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FLEXIBLE JOINT

The present invention relates to a flexible joint for use in conduits and vessels through which a fluid flows. In particular, the present invention relates to a flexible joint for use under aggressive conditions, such as high temperatures and for handling of fluids of a corrosive or abrasive nature.

The need for flexible joints in conduits and vessels arises frequently in the design and construction of chemical process plants. In many circumstances, conventional vessel and pipe constructions are too rigid for the prevailing process operating conditions and operation of such a rigid construction would result in unacceptably rapid deterioration and failure of the process equipment. Accordingly, there is a need for a flexible joint which may be incorporated in the wall of a vessel or pipe, which flexible joint combines the necessary degree of flexibility with the required integrity to withstand the process operating conditions. Designs of flexible joints have been available for many years. Reference is made to Chemical Engineers' Handbook, Fifth Edition, Edited by R.H. Perry and C.H. Chilton at page 6-48 for a general discussion of flexible joints for use in piping constructions. A typical flexible joint for use in a vessel, pipe or the like comprises a first and second rigid wall portion connected by a flexible wall portion. The three wall portions define a longitudinal passage through which a process fluid can flow and are arranged along the length of the passage. The flexible wall portion is typically in the form of an undulant wall, often referred to in the art as "bellows".

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More recently, as chemical processes advance, it has been found necessary to provide flexible joints which are able to withstand ever harsher environments, such as exposure to fluids at high temperatures, corrosive fluids and abrasive fluids. One example of a particularly harsh process environment may be found in the fluid catalytic cracking of hydrocarbons, in which it is necessary to contain and transport fluids containing hydrocarbon vapours and entrained catalyst particles at high temperatures. Typical process operating temperatures are of the order of 550°C in the reaction stage and 750°C in the regeneration stage. It will be readily appreciated that such high operating temperatures and the presence of an abrasive component, such as the cracking catalyst, give rise to a very aggressive environment for the flexible portion of the flexible joint. In order to prevent premature failure of the flexible portion of the joint, it has been found necessary to construct the joint from suitable resistant materials, for example alloys of steel, and protect the flexible portion from direct exposure to the process fluid.

European patent application No. 445 352 discloses a flexible joint comprising a first rigid wall portion, a second rigid wall portion, and a flexible wall portion of which the ends are welded to the rigid wall portions, which three wall portions define a longitudinal passage through the joint, which joint further includes a sleeve member including a sleeve of which one end is secured to the first rigid wall portion and of which the other end extends into the second rigid wall portion, wherein the outer diameter of the sleeve is smaller than the inner diameter of the flexible wall portion and than the inner diameter of the second rigid wall portion.

The known flexible joint further comprises a box filled with heat-insulating material which is arranged on

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the outer surface of the sleeve and a seal arranged between the free end of the sleeve and the second rigid wall portion. In a modification, the part of the first rigid wall portion facing the passage, the inner side of the sleeve and the inner side of the second rigid wall portion are provided with a layer of erosion-resistant material.

The seal arranged between the free end of the sleeve and the second rigid wall portion serves to retain the heat-insulating material and to limit the ingress of process fluid and debris into the cavity. This design provides improved thermal insulation for the flexible portion of the joint. However, it is more complicated to construct and are more difficult to maintain. In addition, it has been found that the seal deteriorates due to corrosion, embrittlement and/or relative movement between the sleeve and the second rigid wall portion, leading to an eventual failure of the seal. Debris from the seal may then be carried by the process fluid into other parts of the plant, causing blockages and damage to plant equipment.

When the seal has deteriorated hot process fluid can enter the annular space between the sleeve member and the flexible wall portion. The process fluid will form a stagnant layer which adds to the heat insulation. However, at the entrance of the annular zone the fluid flow will be turbulent and thus high-temperature process fluid is in direct contact with the second rigid wall portion. This contact will increase the temperature of the second wall portion. Although this will not affect the second wall portion itself, it does affect the weld between the flexible wall portion and the second rigid wall portion.

