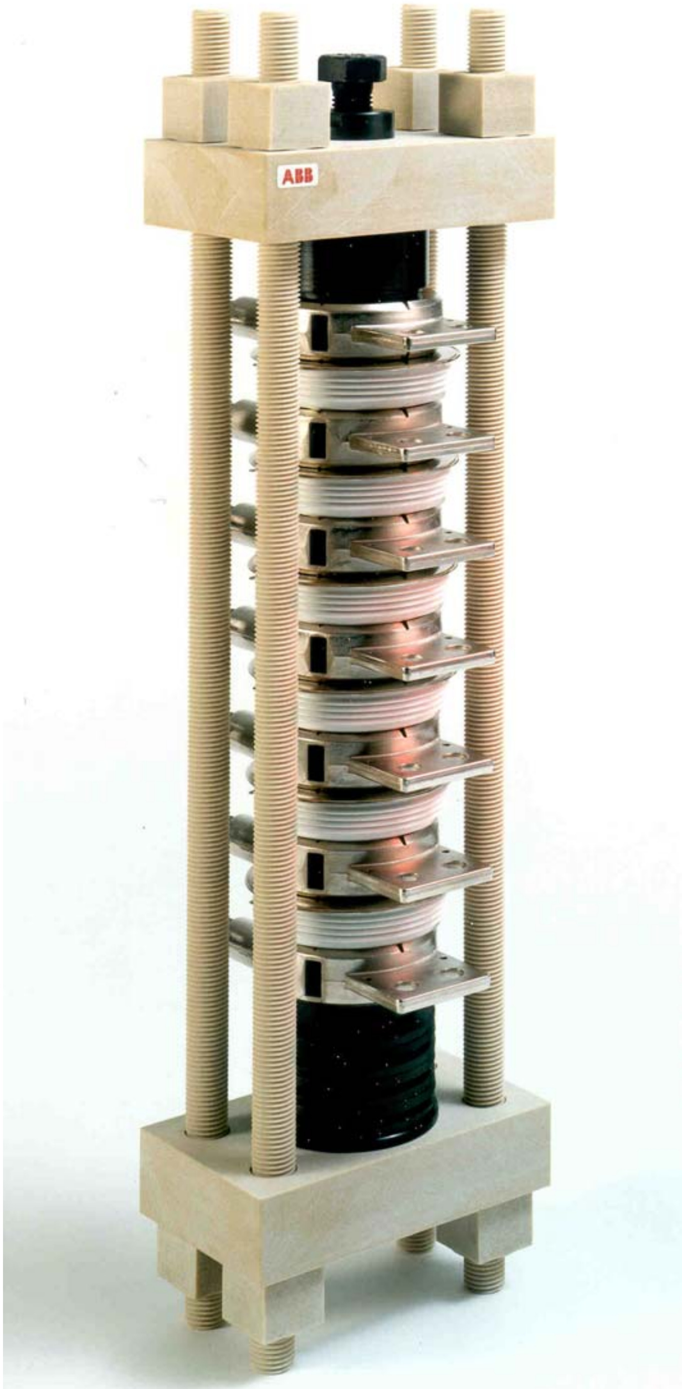
Press Pack High Power Semiconductors

Application note

Recommendations regarding mechanical clamping of Press Pack High Power Semiconductors



Recommendations regarding mechanical clamping of Press Pack High Power Semiconductors

Product Information

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1 Introduction

Press pack high power semiconductors are in many applications very powerful components in controlling electrical power. To utilise their full potential a proper mechanical design of the complete assembly, including press pack high power semiconductors, heat sinks, bus bars and other components, is crucial. In this application note some important issues for the mechanical design and the assembling work for stacks using press pack high power semiconductors are addressed.

2 Recommendations for the interface properties

The current and heat conducting interfaces, in this application note we concentrate on the interface between the press pack high power semiconductor and the heat sink, should be designed to have good conduction properties over the total equipment lifetime. This is accomplished by creating a sufficient number of stable metal-to-metal connections, in contact theory referred to as a-spots, which can efficiently conduct current from the semiconductor through the heat sink to the bus bars. These a-spots must be maintained at hard stress conditions such as load cycling, environmental impact through vibration and chemical contamination as sulphur gases. To achieve this, care must be taken in choosing the right materials for the utilised components. They must be coated properly and have the right surface finish.

