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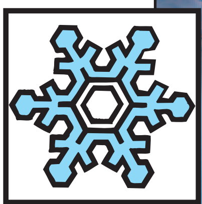
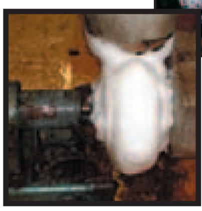
A Guide to Sealing

Cryogenic and Low Temperature Applications





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A GUIDE TO SEALING CRYOGENIC AND LOW TEMPERATURE APPLICATIONS

Introduction

The purpose of this report is to give the reader an appreciation of typical applications and problems encountered when sealing cryogenic and / or low temperature products. The term "cryogenics" can be defined as " the study of low temperatures or the production of the same".

Cryogenics is:

- the study of how to produce low temperatures.
- the study of what happens to materials when you've cooled them down.

Cryogenics is not:

- the study of freezing and reviving people, called "cryonics", a confusingly similar term.

Although cryogenics is often perceived by many to be limited to liquefied gases, it also encompasses low temperature hydrocarbons, refrigerants and coolants, to name a few. Therefore, this report will discuss all applications where the temperature falls below zero degrees Celsius (32 degrees Fahrenheit).

Low temperature applications are found in a many different industries. These will include:

- Pharmaceutical
- Food production
- Brewing
- Chemical
- Refrigeration
- Automotive
- Petroleum
- Textile
- Electronics
- Aerospace

The list above is not exhaustive, but gives the reader an appreciation of potential markets for mechanical seals sealing low temperatures. It is beyond the scope of this report to detail every possible application. Instead the author will discuss the most commonly encountered applications, and suggest suitable sealing solutions.

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Safety & Environmental Issues

Everyone who works with cryogenic liquids (also known as cryogens) must be aware of their hazards and know how to work safely with them. There are four groups of health hazards associated with cryogenic liquids: extreme cold, asphyxiation, toxicity and flammability.

Extreme Cold Hazard: Cryogenic liquids and their associated cold vapours and gases can produce effects on the skin similar to a thermal burn. Brief exposures that would not affect skin on the face or hands can damage delicate tissues such as the eyes. Prolonged exposure of the skin or contact with cold surfaces can cause frostbite. The skin appears waxy yellow. There is no initial pain, but there is intense pain when frozen tissue thaws. Unprotected skin can stick to metal that is cooled by cryogenic liquids. The skin can then tear when pulled away. Even non-metallic materials are dangerous to touch at low temperatures. Prolonged breathing of extremely cold air may damage the lungs.

Asphyxiation Hazard: When cryogenic liquids form a gas, the gas is very cold and usually heavier than air. This cold, heavy gas does not disperse very well and can accumulate near the floor. Even if the gas is non-toxic, it displaces air. When there is not enough air or oxygen, asphyxiation and death can occur. Oxygen deficiency is a serious hazard in enclosed or confined spaces. Small amounts of liquid can evaporate into very large volumes of gas. For example, one litre of liquid nitrogen vaporises to 695 litres of nitrogen gas when warmed to room temperature.

Toxic Hazards: Each gas can cause specific health effects. For example, liquid carbon monoxide can release large quantities of carbon monoxide gas, which can cause death almost immediately. Refer to the customers material safety data sheet for information about the toxic hazards of a particular cryogen.

Flammability: Several types of situations exist that may result in a flammability hazard including: fire, oxygen-enriched air, liquid oxygen, and explosion due to rapid expansion.

a) Fire Hazard: Flammable gases such as hydrogen, methane, liquefied natural gas and carbon monoxide can burn or explode. Hydrogen is particularly hazardous. It forms flammable mixtures with air over a wide range of concentration (4 percent to 75 percent by volume). It is also very easily ignited.

b) Oxygen-Enriched Air: Liquid hydrogen and liquid helium are both so cold that they can liquefy the air they contact. For example, liquid air can condense on a surface cooled by liquid hydrogen or helium. Nitrogen evaporates more rapidly than oxygen from the liquid air. This action leaves behind a liquid air mixture which, when evaporated, gives a high concentration of oxygen. This oxygen-enriched air now presents all of the same hazards as oxygen.

c) Liquid Oxygen Hazard: Liquid oxygen contains 4,000 times more oxygen by volume than normal air. Materials that are usually considered non-combustible, (such as Carbon, Stainless Steels, Cast Iron, Aluminium, Zinc and Teflon / PTFE) may burn in the presence of liquid oxygen. Many organic materials can react explosively, especially if a flammable mixture is produced. Clothing splashed or soaked with liquid oxygen can remain highly flammable for hours. The Oxygen content in air only needs to rise by a few percent for spontaneous ignition to occur.

d) Explosion Due to Rapid Expansion: Without adequate venting or pressure-relief devices on the containers, enormous pressures can build up. The pressure can cause an explosion called a "boiling liquid expanding vapour explosion" (BLEVE). Unusual or accidental conditions such as an external fire, or a break in the vacuum which provides thermal insulation, may cause a very rapid pressure rise. The pressure relief valve may not be able to handle this increased pressure. Therefore, the containers must also have another backup device such as a frangible (bursting) disc.

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Therefore, always observe the following points when working with low temperatures and refer to local site practices:

- Store and work with cryogenic liquids in a well-ventilated area to avoid asphyxiation.
- Safety glasses and face shields should be used.
- For handling of cryogenic liquids, use potholders instead of gloves (as gloves can freeze to the skin).
- Lab coat or overalls are advisable to minimise skin contact.
- Wear trousers over shoe or boot tops to prevent shoes filling in the event of a spillage.
- Cushion glassware in a protective covering to prevent injury caused by flying glass in the event of implosion or explosion.
- Transport fragile cryogenic containers with caution.

All staff using or handling cryogenic liquids must receive training which includes care, selection and use of protective equipment, hazards associated with their use and emergency procedures.

What are Low Temperatures?

Any thermofluid text will relay that the freezing point of water is 0 degrees Celsius (32 degrees Fahrenheit) at atmospheric pressure. However, temperature can be expressed in a number of ways. Besides the familiar temperature scales of Fahrenheit and Celsius (Centigrade), cryogenicists use other temperature scales, the Kelvin and Rankine temperature scales. Geographical standards may play a part in the scales with which you are most familiar, but it is important for the engineer to have an appreciation of the different units and how they relate to each other. Incidentally, at -40 the Celsius and Fahrenheit are comparatively equal. Tables 1 and 2 below clarify how the different units can be converted as well as their relative comparisons:

Temperature Conversion		
From	**To**	**Formula**
Fahrenheit	Celsius	(F - 32) ÷ 1.8
Fahrenheit	Kelvin	(F + 459.67) ÷ 1.8
Fahrenheit	Rankine	F + 459.67
Rankine	Kelvin	R ÷ 1.8
Rankine	Celsius	(R - 491.67) ÷ 1.8
Rankine	Fahrenheit	R - 459.67
Celsius	Fahrenheit	(1.8 x C) + 32
Celsius	Rankine	(1.8 x C) + 491.67
Celsius	Kelvin	C + 273.15
Kelvin	Rankine	1.8 x K
Kelvin	Fahrenheit	(1.8 x K) - 459.67
Kelvin	Celsius	K - 273.15

Table 1 - Temperature Conversions

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	Fahrenheit	Rankine	Kelvin	Celsius
Boiling Point Water	212 ºF	671.67 ºR	373.15 K	100 ºC
Freezing Point Water	32 ºF	491.67 ºR	273.15 K	0 ºC
	0 ºF	459.67 ºR		
	-459.67 ºF	0 ºR	0 K	-273.15 ºC

Table 2 - Relative Temperature Comparisons.

The freezing point of a fluid can be radically altered by the application of pressure. To demonstrate this, consider the case of an ice skater. Let's guess that the weight is about 110 lbs. The skates have a blade that is about 1/8" wide and 8" long, so each skate has an effective surface area touching the ice of about 1 square inch. Even when skating with both feet on the ice, an effective force is applied of 55 pounds per square inch to the ice. The effect of this is to melt the ice beneath the skates so that moving along they ride on a film of water that immediately refreezes (because the pressure is released) when they move past. Effectively, the ice skater has lowered the freezing point of water by the application of pressure.

The amount of contaminants in the product can also lower the freezing point. For example, the application of salt to ice and snow in winter has the effect of melting it. This is because the ice has dissolved a suitable amount of the salt and the freezing point of the new solution has been lowered accordingly. Therefore, it returns to a liquid.

Problems Associated with Sealing Low Temperatures

A cryogenic seal is a long-established name for any mechanical seal that is sealing a product with a temperature below 0 degrees Celsius. Unfortunately, low temperature products create a number of problems for conventional mechanical seals. These problems are highlighted below:

- Whilst rarely presenting a problem with corrosion, cryogenic fluids are often dangerous. This has been extensively highlighted in the previous section on "safety and environmental issues".

- In many cases the application temperature will be too low for conventional elastomeric o-rings. In such a case, special attention may need to be given to the seal design to select an alternative method of sealing. This is one branch of engineering where elastomer selection is key.

- Many cryogenic fluids are poor lubricators, and since mechanical seals rely on the successful creation of a fluid film, this can create problems for conventional mechanical seal face materials. Poor lubrication can lead to "slip-stick" vibration problems and this should be addressed through the correct selection of materials and, if necessary, adequate damping.

- On an extreme cryogenic duty the seal faces and associated components must be dried prior to installing the seal. The presence of any lubricant or moisture may lead to the faces freezing together. This can create problems due to the seal faces shearing or shattering on machinery start-up.

- Cold applications tend to freeze any moisture present in the surrounding area. Since mechanical seals are the junction between the sealed fluid and atmosphere, then it is natural that any space within the seal that is not immersed in the liquid may also freeze. This can present a problem for mechanical seals that have springs located out of the sealed product. Other problem areas arise where the rotating and stationary components are closely located, for example the clamp ring and the gland.

- Differential expansion and contraction may cause an inserted face to become loose or distorted in the holder. Therefore, special attention needs to be given to the face design and / or holder materials of construction.

In some parts of the world, equipment will operate in sub-zero atmospheric conditions for many months of the year. These situations require special attention to ensure that all factors of the application are considered.

