AMORIM T&D

Power Industry

Sealing, noise & vibration control

Technical bulletins

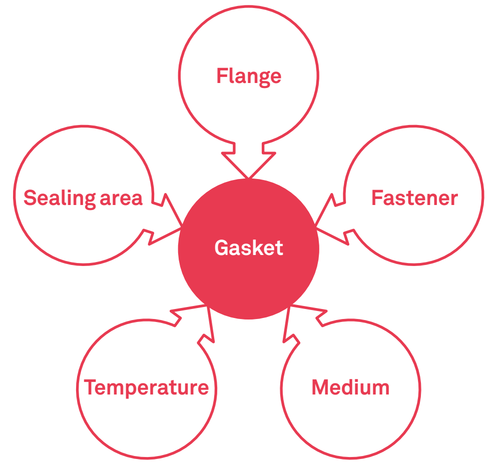
AMORIM CORK COMPOSITES

Contents

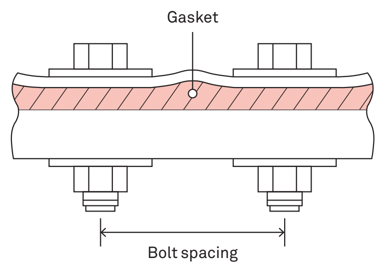
Technical bulletin
Gasket design guidelines

Gasket design guidelines

A Gasket material suitability is defined by a variety of application factors shown in the adjacent diagram. The common perception that temperature and chemical resistance must be assured are only part of the equation. Amorim Cork Composites systems approach ensures joint integrity by considering the multiple variables that are involved.



Flange & Sealing Area



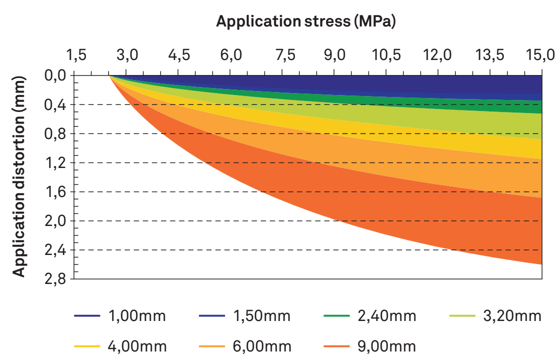
Proper Flange & Gasket Design

Gasket compression design by application of spaced fasteners is also a function of plate thickness, acceptable gasket pressures, gasket performance under compression, and flange dimensions.

Maximum gasket deflection occurs at the location where the fastener applies force.

The amount of bowing or deflection of the cover flange depends on several factors. This effect may be minimized by proper design of the fastener spacing, cover / flange plate thickness and stiffness, and proper selection of gasket materials.

Use our application distortion graphs to define the best material thickness for your application.



Temperature and Medium

Adequate Material Selection
Our products are made to proprietary formulas and are only manufactured by Amorim. There are literally infinite possible formulations within each type of polymer and cork, inclusively the blend of polymer types.

A wide range of variations on physical properties like tensile strength, compressibility, and hardness can be found amongst our products made of the same basic elastomer, and these are all factors that usually greatly affect the functionality in the application.

Other factors like chemical resistance and temperature range also vary, but normally to a lesser degree.

View our detailed Material Data Sheets for temperature and chemical resistance, or contact us for further information.

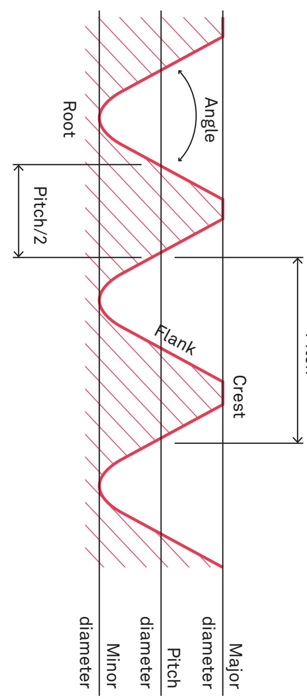
Fasteners

Thread standards
ISO metric screw thread is the preferred series and has displaced many older systems. Other common systems include the British Standard Whitworth, BA system (British Association), and the SAE Unified Thread Standard.

ISO metric screw threads are designated by the letter M followed by the major diameter of the thread in millimeters, e.g. M8 x 1,25.

For sizes 1/4" diameter and larger, The SAE Unified Thread Standard sizes are designated as 1/4"-20, 1/4"-28, etc. the first number giving the diameter in inches and the second number being threads per inch. Most thread sizes are available in UNC or UC (Unified Coarse or Unified Fine Thread).

View extensive thread details in the Joint QTOOL.



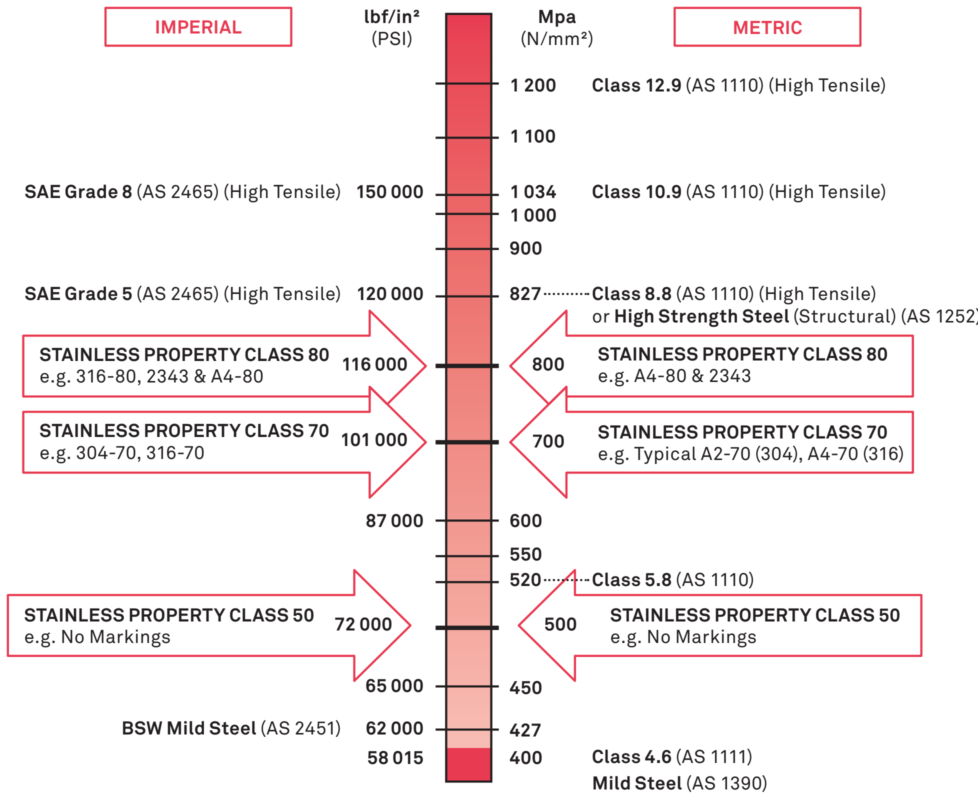
Fasteners

Mechanical classifications

The numbers or shapes stamped on the head of the bolt are referred to as the grade of the bolt and defines the strength of a bolt.

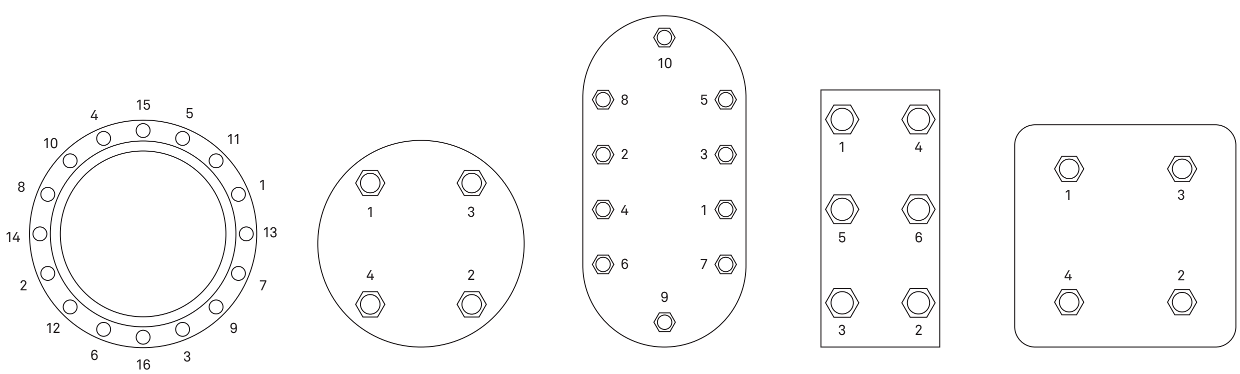
The international standard for metric screws is defined by ISO 898. SAE J1199 and ASTM F568M. In case of imperial sizes the grade is dictated by the number of radial shapes. ASTM and ISO bolts use integer values to indicate grades.

View extensive fastener grade properties in the Joint QTOOL.



Assembly Procedure

- Inspect fasteners, nuts and washers and clean flange surface. Replace any component if necessary.
- Do not use lubricated fasteners unless previously specified by torque evaluation. Evaluate torque using our Joint QTOOL software.
- Use washers under fasteners and nuts where possible
- Install new gasket, never reuse old gaskets or use multiple gaskets.
- Install fasteners in cross pattern sequence (see below) and hand tighten.
- Optimal uniform fastener tightening is obtained 3 steps until the final torque is achieved, following the cross pattern sequence for every step.



