MANUAL

FABRIC EXPANSION JOINTS-
SELECTION AND APPLICATION

DEP 31.24.40.12-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

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The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

1.1 SCOPE

This is a new DEP giving minimum requirements for the selection and application of fabric expansion joints ("fabric compensators") for use at temperatures up to 1100 °C.

The DEP is intended to enable users to scrutinize data supplied by the Manufacturer; it does not, however, contain exact design values for fabric expansion joints, for which the Manufacturer is responsible (4.).

It describes the materials of construction, appropriate selection criteria, construction, installation, testing and handling of fabric expansion joints.

Fabric expansion joints are installed as permanently flexible structural elements in piping and duct systems to compensate for expansion in the metal due to heat or minor misalignments in the system; if necessary, they can also compensate for vibrations in a system.

They shall have the ability to take up complex axial, lateral and torsional movements with low flexibility forces. They shall also be chemically resistant to the flow media and stable under pressure and vacuum conditions.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this DEP is confined to companies forming part of or managed by the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

The DEP is intended for use in oil refineries, chemical plants, gas plants and, where applicable, in exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, installation, and commissioning or management of a project or operation of a facility. The Principal may sometimes undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorized to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets. All publications referred to in this DEP are listed in (6.).

2. MATERIALS OF CONSTRUCTION

All materials of construction shall be new and not recycled. The materials, when combined as a structure, shall produce a fabric expansion joint which meets the performance requirements of this specification.

The Manufacturer shall order the materials in accordance with a written specification. The materials shall be supplied with certification in accordance with ISO 10474 type 3.1.B.

Most fabric expansion joints are tailor-made by laminating various layers of materials (fabrics), each with different mechanical, physical and chemical properties, in a predetermined sequence to form an integral construction (4.2).

Depending on the application, the fabric expansion joint can be constructed from the following structural layer(s):

- insulating or heat-resistant protection layer(s), which should be made from glass fibre or ceramic fibre;
- pressure-tight or sealing layer(s), which should be made from PTFE (and shall be pinhole tested);
- pressure-reinforcing or supporting layer(s);
- protection layer(s), which should be made from FKM-based material (e.g. Viton B).

Occasionally the functions of the various structural layers are combined in a single layer.

Table 1 summarizes various materials (fabrics) with their long-term and short-term (peak) temperature resistance and an indication of their chemical resistance. It should be noted that the chemical resistance may decrease as the temperature increases. Their main function in the fabric expansion joint construction is also given.

In those cases where proprietary materials are not included in the table or deviate from the data given, reference should be made to the properties published by the Manufacturer.

If materials with poor mechanical properties, such as insulating fibres, are used in conjunction with stainless steel wire mesh, care should be taken to prevent foils being damaged by the wires.

Table 1 Materials (1) for fabric expansion joints

Material (2)	Temp. resistance		Resistance (3) to			Main (4) function
	Long-term	Peak	Acids	Alkalis	Solvents	
PTFE (Teflon)	260	280	+	+	+	S/W
Silicone	200	220	-	o	o	S/W
EPDM	120	150	+	+	o	S/W
FKM (Viton B)	200	250	+	o	+	S/W
Polyester	150	180	o	o	o	P
Aramide	180	250	o	o	+	P
Glass	500	600	+ (5)	+	+	I/P
Ceramic	1050	1250	o (5)	o	+	I/P
Silicate	1200	1350	+ (5)	o	+	I
Stainless steel	600	850	+	+	+	P/S
Aluminium	500	550	-	-	+	P/S
Incoloy 800	800	1000	+	+	+	P/S

NOTES:

(1) Local regulations for the safe handling and use may be applicable for certain materials (Appendix 3).

(2) The official abbreviation and, where relevant, a common trade name is given.

(3) Legend:
+ = resistant
0 = limited resistant
- = not resistant

4) I = insulating layer(s)
S = sealing layer(s)
P = pressure-reinforcing (supporting) layer(s)
W = (weathering) protection layer(s)

(5) Poor resistance to HF, although high concentrations of HF at high temperatures may be critical for most of the materials.

3. SELECTION CRITERIA

3.1 GENERAL

Fabric expansion joints shall withstand thermal/mechanical/chemical loads occurring in piping/ducting/equipment components of the system and shall also absorb the stresses, movements and vibrations axially and/or laterally.

Fabric expansion joints are generally multi-layer, tailor-made products and the sequence of the constructive layers will depend upon a number of variables as detailed below.

