to 10 years. Both technologies require very good prefiltration of the process solution prior to introduction into the recovery units.

JUSTIFICATION AND BENEFITS

At anodizing job shops and captive shops across the U.S. diffusion dialysis users report improved anodize quality and reduced rework, often with reduced processing times. Additionally, dialyzed anodize baths tend to run cooler, using less energy, and thus cost less to operate. The following is a summary of benefits being derived from the implementation of acid recycling utilizing diffusion dialysis:

- Savings from reduced or eliminated disposal costs and reduced acid purchases
- Elimination of production downtime associated with the dumping and recharging of acid baths
- Minimization of direct operator contact with dangerous chemicals—reduced operator exposure
- Fully automatic operation, 24 hours per day, 7 days per week, with very minimal operating costs
- Improved process control with consistent anodic thicknesses improves quality and minimizes waste

SUMMARY

Diffusion dialysis for acid recycling has many benefits. It reduces acid purchases and eliminates or lowers neutralization or hazardous waste hauling costs and the related liability. Toxic chemical use is reduced and the required reporting and handling of hazardous materials and associated labor is greatly reduced. Consistent bath strength yields greater product uniformity and better quality with lower operating costs. Diffusion dialysis can dramatically improve a facility's quality and economic performance.

Biography

Daniel E. Bailey is Manager of Industrial Chemical Purification Resources of Palmer, Ma. He has a BS degree in Chemistry from Northeastern University and an MS degree in Applied Management from Lesley College. He has over 17 years of experience in membrane technology and has two patents for acid recycling with diffusion dialysis. MF *high efficiency ~ simple package ~ proven reliability*

AnoPur™

Acid Purification for Aluminum Anodizing Processes

Achieve maximum recovery, maximum cost reduction, and maximum quality consistency with Eco-Tec's acid purification system, AnoPur™

eco-Tec Chemical Recovery

AnoPur™

Since 1976, large anodizers everywhere have used a system called the APU® to purify anodizing solutions. Now, all the benefits of the APU® are available to the smaller anodizer in a cost effective, pre-engineered design.

What is an AnoPur™?

The AnoPur™ System is a small, skid mounted device that connects directly to an anodizing tank, continuously removing aluminum as it is dissolved. The AnoPur™ unit has the flexibility to be connected to one tank or several tanks. It employs a simple PLC (programmable logic controller) in a control panel that uses a graphical display to indicate what the unit is doing at any given time.

The heart of the AnoPur™ unit is a column of ion exchange resin that can absorb acid while rejecting metal salts to waste. The acid is recovered from the resin using a simple water wash.

Why use an AnoPur™?

When aluminum is anodized, a portion of the metal dissolves into the sulfuric acid solution used in the anodizing tank. The aluminum gradually accumulates in the tank and, eventually, the solution must be dumped and replaced with fresh acid. An alternative solution is continuous purification. There are a number of benefits that can be realized by continuous purification:

- reduction in sulfuric acid purchases
- fewer line shutdowns
- reduced treatment and disposal costs
- lower discharge of dissolved salt
- improved anodize finish consistency
- simplified coloring
- reduced electrical and cooling requirements.

How does the AnoPur™ System Work?

A diaphragm pump mounted on the AnoPur™ unit transfers anodizing solution from the bath, through dual stage cartridge filters, to a storage reservoir located on the unit.

An AnoPur™ cycle consists of two basic steps. During the first step, filtered acid is pumped through the resin column. While the acid is absorbed by the resin, metal salt solution passes through the column to waste.

During the second step, water is pumped through the column, removing the acid. This acid stream is returned to the anodizing bath being treated. The cycle lasts two to five (2-5) minutes.

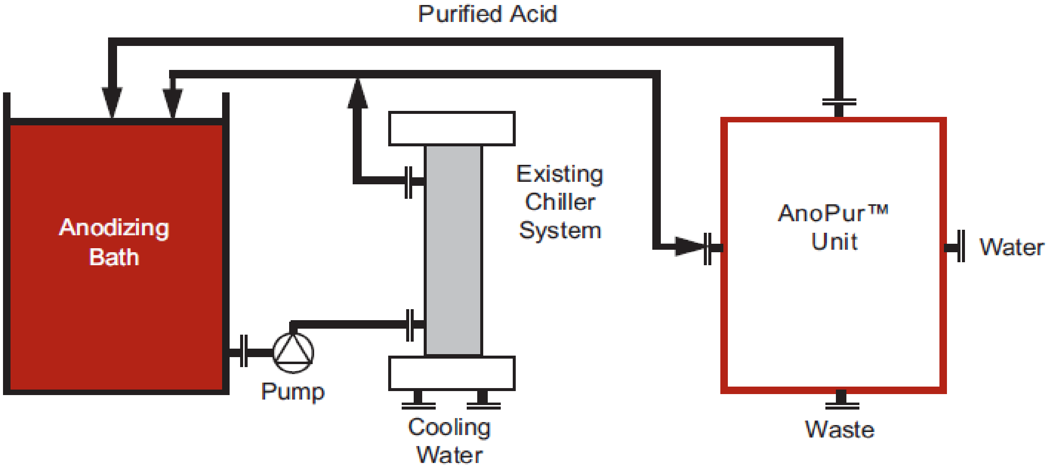
Control panels with simple PLCs employ graphical displays that indicate what the System is doing at all times. The panels have provisions for remote on/off switching.

AnoPur™ Flexibility

With the **Multi-Tank Selector Manifold**, an operator can conveniently select one of up to six (6) different tanks for purifiction. The manifold consists of six (6) sets of manual valves, each set consisting of valves for both the feed and product lines. The manifold is supplied with mounting hardware and instructions for easy hook-up.

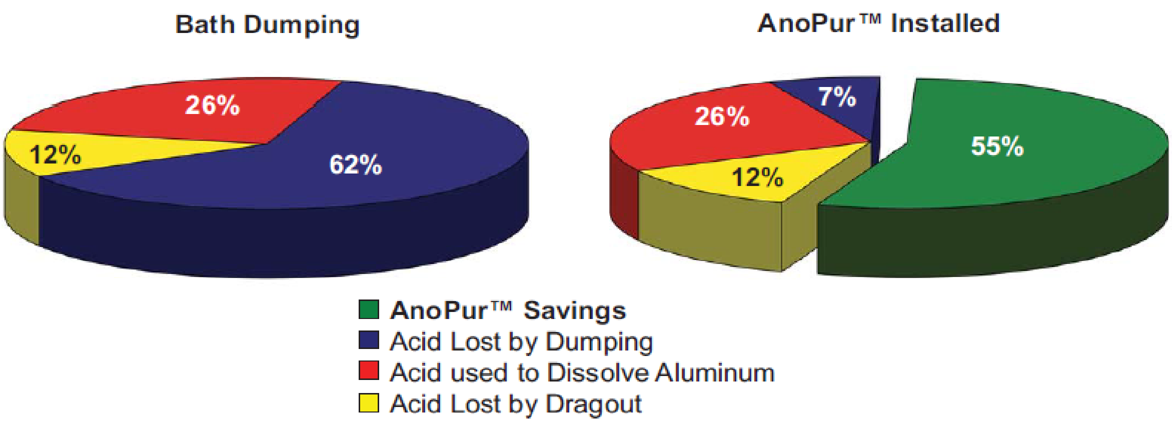
The **Mobile Kit** includes all the necessary items required to make the AnoPur™ unit completely portable. This option is available for the D8+ - D10 mode ls. Wheels, push handles, hoses and quick connect air fittings are supplied with mounting hardware and instructions for easy installation.

AnoPur™ Process Flow



Cost Savings

It is easy to work out the savings you can expect with the installation of an AnoPur™ System. Savings will vary depending on a number of factors such as hours of operation, chemical costs, and disposal methods. These charts show what happens to anodizing acid costs before and after installing the AnoPur™ System.



Basis:

- Class II coating (0.4 mil) - 20 minutes @ 129 amps per sq. meter (12 ASF)
- Dissolving rate = 7 grams per sq. meter (1.4 lbs per 1000 sq. feet)
- Dragout rate = 0.1 liters per sq. meter (2.5 US gals per 1000 sq. feet)
- Sulfuric acid = 180 g/l Aluminum = 12 g/l at time of dump
- Sulfuric acid = 180 g/l Aluminum = 10 g/l with the AnoPur™ System

Remember that the AnoPur™ System also makes it easier to achieve consistent finishes, so you may wish to factor in an allowance for reduction in re-work.

AnoPur™

Installation and Use

Prior to shipment of the System, detailed operating manuals will be mailed out. These manuals include easy to understand installation instructions that offer helpful details on locating the system, piping and wiring. Installation and startup of an AnoPur™ System is simple and straightforward.