Technical bulletin

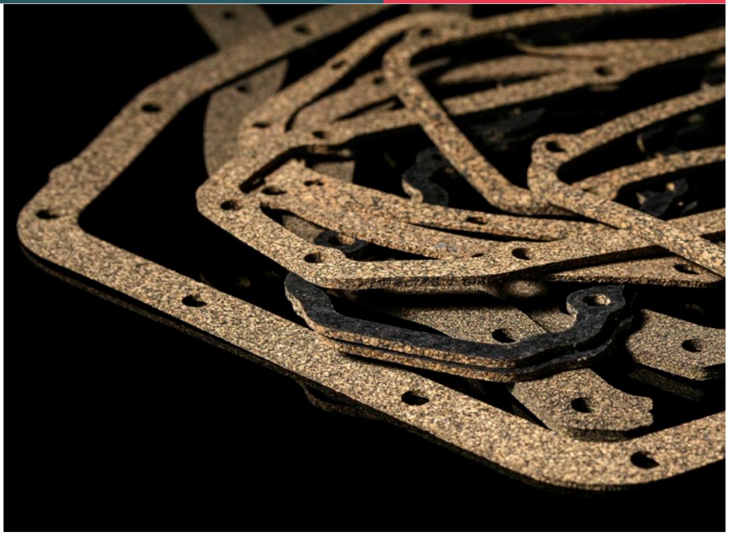
T&D gaskets vs rubber o-rings benchmark

Cost saving solutions using cork rubber flat gaskets

Amorim T&D materials for flat gaskets in transmission and distribution applications offer major indisputable arguments when replacing moulded rubber cord seals.

Benchmark testing comparing Amorim T&D nitrile flat cork rubber gaskets with extruded rubber cord seals (nitrile O-ring) were performed to compare these alternatives system sealing designs.

These tests reveal that using Amorim T&D flat cork rubber gaskets can deliver an equivalent sealing performance, with a more robust solution and clear savings for the OEM.

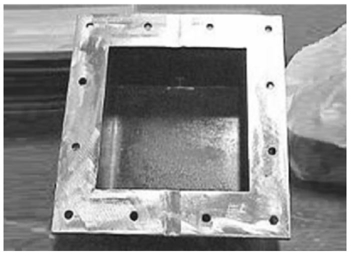


Flat cork rubber cost savings

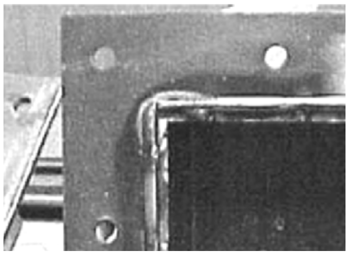
Save on construction and machining or manufacturing processes	Will work in less than perfect surface conditions (roughness) and higher out-of-flatness flanges.
Savings in terms of gasket thickness	Flat cork rubber gaskets have higher working compression ratios, allowing for lower gasket thicknesses.
Eliminate manufacturing and assembly costs of this design element	Flat cork rubber gaskets do not need a compression limiter.
No need to substitute the gasket	Possibility to retorque, resetting the sealing stress to original values.

Benchmark testing

- Assembled in a test fixtures with 1 mm deep recesses
- Load applied through 12xM10 fasteners torqued to 49N.m
- Assembly filled with Nynas GBN mineral oil
- Thermal Cycle test in a static soak 168h@ 100°C.

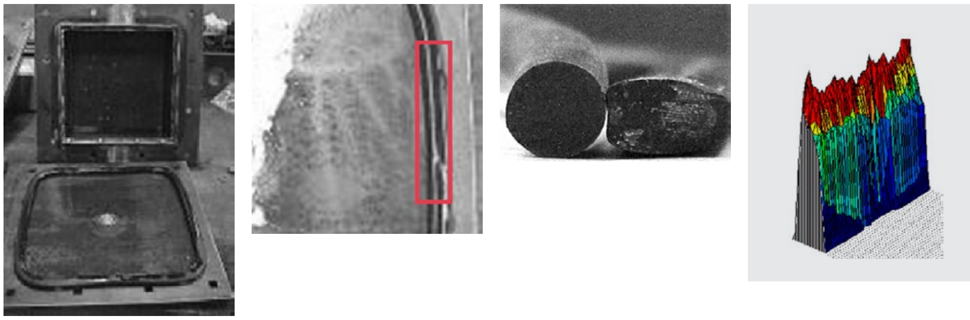


9 mm TD 1120 gasket.
Assembled in free compression.
Average compression of 40%

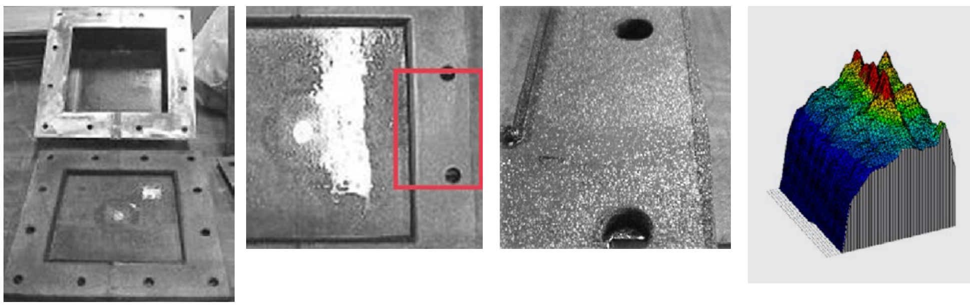


9 mm nitrile rubber cord
Assembled with controlled compression limiters. Average compression of 30%

Results after thermal cycling



Contact area: 648 mm^2
Average stress: 4.0 MPa
Peak stress: 13 MPa



Applied force: 8929 N
Contact area: 2734 mm^2
Average stress: 3.4 MPa
Peak stress: 11 MPa

TD1120 gasket had some adhesion to flanges and lost about 25% of its original thickness; gasket remove in one piece; No leakage.

The rubber cord had no adhesion to the flanges and lost 30% of its original thickness; O-ring joint broken upon disassembly, showing a potential weak point; No leakage.

Benchmark testing demonstrates that:

- Equivalent sealing performance between T&D nitrile cork rubber flat gasket and the moulded nitrile cord is attained – given that none had leakage. It is possible to replace the O-rings.
- Peak stress is higher in the cord seal, basically due to its shape factor. However, our T&D gasket will provide equal average stress.
- Contact area is far greater in our T&D flat gasket and has a substantial impact on the design of the rest of the sealing flanges, in particular:
  - No need for perfect flange Surface Finish Conditions
  - Allows for higher Out-of-Flatness flange planarity.
- At the end of the test the dimensional loss is similar in both seals (25-30%), the T&D gasket allows for retorquing to the original values, repositioning the sealing stress to the original values. This is not possible with rubber cord due to design constraints (compression limiter) and the need to be substituted.
- T&D gaskets can work at higher compression ratios than rubber cords (Max. 30%). For the same thickness, T&D cork rubber gaskets can absorb higher flange distortion, allowing for lower thickness gaskets.

Technical bulletin
T&D low temperature testing

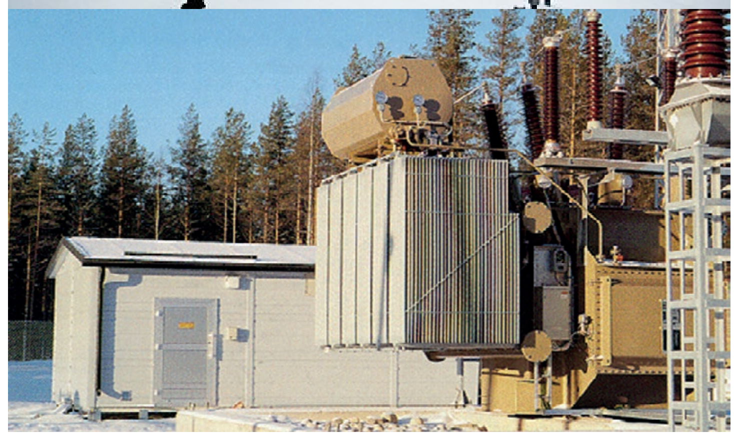
TD1310 low temperature performance

The low-temperature properties of cork rubber materials are important when used in applications in colder climates, or, in environments that have low temperature requirements. There are a number of test methods in use.

When cooled, elastomeric compounds start to lose their elasticity, and at very low temperatures they harden and have glasslike brittleness. When the temperature rises they regain their original properties – i.e., the condition is fully reversible.

Cork rubber materials with good cold flexibility are amongst others specially compounded Nitrile (NBR) - TD1310.

Most low temperature tests are designed to indicate the brittleness point of a material, instead of the beginning of the elastic behaviour region.



Most common test methods for low temperature testing

ASTM
D1329

Evaluating rubber property: retraction at lower temperatures (TR test).

ASTM
E1640

Assignment of glass transition temperature by dynamic mechanical analysis.

ASTM
F147

Low temperature flexibility; modified.

