Henkel Adhesive Technologies

WHITE PAPER

IMPROVED PERFORMANCE OF NEXT GENERATION ANAEROBIC FLANGE SEALANT

LOCTITE®

ABSTRACT

The objective of this document is to show how anaerobic flange sealants (anaerobic gasketing products) offer benefits over other sealing technologies such as compression gaskets. A further aim is to provide customers with insights into the latest technological developments in anaerobic flange sealing. As part of an ongoing Innovation Programme in anaerobic adhesive and sealant technology, Henkel has reformulated key products in each of the anaerobic application technology areas,namely, Thread Locking, Thread Sealing, Flange Sealing, and Retaining. LOCTITE® 518™ is one of Henkel's lead selling anaerobic flange sealants. This document provides an overview of the improved performance characteristics of the next generation product, LOCTITE® 518™ Upgrade.

1. INTRODUCTION

Preventing the leakage of fluids is most often a critical requirement in the transport of a liquid or a gas, in industrial processes and in the operation of machinery. More often than not, when two mating flanges are assembled together, a compression gasket is used to make a seal.

Compression gaskets function by deforming a material into the voids and compensating for imperfections of the two mating surfaces using the clamping forces which hold the components together. Many variables must be considered when designing a compression gasket for an assembly. The gasket must properly deform into the voids to provide intimate contact under the applied clamping forces. It must withstand the chemical attack, pressures and temperatures of the fluid media. The mating surfaces must also have a minimum rigidity and surface finish to ensure any imperfections are sealed by the gasket under operational loads. Perhaps the biggest challenge is ensuring all of this is performed reliably over the service life of the equipment. Compression gaskets tend to fail or leak for many reasons. We will explore these reasons and how an anaerobic gasket overcomes many of these issues.

Compression Set: Relaxation & Creep

One of the inherent issues with compression gaskets is stress relaxation or gasket creep. The result of stress relaxation and gasket creep is compression set. In this type of failure, the gasket which is under compressive loads for long periods of time loses its ability to recover to its original thickness and permanently sets in its compressed shape. With the gasket no longer providing a pressure to return to its original thickness, the gasket no longer seals. Additionally this behaviour causes a loss in bolt tension.

Figure 1. An illustration of relaxation/creep of a compression gasket

Initial Condition: Fasteners are torqued and stretched. This provides a compressive force for the gasket seal.

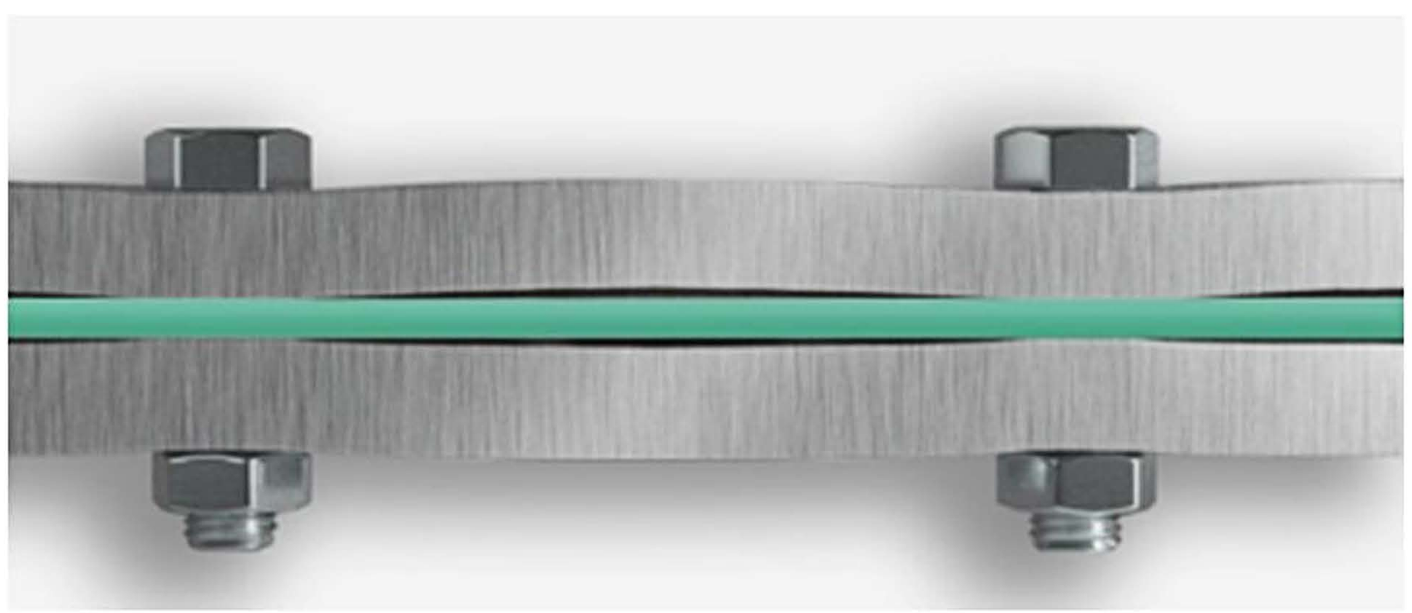
Compression Set: Prolonged compression causes the gasket to relax into a lower thickness. This reduces the compressive force for sealing as the bolts are no longer stretched to the same length.