- Remove the crate and packing materials.
- Move the AnoPur™ System into position.
- Attach any pipework that has been removed for shipping purposes.
- Connect single phase electrical supply, 5.5 bar/ 80 psig air supply and water supply.
- Install piping
  - to and from the anodizing tank
  - for the waste line.
- After hookup is complete, the system can be started. The manual includes checklists and troubleshooting guides.
- **No special adjustments are required as the system is fully tested and calibrated prior to shipment**.

Routine monitoring is recommended and logsheets are provided for this purpose. Preventative maintenance schedules are also included in the manual.

Regular maintenance primarily involves filter cartridge replacement. The replacement requency is difficult to predict as solids levels vary from plant to plant. The System is supplied with replacement parts kit that includes a supply of cartridge filters.

AnoPur™ Systems also include free access to 24/7 customer service. Onsite training and assistance are available, and a full stock of replacement parts can normally be shipped within twenty-four hours.

Selecting the Appropriate AnoPur™

It is simple to select the right AnoPur™ for your needs.

1) Determine the metal buildup rate using the guide below.
2) Select an AnoPur™ unit from the performance specifications chart on the following page. Choose a unit that provides enough metal removal capacity to offset the buildup rate.

Required Information

a) Operating hours per week ________

b) Dump Volume (l/week) ________

c) Dump Aluminum Level (g/l) ________

d) Production (m^2/h) ________

e) Anodize Time (minutes) ________

f) Current Density (amps/m^2) ________

* **Three methods are available to calculate the aluminum buildup rate.**

Conversion Factors:

i) multiply gallons by 3.78 to get liters
ii) divide ft^2/hr by 10.76 to get m^2/hr
iii) multiply amps/ft^2 by 10.76 to get amps/m^2

1. Bath Dump Method

Dump Volume (l/week) ________
x
Dump Aluminum Level (g/l) ________
÷
Operating hours per week ________
=
Build up rate (g/h) ________

Note:

- **Accuracy is important; remember to include any partial decant volumes.**
- **Ensure that your numbers reflect normal or expected production demands.**

2. Production Data Method

0.25
x
Anodize time (minutes) ________
—
1.0
=
Dissolving Factor (g/m^2) ________
x
Production (m^2/h) ________
=
Build up rate (g/h) ________

Note:

- **This method assumes a standard dissolution rate of 15 grams of aluminum per square meter of production per hour of anodizing time.**
- **Your current density must be 100 - 150 amps/m^2. This method is not valid with alternating current (pulse) rectifiers.**

3. Current Density Method

0.0024
x
Anodize time (minutes) ________
x
Current Density (amps/m^2) ________
—
1.0
=
Dissolving Factor (g/m^2) ________
x
Production (m^2/h) ________
=
Build up rate (g/h) ________

Note:

- **This method assumes that a constant portion (40%) of the current used in the anodizing process results in aluminum dissolution.**
- **Your current density must be 100 - 150 amps/m^2. This method is not valid with alternating current (pulse) rectifiers.**

AnoPur™ Performance Specifications

Typical Unit Capabilities

Model Number	Aluminum Removal (g/h)				Flowrates (l/h)	
	@ 6 g/l	@ 8 g/l	@ 10 g/l	@ 12 g/l	Bath Recirculation	Waste
D10A	595	795	995	1195	410	130
D11A	860	1140	1430	1715	595	190
D13A	1525	2035	2540	3045	1055	335
D15A	2370	3160	3950	4740	1650	525
D8A+	140	180	230	275	110	57
D11A+	305	410	515	615	245	130

Notes:

- Removal rates vary with the aluminum level. AnoPur™ can treat any level between 6-20 g/l.
- Models D8+ and D11+ are used where additive recovery is desired. Additives recovered include Novamax SC-700, SC-705 and Anomax, Sandoz Anodal EE, and Reynolds MAE formulations.
- For applications where the anodizing solution is operated cold (0°C to 4.5°C), a cold temperature adder is required. Temperatures below 0°C can not be utilized with AnoPur™.

Typical Stream Compositions with the AnoPur™ System (Models D10A - D15A)

AnoPur™ Stream	Composition (g/l)					
	Sulphuric Acid		Aluminum			
Feed	160	240	6.0	8.0	10.0	12.0
Recovered Acid	154	232	4.6	6.1	7.6	9.1
Waste	16	24	4.6	6.1	7.6	9.1

For Additive Recovery (Models D8A+, D11A+)

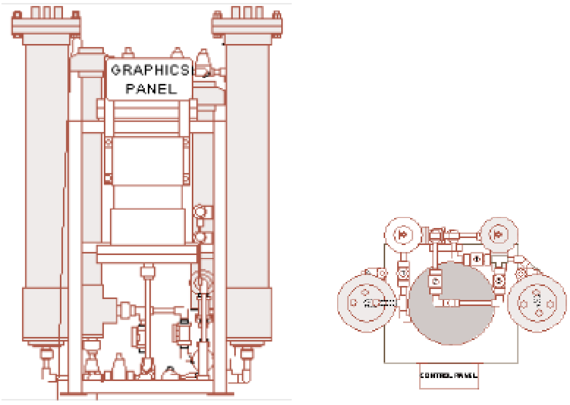
AnoPur™ Stream	Composition (g/l)					
	Sulphuric Acid		Additive	Aluminum		
Feed	160	240	20-24	6.0	8.0	10.0
Recovered Acid	157	235	18-22	4.7	6.3	7.9
Waste	5	8	3.6-4.4	2.4	3.2	4.0

Specifications

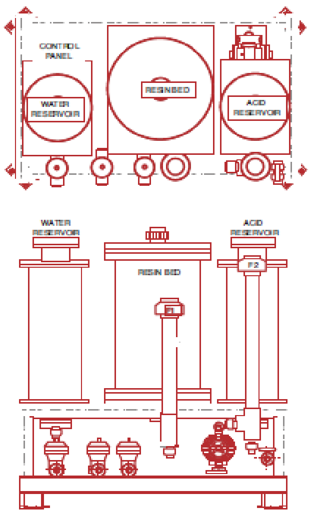
The Eco-Tec AnoPur™ System includes:

- frame mounted, dual stage cartridge filters and diaphragm feed pump for feed acid
- 24V control panel with graphics
- skid mounted design with all piping and valves on a steel frame
- operating & maintenance manuals (3)
- spare parts kits
- remote start/stop (24v signal required)

D8-D10



D11-D15



Model Number	Dimensions (cm/in) Length	Width	Height	Electricity (110/220, 1 , 50/60)	Comp. Air m³/h/SCFM 5.3 bar/80 psig	Water l/h/USGPM 2 bar/30 psig
D8+	112/44	94/37	181/71	5 amps	8.5/5.0	500/2.1
D10					30/17	995/4.4
D11	229/90	135/53	193/76		46/27	1430/6.3
D11+					34/20	1100/4.8
D13					62/36	2540/11.2
D15					84/49	3970/17.5

Notes:

- No provision has been made for the removal of oil, grease or submicron particles from the anodizing bath solution or water fed to the AnoPur™ unit.
- Air must be clean, dry, oil free and filtered to 40 microns. Air filters can be supplied, if required, at additional cost.
- Water should contain less than 200 mg/l Total Dissolved Solids, 135 ppm total hardness (as $CaCO_3$) and must be clean (i.e., municipal source filtered to one micron).

high efficiency ~ simple package ~ proven reliability

Features	Benefits	Impacts
Short bed height and small resin volume	Small equipment size with easy maintenance	Low operating costs
Counter-current operation	Simple, effective performance	Maximum acid recovery
Pre-assembled, skid mounted	Easy installation	Simple startup and interface with anodizing baths
Fully automated with full factory pre-testing	Fast installation, consistent operation	Minimal installation and setup costs

AnoPur™ Partial User's List

Customer	Location
Meyer Industries Ltd	Sriracha, THAILAND
Seco Manufacturing Co Inc.	California, USA
Surf-Tech Industries	British Columbia, CANADA
Izumi Techno	Nagano, JAPAN
Walgren Company Multiple Units	Michigan, USA
Olympus Multiple Units	Nagano, JAPAN
Technova Imaging Systems	Maharashtra, INDIA