Accordingly, there is a need for a flexible joint which combines both simplicity of construction and ease of maintenance, whilst at the same time providing the

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necessary protection for the flexible portion of the joint against the high process fluid temperature being handled. In particular, there is a need for a flexible joint which allows the precise degree of heatinsulation of the flexible wall portion to be controlled. This is important in such applications as the fluid catalytic cracking process mentioned above, where the flexible wall portion must be maintained at a temperature significantly below the temperature of the process fluid, whilst being at a temperature above the dew point of the hydrocarbon vapours being handled. Too high a level of insulation will result in the temperature of the flexible wall portion falling below the dew point of the process fluid, causing condensation to occur on the inside of the flexible joint. This may in turn lead to corrosion and premature failure of the flexible wall portion.

Moreover failure of the weld between the flexible wall portion and the second end portion should be avoided.

To this end the flexible joint according to the present invention comprises a first rigid wall portion, a second rigid wall portion, and a flexible wall portion of which the ends are welded to the rigid wall portions, which three wall portions define a longitudinal passage through the joint and are arranged along the length of the passage, which flexible joint further includes a sleeve member including a sleeve of which one end is secured to the first rigid wall portion and of which the other end extends into the second rigid wall portion, wherein the part of the first rigid wall portion facing the passage, the inner side of the sleeve and the inner side of the second rigid wall portion are provided with a layer of erosion-resistant material, wherein the outer diameter of the sleeve member is smaller than the inner diameter of the flexible wall portion and than the inner

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diameter of the layer of erosion-resistant material on the second wall portion, and wherein the second rigid wall portion is further provided with a layer of heat-insulating material disposed between the second wall portion and the layer of erosion-resistant material.

Applicant had found that the presence of the heat-insulating material reduces during normal operation the temperature of the second rigid wall portion such that damage to the weld is prevented so that the service life of the flexible joint is increased.

The flexible joint may be incorporated in the wall of a vessel or, more typically, in a conduit or pipeline. In cross-section, the wall portions of the flexible joint may have any suitable shape, adapted to match the cross-section of the vessel or conduit into which the joint is to be installed. Most typically, the rigid wall portions will be cylindrical in cross-section. The rigid wall portions are typically constructed from the same material as the adjacent apparatus. Typical materials include mild steel, stainless steel and other steel alloys, with the selection depending upon the prevailing process conditions and the fluid being handled.

The flexible wall portion is disposed between the first and second rigid wall portions and is intended to absorb relative movement between the two rigid wall portions. Such movement typically arises, for example, due to vibration and pressure and temperature differentials which occur in the process equipment. The flexible wall portion may be of any suitable form. Most typically, the flexible wall portion is in the form of an undulant in longitudinal section, more commonly referred to as a "concertina" or "bellows". The size and form of the undulations are selected according to the degree of flexibility and displacement required. Techniques for the selection and design of the flexible wall portions

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are well known in the art. The flexible wall portion may be constructed from any suitable material, including those mentioned hereinbefore in connection with the construction of the rigid wall portions. The flexible wall portion, being generally thin, may be susceptible to higher levels of stress corrosion and embrittlement cracking than the rigid wall portions. Accordingly, more resistant, and hence expensive, materials may need to be selected for the flexible wall portion. It is, however, an advantage of the present invention that more commonly available materials can be employed, for example Inconel and Incoloy alloys.

The sleeve extends along the passage within the flexible joint. At one end, the sleeve is secured to the first rigid wall portion. Any suitable securing means may be employed. Welding is a most suitable means for securing the sleeve to the first rigid wall portion. The sleeve extends within the passage so as to overlap the second rigid wall portion. The sleeve is spaced from the flexible wall portion. The remaining end of the sleeve is not secured, thereby allowing the sleeve to move relative to the second rigid wall portion. Typically, the end portion of the sleeve overlapping the second rigid wall portion will be spaced from the second rigid wall portion.

