The Use of Asbestos Free Materials on Static Sealing on Pumps

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Narrative Biography

Russ Currie is currently Technical Manager for Flexitallic Limited, Eastern Hemisphere operations based in Yorkshire, UK. His role is to provide sealing solutions to worldwide customer base and manages a small team of experienced engineers.
He received a BS Degree (Mechanical Engineering, 1981) from Sheffield Polytechnic. After graduation he completed the selective management-training scheme of the UK Coal industry. He joined Flexitallic in 1995 and took up his current position in 1998.
He travels the world providing sealing solutions to a wide customer base across many industries and applications.

ABSTRACT

The use of asbestos free gaskets to seal flanged connections on various applications. This paper discusses the use of a different style of gasket and details the advantages and benefits resulting from such a change. The discussion includes an analysis, supported by laboratory testing and successful field experiences. The paper is sectioned into three case studies, each topic relating to a type of product.

The development of high strength asbestos free sheet materials for usage on split case pumps using modern man made fibres including successful study using the material on natural gas pumping station on Activated Methyldiethanolamine MDEA. The MDEA removes Carbon Dioxide in natural gas process plant.

The successful implementation in the usage of serrated metal core technology, with various facing materials, in pump case gaskets, used on hydrocarbon service in oil refineries within the UK.

The development and usage of structurally modified ptfe filled products in pumping aggressive chemicals on sealess pumps.

The paper will detail the materials, the application areas, the problems resolved and include design considerations and introduce installation guidance, with discussions on previous failures.

INTRODUCTION

The problem is moving away from established materials based on asbestos products onto asbestos free products. The substitute materials available, along with new styles of gasket, have resulted in many new challenges and opportunities.

The transition from an asbestos-based sheet material onto other non-asbestos products has resulted in a variety of high performance products. The technology employed to manufacture the calendered sheet product is utilized using asbestos free combinations and new developments and manufacturing techniques.

There is not one ideal product to replace the asbestos and have the degree of flexibility. High performance sealing materials such as exfoliated graphite, exfoliated vermiculite along with ptfe products have entered the market place and provided the level of sealing. The material used for the high performance split case pump involved the usage of high strength Aramid with rubber binders.

The introduction of material combinations of metal and non-metallic components in new combinations has seen growth in new areas.

The development and increased usage of modified materials based on ptfe provide effective solutions.

Case1

When the first generation of asbestos-free “it” sealing materials were developed the reinforcing fibres were either Aramid or glass. The usage of alternative materials cellulose, carbon and mineral wool has provided a wider range of products.

The high performance requirement in the split case pump has progressed with the Aramid and glass combination. The main disadvantages of the Aramid is its relatively high cost compared to that of Asbestos and the embrittlement of the fibres at elevated temperature of 200 to 250 Centigrade. The usage of the mono-filament glass provides secondary reinforcement at the elevated temperatures.

The glass used is manufactured using careful tolerance to provide fibre diameters of 6 to 10 micron. This provides the most benefit when combined with the Aramid. The glass has also a surface dressing applied to promote compatibility to the matrix. Included in the mix are coupling agents to promote chemical cross links with the rubber binder.

When the blend of Aramid and glass fibres entangle the mono-filament glass is trapped within the matrix and reduces the tensile strength ratio to around 3. This is required with the high performance product.

The split case pump gasket has traditionally involved a thin sheet product which has to maintain high seating stress due to the pressure containment envelope. Surfaces would be traditionally smooth, usually without any machine marks for the gasket to flow and grip onto.Fig1.1 and Fig1.2 shows typical pump arrangement.

Asbestos based products contained a high percentage of fibrillating fibre which provide strength. The replacement of the fibre by aramid provides a material with superior strength at lower fibre levels.

Typical Mechanical Properties of the sheet material used

Thickness	0.4 mm	
Density	gcm^{-3}	1.60
ASTM Compressibility	%	11
ASTM Recovery	%	62
ASTM Tensile Strength	MPa	20
DIN Gas Permeability	mL/min	0.01
ASTM Oil 3 Thickness Increase	%	4
ASTM Fuel B Thickness Increase	%	8
Specification	BS7531 Grade X	

The case to consider is a Lean Amine Circulation pump on a gas distribution plant in the north west of England. Flange rating for connectors were 900# pressure class with typical operating pressure of 8Mpa at temperature of 50C. The approximate area of sealing face was 525,000mm2. Bolting on the pump is 52 0ff, 1.3/4 grade B7 bolting. The use of the pumps were in the removal of CO2 in the natural gas.

Two pumps were showing leakage on the casing joint. The leaks had occurred after a short period of service time. Several failures had occurred following change of material from an asbestos-based product to a non-asbestos aramid-glass mixture. Previous to the change from asbestos run time greater than 12 months was expected. Two different suppliers had been used and on each occasion failure had occurred after a short period of time.

The examination of the material after removal indicated stress cracks across the sealing face indicating high surface stress. The stress cracks were tangential to the length of the pump. Insufficient material was available to determine if the failure was in line with rotation of calendar or normal to it. Some alignment of fibre can occur when using Calendered technology.

On the material body also indication of media attack from the product. To alleviate any concern of attack to the nitrile rubber binder by the media free immersion tests and clamped tests were carried out using activated MDEA using the company test rig. Placed in an oven the material was heated to 50C to replicate usage. After 3 weeks testing the thickness increase was below 2.3% and weight increase below 16.8%. Leakage from the rig was not reported. Fig1.3 shows rig used.

Release agent and non-stick compounds may work against the operation of the gasket combined with a smooth finish are not recommended in the usage of the high performance products. For these applications with machined smooth non stick coating is not recommended.

Case 2

The usage of semi metallic products in circular applications is long established, particularly where high assembly stress preclude the usage of sheet products. The semi metallic gaskets are used with limited sealing face width and without limitation on compression.

A typical style jacketed gasket is laid out in fig.2.1, there is a metallic envelope, which is cold worked into a variety of shapes around a soft non-metallic core. Depending on diameter and thickness this could be in several forms. On high stress applications such as pumps this usually is totally enclosed.

The materials of construction may be brass, aluminum, soft iron, copper, Monel or stainless steel for the outer jacket with millboard, graphite, ptfe or Vermiculite materials for the filler. The arrangement with the metal outer and non metallic filler requires a high seating stress to deform the metallic jacket onto the flange to effect a seal. To generate a high stress on the gasket, often a stress raising nubbin is machined onto the sealing face, fig2.3. This is unusual in a pump application with sealing areas limited and high-pressure containment.

When load is applied to the gasket deformation occurs of the soft core and reduction in thickness. The metal jacket will deform into the flange face and in areas of overlap of metal higher stress is generated. When the load is removed, deformation of the gasket remains with little recovery. A typical stress strain relationship is given in fig2.2. This is raw data from the rig and when corrected for jig yield the recovery line is near vertical indicating low levels of recovery. The minimum seating stress for the jacketed style range from (5,500psi) to (9,000psi). The compression test was taken up to (70,000 psi) in stages of (10,000psi) increments.

The serrated metallic core is a reverse of the jacketed product. The reverse being a soft outside of conformable facing material and a strong metallic core. The solid metal core is machined to a given profile and both faces of the gasket are covered with a soft deformable material, fig 2.4.