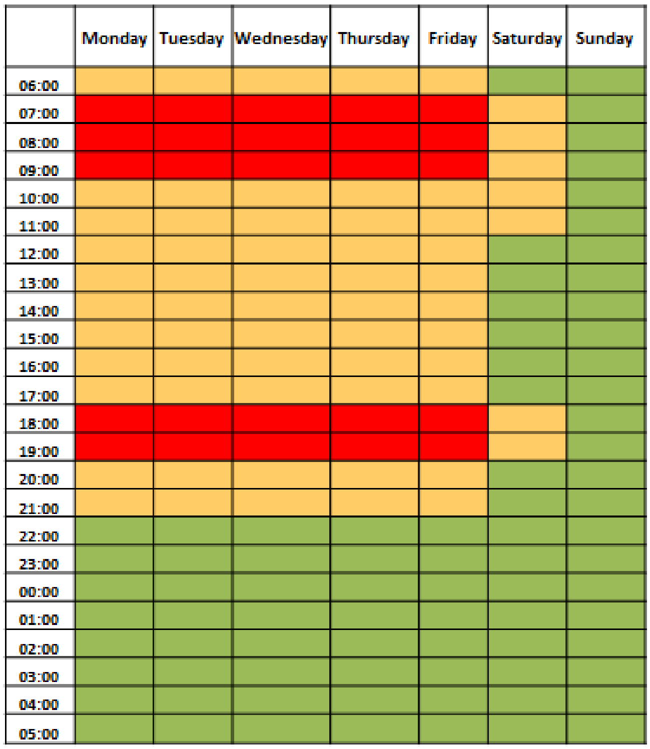
For a Fast Quote - Email: AnoPur@eco-tec.com

www.eco-tec.com
Eco-Tec Inc.
1145 Squires Beach Rd., Pickering, Ontario
Canada L1W 3T9
Tel: (905) 427-0077 Fax: (905) 427-4477
E-mail: ecotec@eco-tec.com

Appendix C – Information used for cost analysis

Electricity

Wispeco Electricity Cost: Peak Hours



7am - 10am

6pm – 8pm

kwh	
1	Peak
2	Standard
3	Off-peak

1 Jul 2011: 20% Elec Increase

2011				
	Summer Jan to May	Winter Jun	Winter Jul, Aug	Summer Sept to Dec
1	R 0.71	R 1.91	R 2.32	R 0.86
2	R 0.47	R 0.67	R 0.81	R 0.56
3	R 0.37	R 0.40	R 0.49	R0.45

Hours	Rate (R/kW)	Electricity consumption in kW	Nr of months rate applicable	Number of operating days per week	Nr of operating weeks per month	TOTAL cost (R/year)
5	0.71	1.5	5	6	4	639
5	1.91	1.5	1	6	4	343.80
5	2.32	1.5	2	6	4	835.20
5	0.86	1.5	4	6	4	619.20
10	0.47	1.5	5	6	4	846
10	0.67	1.5	1	6	4	241.20
10	0.81	1.5	2	6	4	583.20
10	0.49	1.5	4	6	4	705.60
7	0.37	1.5	5	6	4	466.20
7	0.4	1.5	1	6	4	100.80
7	0.49	1.5	2	6	4	251.76
7	0.45	1.5	4	6	4	453.60
					TOTAL	**6 085.56**
					7 pumps x 6 085.56	**42 598.92**

Hours	Rate (R/kW)	Electricity consumption in kW	Nr of months rate applicable	Number of operating days per week	Nr of operating weeks per month	TOTAL cost (R/year)
5	0.71	0.75	5	6	4	319.50
5	1.91	0.75	1	6	4	171.90
5	2.32	0.75	2	6	4	417.60
5	0.86	0.75	4	6	4	309.60
10	0.47	0.75	5	6	4	423
10	0.67	0.75	1	6	4	120.60
10	0.81	0.75	2	6	4	291.60
10	0.49	0.75	4	6	4	403.20
7	0.37	0.75	5	6	4	233.10
7	0.4	0.75	1	6	4	50.40
7	0.49	0.75	2	6	4	123.48
7	0.45	0.75	4	6	4	226.80
					TOTAL	**3 090.78**
					2 pumps x 3 090.78	**6 181.56**

Hours	Rate (R/kW)	Electricity consumption in kW	Nr of months rate applicable	Number of operating days per week	Nr of operating weeks per month	TOTAL cost (R/year)
5	0.71	7.5	5	6	4	3 195
5	1.91	7.5	1	6	4	1 719
5	2.32	7.5	2	6	4	4 176
5	0.86	7.5	4	6	4	3 096
10	0.47	7.5	5	6	4	4 230
10	0.67	7.5	1	6	4	1 206
10	0.81	7.5	2	6	4	2 916
10	0.49	7.5	4	6	4	4 032
7	0.37	7.5	5	6	4	2 331
7	0.4	7.5	1	6	4	504
7	0.49	7.5	2	6	4	1 234.80
7	0.45	7.5	4	6	4	2 268
					TOTAL	**30 907.80**
					1 pump x 30 907.8	**30 907.80**

Hours	Rate (R/kW)	Electricity consumption in kW	Nr of months rate applicable	Number of operating days per week	Nr of operating weeks per month	TOTAL cost (R/year)
5	0.71	0.55	5	6	4	234.30
5	1.91	0.55	1	6	4	126.06
5	2.32	0.55	2	6	4	306.24
5	0.86	0.55	4	6	4	277.04

Hours	Rate	Electricity consumption	Nr of months	Number of operating	Nr of operating weeks	TOTAL cost (R/year)
10	0.47	0.55	5	6	4	310.20
10	0.67	0.55	1	6	4	88.44
10	0.81	0.55	2	6	4	213.84
10	0.49	0.55	4	6	4	295.68
7	0.37	0.55	5	6	4	170.94
7	0.4	0.55	1	6	4	36.96
7	0.49	0.55	2	6	4	90.552
7	0.45	0.55	4	6	4	166.32
					TOTAL	**2 316.57**
					1 pump x 2 316.57	**2 316.57**

Hours	Rate (R/kW)	Electricity consumption in kW	Nr of months rate applicable	Number of operating days per week	Nr of operating weeks per month	TOTAL cost (R/year)
5	0.71	5.852	5	6	4	2 492.952
5	1.91	5.852	1	6	4	1 341.2784
5	2.32	5.852	2	6	4	1 629.1968
5	0.86	5.852	4	6	4	2 415.7056
10	0.47	5.852	5	6	4	3 285.3
10	0.67	5.852	1	6	4	941.0016
10	0.81	5.852	2	6	4	2 275.2576
10	0.49	5.852	4	6	4	3 146.0352
7	0.37	5.852	5	6	4	1 818.8016
7	0.4	5.852	1	6	4	393.2544
7	0.49	5.852	2	6	4	963.47328
7	0.45	5.852	4	6	4	1 769.6448
					TOTAL	**22 471.90**
					1 pump x 22 471.90	**22 471.90**

Total electricity usage cost per year = R 104 476.75

Hours	Rate (R/kW)	Electricity consumption in kW	Nr of months rate applicable	Number of operating days per week	Nr of operating weeks per month	TOTAL cost (R/year)
5	0.71	0.5	5	6	4	42.60
5	1.91	0.5	1	6	4	114.60
5	2.32	0.5	2	6	4	139.20
5	0.86	0.5	4	6	4	51.60
10	0.47	0.5	5	6	4	56.40

Hours	Rate	Electricity consumption	Nr of months	Number of operating	Nr of operating weeks	TOTAL cost (R/year)
10	0.67	0.5	1	6	4	80.40
10	0.81	0.5	2	6	4	97.20
10	0.49	0.5	4	6	4	67.20
7	0.37	0.5	5	6	4	31.08
7	0.4	0.5	1	6	4	33.60
7	0.49	0.5	2	6	4	41.16
7	0.45	0.5	4	6	4	37.80
					TOTAL	**792.84**

Interwaste (Sludge removal)

INTERWASTE

1	01/04/12	7.66	R	814.23	1.14	R	7 110.18
2	02/04/12	4.26	R	814.23	1.14	R	3 954.23
3	03/04/12	6.339	R	814.23	1.14	R	5 884.00
4	05/04/12	7.84	R	814.23	1.14	R	7 277.26
5	11/04/12	6.26	R	814.23	1.14	R	5 810.67
6	12/04/12	17.02	R	814.23	1.14	R	15 798.34
7	13/04/12	9.16	R	814.23	1.14	R	8 502.52
8	14/04/12	13.08	R	814.23	1.14	R	12 141.15
9	15/04/12	5.22	R	814.23	1.14	R	4 845.32
10	16/04/12	6.78	R	814.23	1.14	R	6 293.35
11	17/04/12	7.06	R	814.23	1.14	R	6 553.25
12	18/04/12	23.24	R	814.23	1.14	R	21 571.88
13	19/04/12	2.62	R	814.23	1.14	R	2 431.94
14	20/04/12	14.68	R	814.23	1.14	R	13 626.30
15	21/04/12	8.88	R	814.23	1.14	R	8 242.61
16	22/04/12	4.14	R	814.23	1.14	R	3 842.84
17	25/04/12	8.16	R	814.23	1.14	R	7 574.29
18	26/04/12	6.44	R	814.23	1.14	R	5 977.75
19	27/04/12	3.5	R	814.23	1.14	R	3 248.78
20	28/04/12	28.66	R	814.23	1.14	R	26 602.85
21	30/04/12	5.9	R	814.23	1.14	R	5 476.51
		196.90				**R**	**182 766.02**
		281.28429	R	814.23	1.14	R	261 094.32