In a preferred arrangement, the sleeve member extends from the first rigid wall portion in a manner providing a continuous wall surface, thereby presenting little or no obstacle to the flow of fluid through the flexible joint, that is, the sleeve and a portion of each of the first and second rigid wall portions combine to form a substantially smooth sided passage for the flow of fluid through the joint. The required spacing of the sleeve member from the flexible wall portion is accommodated by having the width of the passage defined by the flexible

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wall portion greater than that of the nominal width of the flexible joint, that is the width of the smooth sided passage formed by the sleeve member and a portion of each of the first and second rigid wall portions. An
5 alternative, less preferred arrangement comprises a sleeve member which extends into the passage, thereby creating a constriction in the fluid flowpath along the joint.

10 The sleeve may be formed from any suitable material which offers the required resistance to the process operating conditions. Typically, the sleeve will be of the same material as the first and second rigid wall portions.

15 It is the intention that, in operation, process fluid is allowed to occupy the annular space between the sleeve member and the flexible wall portion. Process fluid may enter this space between the free end of the sleeve member and the second rigid wall portion. The process fluid in the annular space is relatively still and acts
20 as an insulating medium for the flexible wall portion. In order to allow the process fluid in the annular space to remain still, it is preferred that the first rigid wall portion is at the upstream end of the flexible joint, when installed and in use.

25 Heat-insulating material is provided on a surface of the sleeve. The material may be attached to the surface of the sleeve in direct contact with the process fluid to be handled. Preferably, the insulating material is attached to the surface of the sleeve facing the flexible
30 wall portion. Insulating material may be applied to both surfaces, if desired. The heat-insulating material may consist of one layer of material or may comprise a plurality of layers. If a plurality of layers are employed, the layers may be of the same or different
35 material. The selection of the number and position of

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the layers and the type of heat-insulating material will depend upon the process operating conditions to be experienced by the flexible joint, the material from which the flexible wall portion is constructed and the nature of the process fluid being handled. The heat-insulating material should have a low thermal conductivity at high operating temperatures, thereby allowing a relatively thin layer of the material to provide the required level of insulation. The material should preferably have as low an ash, sulphur and chloride content as possible. The material should be suitable for use under the prevailing process conditions, for example conditions of high temperature. The insulating material is preferably a fibrous ceramic material. Suitable ceramic materials are fibres of silica, alumina, zirconia, magnesia, calcia and mixtures thereof. Suitable materials are available commercially, for example under the trade names "Saffil" and "Zircar". Alternative, less preferred materials for use as the insulating material include graphite and ash paper. Again, such materials are available commercially.

In a preferred embodiment of the present invention, the layer of heat-insulating material on the sleeve is covered by a protective sleeve. The protective sleeve preferably covers substantially all of the insulating material, such that a sandwich of sleeves and insulating material is formed. In a further embodiment, the protective sleeve is not secured to the layer of insulating material, thereby allowing the protective sleeve to move relative to the insulating material. This allows for relative movement between the components arising, for example, from the effects of differential thermal expansion.

The flexible joint is provided with a layer of erosion-resistant material in the form of a refractory

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oxide covering the surface of the sleeve adjacent the process fluid when the joint is in use. Suitable refractory materials are available commercially and well known in the art. Suitable materials include silica, alumina, titania, zirconia, calcia, magnesia and mixtures thereof. One suitable material comprises a mixture of alumina and silica and is available under the trade name "CURAS 90 PF". The refractory oxide is typically applied in the form of a cement or in tiles or blocks. The layer of refractory oxide is relatively thick, compared with that of the layer of insulation material. The refractory oxide is porous, allowing some access of the process fluid to the underlying surface. A primary purpose of the refractory oxide is to provide protection against the abrasion and erosion of the underlying surface. If desired, the layer of refractory oxide may be applied over a layer of insulating material covering the surface of the sleeve.

The layer of heat-insulating material provided on the surface of the second rigid wall portion should cover at least that portion of the surface of the second rigid wall portion overlapped by the sleeve. More preferably, the layer of heat-insulating material extends over substantially more of the surface of the second rigid wall portion. Any of the materials discussed above for use as the layer of heat-insulating material on the sleeve may employed. Again, one or more layers may be used, the layers being comprised of the same or different material. The layer of heat-insulating material is covered with a layer of refractory oxide, as discussed hereinbefore with respect to the refractory oxide applied to the surface of the sleeve.