The core is machined to a pre-determined profile, and covered with a known thickness and density of facing material. It is essential the combinations are maintained to obtain optimum performance. Too little facing will allow penetration of sealing faces and flattening of metallic core, whilst too great a facing reduces gasket blowout.
DIN standards detail some combinations of dimensions but many Gaskets Company have developed internal standards, with parallel, convex and shallow forms.

The serrated metal core gasket requires a lower seating stress to maintain a pressure envelope than the jacketed style product, in some cases 25% lower. The soft facing deforms under the loading and flows into the surface irregularities on the flange and compacts into the serration’s on the gasket. Some facing materials, graphite and vermiculite, also increase in density in the process and provide high levels of stress retention and sealing. A typical seating stress range for a serrated core of 316 stainless with graphite facing would be 20MPa up to 500MPa.

Typical facing materials include Graphite, ptfe, non-asbestos sheeting, soft metals and recently high temperature vermiculite products. Serrated cores are available in many metallic grades.

The load deflection curves for graphite faced and ptfe faced, with stainless 316 core are given in fig2.5 and fig2.6. The serrated metal core with facing of ptfe and graphite has been used to replace the jacketed gasket.

The graphite faced core has been loaded up to a surface stress of 62MPa and reduced to zero and then loaded to 124MPa and unloaded. This has been repeated in 4 off 62MPa increments until reaching a final surface stress.
The ptfe faced core has been loaded up to a surface stress of 500MPa.

The images of the metallic core without facing in fig 2.7, with ptfe facing after loading to 500MPa in fig2.8. The ptfe facing was removed from the metallic and total core penetration of material was not observed fig2.8.

The high loading range of the product allows the usage in many pump applications where arrangements have been designed for solid metallic and jacketed products. Metal to metal contact of outer faces is not required giving ease in installation.

The lower seating stress requirement, higher strength core, overcame uncontrolled bolt up technique, flange misalignment at bolt up.

Case3

Virgin ptfe may be problematic used without modification to the structure. Two methods have been employed to produce a product that has a reduced creep rate.

The expansion or blowing of the ptfe into a soft conformable material, which when used deforms readily to a thin layer. Creep is thickness dependent, thicker ptfe creep more than thinner. The reduction of the thickness therefore reduces the amount of creep. This method provides a universal solution giving excellent chemical resistance but suitable for lower pressure class.

An alternative method of approaching the problem is to introduce a structure into the ptfe through directionality and subsequent filler systems. The usage of micro spheres, Silica and Barytes are used to reduce the creep effects associated with this type of product.

The structural modification of the co polymers of fluorinated hydrocarbons, provide interaction at a molecular level of reinforcement. The sheet is worked mechanically to provide directionality into the sheet, which is then biaxially fibrillated into a multi layer structure. The similar of a plywood sheet, which has grain 90 degree to each layer, could be used to represent the layered structure. The introduction of up to 50% filler into the closed structure has the effect of bulk reinforcement.

The usage of glass microspheres as filler provides a high compression material. The closed structure provides a material with good chemical resistance for low loading.

The material with holes introduced by microspheres is soft and easily conformable.

Thickness (mm)	1.5	3.0
Density (gcm^{-3})	1.40	1.40
ASTM Compressibility (%)	41	30
ASTM Recovery (%)	37	43
ASTM Tensile Strength (Mpa)	11	10
DIN Residual Stress @ 175′C(Mpa)	33	26
DIN Gas Permeability(mL/min)	0.01	0.03
ASTM Liquid Leakage(mL/hr)	0.65	0.75
ASTM Creep Relaxation (%)	31	47

Conductivity of filled ptfe typical 0.25 to 0.4 W/mK.

A guide to the selection of suitable sheet and facing materials are given fig3.1 and 3.2.

Fig 3.1 is a selector chart, general to all industries.

Sigma	ptfe based product
Flexicarb	graphite based products
SF and AF	Calendered Sheeting
Thermiculite	Vermiculite based product

This guideline is reinforced with the chemical / compatibility data for specific applications given in Fig3.2

The effect of gasket creep and thickness can be seen in Fig 3.3. ASTM F38B testing of different forms of ptfe show that creep relaxation increases for gasket thickness and if pure, filled or filled and structurally modified (Sigma).

The structurally modified ptfe out performs all of the other materials at all of the thickness measured.

A further requirement of the case study 3 was to have a material that would also provide a heat shield against components on hot duty. The poor thermal conductivity of the glass microspheres variant material proved suitable.

FIELD REPORT

In the case 1,the gasket was cut and installed and has run successfully exceeding the previous time. Material was installed August, 1998. Further pumps have been changed over to the style of product. Investigation into the condition will be made at next scheduled stoppage.

The change from the jacketed style product to the serrated metal style product has been a total success where implemented. To date 4 pumps on the Alkylation Unit and 10 pumps on the site has been changed over. The product has performed without leakage and has been written into the site standard.

The modified ptfe has not shown the creep effects of virgin and run on test and in usage for over 12 months with recommendations to change all virgin components.

CONCLUSIONS

The usage of asbestos free sheeting containing Aramid and Glass is a successful replacement to asbestos materials.

The usage of serrated metal core gasket (Flexpro) as a replacement for jacketed gaskets is well proven.

The creep failures of virgin un-filled ptfe can be eliminated using modified , filled ptfe.

References

1. Biaxially Orientated Reinforced ptfe Sheet Sealing Material
JR Hoyes, S Wolfenden, 3rd International Symposium on Fluid Sealing
Biarritz, France 15-17 September 1993

2. Fibre Combinations for use in Asbestos-free “it” Calendered Sealing Materials
Dr D A Thomas, JR Hoyes, 14 th International Sealing,
Firenze, Italy 6 – 8 April 1994