2.1 Definitions

Roughness: The surface roughness is a measure of the microstructure of the surface. It is expressed as an Ra-value as per ISO 4287. The roughness is Ra ≤ 0.8 µm for all ABB Switzerland Ltd, Semiconductors (ABB) semiconductor devices.

Flatness: The flatness is ≤ 10 µm for ABB devices with pole piece diameter ≤ 50 mm and ≤ 15 µm for ABB devices with pole piece diameter > 50 mm. It means that the pole piece surfaces are limited by two parallel planes maximum a distance 10 or 15 µm apart.

F_M: The mounting force is the recommended force to be applied for optimal device performance . A too low mounting force will inhibit the use of the data sheet ratings. This since there will be an increase in the thermal impedance and the on-state voltage drop and a decrease in the surge current rating when the force is reduced below the rated value. A too high mounting force may crack the silicon wafer during load cycling.

2.2 Design of the utilised components

When using water cooled heat sinks the cooling should be as homogeneous as possible over the contact surface of the device: a single water channel through the centre of the heat sink may not be sufficient for heavy-duty equipment and could lead to over heating of the device rim. It is advisable to use water channels that provoke some turbulence rather than using simple straight paths (though this may be sufficient for light duty units). ABB supplies compact water-cooled heat sinks for heavy-duty equipment, see figure 1. These heat sinks use a stainless steel wire wound tube at both sides of the surface to reach an optimised cooling. For more information about the heat sinks please contact ABB at e-mail: pulsepower.abbsem@ch.abb.com, or Tel +41-58-5861742.

Figure 1. Water-cooled heat sink supplied by ABB.

The heat sinks must have adequate mechanical robustness to withstand compression with forces up to 135 kN without deformation. Deformation could lead to an inhomogeneous pressure distribution.

Casted or extruded heat sinks need in almost all cases to be machined properly through processes as milling or fine turning to get to the recommended surface finish.

2.3 Surface treatment

Surface finish and treatment are crucial for optimal heat and current conduction over the device and heat sink interface. The press pack high power semiconductors from ABB have a maximum surface roughness of Ra = 0.8 µm and flatness below 10 or 15 µm depending of pole piece size. It is recommended that the heat sink surface has the same flatness and roughness as the press pack high power semiconductor measured over the surface where the device is mounted.

ABB recommend the use of heat sinks with a good quality plating of nickel or silver. For applications with hard component stress ABB recommends chemical plating due to experienced issues with electrolytic plating. Bare copper or aluminium is not recommended due to corrosion that will rapidly deteriorate the contact surfaces. Nickel and Silver do corrode, however silveroxide does not have the harmful effects on the interface that aluminiumoxide does. The ABB press pack high power semiconductors have pole pieces of copper with an about 5 µm thick nickel-plating. It is recommended to use the same nickel plating on the heat sink are that is in contact with the device.

A thin film of a light grease or special silicon oil may be applied on the contact surfaces before the devices are assembled in the heat sink. If used, the interface grease or silicon oil must be carefully chosen for its long-term chemical stability, corrosion inhibiting properties, temperature range, electrical properties and ease of use. ABB has good experience with Silicon oil type SF1154 (GE) supplied by ABB Logistics Center. For further information please contact Ingje Karlsson: E-mail ingje.karlsson@se.abb.com, Tel +46 21 322912.

The recommendations for the heat sinks are also valid for all other components used to contact the press pack semiconductor such as the bus bar connecting the non-cooled side of the press pack semiconductor in single side cooled assemblies.

3 Recommendations for the mechanical design and assembly

The mechanical design and the assembly of the stack are also crucial for the performance and reliability of the press pack high power semiconductor. Inhomogeneous pressure distribution caused by the mechanics is a common cause of device failures. In this section we list some important issues in achieving the aim of getting a reliable stack.