As mentioned hereinbefore, the sleeve member is spaced apart from the flexible wall portion, forming an annular space into which process fluid is allowed to flow

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during operation. The process fluid in the annular space forms a reservoir of relatively still fluid which acts to further insulate the flexible wall portion. For the proper operation of this reservoir of fluid as an insulator, it is important that it remains relatively still. It has now been found that the design of the free end portion of the sleeve member and its relationship with the second rigid wall portion plays an important role in the insulating properties of the process fluid in the annular space, in particular the extent by which the sleeve member overlaps the second rigid wall portion.

The length of the portion of the sleeve member overlapping the second rigid wall portion is at least five times the distance of the sleeve member from the second rigid wall portion, as measured perpendicular to the sleeve member.

Preferably, the length of the portion of the sleeve member overlapping the second rigid wall portion is at least 100 mm, more preferably at least 200 mm, under any condition.

It will be readily understood that the clearance between the free end of the sleeve member and the second rigid wall portion must be sufficient to accommodate any relative movement between the two components when the joint is in use. In a preferred embodiment, the sleeve member and a portion of both the first and second rigid wall portions combine to form a substantially smooth sided passage for the flow of fluid through the joint. In such cases, it is preferred that the distance of the free end of the sleeve from the second rigid wall portion, as measured along a line parallel to the longitudinal axis of the sleeve, is at least 10 mm, more preferably 25 mm under any condition.

The flexible joint of the present invention may be applied in any application requiring a flexible joint.

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As mentioned hereinbefore, the joint is particularly suited to use in the handling of fluids under aggressive conditions, that is in handling fluids of a corrosive nature and/or fluids under conditions of high
5 temperature. The use of refractory oxide materials also provides the joint with a high level of resistance to abrasive and erosive fluids. The joint may be applied in all manner of chemical and refining plants. As mentioned
10 hereabove, the joint is of particular use in processes employing fluidised solid media, such as the fluid catalytic cracking of hydrocarbons and the like. Other specific applications include the handling of gases at very high temperatures, for example the handling of hot
15 flue gases.

The present invention will be further described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of a section through one half of a flexible joint according to a first embodiment of the first aspect of the present
20 invention;

Figure 2 is a diagrammatic representation of a portion of the sleeve of a flexible joint according to a second embodiment of the first aspect of the present
25 invention;

Figure 3 is a diagrammatic representation of a portion of the sleeve of a flexible joint according to a third embodiment of the first aspect of the present invention; and

30 Figure 4 is a diagrammatic of a portion of a flexible joint according to the second aspect of the present invention.

Referring to Figure 1, a generally cylindrical flexible joint for use in a process pipeline, generally
35 identified as 2, comprises a first rigid wall portion 4

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having a narrow cylindrical outer end portion 6 and a wide cylindrical inner end portion 10 connected by a central frustoconical wall portion 8.

5 A generally cylindrical flexible wall portion 12 extends from the inner end of the first rigid wall portion 4 to a second rigid wall portion 14, having similar inner end, central and outer end wall portions (16, 18, 20 respectively) to the first rigid wall
10 portion 4, but in the opposite orientation. The ends of the flexible wall portion are welded to the rigid wall portions. The first, flexible and second wall portions 4, 12, 14 are symmetrically arranged about a single central longitudinal axis and they define a passage P.

15 The flexible wall portion 12 has a undulant form in cross-section commonly applied in the art and often referred to as "bellows".

A cylindrical sleeve member 21 comprising a sleeve 22 is disposed co-axially within the wall portions 4, 12, 14 and is secured at one end to the first rigid wall portion
20 4 in the region of the junction of the outer end portion 6 and the central portion 8 by welds (not shown). The sleeve 22 extends past the flexible wall portion 12 and overlaps the inner end portion of the second rigid wall portion.

25 A layer 26 of erosion-resistant material is disposed on the inner surface of the sleeve 22 and of part of the first rigid wall portion facing the passage P. Moreover a layer 28 of erosion-resistant material is disposed at the inner side of the second rigid wall portion 20.