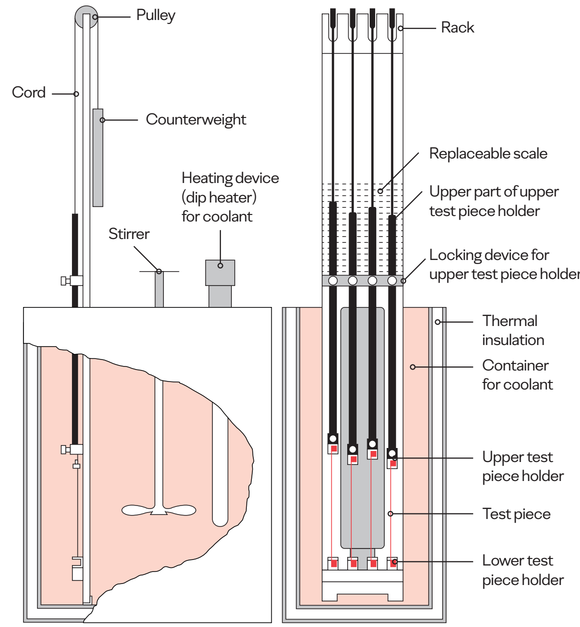
ASTM
D2137

Rubber property: brittleness point of flexible polymers and coated fabrics. (Will not be discussed)

Low temperature testing test description

ASTM D1329 - Evaluating rubber property: Retraction at lower temperatures (TR Test)

The "TR", or "time-to-return" or Retraction Temperature Test uses samples that are stretched to 50% extension in a sample rack and then locked. The samples are then cooled to a low temperature and allowed to reach equilibrium (-70°C).



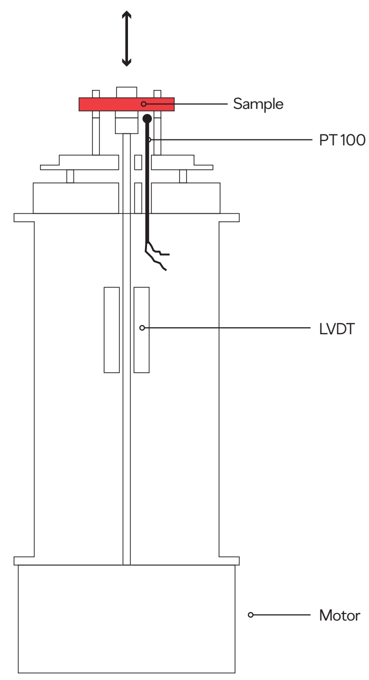
The frozen samples are then released from the rack and allowed to retract freely, while the temperature is raised at a uniform rate of 1°C/minute.

Measurements of the sample length are taken at regular temperature intervals as the sample recovers. When a 10% retraction in the sample length is obtained it is recorded as TR10.

There is a certain relation between TR10 and brittleness point, wherein the brittleness point is lower than the TR10 temperature.

ASTM E 1640 - Assignment of glass transition temperature by dynamic mechanical analysis

DMTA characterizes the viscoelastic nature of polymers. An oscillating force is applied to a sample of the material, the resulting displacement of the sample is measured.



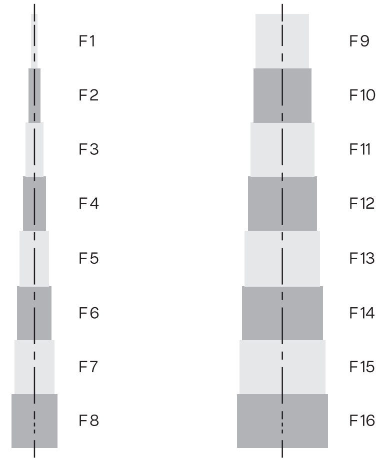
A force (stress) is applied to the sample, through the motor. The stress is transmitted through the drive shaft onto the sample which is mounted in a clamping mechanism. As the sample deforms, the amount of displacement is measured by the LVDT positional sensor. The strain can be calculated from the displacement. The force (or stress) is applied sinusoidally with a defined frequency of 1 Hz, varying the temperature from -80°C to 60°C at a rate of 1°C/minute.

On this basis, the sample stiffness can be determined, and the sample modulus can be calculated. By measuring the time lag in the displacement compared to the applied force it is possible to determine the damping properties of the material.

By scanning the temperature during a DMTA experiment, the change of state can be observed and the glass transition temperature (Tg) can be determined.

ASTM F147 - Low temperature flexibility; modified.
During the test the samples are put in a freezer at a low temperature 50-2°C for a time period of 2,0+0,1 hours. After 2 hours the samples are bent at an angle of 90±5° at the same test temperature.

Visual inspection is performed, and samples are considered as PASS with a specific flexibility factor (which depends on sample thickness and mandrill diameter) if no surface cracks are present.

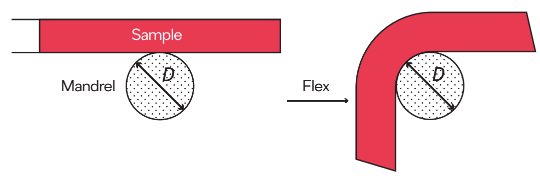


When a sample with thickness of δ is put around a mandrill with a diameter of D, the outside of the sample is stretched, and the inside is compressed. The centre of sample is not stretched or compressed.

If the Elongation of the Sample material is ε, it can be correlated to the diameter of the mandrel and the Thickness of the sample.

$$\text{Flexibility Factor} = \frac{\text{Minimum Mandril Ø}}{\text{Material Thickness}}$$

The value of D gives an idea of the flexibility of the material, and shows its dependence with the sample thickness under test. The smaller the value of D, the better the flexibility. So, if the sample thickness δ is thinner, the value of D is smaller, consequently the flexibility is better. If the elongation of the material is greater, the value of D is smaller, consequently the flexibility is better.

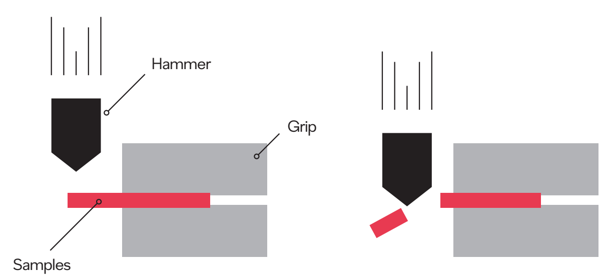


$$D = \frac{(1-\varepsilon)}{\varepsilon} \times \delta$$

δ Sample thickness
D Mandrel diameter
ε Material elongation

ASTM D2137 - rubber property: brittleness point of flexible polymers and coated fabrics.
Brittleness point, means the lowest temperature at which rubber materials exhibit brittle failure when impacted under specified conditions. When testing, test pieces in the form of strips are clamped as shown, and then immersed for 5 min in a cold bath. After 5 min they are subjected to a single impact blow, then examined to see if they show any cracks.

If they have failed, new test pieces are tested at a temperature 2°C higher. The test is then repeated at higher temperatures until no failure is observed. This temperature is recorded as the temperature limit for brittleness.

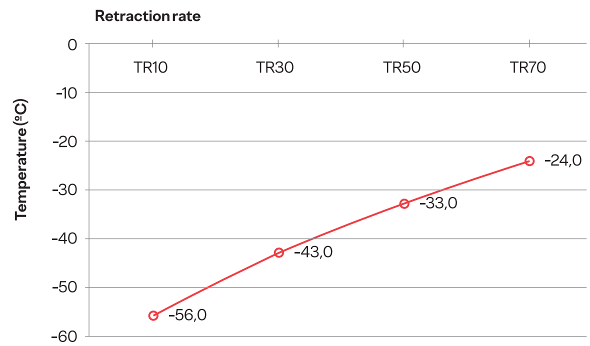


TD1310 - Low temperature nitrile, cork rubber

Retraction at Lower temperatures- TR Test

The TR test was performed in a well-known independent rubber testing laboratory (Akron Rubber Development Laboratory).

The results show that TR10 is achieved at -56°C.
At this point the material regains its rubbery behaviour, this temperature is higher than the brittleness point.

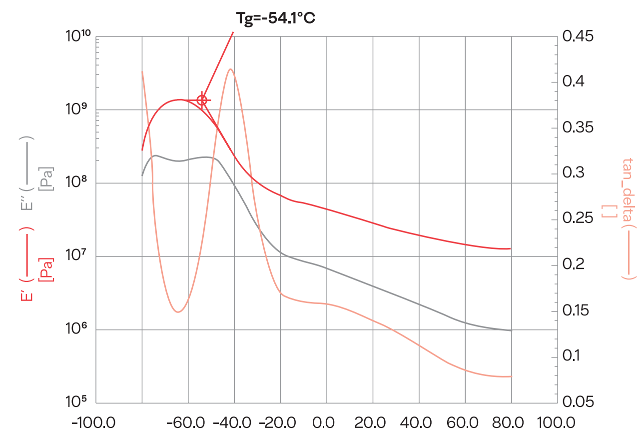


ASTM D1329

Tg- Glass Transition Temperature by DMTA

DMTA Tg testing performed internally shows correlation to TR10 test values, a decrease in E' modulus (Elastic) at -54°C. This is designated its Tg temperature.

These results confirm that these two test methods are aligned with the forecast material low temperature performance.

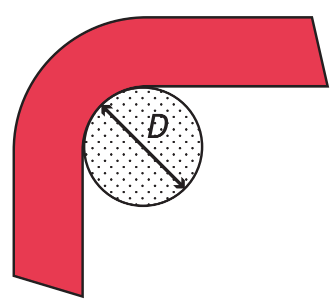


ASTM E1640

Low Temperature Flexibility- Modified

The Low Temperature Flexibility test was performed in a well-known independent rubber testing laboratory (Akron Rubber Development Laboratory).

The results show that this test method also seem to have some correlation to the above. But when thinking about the application, this test method can only be used as a comparative method, due to the strong dependence on the tested thickness.