Material Selection

When specifying any mechanical seal, selecting the correct materials for a given application is paramount. Cryogenic seals are no exception. Their suitability for a certain low temperature duty is directly reliant on the materials of construction. Each of the materials of construction will have their own lower service temperature limit. The following section discusses how the materials of construction of each component of a mechanical seal can influence successful sealing. Each of the standard materials of construction used by AESSEAL® will be discussed and their relative merits highlighted. As well as the main items of elastomers and seal faces, the low temperature can dictate the not so obvious, and often overlooked, items such as gasket material and lubricants.

Seal Faces

As well as considering the suitability of a face material for use in a low temperature environment, the reader should also consider other aspects of the application. For example, the application may be abrasive. In such cases Carbon may not be suitable. The chemical resistance of the face should also be considered. Will the product corrode the face material or the binder? The reader should also be aware that the seal faces will generate heat due to friction. This may present a problem if the product is close to vaporisation. Although each face is initially discussed in isolation, table 3 shows the suitability for use when paired with other materials.

Carbon: Carbon Graphite is naturally a self-lubricating material. It is also one of the most widely used seal faces, where no abrasives are present in the product. We have already highlighted that many cryogenic fluids are non-lubricants. This in itself can create a problem for standard resin-impregnated grades of Carbon in that the release of Graphite cannot readily take place. Moisture must be present for this release to take place. This can hinder the successful creation of a fluid film.

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Seals utilising resin impregnated Carbons that have failed prematurely on cryogenic duties exhibit a failure mode that can only be described as "blistering". At first glance, it would seem strange that a seal face could blister in a cold environment. However, the lack of a stable fluid film, and the hindered release of the Graphite lubricator from the Carbon, could equate to dry-running conditions. It is possible to adopt a different pattern of thought to this. The resin binder in the impregnation may become brittle and brake up due to the extreme temperature. For whatever reason, standard resin impregnated Carbon grades have a temperature limitation due to a phenomenon that the author refers to as "Cryogenic Blistering".

Antimony impregnated grades do not appear to suffer from this problem to quite the same extent. However, Antimony impregnated grades should not be used in Food and Pharmaceutical applications, as Antimony is a recognised poison. The solution of "Cryogenic Blistering" is solved by the use of special grades of Carbon that contain organic matter. This is commonly a mixture containing Molybdenum Disulphide that will allow the release of the Graphite lubricator. Essentially these are dry-running Carbon grades and, in the right environment, can be used to seal extreme temperatures. The two Schunk grades below are recommended for use in a cryogenic application:

- o FH71Z5 AESSEAL® standard dry-running Carbon grade
- o FH71A Antimony impregnated version of the above – made to order only.

Silicon Carbide: Although widely used throughout the mechanical seal industry, Silicon Carbide is inherently brittle due to notch ductility sensitivity. The presence of low temperature would only compound this problem. For this reason alone, Silicon Carbide should be avoided in a cryogenic environment unless no other face material is suitable. Silicon Carbide would normally only be selected for chemical resistance when Tungsten Carbide is not suitable.

Teflon: Initially developed by NASA for the low temperatures experienced in space. Although not as hard as Carbon, a PTFE faced rotary could be substituted for Carbon. This face may be preferred in the Food and Pharmaceutical industries, and in applications where the presence of Carbon would be unacceptable.

Chrome Oxide: This material offers no technical advantage for use in a cryogenic environment. The Food and Pharmaceutical industries do not allow the use of plated materials, due to the possibility of the coating becoming detached. Chrome Oxide should be avoided in a cryogenic environment because there are superior materials.

Ceramic: Alumina Ceramic is chemically inert in its pure form. Due to the fact that Ceramic is an insulator, it is normally limited to moderate speed and pressure duties involving water based applications. However, in certain conditions this could be advantageous. Providing that the product is not close to its vaporisation point, the additional heat retained by the material may assist the surrounding elastomers and mating face. Under the right conditions this could be used for cryogenic applications.

Tungsten Carbide: Although not as chemically resistant as Silicon Carbide, it has many advantages as a seal face material. It is rugged and can resist vibration and mechanical shock. It is highly suited for use in many cryogenic applications, even to extreme temperatures. It is likely that the reason Tungsten Carbide is suitable for cryogenic service is because the Nickel binder retains many of the desirable properties.

Face combinations: Based upon the information above, several face combinations appear to be more suited for use in low temperatures. However, the key to successful sealing is to change the environment in which the seal is operating. If this can be achieved, other face combinations may be used with success. Table 3 below shows the recommended face combinations and their lower service temperature. This should be used as a guide only and the reader should always check the chemical resistance, local site knowledge and actual application details.

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Face Combination	Recommended Lower Service Temperature (deg.C)	Notes
Carbon v Ceramic	> - 35	Suitable for use in a single seal in water based, non toxic environments.
Carbon v Tungsten Carbide	> - 25	Can be used for the inboard seal faces of a double seal providing that a suitable barrier fluid is used. Suitable for many situations. Can be substituted for Antimony Carbon.
Teflon / PTFE v Ceramic	> - 35	Suitable for use in a single seal in water. based, non toxic environments.
Teflon / PTFE v Tungsten Carbide	> - 30	Suitable for use in a single seal in water based, non toxic environments.
Molybdenum Disulphide Carbon v Tungsten Carbide	> - 200	This would be a preferred face combination and can be used to extreme temperatures in the right environments.
Tungsten Carbide v Tungsten Carbide	> - 200	This would be a preferred face combination and can be used to extreme temperatures in the right environments.

Table 3 – Face Combination Lower Service Temperature Limits.

For actual applications and recommendations, refer to the section on typical products.

Elastomers and O-Rings

Traditional elastomers undergo a glass transition at low temperatures. For standard rubber grades, such as Nitrile, this point is reached between –30ºC and –40ºC. As the rubber passes through the glass transition, it becomes brittle and any additional stress on the material may cause cracking. However, the embrittlement is reversible and as the rubber returns to room temperature it will regain flexibility. This would make troubleshooting a problematic seal extremely difficult from an elastomer failure point of view, since the investigation would take place at room temperature.

Each elastomer has a lower service temperature limit and these can be seen in table 4. For clarity, the o-ring materials have been arranged by the lowest service temperature resistance.

O-RING MATERIAL	LOWER SERVICE TEMPERATURE (deg.C)	COMMENTS
PTFE wedges / rings	-250	AESSEAL® standard supply
Graphite Wedges / rings	-200	AESSEAL® standard supply
F.E.P. - Silicone core	-62	AESSEAL® standard supply
Silicone	-60	Supplied to order only
Fluorosilicone	-60	Supplied to order only
EPR peroxide cured E692-75	-57	AESSEAL® standard supply
EPR FDA E300-70	-54	FDA grade, supplied to order only
Nitrile	-40	AESSEAL® standard supply
Neoprene	-40	Supplied to order only
Viton V680-70	-26	FDA grade, supplied to order only
F.E.P. - Viton core	-23	Supplied to order only
Kalrez 4079	-20	AESSEAL® standard supply
Kalrez 6375	-20	AESSEAL® standard supply
Kalrez 7075	-20	Currently supplied to order only
Viton 51414 E60C	-15	AESSEAL® standard supply
Aflas	0	AESSEAL® standard supply

Table 4 – Lower Service Temperature of Elastomers / O-Rings.

Table 4 shows that at the extreme end of the scale, only Graphite or PTFE based o-rings should be used. The lowest service temperature of any commercially available elastomeric compound is that of Silicone, although special compounds of other materials are available that may be marginally lower than this. It is worth noting that the seal chamber may be at a higher temperature than the actual pumped product. Therefore, the actual temperature that the seal will be subjected to should be sought.

In every case, the chemical compatibility of the material should be checked with the product. The end-user site may be able assist with this. The guide below, table 5, details typical low temperature products found throughout industry and compatible o-rings. This should be used in conjunction with the temperature guide in table 4.

Product	Compatible O-Ring for Low Temprature	Product	Compatible O-Ring for Low Temprature
Ammonia + Mineral Oil	Neoprene	Freon 152A	Nitrile, Neoprene
Anhydrous Ammonia	EPR, Neoprene	Freon 21	FEP
Aqueous Ammonia 33%	EPR, Neoprene, Nitrile	Freon 218	Nitrile, Neoprene
Brine (Calcium Chloride)	EPR, Nitrile, Neoprene, Viton	Freon 22	Neoprene, EPR
Brine (Copper Chloride)	EPR, Nitrile, Viton	Freon 22 with Oil	FEP
Brine (Sodium Chloride)	EPR, Nitrile, Viton	Freon 31	Neoprene, EPR
Dichloroethane 85%	FEP, Viton	Freon 32	Nitrile, Neoprene
Dowtherm SR1	Nitrile, Viton, FEP	Freon 502	Neoprene
Ethane	Nitrile, FEP, Viton	Freon C316	Nitrile, Neoprene
Ethanol (aqueous solution)	EPR, Neoprene, Nitrile	Freon C318	Nitrile, Neoprene
Ethyl Alcohol	EPR, Neoprene, Nitrile, Viton	Freon T-P35	Nitrile, Neoprene
Ethylene	Nitrile, Viton	Glycerine	EPR, Neoprene, Nitrile, Viton
Ethylene Glycol	EPR, Nitrile, Neoprene, Viton	Industrial Methylated Spirit (I.M.S.)	EPR, Nitrile
Freon 11 (Freon MF)	Nitrile	Kerosene	Nitrile, Viton, FEP
Freon 11 with Oil	Nitrile, Neoprene	Liquid Nitrogen	PTFE
Freon 112	FEP	Liquid Oxygen	PTFE
Freon 113	Nitrile, Neoprene	Liquefied Carbon Dioxide Gas	FEP, Nitrile
Freon 113B1	Nitrile, Neoprene	Methane Gas	Nitrile, Viton, FEP
Freon 114	Nitrile, Neoprene	Methanol 40%	EPR, Nitrile, Neoprene
Freon 114B2	Neoprene	Methyl Acetate	FEP
Freon 115	Nitrile, Neoprene	Methyl Ethyl Ketone	EPR, FEP
Freon 12	FEP	Methylene Chloride	FEP
Freon 12 with Oil	Nitrile, Neoprene	Propane	Nitrile, FEP, Viton
Freon 13	Nitrile, Neoprene	Propyl Alcohol	EPR, Neoprene, Nitrile, Viton
Freon 13B1	Nitrile, Neoprene	Propylene Glycol	EPR, Nitrile, Viton
Freon 14	Nitrile, Neoprene	Toluene	Viton, FEP
Freon 142B	Nitrile, Neoprene		

Table 5 – Elastomer Compatibility chart.

