AESSEAL®

ENVIRONMENTAL TECHNOLOGY

## A Guide to Sealing

# PHOSPHORIC ACID PLANTS

- SAFETY & ENVIRONMENT
- WET PROCESS
- PUMP TYPES
- SEAL MATERIALS
- SEAL TYPES
- BARRIER SYSTEM
- SEAL LOCATIONS
- API PLANS

ENVIRONMENTAL TECHNOLOGY

# A GUIDE TO SEALING PHOSPHORIC ACID PLANTS

## Introduction

*Phosphoric Acid is a major chemical product, manufactured from phosphate rock using either the 'wet process' or the 'electric furnace process'. The nature of the electric furnace process is such that much of the process is 'dry'. Where pumps are present, the relatively pure Phosphoric Acid poses less severe corrosion problems than those seen on plants using the wet process. This discussion will concentrate on the sealing of plants using the wet process.*

*Phosphoric Acid in its pure form, without contaminants, is less corrosive to many metals and alloys than, for example, Sulfuric or Hydrochloric acid. Under most conditions 316L stainless steel will not suffer high corrosion rates. Care is however needed as temperatures approach boiling point at higher acid concentrations, as both these factors increase corrosion rates.*

*The nature of the wet production process is such that the acid encountered in the process contains a significant concentration of Sulfuric, Hydrofluoric and Hydrofluorosilicic acids. Sulfuric acid is very corrosive at all but the lowest concentrations and temperatures. The presence of Fluorides and Chlorides causes both stress corrosion cracking and pitting/crevice corrosion. These factors make the acid much more corrosive than pure Phosphoric Acid at similar concentrations and temperatures, and care must be taken in choosing suitably corrosion resistant alloys.*

*The value of the rock slurry is determined by the percentage $P_2O_5$ (Phosphoric Anhydride) it contains. The higher the grade of rock, the whiter in colour it appears. The main deposits of phosphate rock have lower grade rock with high percentages of hydrocarbons adjacent to them. The more impure the rock phosphate used, the greater the impurities and hence the chemical attack that will take place downstream in the plant processes. Plants may use techniques such as 'redox adjustment' or 'Mg addition' to reduce corrosion.*

*Through much of the process, slurries are present. Abrasion and erosion effects must be considered in choosing seal types and materials of construction. With so many variables it is important that local experience and practise be considered when specifying seal materials, particularly the metallurgy to be used. The selections given in this document should be considered as general suggestions, which may need to be modified to suit local requirements.*

# AESSEAL plc Disclaimer

EXCEPT AS EXPRESSLY PROVIDED HEREIN, AESSEAL plc SHALL NOT BE LIABLE FOR THE BREACH OF ANY WARRANTY, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTY OF MERCHANTABILITY OF FITNESS FOR A PARTICULAR PURPOSE, OR FOR ANY DAMAGES OR OTHER LIABILITY ARISING OUT OF OR IN CONJUNCTION WITH CUSTOMERS' USE OF SUPPLIER PRODUCTS OR AESSEAL plc OR THE AUTHORISED DISTRIBUTOR DESIGNING, MANUFACTURING OR SELLING SUPPLIER PRODUCTS. IN NO EVENT SHALL AESSEAL plc BE LIABLE FOR DIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING WITHOUT LIMITATION LOST SALES OR PROFIT, LOST PRODUCTION OR OUTPUT, INJURY TO PROPERTY OR REPUTATION, OR ANY OTHER DAMAGES WHETHER ARISING IN CONTRACT OR TORT OR OTHERWISE (WHETHER OR NOT ATTRIBUTABLE TO THE FAULT OR NEGLIGENCE OF AESSEAL plc). UNDER NO CIRCUMSTANCES SHALL ANY RECOVERY OF ANY KIND AGAINST AESSEAL plc BE GREATER IN AMOUNT THAN THE PRICE OF THE PRODUCT TO THE END USER.

This information corresponds to our current knowledge on the subject. It is offered solely to provide possible suggestions for your own experimentations. It is not intended, however, to substitute any testing you may need to conduct to determine for yourself the suitability of our products for your particular purposes. This information may be subject to revision as new knowledge and experience becomes available. Since we cannot anticipate all variations in actual end-use conditions, AESSEAL plc makes no warranties and assumes no liability in connection with any use of this information. Nothing in this publication is to be considered as a licence to operate under or a recommendation to infringe any patent right.



AESSEAL®
ENVIRONMENTAL TECHNOLOGY

# CONTENTS

**Description** **Page**



*ACKNOWLEDGMENTS*

*In particular we acknowledge source material and the following background information provided by:-*

*BARRY SCHÄFFLER*

Contact Details AESSEAL Pty Ltd., Gauteng, South Africa.
Tel: Telephone: +27 (0) 11 466 6500
E-mail: aesseal@iafrica.com

Qualifications: NDIP Mech. E.

*CHRIS BOOTH*

Contact Details: AESSEAL plc, Rotherham, U.K.
Tel: Telephone: +44 (0) 1709 369966
E-mail: chrisb@aesseal.co.uk

Qualifications: B.A., M.A. (Oxon), C.Eng., M.I. Mech. E., M.B.A.

*LANCE BRETT*

Contact Details: AESSEAL Inc., Knoxville, Tennessee, USA.
Tel: Telephone: +1 865 531 0192

Qualifications: 14 Years working in the Sealing Industry

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

# Safety & Environmental Issues

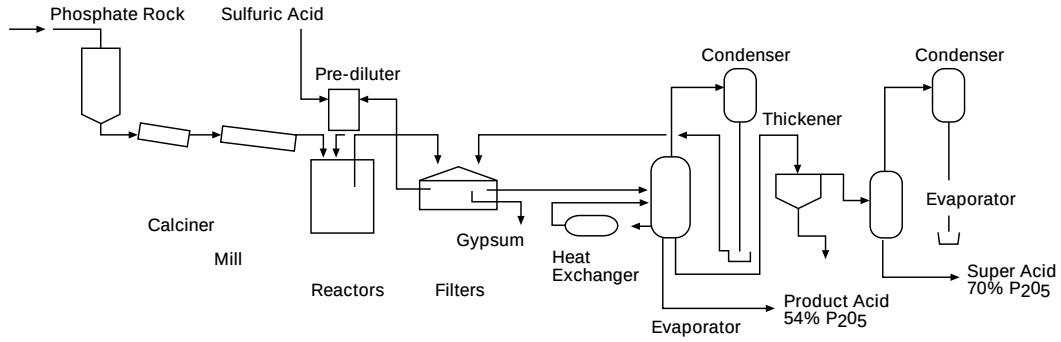
Whenever dealing with Phosphoric Acid remember to wear protective clothing. Safety glasses are important for your eyes. Overalls are best worn to protect your clothing. Shoes, gloves and ear protection are best worn as the industry dictates. Skin contact will result in itchiness and digestion could be lethal.

In its raw form the acid readily corrodes cement or concrete and special measures are required to seal surrounding structures on Phosphoric Acid plants. The impurities in the acid cause it to have a large affinity for silica. When the acid has penetrated the boundaries of it's containment area and reached virgin soil, it reacts with the silica in the soil, resulting in ground upheaval.

For environmental, safety and economic reasons, no "wet process" plant can afford to operate without adequate sealing arrangements on their equipment. Not only do we have a duty to protect our environment and our people, but also the competitive nature of the Phosphoric Acid industry turns product loss directly into financial loss.

# A General Overview of the Wet Process

*Typical flowsheet for a 'wet process' Phosphoric Acid plant*




Phosphate Rock is reacted with Sulfuric Acid to form Gypsum Crystal and Phosphoric Acid. Recirculated Phosphoric Acid is added to the incoming Sulfuric Acid for dilution purposes. The reaction is exothermic and is maintained in a stable condition by cooling the slurry. From the reactor the slurry is fed to a filtration system where the Gypsum Crystals are separated from the Phosphoric Acid. The Gypsum Crystals in slurry form are then pumped to tailing dams where they remain.