3.1 The mechanical design

The clamping must be carefully designed to ensure that the device is clamped with the right force and it must also allow homogeneous pressure distribution over the whole contact surface of the device. Uneven pressure will lead to deformation of the housing and internal stress between the different layers inside the device causing it to fail prematurely during load cycling. Designing for pressure uniformity is not always easy and the complexity should not be underestimated. Simple solutions, such as clamping the device between two rectangular plates by bolting down the corners will exhibit poor reliability. To verify that the pressure distribution is uniform ABB recommends the use of Fuji Prescale film or similar products from other vendors. For information about the Fuji Prescale film see www.fujiprescale.com or www.fujiprescale.net. Most devices are measured using the Fuji Prescale film medium pressure grade, 1 – 5 kN/cm^2, but some devices, mainly large area GTO and IGCT, are measured using low pressure grade, 0.25 - 1 kN/cm^2.

Ideally, the mounting force should be applied from a single point over the centre of the device, our recommendation is that the centre of the force is within 2 mm from the centre of the device, and at a minimum distance equal to half the pole-piece diameter of the device from the device surface, as shown in figure 2. This to achieve a good pressure uniformity considering the “90 ° force cone”. A spherical cup between the mounting clamp and the pressure spreader above the heat sink can act as this single point of force and ensures that the force from the mounting clamp is transferred symmetrical to the device. It also allows the parts within the stack to adapt to inherently present non-parallelisms. There will always be inherent non-parallelisms in a stack since it will not be possible to manufacture heat sinks and press pack high power semiconductors with perfectly parallel surfaces. It should though be striven to reduce the non-parallelisms as much as possible. The non-parallelism between the anode and cathode pole pieces is ≤ 100 µm for ABB devices with pole piece diameter ≤ 50 mm and ≤ 150 µm for ABB devices with pole piece diameter > 50 mm.

Due to the space restrictions in some applications however, it may not always be practical to have the recommended half pole-piece diameter of distance, but reasonable results can with a proper design be obtained with smaller distances, for example, by using Belleville springs.

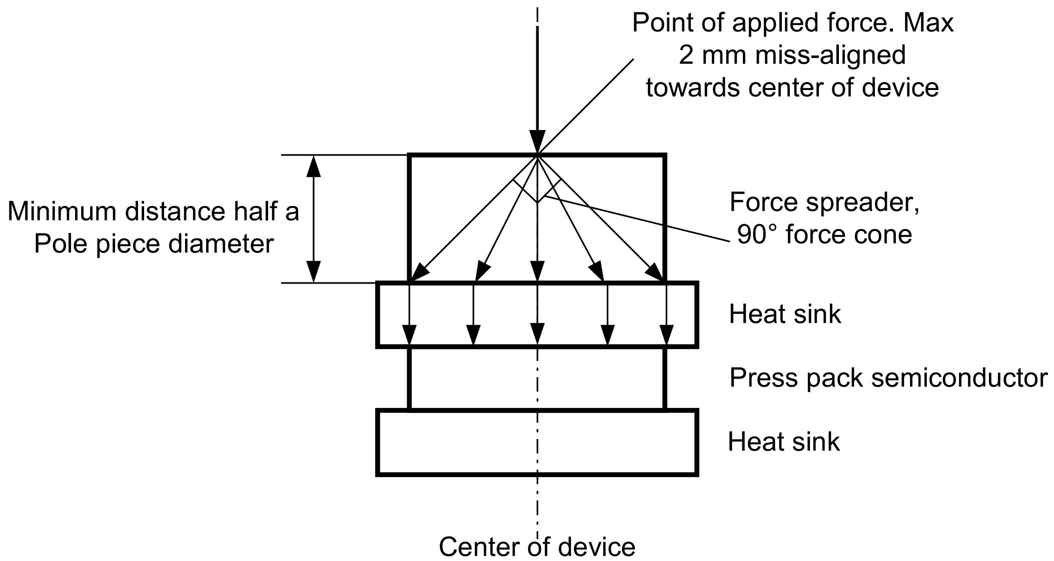

Figure 2. Recommended application of the mounting force.

ABB are manufacturing and selling a series of mounting clamps for mounting forces 4 – 135 kN. For further information please contact Ingje Karlsson, E-mail: ingje.karlsson@se.abb.com Tel +46 21 322912. An example of a 135 kN clamp can be seen in the left stack of figure 3.