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Gaskets

Another, not so obvious, material to consider is the gasket. For a low temperature duty, the successfully sealing of a gasket is largely dependent on a number of factors. The following points should be observed:

- The gasket should be completely dry when installed.
- The seal should be installed at ambient temperature.
- Both the gland material and the bolt material should be capable of functioning at the low temperature.
- The gasket should NOT be re-torqued at low temperature.

Providing that the above practices are adopted, table 6 below summarises the standard AESSEAL® offerings and their suitability for use in low temperatures. Again, chemical resistance should also be checked with the process fluid.

GASKET MATERIAL	LOWER SERVICE TEMPERATURE (deg.C)	COMMENTS
Gylon gaskets	-268	Supplied to order only
GFT 25% glass filled Teflon	-200	AESSEAL® optional gasket
Pure PTFE gasket	-200	AESSEAL® optional gasket
Graphite SLS gaskets	-200	AESSEAL® optional gasket
AF1 Reinz AFM30	-45	AESSEAL® standard gasket

Table 6 - Gasket Lower Service Temperature Limits.

Metallurgy

Metals must be carefully selected for cryogenic service because of the drastic changes in the properties of materials when exposed to extreme low temperatures. Materials, which are normally ductile at atmospheric temperature, may become extremely brittle once exposed to cryogenic temperatures. The materials will also shrink beyond the values normally encountered and leaks can develop that are not detectable at room temperature.

Some suitable metals include Stainless Steel (300 series), Copper, Brass, Bronze, Nickel based alloys, Monel and Aluminium. Once appropriate materials are selected, the method of joining them must be considered to ensure that the desired performance is preserved through proper soldering, welding, brazing or other techniques. Finally, chemical reactivity and compatibility between the fluid and the material must be considered. The designer should consider, for example, the use of anti-sparking materials in certain liquefied gases.

The recommended metals for use in mechanical seals are discussed below:

Stainless Steels: Austenitic Stainless Steels (304, 316) have a unique combination of properties which make them useful at cryogenic temperatures. These steels, at cryogenic temperatures, have tensile strengths substantially higher than at ambient temperature while their toughness is only slightly degraded. Typical austenitic stainless steels used for mechanical seal components include grades such as 304, 316 and their low Carbon equivalents, 304L and 316L.

Ferritic (410S, 430 & 446), martensitic (420, 461) and precipitation hardening (17/4PH) steels are not recommended for use at sub-zero temperatures as they exhibit a significant drop in toughness even at only moderately low temperatures, in some cases not much below room temperature.

The duplex stainless steels (1.4462) have better low temperature ductility than the ferritic and martensitic grades. They are generally quite useable down to at least -50°C, which therefore usually places a lower temperature limit on their usefulness.

Inconel 625: Inconel Nickel-Chromium alloy 625 is widely regarded as having high strength and toughness even at cryogenic temperatures. A typical chemical composition is shown on the next page:

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Nickel 58.0% min
Chromium 20.0 – 23.0%
Iron 5.0% max.
Molybdenum 8.0 – 10.0%
Columbium & Tantalum 3.15 – 4.15%
Carbon 0.10% max.
Remainder: Manganese, Silicon, Phosphorus, Sulphur, Aluminium, Titanium and Cobalt.

Inconel 625 has the added benefit of having thermal expansion rates equivalent to that of traditional seal face materials. This would make the material highly suited for use as a seal face holder to temperatures approaching -196ºC.

Inconel 718: Inconel 718 is an age-hardenable Nickel-Chromium alloy having exceptionally high tensile, yield, creep and rupture strength. It is described as having excellent cryogenic properties down to -217ºC. A typical chemical composition is shown below:

Nickel 50.0 – 55.0% min
Chromium 17.0 – 21.0%
Molybdenum 2.8 - 3.3%
Columbium & Tantalum 4.5 – 5.75%
Carbon 0.10% max.
Remainder: Iron, Manganese, Silicon, Copper, Aluminium and Titanium

Inconel 718 is used extensively as a bellows convolution material for both high and low extremes of temperature.

Alloy 276: Alloy 276 is a versatile corrosion resistant Nickel based super-alloy with good cryogenic notch toughness, even at temperatures approaching -196ºC. The main constituents of Alloy 276 are Nickel (57.0%), Chromium (14.5 – 16.5%) and Molybdenum (15.0 – 17.0%). Alloy 276 has the benefit of having a closer thermal expansion / contraction rate to traditional seal face materials than stainless steels. This would make it a good choice for a rotary holder material for use in a cryogenic atmosphere.

Monel 400: Monel Nickel-Copper alloy 400 is widely used in many fields. It has excellent mechanical properties at sub-zero temperatures. Strength and hardness increase with only a slight impairment of ductility or impact resistance. The alloy does not undergo a ductile-to-brittle transition even when cooled to the temperature of Liquid Hydrogen (-253ºC). Its main constituents are Nickel (63.0%) and Copper (28.0 – 34.0%). Its use within a mechanical seal would be limited to product wetted parts where Alloy 276 is unsuitable.

Lubricants / Greases

Another factor to consider in the assembly of a mechanical seal for cryogenic duties is the use of grease or lubricant. As a general rule, their use should be avoided at low temperatures, because of the possibility of freezing. In fact any moisture or lubrication on the seal faces, o-rings, and gasket may lead to the failure of the seal. When building a seal for cryogenic use the following points should be observed:

- All seal parts should be assembled without the use of grease or lubricants.
- Assembly should take place in a clean environment, free of dust and contaminants.
- The assembler should wear suitable gloves to ensure no oil contact from the skin.
- Seals should not be water pressure tested, as this will remain in the seal cavity.
- Use with certain liquefied gases, such as Liquid Oxygen, will require the seals to be cleaned to recognised standards.

Table 7 details the commonly used AESSEAL® greases and lubricants and their recommended lower service temperature.

Grease	Lower Service Temperature (deg.C)	Comments
Molykote 111	-40	FDA compliant grease
Mobilgrease FM462	-20	Low speed Mixer bearing grease FDA compliant
Mobilgrease FM102	-20	High speed Mixer bearing grease FDA compliant
Molykote 55M	-65	General standard seal grease sent with seals in sachets
M2-WPG 2104 Silicon Grease	-40	General assembly grease

Table 7 – AESSEAL® Standard Greases and Lubricants.

Seal Selection

When selecting a mechanical seal design for use in a low temperature environment, a number of key design elements should be addressed:

Face type: The use of a stainless steel shrink-fitted rotary should be avoided. This can lead to face rotations due to the different thermal contraction rates of the face holder and insert. The use of an alternative rotary holder material can solve this problem to an extent. This has been extensively proven by the use of bellows seals in high temperature applications. There is no reason why the same principle cannot be applied to sub-zero temperatures. The use of Alloy 276, Alloy 42 and other low expansion alloys would therefore offer a solution. The other alternative is to eliminate the shrink-fit altogether by utilising a seal design with either a monolithic seal face or a design that features a crimped insert.

Spring position: It is widely regarded in many applications that it is an advantage to position the springs out of the sealed product. This is to ensure that they are operating in a clean environment and their movement cannot be hindered. Cryogenics is one application where this is not necessarily true. If the springs are positioned on the atmospheric side of the seal, it is possible for the moisture in the surrounding air to freeze, forming ice. This may then cause the springs to hang-up, and consequently, the seal to fail.

Reduce elastomer usage: These are the main hurdles for standard mechanical seals. Wherever possible they should be eliminated. Typical ways are:

a) Wedges
b) Metal bellows
c) Stepped shafts
d) Gaskets

The bellows design shown in figure 8 utilises many of these key items to produce a design without conventional elastomers.

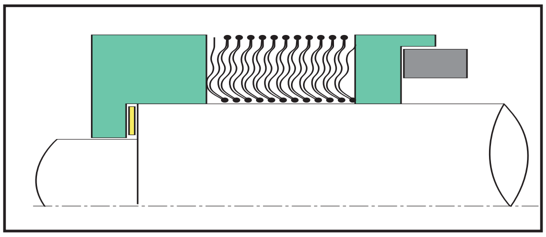

Figure 8 – Typical Rotary Bellows Design Without Elastomers.

Certain seal designs are naturally suited for use in low temperature environments. Unfortunately, many of the standard AESSEAL® seal designs are not suited to the extreme temperatures often encountered in liquefied gas duties. However, there are many applications where certain designs can be used successfully. In many cases the equipment design will directly influence the choice of seal. This will be discussed in more detail in the section on equipment.

The following paragraphs discuss the relative merits of various AESSEAL® designs for use in cryogenic duties.

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CRYOGENIC INDUSTRY

SINGLE SPRING DESIGNS

The majority of these designs are used internally and so will not suffer from the springs freezing on the atmospheric side. Enclosed bellows designs would not be suitable because of the potential for the rubber bellows to tear, as they become brittle at low temperature. The PO-series may be used with certain success in brine applications down to –30° Celsius, with a Carbon face running against a suitable Ceramic faced stationary seat.

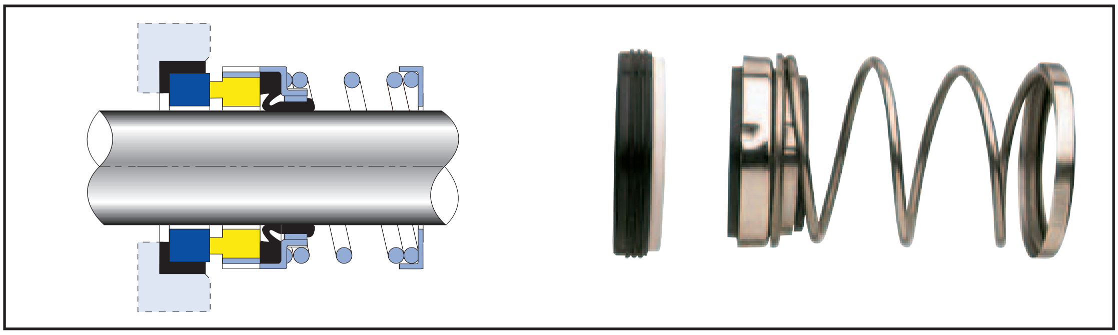

Figure 9 – The P01™ Internal Seal Design.

