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## Fabric compensators

### 1.0 General Information

Several decades ago, when Kempchen first began producing soft-material compensators, metal compensators were still predominantly being used in the field of power plants and chemicals.

Today, Kempchen soft-material compensators have found a solid range of applications. Without these versatile assembly parts, modern industrial plants would not be possible. Without the use of soft-material compensators, the costs of such plants would be considerably greater.

The main advantage of soft-material compensators is their multidimensional absorption of movement despite having very low reaction force. Their superior movement absorption allows for cost-effective piping, while their low reaction force permits cost-effective fix point construction.

Kempchen has developed a patented method for sintering PTFE sheets onto all types of fabrics. This has brought significant improvements to the properties of soft-material compensators.



Kempchen compensators in flue gas distributing main

#### 1.1 Range of application

Soft-material compensators have been proven to withstand:

- in pipes and ducts for gaseous media such as air, flue gas, exhaust gas
- temperatures of up to 700 °C and higher
- pressures of up to 500 mbar

- major axial movement and – often concurrently – lateral or angular loads
- all industry sectors such as thermal power plants, gas turbine plants, the chemicals industry, flue gas desulphurisation plants, chimney and flue construction, ship construction, stationary diesel generator sets, waste incineration plants, flue gas treatment plants, dedusting plants, metallurgical industry.

Only materials that pass our quality inspection are used for the production of soft-material compensators and other assembly parts. The requirements profiles for our material properties are based on decades of experience, and serve as the criteria for purchase and incoming goods inspection.



Kempchen makes the distinction between the groups of components used in the assembly of soft-material compensators and/or the necessary steel constructions:

Soft-materials compensators:

Quality brand for  
fabric compensators

Insulation layers, insulation packs,  
sealing foils, sealing layers  
supporting layers,  
protective layers, reinforced edges

Compensator protection components:

Internal pass tube,  
pre-insulation,  
external protective grating or equiv.  
outlet nozzle,  
sash frame

Compensator connection: Bolted

counterflanges, clamping  
flanges, band clamps

## Fabric compensators

### 2.0 Materials

#### 2.1 Kempchen soft-material compensators and their construction

Soft-material compensators are generally made up of several layers. In most cases, these layers are not glued or sewn together. In the clamping area, however, the individual layers of the soft-material compensator are always connected for transport reasons.

As is explained in greater detail in Section 6.0 "The sealing of soft-material compensators and impermeability testing", superstructures with multiple layers, such as those necessary for controlling high temperatures, are more difficult to assess with respect to impermeability than are soft-material compensators consisting of just one or two layers.

If impermeability is a particularly important concern, it can be achieved by using special heat-dispelling constructions of one- or two-layer Kempchen soft-material compensators.

##### 2.1.1 Insulation layers, insulation packs

Insulation layers are necessary if the temperature of the media is higher than the maximum allowable sustained temperature of the sealing layers. The different types of insulation layers vary widely in their mechanical stability and their resistance to temperature and chemicals. They are therefore selected based on conditions in which they will be used.

Insulating felts are used as insulation packs. Due to their low resistance, these are wrapped in stabler, more heat-resistant fabrics or bound in high-grade steel wire mesh. In the case of larger movements, at least two such insulation packs are located so as to be moveable in front of the sealing layer.

##### 2.1.1.1 Temperature and media resistance

Conditions for use	Sustained temperature resistance		Short-term peak temperature		Acid-proof	Base-proof	Solvent-proof
	°C	°F	°C	°F			
Fabric and mats							
Aramid	180	356	250	482	0	0	+
Glass fibre weave	400	752	450	842	+	0	+
Glas felt mats	500	932	650	1202	+	0	+
Rock wool mats	700	1292	750	1382	0	0	+
Silicate felt mats	1200	2192	1350	2462	+	0	+
Silicate fibre weave	1200	2192	1350	2462	+	0	+

(+) = yes (o) = conditional (-) = no

#### 2.1.2. Sealing foils, sealing layers

Depending on the temperature range, various types of synthetic rubber, metal foils, and plastics are used either on their own or as a fabric coating

The sealing layer is of major importance, as soft-material compensators are always part of leak-proof piping or duct systems. Three aspects are of particular significance:

##### 2.1.2.1

The pressure differential acting at the sealing layers, causing strain. For this reason, supporting layers are placed in the direction of the decrease in pressure behind the sealing layers for support: they are located outside for internal pressure and inside in front of the sealing layers for low pressure.