The acid from the filtration process is ready for further concentration. This is accomplished in evaporators, which operate under vacuum to lower the boiling point of the water in the mixture. The Phosphoric Acid is heated by cycling it through a heat exchanger and back into the evaporator. The evaporation may be a multi-stage process, typically from 27% to 40%, then 40% to 54%.

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

It is important to understand that the internal sealing materials of the evaporator limit the maximum operating temperature of the unit. Generally these vessels are rubber lined and the operational temperature is approximately 95ºC (203ºF). When the concentration of the acid reaches 54% during the evaporation cycle, it is exported to a holding tank. There the acid is further refined by clarification. The new product is classified as Merchant Grade Phosphoric Acid and is ready for export.

For certain industries it may be necessary to remove a large percentage of the hydrogen fluoride from the acid. This additional process is called defluorination. The hydrogen fluoride in the acid has an affinity for silica. By adding silica to the system a reaction between the hydrogen fluoride and the silica takes place. The by-product will precipitate out of the solution and the remaining product, defluorinated acid, is then more suitable for the food and animal feed industry.

A further evaporation step can be used to concentrate deflourinated acid to produce 70% 'Superphosphoric Acid' (sometimes referred to as '120% acid').

*For the purpose of this manual the process will be broken down into the following main sections.*

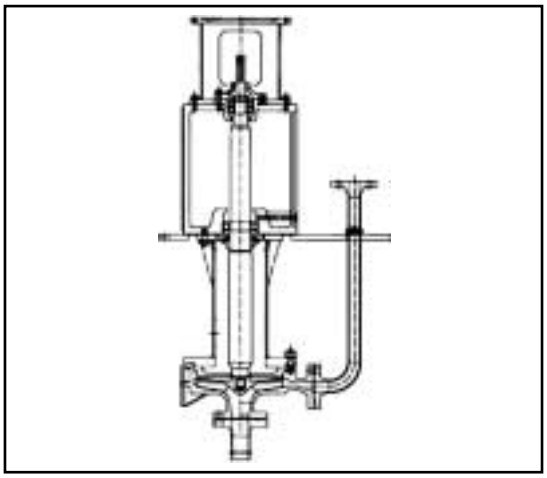
| | |
|---|---|
| A. Rock Slurry Storage and Export.<br>B. Raw Acid Production.<br>C. Filtration Process.<br>D. Gypsum Slurry.<br>E. Evaporation Process.<br>F. Clarification. | G. Deflourination<br>H. Export and Wash Stations.<br>I. Cooling Towers and C.I.P.<br>J. Super Phosphates.<br>K. Auxiliary Systems. |

# *Pumps Used on Wet Process Phosphoric Acid Plants*

*Vertical Spindle (Cantilever-shafted) Pumps*

Vertical spindle pumps are often used on aggressive slurries such as those found in the reactor area of a wet process Phosphoric Acid plant, particularly filter-feed and filtrate applications. This type of pump uses an impeller mounted at the bottom of a hollow tube, with the motor and bearing frame at the top. They will usually be of the 'cantilever-shafted' type, with no bearing in the process fluid. Manufacturers such as Lewis pumps, Ensival and others have developed heavy duty pumps, particularly for use in acid production plants. The sealing area is out of the liquid, and sees only product vapours in normal operation. A variety of techniques are used for sealing, including labyrinth seals, lip seals and packing. Any vapour leakage past these can lead to corrosion of the bearing frame, motor and supporting structure.

Where mechanical seals are to be fitted, these must be specified for dry-running capability. A double seal with un-pressurized or low-pressure barrier pot can be used, such as the AESSEAL® CURE™ or CDSA™ seals with an SSE10™ pot or a Buffer Reservoir. With any vertical shaft application extreme care must be taken on installation to ensure the seal is fully purged of air.



Some vertical spindle pump designs have limited space available in the sealing area, and modification is required in order to fit a mechanical seal.

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

### *Axial Flow Pumps*

Axial Flow Pumps (sometimes referred to as 'Propeller Pumps') from Lewis, Ensival, Goulds and others provide high flows at low pumping heads, ideal for re-circulation duties such as pumping acid around the evaporator and heat exchanger loop. Long unsupported shaft lengths and large heavy impellers lead to problems with balance and radial shaft motion in service. Seals must be chosen with this in mind. Conversion of a packed pump may require the fitting of an additional shaft support bush.

### *Rubber-Lined Slurry Pumps*

Elastomeric materials can withstand the abrasive and corrosive conditions found in slurry pumps, and manufacturers such as Warman, Denver and Envirotec have used this to advantage. Modern pump designs are particularly effective with mechanical seals, and AESSEAL® has worked with manufacturers over many years to develop seals optimized for these duties. Replacement 'seal friendly' back-plates are available for conversion of packed pumps.

# Materials of Construction for Mechanical Seals

### *Metallurgy:*

The use of 316L is limited to the early 'rock slurry' stages of the process, where the product is chemically inert, and to utility pumps. In the main process stream, Alloy 20 has been used successfully for many years, in all but the most corrosive or erosive applications. Over the last 25 years extensive use has also been made of Alloys 904L, 904hMo and 28. Alloys 625 and C-276 are used for additional corrosion resistance in particularly arduous applications, particularly where any Chloride impurities are present. Duplex alloys such as 255 can provide better erosion resistance where needed. Table 1 shows some of the trade names used for these materials.

| Generic Name | Trade Name | UNS | EN | ACI |
|---|---|---|---|---|
| Alloy 20 | Carpenter 20 | N08020 | 2.4660 | |
| Alloy 20 (cast) | Durimet 20, Alloyco 20 | | | CN-7M |
| 904hMo | Avesta 254SMo | N08925 | 1.4547 | |
| 904L | Uranus B6, 2RK65 | N08904 | 1.4539 | |
| C-276 | Alloy C-276 | N10276 | 2.4819 | |
| 625 | Inconel 625 | N06625 | 2.4856 | |
| 28 | Sanicro 28 | N08028 | 1.4563 | |
| 255 | Ferralium | S32550 | | |
| 316L | | S31603 | 1.4404 | CF-3M |
| 316 | | S31600 | 1.4401 | CF-8M, CF-12M |
| 318 | | S32205 | 1.4462 | |

*Table 1 Alloys used on Wet Process Phosphoric Acid Plants*

AESSEAL® ENVIRONMENTAL TECHNOLOGY

Variations in impurities and plant conditions mean that local experience should always be considered when specifying seal materials. AESSEAL® has extensive stock of material and components in Alloy 20, Alloy 276 and others, and also material stocks in 255 and 625. These Alloys should be considered first in specifying any AESSEAL®. Alloys 904L and 28 can be specified where local conditions demand but may result in increased cost and delivery lead time.
N.B. 904L in particular has been widely adopted by the industry, due in part to its cost advantage over Alloy 20 when purchased in larger quantities for the construction of process plant, but this cost advantage disappears when only smaller quantities are required.

*Seal Faces:*

Rock slurry is not particularly acidic, and here the toughness and durability of Tungsten Carbide seal faces can be used to advantage. For acid duties the chemical resistance of Silicon Carbide is needed, either as a hard-faced pair or running against triple resin-impregnated Carbon on non-abrasive lower temperature duties.

Outboard faces for double seals usually use Carbon/Tungsten Carbide or Carbon/Silicon Carbide, with the hard face chosen to reflect the inboard faces. With double seals the choice of outboard face combinations is wider, as these only provide sealing for the barrier fluid in normal operation. It is usual to have one Carbon face, as the use of two hard faces externally risks vapourising the barrier fluid inside the seal cavity. The hard face should be chosen to allow sufficient time for planned action and minimal product loss in the event of failure of the inboard faces, and hence it is usual to use the same face as used on the inboard seal. Carbon/Chrome Oxide can be used to reduce seal cost where appropriate, particularly on larger seals.

*Elastomers:*

Viton has excellent acid resistance, and can be considered a general purpose elastomer for wet process plants. Problems can sometimes be experienced with Viton in hot acids due to its limited resistance to hot water & steam, and in these cases Aflas can be used to advantage.
Kalrez is required where Hydrofluoric and Hydrofluorosilicic acids can concentrate, particularly the reactor top and evaporators. Compounds 6375 or 4079 are suitable.
AESSEAL® keep extensive stocks of O rings in Viton, EPR (EPDM), Aflas and Kalrez (we are UK distributors for DuPont-Dow Kalrez).