The components and the clamp design must be chosen to withstand without damage the temperature levels and the forces caused by mechanical expansions and contractions due to temperature changes that appear at working conditions. This over the whole equipment lifetime. The design must also allow temperature expansion and contraction without the appearance of large changes in force and pressure distribution on the press pack high power semiconductor.

In long stacks with more than 2 devices and their heat sinks, it may be difficult to get a good mechanical stability when using a design with 2 rods and a standard mounting clamp. Therefore ABB recommends the use of a 4-rod Belleville spring construction for in long stacks as shown in figure 3.

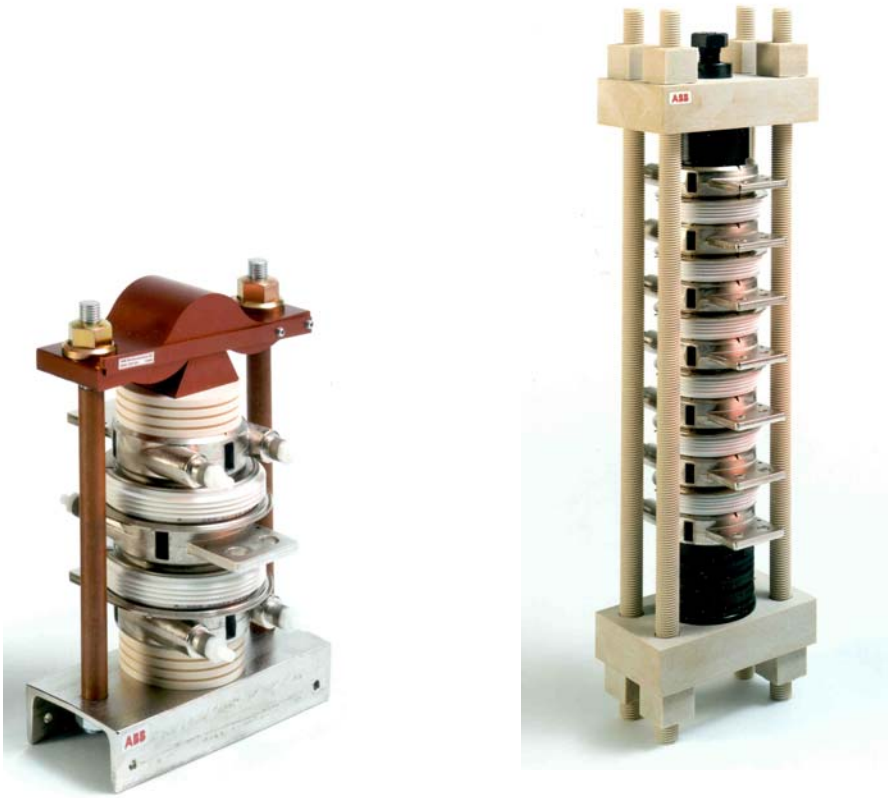

Figure 3. Two rods are enough for shorter stacks but for long stacks 4 rods are recommended.

Press pack high power semiconductors, also when parallel or anti-parallel connected, should always be separately clamped as shown in figure 4, unless they are stacked on top of each other as shown in figure 3. Due to the mechanical tolerances there will be differences in height and parallelism that in many cases will create mechanical forces large enough to significantly reduce the life time of or even destroy the devices if 2 or more devices are clamped together between two rigid bus bars or heat sinks.