ASTM F147

No cracks
PASS @ -50°C

Sample thickness
3,14mm

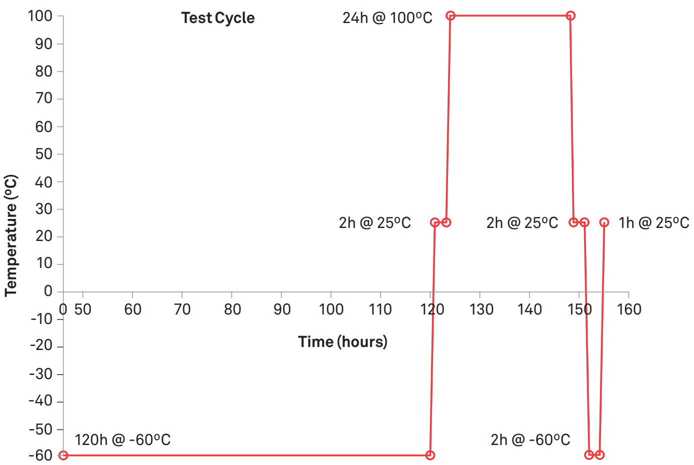
Flexibility Factor
1,57

D (Diameter)
5mm => F2 Flexibility

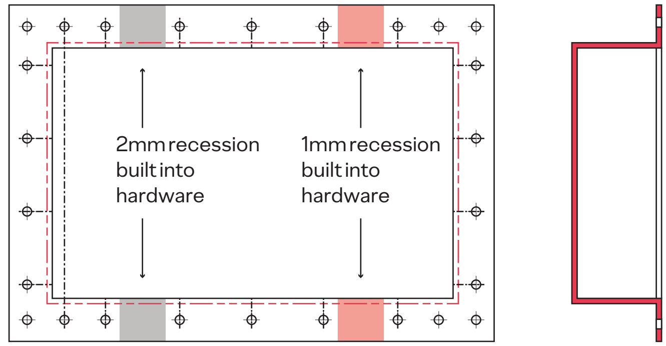
TD1310 - Low temperature application testing

Functional performance of TD1310 low temperature Nitrile material at -60°C. Objective is to simulate the storage/transport of the transformers in extreme cold conditions.

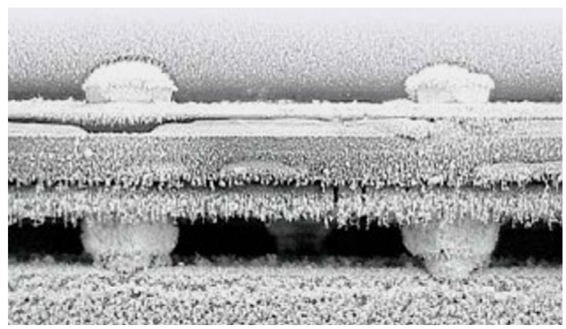
Thermal Cycle with observation steps at 25°C.



No leakages were observed at any point during the entire thermal cycle. Material responds to the temperature gradient of -60°C to 100°C, even though the lower limit temperature is stated at -50°C.



Test fixture with 1 and 2 mm recesses, was assembled with TD1310 @ 9mm thick and filled with Mineral Transformer Oil. Load was applied through a 49N.m torque.



TD1310 Grade under artic conditions

Conclusion

Comparative testing shows that there is correlation between the low temperature testing methods, although care must be taken when extrapolating to the application. In short, the various methods proposed for evaluation of low temperature properties apply to a limited set of conditions:

- In case of low temperature compression or elongation (TR test) tests, if the initial compression or elongation applied is not adjusted to the materials' compressibility or elongation working curve, results can be shifted from the materials' real life operating conditions
- Low Temperature Flexibility tests are highly operator dependant, and sometimes typical material properties can be interpreted as cracks.
- Measurements performed by DMTA for Tg value significantly diminishes the impact of the test conditions, by measuring the response of the materials elastic and visco-elastic properties. This makes this test a reliable and relevant source of information.

Application testing under extreme temperature conditions corroborate the results obtained through TD1310 material tests, making it suitable for -50°C operating temperatures.

Technical bulletin
Dovetail interlock design

Dovetail interlock design

Large sealing areas used in transmission and distribution equipment implement dovetail designs on flat gaskets, to increase material yields and significantly reduce scrap rates, which has a direct impact on cost savings in terms of materials and products.

By definition, a dovetail is a tongue and groove that fit tightly together, thus creating an interlocking joint between two pieces which resist being pulled apart in all directions, except one.

Dovetails can be shaped like a bird's tail spread, or not, depending on the punch or tooling manufacturer. Their dimensions vary (depending on tooling design). As a rule of thumb the dovetail's maximum width should occupy approximately 1/ 2 to 3/ 4 of the gasket's width (leaving a 1/ 4 - 1/ 8 of gasket width on each side). For larger gasket widths, multiple dovetails can be made side-by-side, facing the same direction or inverted.

The dovetail interlock should guarantee a comfortable fit before compression. The interlock will seize once the gasket is under compression, eliminating any possible leak paths.

Example of dovetail punches and sizes

Dovetail design and selection guidelines

- We strongly recommend that the dovetail joint be positioned between bolt holes away from the flange corners, use corner parts to distance dovetails from the flange edges.
- Various dovetail geometries and designs are available, and should contemplate large perimeter contact areas and radii to eliminate high point stress conditions (when under compression).
- Dovetail base geometry should be sufficiently wide to eliminate any possible rotation (also ensuring there is no tearing or deformation) and at the same time guarantee the interlocking function.
- When using glue or RTV on the dovetail joints, to aid in assembly or positioning, use as little as possible. An excessive amount will serve as a lubricant between the contacting surfaces, leading to possible extrusion of the dovetail joint and eventual sealing failure.

Possible dovetail designs

Technical bulletin
Transformer insulation fluids

Transformer insulation fluids

Many transformers and T&D Equipment such as load-tap changers, voltage regulators, bushings, switchgears and circuit breakers use oil as an insulating medium between contacts.

Because many problems in transformers and other T&D equipment are directly related to changes in the dielectric properties of the oil, an effective proactive approach to maintaining oil-insulated equipment is to control polar contaminants, such as particles, moisture and by-products of oil oxidation – i.e. the forcing factors associated with a change in the dielectric constant (insulator properties).

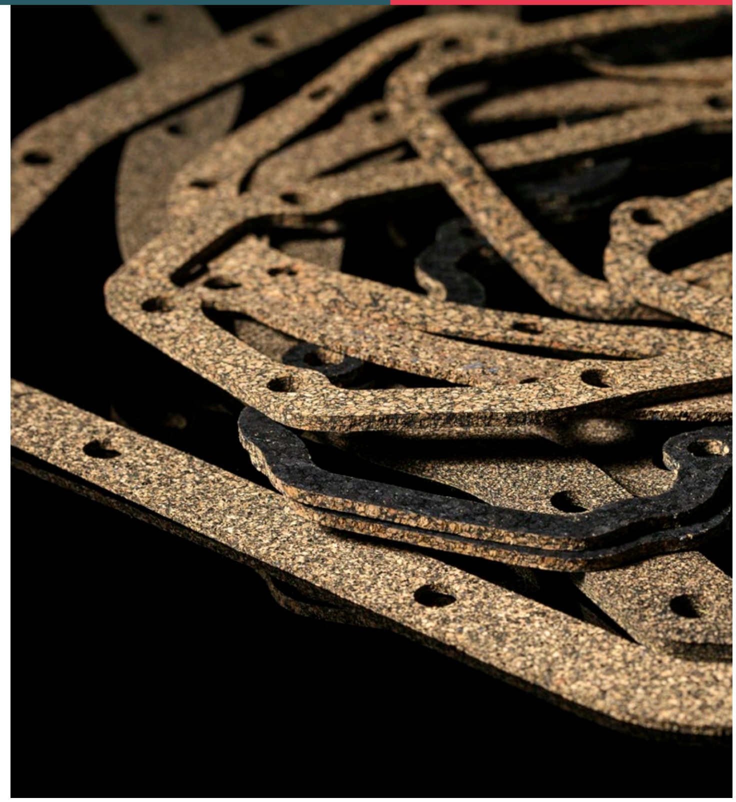
The high cost of repairing transformers and other T&D equipment and the loss of revenue associated with failure, have caused electric power industry organizations to place considerable emphasis on strategies for extending equipment life and improving operational reliability of T&D system components such as insulating oil.

The industry has devised several standards that regulate oil specifications and others that dictate the compatibility between the T&D construction material and the insulating oil (view last page), namely the gasket material.

Fluid cleanliness and condition is a key metric that affects the performance of electrical insulating oils, and directly impacts Amorim T&D equipment's performance and longevity.

ASTM D 3455-95 compatibility between construction material and electrical insulating oil of petroleum origin.

The acceptance criteria are based upon Industry Reference bodies such as IEC and IEEE, which generally have a wider acceptance range when compared to ASTM standard criteria.



Colour [clear & bright]	Indicates a colour change and whether or not for further research is required.
Interfacial Tension Test	Measured in miliNewtons(mN) per metre of mineral oils against water, indicating the amount of polar contaminants (such as water).
Neutralisation Number [mg KOH/g]	Determines the amount of acidic constituents in the insulating oil.
Dielectric Dissipation Factor or Power Factor (tgδ) [%]	Indicates the dielectric loss (leakage current associated with watts loss) of the insulating oil.
Dielectric Breakdown Test (kV)/ Dielectric Strength	Measures the voltage at which the oil electrically breaks down and begins to conduct.