The selection of the fabric expansion joint should be based on the maximum operating conditions rather than on the maximum design (upset) conditions.

If the Manufacturer's quotation includes only a general drawing, in case of an order a detailed drawing should be made based on the actual condition.

3.2 TEMPERATURE

The long-term and peak temperature of the various materials is given in (2).

The Manufacturer should provide, if requested by the Principal, a temperature curve for the various alternative layers, so that it can be assessed that the maximum temperature and/or chemical resistance of each individual successive layer will not be exceeded.

The calculation should cover the practical installation condition, i.e. some material parts in a convoluted form are exposed to more severe conditions than other parts.

In case the temperature of the medium is higher than the allowable temperature of the pressure-reinforcing layer(s), it will be necessary to use insulating layer(s).

An alternative for high-temperature application is a fabric expansion joint with a pre-insulation (Appendix 1, Figure 1). Pre-insulation can also be used to achieve acoustic insulation or to prevent accumulation of dust.

External insulation should only be applied if the maximum allowable temperatures of the various ply materials are not exceeded. External insulation will hamper visual inspection during service.

3.3 PRESSURE

Resistance to pressure and pressure tightness shall be achieved by the application of pressure-tight (sealing) layer(s) and/or pressure-reinforcing (supporting) layer(s) in the multi-ply fabric expansion joint. If pressure-reinforcing (supporting) layer(s) are used, it will be necessary to allow for a reduction in flexibility.

For pressure applications, the pressure-reinforcing (supporting) layer(s) shall be positioned on the outside of the pressure-tight (sealing) layer(s). For vacuum applications, the pressure-reinforcing (supporting) layer(s) shall be positioned on the inside of the pressure-tight (sealing) layer(s). The layer sequence can then be summarised as follows:

	Pressure application	Vacuum application
OUTSIDE	W	W
	P	S
	S	P
INSIDE	I	I

where:
W = (weathering) protection layer(s)
P = pressure-reinforcing (supporting) layer(s)
S = sealing layer(s)
I = insulating layer(s)

3.4 MEDIUM

Section 2 presents a general indication of the chemical resistance of the various fabric expansion joint ply-materials.

Where the material layers lie freely one on top of the other, there will be a degree of permeability and small amounts of gas can diffuse straight through the fabric layers. The negative effect of accumulation of condensation in a ply and the relative sensitivity to flue gas condensate attack of metal reinforcement should be considered.

A draining device should be installed if it is expected that condensate will accumulate (e.g. horizontal installation of the fabric expansion joint).

Where the gas stream carries a lot of dust, or at gas velocities above 10 m/s, an internal single or double sleeve or metal deflector plate should be used to prevent the collection of dust in the convolutions (Appendix 1, Figures 2, 3 and 4).

3.5 MOVEMENTS AND VIBRATIONS

The maximum/normal axial/lateral/torsional movements at both peak/normal temperature should be considered in the design of the fabric expansion joint. Also, fixed points and supports play an important role.

Both pressure-tight (sealing) layer(s) and pressure-reinforced (supporting) layer(s) will reduce the flexibility. Fabric expansion joints which have to deal with large movements may need to have at least two layers of this supporting material so that a relative movement is possible between them.

Supporting layers with different expansion characteristics should not be used together, as only the stiffest layer with the smallest movement capability is effective.

High frequent tensile/compression vibrations will cause failure of the metal reinforcement by fatigue.

Vibrations are also harmful to all woven materials. Where vibrations will occur, rubber or synthetic materials should be used.

4. CONSTRUCTION

4.1 GENERAL

The design shall be approved by the Principal before manufacturing is started. The design documents shall give the construction details as specified in this section.

The Manufacturer should mark the fabric expansion joint with "inside/outside", in case actual installation could give rise to confusion.

The Manufacturer shall also mark the "flow direction" if the fabric expansion joint is provided with an internal sleeve (4.3).

4.2 SEQUENCE OF LAYERS

A fabric expansion joint is constructed by laminating several layers of materials or fabrics. Usually, these layers lie freely one on top of the other. Sometimes the layers at the end connection are joined together. All points in the construction where ingress of products is possible (e.g. all seams) shall be sealed properly.

From inside to outside, the following layer(s) can be used:

1. **Insulating or heat-resistant protection layer(s)**

   This layer(s) is used to compensate for the lower maximum temperature resistance of the various subsequent constructive layers.