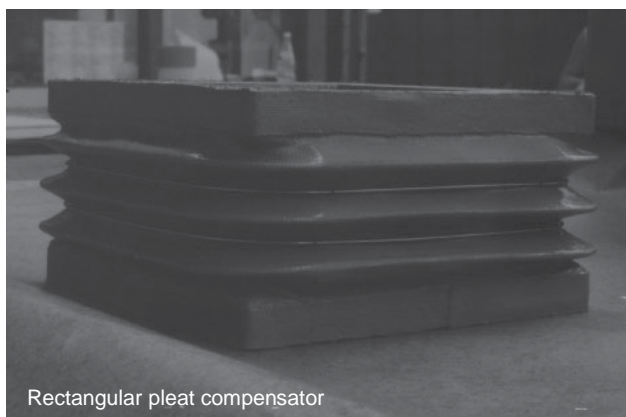
##### 2.1.2.2

Since condensation may collect in front of the sealing layers, the resistance of the insulation and any insulating fabric layers must be taken into consideration.

## Fabric compensators

### 2.1.2.3

It is important to note that rubber and plastic foils and laminated fabrics are not entirely gas-tight. Only metal foils may be used as a gas barrier. One disadvantage of metal foils is their relatively high sensitivity, e.g. to flue gas condensation; another is their low expandability.



### 2.1.2.4 Temperature and media resistance

The table shows the resistance to sustained and temporary temperatures of various foils and coated fabrics used in soft-material compensators. Resistance to acids, bases and solvents can only be given in this catalogue in terms of tendencies.

In the event of a thermal load greater than the sustained temperature resistance indicated in Table 2.1.2.4., both constructive and insulation-related measures must be taken (see 2.2.).

### 2.1.2.5

The sealing layers in the compensator's clamping area must be tightly screwed to the clamping flanges. To achieve this, we recommend that a surface pressure of 5 N/mm<sup>2</sup> always be present between the fabric and steel flange.

This can be easily attained at temperatures up to and including the sustained temperature resistance of the sealing layers.

However, if the flange temperature is higher than the sustained temperature resistance in the sealing layer area, the porosity of the insulation layers will make sealed closure more difficult.

There are three ways to solve this problem:

- Impregnate the insulation layers in the flange area with the appropriate impregnation agents to create internal impermeability. The resulting slight reduction in the insulation effect is compensated by the corresponding thickness. At higher temperatures, a certain acceptable amount of permeability is inevitable both after assembly and after a long period of operation.

			sustained temperature resistance		temporary peak temperature		acid-proof	base-proof	Solvent-proof
			°C	°F	°C	°F			
Foils									
PTFE			260	500	280	536	+	+	+
Aluminum			500	932	550	1022	-	-	+
High-grade steel			600	1112	850	1562	+	+	+
Coating Fabric									
PVC	Polyester		60	140	65	149	+	+	-
EPDM	Fibre glass	*	100	212	120	248	+	+	0
Silicon	Fibre glass		220	428	230	446	-	-	0
FKM	Fibre glass	*	205	401	250	482	+	+	0
PTFE <sup>1)</sup>	Fibre glass	*	260	500	290	554	+	+	+
Single-layer composite material									
EPDM with	1.4539 <sup>3)</sup>	*	100	212	130	266	+	+	-
FKM with	1.4539 <sup>3)</sup>	*	180	401	>250 <sup>2)</sup>	>572 <sup>2)</sup>	+	+	0

<sup>1)</sup> sintered

<sup>2)</sup> temporary peak temperature; please contact Kempchen concerning insulation