O-ring designs have the limit of elastomer service temperature, but the M0-series of seals with a PTFE wedge represent an interesting choice. They have the benefit of a crimped monolithic face and so eliminate the problem of face rotations. However, these may be limited by the availability of face materials. With the correct seal face, and the option of a graphite wedge, the MO-series could be adapted for much lower cryogenic service.

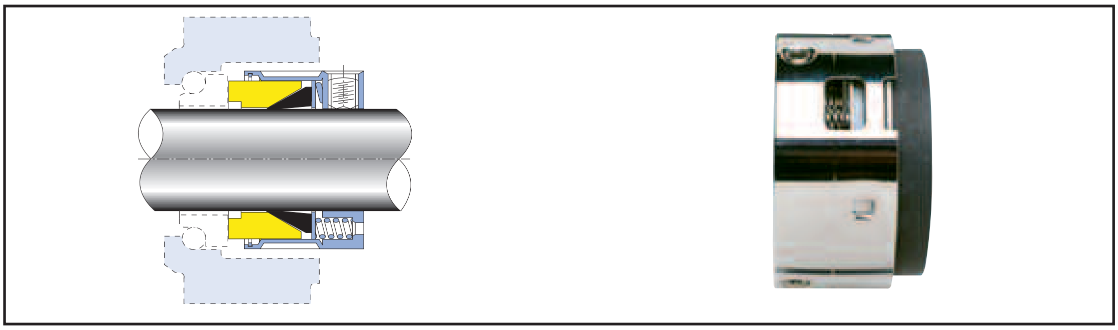

Figure 10 – The M03™ Internal Seal Design.

CS™/NCE™

These seals are normally mounted externally and could suffer from the problem of the springs freezing in the surrounding atmosphere. However, the external distance from the product to the springs on a CS™ is quite large, and may ensure that the springs don't freeze. The seal features a shrink-fitted face and so success will be limited to applications that are water based down to –30ºC. A suggested face combination would be Carbon v Ceramic T-Shaped stationary to maintain as much localised heat as possible and stop the Carbon face from blistering.

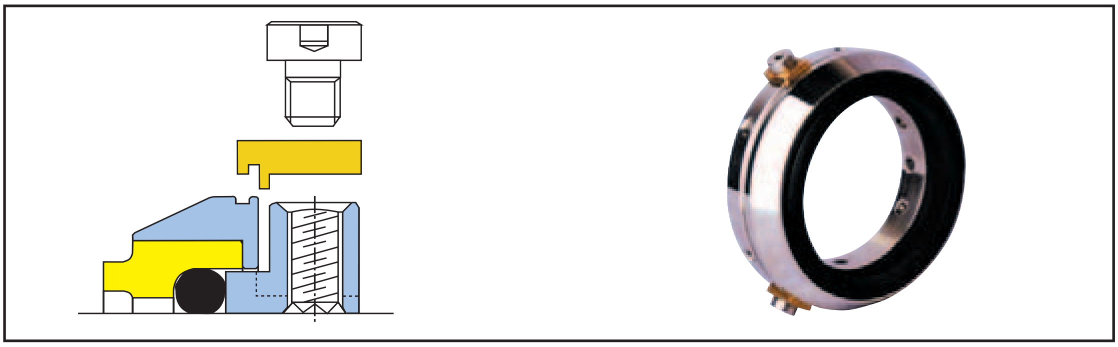

Figure 11 – The CS™ External Seal Design.

SAI™ / CONVERTER II™ / SCUSI™ / CURC™ / CDSA™ & VARIANTS

These seal designs have a number of features that make them unsuitable for cryogenic service. Firstly, they are shrink-fitted designs and, at low temperature, face rotations will become a problem. The use of an exotic rotary holder may partially alleviate this. The next problem would be the springs out of the sealed product and barrier fluid on the CDSA™ design. This may lead to the moisture in the surrounding atmosphere freezing, to form ice. This would cause the springs to hang-up. Figures 12 and 13 below highlight the areas of concern.

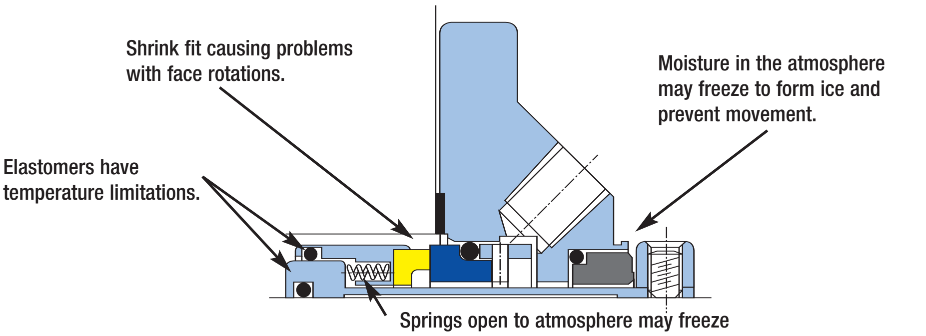

Figure 12 – Low Temperatures and the CURC™ Design.

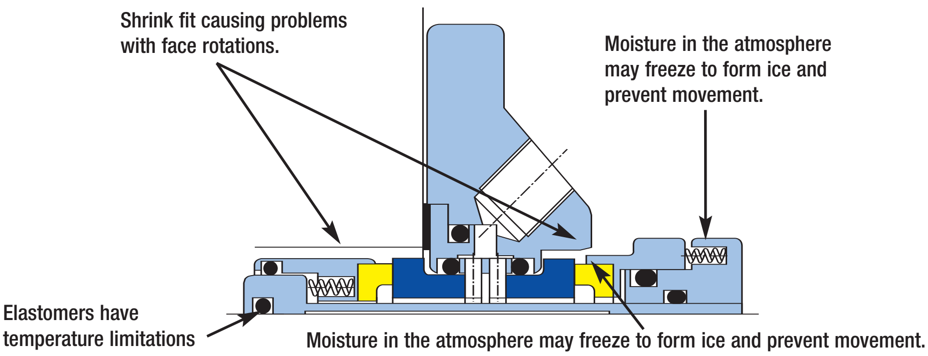

Figure 13 – Low Temperatures and the CDSA™ Design.

Having considered all this, there are isolated instances where these designs have been used with success at marginally cryogenic temperatures. The use of a flush (API plan 11, 13 or 32) or a warmed barrier fluid (API plan 53, 54 or 62) may assist their use.

SMSS™

The monolithic faces of the SMSS™ design eliminate the problems associated with a shrink fit. However, the springs are located out of the product. Providing that the application is within the limits of the elastomer, the SMSS™ can be used on a variety of duties. Tungsten Carbide v Tungsten Carbide seal faces are recommended. Wherever possible, the seal should be assisted by the use of a flush (API plan 11, 13 or 32), as this will serve to agitate the fluid and prevent freezing.

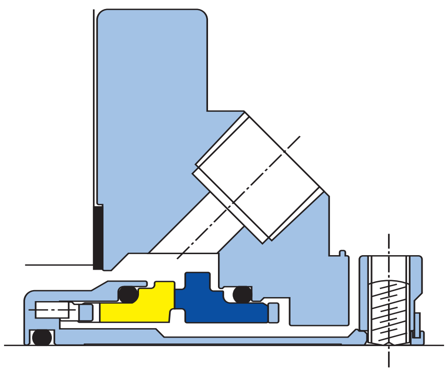

Figure 14 – The Single Monolithic SMSS™ Design.

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DMSF™ / DMSC™

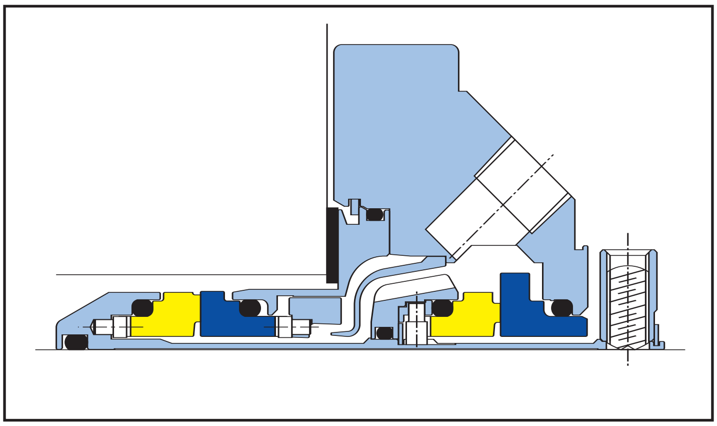

Figure 15 – The Double Monolithic DMSF™ Design.

This design has many notable features making it suitable for use in cryogenic duties.

- Monolithic faces eliminate face rotation problems caused by a shrink-fit.
- Springs are located within the barrier fluid which, providing that the correct barrier fluid medium is chosen, should always be liquid.
- Increased heat generation and an integral pumping scroll will help to resist the formation of ice.
- Wide choice of face materials ensuring that each application is catered for.

BELLOWS DESIGNS

Bellows designs are extensively used on liquefied gas cryogenic duties. The main benefit is that they can all but eliminate the use of elastomers. The majority of AESSEAL® Bellows designs incorporate elastomers, but designs such as the BSFG™ and BSAI-G™ have none.

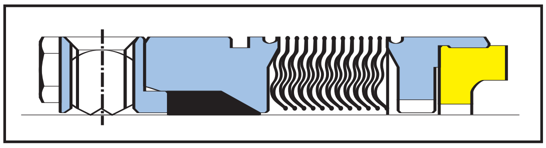

Figure 16 – The BSAIG™ Design.

