Flexitallic

innovate / customize / educate

PRODUCT DATASHEET

THERMICULITE® 866

Thermiculite® 866 cut gasket samples

Thermiculite 866® is a high temperature sealing material designed for solid oxide fuel cell applications. It is based upon the mineral vermiculite and contains no organic binder or any other organic component.

Thermiculite®
innovative. versatile. complete.

Thermiculite® 866 is giving excellent sealing service in SOFC applications and is being used by many SOFC development groups around the world.

Vermiculite is a natural sheet silicate mineral formed by hydro-thermal modification of biotite and phlogopite mica, it retains all the thermal and chemical durability of mica and remains electrically insulating. Like mica, vermiculite occurs as plate morphology particles, "books", consisting of thousands of individual platelets, each nanometres thick, positioned one on top of the next. These particles can be opened up, "exfoliated", like the pages of a book to reveal the individual platelets.

The traditional method of exfoliation is thermal and in this thermally exfoliated form vermiculite is well known as a thermal insulation, a packaging material and in many other applications. Another method of exfoliation is chemical exfoliation. This produces a dispersion of individual platelets which are separated from each other. These platelets are highly flexible and conform to the surfaces of other particles to bind them together.

This binding action allows a sheet material to be manufactured without any organic binding agents being present, thus Thermiculite® 866 consists just of the chemically exfoliated vermiculite and a second filler material. The second filler material is a very familiar mineral, talc, also known as steatite or soapstone. Like mica and vermiculite, steatite is also a naturally occurring, high temperature stable, sheet silicate mineral but it is characterized in that it is very soft.

The combination of the chemically exfoliated vermiculite with steatite results in a material that retains all the chemical and thermal durability usually associated with mica but which is very soft and conformable. The manufacturing method used to produce the Thermiculite® 866 results in the vermiculite and steatite platelets being aligned parallel to each other and parallel to the plane of the foil.

The softness of the material and the platelet alignment result in a material which compresses under very low load to produce a compacted material that offers a very tortuous, passage-stopping, path to any gas trying to permeate through it in the plane of the sheet or perpendicular to that plane. This means that the material has superb sealing characteristics combined with peerless thermal stability. This makes it admirable for SOFC sealing applications.

A gasket must first create a seal and must then maintain that seal for the required lifetime. Thermiculite® 866 is excellent in both of these respects.

It is soft and highly conformable and therefore creation of both macro and micro sealing is readily achieved. Also, maintaining the seal is not a problem as it contains no organic components that would result in relaxation or creep and, in a connection stressed by bolts, lead to loss of surface load on the gasket.

Until Thermiculite® 866 has been raised to 570°C or more for the first time it has poor water resistance so care should be taken to ensure that in areas where condensed water is likely to be present that no part of the gasket that is not compressed protrudes into the area where that water is likely to be present.

Flexitallic

innovate / customize / educate

PRODUCT DATASHEET

Approvals / Compliance:
BAM for Oxygen approved.

Availability:
Thermiculite® 866 is available as either cut gaskets or in sheet form. Thermiculite® 866 is made at a width of 450mm and can be supplied in lengths of up to 1000mm. A popular sheet size is 450mm x 350mm.

Thermiculite® 866 is supplied at a density of 1.9gm / cm^3 and thicknesses on 0.3, 0.5, 0.7 and 1.0mm are routinely stocked with intermediate thicknesses being available on special request.

Thermiculite® 866 can be easily cut into complex shape gaskets by the traditional gasket cutting techniques but laser and water jet cutting methods should not be used. As a service to customers a gasket cutting service at no extra charge is available. For confidential gasket shapes a non-disclosure agreement will be signed to ensure the confidentiality of the shape information supplied.

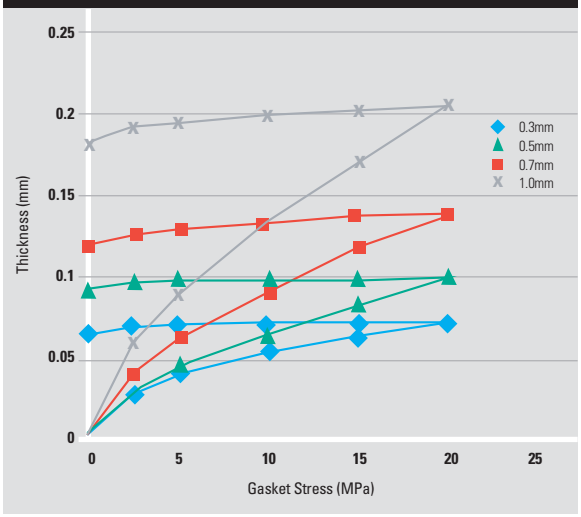
Typical Physical Properties:
Figure 1 shows the compression characteristics of Thermiculite® 866 of the standard thicknesses.