*Gaskets:*

Glass-filled PTFE (also known as GFT) gasketing has good acid resistance with Phosphoric and Sulfuric Acids, and can be used as a ‘general-purpose’ gasket on wet process plants. However where Hydrofluoric and Hydrofluorosilicic acids can concentrate, such as the reactor top and the evaporators, then a specialist gasket material such as Gylon 3510 is needed.



AESSEAL®
ENVIRONMENTAL TECHNOLOGY

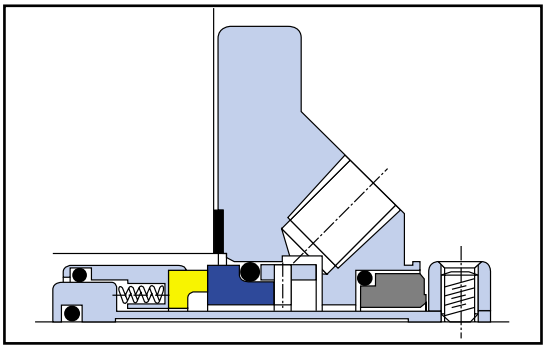
# AESSEAL® Cartridge Mechanical Seals

Extensive use is made of modular design and construction throughout the AESEAL® range to allow delivery lead times to be kept short and prices competitive.
Only a small selection of the AESSEAL® range is shown below. For further details please refer to the product range brochure.
In addition to the standard seal glands shown below, all seals are available with fully-machined glands to suit particular equipment. Glands are available from stock to suit many Progressing Cavity Pump types.

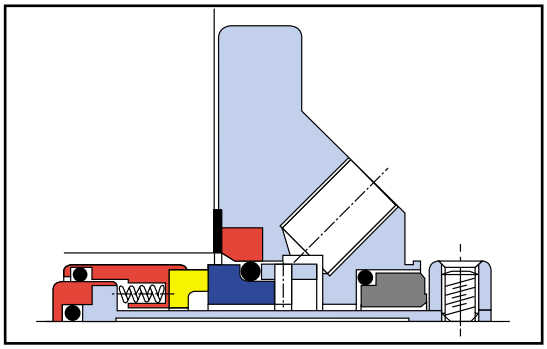
## CURC™

A robust, general purpose single cartridge seal with integral flush, quench and drain connections, available in a wide variety of seal face and elastomer combinations. All metallic components are manufactured in 316L (cast glands from 316) with Alloy 276 springs. In the BI-METAL CURC™ design the product-wetted components are available in Alloy 276, Alloy 20, Titanium or other materials to suit particularly aggressive applications. A Carbon Restriction Bush is standard to limit leakage in the event of seal failure.

*CURC™*



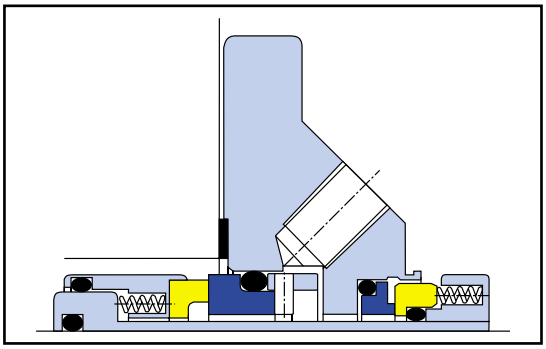
*BI-METAL CURC™*



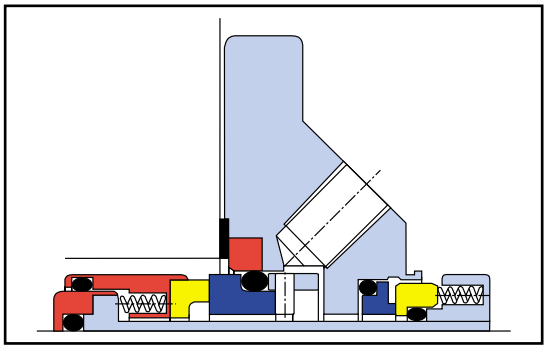
## CURE™

The inclusion of a space-effective set of outboard seal faces allows the use of a low-pressure or un-pressurized barrier fluid for face cooling on moderately hot applications, dry-running protection or prevention of crystallisation on the inboard seal faces. The short overall length of the CURE™ allows its use where space is limited.

*CURE™*



*BI-METAL CURE™*

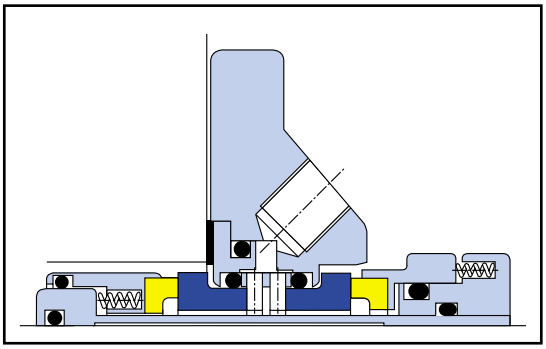


AESSEAL®
ENVIRONMENTAL TECHNOLOGY

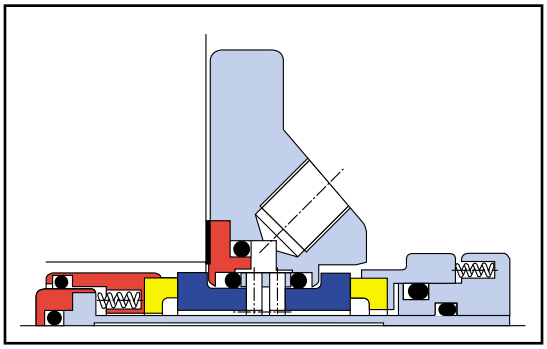
## CDSA™

A robust, general-purpose double cartridge seal available in a wide variety of seal face and elastomer combinations. Manufactured in 316/316L as standard with Alloy 276 springs, with BI-METAL version in a full range of materials. The Face-to-Face design provides additional safety in that it can withstand product pressure surges or loss of barrier fluid pressure without excessive leakage of product into the barrier system.

*CDSA™*



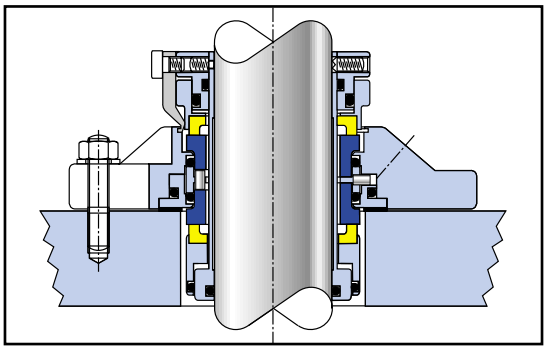
*BI-METAL CDSA™*



## CDM™

Similar in design to the CDSA™ double cartridge seal, internal clearances are optimized to allow use on equipment where some radial shaft motion is expected, such as mixers and agitators.

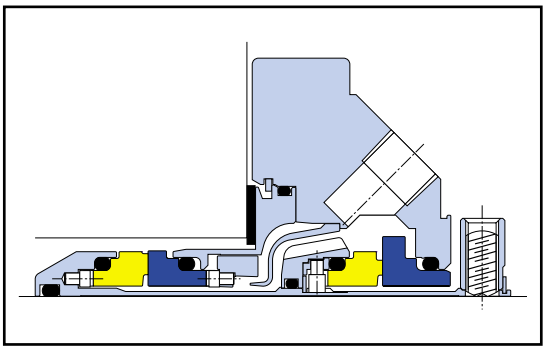
*CDM™*



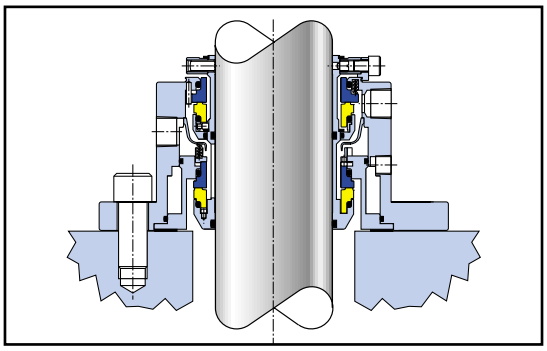
## DMSF™

'Monolithic' wide faces and sprung stationary faces provide ultimate sealing performance across a wide range of shaft speeds and product pressures. Again manufactured in 316/316L as standard with Alloy 276 springs, with BI-METAL version in a full range of materials. The DMSF™ incorporates an extremely effective pumping device with internal flow guides to ensure the faces are properly cooled and flushed by the barrier fluid.