3. Draft EN 1514

Appendix 1

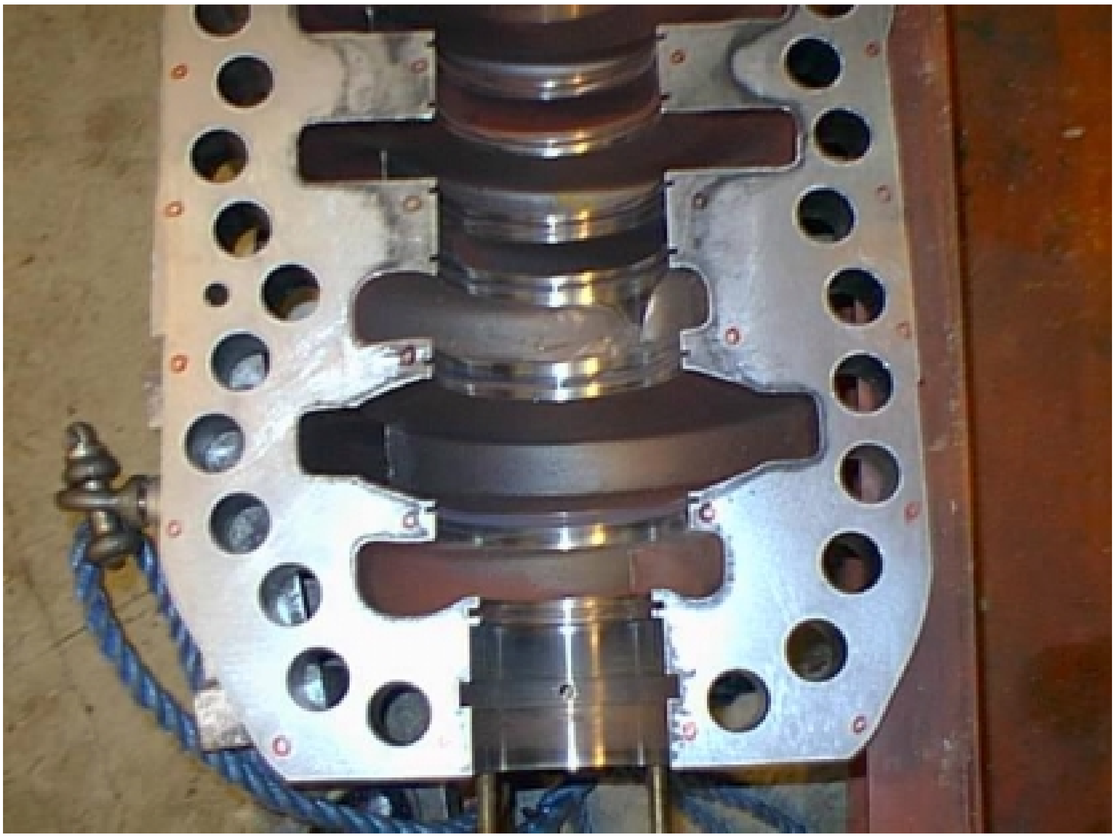


Fig 1.1 Typical Pump sealing Face

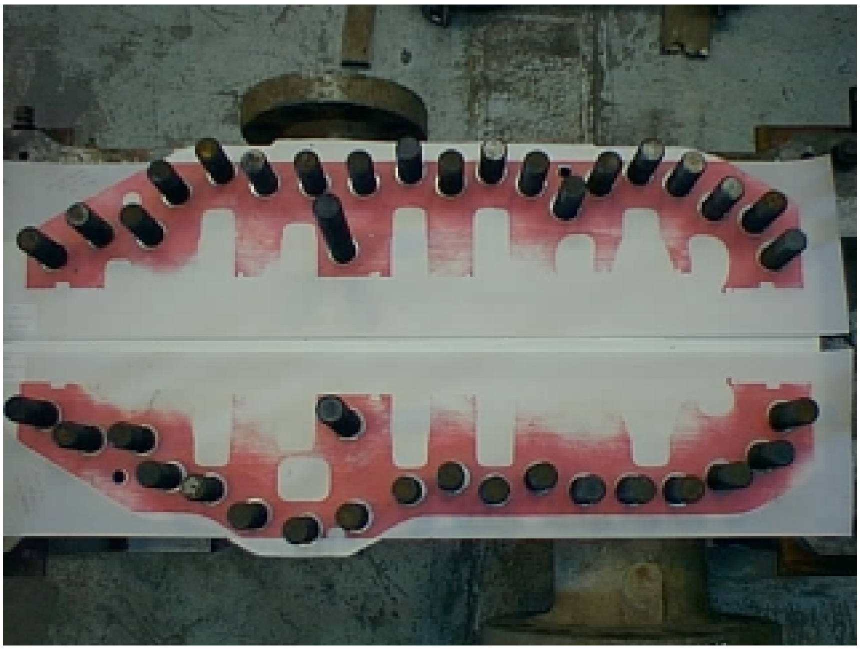


Fig. 1.2 Typical Compression Pattern on Stress Sensitive Film

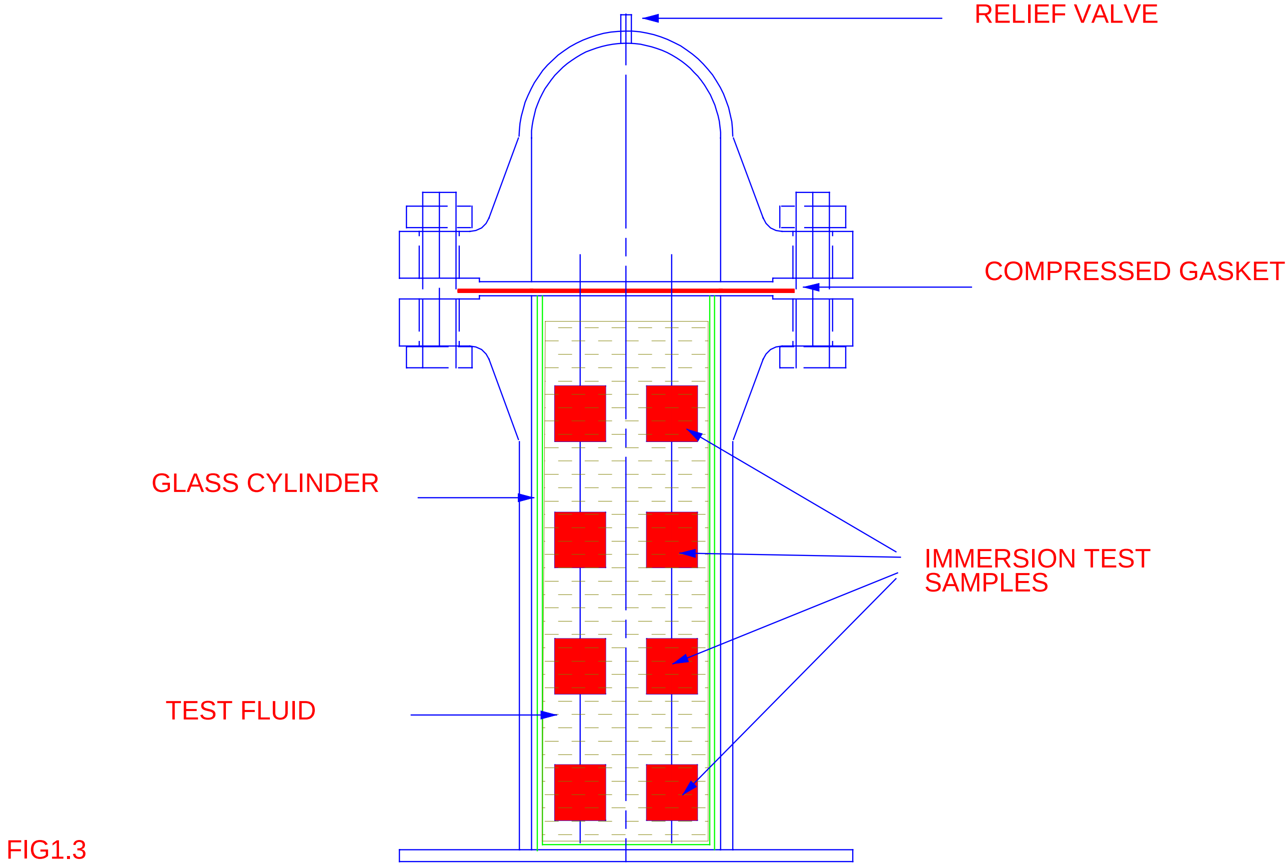


Fig1.3 Immersion Test Rig

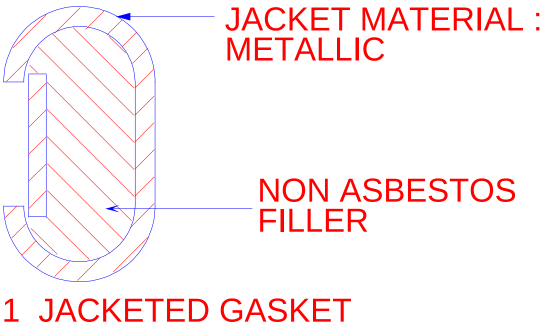


Fig 2.1 Jacketed Gasket Styles

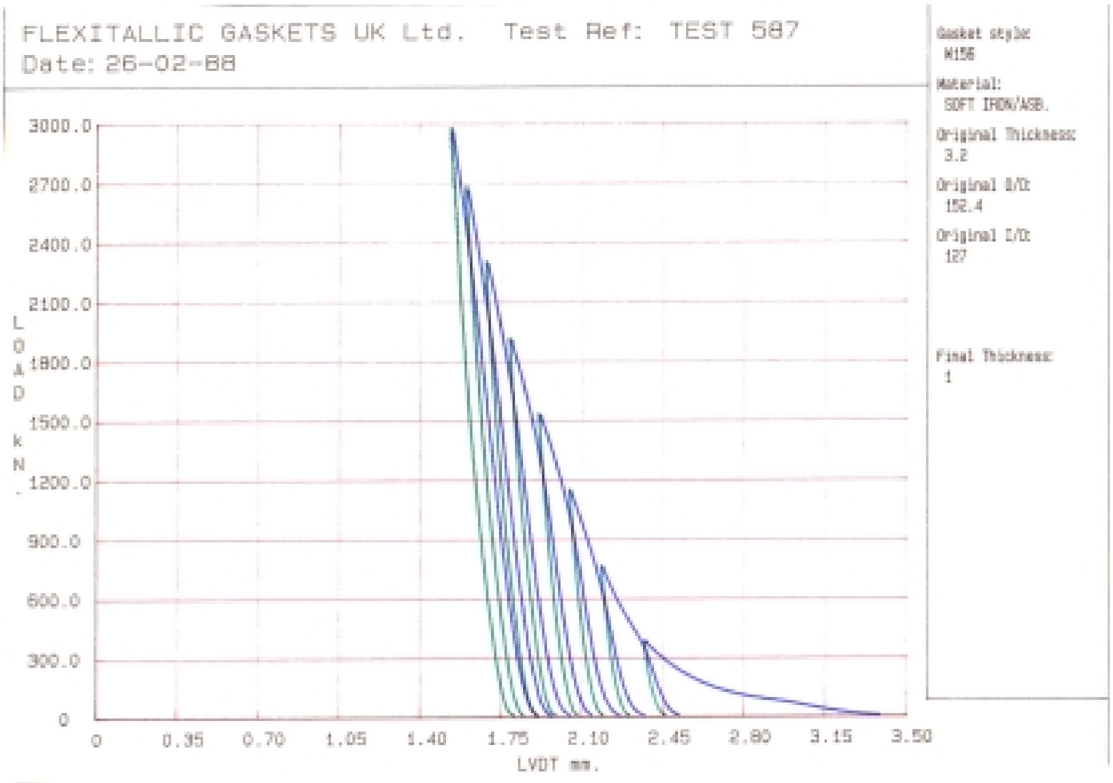
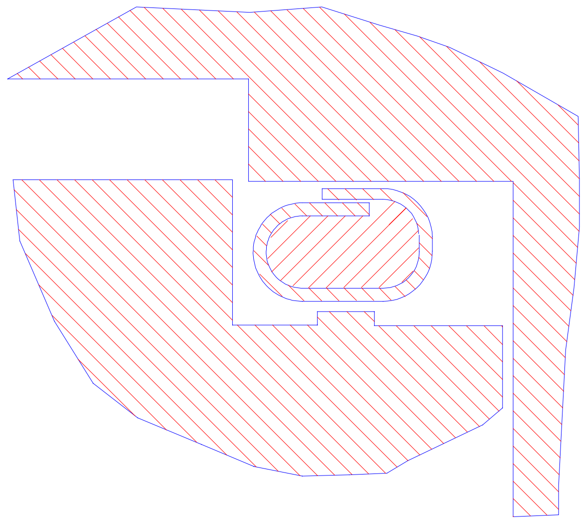