This mode of failure is exacerbated by the fact that installation torque specifications are often based on assumptions of friction, or installation made with inaccurate tools. This leads to inaccurate bolt tension and therefore clamping forces that were not designed for the gasket.

Flange Bowing

Incorrect bolt tension is also a cause for flange bowing. Often when a flanged assembly is found to be leaking, maintenance staff will re-tighten the fasteners to achieve a seal. In this type of failure, the bolt tension has exceeded the appropriate compressive loads of the gasket but also has exceeded flexural strength of the flanges. This could also be inherent in the design if the flanges are too thin for the design loads. Additionally, this failure mode can be caused by differential thermal expansion of the mating flange surfaces.

Figure 2. An illustration of flange bowing due to excessive bolt tension

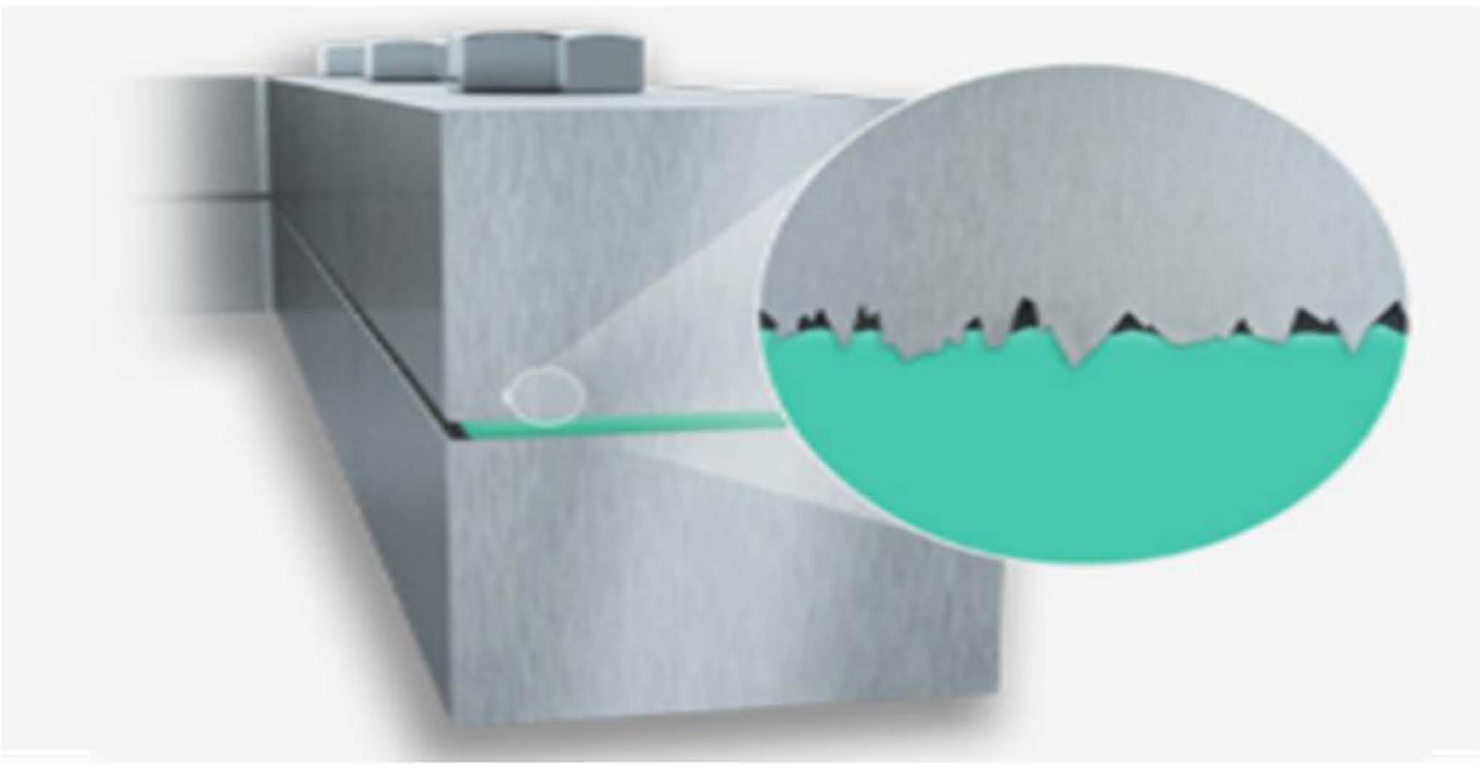


Surface Irregularities

As has been previously mentioned, mating surfaces must have a minimum level of surface finish or the gasket will not make adequate contact to provide a seal. Even if the surface is adequately machined, a single scratch across the flange from handling could create a fluid path.

This is most often seen during service of a flange where proper care is not taken when removing an old gasket that has been baked onto the flange.

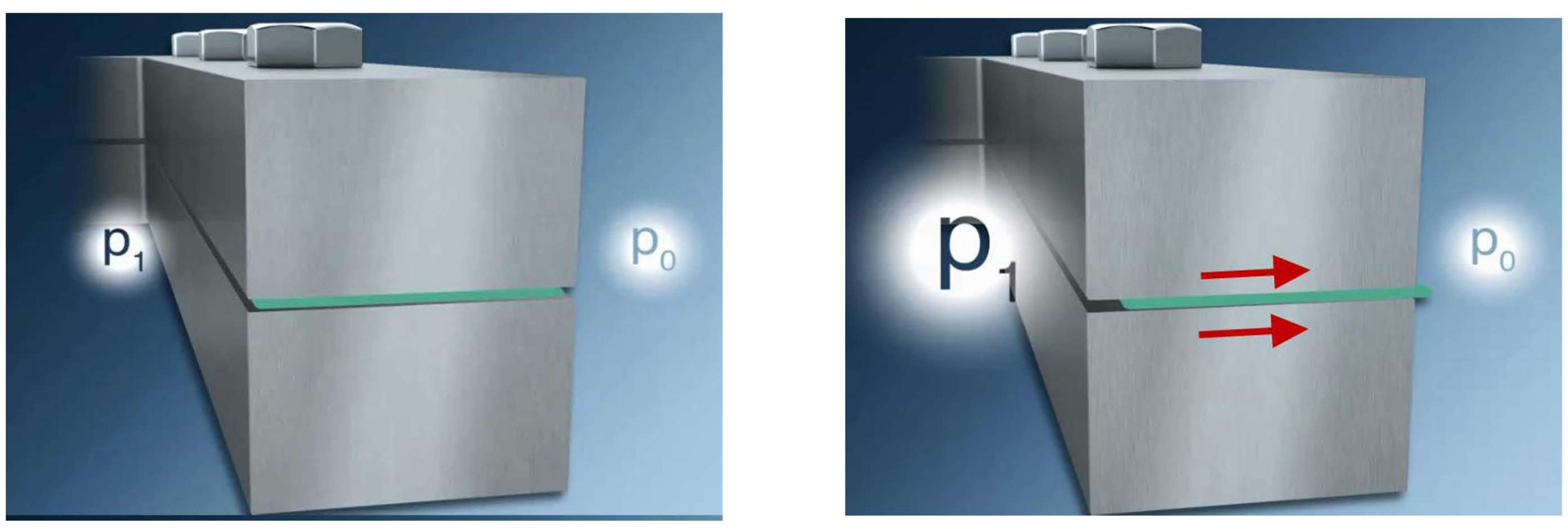
Figure 3. An illustration of surface irregularities, a potential cause of seal failure with a compression gasket



