ALMA MEMO 551

Cross-polarization characterization of GORE–TEX® slabs at band 9 frequencies

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Abstract
GORE–TEX® material, commonly used in radomes, is known to be transparent at microwave bands [1]. In ALMA a thin GORE–TEX® membrane will cover the aperture through which the RF beam enters the cabin at the primary vertex hole [2]. Slabs of GORE–TEX® are also generally employed in windows for intermediate temperature shields inside the cryostat. The purpose of these windows ideally is to allow the beam to pass through them without introducing any alteration of the beam properties. Main concern has to be put on RF loss, but also in cross-polarization efficiency degradation. This report will stress on the results we have obtained in relation of loss of cross-polar efficiency of a linearly polarized beam passing through a GORE–TEX® slab, depending on its orientation relative to the direction of polarization of the beam.

Polarization properties of Mupore® and Rohacell® were also investigated.

Keywords: GORE–TEX, cross-polar level, anisotropy.

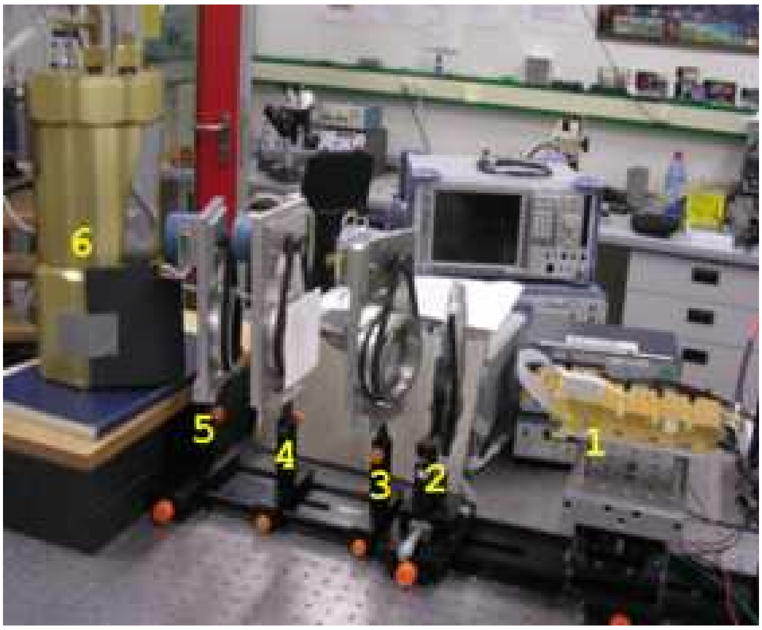
1. INTRODUCTION

For the band 9 cryogenic receiver GORE–TEX®[1] slabs are used at the windows of 12 and $90K$ intermediate shield temperature cryostat stages. The parameter sheet for this material is attached at the end of this memo. During a cross-polarization measurement campaign of the two beam polarization of the band 9 receiver, we noticed poor cross-polar efficiency performance of the system compared with the design expectation. After some trouble shooting it remained to verify the transparency of the GORE–TEX® windows. It came out that the slab of GORE–TEX® was inducing extra cross-polarization levels according to its relative orientation with the signal polarization passing through it. Further systematic analysis confirmed this indicating an anisotropic behavior of the GORE–TEX® material. The aim of this MEMO is to report the cross-polar measurements we have taken on various samples of GORE–TEX® slabs. In section 2. we give a brief description of the measurement set-up and the kind of measurement techniques we adopted in order to show the initial hypothesis. Section 3. shows the results obtained followed by conclusions.