Instead they rely on the use of graphite wedges, gaskets and sealing rings. The metal bellow also replaces the multiple springs of a conventional mechanical seal design and is located inside the product. Since this should always remain in the liquid state, there should be no problems with hang-up due to freezing. The correct bellows head materials can be selected for the cryogenic duty to ensure good strength and toughness and to eliminate face rotations. A typical bellows head material for cryogenic use would be a 316L Stainless Steel end cap, an Inconel 718 bellows and an Alloy 42 face holder (S7C). Suitable face materials may be Molybdenum Disulphide bonded Carbon v Tungsten Carbide, or Tungsten Carbide v Tungsten Carbide.

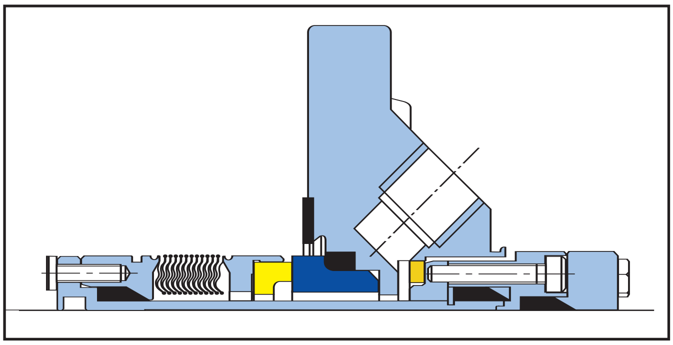

Figure 17 – The BSFG™ Design.

Whilst the current AESSEAL® bellows range is not primarily designed for cryogenic use, the necessary design features and principles are there to be seen. Please see the section on equipment for a typical cross section of a bellows seal for use in a cryogenic environment.

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Barrier Fluid Systems

System

Whenever a double seal is specified for a particular application, a suitable barrier fluid system should be selected to operate with it. AESSEAL® have a number of barrier fluid systems that are suitable for use in a cryogenic environment. In many applications the AESSEAL® SSE10™ systems are appropriate, because removal of excess heat is not normally a problem. Instead, the system will be utilised to:

a) Maintain the correct operating pressure.
b) Ensure that the seal faces are lubricated.
c) Provide early warning of seal failure.
d) Ensure that the product cannot escape to atmosphere.

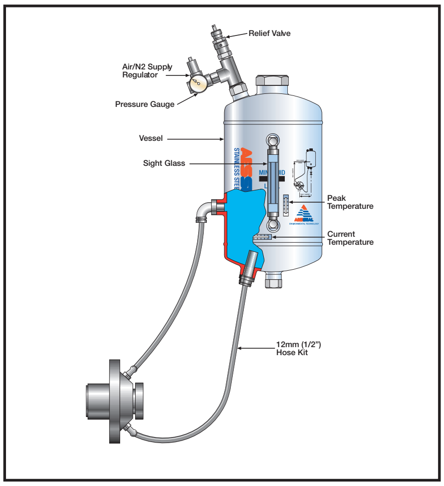

Diagram 18 – The AESSEAL® SSE10-P2 Thermosyphon Vessel.

Any auxiliary equipment to compliment the vessel should be selected according to site standards. It is recommended that each and every portion of the cryogenic system have uninterruptible pressure relief. Any part of the system that can be valved off from the remainder must have separate and adequate provisions for pressure relief. On extreme duties, it may also be wise to hard-pipe the system.

A basic starting point would be the SSE10-P2 system operating with a Nitrogen or air pressurised barrier fluid. The basic system is shown in diagram 18.

A Nitrogen pressurised system has been selected over a water management based system, i.e. the SSE10-W2, as this would have the potential to freeze in a cryogenic application. However, on marginally cold duties, the newly developed "Freeze Fuse" system may be of use where a Nitrogen source is not available. This can only be recommended where the process fluid is at, or around, zero degrees Celsius or where ambient temperature conditions can vary in Winter time. Diagram 19 below shows the principle of the freeze fuse system.

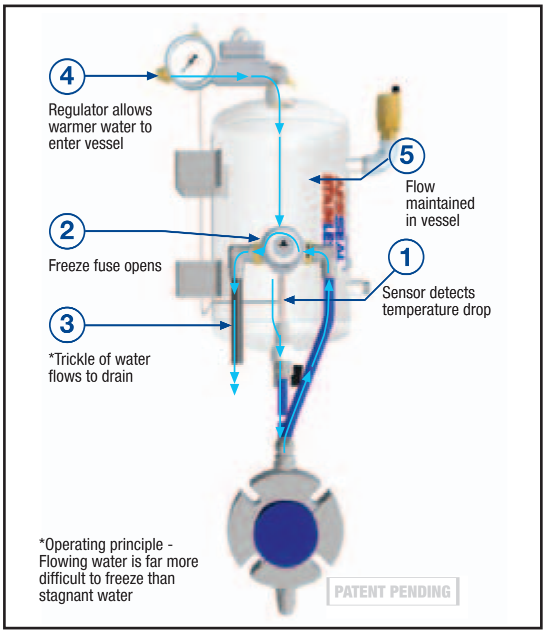

Diagram 19 – The AESSEAL® "Freeze Fuse" System.

The principle of the freeze fuse system is that flowing water is far more difficult to freeze than stagnant water. Once the sensor detects a temperature drop in the barrier fluid, the freeze fuse opens and releases cold water to drain. The regulator will then allow warmer water into the vessel to replace the cold water. The constant replenishment of warmer water will prevent the barrier fluid, and more importantly the seal inlet and return lines, from freezing.

AESSEAL® ENVIRONMENTAL TECHNOLOGY

Barrier Fluid media

Selecting the correct barrier fluid for a particular process is very important, as this will directly influence the success of a particular seal. Any barrier fluid should be pre-mixed before it is poured into the vessel. The following points should be considered when selecting a barrier fluid:

1. It should be compatible with the process fluid so it will not react with it or form gels or sludge when the fluids are intermixed.
2. It should be compatible with the seal metallurgy, elastomers and materials of the seal / system.
3. It should offer good lubrication for the seal faces and heat transfer to and from the vessel.
4. It should be benign to the surrounding environment and not create a further hazard of its own.
5. It should not endanger the workers in the surrounding area.
6. And most importantly in a cryogenic duty, IT SHOULD NOT FREEZE at the operating temperature.

The final point would dictate that the "old favourite", water, should not be used at 100% concentration. Virtually all cryogenic duties will freeze the water in the seal supply lines and vessel. If a barrier fluid in a system or connecting pipework is allowed to freeze, then the first problem is that expansion may fracture or damage the pipework, tank or other items such as pressure gauges. When water freezes to ice, its volume increases, generating enormous stresses on any containing walls. Seal failure would then be imminent. To overcome this problem, engineers have been using various "antifreeze" mixtures to lower the freezing point of pure water. The following text highlights the main barrier fluids used for low temperature applications.

Glycols

Glycols are a large family of chemicals. The two widely used varieties for anti-freeze purposes are Ethylene Glycol and Propylene Glycol. It should be understood that the grades below should be purchased from chemical companies and are often referred to as "industrial" or "chemical" grades. Cheaper automotive or commercial grades should be avoided, as they often contain anti-corrosion additives that can damage mechanical seal faces. Additives and inhibitors should be explicitly avoided.

Ethylene Glycol: Ethylene Glycol (C.A.S. 107-21-1) is a colourless, sweet-tasting liquid which is used primarily as an anti-freeze and in the manufacture of polyester fibre and film. It is an odourless liquid completely miscible with water and many organic liquids. Miscibility is described as the ability of a liquid or gas to dissolve uniformly in another liquid or gas.

Ethylene Glycol is regulated by the Food and Drug Administration as a residual on food. It is toxic by inhalation, ingestion and skin absorption. Listed as a 'toxic chemical' under SARA; 100 ccs is the reported lethal dose. Care is required in handling, and of course used barrier fluid must be properly disposed of.

Ethylene Glycol markedly reduces the freezing point of water. The freezing point of Ethylene Glycol reduces as the concentration increases, but the freezing point begins to increase in higher concentrations beyond 70%. Also, as the concentration increases, the viscosity increases and the heat transfer characteristics are detrimentally affected. This will reduce the effectiveness of a thermosyphon system to the extent that a pumped system may need to be utilised. Table 20 highlights the freezing point of Ethylene Glycol in water.

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EG Conc Wt.% (Vol.%)	Freezing Point, (deg.C)
0 (0)	0
10 (9)	-4
20 (18)	-7
30 (28)	-15
40 (38)	-23
50 (48)	-34
60 (58)	-48
70 (68)	*<-51*
80 (79)	-46
90 (90)	-29
100 (100)	-12

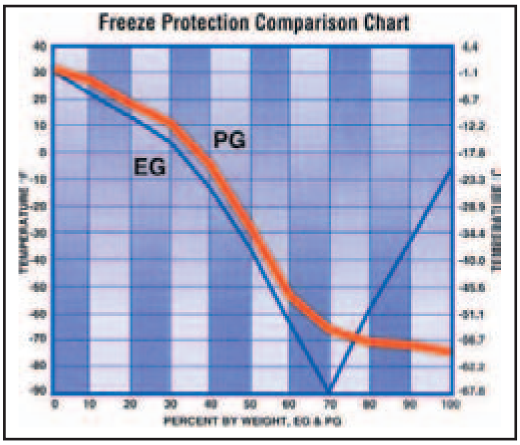
Table 20 - Freezing Point of Ethylene Glycol in Water.

PG Conc Wt.% (Vol.%)	Freezing Point, (deg.C)
0 (0)	0
10 (10)	-4
20 (19)	-7
30 (29)	-12
40 (40)	-21
50 (50)	-34
60 (60)	*-51*
70 (70)	<-51
80 (80)	<-51
90 (90)	<-51
100 (100)	<-51

Table 21 - Freezing Point of Propylene Glycol in Water.