Nynas Nytro 10 XN (mineral oil)

Oil compatibility
According to: ASTM D 3455- 95 compatibility between construction material and electrical insulating oil of petroleum origin.

Colour [clear & bright]
ASTM D1500 standard test method for the colour of petroleum products. Industry criteria's range from 0 to 1.0 max. change

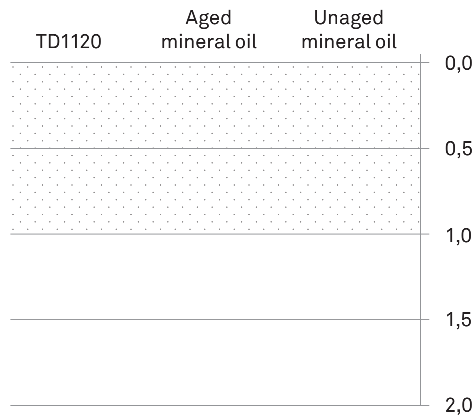
The following characteristics were measured after ageing the transformer oil for 164h @ 100°C;
- With samples of TD 1120 immersed.
- Without any samples and comparing with unaged oil.

Interfacial tension test [mN/m]
ASTM D971 standard test method for interfacial tension of oil against water by the ring method.
Industry criteria's range from 22 to 32 min.

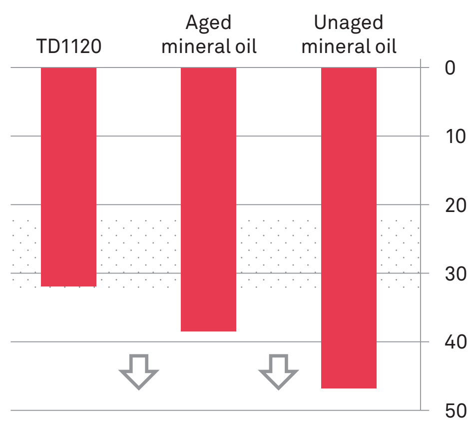
Particles in oil weaken the interfacial (lowering the IFT number) - a Measure of Contamination

Neutralisation number [mg KOH/g]
ASTM D974 standard test method for neutralization number by colour indicator titration. Industry criteria's ranges up to 0,3mg max. change

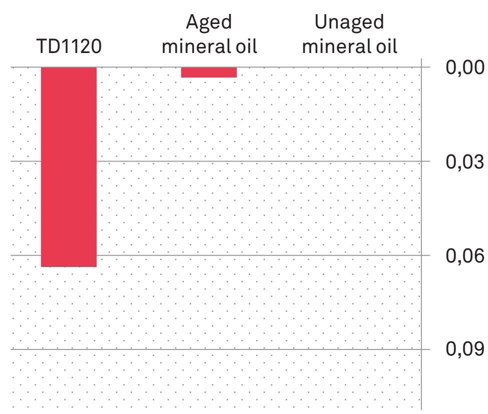
Unused transformer oils contain practically no acid. Oxidation of the insulating oils form acids as the transformer ages. The acids attack metals inside the tank and forms soaps (sludge). Acid also attacks and accelerates cellulose insulation degradation.



Colour [clear & bright]



Interfacial tension test [mN/m]

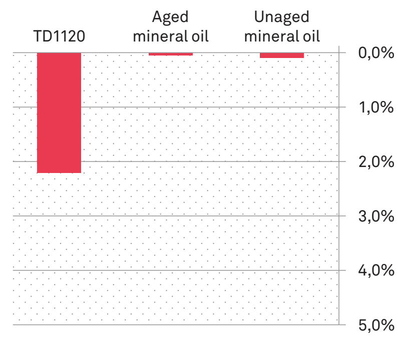


Neutralisation number [mg KOH/g]

Dielectric dissipation factor or power factor (tg δ)

ASTM D924 standard test method for dissipation factor (or power factor) and relative permittivity (dielectric cant) of electrical insulating liquids.
Industry criteria's range up to 5% max.

A high power factor indicates deterioration and/or contamination from by-products such as water, carbon, or other conducting particles, including metal soaps caused by acids attacking transformer metals, and products of oxidation.

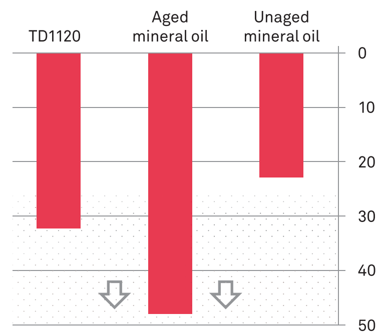


Dielectric dissipation factor or power factor (tg δ)

Dielectric breakdown test (kV) or dielectric strength

ASTM D1816 standard test method for dielectric breakdown voltage using VDE electrodes. Industry criteria's range from 23 to 60 kvmin.

The dielectric strength test is not particularly valuable; moisture in combination with oxygen and heat will destroy cellulose insulation long before the dielectric strength of the oil has indicated anything is going wrong.



Dielectric breakdown test (kV) or dielectric strength

Oil specifications

ASTM D 3487 - 93	Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus
ASTM D 5222- 98	Standard Specification for High Fire-Point Mineral Electrical Insulating Oils
ASTM D 2225- 92	Silicone Fluids used for electrical Insulation
ASTM D 6871 - 03	Standard Specification for Natural (Vegetable Oil) Ester Fluids Used in Electrical Apparatus
CEI- IEC 60296: 2003	Fluids for electro technical applications- Unused mineral insulating oils for transformers and switchgear
BS 148: 1998	Specifications for Unused mineral insulating oils for transformers and switchgear

Oil compatibility

ASTM D 3455 - 95	Compatibility between Construction Material and Electrical Insulating Oil of Petroleum Origin
ASTM D 5282 - 98	Compatibility between Construction Material and Silicone Fluid used for Electrical Insulation

Technical bulletin
T&D bushing gasket materials

T&D bushing gasket materials

Amorim Cork Composite offer materials that can be applied in bushning applications.

The necessity to improve sealing characteristics in GEO areas that require particularly rigorous performance has led Amorim Cork Composites to develop materials for bushing sealing applications.

Bushing requirement → Evaluate Application Stress/Compression, Required Temperature Resistance, Required Chemical Resistance → **ACC materials selections**

To select Amorim T&D material please refer to the MDS, where you will find the materials' operating conditions (Stress Range, Temperature Range and Chemical Resistance).

Physical properties (view below) alone may not be sufficient to guarantee trouble-free transition.

Amorim T&D materials offer:

- Proven long term ageing performance.
- Tested for chemical compatibility.
- Tolerance to extreme surface finish conditions and high out-of-flatness flanges.
- Extended technical support.

General physical properties are as follows

Hardness (Shore A)	ASTM D2240
Compressibility, 400 psi (%)	ASTM F36
Recovery, 400 psi (%)	ASTM F36
Density (Kg/m3)	ASTM D297
Tensile Strength (MPa)	ASTM D 412, Die C

Note: for more detail of our materials performance please check MDS or contact or technical team

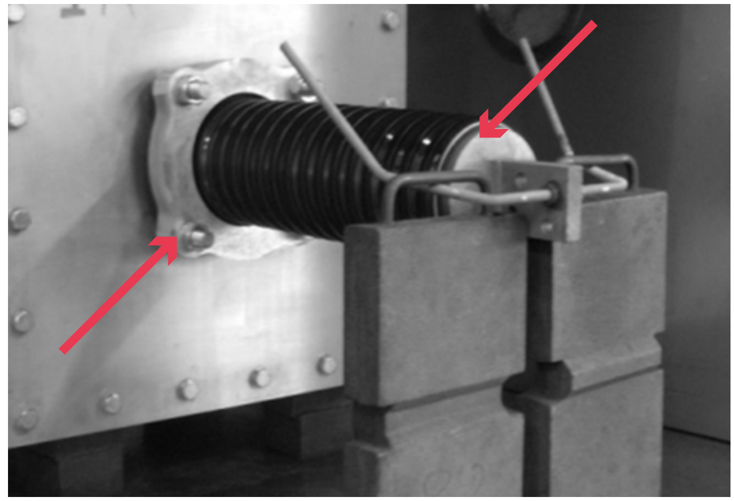
Tested for success

Indicative test that were performed to evaluate the behavior of our material in the application.

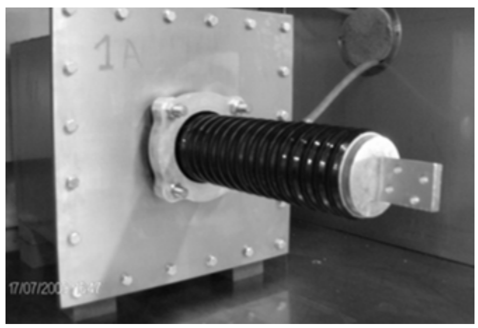
A cable box bushing in a cantilever position assembly, filled with Nynas Lybra insulation oil, immersing the bushing's active part in the reservoir, with internal pressure.

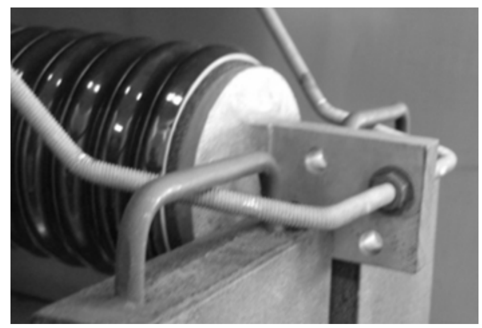
Masses (2 x 10kg) applied to the end of the bushing to simulate a cantilever effect exerted by the cable fixing to the bushing's terminal.