9.3761

	Date	Moisture %	Quantity (tonne)			Total (inc vat)	Operator	
	11/07/01	77	2.65	0.56%	0.431988991	2346	Hlanganani	885.283
1	11/07/01	77	2.65	0.56%	0.431988991	2346	Hlanganani	885.283
	11/07/01	68	2.5	0.53%	0.359902615	2213	Sylvester	885.2
2	11/07/02	74	3	0.64%	0.469990473	2655	Innocent	885
3	11/07/03	76	3.28	0.69%	0.527744257	2903	Thabiso	885.061
4	11/07/04	69	3.74	0.79%	0.546332169	3310		885.0267
5	11/07/05	78	6.88	1.46%	1.136106701	6090	Thabo	885.1744
6	11/07/10	78	2.6	0.55%	0.429342648	2094	Innocent	805.3846
7	11/07/18	73	3.68	0.78%	0.568730814	3257	Thabo	885.0543
8	11/07/20	78	6.92	1.47%	1.142711972	6125	Thabo	885.1156
9	11/07/21	80	3.58	0.76%	0.606330052	3169	Hlanganani	885.1955
10	11/07/22	77	7.56	1.60%	1.232391235	6692	Thabo	885.1852
11	11/07/23	82	4	0.85%	0.694400339	3540	Tumelo	885
12	11/07/24	64	2.36	0.50%	0.319762888	2089	Amdile	885.1695
13	11/07/26	65	7.46	1.58%	1.026569281	8250	Paul	1105.898
14	11/07/27	71	7.86	1.66%	1.18145443	6957	Ngxameleni	885.1145
15	11/07/28	80	8.26	1.75%	1.398962634	7311	Thabo	885.109
	11/07/28	69	11.37	2.41%	1.660908225	10055	Sylvester	884.3448
16	11/07/29	69	3.46	0.73%	0.505430295	3063	Thabo	885.2601
17	11/07/30	79	7.14	1.51%	1.194156875	6320	Sylvester	885.1541
18	11/07/31	78	3.06	0.65%	0.505303271	9984	Sylvester	3262.745
19	11/08/01	81	3.12	0.66%	0.535026993	2762	Thabo	885.2564
20	11/08/02	73	3.14	0.66%	0.485275749	2779	Thabo	885.0318
21	11/08/03	80	7.46	1.58%	1.263469885	6603	Ngxameleni	885.1206
22	11/08/04	78	3.64	0.77%	0.601079708	3222	Thabo	885.1648
	11/08/04	80	3.26	0.69%	0.552132952	2885	Thabo	884.9693
23	11/08/05	71	8.08	1.71%	1.214523129	7152	Thabo	885.1485
24	11/08/06	80	5.62	1.19%	0.951836562	4974	Thabo	885.0534
25	11/08/07	75	3.36	0.71%	0.533502699	2974	Ngxameleni	885.119
26	11/08/10	78	6.6	1.40%	1.0898698	5842	Paul	885.1515
27	11/08/11	76	3.48	0.74%	0.559923785	3080	Thabo	885.0575
28	11/08/12	71	6.24	1.32%	0.937948555	5523	Ngxameleni	885.0962
29	11/08/13	80	3.18	0.67%	0.538583677	2815	Sylvester	885.2201
30	11/08/16	77	6.18	1.31%	1.00743093	5470	Paul	885.1133
	11/08/16	74	6.16	1.30%	0.965047105	5452	Paul	885.0649
31	11/08/17		6.92	1.47%	0	6125	Isal	885.1156
32	11/08/18	69	10.92	2.31%	1.595173071	9666	Tumelo	885.1648
33	11/08/19	68	7.04	1.49%	1.013485763	6231	Thabo	885.0852
34	11/08/20	71	3.34	0.71%	0.502042977	2956	Elton	885.0299
	11/08/20	69	3.72	0.79%	0.543410607	3293	Hlanganane	885.2151
35	11/08/21	80	2.84	0.60%	0.480999259	2514	Ngxameleni	885.2113
	11/08/21	72	3.58	0.76%	0.545697047	3169	Ngxameleni	885.1955

36	11/08/22	72	7.94	1.68%	1.210288981	7028	Thabo	885.1385
37	11/08/23	64	2.96	0.63%	0.401058537	2620	Thabo	885.1351
38	11/08/24	64	6.58	1.39%	0.891542289	5828	Tumelo	885.7143
39	11/08/25	75	7.06	1.49%	1.120990791	6249	Thabo	885.1275
	11/08/25	73	3.38	0.72%	0.522366889	2992	Thabo	885.2071
40	11/08/26	75	8.06	1.71%	1.279771356	7134	Thabo	885.1117
41	11/08/28	72	3.7	0.78%	0.563988568	3275		885.1351
42	11/08/29	79	3.8	0.80%	0.635545676	3363	Thabo	885
43	11/08/30	73	6.26	1.33%	0.967460569	5541	Thabo	885.1438
44	11/08/31	79	7.24	1.53%	1.210881761	6408	Ngxameleni	885.0829
45	11/09/01	71	3.78	0.80%	0.568180375	3346	Innocent	885.1852
	11/09/01	80	3.38	0.72%	0.572456865	2992	Innocent	885.2071
	11/09/01	70	3.66	0.77%	0.542394411	3240	Innocent	885.2459
46	11/09/02	74	3.88	0.82%	0.607854345	3434	Thabo	885.0515
	11/09/02	72	3.42	0.72%	0.521308352	3027	Paul	885.0877
	11/09/02	75	3.04	0.64%	0.482692918	2691	Paul	885.1974
	11/09/02	72	7.24	1.53%	1.103588441	6408	Thabo	885.0829
47	11/09/03	77	3.64	0.77%	0.593373558	3222	Ngxameleni	885.1648
48	11/09/04	72	7.06	1.49%	1.076151159	6249	Ngxameleni	885.1275
49	11/09/06	81	2.92	0.62%	0.500730391	2585	Thabo	885.274
50	11/09/07	70	6.94	1.47%	1.028474648	6123	Thabo	882.2767
51	11/09/08	76	6.54	1.38%	1.052270562	5789	Innocent	885.1682
52	11/09/09	79	2.8	0.59%	0.468296814	2478	Thabo	885
	11/09/09	73	6.1	1.29%	0.942733143	5399	Thabo	885.082
53	11/09/10	70	7.62	1.61%	1.12924738	6745	Thabiso	885.1706
54	11/09/11	76	2.8	0.59%	0.45051339	2478	Ngxameleni	885
55	11/09/13	78	2.66	0.56%	0.439250556	2354	Ngxameleni	884.9624
56	11/09/14	71	3.12	0.66%	0.468974278	2762	Paul	885.2564
	11/09/14	69	11.08	2.35%	1.61854557	9807	Sylvester	885.1083
57	11/09/15	73	6.78	1.44%	1.047824706	6001	Sylvester	885.1032
58	11/09/16	69	7.28	1.54%	1.063448714	6444	Thabo	885.1648
59	11/09/17	77	3.92	0.83%	0.639017678	3470	Sylvester	885.2041
	11/09/17	80	4.08	0.86%	0.69101302	3611	Sylvester	885.049
60	11/09/18	69	4.12	0.87%	0.601841855	3647	Ngxameleni	885.1942
61	11/09/19	76	4.56	0.97%	0.733693236	4036	Thabo	885.0877
62	11/09/20	85	7.56	1.60%	1.360431883	6692	Hlanganani	885.1852
63	11/09/21	77	2.96	0.63%	0.482523552	2620	Hlanganani	885.1351
64	11/09/22	44	8.36	1.77%	0.778744575	7400	Hlanganani	885.1675
65	11/09/23	86	11.24	2.38%	2.046448608	9949	Thabo	885.1423
66	11/09/24	70	3.92	0.83%	0.580925161	3470	Elton	885.2041
	11/09/24	79	3.94	0.83%	0.658960517	3487	Elton	885.0254
	11/09/24	78	4.26	0.90%	0.703461416	3771		885.2113
67	11/09/25	71	4.44	0.94%	0.667386472	3930	Thabiso	885.1351
68	11/09/26		3.42	0.72%	0	3027	Thabo	885.0877