Fig2.2 Load Deflection Curve for Jacketed Gasket



2.3 Jacketed Gasket in Flange with Stress Raising Nubbin

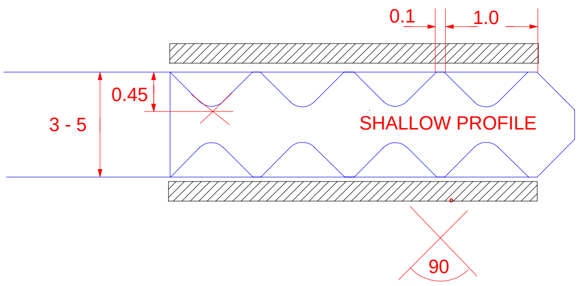


Fig2.4 Section Serrated Metal Core with Facing

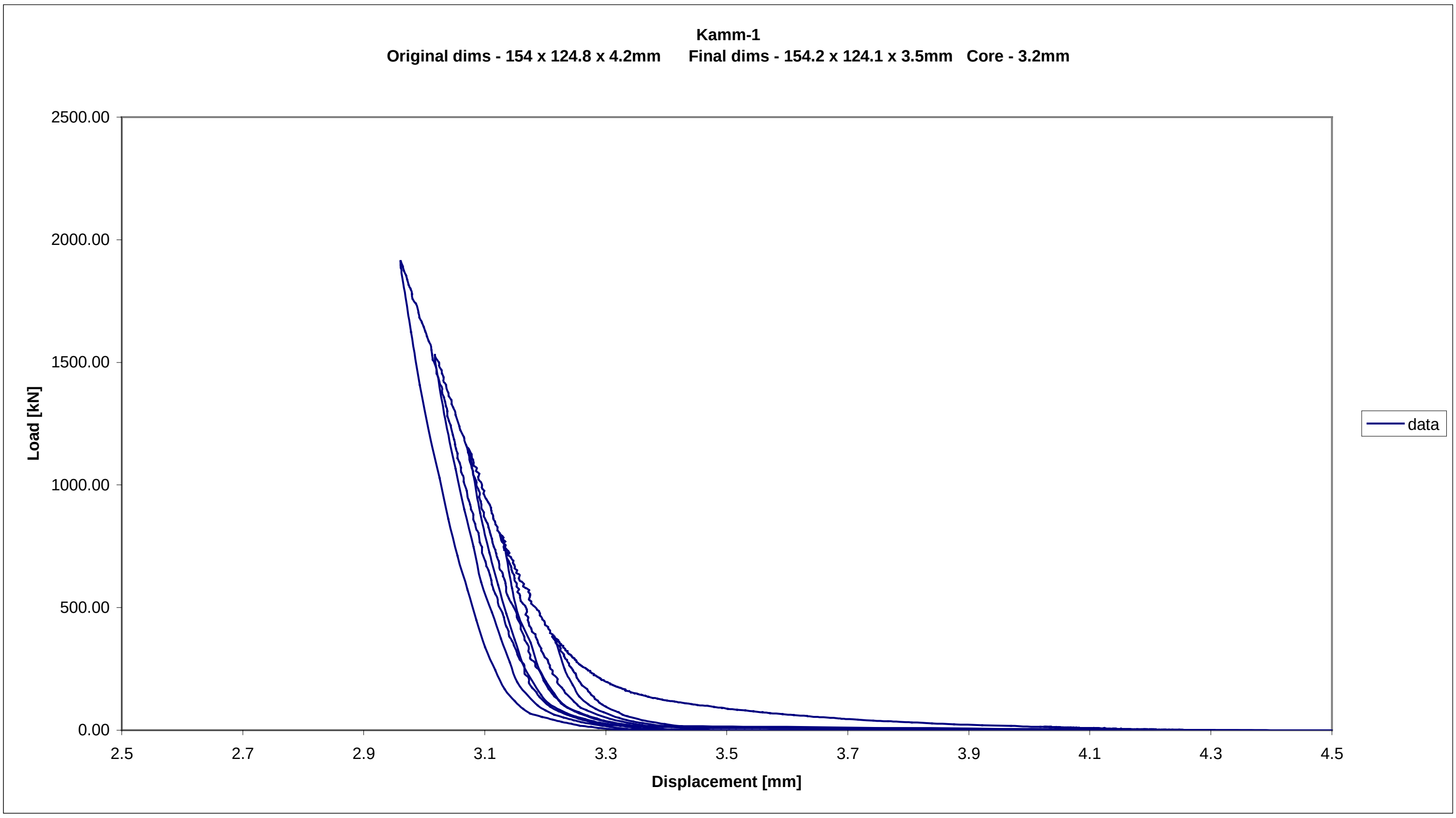


Fig 2.5 Load v Deflection of Serrated Core with Graphite Facing

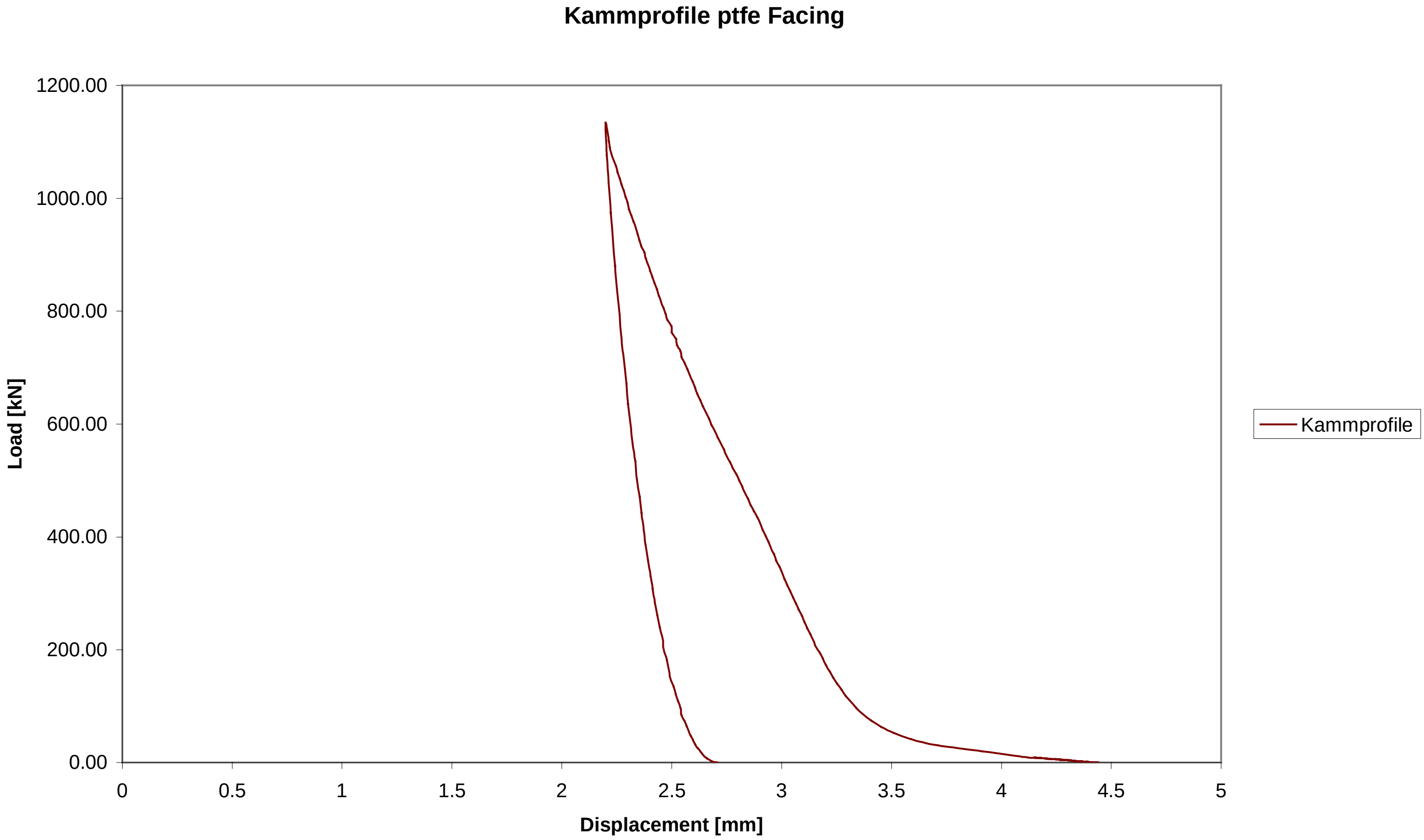


Fig2.6. Load v Deflection for ptfe Faced Serrated Core

Fig 2.7 Serrated Metallic Core Unfaced

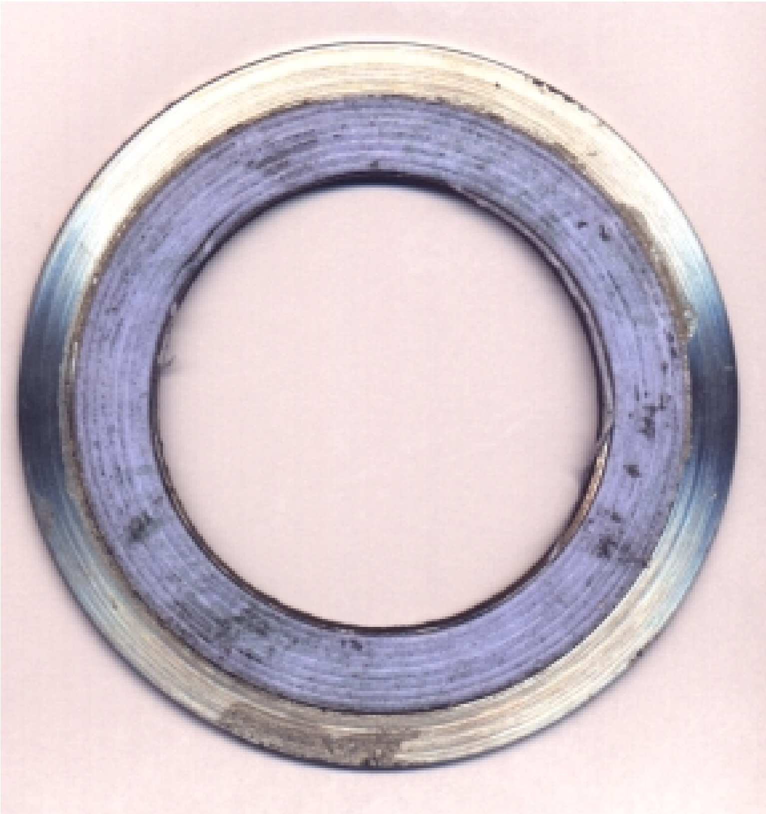


Fig 2.8 Serrated Metallic Core ptfe Faced after Compression

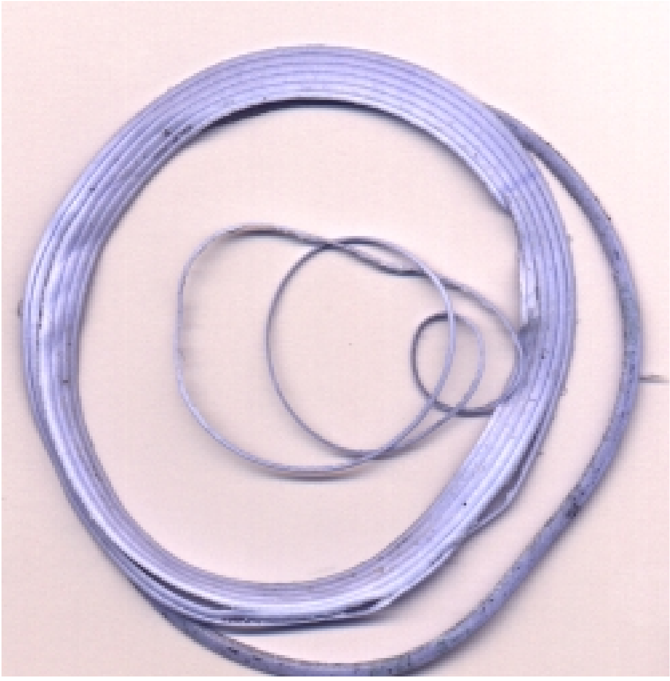


Fig 2.9 ptfe facing removed from Serrated Core after Compression

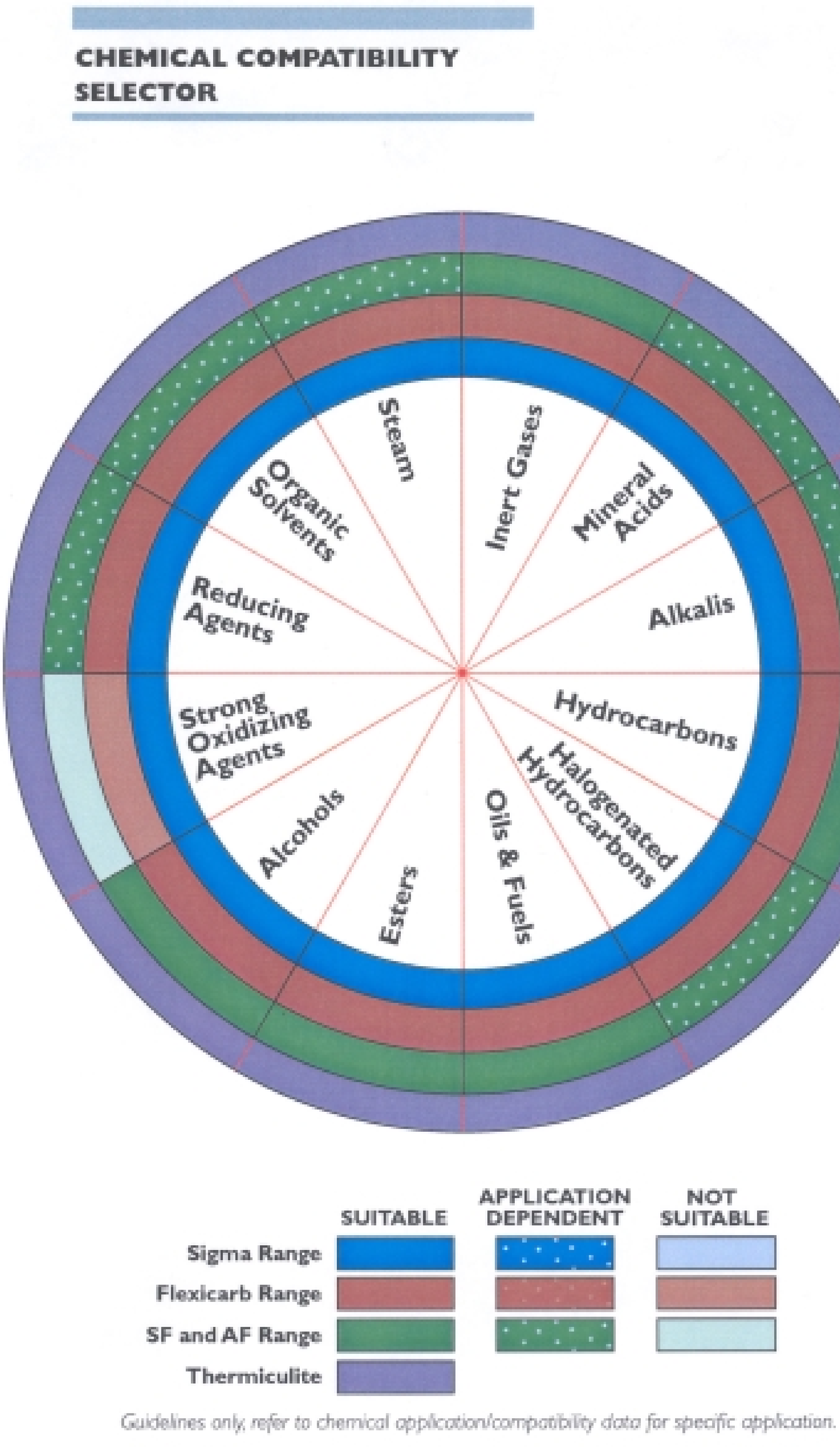


Fig3.1 Chemical Selector Chart

APPLICATION/ COMPATIBILITY GUIDE

	SF3300	SF2400/2800	SF1670	SF2500	SIGMA	RGS	THERMICULITE 815
Acetic Acid Glacial	✔	✔	✘	✔	✔	✔	✔
Acetone	✔	✔	✘	✔	✔	✔	✔
Acetylene	✔	✔	✔	✔	✔	✔	✔
Acrylic Acid	✔	✔	✘	✔	✔	✔	✔
Acrylonitrile	✔	✔	✘	✔	✔	✔	✔
Air	✔	✔	✔	✔	✔	✔	✔
Alkaline Lye	✔	O	✘	✔	✔	✔	✔
Aluminium Chloride	✔	O	✘	✔	✔	✔	✔
Ammonia Gas	✔	✔	O	✔	✔	✔	✔
Ammonia	✔	✔	✘	✔	✔	✔	✔
Amyl Acetate	✔	✔	✔	✔	✔	✔	✔
Amyl Alcohol	✔	✔	✔	✔	✔	✔	✔
Aniline	✔	O	✘	✘	✔	✔	✔
Aqua-Regia	✘	✘	✘	O	✔	✘	✔
Aviation Fuel	✔	✔	✔	✔	✔	✔	✔
Beer	✔	✔	✔	✔	✔	✔	✔
Benzene	✔	✔	O	✔	✔	✔	✔
Benzoyl Chloride	✔	✔	✘	✔	✔	✔	✔
Biphenyl	✔	✔	✘	✔	✔	✔	✔