   If large movements have to be compensated, at least two layers should be used so that movement between them is possible (as the mechanical properties of the insulating materials are rather low).

2. **Pressure-tight or sealing layer(s)**

   Foils are used to achieve the required gas tightness (no pinholes with 10 kV spark testing). If metal foils are used, it should be realized that they are prone to buckling and will reduce the flexibility of the expansion joint. Unless special constructions are used, some leakages may also occur at the end connections (4.5).

   For pressure applications the sealing layer(s) should be followed by the supporting layer(s), while for vacuum applications the sequence should be the opposite (3.3).

3. **Pressure-reinforcing or supporting layer(s)**

   This layer(s) is used to achieve the mechanical strength required for the duty.

   An increasing number of these layers will reduce the flexibility of the expansion joint. Layers with different expansion characteristics should not be used together as only the stiffest layer with the smallest movement capability is effective.

4. **Protective layer(s)**

   This layer(s) is used to protect against atmospheric effects.

   Sometimes it may be desirable to protect the fabric expansion joint with an external protection cage or external insulation.

   External insulation should only be applied when the internal temperature is lower than the maximum allowable temperature of the pressure-tight (sealing) layer(s) or protective layer(s).

   The end connections (4.5) of the expansion joint are generally also not insulated, in order to prevent local overheating of the layer(s) at those places.

4.3 INTERNAL SLEEVE

An internal single, double or floating sleeve can be used to protect the internal surfaces of the fabric expansion joint from:

1. Heavy concentrations of dust, which may accumulate in the convolutions of the expansion joint (Appendix 1, Figures 2, 3 and 4).

2. Excessive temperatures caused by filling the space with thermal insulating material (Appendix 1, Figure 1).
3. Excessive turbulence and abrasion by high gas stream velocities (above 10 m/s).

For horizontal applications, the open end of the internal sleeve shall point in the direction of the flow.

For vertical applications, the open end of the internal sleeve shall point downwards, even if the flow is upwards.

4.4 DRAINAGE DEVICES

If condensate is expected to accumulate in the lower parts of the expansion joint, a special drainage device should be provided at those positions to allow the fluid to be drained conveniently.

4.5 END CONNECTIONS

The flange of the metallic duct should be at least 20 to 30 mm larger in diameter than the mating flange of the expansion joint, in order to achieve optimum jointing.

The end connections are generally not insulated, in order to prevent local overheating.

Various end connection methods for fabric expansion joints are given in Appendix 2.

1. **Bolted counter-flanges** (Figure A)

   This is the usual connection method. A relative difficulty is obtaining a good sealing effect. Reference is also made to Standard drawings S 24.301 and S 24.404.

2. **Clamping Flanges** (Figure B)

   These should be used if tighter sealing is required. The disadvantage is the high bolt stress, about twice as high as the normal bolted flanges. Another disadvantage is the low securing force, so that sometimes alternatives (such as additional bolt-holes and bolts) are necessary to have the appropriate clamping effect.

5. TESTING, INSTALLATION, REPAIR, TRANSPORT, STORAGE AND DOCUMENTATION

5.1 TESTING

Each fabric expansion joint shall be inspected visually for compliance with the approved design (4.1).

The Manufacturer should provide a temperature curve over the wall of the fabric expansion joint, indicating the temperature for each individual layer.

If requested by the Principal, the Manufacturer shall carry out a prototype test of a fabric expansion joint. This test should comprise pressure testing at room temperature for 6 hours at a test pressure of 1.5 times the maximum operating pressure, with the actual axial/lateral/torsional movement, without exceeding the specified pressure loss.

5.2 INSTALLATION

The Manufacturer shall provide installation instructions and should be engaged to provide supervision at all stages of installation.

Fabric expansion joints should be installed carefully, so that damage by sharp edges and pointed objects is prevented.

Fabric expansion joints should not be exposed beyond their design limits (temperature, pressure, movements, alignment). The convolutions, if any, should be formed during manufacturing (in the shop) and should be such that overstressing in the field will not occur.

In case welding or painting is carried out in the vicinity of the fabric expansion joint, shielding shall be provided to prevent damage by excessive heat or weld spatter or by spillage of solvents.

Reference is made to (4.3 and 4.4) for the installation of fabric expansion joints with an internal sleeve or for cases where condensate accumulation at the lower part may be expected.

5.3 REPAIR

Repair should only be considered when neighbouring material near the damaged spot retains sufficient strength, and should be carried out by, or in consultation with, the Manufacturer.