Propylene Glycol: Propylene Glycol (C.A.S. 57-55-6) is an effective antifreeze. It has a variety of uses including solvents in paints and cleaners and use in industrial chiller units. It is clear, colourless and tasteless. It is widely regarded as safe and some grades even carry FDA compliancy. The freezing point of Propylene Glycol reduces as the concentration increases. However, as the concentration increases, the viscosity increases and the heat transfer characteristics are detrimentally affected. This will reduce the effectiveness of a thermosyphon system to the extent that a pumped system may need to be utilised. Table 21 highlights the freezing point of Propylene Glycol in water.

Graph 22 below compares the relative freezing points of both Ethylene and Propylene Glycol at different concentrations.



Graph 22 – Ethylene Glycol v Propylene Glycol.

Glycerine

(C.A.S. 56-81-5) Also known as Glycerol or glycyl alcohol. It is a clear, colourless, non-toxic, hygroscopic liquid, with a sweet taste and syrupy consistency. Glycerine is used as an ingredient in cosmetics, medicines, toothpaste, esters, liquid soaps, tobacco and food products. Because of this, many grades are FDA compliant or GRAS (Generally Regarded As Safe). It is also used extensively as an intermediate in the production of polyester, polyurethane and alkyd resin formulations. It may be used as an anti-freeze where Glycols are unacceptable. Like Ethylene Glycol, the freezing point reduces as concentration increases, up to around 66% concentration. Higher concentrations than this actually have a higher freezing point. Heat transfer characteristics are lost and viscosity increases as concentration increases. Table 23 highlights the freezing point of Glycerine at various concentrations in water.

Glycerine by Wt. (%)	Water (%)	Freezing Point, (deg.C)
0.0	100.0	0.0
5.0	95.0	-0.6
10.0	90.0	-1.6
15.0	85.0	-3.1
20.0	80.0	-4.8
25.0	75.0	-7.0
30.0	70.0	-9.5
35.0	65.0	-12.2
40.0	60.0	-15.4
45.0	55.0	-18.8
50.0	50.0	-23.0
55.0	45.0	-28.2
60.0	40.0	-34.7
65.0	35.0	-43.0
66.7	*33.3*	*-46.5*
70.0	30.0	-38.9
75.0	25.0	-29.8
80.0	20.0	-20.3
85.0	15.0	-10.9
90.0	10.0	-1.6
95.0	5.0	7.7
100.0	0.0	17.0

Table 23 - Freezing Point of Glycerine in Water.

Ethyl Alcohol

(C.A.S. 64-17-5) Also known as Alcohol, Grain Alcohol and Ethanol. It is a colourless, volatile liquid with a freezing point of -117°C. It is soluble in water, methyl alcohol and ether. It is used as a solvent and in the manufacture of dyes, synthetic drugs, synthetic rubber, detergents, cleaning solutions, cosmetics, pharmaceuticals and explosives. It is also used as an anti-freeze, as a beverage and a rocket fuel. As this is a volatile fluid, care must be taken to ensure that the boiling point is not exceeded. Table 24 shows the concentrations of Water / Ethyl Alcohol and the freezing point.

Ethyl Alcohol Vol. % (Wt)	Freezing Point (deg.C)
0 (0)	0
10 (8)	- 4
20 (17)	- 9
30 (26)	- 15
40 (34)	- 23
50 (44)	- 32
60 (54)	- 37
70 (65)	- 48
80 (76)	- 59
90 (88)	*<-73*
100 (100)	<-73

Table 24 - Freezing Point of Ethyl Alcohol in Water.

Propyl Alcohol

(C.A.S. 71-23-8) Also known as Propanol or Isopropyl Alcohol. Normal propanol is made commercially from ethylene and synthesis gas, a mixture of hydrogen and carbon monoxide, in the presence of a rhodium or cobalt catalyst. Propyl alcohol is used to prepare other chemicals, and it is used as a solvent for resins. It boils at 98ºC and freezes at -126ºC. As this is a volatile fluid, care must be taken to ensure that the boiling point is not exceeded. Table 25 shows the concentrations of Water / Propyl Alcohol and the freezing point.

IPA Conc. Vol. % (Wt.)	Freezing Point, (deg.C)
0 (0)	0
10 (8)	- 4
20 (17)	- 7
30 (26)	- 15
40 (34)	- 18
50 (44)	- 21
60 (54)	- 23
70 (65)	- 29
80 (76)	- 37
90 (88)	- 57
100 (100)	*<-73*

Table 25 - Freezing Point of Propyl Alcohol in Water.

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Typical Equipment Used

Rotating equipment used for cryogenic applications can vary according to the duty and temperature range. Research has proven that in the correct environment standard popular centrifugal pump designs can be utilised for many duties. Typical pump designs used for applications down to -50 degrees Celsius include the Durco MK I II & III, Goulds 3196 series, Worthington Simpson, Dean Bros, ABS Scanpump and SIHI Ryland. This is by no means an exclusive list.

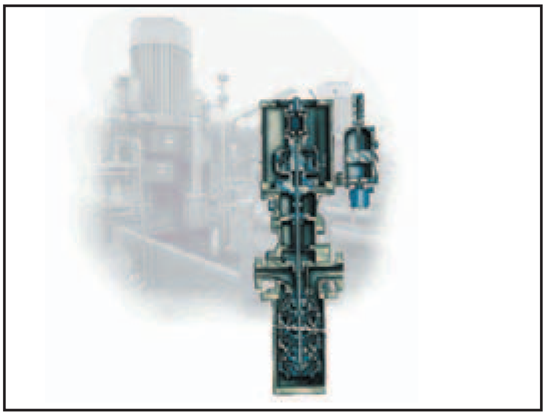

Diagram 26 – The David Brown DB62C Cryogenic Vertical Pump.

As the application temperature falls below –50ºC, there is a trend to use a vertical pump. Typical pump designs in this category include the Sulzer JVCR, JCVA and JHPB models, and the David Brown DB62C. These designs have the advantage that the cold product is isolated from the mechanical seal by a gas chamber. This acts as a thermal buffer to ensure that the mechanical seal will only ever operate in a reasonable temperature environment. As the inboard side of the mechanical seal will be in contact with the gas chamber, a double back-to-back design is used.

The barrier fluid is normally a light oil, supplied by an accumulator system, that can be warmed if necessary. The accumulator system ensures that the barrier fluid is always pressurised in excess of the inboard pressure. Diagram 26 shows a David Brown DB62C arrangement.

The exceptions to the above are mobile road tanker or site based transfer pumps. These are almost always sealed with a single bellows component seal. These are typically used to convey products such as Liquid Oxygen, Liquid Nitrogen, Liquid Argon and Liquid Carbon Dioxide. The self-professed European market leader of this type of pump is the French based manufacturer, Cryostar. Other specialist manufacturers of this type of pump are ACD, CVI, Barber Nichols, Cosmodyne, Airco Paul and JC Carter. As with any industry, there are numerous copycat manufacturers, many of them utilising 50-year old designs. A typical seal arrangement for a tanker off-loading pump is shown in diagram 27.

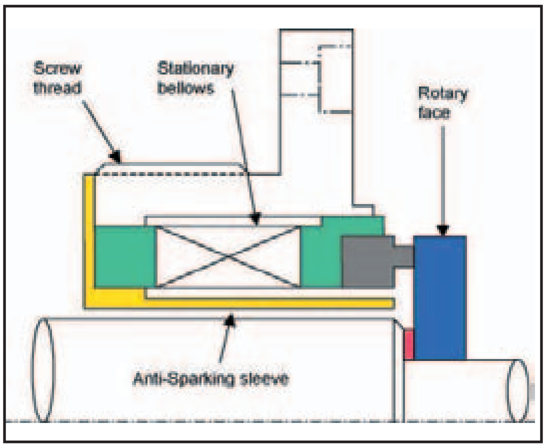

Diagram 27 – A Typical Stationary Bellows Tanker Off-Loading Pump Seal.

The design has a number of key features that make it suitable for cryogenic use:

a) The stationary metal bellows eliminates the need for elastomers.

b) The anti-sparking shroud ensures no contact with the rotating shaft.

c) The monolithic rotary face is clamped in place with the use of a gasket.

d) The stationary component is attached to the pump either by screwing to the housing or alternatively flange-mounting.

Unfortunately, equipment of this type is prone to operating in the gaseous phase of the product. Therefore, this reduces the life of the mechanical seal accordingly.

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Table 28, summarises the typical equipment arrangements encountered for transferring cryogenic products:

Pumped Temperature (deg.C)	Seal Chamber Temperature (deg.C)	Medium in the seal chamber	Equipment Details & Duty	Typical Seal Arrangement
0 to -50	0 to -50	Liquid	Standard Vertical or Horizontal Centrifugal or PD pump	Single or double with icing protection
-50 to -100	> -50	Liquid	Vertical pump	Double back to back with system
< -100	< -100	Liquid or Gas	Site based or road tanker off loading pumps for liquefied gases	Single metal bellows, gas seal or hermetically sealed

Table 28 – Typical Equipment Used on Cryogenic Duties.

Typical Products

Normally, liquids are pumped in the cryogenic state for one of two reasons:

1) For circulation to maintain a cooling / refrigeration process, or
2) To transfer them in the liquid state, rather than the gaseous state. Liquefied gases occupy a much smaller volume, so it makes sense to transport and store them in this state.

The majority of commonly encountered applications fall into the first category. Many industrial refrigeration applications use indirect compression systems in which a refrigerant chills a refrigerating medium (air, water or brine) that is circulated through the areas to be cooled.

In direct expansion systems, by contrast, the refrigerant expands into the area to be cooled. Indirect systems are often used to cool large areas or when distance from the compressor is great, pressure is hard to control and vapours must be contained. Typical products encountered are discussed below.

Where a recommended specification has been shown, the common seal face abbreviations are shown below:

CAR Standard resin impregnated Carbon *
TC Tungsten Carbide (Nickel bonded)
CER Alumina Ceramic

* The Antimony or Molybdenum Disulphide grades of Carbon recommended earlier can be substituted where the seal design and material availability allows.