30 The outer diameter of the sleeve member is smaller than the smallest inner diameter of the flexible wall portion 12 and smaller than the inner diameter of the layer of erosion-resistant material 30 on the second rigid wall portion 20.

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Moreover a layer 30 of heat-insulating material is disposed between the inner surface of the second wall portion 20 and the layer 28 of erosion-resistant material.

5 It is to be understood that conventional fittings to flexible joints, such as the expansion limiting rods, leak detection system, weather shrouding and the gas purge connection have been omitted for the sake of clarity.

10 In use, the flexible joint 2 of Figure 1 is arranged so that process fluid flows in a direction from the first rigid wall portion 4 to the second rigid wall portion 14, as indicated by the arrow A. Process fluid enters the space remaining between the sleeve 22 and the flexible
15 wall portion 12 through the annulus between the sleeve 12 and the inner end portion 16 of the second rigid wall portion 14, to form a heat-insulating layer.

The heat insulation is provided by a stagnant layer of process fluid in the annular between the sleeve
20 member 21 and the flexible wall member 12. The fluid in the annulus between the sleeve member 21 and the inner end wall portion 16 of the second rigid wall portion 14 is constantly mixed with process fluid in the passage P. Consequently, in the absence of the layer 30 of heat
25 insulating material, the temperature of the inner end wall portion 16 would rise to such a level that the weld with which the flexible wall member 12 is joined to the second rigid wall portion 14 is affected.

Referring to Figure 2, there is shown an enlarged
30 view of the sleeve member 21 and the insulating material disposed thereon in the region adjacent the first rigid wall portion 4. In the embodiment of Figure 2, the sleeve member 2 includes a layer of heat-insulating material 32 disposed on the inner surface the sleeve 22.

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The layer of refractory oxide 26 extends over the layer of insulating material 32.

Referring to Figure 3, showing a similar view to Figure 2 of an alternative, particularly preferred embodiment, the sleeve member 21 comprises a layer of heat-insulating material 36 disposed on the outer surface of the sleeve 22. A cylindrical protective sleeve 38 extends over the layer of heat-insulating material 36. The layer of refractory oxide 26 is disposed on the inner surface of the sleeve 22. The layer of heat-insulating material 36 and the protective sleeve 38 should preferably extend as close as possible to the first rigid wall portion 4, whilst still allowing sufficient space to accommodate any relative movement between the various components. Space will be required, for example, in the case in which the protective sleeve 38 is not rigidly secured to the layer of heat-insulating material 36.

Typically, for the embodiments shown in Figures 1 to 3 adapted for application in a pipeline in the fluid catalytic cracking process referred to above, the sleeve has a thickness of the order of 10 mm. The layer of insulating material or multiple layers thereof, if employed, has a total thickness of the order of 3 to 10 mm. The layer of refractory oxide has a thickness of the order of 25 mm. The protective cover, if present, has a thickness of the order of 3 to 6 mm. It will be readily understood that the thickness of the various components will be determined by the application in question.

Figure 4 shows a detail (not to scale) of a flexible joint according to the present invention. Identical components to those described above with reference to Figure 1 have the same reference numeral in Figure 4, and for the sake of clarity the heat-insulating material of the second rigid wall portion 14 is not shown. Thus, in

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Figure 4, the sleeve member 21 extends so as to overlap the inner end portion 16 of the second rigid wall portion 14. The distance d in Figure 4 is the distance between the outer surface of the sleeve member 21 and the inner surface of the inner end portion 16 provided with the layer of erosion-resistant material 28, measured perpendicular to the longitudinal axis of the sleeve 22. The overlap of the sleeve member 21 within the second rigid wall portion 14, represented by the distance l in Figure 4, is at least 5 times the distance d . Preferably, l is at least 200 mm. The distance a measured from the end of the sleeve member 21 to the second rigid wall portion 14 along a line parallel to the longitudinal axis of the sleeve 22 is at least 25 mm.

The present invention will be further described by way of the following illustrative example.