Gasket Displacement/Extrusion

One might think that if a flange is machined to a mirror like finish then the gasket would have no issue filling all the surface irregularities. Doing so would lead to gasket displacement or blow-out. A gasket requires a minimum level of friction and appropriate compression (sealing stress) to prevent the fluid pressures from extruding the gasket from the flange. This type of failure is most common with PTFE or graphite based gaskets due to their inherent low friction surfaces.

Figure 4. An illustration of gasket blow-out due to insufficient surface friction. In both graphics P1>P0, where P represents pressure



Bolt Hole Distortion

High stresses are transferred to the gasket material under the bolt head causing the gasket to crack, tear, rupture or extrude [1].

Traditional Gasket Summary

There are many choices for compression gasket materials but with all of these variables one realizes that best design to have would actually be to have no gasket at all. This is the concept behind a liquid form-in-place gasket such as an anaerobic gasket.

Anaerobic Flange Sealants

Anaerobic flange sealants or gasketing products are designed to create form-in-place gaskets between rigid metal flanges that are bolted together - metal surface to metal surface, as if the gasket did not exist, filling only the microscopic voids which exist between the mating surfaces. The anaerobic gasket remains liquid when exposed to air, but cures to a thermoset plastic when confined between mating flanges.
Contrasting this technology to traditional compression gaskets it is easy to see how the most common reasons for leaks do not occur.

Since a form-in-place gasket is not under compression, it will not experience the detrimental effects of relaxation and creep. Because it is liquid, it will fill any voids or surface irregularities and key into these irregularities once it cures, lightly adhering the surfaces together. This therefore prevents any gasket displacement. Excessive bolt tension could still cause bowing of a flange but because the surfaces are now bonded together with the anaerobic, there is an increase in rigidity of the flange surfaces and an increased ability to transfer loads. Anaerobic flange sealants are best suited for rigid metal-to-metal assemblies where the sealing gap is small. For example, surface flatness should not exceed 0.1mm over a length of 400mm [2]. The maximum gap at surface imperfections must be within the maximum gap cure of the product [2]. Typical maximum gap cure of anaerobic flange sealants range from 0.1 to 0.25mm [3].

The original Loctite range of anaerobic gasketing products has evolved to include a large array of products, with different performance attributes. Table 1 provides an overview of important properties for key products in this range.

TABLE 1. Properties of key anaerobic gasketing products

Product	Attributes
LOCTITE® 518™ Upgrade	Semi-flexible generalist anaerobic gasketing product, exhibiting excellent performance on all key performance parameters including gap cure, contamination tolerance, and instant seal capability.
LOCTITE® 515™	Semi-flexible generalist anaerobic gasketing product.
LOCTITE® 5127™	First generation flexible anaerobic gasketing product, used on rigid grey-cast iron parts.
LOCTITE® 5188™	Highly flexible grade. Optimised for use on Aluminium parts.
LOCTITE® 510™	High temperature grade, up to 200°C. Rigid grade, broad chemical resistance.
LOCTITE® 5800™	Health and Safety label free grade (Europe). Rigid grade. Broad chemical resistance
LOCTITE® 574™	Rigid general purpose grade. Fast fixture time. Broad chemical resistance.

Upgrade Requirements

Common challenges faced by anaerobic gasketing products include:

- Cure on metal surfaces contaminated with oils and cleaners
- Cure on inactive surfaces (e.g. low copper aluminium)
- Gap cure
- Degradation and loss of flexibility onexposure to elevated temperatures

The product profile for LOCTITE® 518™ Upgrade required us to focus on each of these characteristics in order to achieve improvements in all these areas.

Definitions

- Contamination Tolerance: The ability of an adhesive to form a robust cure on contaminated parts.
- Gap Cure: The ability of an adhesive to cure through an induced gap.
- Cure on Inactive Surfaces: The ability of an adhesive to cure on metal surfaces with low activity.
- Flexibility Retention: The ability of a cured adhesive film to retain flexibility after exposure to elevated temperatures.