*DMSF™*



*CDMSC™*



## CDMSC™

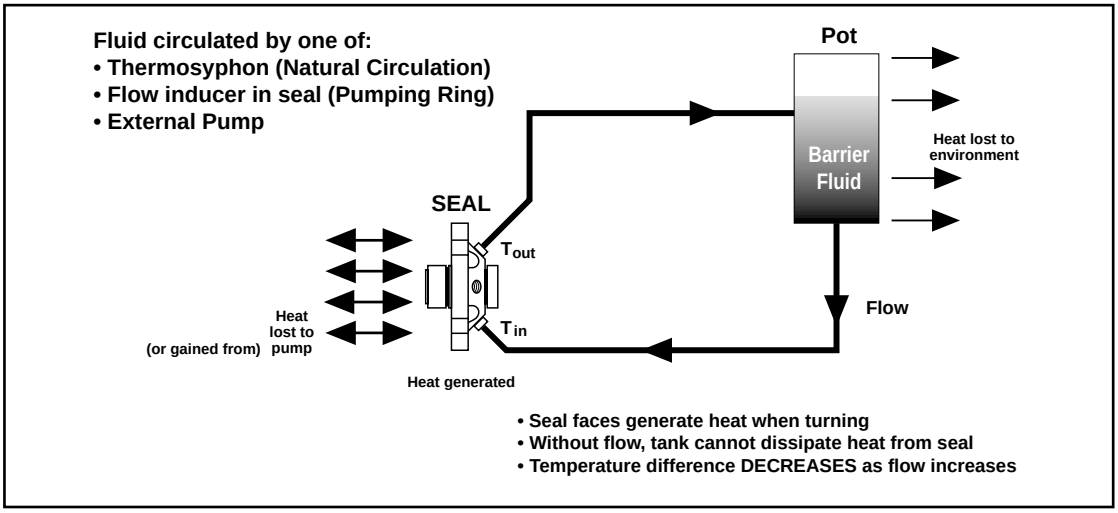
Optimized internal clearances and 'canister' seal gland to suit equipment where a degree of radial shaft motion is expected. Excellent performance on applications where high temperatures or temperature cycling will be encountered.

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

# Barrier Systems for Double Seals

A double seal has an inboard and an outboard seal, with a cavity between which is filled with cool, clean barrier fluid. A pressurized barrier fluid serves two purposes. First it prevents the abrasive particles in a slurry from entering between and damaging the seal faces, and second it cools the outboard seal faces during operation. A double seal also provides an additional safety shield in that a pressurized barrier system, properly monitored, will give an indication of seal deterioration before there is any product loss. An un-pressurized barrier system can provide cooling and prevent product crystallization on the seal faces, but cannot prevent damage of the inboard faces from abrasives in the product, nor can it provide a positive safety barrier.

The double seal is often connected to a local barrier fluid reservoir ('pot'). Two pipes must be used, to allow a flow through the seal and back to the pot for cooling purposes. The seal can incorporate a pumping device (e.g. the AESSEAL® DMSF™ seal). On cooler or slower duties a 'thermosyphon' can be used. Here the warm fluid in the seal rises by natural convection up to the pot, where it cools before returning to the seal.




*Fluid flow in Double Seal Barrier System*

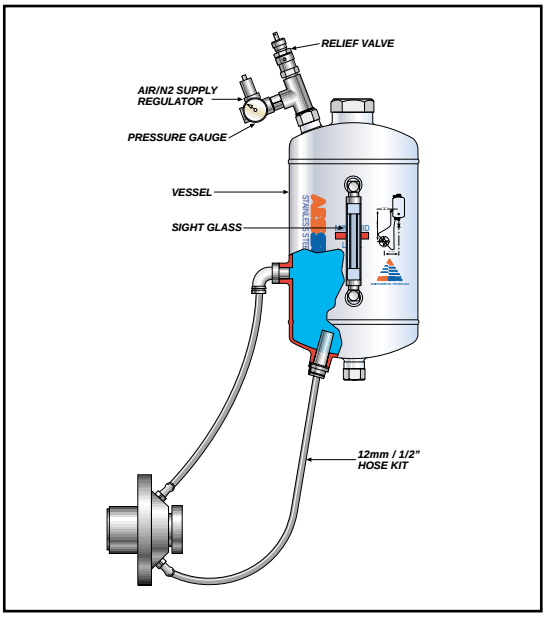
The barrier system can be pressurized by running Nitrogen to the pot via a pressure regulator. The Nitrogen may be already piped around the plant, or bottled gas can be used. Plant compressed air can be used to pressurize systems using aqueous barrier fluids on aqueous products, but should never be used with oil or organic barrier fluids or products due to the possible risk of explosion. A sight glass allows the liquid level in the pot to be monitored, backed-up by a level switch if appropriate. Some small leakage of barrier fluid into the product is inevitable; the rate will vary with seal size, speed, pressure across the faces, seal wear, temperature, vibration, etc. Provision must be made to regularly check the level in the pot and top-up if necessary.

The AESSEAL® Water Management System can provide an easy-to-operate, pressurized barrier wherever a suitable plant water supply exists. The pot is fitted with an automatic air vent valve, and the water supply piped into the pot via a pressure regulator and a flow indicator and/or sensor. On commissioning the water supply fills the pot, then once the air vent valve closes the supply pressurizes the pot and flow ceases. In operation the water supply maintains the pressure in the pot and makes good any small loss of barrier fluid. The flow indicator and/or sensor are used to detect seal problems leading to excessive barrier fluid loss.

Where the function of the barrier system is purely to provide moderate seal face cooling and/or dry-running protection, an un-pressurized pot or Buffer Reservoir may be used.

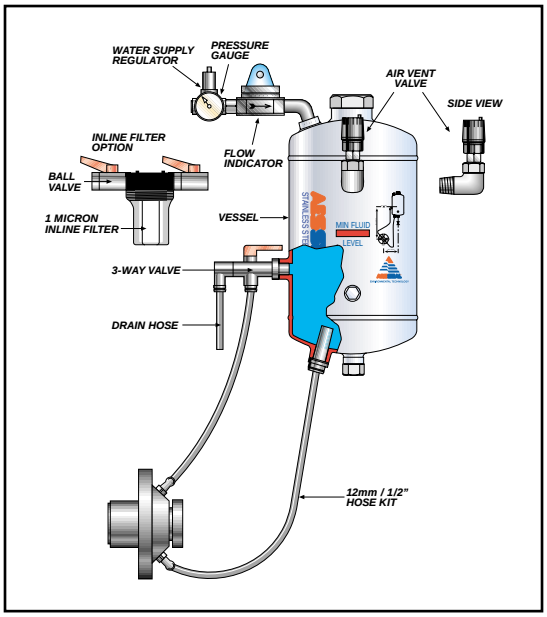
AESSEAL®
ENVIRONMENTAL TECHNOLOGY

*SSE10™ System P2*

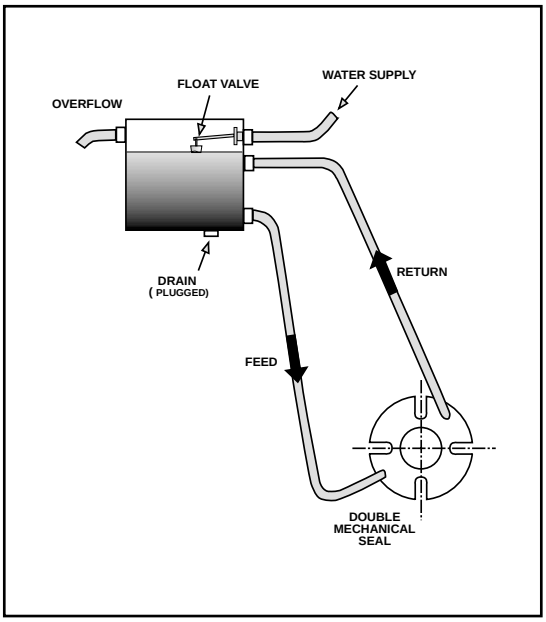



*Air/Nitrogen Pressurized Barrier System*

*SSE10™ System W2*




*Water Management System*




*Buffer Reservoir*

The pressure in a pressurized barrier system should be set to 1 to 2 bars (15 to 30 psi) above the maximum seal chamber pressure likely to be encountered in operation. A pressure gauge should always be fitted to the pot to allow this pressure to be monitored; a pressure switch can also be fitted on critical applications.
For higher temperature applications, finned heat-exchange tubing can be fitted into the pipe work, and/or pots fitted with internal water cooling coils. A full modular range of barrier fluid systems is available from stock.