Figure 2 demonstrates the creep resistance of Thermiculite® 866 at ambient and elevated temperature. The temperature of 450°C being a test equipment limitation, not a material limitation.

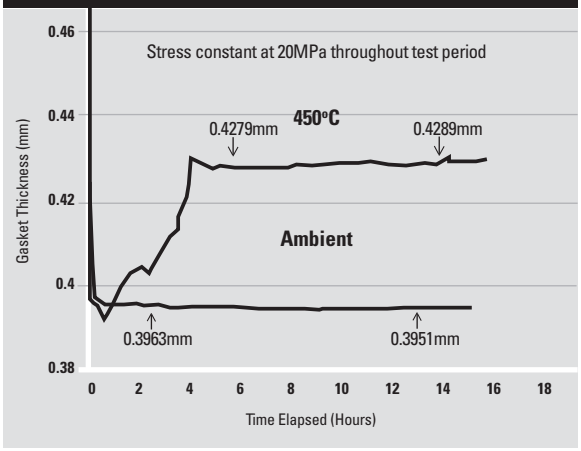
Figure 3 compares the sealing performance of Thermiculite® 866 and mica and clearly demonstrates, even at ambient temperature, the superiority of Thermiculite® 866. At an elevated temperature the difference would be greater.

Continued

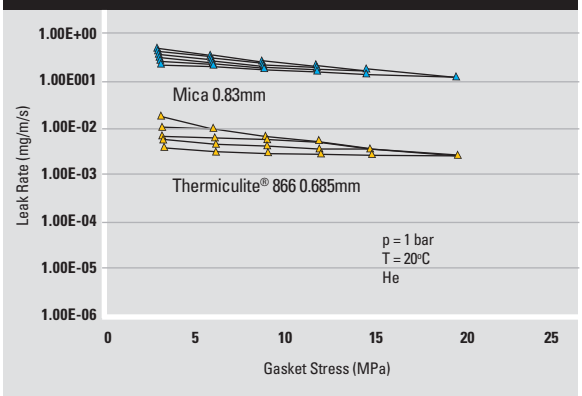
1 COMPRESSION & RECOVERY OF TH866 VS STRESS



2 CREEP CHARACTERISTICS OF THERMICULITE® 866, 0.47mm



3 COMPARISON OF SEALING OF THERMICULITE® 866 & MICA



Flexitallic®

innovate / customize / educate

PRODUCT DATASHEET

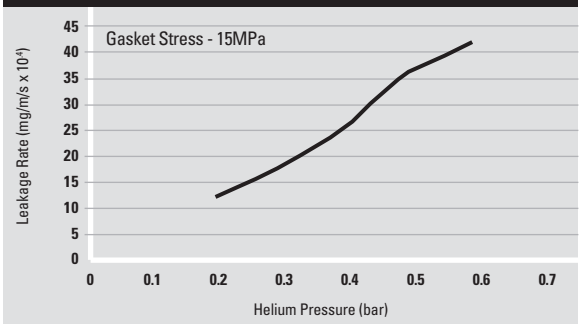
Typical Physical Properties:

Figure 4 shows how the sealing of Thermiculite® 866 improves as the pressure to be sealed reduces.

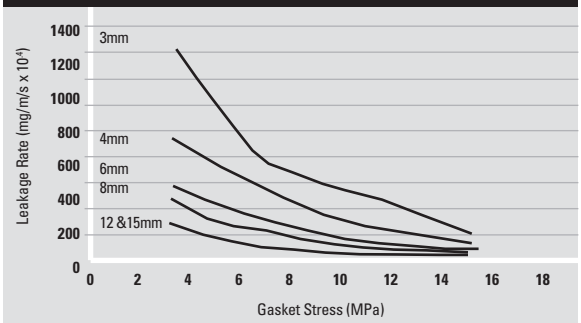
Figures 5 and 6 show further how the sealing of Thermiculite® 866 is influenced by the gas pressure to be sealed and on the landwidth of the gasket, the land width is half the difference between the compressed external and internal dimensions of the gasket.