ANALYSIS

Methods

The following standard practices and standard test methods were used.

ISO 4587:2003 – Adhesives - Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies.
ASTM D882-09 – Standard test method for tensile properties of thin plastic sheeting.

Materials

The following materials were used.

Steel Lap-Shear RE-14 cold rolled steel (SAE 1010), half hardened (T2B 70-85)
Aluminium Lap-Shear, AR-14, 2024T3.

Procedures

Oil Contamination Procedure:

All substrate specimens were degreased with isopropyl alcohol prior to use. Solutions of various oils were prepared using proprietary methods, depending on their category as outlined below.

Four categories of oils were included in these tests.

- Hydrophobic oils: Oils such as motor oil which are not miscible with water.
- Emulsifiable oils: Oils such as water emulsifiable corrosion protectants.
- Solvent based oils: Oils such as corrosion inhibitors, which come pre-prepared in solvent.
- Synthetic lubricants

The adhesive strength was measured as a lap shear strength on non-gritblasted mild steel lapshears [ISO 4587:2003], after a cure time of 168 hours at 22°C. Oiled lapshear strengths were determined and compared with strengths obtained on non-oiled lapshears.

Cleaner Contamination Procedure

All substrate specimens were degreased with isopropyl alcohol prior to use.

Prior to adhesive application and assembly, the to-be-bonded end of each steel lap shear specimen were immersed in cleaner solution. The cleaner-coated substrates were allowed to dry for 24 hours at ambient temperature. The adhesive strength was measured as a lap shear strength on non-grit blasted mild steel lap shears [ISO 4587: 2003], after a cure time of 168 hours at 22°C.

Gap Cure Procedure

All substrate specimens were degreased with isopropyl alcohol prior to use. Additionally, the test specimen surfaces were grit blasted.

Appropriate gaps were induced in the test substrate bond lines. The adhesive strength was measured as a lap shear strength on grit blasted mild steel lap shears [ISO 4587:2003], after a cure time of 168 hours at 22°C.

Flexibility Retention Procedure

The procedures outlined in ASTM D882-09 were followed for flexibility measurement of test strips.

RESULTS AND DISCUSSION

Oil Tolerance

Oil tolerance is an important property of anaerobic adhesives as customers may find it difficult to completely clean metal parts, or in some cases use them as received. To test for oil tolerance, the general approach involves application of oil to cleaned parts in a controlled manner to achieve a thin homogenous film followed by determination of the strength of the adhesive on these parts upon curing. The strength results are compared to those obtained on the same type of part not treated with oil. Oil tolerance is an inherent property of the formulation. Ingredients are chosen which enhance the ability of the product to cure in the presence of the oil.

Oil Tolerance of LOCTITE® 518™ Upgrade versus LOCTITE® 518™ Original

Table 2 demonstrates the enhanced oil tolerance performance of LOCTITE® 518™ Upgrade versus LOCTITE® 518™ Original on a range of oils including; motor/engine oil, aqueous based corrosion prevention oils, solvent based corrosion prevention oils, cutting fluids and synthetic gear oils. In all cases, higher strengths are obtained with the Upgrade product

TABLE 2. Lap shear strength comparison of Loctite 518 Upgrade versus LOCTITE® 518™ Original on oiled surfaces

Oil Type	Oil Function	LOCTITE® 518™ Original [N/mm²]	LOCTITE® 518™ Upgrade [N/mm²]
None	N/A	3.7	5.5
Hydrophobic	Motor/Engine	3.4	5.2
Emulsion 1	Anti-corrosion	2.2	5.8
Emulsion 2	Anti-corrosion	2.0	5.3
Emulsion 3	Cutting Fluid	2.0	4.7
Emulsion 4	Cutting Fluid	3.0	5.1
Emulsion 5	Cutting Fluid	3.2	5.6
Emulsion 6	Cutting Fluid	2.6	6.2
Synthetic lubricant	Gear Oil	3.0	6.0
Solvent Based	Anti-corrosion	1.4	4.5

Cleaner Contamination Tolerance

Cleaner contamination tolerance is also a significant issue for anaerobic adhesives as cleaner residues are often present on metal parts after they have been put through a cleaning process prior to bonding. The achievement of cleaner tolerance is complex. Improvement requires formulation optimization to improve performance on parts which may be contaminated with active site blocking agents (corrosion inhibitors), residual liquids and other components from cleaners. Testing for cleaner contamination tolerance involves a similar approach to that adopted for oil contamination tolerance. Cleaners are applied to degreased parts in a controlled manner to achieve a thin homogenous film followed by determination of the strength of the adhesive on these parts upon curing. Table 3 demonstrates the significant improvements we have been able to achieve in performance for LOCTITE® 518™ Upgrade versus LOCTITE® 518™ original on cleaner contaminated parts.