2. MEASUREMENT SET-UP

In order to characterize various thicknesses of GORE–TEX® samples we assembled an ad hoc measurement bench set-up. The system is depicted in figure 1(a) with the numbering of the items that compose it. The system can allow total power measurement of a submillimeter signal using a computer controlled broadband source ($600-700\ GHz$) (item #1) and a cryogenic high sensitivity bolometer (item #6). The millimeter signal is obtained from a Gunn diode at 100 GHz and further multiplied time 6 by a $x2$ and $x3$ multiplier. The output of the source is radiated to the free space by mean of a diagonal horn. A plano-convex Teflon made lens (item #2) is used to refocus the beam power along the other system components and finally at the bolometer aperture. In order to obtain a pure linear polarized signal at the Sample Under Test (SUT) (item #4) a rotatable wired grid (item #3) is located between the SUT and the lens. A second wired grid (item #5) between the SUT and the

[1] GORE–TEX GR® sheet gasketing, according DIN 28091, TF-0-0.



(a) Measurement Set-up

(b) GORE–TEX sample

Fig. 1: Measurement set-up for the characterization of GORE–TEX® GR sample.

bolometer is used to allow power detection of the co- or cross-polar polarization of the SUT transmitted signal. The standing wave phenomena occurring along the chain set-up was minimized by using Ecosorb sheets and rotating items $2, 3, 4, 5$ in such a way the standing waves couldn't form. The SUT is mounted on a computer controlled rotational support. Grids #5 and #3 were manually rotated in order to ensure the measurement of only co- or cross- polar signal at the bolometer. The system as it is can be used for SUT power transmission measurements sweeping the source frequency and co- and cross-polarization power signal measurements of the transmitted signal at different rotation angles of the SUT. The aim of the first kind of measurement is to show at which frequencies the SUT is transparent. If this measurement procedure is taken for the two principal axis directions of the SUT than we can highlight the possible anisotropic properties. The second measurement procedure is performed at a fixed frequency but with the SUT rotating around the axis normal to the SUT surface. By measuring co- and cross-polar power versus the rotation angle of the SUT it is possible to show the level of cross-polarization introduced by the SUT at different relative orientation angles in relation with the source linear polarization direction.

3. RESULTS

It has been noticed that by rotating the sample of GORE–TEX® around the normal at the surface of the sample, different levels of power were read when the system of figure 1(a) was tuned to a fixed polarization direction. This suggests that there is a material anisotropic behavior. It has also been noticed that there is a direction of preference of the sample rotation. When the text on the sample (figure 1(b)) is aligned or at 90° with the polarization of the incident beam we have a peak in the transmitted signal. Thus in the following pictures the 0 in the abscissa axis will refer to co-alignment of the text with the polarization of the incident signal.

3.1. Transmission

The aim of this measurement is to show possible differences in the refraction index along the two main axis directions of the sample (along and at 90° of the text direction). As an example a slab of 2.8 mm was tested sweeping the frequency source from 590 GHz to 700 GHz. Figure 2 show the transmission varying with frequency and also with the sample rotation, indicating a different refraction index along these directions. For the purpose of finding the peaks of transmission a sine curve was fitted to the data. At these peaks (607.7 and 657.4 GHz

for 0° – 614.0 and 663.8 GHz for 90°) the refractive index n, can be evaluated from the expression that gives the phase delay inside the slab of thickness d: $\phi = 2\pi dn/\lambda_0$. At peak locations the phase delay is an integer multiple of π. Solving this expression for two frequencies of maximum transmission we found a refractive index of 1.0587 at 0° and 1.048 at 90°. This preliminary result shows the anisotropy of GORE–TEX® and brought us to investigate the cross-polarization properties of this material.