The repair material (layers) should have the same composition as the original material. The damaged layer(s) should be removed until sound material layer(s) is reached. The repair material should be sewn with wire or fibre yarn and the points where the needle has penetrated should be sealed afterwards with a suitable rubber solution.

Re-using exposed material may be difficult as most materials will have undergone some ageing in service. Appendix 3 lists recommendations for safe handling of fibrous materials.

Temporary repair can also be made by wrapping the fabric expansion joint; however, this will reduce the flexibility.

5.4 TRANSPORT AND STORAGE

Fabric expansion joints are sensitive to mechanical damage and should be handled with care.

Each fabric expansion joint should be packed individually and be labelled durably. The packaging should only be removed just before installation.

5.5 DOCUMENTATION

5.5.1 Quality Control

The Manufacturer shall keep a traceable record of all quality control tests performed and shall maintain this record for a minimum period of five years from the date of manufacture.

5.5.2 Certification

The Manufacturer shall submit a certified record of inspection and testing together with a statement of compliance with the requirements. These shall also include the certificates of the steel parts, if any.

6. REFERENCES

In this DEP, reference is made to the following publications:

Note: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Index to standard drawings	DEP 00.00.06.06-Gen.

STANDARD DRAWINGS	**Drawing No.**
Flanged connection for flue duct	S 24.301
Flexible flanged connection for hot air duct	S 24.404

NOTE: The latest revisions of Standard Drawings are identified in DEP 00.00.06.06-Gen.

INTERNATIONAL STANDARDS

Steel and steel products - Inspection documents	ISO 10474

Issued by:
Central Secretariat of International
Organisation for Standarization (ISO)
1, Rue de Varembé
CH-1211 Geneva 20
Switzerland.