Brine

Brine may be defined as liquid of low freezing point used in transmission of refrigeration without change of state. The brines commonly employed in refrigeration are Calcium Chloride and Sodium Chloride. Calcium Chloride brines are used as refrigeration media in a broad array of industrial applications, including ice plants, ice rinks, cold storage and frozen food. Sodium Chloride is cheaper but cannot be used below minus 15ºC. Calcium Chloride of commercial grade can operate satisfactorily down to minus 40ºC. Use of

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Product: Calcium Chloride Brine (30% Calcium Chloride, 0.5% Sodium Dichromate, 69.5% water) @ minus 20 to minus 30 degrees Celsius	
	Recommended Specification
Seal	DMSF™
Faces	TC/TC/TC/CAR
Elastomer	EPR
Metallurgy	Alloy 276 wetted parts
System	SSE10-P2
API Plan	53
Barrier Fluid	Glycol based

Table 29

Calcium Chloride above 33% should be avoided as it results in crystallisation causing reduced efficiency. Although these brines have the great advantage of low cost, they have the disadvantage of being extremely corrosive. However, corrosion in closed systems can be largely overcome by the addition of a Sodium Dichromate corrosion inhibitor. The Calcium Chloride is commonly adjusted to a pH of around 8 by the addition of caustic. This makes the product slightly alkaline. Calcium Chloride brine is a good refrigerating medium because it:

- Remains liquid to very low temperatures.
- Undergoes no serious change in character, such as precipitation, if refrigerants leak into it.
- Has a high enough specific heat for economic operation so excessive amounts are not needed.

Calcium Chloride significantly reduces the freezing point of water. Freezing temperature depends to a great extent on brine temperature and CaCl2 concentration.
The example above shows a typical concentration and the recommended sealing solution.

Ammonia

Ammonia is widely accepted as the most efficient and environmentally friendly refrigerant. It does not deplete the ozone layer, does not contribute to global warming and has superior thermodynamic qualities. However, its unpleasant odour and mild toxicity have limited its use to industrial plants away from heavily populated areas. Ammonia can be found in a number of forms serving a number of different processes. The most common are aqueous and anhydrous, but occasionally the product may contain oil. This must be established, as it effects the elastomer selection. Typical sealing solutions are highlighted below:

Product: 33% Aqueous Ammonia or Anhydrous Ammonia @ minus 20 to minus 50 degrees Celsius		
	Minimum Specification	Recommended Specification
Seal	MO-Series v suitable seat	DMSF™
Faces	CAR/CER or CAR/Ni-Resist	TC/TC/TC/CAR
Elastomer	PTFE / EPR	EPR
Metallurgy	304L SS	316L SS
System	N/A	SSE10-P2
API Plan	N/A	53
Barrier Fluid	N/A	Propylene Glycol

Table 30

Product: Ammonia + Mineral Oil @ minus 30 to minus 40 degrees Celsius		
	Minimum Specification	Recommended Specification
Seal	SMSS	DMSF™
Faces	TC/TC	TC/TC/TC/CAR
Elastomer	Neoprene	Neoprene
Metallurgy	316L SS	316L SS
System	N/A	SSE10-P2
API Plan	11	53
Barrier Fluid	Product flush	Mineral Oil

Table 31

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Alcohols

Various Alcohols are used as refrigerants and are commonly found in breweries, as they are compatible with the end product. They are almost always an aqueous solution. However, the reader should note that the higher the concentration, the lower the boiling point and hence they also become more volatile. The more common types are Methanol, Ethanol and Industrial Methylated Spirit (I.M.S.).

Products: Methanol, Ethanol and Industrial Methylated Spirit @ minus 20 to minus 30 degrees Celsius	
	Minimum Recommended Specification
Seal	CS or MO-Series v suitable seat
Faces	CAR/CER
Elastomer	EPR / PTFE
Metallurgy	316L / 304L SS
System	N/A
API Plan	N/A

Table 32

Glycols

The use of Glycols has been extensively covered in the section on barrier fluids. There are many instances where they are used as a marginally low temperature refrigerant. A typical seal specification is shown below:

Product: Glycol (50% Ethylene Glycol / 50% Water) @ minus 10 to minus 20 degrees Celsius		
	Minimum Specification	Recommended Specification
Seal	PO or MO-Series v suitable seat	SMSS™
Faces	CAR/CER	TC/TC
Elastomer	EPR / PTFE	EPR
Metallurgy	304L SS	316L SS
System	N/A	N/A
API Plan	N/A	11
Barrier Fluid	N/A	Product flush

Table 33

Methylene Chloride

Methylene Chloride has many uses including paint removers, solvent degreasing, plastics processing, blowing agent in foams, solvent extraction, solvent for cellulose acetate and aerosol propellant. It is often transferred at low temperatures due to its freezing point of minus 97ºC. It is a suspected human carcinogen, a narcotic and has a TLV of 50 PPM in air. A recommended seal specification is shown below:

Products: Methylene Chloride @ minus 70 to minus 75 degrees Celsius	
	Recommended Specification
Seal	BDFI-G™
Faces	TC/TC/TC/CAR
Elastomer	Graphite / Silicone Cored FEP
Metallurgy	HHH bellows stack, 316L SS
System	SSE10-P2
API Plan	53
Barrier Fluid	Water or Alcohol based

Table 34

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Hydrocarbons

Hydrocarbons are a common group of products that are often transferred at cryogenic temperatures. It is normal for the temperature range to vary enormously on the same duty and so any seal specification should be capable of handling both extremes. Typical products are Siltherm, Dowtherm, Ethane, Methane and Propane. Recommended seal specifications are shown below:

Product: Siltherm, Dowtherm J, Dowtherm SR1 @ minus 51 to + 43 degrees Celsius		
	Minimum Specification	Recommended Specification
Seal	SMSS™	BDFI™
Faces	TC/TC	TC/TC/TC/CAR
Elastomer	Fluorosilicone	Fluorosilicone
Metallurgy	316L SS	HHH bellows stack, 316L SS
System	N/A	SSE10™-P2™
API Plan	11	53
Barrier Fluid	Product flush	Siltherm or Dowtherm

Table 35

Current Industry Trends

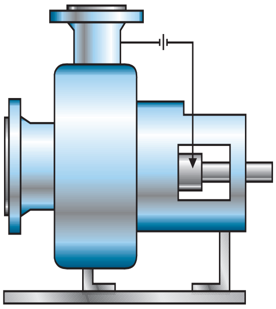
There are a number of recent developments and trends throughout industry relating to the use of cryogenics. Many industries are constantly searching for new methods to economically produce their product. Nowhere is this more prevalent than the Pharmaceutical industry. This is one particular industry that is beginning to realise the benefit of operating at cryogenic temperatures. Such benefits include:

- The use of cryogenics can slow the process reaction to a more manageable rate to produce a more controlled, precise reaction.
- The materials used in the reaction will not flash or evaporate at such a reduced temperature.
- The reduced temperatures mean that it is no longer necessary to maintain such high pressure to keep the materials in the liquid state.

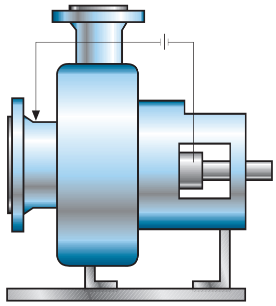
The current sealing trend within the Pharmaceutical industry is to move away from double wet seals because of contamination issues. Many of the seals utilised throughout this industry are top-entry reactors operating in the gaseous phase. This is one particular area where our Mixmaster seal designs could be adapted for cryogenic service. Maintaining temperature at the seal faces should not be that much of a problem. It may even be possible, due to the physical seal location within the equipment, to utilise a heated spool piece between the seal housing and the vessel. If positioned correctly, heat transfer to the product could be kept to a minimum, rather like a stuffing box jacket. The seal can even be positioned further outboard towards the bearing. This could create an air pocket and, since air is a poor conductor of heat, will assist in reducing heat transfer.

API Plans

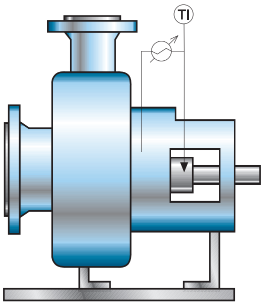
Throughout this report, API system plan numbers have been referred to. These plan numbers and there meaning are summarised below:



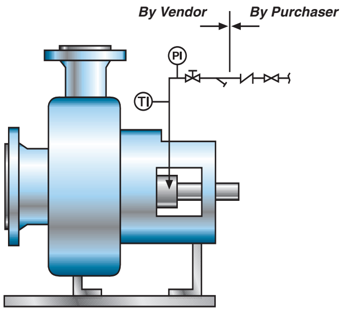
API PLAN NO.11
Product Recirculation from Pump Discharge to Seal through a Flow Control Orifice.



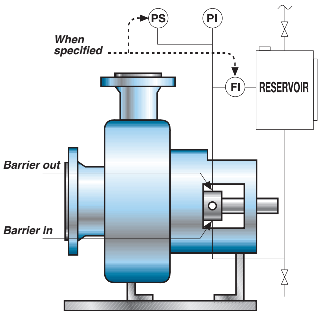
API PLAN NO.13
Product Recirculation from Seal Chamber to Pump Suction via a Flow Control Orifice.



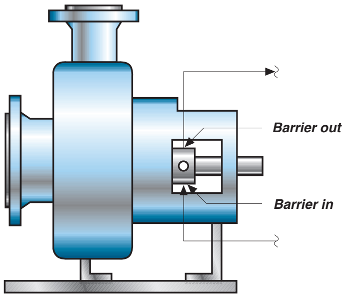
API PLAN NO.23
Product Recirculation from Seal Cavity through Heat Exchanger and back to the Seal Chamber. Normally includes some form of Pumping Ring.



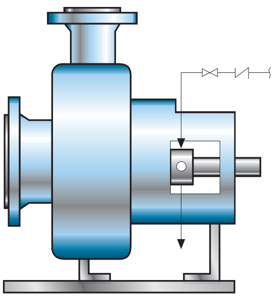
API PLAN NO.32
Flush injected from an External Source.



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.54
Pressurized External Barrier Fluid, Normally from a separate Pumped system (e.g. PUMPPAC™).



API PLAN NO.62
External Quench straight through to Drain.