69	11/09/27	79	5.74	1.22%	0.960008468	5081	Paul	885.1916
70	11/09/28	76	3.04	0.64%	0.489128824	2691	Thabo	885.1974
	11/09/28	76	6.76	1.43%	1.087668043	5983	Thabo	885.0592
71	11/09/29	79	7.9	1.67%	1.32126601	6992	Paul	885.0633
72	11/09/30	80	7.52	1.59%	1.273631841	6656	Ngxameleni	885.1064
		74.3932584	472.35	100%	72.44532656	426781		

6.560416667

	Date	Moisture %	Quantity (tonne)	Total (inc vat)	Operator		
	11/07/01	77	2.65	2346	Hlanganani	885.283	
1	11/07/01	77	2.65	2346	Hlanganani	885.283	
	11/07/01	68	2.5	2213	Sylvester	885.2	
2	11/07/02	74	3	2655	Innocent	885	
3	11/07/03	76	3.28	2903	Thabiso	885.061	
4	11/07/04	69	3.74	3310		885.0267	
5	11/07/05	78	6.88	6090	Thabo	885.1744	
6	11/07/10	78	2.6	2094	Innocent	805.3846	
7	11/07/18	73	3.68	3257	Thabo	885.0543	
8	11/07/20	78	6.92	6125	Thabo	885.1156	
9	11/07/21	80	3.58	3169	Hlanganani	885.1955	
10	11/07/22	77	7.56	6692	Thabo	885.1852	
11	11/07/23	82	4	3540	Tumelo	885	
12	11/07/24	64	2.36	2089	Amdile	885.1695	879.4381
13	11/07/26	65	7.46	8250	Paul	1105.898	
14	11/07/27	71	7.86	6957	Ngxameleni	885.1145	
15	11/07/28	80	8.26	7311	Thabo	885.109	
	11/07/28	69	11.37	10055	Sylvester	884.3448	
16	11/07/29	69	3.46	3063	Thabo	885.2601	
17	11/07/30	79	7.14	6320	Sylvester	885.1541	884.9965
18	11/07/31	78	3.06	9984	Sylvester	3262.745	**Avg July = 882.21727 (R per ton)**
		TOTAL	**104.01**	100769			
19	11/08/01	81	3.12	2762	Thabo	885.2564	
20	11/08/02	73	3.14	2779	Thabo	885.0318	
21	11/08/03	80	7.46	6603	Ngxameleni	885.1206	
22	11/08/04	78	3.64	3222	Thabo	885.1648	
	11/08/04	80	3.26	2885	Thabo	884.9693	
23	11/08/05	71	8.08	7152	Thabo	885.1485	
24	11/08/06	80	5.62	4974	Thabo	885.0534	
25	11/08/07	75	3.36	2974	Ngxameleni	885.119	
26	11/08/10	78	6.6	5842	Paul	885.1515	
27	11/08/11	76	3.48	3080	Thabo	885.0575	
28	11/08/12	71	6.24	5523	Ngxameleni	885.0962	

29	11/08/13	80	3.18	2815	Sylvester	885.2201	
30	11/08/16	77	6.18	5470	Paul	885.1133	
	11/08/16	74	6.16	5452	Paul	885.0649	
31	11/08/17		6.92	6125	Isal	885.1156	
32	11/08/18	69	10.92	9666	Tumelo	885.1648	
33	11/08/19	68	7.04	6231	Thabo	885.0852	
34	11/08/20	71	3.34	2956	Elton	885.0299	
	11/08/20	69	3.72	3293	Hlanganane	885.2151	
35	11/08/21	80	2.84	2514	Ngxameleni	885.2113	
	11/08/21	72	3.58	3169	Ngxameleni	885.1955	
36	11/08/22	72	7.94	7028	Thabo	885.1385	
37	11/08/23	64	2.96	2620	Thabo	885.1351	
38	11/08/24	64	6.58	5828	Tumelo	885.7143	
39	11/08/25	75	7.06	6249	Thabo	885.1275	
	11/08/25	73	3.38	2992	Thabo	885.2071	
40	11/08/26	75	8.06	7134	Thabo	885.1117	
41	11/08/28	72	3.7	3275		885.1351	
42	11/08/29	79	3.8	3363	Thabo	885	
							Avg Aug
43	11/08/30	73	6.26	5541	Thabo	885.1438	**= 885.14132**
44	11/08/31	79	7.24	6408	Ngxameleni	885.0829	**(R per ton)**
		TOTAL	164.86	145925			
45	11/09/01	71	3.78	3346	Innocent	885.1852	
	11/09/01	80	3.38	2992	Innocent	885.2071	
	11/09/01	70	3.66	3240	Innocent	885.2459	
46	11/09/02	74	3.88	3434	Thabo	885.0515	
	11/09/02	72	3.42	3027	Paul	885.0877	
	11/09/02	75	3.04	2691	Paul	885.1974	
	11/09/02	72	7.24	6408	Thabo	885.0829	
47	11/09/03	77	3.64	3222	Ngxameleni	885.1648	
48	11/09/04	72	7.06	6249	Ngxameleni	885.1275	
49	11/09/06	81	2.92	2585	Thabo	885.274	
50	11/09/07	70	6.94	6123	Thabo	882.2767	
51	11/09/08	76	6.54	5789	Innocent	885.1682	
52	11/09/09	79	2.8	2478	Thabo	885	
	11/09/09	73	6.1	5399	Thabo	885.082	
53	11/09/10	70	7.62	6745	Thabiso	885.1706	
54	11/09/11	76	2.8	2478	Ngxameleni	885	
55	11/09/13	78	2.66	2354	Ngxameleni	884.9624	
56	11/09/14	71	3.12	2762	Paul	885.2564	
	11/09/14	69	11.08	9807	Sylvester	885.1083	
57	11/09/15	73	6.78	6001	Sylvester	885.1032	
58	11/09/16	69	7.28	6444	Thabo	885.1648	
59	11/09/17	77	3.92	3470	Sylvester	885.2041	
	11/09/17	80	4.08	3611	Sylvester	885.049	
60	11/09/18	69	4.12	3647	Ngxameleni	885.1942	
61	11/09/19	76	4.56	4036	Thabo	885.0877	

62	11/09/20	85	7.56	6692	Hlanganani	885.1852		
63	11/09/21	77	2.96	2620	Hlanganani	885.1351		
64	11/09/22	44	8.36	7400	Hlanganani	885.1675		
65	11/09/23	86	11.24	9949	Thabo	885.1423		
66	11/09/24	70	3.92	3470	Elton	885.2041		
	11/09/24	79	3.94	3487	Elton	885.0254		
	11/09/24	78	4.26	3771		885.2113		
67	11/09/25	71	4.44	3930	Thabiso	885.1351		
68	11/09/26		3.42	3027	Thabo	885.0877		
69	11/09/27	79	5.74	5081	Paul	885.1916		
70	11/09/28	76	3.04	2691	Thabo	885.1974		
							Avg Sept	
	11/09/28	76	6.76	5983	Thabo	885.0592	=	885.06059
71	11/09/29	79	7.9	6992	Paul	885.0633		(R per ton)
72	11/09/30	80	7.52	6656	Ngxameleni	885.1064		
		TOTAL	203.48	180087				
		74	741.22	673475				

Water costs

EKURHULENI METROPOLITAN MUNICIPALITY
Customer Care Centre: Germiston
Directorate: INFRASTRUCTURE SERVICES
Industrial Effluent Analysis Report
Period: 2012/01/01 - 2012/01/31

ENQUIRIES: LEBOGANG MOFFAT
TELEPHONE: 0119992649

ANSO PRODUCTS
SI0066
Account Number: 2100126376

Days per Month: 31

TREATMENT CHARGE

$$T_i = \frac{C}{12} \times \frac{Q_i}{Q_t} \times \left[0.50 + (0.26 \times \frac{COD_i}{COD_t}) + (0.16 \times \frac{P_i}{P_t}) + (0.15 \times \frac{N_i}{N_t}) + (0.14 \times \frac{SS_i}{SS_t})\right]$$

$$= \frac{470000000}{12} \times \frac{87.79}{607400} \times \left[0.50 + (0.26 \times \frac{372.00}{803}) + (0.16 \times \frac{0.20}{5.7}) + (0.15 \times \frac{12.50}{23.4}) + (0.14 \times \frac{46.00}{304})\right]$$

= **R 16 226.28**

R/kl = **R 5.96**

ACTUAL CALCULATED VALUES	
Minimum Value:	R 1 068.00
Value by Formulae:	R 4 117.70
* Value by Sliderule:	R 16 226.28

ADDITIONAL TARIFF (NON-COMPLIANCE)

= Q x Sum (Number exceeding limits of individual parameters) x Tariff

= 2721.55 x 4 x 1.18

= **R 12 845.71**

Effluent Charge Excl VAT: R 29 071.99

(Please note: This is only an information sheet and will be reflected on your account)