Two gaskets on the base of the bushing and one gasket on the bushing terminal were applied.



Gaskets





Thermal cycle of +5°C for 8h to 110°C for 14h; 14 days

Bushing disassembly: from the feedback shared, no leakage were verified after 336h

As a whole Amorim T&D materials have been designed and tested to perform in T&D applications.

These applications have a life cycle that is much higher than any other common static sealing system (20 – 30 years) and therefore ageing characteristics are extremely important.

Technical bulletin

T&D vibration and noise control solutions

Vibration and Noise Control in T&D

T&D industry trends and requirements have created high demand for low noise equipment with a good long-term performance. Amorim Cork Composites, as a worldwide supplier to the T&D Industry, has invested in R&D, established its VC (Vibration Control) product range and successfully implemented noise reduction solutions through vibration control.

It is very often said that "just putting some rubber" to isolate structures creates an inefficient or even a vibration isolation problem, that fails to take into account the characteristics of the overall system; such as media environment and temperature, material stiffness adjusted to the application load, surface area, material transmissibility, as well as pad design techniques, such as shape factor conformity - which is fundamental to ensure the selection of a good anti-vibration material and consequent noise reduction.

Through its experience in T&D applications, Amorim Cork Composites has implemented a priority 4-step system approach (fig.1) in analysis and treatment of "noisy" equipment. Our 4-step approach focuses on the need to control vibration before it reaches the tank structure (i.e. intervening closer to the source of the vibration), thereby preventing structural vibrations on the tank from being transformed into airborne noise through the amplitude vibration of the tank walls, acting as "speakers".

Typical noise reduction gains (cumulative gains) can also be observed in fig.1 when designing with ACC methodology (values based on project statistics).

Internal Vibration Pads -1dB → -2dB

⇩

Core Clamping Mechanism -3dB → -5dB

⇩

CLD - Compressed Layer Damper -6dB → -8dB

⇩

External Vibration Pads -8dB → -9dB

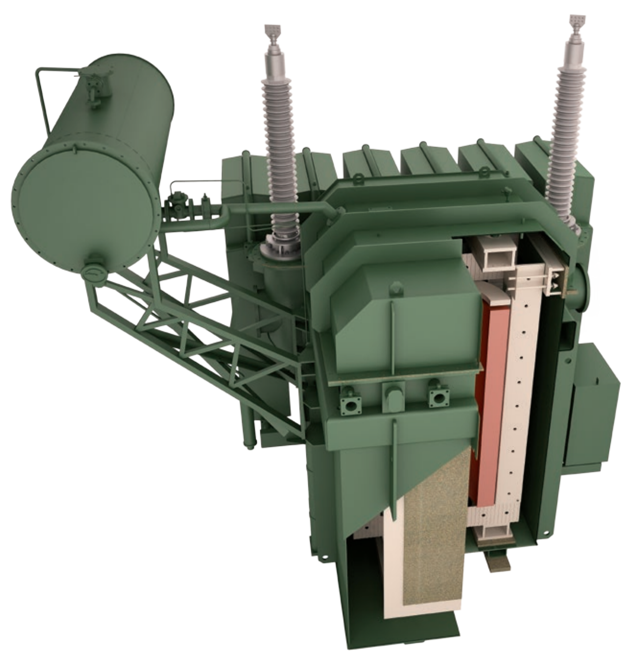
fig.1

The noise paradigm

As T&D equipment becomes larger and more powerful, due to electrical grid complexity and natural energy sources, general tank construction relies on rigidity and stiffness to reduce the amplitude of vibrations that reach the tank wall, which are then released as airborne noise.

Whilst the increase of stiffness of the tank is achieved through the use of U-beams and profiles, this also increases the actual natural frequency (fn) of the tank structure narrowing the gap between the disturbing frequency derived from the active part. The closeness of these two frequencies leads to an amplification in transmissibility and a consequent increase in noise.

Though optimal mechanical construction is imperative for the equipment's functional characteristics, noise level restrictions now form part of utilities requirements due to demand from end consumers.

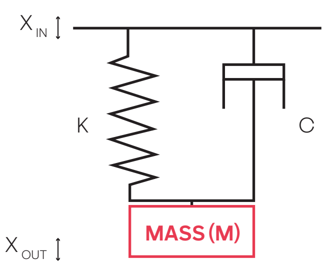


Vibration control basics

Natural Frequency

All anti-vibration pads/materials, components and systems have a natural frequency (fn). In case of the anti-vibration pad, the natural frequency, fn, is dependent upon the stiffness of the pad material, K, and the mass of the load that it is supporting (M).

In elastomeric materials the fn is not only defined by the actual material but also by its thickness and shape (see shape factor). ACC has defined the natural frequency in various thicknesses under dynamic conditions for its materials.

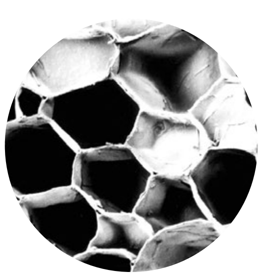


$$f_n = \frac{1}{2\pi}\sqrt{K/M}$$

Damping

Damping is the dissipation of energy, usually by releasing it in the form of low-grade heat. The loss factor (η) quantifies the level of damping of a material. It is the ratio of energy dissipated from the system to the energy stored in the system for every cycle. The damping ratio (ζ) can be obtained from the loss factor, using the following expression $\eta=2\zeta$.

Due to cork's closed cell structure, filled with air, cork has a higher loss factor than rubber, essential to the damping function and consequent dissipation of energy. Our specific polymer formulations and the inclusion of cork, with unique compressibility and recovery characteristics, absorbs energy, yielding high material loss factors.



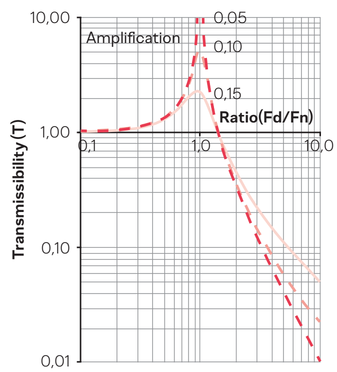
$$\eta \approx 2C/C_c \approx 2\zeta$$

Vibration Isolation

The performance of an isolation system is determined by the transmissibility of the system, the ratio of the Energy going into the system to the Energy coming out of the system. Vibration control design aims to place the system's disturbing frequency in the isolation region.

The amount of damping in the isolation system will determine the height of peak transmissibility (T) for the system. As damping increases, this peak value will decrease.

Amorim Vibration Control Materials exhibit significant material loss factors resulting in a lower amplification at resonance (fd=fn), giving them operational effectiveness over a broad range of frequencies.

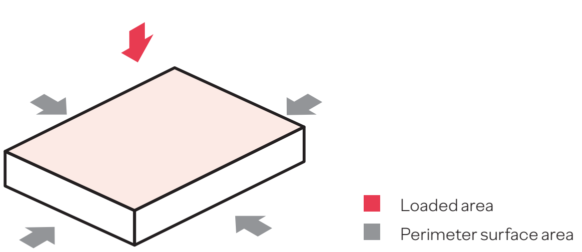


$$T = |A_{out}/A_{in}| = \sqrt{\frac{1+\left(2\zeta\, f_d/f_n\right)^2}{\left[1-\left(f_d/f_n\right)^2\right]^2+\left[2\zeta\, f_d/f_n\right]^2}}$$