APPENDICES

APPENDIX 1 SPECIAL FORMS OF FABRIC EXPANSION JOINT

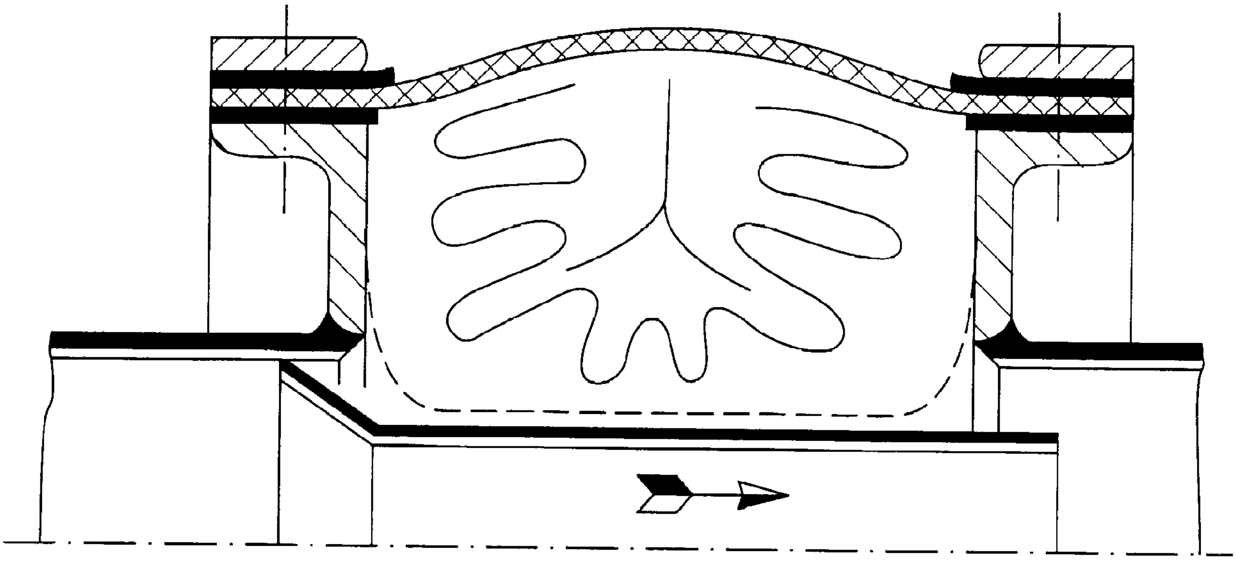

Figure 1 Pre-insulation

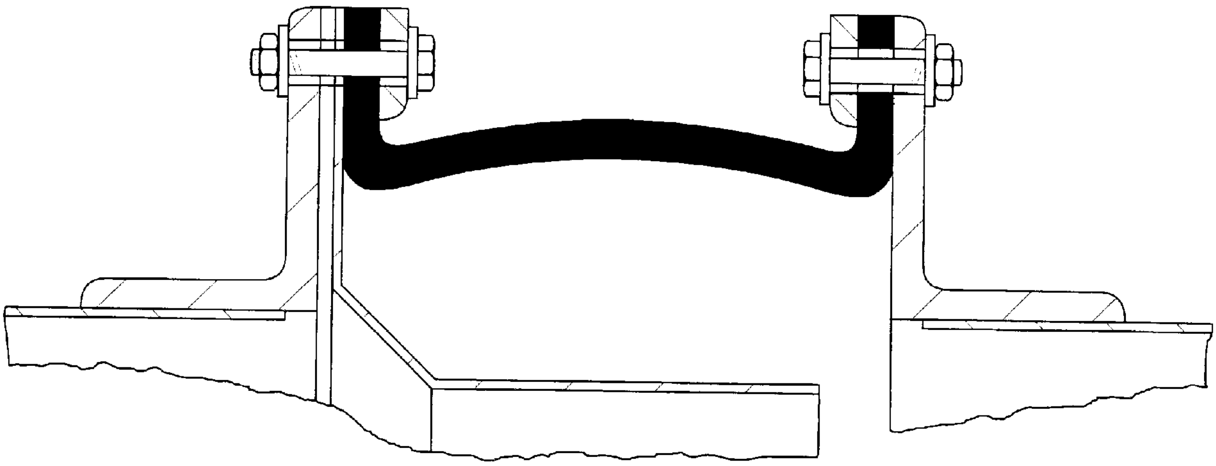

Figure 2 Internal single sleeve

* Damage of fabric expansion joint material by sharp flange edges or bolts should be prevented.