3.2. Cross-Polarization

We then acquired more data for different thicknesses and at different frequencies in order to find out how the transmitted cross-polar level was affected by the SUT at different rotation angles respect to the incident polarization signal. We first considered the sample of 2.8 mm at three frequencies (608, 648 and 687 GHz). In figure 3 we observe that indeed the GORE–TEX® slab introduces cross-polarization. The lowest peaks (no cross-polar introduced) coincide with the direction of the text on the slab surface and its orthogonal direction. At 45° and at 90° spaced multiples we notice a level of cross-polar introduced by the SUT of -14 dB at highest frequencies. Other two different sample thicknesses were tested, 1.57 mm and 6 mm. As expected for a thinner slab the cross-polarization introduced is lower compared with the 2.8 mm previous case. For a slab of 6 mm the extra cross-polarization doesn't appear to increase much more because of twice the thickness, in fact at 45° the level is at $-13dB$.
Another interesting experiment was to measure the cross-polarization of a pair of same thickness sheet samples (2.8 mm) facing each other at 90°. The idea is that the second slab will re-scatter the cross-polar component back to the co-polar polarization. Figure 5 shows the results of this experiment. Indeed we observe a cancelation of the cross-polarization effect, leading to a low level flattered cross-polarization response.

4. ALMA SPECIFIC MATERIAL MEASUREMENTS

In order to test different candidates for ALMA cryostat heat filters and ALMA receiver cabin cover membrane we performed a transmission measurements of slabs of following materials:

- GORE-TEX® type RA 7956 sheet of 0.47 mm thickness. It is the same material that is planned to be used for ALMA receiver cabin cover membrane.
- Mupor® PM131 sheet of 0.211 mm thickness. This film transmission is optimized for 492 GHz central frequency.
- Mupor® PM1E sheet of 0.242 mm thickness. This film transmission is optimized for 615 GHz central frequency.
- Mupor® PM3V sheet of 0.175 mm thickness. This film transmission is optimized for 715 GHz central frequency.

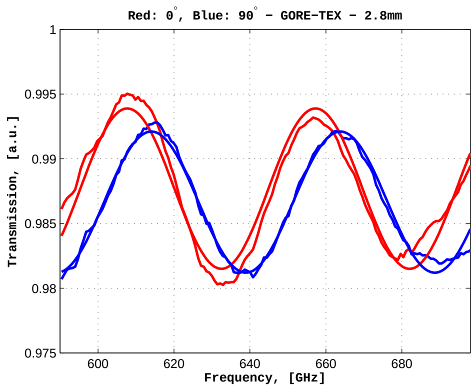
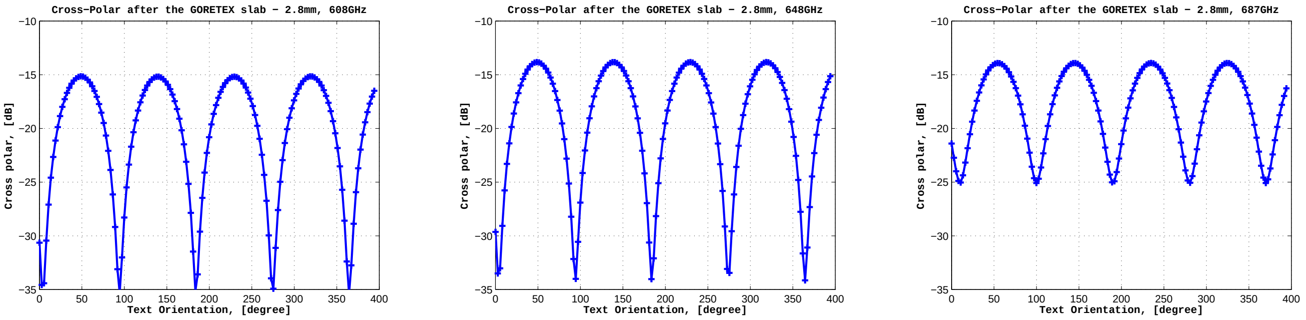


Fig. 2: Transmission for a 2.8 mm GORE–TEX® GR slab at band 9 frequencies.



(a) 608 GHz. (b) 648 GHz. (c) 687 GHz.