Blast Furnace Gas	✔	✔	✘	✔	✔	✔	✔
Bleach (Solution)	✔	✔	O	✔	✔	✔	✔
Boiler Feed Water	✔	✔	✔	✔	✔	✔	✔
Brine	✔	✔	✔	✔	✔	✔	✔
Bromine	✘	✘	✘	✘	✔	O	✘
n-Butyl Acetate	✔	✔	✔	✔	✔	✔	✔
Calcium Chlorate	✘	✘	✘	✔	✔	✔	✔
Caprolactam	✔	✔	O	✔	✔	✔	✔
Carbolic Acid	✘	✘	✘	✔	✔	✔	✔
Carbon Dioxide	✔	✔	✔	✔	✔	✔	✔
Carbon Disulphide	✘	✘	✘	✘	✔	✔	✔
Carbon Monoxide	✔	✔	✔	✔	✔	✔	✔
Carbon Tetrachloride	✔	✔	✘	✘	✔	✔	✔
Chile Saltpetre	✔	✔	✔	✔	✔	✔	✔
Chlorine Dry	✘	✘	✘	✔	✔	✔	✔
Chlorine Wet	✘	✘	✘	O	✔	✔	✔
Chlorinated Hydrocarbons	O	O	O	O	✔	✔	✔
Chloroacetic Acid	✔	O	✘	✔	✔	✔	✔
Chlorobenzene	✔	✔	✘	O	✔	✔	✔
Chromic Acid	✘	✘	✘	O	✔	O	O
Copper Sulphate	✔	✔	✔	✔	✔	✔	✔
Creosote	✔	✔	✘	✘	✔	✔	✔
Cresol	✘	✘	✔	O	✔	✔	✔
Crude Oil	✔	✔	O	✔	✔	✔	✔
Cyclohexanol	✔	✔	✔	✔	✔	✔	✔
1,4 Dichlorobenzene	O	O	✘	✘	✔	✔	✔
Diesel Oil	✔	✔	O	✔	✔	✔	✔
Dowtherm	✔	✔	✘	✔	✔	✔	✔
Dye Liquor	✔	O	O	✔	✔	✔	✔
Ethyl Acetate	✔	✔	✘	O	✔	✔	✔
Ethyl Alcohol	✔	✔	✔	✔	✔	✔	✔
Ethylene Glycol	✔	✔	✔	✔	✔	✔	✔
Ethylene Oxide	✔	✔	✘	✘	✔	✔	✔
Ethyl Ether	✔	✔	✔	✔	✔	✔	✔
Ethylene	✔	✔	✔	✔	✔	✔	✔
Ethylene Chloride	✘	✘	✘	✔	✔	✔	✔
Fatty Acids	✔	✔	✔	✔	✔	✔	✔
Ferric Chloride	✔	✔	O	✔	✔	O	✔
Fluorine	✘	✘	✘	✘	✘	✔	✘
Fluorosilicic Acid	✘	✘	✘	✔	✔	✔	✘
Formaldehyde	✔	✔	O	✔	✔	✔	✔
Formic Acid (85%)	O	O	✘	✔	✔	✔	✔
Formic Acid (10%)	✔	✔	O	✔	✔	✔	✔
Gas Oil	✔	✔	O	✔	✔	✔	✔
Gasoline	✔	✔	✔	✔	✔	✔	✔
Freons	O	O	✘	✘	✔	✔	✔