EXAMPLE

The operating temperature of the flexible wall portion of a flexible joint according to the present invention can be calculated. A flexible joint was considered having the general structure shown in Figure 1, but employing the arrangement of layers of insulating material, protective sleeve and layer of refractory oxide shown in Figure 3. The joint was considered as being installed in the catalyst stand-pipe of the regenerator of a conventional fluid catalytic cracking plant. The process fluid being handled was assumed to comprise hydrocarbon gases and entrained catalyst. As a worst case scenario, the space between the sleeve and the flexible wall portion was assumed to be filled with gas, with no catalyst being present. The flexible joint was assumed to have a geometry at the free end of the sleeve in accordance with the requirements of the second aspect of the present invention, as shown in Figure 4. Details of the construction of the joint, the

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operating temperature and the resulting temperature of the flexible wall portion of the joint are shown in the Table below.

5 For comparison purposes, a similar calculation was conducted for a flexible joint of identical structure, but with the omission of the insulating materials. The details and results of this experiment are also set out in the Table.

TABLE

	Example	Comparative Example
Sleeve Thickness (mm)	3	10
Ceramic Fibre Insulating Layer 36 Thickness (mm)	3	None
Protective Sleeve Thickness (mm)	3	None
Weather Enclosure	Yes	Yes
Maximum Process Temperature (°C)	750	750
Maximum Temperature of Flexible Wall Portion (°C)	324	497

10 From the data in the Table, it can clearly be seen that the flexible joint constructed according to the present invention would result in a significantly lower temperature being experienced by the flexible wall portion of the joint. This in turn would lead to prolonged life of the joint and the opportunity to employ
15 more commonly available, and hence more economical, materials of construction.

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C L A I M S

1. A flexible joint comprising a first rigid wall portion, a second rigid wall portion, and a flexible wall portion of which the ends are welded to the rigid wall portions, which three wall portions define a longitudinal passage through the joint and are arranged along the length of the passage, which flexible joint further includes a sleeve member including a sleeve of which one end is secured to the first rigid wall portion and of which the other end extends into the second rigid wall portion, wherein the part of the first rigid wall portion facing the passage, the inner side of the sleeve and the inner side of the second rigid wall portion are provided with a layer of erosion-resistant material, wherein the outer diameter of the sleeve member is smaller than the inner diameter of the flexible wall portion and than the inner diameter of the layer of erosion-resistant material on the second wall portion, and wherein the second rigid wall portion is further provided with a layer of heat-insulating material disposed between the second wall portion and the layer of erosion-resistant material.
2. A flexible joint according to claim 1, wherein the sleeve member and a portion of both the first and second rigid wall portions combine to form a substantially smooth sided passage for the flow of fluid through the joint.
3. A flexible joint according to claim 1 or 2, wherein the sleeve member, includes a layer of heat-insulating material disposed between the sleeve and the layer of erosion-resistant material.
4. A flexible joint according to any one of the claims 1-3, wherein a layer of heat-insulating material



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is disposed on the surface of the sleeve facing the flexible wall portion.

5. A flexible joint according to claim 4, wherein the layer of heat-insulating material of the sleeve member is covered by a protective sleeve.

6. A flexible joint according to claim 5, wherein the protective sleeve is not secured to the layer of heat-insulating material, thereby allowing the protective sleeve to move relative to the heat-insulating material.

7. A flexible joint according to any one of the claims 1-6, wherein the heat-insulating material comprises a fibrous ceramic material, preferably a material comprising fibres of silica, alumina, zirconia, magnesia, calcia and mixtures thereof.

8. A flexible joint according to any one of the claims 1-7, wherein the erosion-resistant material is refractory oxide, suitably selected from silica, alumina, titania, zirconia, calcia, magnesia and mixtures thereof.

9. A flexible joint according to any one of the claims 1-8, wherein the length of the portion of the sleeve member overlapping the second rigid wall portion is at least five times the distance of the sleeve member from the second rigid wall portion provided with the layer of erosion-resistant material, as measured perpendicular to the sleeve.

10. A flexible joint according to claim 3, wherein the length of the portion of the sleeve member overlapping the second rigid wall portion is at least 100 mm, more preferably at least 200 mm.

11. The use of a flexible joint according to any preceding claim in the fluid catalytic cracking of hydrocarbons and the like or the handling of hot flue gases.