N.B. Extreme care must be taken with any double seal on a vertical shaft application to ensure that the seal is properly purged of air on installation. AESSEAL® will be pleased to advise on how this is best achieved.

There are many variations in the 'environmental controls' which can be used with mechanical seals. These are often defined by 'API plan number' as shown in the diagrams at the end of this guide.

*With the exception of hard piping option all SSE10™ systems are supplied complete with all fittings and accessories.*

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

# Wet Process Phosphoric Acid Plant Seal Locations

## A. Rock Slurry Storage and Export

The raw material phosphate rock is commonly referred to as rock slurry. Rock slurry is stored in storage tanks often referred to as a battery. When required the rock slurry is pumped to the reactor where it is reacted with Sulfuric Acid. The reaction process will be described later. During storage the rock slurry is constantly agitated and it may be possible for plant personnel to add water to the slurry to make it easier to either agitate or to pump to the reactor. It is also possible for plant personnel to use compressed air in the tanks ('sparging') to aid in the agitation of the slurry. Although this method of aiding agitation is very effective, any air trapped within a pump may result in cavitation.

Stable conditions are needed in the reactor. The flow rates of the rock slurry and diluted Sulfuric Acid into the reactor are controlled to maintain a stable reaction. For this reason it is important not to add water to the system whilst rock slurry is being pumped from the tank to the reactor, and hence a single seal with a clean water flush is not a preferred option.

The slurry is very abrasive, but is not particularly corrosive. The best sealing option is a pressurized double cartridge seal such as the AESSEAL® DMSF™. Water is a readily available and acceptable medium for the barrier fluid. When the seal eventually starts to fail, the effect of minor water contamination is negligible since the product is a water-based slurry.

The level in the tank will vary, and hence so will pump suction pressure. The barrier pressure should be set to between 1 and 2 bars (15 to 30 psi) above maximum stuffing box pressure.

### *Rock Slurry Pumps - Seal Selection*

| Option | Minimum Required | Best Available Option |
|---|---|---|
| Seal Type | Cartridge Double Seal | Cartridge Double Seal |
| Design | CDSA™ | DMSF™ |
| Metal Parts | 316L | 316L |
| Inboard Faces | Tungsten/Tungsten | Tungsten/Tungsten |
| Outboard Faces | $CrO_2$/Carbon | Tungsten/Carbon |
| Gasket | GFT | GFT |
| Elastomer | Viton | Viton |
| System | API Plan 53, SSE10™ W2 | API Plan 53, SSE10™ W2 |

Tungsten and Silicon Carbide (SiC) are the only options available for the duty required from the inboard seals. Soft faces such as Carbon will quickly be impregnated with slurry particles and wear away both faces. Ideally an AESSEAL® Water Management System (see section 4 above) should be used to maintain a barrier pressure.
Seal life may be improved on some plants by the use of Alloy 20 or 904L.

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

## *B. Raw Acid Production*

Concentrated Sulfuric Acid is often pre-diluted with re-circulated Phosphoric Acid to provide better control of the exothermic reaction and to reduce the corrosivity of the reactor contents.

### *Dilution Pumps (Sulfuric, Recycled Phosphoric Acid) – Seal Selection*

| | |
|---|---|
| **Seal Type** | **Cartridge Double Seal** |
| **Design** | **BI-METAL CDSA™** |
| **Metal Parts** | **Alloy 20 or 904L** |
| **Inboard Faces** | **Silicon Carbide/Silicon Carbide** |
| **Outboard Faces** | **Silicon Carbide/Carbon or $Cr_2O_2$/Carbon** |
| **Elastomer** | **Viton** |
| **Gasket** | **GFT** |
| **System** | **API Plan 53, SSE10™ W2** |

The reactor usually consists of several chambers through which the acid is passed. To keep the reaction at a constant temperature, typically around 80°C (180°F) the acid is pumped through flash coolers. From the last chamber of the reactor the acid is pumped to the filters to separate the gypsum crystals from the raw acid. Newer design 'isothermal reactors' use higher agitation velocities.

During the reaction poisonous and highly corrosive vapours (including Hydrofluoric and Hydrofluorosilicic acids) are given off and collect in the gaseous chamber between the roof of the reactor and the acid surface. Fume scrubbers are used to 'scrub' the gases before passing the 'clean' air to atmosphere. It is essential to ensure all the vapours are removed to the scrubbing unit by sealing the reactor correctly. Gearboxes, motors, support structures and other equipment are not generally manufactured from exotic materials, so it is also necessary to seal the vapours effectively to prevent these being severely corroded. The reactor should not have an airtight seal, and a source where air can be drawn in to keep the gas pressure near atmosphere is necessary.

### *Reactor – Seal Selection*

| | |
|---|---|
| **Seal Type** | **Cartridge Double Mixer Seal** |
| **Design** | **CDMSC™, CDM™ (Check radial deflection limits! 'Bearing' seals also available, e.g. Mixmaster IV™ )** |
| **Metal Parts** | **Alloy C-276 or Alloy 625** |
| **Inboard Faces** | **Silicon Carbide/Silicon Carbide** |
| **Outboard Faces** | **Silicon Carbide/Carbon or $Cr_2O_2$/Carbon** |
| **Elastomer** | **Kalrez, 4079 or 6375** |
| **Gasket** | **Gylon 3510** |
| **System** | **API Plan 53, SSE10™ W3** |

Due to the corrosive nature of the gases, the metal parts, inboard seal faces and elastomers are upgraded. To cope with the elevated temperatures within the reactor, the seal faces require cooling. Hence a double seal is chosen with a pressurized barrier cooling system. An un-pressurized barrier system may be used, but the barrier fluid must be regularly changed to avoid any build-up of corrosive contaminants. The CDMSC™ also incorporates a water cooling jacket in the seal gland.

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

It is important to note that the operating temperature of the reactor will have an effect on the lubrication temperature within the bearing housing of the pumps and mixers. A planned programme of inspections and lubrication replacement will avoid failures due to contamination of the lubrication before reaching the end of its useful life.

## *C. Filtration Process*

During filtration the gypsum crystals are separated from the Phosphoric Acid by passing the slurry through filters. The gypsum crystals are collected in a common tank and then pumped to the tailing dams. The filters are divided into different sections where acid is collected into circulation vessels, from there it is either pumped back to the filter for recycling or to the reactor to help stabilise the reaction. This cyclic action typically consists of filters utilising vacuum to draw the acid through a linear screen cloth, and maximizes the efficiency of the system. Another possible process is one where acid is pressurized through a liner screen cloth and the remaining gypsum crystals are then washed away with high-pressure nozzles. In both instances gypsum slurry needs to be pumped away, which is dealt with later.

The Phosphoric Acid from the filters is in its crude form and is then pumped to storage tanks. The acid is kept in the storage tanks ready to be used during the evaporation process.