Figure 7 shows the robustness of the sealing of Thermiculite® 866 against thermal cycling. In this figure the sealing after the five thermal cycles, shown as dashed lines, remains as expected from the data obtained before the thermal cycles.

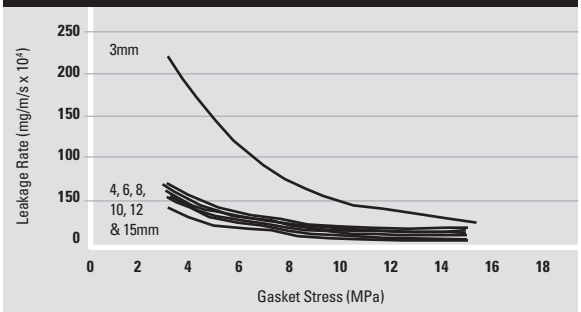
4 THE INFLUENCE OF THE INTERNAL PRESSURE ON THE LEAKAGE RATE OF THERMICULITE® 866



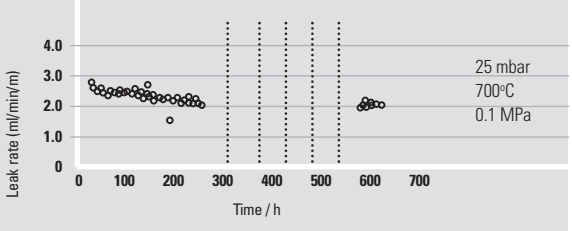
5 THE EFFECT OF LAND-WIDTH ON THE LEAKAGE RATE HELIUM PRESSURE = 1 BAR



6 THE EFFECT OF LAND-WIDTH ON THE LEAKAGE RATE HELIUM PRESSURE = 0.3 BAR



7 THE ROBUSTNESS AGAINST THERMAL CYCLING AND SEALING PERFORMANCE OF THERMICULITE® 866



Flexitallic

innovate / customize / educate

PRODUCT DATASHEET

Electrical insulating resistance of Thermiculite® 866 determined by IE 167 (BS 2782: Part 2: 1992):

	Megohms	
	As Received	After 50°C for 24 hours
0.5mm	0.33	7.5
0.7mm	0.50	7.5

The specific heat capacity of Thermiculite® 866:

	J / g / K
0.5mm	0.949
0.7mm	0.950

The thermal conductivity of Thermiculite® 866 determined by ISO 8301 (DIN 52612 & ASTM C518):

	W / m / K
0.7mm	0.19

Best Sealing Practice:

To obtain the best performance from a sealing material the following considerations apply just as much to an SOFC as to an industrial pipeline gasket:

- Minimize the gasket area as far as possible taking into consideration the minimum landwidth requirement for gasket handling and sealing
- Maximize the compressive load available
- Use studs of the appropriate metal and stress to a high percentage of yield
- Minimize load loss by making the studs as compliant as possible by using the minimum stud diameter suitable and by using extension collars or constant load washers such as Belville washers
- Tighten the studs in a cross pattern manner
- Tighten the studs using either controlled torque or hydraulic tensioners
- With torque tensioning use a reliable lubricant having a known friction factor
- Unless the gasket is compensating for connection defects, always use the minimum practical thickness
- The surfaces to be sealed should preferably have ground rather than a turned finish but they should certainly be free from transverse machining marks or scratches. An appropriate surface finish is N6, Ra 0.8µm, CLA 32µ" / Rz 3.20µm, 126µ" or better.

When correctly selected and used an appropriate gasket is able to provide a seal, whilst allowing the cost of the SOFC stack to be reduced via the use of less bolt load, less rigid stack components and reduced tolerances for the components to be sealed.

Health & Safety

This product is believed to present no health and safety hazard during gasket cutting, in use or on removal after service. In normal use it is unlikely that the product will give rise to significant levels of exposure to the constituent materials.

Flexitallic Thermiculite® 866 comprises only chemically exfoliated vermiculite and steatite.