APPENDIX 1 (Cont'd) SPECIAL FORMS OF FABRIC EXPANSION JOINT

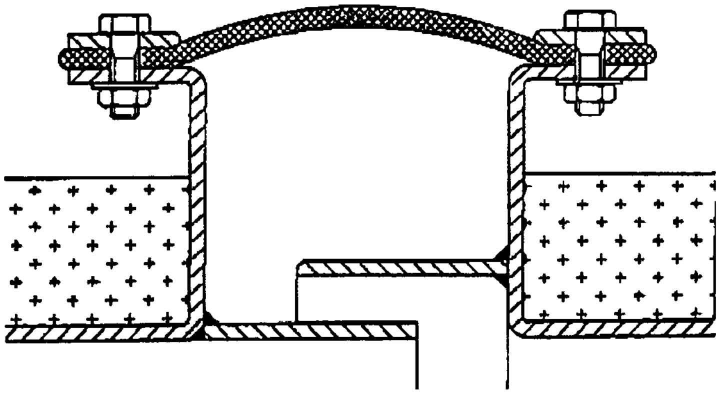

Figure 3 Internal double sleeve

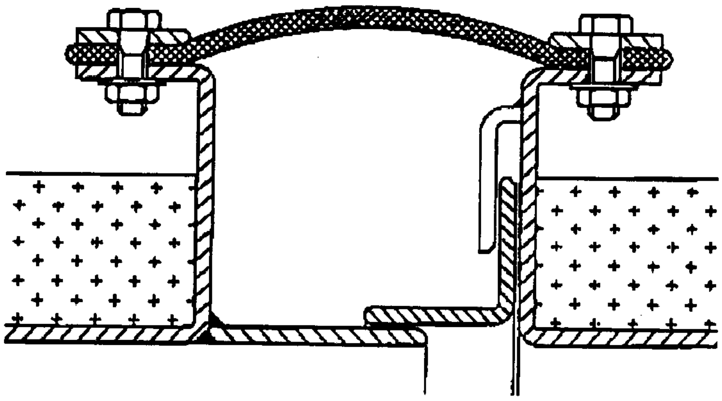

Figure 4 Internal floating sleeve

APPENDIX 2 TYPES OF END CONNECTIONS

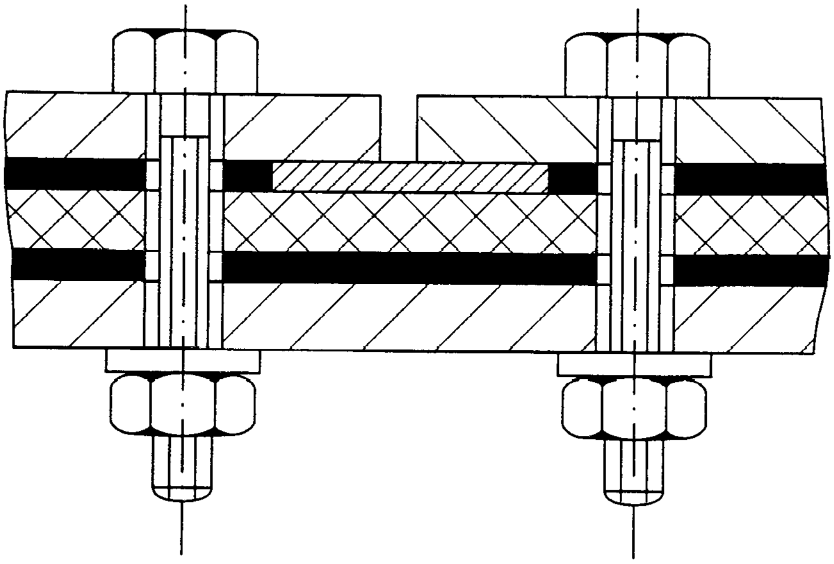

Figure A Bolted counter-flanges

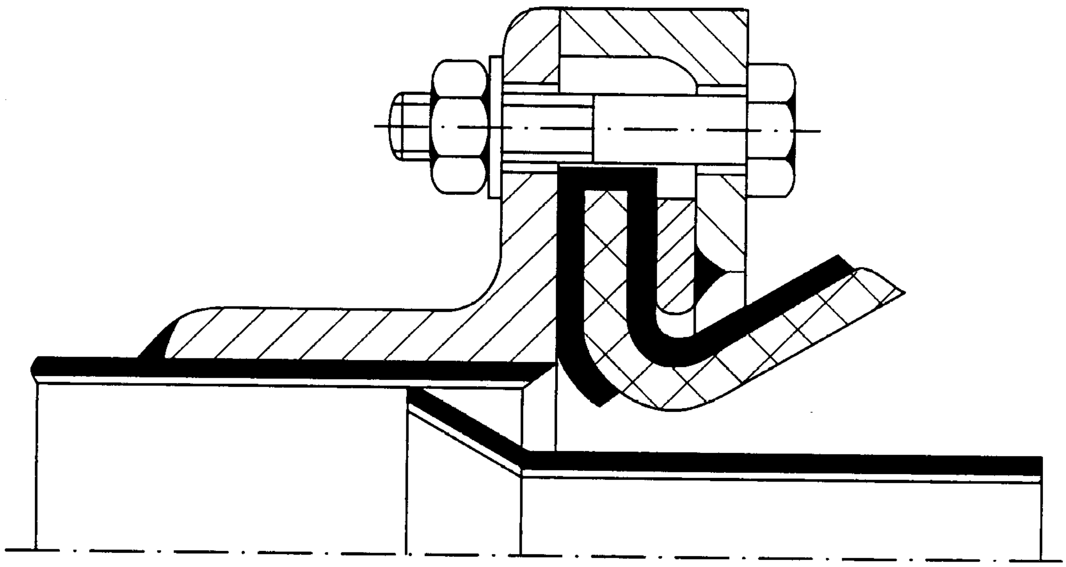

Figure B Clamping flanges

APPENDIX 3 RECOMMENDATIONS FOR HANDLING MAN-MADE MINERAL FIBRES

In handling man-made mineral fibres (MMMFs):

- A combination of engineering controls, personnel protection and good hygiene practices should be applied to ensure that exposures are maintained as low as practicable.
- After prolonged use above 870 °C, protective clothing and adequate dust extraction or high efficiency respirators should be used when removing ceramic fibres. This applies particularly to ceramic fibres with an alumina content less than 72%, which may degrade and release cristobalite with prolonged heating above 870 °C. The amount and rate of cristobalite formation depends on the temperature and time of exposure and the composition of the original fibre. Cristobalite is a form of crystalline silica which can be dangerous if inhaled, and an exposure limit of 0.05 mg/m^3 of respirable cristobalite dust should be observed.
- Waste MMMF should be handled in a controlled manner to minimize potential exposure. The material should be placed in sealed and labelled plastic bags, and be disposed of by an approved and licensed waste contractor.

There is no evidence that graphite fibres have any hazardous effect.