EKURHULENI METROPOLITAN MUNICIPALITY

Customer Care Centre: Germiston

Directorate: INFRASTRUCTURE SERVICES

Industrial Effluent Analysis Report

Period: 2012/02/01 - 2012/02/29

ENQUIRIES: LEBOGANG MOFFAT
TELEPHONE: 0119992649

ANSO PRODUCTS
SI0066
Account Number: 2100126376

Days per Month: 29

TREATMENT CHARGE

$$Ti = \frac{C}{12} \times \frac{Qi}{Qt} \times \left[0.50 + (0.26 \times \frac{CODi}{CODt}) + (0.16 \times \frac{Pi}{Pt}) + (0.15 \times \frac{Ni}{Nt}) + (0.14 \times \frac{SSi}{SSt}) \right]$$

$$= \frac{470000000}{12} \times \frac{96.57}{607400} \times \left[0.50 + (0.26 \times \frac{450.00}{803}) + (0.16 \times \frac{0.90}{5.7}) + (0.15 \times \frac{12.40}{23.4}) + (0.14 \times \frac{144.00}{304}) \right]$$

= **R 16 496.11**

R/kl = **R 5.89**

ACTUAL CALCULATED VALUES	
Minimum Value:	R 1 068.00
Value by Formulae:	R 5 085.94
* Value by Sliderule:	R 16 496.11

ADDITIONAL TARIFF (NON-COMPLIANCE)

= Q x Sum(Number exceeding limits of individual parameters) x Tariff

= 2800.45 x 2 x 1.18

= **R 6 609.06**

Effluent Charge Excl VAT: R 23 105.17

(Please note: This is only an information sheet and will be reflected on your account)

EKURHULENI METROPOLITAN MUNICIPALITY

Customer Care Centre: Germiston

Directorate: INFRASTRUCTURE SERVICES

Industrial Effluent Analysis Report

Period: 2012/04/01 - 2012/04/30

ENQUIRIES: LEBOGANG MOFFAT
TELEPHONE: 0119992649

ANSO PRODUCTS
SI0066
Account Number: 2100126376

Days per Month: 30

TREATMENT CHARGE

$$Ti = \frac{C}{12} \times \frac{Qi}{Qt} \times \left[0.50 + (0.26 \times \frac{CODi}{CODt}) + (0.16 \times \frac{Pi}{Pt}) + (0.15 \times \frac{Ni}{Nt}) + (0.14 \times \frac{SSi}{SSt}) \right]$$

$$= \frac{470000000}{12} \times \frac{0.00}{607400} \times \left[0.50 + (0.26 \times \frac{333.00}{803}) + (0.16 \times \frac{0.05}{5.7}) + (0.15 \times \frac{20.30}{23.4}) + (0.14 \times \frac{190.00}{304}) \right]$$

= **R 1 068.00**

R/kl = **R 0.00**

ACTUAL CALCULATED VALUES	
* Minimum Value:	R 1 068.00
Value by Formulae:	R 0.00
Value by Sliderule:	R 0.00

ADDITIONAL TARIFF (NON-COMPLIANCE)

= Q x Sum(Number exceeding limits of individual parameters) x Tariff

= 0.00 x 3 x 1.18

= **R 3 513.00**

Effluent Charge Excl VAT: R 4 581.00

(Please note: This is only an information sheet and will be reflected on your account)

EKURHULENI METROPOLITAN MUNICIPALITY

Customer Care Centre: Germiston

Directorate: INFRASTRUCTURE SERVICES

Industrial Effluent Analysis Report

Period: 2012/06/01 - 2012/06/30

ENQUIRIES: LEBOGANG MOFFAT
TELEPHONE: 0119992649

ANSO PRODUCTS

SI0066

Account Number: 2100126376

Days per Month: 30

TREATMENT CHARGE

$$Ti = \frac{C}{12} \times \frac{Qi}{Qt} \times \left[0.40 + (0.26 \times \frac{CODi}{CODt}) + (0.16 \times \frac{Pi}{Pt}) + (0.15 \times \frac{Ni}{Nt}) + (0.14 \times \frac{SSi}{SSt}) \right]$$

$$= \frac{601600000}{12} \times \frac{137.35}{639280} \times \left[0.40 + (0.26 \times \frac{385.00}{812}) + (0.16 \times \frac{0.05}{5.3}) + (0.15 \times \frac{37.60}{22.7}) + (0.14 \times \frac{118.00}{318}) \right]$$

= **R 26 288.79**

R/kl = **R 6.38**

ACTUAL CALCULATED VALUES	
Minimum Value:	R 1 196.00
Value by Formulae:	R 8 888.32
* Value by Sliderule:	R 26 288.79

ADDITIONAL TARIFF (NON-COMPLIANCE)

= Q x Sum(Number exceeding limits of individual parameters) x Tariff

= 4120.50 x 2 x 1.31

= **R 10 795.71**

Effluent Charge Excl VAT: R 37 084.50

(Please note: This is only an information sheet and will be reflected on your account)

Appendix D – Annual acid purchases

STM_PROD	STM_TDATE	Quantity	Cost/litre?	COST		Cost of acid purchases per year ®
ACSLPHACD	70724	30160	0.62	R 18 699.20	259 320	R 140 950.80
ACSLPHACD	70823	32000	0.62	R 19 840.00	litre acid	(half a year in 2007)
ACSLPHACD	70914	31860	0.62	R 19 753.20	for half	plus
ACSLPHACD	71005	6180	0.62	R 3 831.60	year	31 980 x 0.62 = R 19 827.6
ACSLPHACD	71005	31880	0.62	R 19 765.60	2007	**R 160 778.40**
ACSLPHACD	71025	31260	0.62	R 19 381.20		
ACSLPHACD	71114	32140	0.62	R 19 926.80		
ACSLPHACD	71120	31860	0.62	R 19 753.20		
ACSLPHACD	71130	31980	**1.50**	R 47 970.00		
ACSLPHACD	80122	32360	**1.50**	R 48 540.00	652 200	R 364 962.40
ACSLPHACD	80122	31980	**1.50**	R 47 970.00	litre acid	plus
ACSLPHACD	80125	32680	**1.50**	R 49 020.00	for 2008	32 360 x 0.67 = R 21 681.2
ACSLPHACD	80219	29720	0.67	R 19 912.40		31 980 x 0.67 = R 21 426.6
ACSLPHACD	80303	32080	0.67	R 21 493.60		32 680 x 0.67 = R 21 895.6
ACSLPHACD	80314	31920	0.67	R 21 386.40		10 460 x 0.67 = R 7 008.2
ACSLPHACD	80407	32660	0.67	R 21 882.20		**R 436 973.90**
ACSLPHACD	80423	32340	0.67	R 21 667.80		
ACSLPHACD	80526	32680	0.67	R 21 895.60		
ACSLPHACD	80610	32100	0.67	R 21 507.00		
ACSLPHACD	80623	32380	0.67	R 21 694.60		
ACSLPHACD	80709	32300	0.67	R 21 641.00		
ACSLPHACD	80723	31840	0.67	R 21 332.80		
ACSLPHACD	80808	31620	0.67	R 21 185.40		
ACSLPHACD	80829	30880	0.67	R 20 689.60		
ACSLPHACD	80916	**10460**	**4.25**	**R 44 455.00**	**invalid**	
ACSLPHACD	81007	5460	0.67	R 3 658.20	**data**	
ACSLPHACD	81010	13640	0.67	R 9 138.80	**point**	
ACSLPHACD	81029	31780	0.67	R 21 292.60		
ACSLPHACD	81029	14720	0.67	R 9 862.40		
ACSLPHACD	81107	32140	0.67	R 21 533.80		
ACSLPHACD	81125	32350	0.67	R 21 674.50		
ACSLPHACD	81211	32110	0.67	R 21 513.70		
ACSLPHACD	90120	3280	0.67	R 2 197.60	541 050	**R 362 503.50**
ACSLPHACD	90122	32080	0.67	R 21 493.60	litre acid	
ACSLPHACD	90209	31760	0.67	R 21 279.20	for 2009	
ACSLPHACD	90213	32200	0.67	R 21 574.00		
ACSLPHACD	90313	30000	0.67	R 20 100.00		
ACSLPHACD	90406	32070	0.67	R 21 486.90		
ACSLPHACD	90511	32460	0.67	R 21 748.20		
ACSLPHACD	90625	32920	0.67	R 22 056.40		
ACSLPHACD	90720	30980	0.67	R 20 756.60		