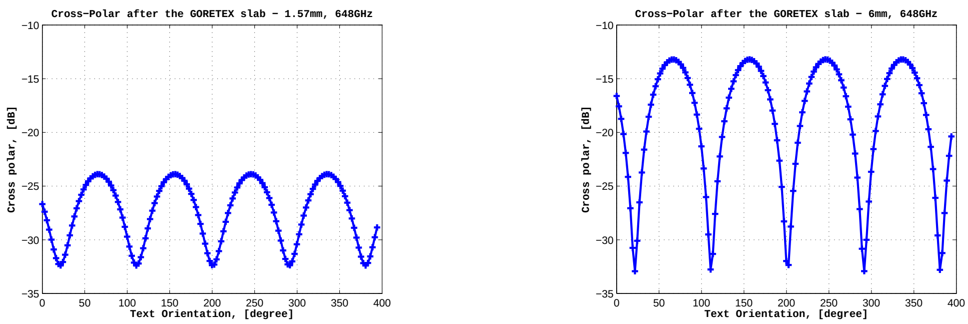
Fig. 3: Cross-polarization introduced by a 2.8 mm slab of GORE–TEX® GR at various frequencies.

- Rohacell® 31 HF This material is commonly used for radomes in microwave frequencies. The sheet thickness is 5 mm

Results of transmission measurements are shown in figure 6. The GORE–TEX® type RA 7956 sheet shows about 97% transmission for ALMA band 9 frequencies and Mupor® show excellent transmissions of about 98..100% corresponding to design central frequencies. These measurements were done with the polarization sensitive set-up similar to one described in section 2.. ALMA prototype x9 and x6 LO chains from NRAO were used as source and a cooled InSb bolometer was used as detector. An improved stability of source allowed to avoid chopping by the sample and background and sample data were taken as consequent traces.

A cross polarization measurements of GORE–TEX® type RA 7956 has performed at a single frequency of 702 GHz. The sample was rotated between two crossed grids. The axis of rotation was perpendicular to the plane of the slab (or along the beam propagation axis). First a single layer was measured and then a combination of two layers which were aligned and then rotated relatively to each other by 90 degrees. The measurement results are presented in figure 7. Single film shows the same cross polarization properties as GORE–TEX GR®-0-0. The peak cross-polar signal of approx -27dB relative to the input signal power is observed. It is again polarization dependent with a distinct directions (90 deg to each other) where cross-polarization power is minimized. One must note that an amount of cross polarization power depends on the thickness of material and, if the actual ALMA antenna membrane is thicker, that may significantly deteriorate receiver polarization properties.

It is also possible to compensate the cross-polarization effects of the GORE–TEX® film by combining two films and rotating one relative to another by 90 degrees. In that respect the GORE–TEX® RA 7956 is similar to the previously measured GORE–TEX® GR-0-0.



(a) 1.57 mm. (b) 6 mm.

Fig. 4: Cross-polarization introduced by 1.57 mm and 6 mm slabs of GORE–TEX® GR at 648 GHz.

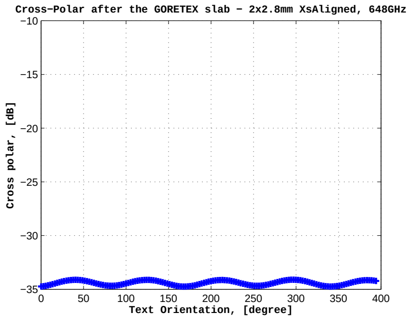


Fig. 5: Cross-polarization introduced by a pair of same thickness sheet samples (GORE–TEX® GR 2.8 mm) facing each other at 90°. $f = 648\ GHz$.

Cross-polarization measurements of Mupor® and Rohacell® are shown in the figure 7. There is no angle dependance for these materials. They also produce a cross-polarization most likely by uniform scattering on the granular structure from which these materials are made of. Typically this effect is expected to scale with the slab thickness and wavelength.