Heating Oil	✔	✔	✔	✔	✔	✔	✔
Hydraulic Oil (Glycol)	✔	✔	✔	✔	✔	✔	✔
Hydraulic Oil (Mineral)	✔	✔	✔	✔	✔	✔	✔
Hydraulic Oil (Ester)	✔	✔	O	O	✔	✔	✔
Hydrazine	✔	✔	✘	✔	✔	✔	✔
Hydrocarbons (Aromatic)	✔	✔	✘	✔	✔	✔	✔
Hydrocarbons (Aliphatic S)	✔	✔	O	✔	✔	✔	✔
Hydrocarbons (Aliphatic U)	✔	✔	O	✔	✔	✔	✔
Hydrochloric Acid (37%)	O	✘	✘	✔	✔	✔	✔
Hydrofluoric Acid	✘	✘	✘	O	O	✔	✘
Hydrogen	✔	✔	O	✔	✔	✔	✔
Hydrogen Chloride	✘	✘	✘	✔	✔	✔	✔
Hydrogen Fluoride	✘	✘	✘	O	O	✔	✘
Hydrogen Peroxide	✘	✘	✘	O	✔	O	✔
Hydrogen Sulphide	✔	✔	O	✔	✔	✔	✔
Isopropyl Acetate	✔	✔	✔	✔	✔	✔	✔
Isopropyl Alcohol	✔	✔	✔	✔	✔	✔	✔
Kerosene	✔	✔	✔	✔	✔	✔	✔
Lime (Quick)	✔	✔	✔	✔	✔	✔	✔
Lubricating Oil	✔	✔	O	✔	✔	✔	✔
Machine Oil	✔	✔	O	✔	✔	✔	✔
Magnesium Sulphate	✔	✔	✔	✔	✔	✔	✔
Malic Acid	✔	✔	O	✔	✔	✔	✔
Methane	✔	✔	✔	✔	✔	✔	✔
Methyl Acrylate	✔	✔	✘	O	✔	✔	✔
Methyl Alcohol	✔	✔	✔	✔	✔	✔	✔
Methyl Isobutyl Ketone	O	O	O	O	✔	✔	✔
Methyl Methacrylate	✔	✔	O	O	✔	✔	✔
Methylene Chloride	✘	✘	✘	O	✔	✔	✔
Mineral Oil	✔	✔	O	✔	✔	✔	✔
Mobiltherm	✔	✔	✘	✔	✔	✔	✔
Naphthalene	✔	✔	O	✔	✔	✔	✔
Natural Gas	✔	✔	✔	✔	✔	✔	✔
Nitric Acid (50%)	✘	✘	✘	✔	✔	O	✔
Nitric Acid (95%)	✘	✘	✘	✘	✔	✘	✔
Nitrogen	✔	✔	✔	✔	✔	✔	✔
Oleum	✘	✘	✘	✘	✔	✘	O
Oxygen	✔	✔	✘	✔	✔	O	✔
Paraffin	✔	✔	✔	✔	✔	✔	✔
Pentachlorophenol	✘	✘	✘	✘	✔	✔	✔
Perchloric Acid	✘	✘	✘	✔	✔	✘	✘
Petrol	✔	✔	✔	✔	✔	✔	✔
Phenol	✘	✘	✔	O	✔	✔	✔
Phosgene	✘	✘	✘	✘	✔	✔	✘
Phosphoric Acid (Conc)	✘	✘	✘	✔	✔	✔	✔