Under harsh mechanical treatment (e.g. high speed stamping operations or abrasion) the constituents may give rise to irritant dust which, in extreme cases of exposure, could lead to more serious respiratory problems. Occupational exposure to such dusts should therefore be minimised and kept below relevant national exposure limits. Good standards of hygiene should be applied during gasket cutting operations and off-cuts should be disposed of by transfer to a site appropriately licensed to accept industrial materials of this nature.

Sample material for evaluation

Sample material or sample cut gaskets for evaluation can be obtained without charge from:

For Europe and Asia
John Hoyes
www.flexitallicsofc.com
Email: jhoyes@flexitallic.eu
Phone: + 44 7767 341985

For the Americas and China
Stephen Bond
www.flexitallic.com
Emai: sbond@flexitallic.com
Phone: +1 281 604 2477

Flexitallic

innovate / customize / educate

PRODUCT DATASHEET

THERMICULITE® 866 LS

Thermiculite® 866 cut gasket samples

A compression sealing material designed for solid oxide fuel cell (SOFC) applications where the service temperature is 700°C or more and the compressive loading only generates a low compressive stress, even as low as 0.1 MPa.

Thermiculite®
innovative. versatile. complete.

This material consists of Thermiculite® 866 with a thin coating on each sheet surface of a beige coloured finish which contains a glass powder. The glass used was formulated for SOFC sealing applications, is very finely ground, and melts at below 700°C. Thermiculite® 866LS was designed to allow excellent sealing in those applications where the loading on the gasket is not high enough to allow a seal to be created with Thermiculite® 866.

The beige coloured surface finish contains, apart from the glass powder, an acrylic binder, organic pigments and processing aids and a minor amount of borax. In service this binder system burns off before the temperature reaches the melting point of the glass powder. Once the glass powder melts it creates a conformable and viscous layer between the Thermiculite® 866 core and the surfaces to be sealed. This layer fills the surface imperfections in the surfaces to be sealed and allows the creation of a seal at a much lower stress than is possible with Thermiculite® 866 alone.

During the use of Thermiculite® 866LS gaskets no initial glass sintering cycle to above the operating temperature of the SOFC stack is required. Provided that the stack operating temperature is at least 700°C the glass coating will form the required seal.

The details of the Thermiculite® 866 core are given in the Thermiculite® 866 Data Sheet and will not be repeated here.

Approvals / Compliance:
BAM for Oxygen approved.

Availability:
Thermiculite® 866LS is available as either cut gaskets or in sheet form.

Maximum sheet size:
450mm x 350mm.

The stocked thicknesses of Thermiculite® 866LS are produced by applying the LS coating to Thermiculite® 866 of the standard 0.3, 0.5, 0.7 and 1.0 mm thicknesses. Other thickness are available on request.

The coating increases the sheet thickness by about 0.15 mm but in service, when the organic components of the coating have burnt off, the glass will have a thickness of about 18µm on each side of the gasket core.

If required, cut gaskets of Thermiculite® 866LS can be supplied rather than sheet. This service is offered at no extra charge and, if required, an non-disclosure agreement will be signed to protect the confidentiality of the drawings required in order to offer this gasket cutting service.

Continued on the following page

Flexitallic

innovate / customize / educate

PRODUCT DATASHEET

Typical Physical Properties:

Typical properties of Thermiculite® 866 are detailed in the Thermiculite® 866 data sheet.

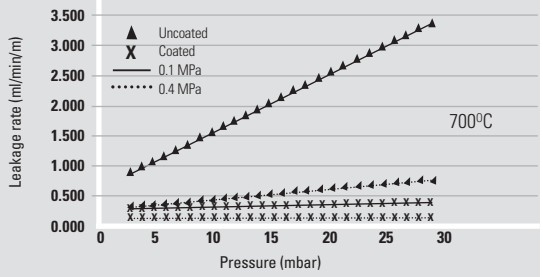
For the Thermiculite® 866LS data given below the test samples were heated at 60K / hour and there were no dwell periods during the heat up to the test temperature. The test temperatures were 700°C unless otherwise stated.

Figure 1, right, gives a comparison at 700°C of the sealing of Thermiculite® 866 and Thermiculite® 866LS as a function of gas pressure and gasket stress.