TABLE 3. Bond strength comparison of LOCTITE® 518™ Upgrade versus LOCTITE® 518™ original on cleaner contaminated surfaces

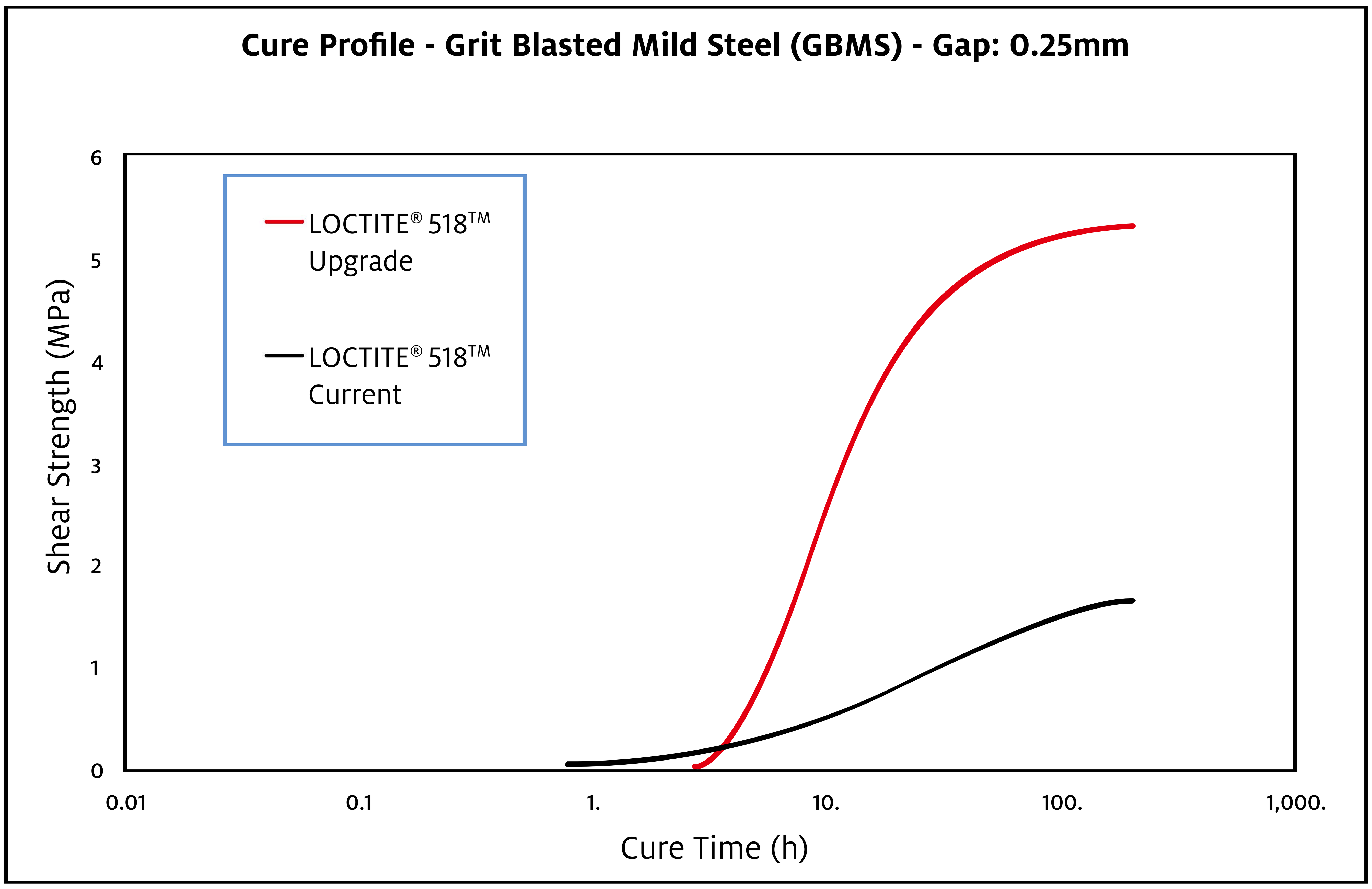
	Degreased	P3 Neutracare 3300	P3 Neutracare 300	P3 Emulpon 6765
Company Name		Henkel	Henkel	Henkel
Cleaner Function	N/A	Neutral Metal Cleaner/ Corrosion inhibitor	Neutral Metal Cleaner/ Corrosion inhibitor	Metal Cleaner/ Corrosion inhibitor
Lap shear strength (Nmm-2) measured on non-gritblasted mild steel lap shears				
LOCTITE® 518™ Upgrade	5.5	4.3	5.9	7.2
LOCTITE® 518™ Upgrade	3.3	0.0	0.7	2.1