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Case Histories

Case History 1837K

In a cold store in the US a 1.875" SMSS™ was installed on an Ammonia refrigeration duty. This was installed on a horizontal DURCO MK2 GRP3 pump at 1745rpm. The product is circulated at a temperature of minus 33ºC and a seal chamber pressure of 1.5 bar. Materials of construction are Tungsten Carbide versus Tungsten Carbide seal faces, with Neoprene o-rings and 316L Stainless Steel metallurgy. The seal is supported by API Plan 11, product flush from discharge, directly into the seal chamber.

Case History 1987K

A 45mm SMSS™ seal is installed on a Solvent duty at a temperature of minus 53ºC. This is installed on a horizontal Nuovo Pignone TC-A pump. The seal is supported by an API Plan 32 ambient temperature flush, ensuring that the seal is operating in an ambient temperature atmosphere. The seal chamber is reported to be long and restricted to ensure minimal flush fluid ingress into the bulk product. The seal specification is Tungsten Carbide versus Tungsten Carbide, with Viton o-rings. The exact chemical composition of the product is unknown, but Viton is reported to be the only compatible low-cost elastomer.

Case History 1988K

A 45mm CURC™ seal is installed on a Solvent duty at a temperature of minus 4ºC. This is installed on a horizontal Nuovo Pignone TC-A pump. The seal is supported by an API Plan 32 ambient temperature flush, ensuring that the seal is operating in an ambient temperature atmosphere. The seal chamber is reported to be long and restricted to ensure minimal flush fluid ingress into the bulk product. The seal specification is Tungsten Carbide versus Tungsten Carbide, with Viton o-rings. The exact chemical composition of the product is unknown, but Viton is reported to be the only compatible low-cost elastomer.

Case History 1989K

A 45mm SMSS™ seal is installed on a Solvent duty at a temperature of minus 64ºC. This is installed on a horizontal Nuovo Pignone TC-A pump. The seal is supported by an API Plan 32 ambient temperature flush, ensuring that the seal is operating in an ambient temperature atmosphere. The seal chamber is reported to be long and restricted to ensure minimal flush fluid ingress into the bulk product. The seal specification is Tungsten Carbide versus Tungsten Carbide, with Viton o-rings. The exact chemical composition of the product is unknown, but Viton is reported to be the only compatible low-cost elastomer.

Case History 1990K

A 60mm SMSS™ seal is installed on a Hydrocarbon duty at a temperature of minus 45ºC. This is installed on a horizontal Nuovo Pignone TC-B pump. The seal is supported by an API Plan 32 ambient temperature flush, ensuring that the seal is operating in an ambient temperature atmosphere. The seal chamber is reported to be long and restricted to ensure minimal flush fluid ingress into the bulk product. The seal specification is Tungsten Carbide versus Tungsten Carbide, with Viton o-rings.

Case History 1991K

A 45mm SMSS™ seal is installed on a Solvent duty at a temperature of minus 41ºC. This is installed on a horizontal Nuovo Pignone TC-A pump. The seal is supported by an API Plan 32 ambient temperature flush, ensuring that the seal is operating in an ambient temperature atmosphere. The seal chamber is reported to be long and restricted to ensure minimal flush fluid ingress into the bulk product. The seal specification is Tungsten Carbide versus Tungsten Carbide, with Viton o-rings. The exact chemical composition of the product is unknown, but Viton is reported to be the only compatible low-cost elastomer.

Case History 1992K

A 2.500" ESM seal was installed on a vertical top-entry Transkem Mixer at a coffee manufacturer. Product was described as Freeze Dried Coffee Essence at a temperature range of minus 175ºC to +100ºC. The exact temperature at the seal position is unknown.

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Seal specification is Carbon v Ceramic, with Graphoil wedge / gaskets. Seal Z-reference AZA8730, drawing number 7116981.

Case History 1993K

In a chemical plant in the US a number of 1.750" ANSI+ Alloy 276 CDSA's are installed on horizontal Goulds 3196 MTX centrifugal pumps. The pumped product consists of 30% Calcium Chloride, 0.5% Sodium Dichromate with a balance of water at a temperature of minus 23ºC to minus 28ºC. The Sodium Dichromate is believed to be used as a corrosion inhibitor. The product is described to be abrasive and corrosive, hence Alloy 276 metallurgy and a seal specification of SIC/SIC/SIC/CAR with EPR o-rings. Seal chamber pressure is 40 PSI. The barrier fluid system is an SSE10, operated as API plan 53 @ 55 to 60 PSI, with a mixture of Water and Glycol. MTBF is over a year.

Case History 1994K

A 30mm DMSF TC/TC/TC/CAR EPR GFT is operating successfully on a 33% Aqueous Ammonia duty in a Food and Drug company in the North East of England. This is installed on a horizontal SIHI Ryland pump @ 2950 rpm. The product temperature is reported to be between minus 40ºC and minus 50ºC. The barrier fluid system is an AESSEAL® SSE10-P2, operated as per API plan 53, with a 100% Propylene Glycol barrier fluid. This seal specification has operated successfully for over a year. However, the initial DMSF failed prematurely due to the wrong barrier fluid type. The previous sealing device was a PTFE wedge seal with a back-up lip seal. This caused a major incident on site when it failed due to a release of Ammonia.

Case History 1995K

A 38mm DMSF TC/CAR/TC/CAR EPR GFT is operating successfully on a 33% Aqueous Ammonia duty in a Food and Drug company in the North East of England. This is installed on a horizontal ABS SCANPUMP NB series 80-65/16 @ 2950 rpm. The product temperature is reported to be between minus 40ºC and minus 50ºC. The barrier fluid system used is the existing 10-litre vessel, operated as per API plan 53, with a 100% Propylene Glycol barrier fluid. This seal specification has operated successfully for over a year.

Case History 2001K

Two 35mm SMSS™ seals, with a specification of SIC/SIC Kalrez 6375, are installed on a Calcium Carbonate Brine duty in the North West of England. These are installed on a JP pump with a pumped temperature of minus 15ºC. The seals are supported by API plan 11 product flush from pump discharge through a flow control orifice.

Case History 2002K

Several applications in the US are operating using a 2.625" SMSS23™ TC / TC / FLUOROSILICONE seal on a Siltherm duty. Operating temperature range is from minus 51ºC to + 43ºC. The pump models are DURCO Group I, II and III. Early failures on the pumps were due to Viton o-rings, these have since been changed to the specification shown. Seal life is now 2.5 years plus. The barrier fluid is circulated, via API Plan 23, through an AESSEAL® SSE10 pot and back to the seal. Thermal equilibrium is reached from 24ºC to 27ºC. Due to the nature of the application, no cooling coil or heat exchanger is required.

Case History 2003K

Several applications in the US are operating using a 2.625" BDFI™ TC/TC/TC/CAR with FLUOROSILICONE o-rings on a Siltherm duty. Operating temperature range is from minus 51ºC to + 43ºC. The pump models are DURCO Group I, II and III. Early failures on the pumps were due to Viton o-rings, these have been since changed to the specification shown. Seal life is now 2.5 years plus. The barrier fluid system is an AESSEAL® SSE10™, operated API plan 53, with either Siltherm or Dowtherm as a barrier fluid. Thermal equilibrium is reached at approximately 38ºC.

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Case History 2004K

An 80mm BDFI-G™ seal is installed on a Methylene Chloride duty in the US. The seal specification is CAR/TC/TC/CAR with a full Alloy 276 bellows stack. Elastomers are Graphoil, where appropriate, with Silicone cored FEP elsewhere. The application temperature is minus 73ºC and 2-bar seal chamber pressure. This is installed on a Goulds 3196 XL standard bore pump at 1200 rpm with an API plan 54 barrier fluid system. Seal is reported to be operating successfully for over a year.

Case History 2005K

In an Automotive plant in the UK there is a Girdlestone horizontal centrifugal pump pumping Dowtherm. The application temperature ranges from minus 42ºC to + 130ºC. The pump is fitted with a 45mm SAI™ and DIN stationary SIC/SIC/EPR with a Titanium grade 2 rotary holder. This is operating API Plan 02 and the seal is reported to be operating successfully.

Case History 2006K

In an Automotive plant in the UK there is a Siemens & Hinsh NOW-Y-3213 ATDM0102 pump with a Dowtherm J product. The application temperature ranges from minus 42ºC to + 130ºC. The pump is fitted with a 32mm M03™ and S010™ stationary CAR/SIC/PTFE operating API Plan 02. The seal is reported to be operating successfully.

Case History 2008K

A 1.875" SMSS™ TC/TC/NEOPRENE seal is operating successfully in a cold store in the US. The duty is refrigerant circulation of Ammonia and Mineral oil at a temperature of minus 33ºC on a horizontal DURCO pump. The seal is supported by API plan 11 product flush from pump discharge through a flow control orifice. A number of previous seals have failed in quick succession. The original seal was a CAR/SIC single cartridge seal that failed due to blistered Carbons. The AESSEAL® M05S v S070 CAR/SIC and SMSS™ Antimony Car/TC all failed quickly in a similar way. The current seal specification has successfully completed a 3-month trial.

Case History 2009K

In a poultry processing factory in the UK there is a 2.375" SAI™ and Boot mounted stationary CAR/CER/VITON operating on a Calcium Chloride Brine duty. The pump supplies the main freezing process at a temperature of minus 32ºC. The pump type is a Pullen SK125 vertical pump at 1420 rpm with an internal re-circulation of product from pump suction back into the seal chamber.

Case History 2010K

In a poultry processing factory in the UK there are a number of 2.375" P02 and Boot mounted stationary seals CAR/CER/VITON operating on a Calcium Chloride Brine duty. The pump supplies the main freezing process at a temperature of minus 32ºC. The pump type is a Pullen SK125 vertical pump at 1420 rpm with an internal re-circulation of product from pump suction back into the seal chamber.

Case History 2011K

In the Food and Drug industry a horizontal Girdlestone 2V58C centrifugal pump is fitted with a Carbon faced CS external rotary seal complete with a Ceramic T-shaped stationary seat. The o-rings on the rotary component are EPR. The product is a minimum of 40% Methanol in water at a temperature of minus 27ºC. The previous sealing device was a PTFE wedge seal / Carbon / Ceramic / PTFE which also ran successfully. This was mounted externally like a CS.

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- **WEAR PROTECTIVE CLOTHING**

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