ACSLPHACD	90720	30640	0.67	R 20 528.80		
ACSLPHACD	90804	32540	0.67	R 21 801.80		
ACSLPHACD	90828	31780	0.67	R 21 292.60		
ACSLPHACD	90911	33080	0.67	R 22 163.60		
ACSLPHACD	90917	400	0.67	R 268.00		
ACSLPHACD	91006	29220	0.67	R 19 577.40		
ACSLPHACD	91021	32120	0.67	R 21 520.40		
ACSLPHACD	91103	32580	0.67	R 21 828.60		
ACSLPHACD	91123	31980	0.67	R 21 426.60		
ACSLPHACD	91207	28960	0.67	R 19 403.20		
ACSLPHACD	100114	32040	0.67	R 21 466.80	535 800	**R 405 684.74**
ACSLPHACD	100128	10800	0.67	R 7 236.00	litre acid	
ACSLPHACD	100203	32520	0.67	R 21 788.40	for 2010	
ACSLPHACD	100223	31900	0.67	R 21 373.00		
ACSLPHACD	100315	32100	0.67	R 21 507.00		
ACSLPHACD	100419	11500	0.67	R 7 705.00		
ACSLPHACD	100429	32500	0.67	R 21 775.00		
ACSLPHACD	100527	32440	0.89	R 28 871.60		
ACSLPHACD	100528	33160	0.89	R 29 512.40		
ACSLPHACD	100623	31980	0.89	R 28 462.20		
ACSLPHACD	100728	31980	0.769	R 24 592.62		
ACSLPHACD	100806	31760	0.769	R 24 423.44		
ACSLPHACD	100826	31900	0.769	R 24 531.10		
ACSLPHACD	100930	31180	0.769	R 23 977.42		
ACSLPHACD	101015	32100	0.769	R 24 684.90		
ACSLPHACD	101108	31960	0.769	R 24 577.24		
ACSLPHACD	101124	32400	0.769	R 24 915.60		
ACSLPHACD	101207	31580	0.769	R 24 285.02		
ACSLPHACD	110111	32400	0.769	R 24 915.60	510 320	**R 392 436.08**
ACSLPHACD	110127	32820	0.769	R 25 238.58	litre acid	
ACSLPHACD	110223	32060	0.769	R 24 654.14	for 2011	
ACSLPHACD	110311	32420	0.769	R 24 930.98		
ACSLPHACD	110401	31540	0.769	R 24 254.26		
ACSLPHACD	110421	31740	0.769	R 24 408.06		
ACSLPHACD	110519	31500	0.769	R 24 223.50		
ACSLPHACD	110613	33040	0.769	R 25 407.76		
ACSLPHACD	110722	32200	0.769	R 24 761.80		
ACSLPHACD	110810	31960	0.769	R 24 577.24		
ACSLPHACD	110825	32020	0.769	R 24 623.38		
ACSLPHACD	110921	31820	0.769	R 24 469.58		
ACSLPHACD	111017	29900	0.769	R 22 993.10		
ACSLPHACD	111031	32180	0.769	R 24 746.42		
ACSLPHACD	111116	32120	0.769	R 24 700.28		
ACSLPHACD	111207	30600	0.769	R 23 531.40		
ACSLPHACD	120117	32080	0.769	R 24 669.52	278 780	**R 262 452.32**
ACSLPHACD	120207	27200	0.769	R 20 916.80	litre acid	for half a year of 2012
ACSLPHACD	120228	31600	0.988	R 31 220.80	for half	
ACSLPHACD	120319	30600	0.988	R 30 232.80	year	
ACSLPHACD	120412	30620	0.988	R 30 252.56	2012	

ACSLPHACD	120503	31620	0.988	R 31 240.56
ACSLPHACD	120528	31660	0.988	R 31 280.08
ACSLPHACD	120619	31680	0.988	R 31 299.84
ACSLPHACD	120717	31720	0.988	R 31 339.36

Appendix E – Survey forms from suppliers

Mech-Chem

Mech-Chem Associates, Inc. 144 Main Street, P.O. Box 473, Norfolk, MA 02056 Tel. 508-528-5990 Fax 508-528-8972

ACID PURIFICATION UNIT CUSTOMER APPLICATION QUESTIONNAIRE

Contact Name: NATALI JOUBERT
Company Name: WISPECO ALUMINIUM SOUTH AFRICA
Address: ALBERTON, GAUTENG City: State: / Zip:
Tel.: N/A Fax: N/A email: natali.skrps@gmail.c

Please supply the information requested below. This information will enable us to discuss your specific process & equipment requirements.

Acid Tank #1: List type(s) of acid to be purified / recovered:

a. Type(s) sulphuric acid Conc.(s):

Major Dissolved metal(s):
b. Type: Aluminium Concentration at dumping: 14 g/l
c. Type: Concentration at dumping:

Process Tank Dump (decant) frequency: Weekly Volume: 11 000 l

Acid Tank #2: List type(s) of acid to be purified / recovered:

a. Type(s) Sulphuric acid Conc.(s):

Major Dissolved metal(s):
a. Type: Aluminium Concentration at dumping: 14 g/l
b. Type: Concentration at dumping:

Process Tank Dump (decant) frequency: Weekly Volume: 11 000 l

Process Tank Dump (decant) frequency: Volume:

OPTIONAL INFORMATION FOR PAYBACK CALCULATION: R1.00 / liter (SA-rand)

1. What is the purchase price **per gallon** for the acid: 1.) $ 2.) $
2. Do you haul the waste acid off-site or neutralize in-house? neutralize in-house
3. What is the purchase price **per pound** of the caustic utilized for treatment? $ —
4. Is there an existing wastewater treatment system on-site? If so, describe: YES, effluent plant.

ECO-TEC

ENGINEERING SURVEY FORM ES-2.2.1
(Supercedes ES-141)

FOR

ACID PURIFICATION - SULPHURIC ACID ANODIZING

NOTE: AN ACCURATELY COMPLETED SURVEY FORM PROVIDES ECO-TEC WITH THE BASIS FOR SIZING AND PRICING A SYSTEM TO MEET THE CUSTOMER'S SPECIFIC NEEDS. THEREFORE, IT IS NECESSARY THAT THE INFORMATION SUBMITTED ON THIS FORM BE UP-TO-DATE AND COMPLETE.

DATE: 30/08/2012

COMPLETED BY: ________

RETURN TO :

☐ ECO-TEC INC.	☒ PROSEP TECHNOLOGIES LTD	☐ REPRESENTATIVE
1145 Squires Beach Rd.	Unit 6A, Zone 4	________
Pickering, Ontario	Burntwood Business Park	________
L1W 3T9	Burntwood, Staffordshire	________
Tel: (905) 427-0077	U.K. WS7 3XD	________
Fax: (905) 427-4477	Tel: (44) 01543 - 675731	________
	Fax: (44) 01543 - 679484	________

A. CUSTOMER INFORMATION

Company: Wispeco Aluminium
Address: Alrode, Alberton, Gauteng Province, South Africa
Attention: ______ Title: ______
Phone: ______ Fax: ______
Representative: Natali Joubert E-mail: natali.skrps@gmail.com

B. INSTALLATION DESCRIPTION

1. Hours of operation per day: 24
   Days of operation per week: 5
   Weeks of operation per year: 45

2. Process description:

   ☒ Architectural Anodizing
   ☒ Decorative Anodizing
   ☐ Hard Anodizing
   ☐ Other ______

3. Anodizing line description:

   ☒ Automatic
   ☐ Hoist
   ☒ Manual
   ☐ Coil
   ☐ Other ______

4. Shape of work anodized:

   ☒ Sheet
   ☒ Castings
   ☒ Extrusions
   ☐ Continuous strip
   ☐ Tubular
   ☒ Rolled form
   ☐ Other ______

5. Alloys processed: % Of Total Anodized

   ☒ 6063 ______
   ☒ 6061 ______
   ☐ 5005 ______
   ☐ Other ______ ______

6. Is acid purification to be designed for future expansion?

   ☐ Yes, %increase ______
   ☒ No

   If Yes, please explain nature of expansion:

   ☐ longer operating hours
   ☐ new plant/line
   ☐ utilizing full capacity
   ☐ Other ______

7. How many anodizing lines?

   ☐ 1 ☒ 2 ☐ 3 ☐ 4
   ☐ 5 ☐ 6 ☐ 7 ☐ 8
   ☐ Other ______

8. How many anodizing baths per line?

   Line 1 3 Line 2 3 Line 3 ______ Line 4 ______
   Line 5 ______ Line 6 ______ Line 7 ______ Line 8 ______

9. Please indicate distances between baths:

Line #	Distance Between	is	Distance Between	is
	Bath # & Bath #		Bath # & Bath #	
	Bath # & Bath #		Bath # & Bath #	
	Bath # & Bath #		Bath # & Bath #	
	Bath # & Bath #		Bath # & Bath #	
	Bath # & Bath #		Bath # & Bath #	
	Bath # & Bath #		Bath # & Bath #	
	Bath # & Bath #		Bath # & Bath #	

C. PROCESS BATHS

1. This table will be used to size your system, please fill it out as accurately and completely as possible. Please check units of concentrations, volume, temperature and dump frequency on the following page.