<sup>3)</sup> also available with fibre glass

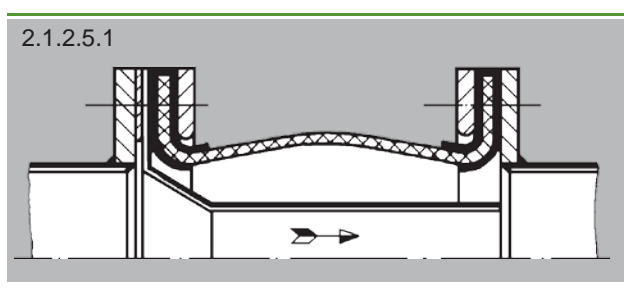
(+) = yes, (o) = conditional (-) = no

\* flue gas desulphurisation plants, flue gas cleaning plants, waste incineration plants

## Fabric compensators

b) Another option is to fold in the outer protective layer and seal it at the flange; or wrap an additional fabric casing, for instance one which is coated with silicon rubber, all the way around the compensator flange as shown in Figure 2.1.2.5.1. This measure yields a suitably air-tight construction. After a long period of operation, however, greater permeability results with this measure than with solution a) above.

c) Another solution is construction according to 3.4.6.



### 2.1.2.6 Pulsation

High-frequency pulsating pressures such as exist in exhaust systems must be viewed extremely critically. Gaps in the compensator area must be kept as small as possible, and there

Vibrations are harmful to glass weave and quartz fabric (and to all other fabric as well). For this reason, compensators for shaking trough, for instance, should use sealing layers made of rubber foils or plastic foils, preferably without fabric if possible, or with polyester, nomex or Kevlar fabrics, which are more resilient.

### 2.1.3 Supporting layers

Characteristic properties of supporting layers are their lesser expandability and greater stability in comparison to the sealing layers. The following reductions can be made if several supporting layers of equal expandability are arranged consecutively:

2 layers at  $k = 0.8$

3 layers at  $k = 0.7$

4 layers at  $k = 0.6$

As a rule, the operating temperature must be below the sustained temperature resistance. If temporary peaks in temperature may be anticipated, please confer with our engineering consultants about the duration of these peaks and their potential reduction of stability and temperature resistance.

The supporting layers are always arranged behind the sealing layers in the direction of the decreasing pressure. The choice of the appropriate supporting layer in terms of temperature resistance and stability greatly depends on the proper pre-insulation, the reduction in pressure and the allowable sustained temperature resistance of the sealing foils.

Variations in expandability of the supporting layers are to be avoided, as the expandability of the least expandable layer will count.

Kempchen uses the following supporting layers for the various temperature and operating conditions:

Supporting layer, e.g.	Sustained temperature resistance		Temporary peak temperature	
	°C	°F	°C	°F
Polyester fabric	150	302	160	320
Aramid fabric	180	356	250	482
Fibre glass	400	752	450	842
High-grade steel wire mesh	600	1112	850	1562
Silicate fabric	1200	2192	1350	2462

### 2.1.4 Protective layers, reinforced edge

#### 2.1.4.1 Protective layers

The outer layer of the soft-material compensator serves to protect against environmental impact factors such as sun, rain, dust, industrial climate, sandstorms, etc. In order to provide adequate protection, the outer layer must also be mechanically resistant.

Protective layers made of fabrics laminated with materials such as neoprene/hypalon, viton, silicon, and PTFE have proven to be satisfactory in this regard.

It is important that heat-resistant protective layers made from glass weave sintered with PTFE foil allow surface temperatures up to 260 °C. The sealing layer, which might for instance also be made of PTFE, can then reach temperatures greater than the dewpoint and the formation of condensation can be reduced or prevented.

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### 2.1.4.2 Internal flange sealing

Proper training in flange sealing is of major significance for the total concept of soft-material compensators.