5. CONCLUSIONS

In this MEMO we have shown the cross-polarization effect introduced by a slab of GORE–TEX® of different thicknesses at the frequencies of ALMA band 9. We have pointed out that there is a dependence on the rotation of the sample in relation to the incident signal linear polarization. In particular it seems that due to fabrication procedures, there are two preferred directions of minimum cross-polarization effect: along and normal to the text on the GORE–TEX® sheets. At 45° it has been shown that there is indeed a high cross-polarization effect scattering co-polar power to the cross-polar component of the transmitted signal up to $-13dB$ of cross-polarization efficiency for a thickness of 6 mm. A further experiment having two identical sheet samples of 2.8 mm thickness orthogonally faced has demonstrated that the cross-polarization effect induced by the first sheet can be canceled by the second one, by re-scattering the cross-polar component back to the co-polar.

GORE–TEX® type RA 7956 material that used in ALMA Antenna shows reasonable transmission of 97% (for 0.5 mm thickness) and cross polarization properties that are similar to GORE–TEX® GR-0-0. It may deteriorate ALMA receiver polarization response if a thicker layer is used.

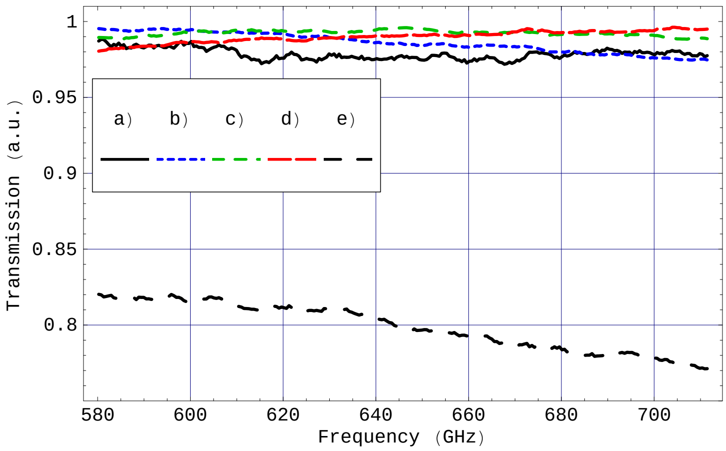
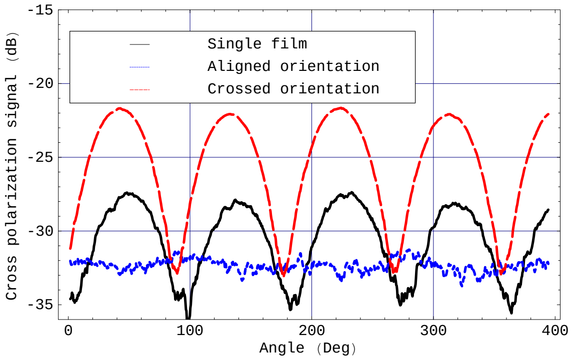
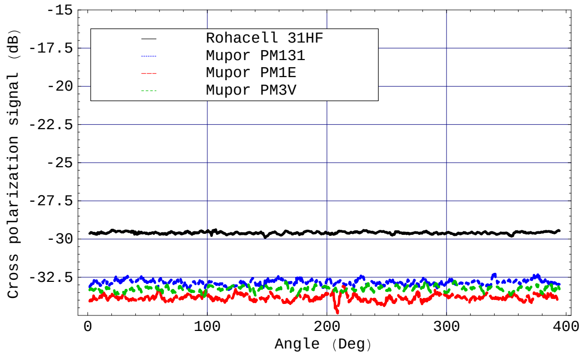


Fig. 6: Transmission of different materials: a) GORE–TEX® RA 7956, b) Mupor® PM131, c) Mupor® M1E, d) Mupor® M3V, e) Rohacell® 31 HF



(a) GORE-TEX® RA 7956 at 702 GHz. Single film and a sandwich of crossed and co-aligned films are shown.



(b) Mupor® PM131, Mupor® M1E, Mupor® M3V, Rohacell® 31 HF measured at 648 GHz

Fig. 7: Cross-polarization introduced by different materials v.s. rotation angle.

Mupor® material is an excellent candidate for use as an floating infrared filter instead of GORE–TEX® as it shows better cross-polarization response and better transmission. The IR transmission properties of this material still are needed to be investigated.