Phosphoric Acid (Dil)	✔	✔	✘	✔	✔	✔	✔
Phosphorous	✘	✘	✘	✘	✔	O	✘
Phthalic Anhydride	✘	✘	✘	O	✔	✔	✔
Potassium Hydroxide	O	O	✘	✔	✔	✔	✔
Potassium Nitrate	✔	✔	✔	✔	✔	✔	✔
Potassium Permanganate	✔	✔	✔	✔	✔	✔	✔
Producer Gas	✔	✔	✔	✔	✔	✔	✔
Pyridine	✘	✘	✘	✘	✔	✔	✔
Sea Water	✔	✔	✔	✔	✔	✔	✔
Silicone Oil	✔	✔	✔	✔	✔	✔	✔
Soda Ash	✔	✔	✔	✔	✔	✔	✔
Sodium Bicarbonate	✔	✔	✔	✔	✔	✔	✔
Sodium Carbonate	✔	✔	✔	✔	✔	✔	✔
Sodium Cyanide	✔	✔	✔	✔	✔	✔	✔
Sodium Hydroxide (40%)	✘	✘	✘	✔	✔	✔	✔
Sodium Hydroxide (Dil)	✔	✔	✘	✔	✔	✔	✔
Sodium Hypochlorite	✔	✔	O	✔	✔	✔	✔
Sodium Nitrate	✔	✔	✔	✔	✔	✔	✔
Starch	✔	✔	✔	✔	✔	✔	✔
Steam	✔	✔	O	✔	✔	✔	✔
Steam Condensate	✔	✔	✔	✔	✔	✔	✔
Styrene	O	O	✘	✘	✔	✔	✔
Sulphur	✔	✔	O	✔	✔	✔	✔
Sulphur Dioxide	✔	✔	✔	✔	✔	✔	✔
Sulphur Trioxide	✘	✘	✘	✔	✔	✘	✔
Sulphuric Acid (Conc)	✘	✘	✘	✔	✔	✘	✔
Sulphuric Acid (Fuming)	✘	✘	✘	✘	✔	✘	O
Tar	✔	✔	✘	✔	✔	✔	✔
Turpentine	✔	✔	✔	✔	✔	✔	✔
Toluene	✔	✔	✘	✔	✔	✔	✔
Towns Gas	✔	✔	✔	✔	✔	✔	✔
Transformer Oil	✔	✔	O	✔	✔	✔	✔
Tributyl Phosphate	✔	✔	✔	✔	✔	✔	✔
Triethanolamine	✔	✔	✔	✔	✔	✔	✔
Urea	✔	✔	✔	✔	✔	✔	✔
Vegetable Oil	✔	✔	✔	✔	✔	✔	✔
Vinyl Acetate	✔	✔	O	✔	✔	✔	✔
Vinyl Chloride	✔	✔	O	✔	✔	✔	✔
Vinylidene Chloride	✔	✔	O	✔	✔	✔	✔
Water	✔	✔	✔	✔	✔	✔	✔
Water Condensate	✔	✔	✔	✔	✔	✔	✔
Water Distilled	✘	✘	✘	✘	✔	✔	✔
Whisky	✔	✔	✔	✔	✔	✔	✔
Wine	✔	✔	✔	✔	✔	✔	✔
White Spirit	✔	✔	O	✔	✔	✔	✔
Xylene	✔	✔	✘	✔	✔	✔	✔