	Line# 1 Bath#1,2,3	Line# 2 Bath#1,2,3	Line# Bath#	Line# Bath#	Line# Bath#	Line# Bath#	Line# Bath#
Fresh Bath							
H_2SO_4	63 000kg	63 000 kg					
Al	0	0					
Additive*	Water	Water					
Other	(26 500 kg)	(26 500 kg)					
Volume	33 000 liter	33 000 liter					
Specific gravity							
Temperature	18 - 22 degrees Calcius	18 - 22 degrees Celcius					
Spent Bath							
H_2SO_4							
Al	10 g/liter	10 g/liter					
Other							
Vol. Decanted/wk	11 000 liter	11 000 liter					
Specific gravity							
Temperature	18 - 22 degrees Celcius	18 - 22 degrees Celcius					
Bath Dump							
Volume	11 000 liter	11 000 liter					
Frequency	weekly	weekly					

*What is the additive? ____________ Enclose copy of additive supplier's technical sheets.

	Line# Bath#	Line# Bath#	Line# Bath#	Line# Bath#	Line# Bath#	Line# Bath#	Line# Bath#
Preferred Bath	This is the same as for a fresh bath						
H_2SO_4							
Al							
Other							
Specific gravity							
Temperature							

Units of values shown above are expressed as:

Acid:
- ☐ Percent weight by weight
- ☐ Percent volume by volume
- ☐ Percent weight by volume
- ☒ Grams per litre
- ☐ Ounces per ☐ Imp. gal. ☐ US gal

Metal:
- ☐ Percent weight by weight
- ☐ Percent volume by volume
- ☐ Percent weight by volume
- ☒ Grams per litre
- ☐ Ounces per ☐ Imp. gal ☐ US gal

Additive:
- ☐ Percent weight by weight
- ☐ Grams per litre
- ☐ Percent volume by volume
- ☐ Other NONE ____________
- ☐ Percent weight by volume
- ☐ Ounces per ☐ Imp. gal ☐ US gal

Note: If concentrations are expressed as %w/w report specific gravity.
If concentrations are expressed as %v/v specify concentration of chemical used

2. Method of cooling:
☒ anodizing acid is pumped through chiller
☒ cooling liquid pumped through in-tank heat exchanger
☐ other ______________________

3. If Anodizing Acid is pumped through a chiller:

Chiller pump(s) discharge:

Flowrate	250	☐ US gal/min ☐ m^3/min	☐ Imp. gal/min ☒ L/min	
Pressure	3	☐ psi	☒ bars	☐ kg/cm^2

4. Current method of aluminum control?
☒ periodic bath dumps, with volume dumped and frequency as described in No.1
☐ continuous bath bleed to treatment, rate ______ ☐ US gal/hr ☐ m^3/hr ☐ Imp. gal/hr ☐ L/hr

If continuous bath bleed, fill the concentration of the bleed into No. 1 of this section.
Indicate: Line No.__________ Bath(s) No.__________

D. PRODUCTION CHARACTERISTICS

1. Anodic film thickness: 10 - 25 ☒ microns ☐ thousands of an inch

2. Anodizing time ______ minutes
Total number of loads per hour ______

3. Current Density ______ ☐ Amps/ft^2 ☒ Amps/m^2
Area per load 55 ☐ ft^2 ☒ m^2
Total curent ______ Amps

4. Type of current
☒ DC
☐ AC Superimposed on DC
☐ Pulsed DC
☐ Interrupted DC

5. Voltage 18 volts

6. Typical anodizing production:

Line 1	200	☐ ft^2/hr	☒ m^2/hr
Line 2	250	☐ ft^2/hr	☒ m^2/hr
Line 3		☐ ft^2/hr	☐ m^2/hr
Line 4		☐ ft^2/hr	☐ m^2/hr

7. Maximum anodizing production:

Line 1	250	☐ ft^2/hr	☒ m^2/hr
Line 2	300	☐ ft^2/hr	☒ m^2/hr
Line 3		☐ ft^2/hr	☐ m^2/hr
Line 4		☐ ft^2/hr	☐ m^2/hr

8. Average area of aluminum anodized per year:

Line 1	900 000	☐ ft^2	☒ m^2
Line 2	1 100 000	☐ ft^2	☒ m^2
Line 3		☐ ft^2	☐ m^2
Line 4		☐ ft^2	☐ m^2

9. Does the plant also carry out any of these processes?

- ☒ Caustic soda etching
- ☐ Chromic acid anodizing
- ☐ Phosphoric acid brightening
- ☐ Electrolytic graining

Are survey forms for these enclosed ? NO

Would you like additional information about recovery / purification for these processes? ______

ecoTec

E. BATH ADDITIONS

1. Monthly chemical additions (excluding make-up volume):

Amount				Cost		
Sulphuric acid	30 000	☒ kg	☐ lb	/	☐ kg	☐ lb
Additive		☐ kg	☐ lb	/	☐ kg	☐ lb
Other		☐ kg	☐ lb	/	☐ kg	☐ lb

Currency ☐ US ☐ Can ☐ Euros ☐ £ ☐ Other ______

Please state grade of sulphuric acid: ☐ 93% w/w ☐ Other 98%

F. PRESENT WASTE TREATEMENT

1. Describe present technique employed for treatment of waste:

a) No treatment: waste from bath goes directly to sewer ☐ Yes ☒ No
waste from rinse goes directly to sewer ☐ Yes ☒ No

b) Haulage ☐ Yes ☒ No
If Yes ______ ☐ L/week ☐ US gal/week ☐ Imp. gal/week

Does this haulage figure include: ☐ bath and rinse waste ☐ bath waste only ☐ rinse waste only

c) In House Waste Treatment
If waste is treated, is treatment for: ☐ bath only ☐ rinse only ☒ bath and rinse

Cost

Waste Treatment Chemical Usage/Sludge

Spent Caustic Etch		☐ kg ☐ lb/day		/	☐ kg	☐ lb
Lime		☐ kg ☐ lb/day		/	☐ kg	☐ lb
Fresh Caustic		☐ kg ☐ lb/day		/	☐ kg	☐ lb
Other ____		☐ kg ☐ lb/day		/	☐ kg	☐ lb
Sludge Haulage/Disposal		☐ kg ☐ lb/day		/	☐ kg	☐ lb
Labour		hrs/day		/hour		

Currency: ☐ US ☐ Can ☐ £ ☐ Euros ☐ Other ______

If the chemicals are not purchased as 100% pure, please state purity: Chemical ______ Purity ______

How is sludge dewatered? ☐ Filter press ☐ Vacuum filter ☒ Centrifuge ☐ Other ______

d) Other: ______

2. Environmental limits: (If Government information available, please enclose)

Aluminum	20 ppm	pH	5.9 - 10 ppm
Other	ppm	Suspended Solids	1000 ppm
	ppm		ppm

3. Give names and address of pertinent waste treatment regulatory agency:

____

____

I. ADDITIONAL INFORMATION

1. Reason for request:

i) Economic-chemical savings: ☒ Yes ☐ No
ii) Production improvement: ☒ Yes ☐ No
iii) Environmental: ☒ Yes ☐ No
If Yes; ☐ to meet current regulation
☒ to meet future regulation
iv) Quality improvement - consistency ☒ Yes ☐ No
iv) Other: ______________________

____

____

2. Timetable for purchase of system is:
☐ immediate
☐ 3-6 months away
☐ 6-12 months away
☐ possible future
☒ for budget approval now to to purchase in future

3. Special Equipment Requirements

Does your plant insist on particular components for purchased equipment such as a particular make of pump, programmable controller?
If yes, please provide details.*

Pumps ______________________

Electrical ______________________

Other ______________________

* Eco-Tec manufactures from its standard designs using components of a high industrial quality. Substitution of standard components for an alternate specified by the customer may be accommodated at additional cost. Alternate components are not covered under Eco-Tec's warranties.

Appendix F – Acid analysis

PROCESS	CUSTOMER	FAX / E-MAIL
Anodising	Wispeco Anodising	lindie@wispeco.co.za
TANK CAPACITY (Litres)	**ATTENTION**	**TEL**
18000	Lindie Pienaar	0113890007

Bennie Vorster

DATE	ANALYSIS						ADDITIONS			REMARKS
	Free Sulphuric Acid	Total Sulphuric Acid	Aluminium				Sulphuric Acid			
[Optimum Conc.]	g/ℓ	g/ℓ	g/ℓ				kg			
	180	340	15							
Allowed	160 - 200		8 - 28							
28.08.12	182	248	12.1				0.0			