Within the limitations described above, either the crossed GORE–TEX® or Mupor® material might be suitable for ALMA receiver infrared filters or receiver cabin cover.

The Rohacell type of material is not suitable for submm wavelengths as it introduces too much losses.

ACKNOWLEDGMENT

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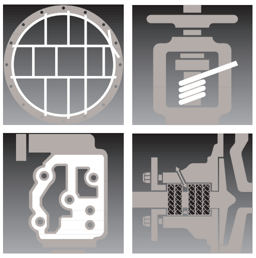
REFERENCES

[1] *http://www.gore.com/en_xx/products/fabrics/microwave/microwave.html*

[2] V. Gasho, S. Stanghellini, *Technical Specification for the Design, Manufacturing, Transport and Integration on Site of the* 64 *ALMA ANTENNAS*, ALMA-34.00.00.00-006-A-SPE Version: A, December 15^{th}, 2003.



GORE-SEALANT TECHNOLOGIES

GORE-TEX GR® Sheet Gasketing
PRODUCT INFORMATION

GORE-TEX GR® sheet gasketing material is manufactured using Gore's unique, proprietary expanded polytetrafluoroethylene (ePTFE) process. Its multi-directional strength inhibits creep and cold flow and also limits the possibility of blow out.

GORE-TEX GR® sheet gasketing is ideal for rough or damaged flange faces. Once installed GORE-TEX GR® gaskets seldom need retorquing and give long lasting performance. Universal chemical resistance allows gaskets cut from GORE-TEX GR® sheet to be used in virtually any application. Excellent results can be achieved with limited bolt-forces and irregular or fragile flanges, e.g. glass or plastic.

The gaskets are suitable for insertion in pipeline joints. Sheet dimensions are shown overleaf.

Technical Data

Material
100% expanded PTFE with high multi-directional tensile strength. Free from asbestos and any other lung damaging component.

Temperature Range
– 240 °C to + 270 °C, to + 315 °C for short periods (33 K to 543 K, to 588 K for short periods)

Chemical Resistance
Resistant to all media in the range pH 0–14, except molten alkali metals and elemental fluorine, particularly at elevated pressures and temperatures.

Physiological Safety
Physiologically harmless in prolonged installation at temperatures up to + 260 °C according to VDI/VDE guideline 2480; complies to FDA 21 CFR 177.1550 (PTFE) requirements for food.

Stability
GORE-TEX GR® sheet gasketing is not subject to ageing and can be stored indefinitely.

Stress to Seal Performance

K_0 K_D to 40 bar	24,5 x b_D
K_1	2,5 x b_D

Maximum Permissible Gasket Stress
150 N/mm^2

Pressure
Maximum 210 bar, depending on use and installation.

Test data according to DIN 28090 and 28091, as well as ASME, are available on request.

Typical installations for gaskets cut from GORE-TEX GR® Sheet Gasketing

- complex gasket shapes
- gaskets with very small dimensions
- pipe flange gaskets
- applications where a full-faced covering of the flange is needed
- flanges with precise geometries
- stock item for maintenance purposes, gaskets can be made on the spot by cutting with scissors or a knife
- cut gaskets for OEM's
- for glass-lined steel, glass and graphite flanges

Quality Assurance

This forms the basis of the high level of quality of GORE-TEX® sealants.

ZERTIFIZIERTES DIN EN ISO 9001 DQS QUALITÄTSMANAGEMENTSYSTEM
Reg. Nr. 3567-01

The GORE Quality Control system is certified according to DIN EN ISO 9001 by DQS. Component suppliers are also integrated into this system.