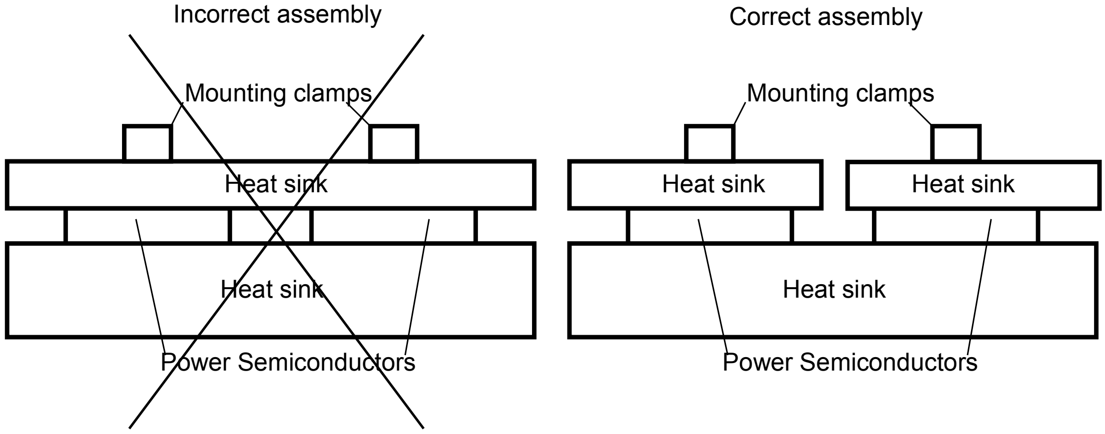

Figure 4. Devices should be individually clamped.

If the mounting clamp and the bolts holding the stack together has to be on ground potential, the right materials and the right air and creepage distances must be utilised. For more about insulation co-ordination consult standards IEC 60664-1 and UL840. Insulating materials, as Vetresit®, a glass-fibre epoxy from ABB, can be used for the bolts making a simplified or more compact stack compared with the case using steel bolts, that either have to have an insulator around them or have enough air strike distance from the live parts.

If several devices are assembled together in one stack with the same mounting clamp, the devices must have the same rated mounting force. This to avoid over stress or too low pressure for some of the devices in the stack. It is also advisable to use devices with the same pole piece diameter to simplify the heat sink design in order to achieve a good pressure distribution on all devices. If the heat sink cannot spread the pressure well and devices with different pole piece diameters are used, there is a large risk that either the rim of the smaller device gets too high pressure or the rim of the large device gets too low pressure. An example of a well-dimensioned stack is shown in figure 5. Figure 6 shows a bad designed stack using bad force spreaders and insufficient heat sinks that do not spread the force for the devices with different diameters. ABB do not recommend it but with well-designed heat sinks assemblies as shown in figure 7 can be made.

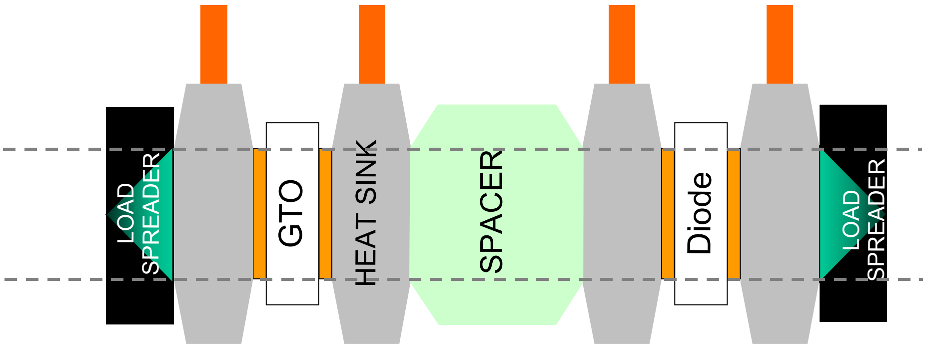

Figure 5. Good stack with effective load spreaders and similar device diameters.