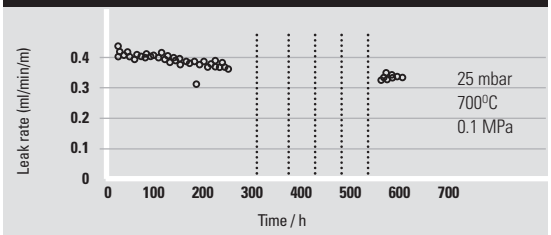
Figure 2 shows the robustness of the sealing of Thermiculite® 866LS against thermal cycling. In this figure the sealing after five thermal cycles, shown as the dashed lines, remains as expected from the data obtained before the thermal cycles.

Figures 3 and 4 illustrate the sealing performance of Thermiculite® 866LS at 700°C and 850°C respectively.

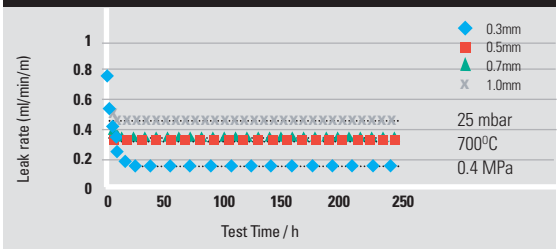
1 COMPARISON OF SEALING OF THERMICULITE® 866 &THERMICULITE® 866 LS AS A FUNCTION OF GAS PRESSURE AND GASKET STRESS



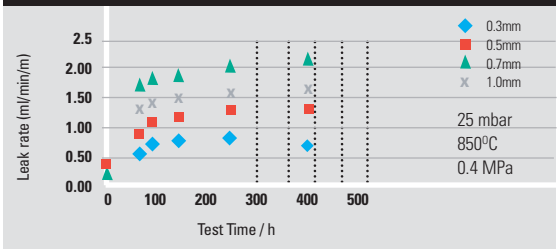
2 THE ROBUSTNESS AGAINST THERMAL CYCLING AND SEALING PERFORMANCE OF THERMICULITE® 866 LS



3 SEALING RESULTS AS A FUNCTION OF GASKET THICKNESS AT 700°C



4 SEALING RESULTS AS A FUNCTION OF GASKET THICKNESS AT 850°C



Best Sealing Practice:

To obtain the best performance from a sealing material the following considerations apply just as much to an SOFC as to an industrial pipeline gasket:

- Minimize the gasket area as far as possible taking into consideration gasket handling
- Maximize the compressive load available
- Use studs of the appropriate metal and stress to a high percentage of yield
- Minimize load loss by making the studs as compliant as possible by using the minimum stud diameter suitable and by using extension collars or constant load washers such as Belville washers
- Tighten the studs in a cross pattern manner
- Tighten the studs using either controlled torque or hydraulic tensioners
- With torque tensioning use a reliable lubricant having a known friction factor
- Unless the gasket is compensating for connection defects, always use the minimum practical thickness
- The surfaces to be sealed should preferably have ground rather than a turned finish but they should certainly be free from transverse machining marks or scratches. An appropriate surface finish is N6 , Ra 0.8 µm, CLA 32µ" / Rz 3.20 µm, 126µ" or better.

When correctly selected and used, an appropriate gasket is able to provide a seal whilst allowing the cost of the SOFC stack to be reduced via the use of less bolt load, less rigid stack components and reduced tolerances for the components to be sealed.

Health & Safety

This product is believed to present no health and safety hazard during gasket cutting, in use or on removal after service. In normal use it is unlikely that the product will give rise to significant levels of exposure to the constituent materials.

Flexitallic Thermiculite® 866LS comprises chemically exfoliated vermiculite and steatite with a coating as detailed in ther third paragraph of this document.

Under harsh mechanical treatment (e.g. high speed stamping operations or abrasion) the constituents may give rise to irritant dust which, in extreme cases of exposure, could lead to more serious respiratory problems. Occupational exposure to such dusts should therefore be minimised and kept below relevant national exposure limits. Good standards of hygiene should be applied during gasket cutting operations and off-cuts should be disposed of by transfer to a site appropriately licensed to accept industrial materials of this nature.

Sample material for evaluation

Sample material or sample cut gaskets for evaluation can be obtained without charge from:

For Europe and Asia
John Hoyes
www.flexitallicsofc.com
Email: jhoyes@flexitallic.eu
Phone: + 44 7767 341985

For the Americas and China
Stephen Bond
www.flexitallic.com
Emai: sbond@flexitallic.com
Phone: +1 281 604 2477