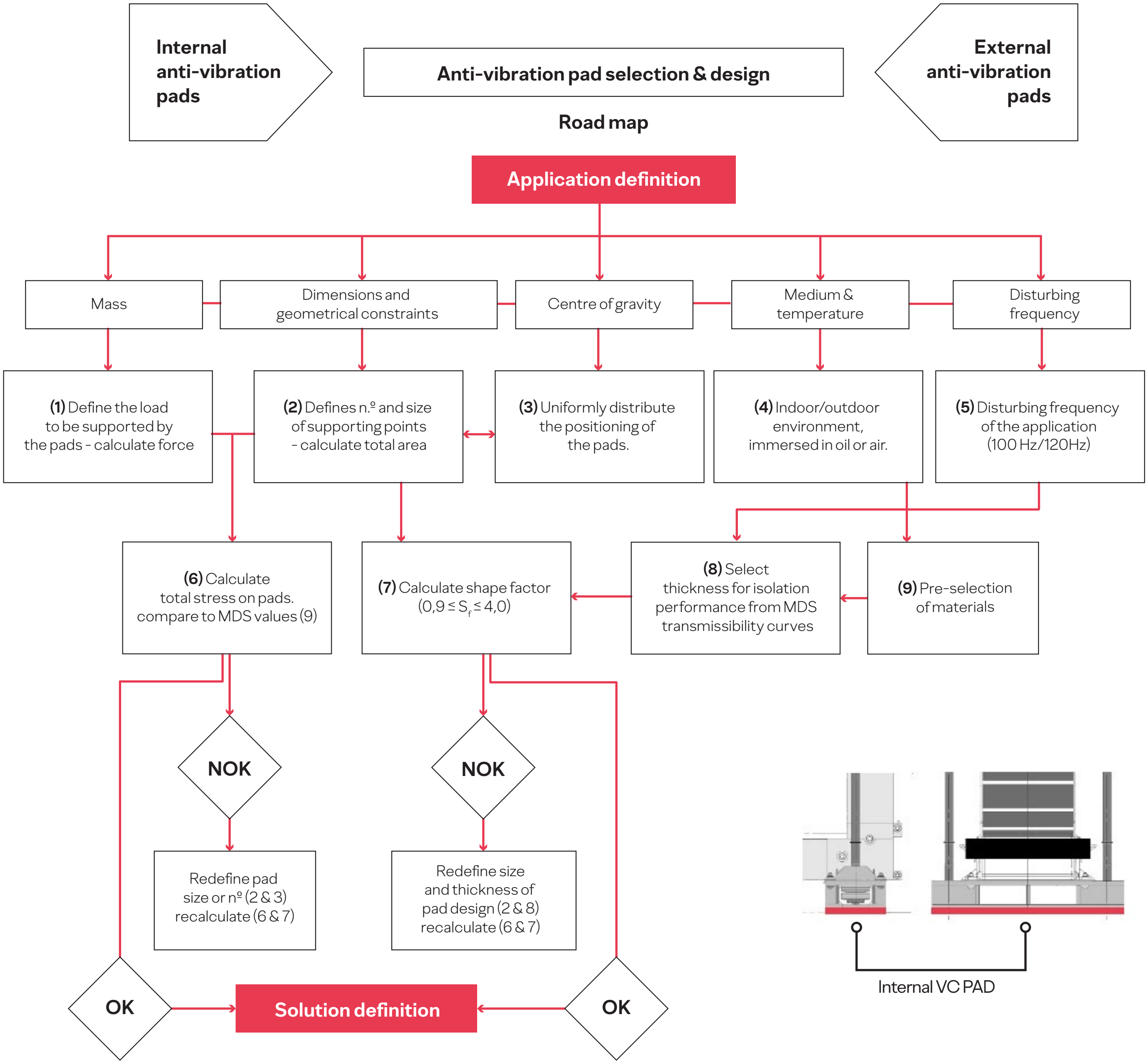
Shape Factor

Sf is the geometric measure for the shape of an anti-vibration pad, defined by the ratio of the loaded area to the area of the sum of the perimeter surfaces. The correct design of the shape factor is important to achieve the correct stiffness.

While rubbers are considered incompressible, and require space to displace the compressed volume, cork rubber displaces much less volume due to cork's internal compression (lower Poisson ratio), allowing for a wider Sf tolerance, which in turn affects the robustness of the design.



Design structure

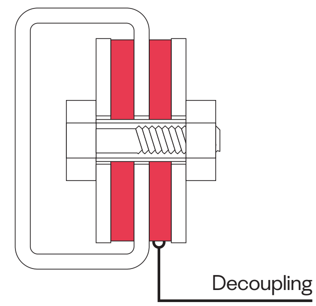


Careful analysis of the system is crucial; extraordinary loadings should be taken in to account, such as oil mass, loads introduced through anchoring or significant connections that may impact the overall seating stress on the anti-vibration pad.

As rule of thumb whenever possible design for the lower end of the material stress range, to account for load variations and long term creep effects. Detailed information is available in our Data Sheets.

Design structure

Decoupling active part design — Road map



Core clamping mechanism

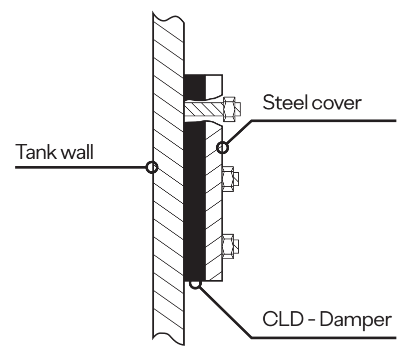
Identify all connection points between active part and tank

Evaluate loading on connections due to transport or assembly.

Redesign and implement decoupling material, eliminating steel/steel connections

Due to the fact that each manufacturer has a unique design and clamping requirements, which is then replicated throughout its product range, every design needs to be uniquely evaluated. The importance of adequate decoupling at the clamping points, significantly enhances the effectiveness of the interior vibration pads, preventing flanking paths from the active part to the tank structure. Amorim VC2100 is used for the decoupling function.

Structural damping design — Road map



Compressed layer damper (CLD)

Identity all tank wall areas with highest vibration amplitude/noise

Define CLD area in function of mechanical constraints, in approximately 50% of the wall area

Design clamping mechanism to compress the CLD nominally at 10%

Structural damping provides a means of converting mechanical energy (vibrations) in to low-grade heat, if correctly implemented it can significantly reduce noise. Thickness of the CLD is defined by the tank wall. In an optimized design the CLD thickness should be similar to the tank wall thickness. If the wall is too thin it will have minimal effect, or no effect at all. It should be implemented in the interior wall. Amorim VC2100 is the selected material for the CLD

In equipment with a shunt wall, the current shunt wall can serve as the compressing element of the CLD against the interior tank wall. This construction will also reduce the vibrations that are passed on by the shunt wall to the tank structure, due to the loss currents from the active part.

Technical bulletin
VC2100 internal vibration control

Accelerated ageing

Power Transformers are now often installed in close proximity to residential areas, where strict noise level requirements are imposed. The demand for low and ultra-low noise transformers and reactors, has intensified in metropolitan areas around the world.

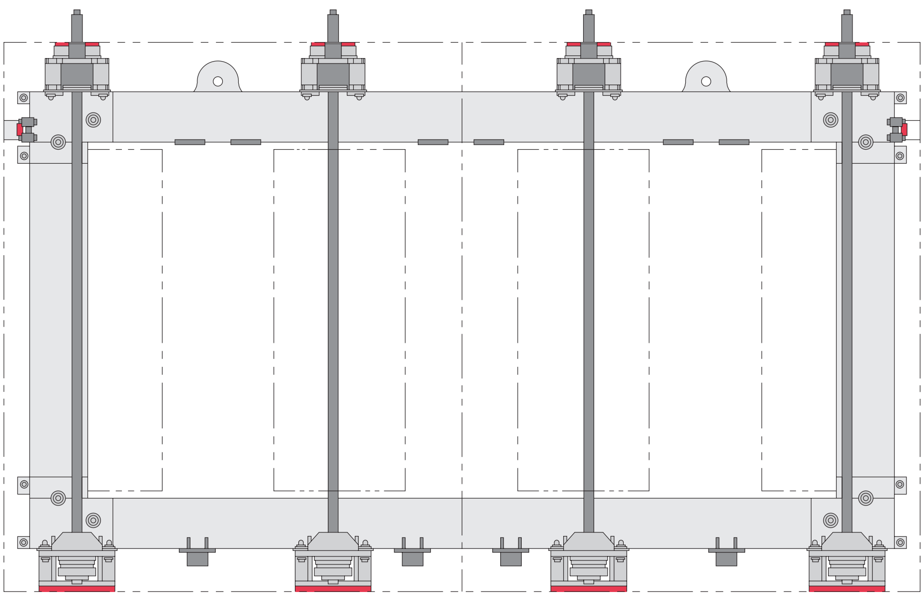
The main sources of noise radiated by transformers are:

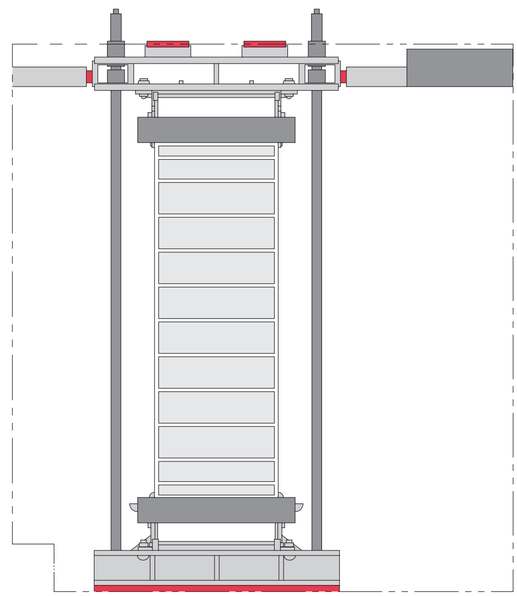
a. The core
b. The windings (and tank)
c. The cooling equipment.

The core sound, primarily consisting of a double power frequency tone and its harmonics, is generally dominant in overall level. However, in some transformers with forced air cooling, the cooling equipment sound can dominate.

A power transformer is the most expensive equipment in an electrical network; during a transformer operation the insulation oil and core mechanical properties are continuously degrading as are components such as vibration control materials. This alteration constitutes an irreversible change.

Amorim Cork Composites has been supplying VC2100 internal vibration control material to the industry for several years, thereby gaining and developing specific knowledge and experience in the application of vibration control materials immersed in oil over the lifetime of the transformer. VC2100 is used by low and ultra low noise transformer manufacturers and recognized as a superior noise abatement product.





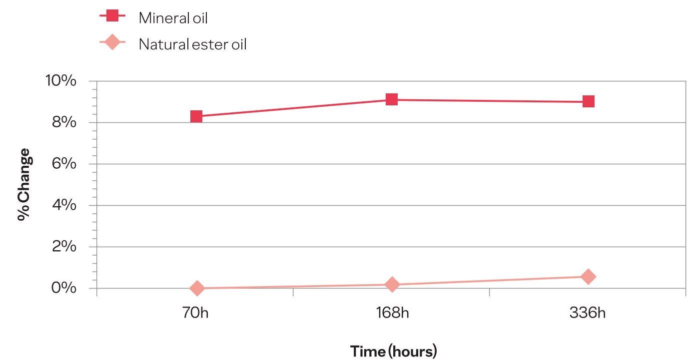
Transformer noise is caused by mechanical movement of the individual lamination of the core under magnetization. The pulsation will cause not only air disturbances, thus producing noise, but also physical vibration of the core structure and everything attached to it.