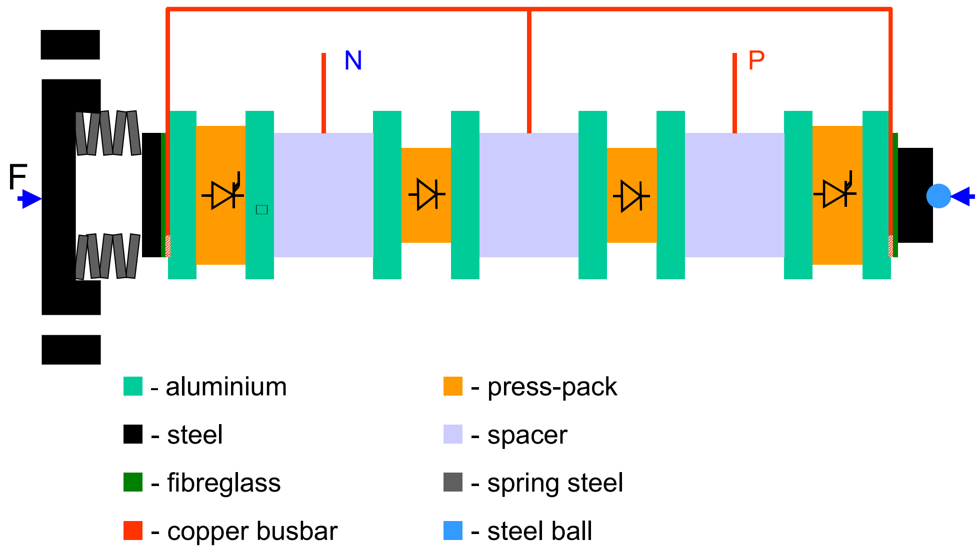

Figure 6. Bad stack with ineffectual load spreaders and dissimilar device diameters.

Bus bars or their connections to the stack should have a flexible part to avoid mechanical stress to the stack assembly. Mechanical stress can occur either due to mechanical tolerances or due to heat expansion and contraction during changes in the electrical load.

For IGCT-assemblies an additional issue is that the integrated gate drive needs a fixture in order to withstand vibration stress applied in stationary operation and during equipment transportation. Note that the gate unit, and for the large devices also the metal casing around the gate unit, are on cathode potential and need to be insulated from the rest of the assembly.

The gate cables for PCT and GTO should be laid properly to make sure that they do not come in contact with anode potential and also to minimise Electro-Magnetic Disturbances. Twisted or coax cables are recommended to reduce EMC sensitivity. The cables should be as short as possible and they should preferably be laid in a 90 ° angle to the main current conduction direction.

For water cooled assemblies very stiff tubes used between the different heat sinks can cause problems due to mechanical forces caused by thermal expansion and contraction. The tube length between heat sinks with different potential must be large enough since water is electrically conducting. De-ionised water should be used together with water treatment equipment that is needed to take away conducting particles and to keep the water conductivity low. For water tubes ABB recommend the use of non-corroding material as stainless steel, Teflon and PTFE but not copper or aluminium.

For equipment used at severe environmental conditions special care must be taken to ensure that the press pack high power semiconductors do not get harmed by for instance vibrations and temperature variations. Special care for vibrations must be taken in applications for rolling stock.

3.2 Example GTO fixture

In figure 7 an example of a GTO-stack is shown with a short reference to some of the issues mentioned in section 3.1.

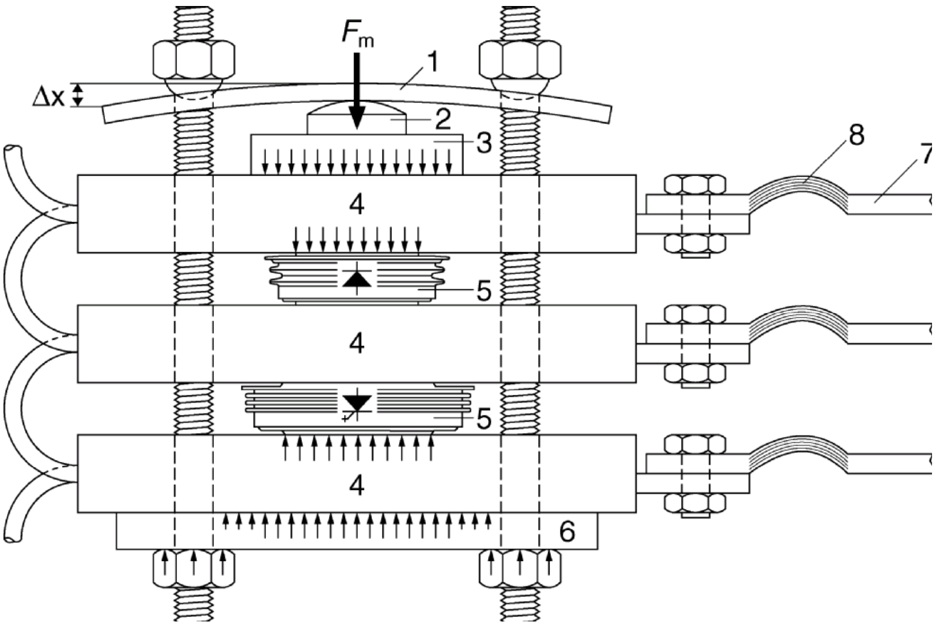

Figure 7. Example of a stack, illustrating the basic rules for correct clamping of press pack high power semiconductors:

1. Leaf spring. Spring excursion Δx must be large in comparison with thermal expansion of stack parts in order to keep F_m constant over time and temperature variations.
2. Spherical cup ensures that F_m is transferred symmetrically to the press pack high power semiconductors and allows the parts within the stack to adapt to inherently present non-parallelisms.
3. Strong steel plate for homogeneous pressure transfer to heat sink (4), symbolised by small arrows.
4. High-quality heat sink: Clean and parallel surfaces with flatness and roughness as per paragraph 2.3.
5. Press pack semiconductor: Surfaces cleaned and covered with thin film of silicone oil before mounting.
6. Strong yoke ensures homogeneous pressure distribution on heat sink (4), symbolised by small arrows.
7. Bus bars (7) connected to heat sinks (4) by means of flexible connections (8) to avoid that uncontrolled "external" forces disturb the homogeneous pressure distribution within the stack.
8. Before mounting the stack parts in the clamping system, the various surfaces should be cleaned with alcohol, ethanol or similar, and it may be advantageous to lubricate them with a *thin* film of silicon oil to improve the thermal contact, and to prevent oxidation if the stack is exposed to an aggressive environment. However, it should be noticed that silicon oil or contact grease will never compensate for poor-quality heat sink surfaces!

3.3 Recommendations for the assembly

Even the best of designs will not lead to the intended result if the assembly is not done correctly. In this paragraph some issues of importance for the assembly work are listed.

If needed the surfaces heat sink and semiconductor should first be lightly polished with 3M Scotchbrite™ or similar. Before assembling, the contact surfaces must be properly cleaned using ethanol (or similar solvent) and a lint-free cloth. The assembly should be done at a clean place to avoid dust and humidity since the surfaces must be kept clean during the whole assembly procedure. Heat sink and semiconductor surfaces should not be touched by bare hands. We recommend the use of lint-free gloves for handling of semiconductor devices.

The heat sinks and press pack high power semiconductors should be handled with care to avoid scratches and other damages to the surfaces. Small scratches are neither nice nor desirable but are sometimes not that harmful since the overall surface finish is more important for heat and current transfer. The surface structure must though be within the specification given in paragraph 2.1.

If using silicon oil or grease put on only very small quantities, spread it well and make sure that the whole surface gets covered with a very thin film. Too much silicon oil or grease will establish a film that prevents the intended metal-to-metal contacts.

Make sure that the devices are placed with the right polarity, that the gate cables for thyristors and GTO's are placed correctly and make sure that the devices are well centered and fixed. The centering is normally done either through a holder gripping on the pole pieces or the ceramic or through a central pin fitting into the centering hole in the device.

For clamps it must be made sure that the mounting force indicator is at the zero-indication at start and that it remains in the right position during the whole assembly procedure. Follow the recommendations from the mounting clamp supplier regarding the assembly procedure, as how fastening the bolts and how force is indicated, to make sure that the right force gets applied on the semiconductor. When using Belleville springs make sure that the compression distance for the right force is known and correctly measured.

Clamp the press pack high power semiconductors before attaching bus bars to the assembly. This to avoid building up mechanical tension to the press pack high power semiconductors during the assembly.

4 Additional notes

4.1 Further things to consider

Unless the press pack high power semiconductors and heat sinks are mechanically well supported, long stacks with several devices should be transported in the upright position. Having the stack lie down can cause tension to the press pack high power semiconductors and vibrations or bumps may lead to device destruction.

When making the stack design, considerations about the stack installation in a cubicle or at site should be made. This to make the installation easy and to make sure that the stack can be fixed properly in the cubicle and the external connections fit. If using conductive material in the clamp, include connection points for grounding of the stack should. Heavy stacks should have hooks or other support for handling purposes. For air-cooled units, both convection and forced air, adequate airflow must be assured and pressure drops and additional heating in the cubicle must be considered in the thermal dimensioning of the unit.

4.2 Application support for assemblies

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