The acid in the circulating vessels used during filtration is not pure and often contains a certain amount of gypsum crystals. These readily precipitate and deposit on the vessel walls and floors. For this reason they are cleaned frequently to remove the deposits. Vertical spindle pumps are often used in this area to avoid the deposits building up on the suction side of the pump. The acid at this stage is still relatively warm and the mist, which rises from the acid, readily condenses on any cool surface it comes in contact with. The vapour contains traces of Hydrofluorosilicic Acid and for this reason Silicon Carbide is chosen over Tungsten.

It is important to note whether or not the vessel levels are controlled or not. If the level of the vessel is not controlled then it is advisable to use a spindle pump with the best $L^3/D^4$ ratio possible and run-dry capabilities. Although several options are available for level control, the system must be checked regularly as a system failure could cause product loss or premature seal failure.

These spindle pumps have much of the same sealing criteria as the spindle pumps used in the reactor. The only major difference being that the acid temperature is much lower.

### *Vertical Spindle Pumps – Seal Selection*

| | |
|---|---|
| **Design** | **BI-METAL CDM™** |
| **Metal Parts** | **Alloy 20 or 904L** |
| **Inboard Faces** | **Silicon Carbide/Silicon Carbide** |
| **Outboard Faces** | **Silicon Carbide/Carbon** |
| **Gasket** | **Gylon 3510** |
| **Elastomer** | **Aflas** |
| **System** | **API Plan 53, SSE10™ W2** |

*With any vertical shaft application extreme care must be taken on installation to ensure the seal is fully purged of air.*

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

## *D. Gypsum Slurry*

From the filters the gypsum slurry is dumped into tanks where it is then pumped to the tailing dam. Usually water is used to wash the gypsum slurry from the hopper of the filter to a tank before it is then exported. Quite often this tank is also used to collect any wastewater that cannot be recycled into the process. For this reason any given impurity at any possible concentration may be present. The pump is also generally oversized to accommodate the maximum possible duty required and level controls are necessary to maintain the required suction head of the pump and prevent cavitation.

### *Gypsum Slurry - Seal Selection*

| | With Flush | Without Flush |
|---|---|---|
| Seal Type | Single Cartridge | Double Cartridge |
| Design | BI-METAL CURC™ | DMSF™ |
| Metal Parts | Alloy 20 or 904L | Alloy 20 or 904L |
| Faces, Inboard | SiC/SiC | SiC/SiC |
| Faces, Outboard | N/A | Silicon Carbide/ Carbon |
| Elastomer | Viton | Viton |
| Gasket | GFT | GFT |
| System | API Plan 32 | API Plan 53, SSE10™ W2 |

## *E. Evaporation Process*

In the evaporation process, crude Phosphoric Acid is cycled through an evaporator under vacuum and heated with a steam heat exchanger. The vacuum decreases the boiling point of water and increases the rate at which it can be removed from the acid to increase its concentration. Evaporators can be run in series or in parallel or a combination of both. Since most evaporators are rubber-lined the maximum operating temperature is around 90ºC (194ºF). Axial flow pumps are usually used to circulate the acid in the concentrator.

Solids content is approximately 10% within the evaporator however the acid is inclined to crystallise when cooling below 60ºC (140ºF). It is also essential not to add flush water to the process as it will dilute the acid and defeat the object of the operation. The whole operation of the evaporator is critical as a sudden drop in temperature or pressure could cause tube failure in the heat exchanger, which is a costly exercise. For this reason a double cartridge seal is necessary. The outboard seal provides limited back-up in the event of inboard seal failure enabling the evaporator to be shut down without risking the loss of the heat exchanger or costly product.

Crude Phosphoric Acid is pumped to the evaporator from the crude acid storage tanks. When acid in the evaporator has reached the desired conditions, it is then transferred to the final storage tanks ready for export or further refining.



AESSEAL®
ENVIRONMENTAL TECHNOLOGY

### *Evaporator Pumps - Seal Selection*

| Axial Flow Pumps (Evaporator Circulation) | |
|---|---|
| Seal Type | Cartridge Double Seal |
| Design | DMSF™ |
| Wetted Parts | Alloy 20 or 904L |
| Faces, Inboard | Silicon Carbide/Silicon Carbide |
| Faces, Outboard | Silicon Carbide/Carbon |
| Elastomer | Aflas |
| Gasket | Gylon 3510 |
| System | API Plan 53, SSE10™ W3 or P4 |

| Transfer Pumps | |
|---|---|
| Seal Type | Cartridge Double Seal |
| Design | BI-METAL CDSA™ |
| Wetted Parts | Alloy 20 or 904L |
| Faces, Inboard | Silicon Carbide/Silicon Carbide |
| Faces, Outboard | Silicon Carbide/Carbon |
| Elastomer | Aflas |
| Gasket | GFT |
| System | API Plan 53, SSE10™ W2, Pressurized. |

It is necessary to ensure that the transfer pumps operate with adequate level controls and sufficient NPSH. The evaporator operates under vacuum, which could result in there being a negative NPSH if the liquid level in the suction is too low.

### *Drainage Pumps - Seal Selection*

| | |
|---|---|
| Seal Type | Cartridge Double Seal |
| Design | BI-METAL CDSA™ |
| Wetted Parts | ALLOY 20 OR 904L |
| Faces, Inboard | Silicon Carbide/Silicon Carbide |
| Faces, Outboard | Silicon Carbide/Carbon |
| Elastomer | Viton |
| Gasket | GFT |
| System | API Plan 53, SSE10™ W2, Pressurized. |

The function of the drainage pumps will be discussed further in the Clean-In-Process (CIP) section.

## *F. Clarification*

During the clarification process, the 54% Phosphoric Acid is stored in tanks where it is ‘aged, cooled and clarified’. The end product is a ‘Merchant Grade’ acid that has only 1% solids. During the process the sludge which settles on the bottom of the tanks is pumped to a system designed to handle the solids and recycle the acid. Some plants use a pressurized filter system to pressurise the acid through linear screen cloths to reclaim it.

The pumps used to remove the sludge are generally positive displacement types such as peristaltic pumps. Horizontal pumps or spindle pumps are used to transfer acid between tanks. The spindle pumps sit in holding tanks, which are filled by allowing the storage tank to drain by gravity feed. The level is kept constant by the use of a control valve and level switch.

*Product Acid Pumps – Seal Selection*

| Horizontal Transfer Pumps | |
|---|---|
| Seal Type | Cartridge Double Seal |
| Design | BI-METAL CDSA™ |
| Wetted Parts | Alloy 20 or 904L |
| Faces, Inboard | Silicon Carbide/Silicon Carbide |
| Faces, Outboard | Silicon Carbide/Carbon |
| Elastomer | Viton |
| Gasket | GFT |
| System | API Plan 53, SSE10™ W2 |

| Vertical Spindle Pumps | |
|---|---|
| Seal Type | Cartridge Double Seal |
| Metal Parts | Alloy 20 or 904L |
| Design | BI-METAL CDM™ |
| Inboard Faces | Silicon Carbide/Silicon Carbide |
| Outboard Faces | Silicon Carbide/Carbon |
| Gasket | GFT |
| Elastomer | Viton |
| System | API Plan 53, SSE10™ W2 |

*With any vertical shaft application extreme care must be taken on installation to ensure the seal is fully purged of air.*

The same conditions discussed earlier for vertical spindle pumps will apply to the pumps. Should the same pumps be used, it will be possible to standardise on a seal arrangement. Once again level control is essential.

## *G. Defluorination*

It is necessary to remove Hydrofluoric and Hydrofluorosilicic Acid impurities from the Phosphoric Acid for some markets, such as animal feeds, etc. The process is simple and takes advantage of the affinity these impurities have for Silica. A batch of acid is stored in a large open vessel with an agitator. Silica is then added to the acid in an external mixing tank. The mixture is allowed to stand, then the deflourinated acid is pumped away. These tanks are regularly drained, and any sludge build-up removed by mechanical means. The sludge has no value, nor can acid be reclaimed, so it is fed to the tailing dams.

A vertical spindle pump is often mounted in the external mixing tank, similar to those used in the Clarification section. The same considerations discussed earlier for vertical spindle pumps will apply to the pumps. Should the same type of pumps be used, it will be possible to standardise on a seal arrangement. Once again level control is essential.