Amorim VC2100 vibration control material is used as vibration pads placed beneath the core as well as decoupling supports between the core structure and the tank wall or tank cover. VC2100 appropriately applied is able to reduce overall transformer noise by up to 5dB.

Material ageing in oil

Volume change @ 125°C up to 336h in mineral and ester insulation oil

In the transformer industry, chemical compatibility between the material and the oil is important - to ascertain that there is no significant contamination to the insulation oil, which would reduce its dielectric function in the transformer. From the VC2100 point of view, volume change and hardness/flexibility change are tested to determine whether the fluids (insulation oils) have a negative effect on the polymer life.



Properties change @ 125°C, 504h in mineral insulation oil

A moderate and stable positive volume change of the VC2100 indicates chemical resistance to the oil, meaning that the material will not experience chemical breakdown due to its immersion in the insulation oil. Hardness of the material (an indicator of the compressibility/Young modulus) is practically unaltered, as well as the flexibility of the material.

Hardness Change [Shore A]	2
Flexibility	3*

*1 flex above original value

VC2100 has been tested at Nynas Labs for oil compatibility as well as at M&I Materials (Midel oil manufacturer), and were considered compatible.

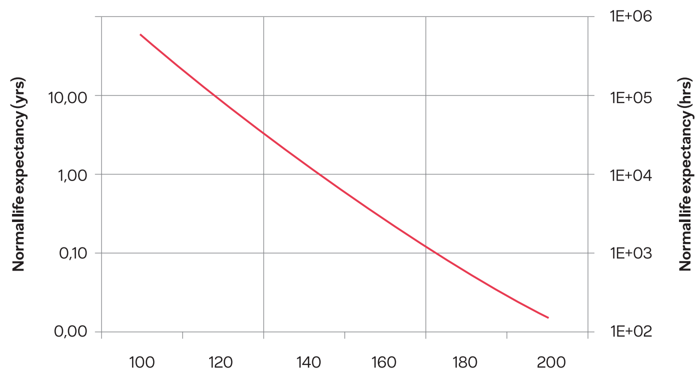
Reports available upon request.

Accelerated ageing testing procedure

Ageing was performed to simulate the performance in the application considering an Arrhenius reaction rate adapted for insulation deterioration of transformers.

The practical use of this finding is to estimate the life of electrical insulation, but it can also be transposed to other materials used in the transformer, to accomplish an accelerated life test.

At 106°C the average life expectancy (based on statistical values) is calculated at 30 years, following the curve down to an acceptable accelerated testing time required at 160°C for 2224h (approx. 92 days).



$$\log_{10} \text{life(h)} = -11.269 + \frac{6328.8}{T}$$

Real temperature		$\log_{10}$(h)	Expected life	
106 °C	379 K	5,43	268 956 h	31 yrs
160 °C	433 K	3,35	2 224 h	0,25 yrs
Test temperature		**$\log_{10}$(h)**	**Test time**	

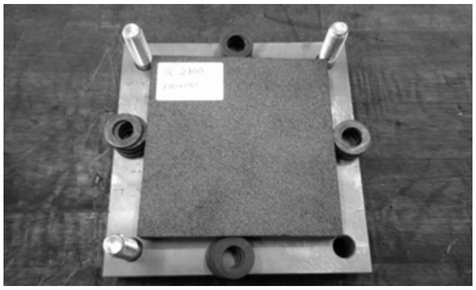
Did you know?

The Arrhenius equation is a simple, but accurate formula for the temperature dependence of the reaction rate constant, and therefore, the rate of a chemical reaction. The equation was first proposed by the Swedish chemist Svante Arrhenius in 1884. Five years later, in 1889, the Dutch chemist J. H. van 't Hoff provided a physical justification and interpretation for it. Currently, it is best seen as an empirical relationship. It can be used to model the temperature-variance of diffusion coefficients, like creep rates, and many other thermally-induced processes/reactions.

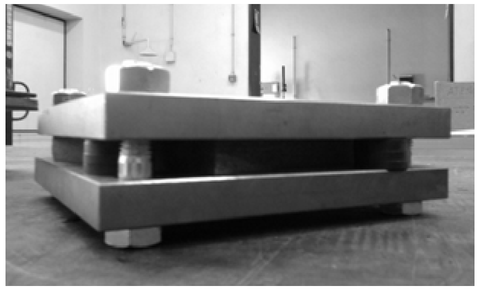
Svante Arrhenius, 1859 – 1927

Accelerated ageing testing assembly and results

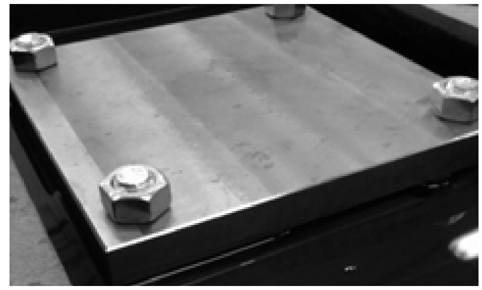
VC2100 pad (20mm thick) was subject to the thermal conditioning immersed in Diala D mineral insulation oil for 93days (2232 hours) @ 106°C, compressed to 15% of thickness.



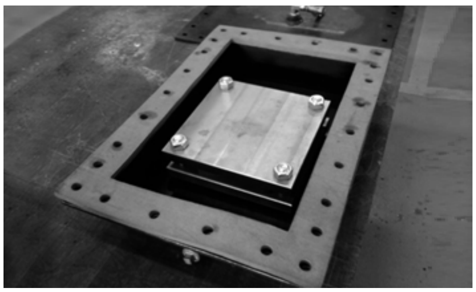
Pad Assembly



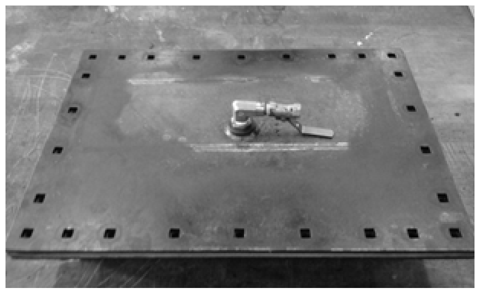
Pad compressed into position



Assembly immersed in mineral insulation oil

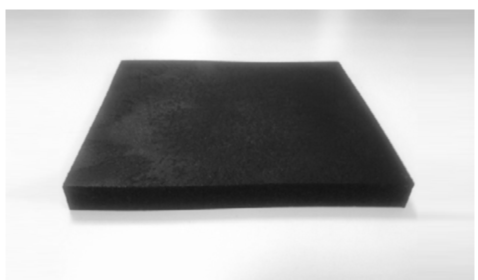


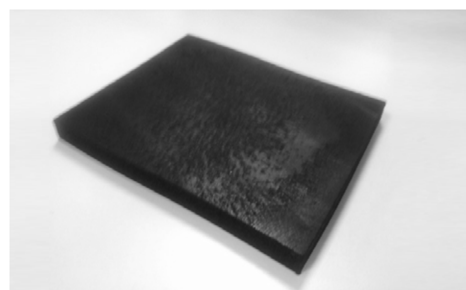
Assembly immersed in mineral insulation oil



Metal Box sealed and closed, was placed in oven at 160°C for 93 days

VC2100 vibration control material (20mm thick) after thermal conditioning immersed in Diala D mineral insulation oil





Pad at end of test, after disassembly

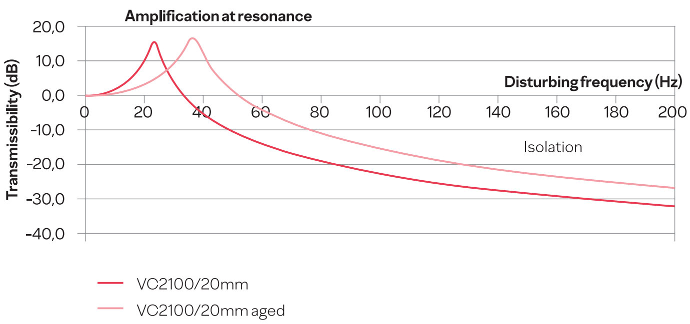
Disassembly showed no deterioration, i.e. no material disaggregating from the pad or stress cracks were observed, showing that it resisted to the load/ compression under the chemical and thermal conditions imposed. Oil was visually clean and transparent with a slight yellowish colour.

VC2100 vibration isolation characterization after thermal conditioning

After thermal conditioning, the pad was evaluated for isolation characteristics, namely to determine the new natural frequency after the accelerated ageing test. Comparison of the transmissibility curves of the aged and un-aged VC2100 at 20mm is provided below.

The graph shows an increment in natural frequency for the aged VC2100 which is expectable, taking into account that it was subject to an accelerated ageing test.

Isolation values obtained through dynamic testing of an aged VC2100 pad (after thermal conditioning, representative of 30 years in service under transformer application conditions at 105°C in mineral insulation oil), reveal that the material continues to exhibit a high isolation performance at the requested frequencies, when compared to the unaged material.



	Unaged	Aged
Tg δ	0,17	0,15
Pad Natural Frequency – fn [Hz]	23,5 Hz	36,6 Hz
Isolation at 100 Hz [dB]	-22,8 dB	-15,6 dB
Isolation at 100 Hz [%]	92,8 %	83,3 %
Isolation at 120 Hz [dB]	-25,6 dB	-18,9 dB
Isolation at 120 Hz [%]	94,7 %	88,6 %

The VC2100 affords physical, chemical and thermal resistance, and continues to isolate the transformer disturbance frequencies effectively throughout the life of the transformer

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