GAP CURE

Gap cure capabilities are important for damaged, poorly machined or poorly designed metal flanges. Cure through induced gaps is typically a limitation for anaerobic products. Anaerobic products are designed to cure in the absence of air (oxygen); hence the term 'Anaerobic'. As a consequence of the presence of an induced gap, oxygen cannot be fully eliminated from the bond line, inhibiting cure. It is difficult to improve cure under these conditions. The primary reason for this difficulty is simply that in order to improve gap cure, the product developer must make the product more reactive. This can be done by optimisation of the cure system. However, at all times, the long term stability of the product in pack is critical, so achieving an optimum balance is important.

Fig. 5 demonstrates the significantly improved gap cure performance of LOCTITE® 518™ Upgrade versus Loctite 518 original at 0.25 mm induced gap. In this example the final cured strength of LOCTITE® 518™ has been increased from approximately 2 to 5 Nmm-2 on grit blasted mild steel. Similar improvements are also achieved for other substrates such as aluminium and non-grit blasted mild steel.

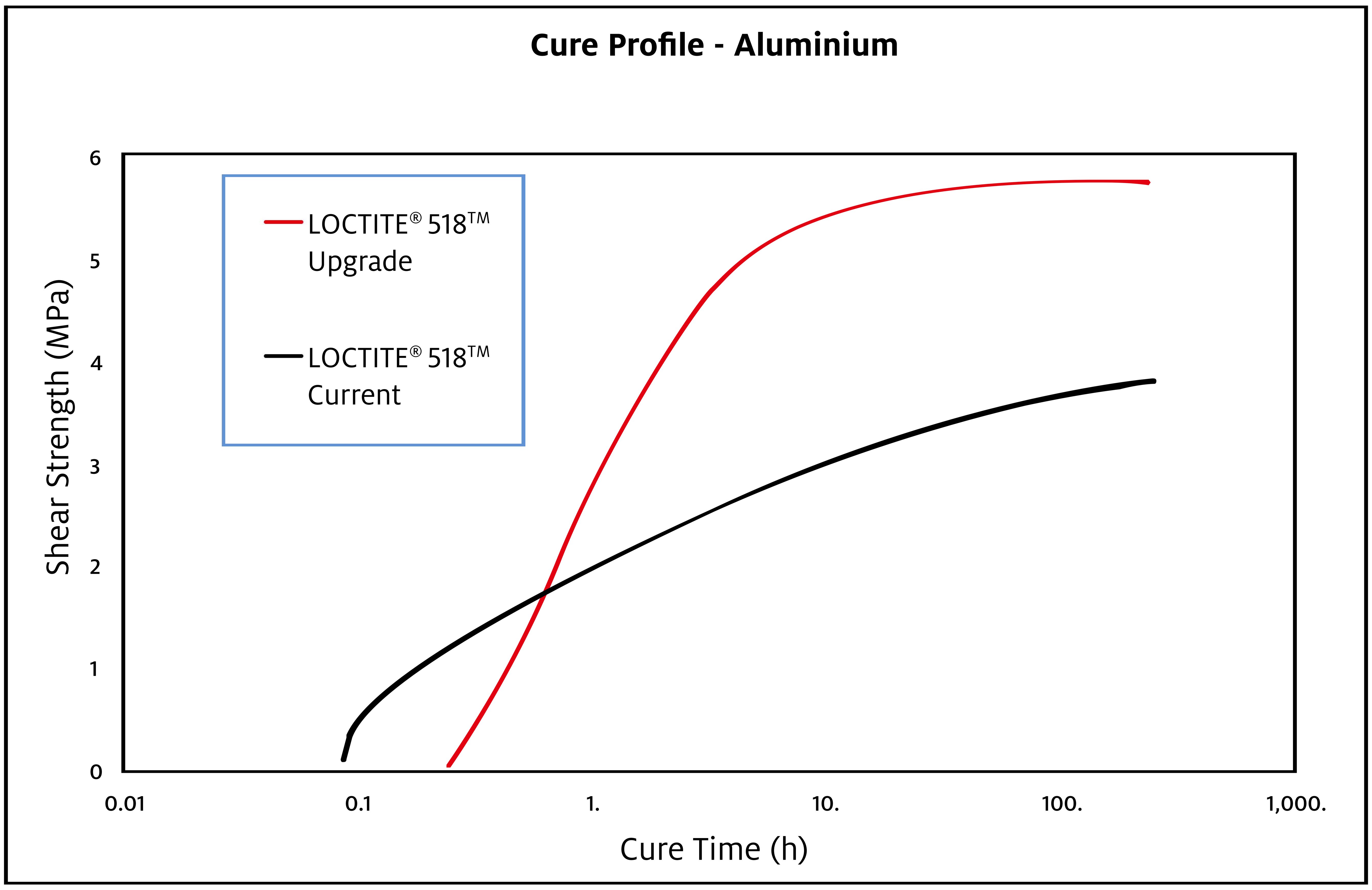
Figure 5. Gap cure performance of LOCTITE® 518™ Upgrade versus LOCTITE® 518™ original.