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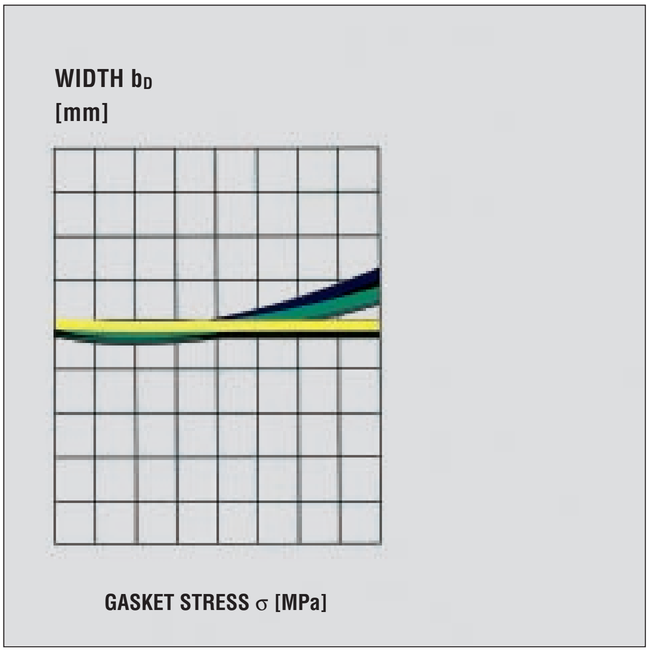
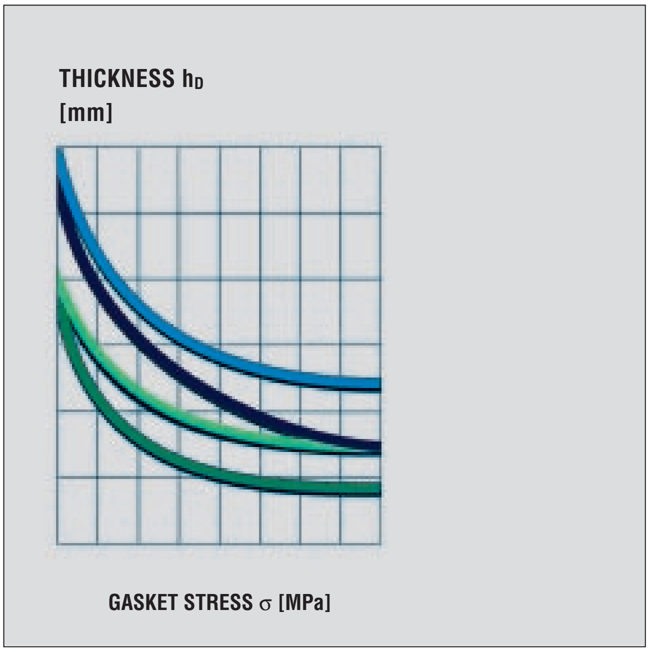
Deformation of Gaskets Cut from GORE-TEX GR® Sheet Gasketing





Available Sizes

GORE-TEX GR® sheet gasketing is available from stock in the following Sizes:

Type	Size l x w [mm]	Thickness [mm]
GORE-TEX GR® 05	1524 x 1524	0,5
GORE-TEX GR® 10	1524 x 1524	1,0
GORE-TEX GR® 15	1524 x 1524	1,6
GORE-TEX GR® 20	1524 x 1524	2,0
GORE-TEX GR® 30	1524 x 1524	3,2
GORE-TEX GR® 60	1524 x 1524	6,4

On request we can deliver pre-cut gaskets in any desired shape and quantity, this includes partially precompressed gaskets for applications with low bolt loads, such as FRP pipe-work.

Installation Guide

Working with the Material
The material is so soft it can be easily cut with scissors or a knife.

Clean the flange faces and lay on the gasket. Imperfections in the flange face can be compensated. For severe distortion it may be necessary to use GORE-TEX® DE sealant in addition.

Ordering Details

GORE-TEX GR® sheet gasketing, according DIN 28091, TF-0-0.
Dimensions: 1524 x 1524 x thickness [in mm].
For pre-cut gaskets, give sheet gasket type, dimensions and number of pieces.

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