✔ Suitable O Application Dependent ✘ Not Suitable

Fig3.2 Chemical compatibility guide for different materials

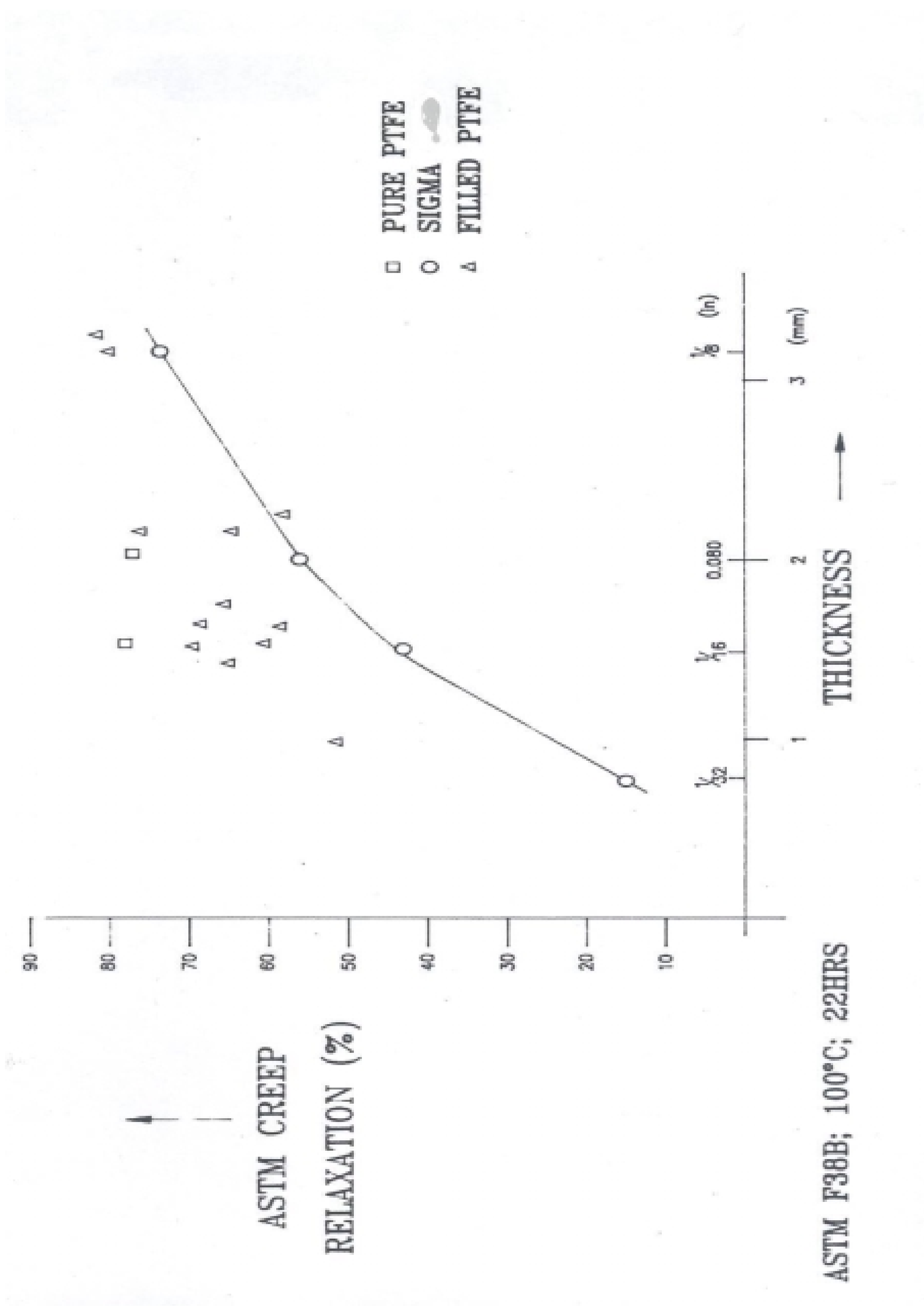


Fig3.3 Creep Relaxation of ptfe Types