Cure on Inactive Surfaces

Cure on, and adhesion to, less active surfaces such as aluminium has become increasingly important for our anaerobic gasketing products in recent years. These surfaces present two challenges to the product developer. Firstly, they can contain very low levels of redox active metals which requires the use of very reactive cure systems. Secondly, after cure, adhesion to the surface can be compromised especially on aluminium - necessitating the use of adhesion promoters. Fig. 6 demonstrates the significantly improved cure and adhesion to aluminium of LOCTITE® 518TM Upgrade versus LOCTITE® 518TM original.

Figure 6. Cure profiles for LOCTITE® 518™ Upgrade and LOCTITE® 518™ original.



Flexibility

Anaerobic gasketing products are best suited for rigid metal-to-metal assemblies where the sealing gap is small. However, gaps may be present in cases where the metal flanges are damaged, poorly machined or poorly designed. In such cases the ability of the adhesive to deal with micro-movements is important. Accordingly, it is advantageous for the cured anaerobic adhesive to have some flexibility to avoid cracking and ensure a good seal. Anaerobic products tend to be brittle when cured. We have developed a methodology to prepare cured films under controlled conditions which can be used to measure elongation at break. The flexibility of Loctite 518 has been increased from 20% for the original version to 65% for the Upgrade. This should further enhance the ability of the product to tolerate micro-movements.

CONCLUSION

Henkel as a leading supplier in the adhesives and sealants market, is committed to innovation and providing our customers with high performance products that work reliably in their applications.
LOCTITE® 518TM has undergone significant re-development and has been successfully upgraded to offer:

- Better, more consistent cure through the light oil and cleaner contaminations experienced under real-world production and maintenance conditions
- Improved gap cure
- More robust cure and higher strength on passive metal surfaces.
- Higher flexibility
- All of these improvements contribute to an enhanced sealing capability of the product under non-ideal conditions of use.

These product enhancements have been achieved while maintaining the product's core characteristics such as appearance, fluorescence and viscosity and without any change to the existing health and safety classification. LOCTITE® 518TM Upgrade also maintains approvals such as NSF P1 for incidental food contact

REFERENCES

Loctite Worldwide Design Handbook, 2nd Edition, Chapter 6, p99.

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