*Vertical Spindle Pumps – Seal Selection*

| | |
|---|---|
| Seal Type | Cartridge Double Seal |
| Metal Parts | Alloy 20 or 904L |
| Design | BI-METAL CDM™ |
| Inboard Faces | Silicon Carbide/Silicon Carbide |
| Outboard Faces | Silicon Carbide/Carbon |
| Gasket | GFT |
| Elastomer | Viton |
| System | API Plan 53, SSE10™ W2 |

*With any vertical shaft application extreme care must be taken on installation to ensure the seal is fully purged of air.*

A rubber-lined slurry pump may be used to drain the tank for removal of sludge build-up.

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

### *Horizontal Drainage / Transfer Pumps - Seal Selection*

| | |
|---|---|
| **Seal Type** | **Cartridge Double Seal** |
| **Design** | **BI-METAL CDSA™** |
| **Wetted Parts** | **Alloy 20 or 904L** |
| **Faces, Inboard** | **Silicon Carbide/Silicon Carbide** |
| **Faces, Outboard** | **Silicon Carbide/Carbon** |
| **Elastomer** | **Viton** |
| **Gasket** | **GFT** |
| **System** | **API Plan 53, SSE10™ W2** |

## *H. Export and Wash Stations*

When the acid is ready for export it is pumped to a holding tank. The holding tank usually has two or more vertical spindle pumps, depending on the size of the loading bay. The acid is then pumped from the holding tank into road or rail tankers. If there is any spillage, it will drain to a central sump where it is then pumped back to an acid recycling/reclaiming system such as that described in the clarification process.

During the transportation the solids often precipitate out of the acid. The tankers are then usually washed in the same area using 39% Phosphoric Acid to wash out the slurry/sludge build up inside the tank. This slurry mixture is then also pumped back to the recycling/reclaiming system.

The 39% Phosphoric Acid used is usually pumped into the tankers during the cleaning process by a horizontal pump. These pumps have high pressure and large volume capacity. The acid pumped is usually warmed to prevent crystallising in the pipe work. From there it drains to the central sump.

As described before, all the conditions regarding the vertical spindle pumps can be applied.

### *Vertical Spindle Pumps – Seal Selection*

| | |
|---|---|
| **Seal Type** | **Cartridge Double Seal** |
| **Metal Parts** | **Alloy 20 or 904L** |
| **Design** | **BI-METAL CDM™** |
| **Inboard Faces** | **Silicon Carbide/Silicon Carbide** |
| **Outboard Faces** | **Silicon Carbide/Carbon** |
| **Gasket** | **GFT** |
| **Elastomer** | **Viton** |
| **System** | **API Plan 53, SSE10™ W2** |

*With any vertical shaft application extreme care must be taken on installation to ensure the seal is fully purged of air.*

### *Wash Pumps – Seal Selection*

| | |
|---|---|
| **Seal Type** | **Cartridge Double Seal** |
| **Design** | **BI-METAL CDSA™** |
| **Wetted Parts** | **Alloy 20 or 904L** |
| **Faces, Inboard** | **Silicon Carbide/Silicon Carbide** |
| **Faces, Outboard** | **Silicon Carbide/Carbon** |
| **Elastomer** | **Viton** |
| **Gasket** | **GFT** |
| **System** | **API Plan 53, SSE10™ W2 Pressurized** |

## *I. Cooling Towers and C.I.P.*

The cooling towers and the clean in process (C.I.P.) pumps are integrated. During the scrubbing process in the Evaporator, a Hydrofluoric and Hydrofluorosilicic acid mix is formed and this is stored in the Swift Towers. This is often used for a "pickling" process to clean the Evaporators and/or any pipe work which has been scaled up during the operation of the plant. Hydrofluorosilicic acid is highly corrosive and care must be taken when selecting the wet end materials. After the C.I.P. is complete in the evaporator, the drainage pumps are often used to drain the evaporators which otherwise would have to drain by gravity feed. This allows the plant to reach operating condition sooner.

Generally it will be found that the pumps used in these applications are similar in nature to the other slurry pumps on the plant. They are generally rubber-lined and often need frequent adjustment to re-establish impeller clearances as wear occurs in the wet end.

### *Cooling Tower and Drainage Pumps – Seal Selection*

| Process | Drainage Pumps | Cooling Towers/CIP |
|---|---|---|
| Seal Type | Double Cartridge | Single |
| Design | BI-METAL CDSA™ | BI-METAL CURC™ |
| Wetted Parts | Alloy 20 or 904L | Alloy 20 (316L may be OK) |
| Faces, Inboard | Silicon Carbide/Silicon Carbide | Silicon Carbide/Silicon Carbide |
| Faces, Outboard | Silicon Carbide/Carbon | N/A |
| Elastomer | Viton | Viton |
| Gasket | GFT | GFT |
| System | API Plan 53,<br>SSE10™ W2 | API Plan 32 |

## *J. Super Phosphates*

Some plants produce triple super phosphate by mixing ground rock phosphates with 54% Phosphoric Acid. Diammonium Phosphate (DAP) is produced by reacting 44% Phosphate acid with Ammonia. Both of the processes are handled as slurries to the point of the drying operation. Thereafter solids handling equipment is used.

| | Triple Super Phosphate | Diammonium Phosphate |
|---|---|---|
| Seal Type | Double Cartridge | Double Cartridge |
| Design | CDSA™ | CDSA™ |
| Wetted parts | 316L | 316L |
| Faces, Inboard | Silicon Carbide/ Silicon Carbide | Silicon Carbide / Silicon Carbide |
| Faces, Outboard | Carbon/ Silicon Carbide | Carbon/ Silicon Carbide |
| Elastomer | Viton | Viton |
| Gasket | GFT | GFT |
| System | API Plan 53,<br>SSE10™ W2 | API Plan 53,<br>SSE10™ W2 |

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

## K. Auxiliary Systems

### Condensate

Steam is used to heat the acid in the evaporators, as it circulates through the heat exchanger. Acid flows through the tube side of the shell and tube exchanger, with steam on the shell side. Condensate is collected at the base of the exchanger then recycled back to the boilers, generally at temperatures of 95°C to 105°C (200°F to 220°F) depending on the pressures used in the system. Careful consideration of the condensate removal system must be made, as they will vary considerably between plants. Steam pressure may vary from 7 to 15 bars (105 to 225 psig). The condenser may on occasions allow steam to blow through into the condensate return system.

Contamination of the condensate can occur, due to leaks in the heat exchanger. The acidity (pH) is monitored, and condensate with a pH below 5 is sent to a caustic dosing tank where caustic is added until the pH is acceptable. Treated condensate cannot be sent back to the boilers, and instead it is usually sent to the plant water reservoir to be used as cooling water, etc.

Conditions are such that a single seal is unlikely to give reliable service due to vaporisation ('flashing-off') between the faces. The CURE™ seal with an un-pressurized barrier provides cooling to the faces to prevent this vaporisation, and also protects the seal from dry-running. This is suitable for use on condensate at temperatures up to 105°C (220ºF); higher temperature condensate will require the use of a CDSA™ seal with a pressurized barrier.

*Condensate Pumps – Seal Selection*

| | |
|---|---|
| **Seal Type** | **Cartridge Double Seal** |
| **Metal Parts** | **316L** |
| **Design** | **CURE™** |
| **Inboard Faces** | **Carbon (Antim)/Tungsten Carbide** |
| **Outboard Faces** | **$CrO_2$/Carbon** |
| **Elastomer** | **Aflas** |
| **Gasket** | **AF1** |
| **System** | **API Plan 52, Buffer Reservoir or SSE10™ P1** |

### Water

Plant water quality can vary enormously. Clean cool water is easily sealed using a Carbon/Chrome Oxide single seal, but if solids are present then the Carbon face can suffer rapid wear and a hard face pair is needed. A Tungsten Carbide/Tungsten Carbide face combination is tough and robust. Silicon Carbide/Silicon Carbide may be needed in some circumstances if acid contamination is expected. With any single seal, care must be taken to avoid dry-running in operation.

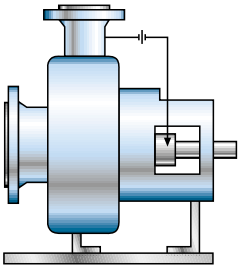
*Water Pumps – Seal Selection*

| Option | Minimum Required | Option where Solids/Acids present |
|---|---|---|
| **Seal Type** | **Cartridge Single Seal** | **Cartridge Single Seal** |
| **Metal Parts** | **316L** | **316L** |
| **Design** | **CURC™** | **CURC™** |
| **Faces** | **$CrO_2$/Carbon** | **Silicon Carbide/Silicon Carbide** |
| **Gasket** | **AF1** | **GFT** |
| **Elastomer** | **Viton** | **Viton** |

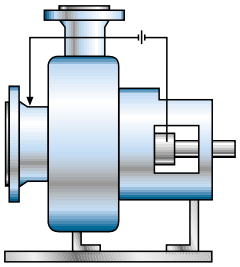
AESSEAL®
ENVIRONMENTAL TECHNOLOGY

# API PLAN SCHEMATIC DETAILS

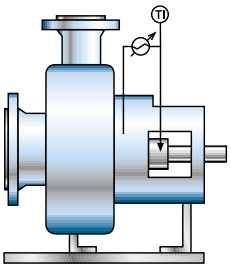
Throughout seal selection, system plan numbers are referred to. These plan numbers and their meaning have been summarized below:-



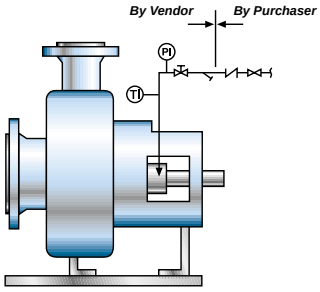
**API PLAN NO.11**
*Product Recirculation from Pump Discharge to Seal through a Flow Control Orifice.*



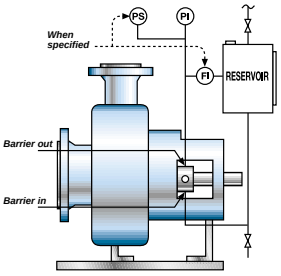
**API PLAN NO.13**
*Product Recirculation from Seal Chamber to Pump Suction via a Flow Control Orifice.*



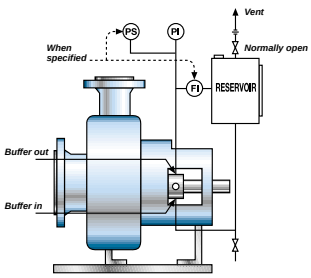

**API PLAN NO.23**
*Product Recirculation from Seal Cavity through Heat Exchanger and back to the Seal Chamber. Normally includes some form of Pumping Ring.*



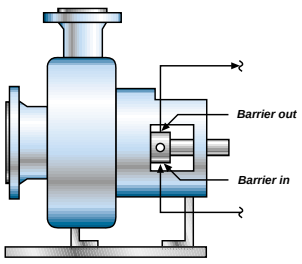

**API PLAN NO.32**
*Flush injected from an External Source.*



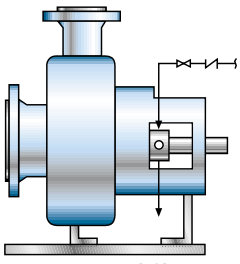

**API PLAN NO.53**
*Pressurized Barrier Fluid Reservoir. Barrier pressure is greater than Product pressure. Circulation is maintained by a Pumping Ring.*




**API PLAN NO.52**
*Unpressurized Buffer Reservoir, Circulation normally maintained by Pumping Ring. Also system normally continuously vented.*




**API PLAN NO.54**
*Pressurized External Barrier Fluid, Normally from a separate Pumped system (e.g. PUMPPAC™).*



**API PLAN NO.62**
*External Quench straight through to drain.*

AESSEAL®
ENVIRONMENTAL TECHNOLOGY

ENVIRONMENTAL TECHNOLOGY

**The AESSEAL® Group of Companies**

| | |
|---|---|
| AESSEAL plc, Rotherham, U.K. | Telephone: +44 (0) 1709 369966 |
| AESSEAL plc, Derby, U.K. | Telephone: +44 (0) 1332 366738 |
| AESSEAL plc, Peterborough, U.K. | Telephone: +44 (0) 1733 230787 |
| AESSEAL plc, Scotland, U.K. | Telephone: +44 (0) 1698 849808 |
| AESSEAL plc, Middlesbrough, U.K. | Telephone +44 (0) 1642 245744 |
| AESSEAL plc, Essex, U.K. | Telephone: +44 (0) 1708 256600 |
| AESSEAL plc, Pontypridd, U.K. | Telephone: +44 (0) 1443 844330 |
| AESSEAL (MCK) Ltd., Lisburn, U.K. | Telephone: +44 (0) 28 9266 9966 |
| AESSEAL (MCK) Ltd., Co. Cork, Ireland. | Telephone: +353 (0) 214 633477 |
| AESSEAL Inc., Knoxville, Tennessee, USA. | Telephone: +1 865 531 0192 |
| AESSEAL Inc., Seneca Falls, New York, USA. | Telephone: +1 315 568 4706 |
| AESSEAL Inc., Kingsport, Tennessee, USA. | Telephone: +1 423 224 7573 |
| AESSEAL ESP LLC, Cedar Rapids, Iowa, USA. | Telephone: +1 319 393 4310 |
| AESSEAL Deutschland AG. | Telephone: +49 (0) 60 74 881293 |
| AESSEAL Italia SRL. | Telephone: +39 (0) 33 197 0556 |
| AESSEAL Pty Ltd., Gauteng, South Africa. | Telephone: +27 (0) 11 466 6500 |
| AESSEAL Pty Ltd., Confluid Branch, Amanzimtoti, South Africa. | Telephone: +27 (0) 31 903 5438 |
| AESSEAL Malaysia SDN. BHD. | Telephone: +603 8062 1233 |
| AESSEAL Nederland. | Telephone: +31 (0) 76 564 9292 |
| AESSEAL Ibérica S.L. | Telephone: +34 977 55 43 30 |
| AESSEAL Danmark, Greve, Denmark. | Telephone: +45 56 64 14 00 |
| AESSEAL France S.A.R.L. | Telephone: +33 (0) 3 2017 2850 |
| AESSEAL Turkiye, Istanbul, Turkey. | Telephone: +90 (0) 212 237 40 47 |
| AESSEAL Canada Inc. | Telephone: +1 807 624 2727 |
| AESSEAL China Ltd. | Telephone: +86 574 8770 1888 |

FOR FURTHER INFORMATION AND SAFE OPERATING LIMITS CONTACT OUR TECHNICAL SPECIALISTS AT THE LOCATIONS BELOW.

THE QUEEN'S AWARDS FOR ENTERPRISE 2000

INVESTOR IN PEOPLE

WINNER OF THE NATWEST SUNDAY TIMES COMPANY OF TOMORROW AWARD

**USE DOUBLE MECHANICAL SEALS WITH HAZARDOUS PRODUCTS. ALWAYS TAKE SAFETY PRECAUTIONS**

- **GUARD YOUR EQUIPMENT**
- **WEAR PROTECTIVE CLOTHING**

**WARNING**

AESSEAL plc
Mill Close
Templeborough
Rotherham
S60 1BZ
United Kingdom

Telephone: +44 (0) 1709 369966
Fax: +44 (0) 1709 720788
E-mail: seals@aesseal.com
Internet: http://www.aesseal.com



AES / DOC / IN 4497 01/2002

Distributed by:

USA Sales & Technical advice:
AESSEAL Inc.
10231 Cogdill Road
Suite 105
Knoxville, TN 37932
USA

Telephone: 865 531 0192
Fax: 865 531 0571



ALL SIZES ARE SUBJECT TO MANUFACTURING TOLERANCES.
WE RESERVE THE RIGHT TO MODIFY SPECIFICATIONS AT ANY TIME.

Reference Issue • L - UK/US - PHOS - 02