Flange sealing on the heated inner surface serves the following purposes:

- a) secures the insulation required of the other layers, particularly the sealing layer, and
- b) ensures the functioning of the sealing in the flange area

This gives rise to somewhat of a conflict of interests; on the one hand, the flange sealing should be porous in order to retain heat in the flange; on the other hand, however, the sealing should be impermeable. Kempchen uses the following materials for flange sealing depending on the temperature range and permeability requirement:

	approx. °C	approx. °F
Fabric strips from Aramid thread	180	350
Fluorelastomer	200	400
PTFE strips	260	500
Fibre glass strips, non-impregnated	450	850
Fibre glass strips, impregnated	450	850
Quarz fabric strips, non-impregnated	1000	1800
Quarz fabric strips, impregnated	1000	1800

As an additional means of sealing the flange area, Kempchen has developed a sintered PTFE flange barrier (DBP).

### 2.1.4.3 Reinforced outer edge

The same materials are used here as described above. It is important that the outer edge reinforcement of bellied form compensators be wide enough to prevent contact between outer protective layer and the counterflange, which is often at a high temperature, and the screw.

### 2.1.5 Materials for FGD\* plants

Depending on the intended use, we recommend our ReaFlex and ReaTex compensators for FGD plants, see page 213.

\* flue gas desulphurisation (German: REA)



## Fabric compensators

### 2. 2 Compensator protection components

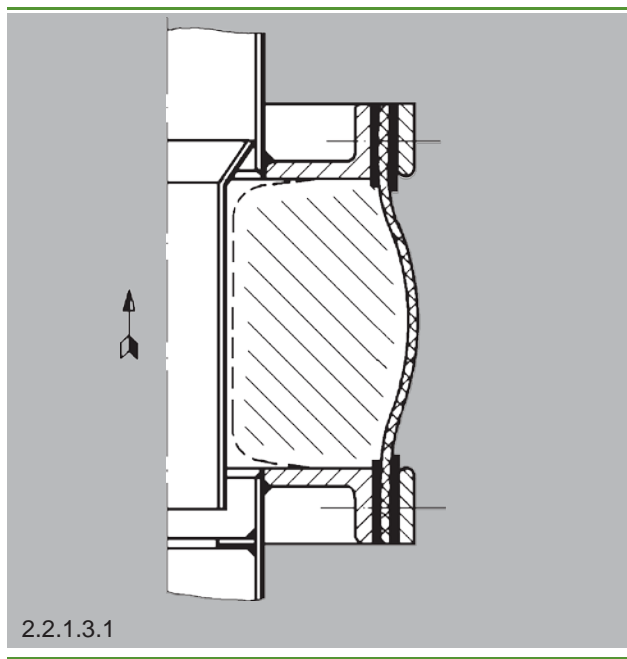
#### 2.2.1 Internal pass tube

Pass tubes should always be used to protect fabric compensators.

Pass tubes prevent abrasion in dust-laden gas flows, protecting the fabric compensator from becoming damaged.

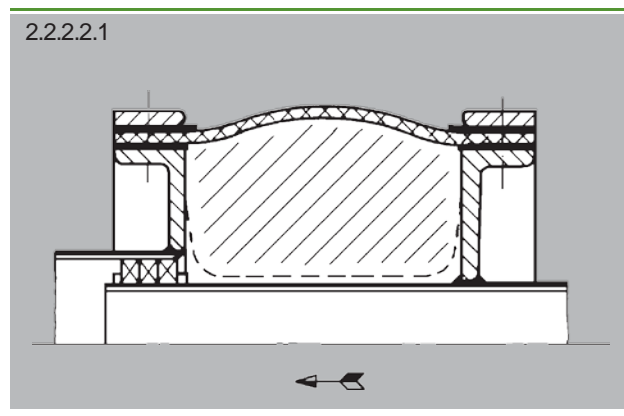
In clean gas flows, the use of a pass tube reduces the loss of pressure by allowing for more favourable operation in terms of flow technology. The temperature at the compensator is also reduced by using a pass tube. The space between the pass tube and the compensator can be used for insulation when filled with a heat-absorbing material, see 2.2.3.

In horizontal ducts, the pass tube should always be placed in the direction of the flow. In vertical or inclined ducts, it may be beneficial to arrange the pass tube against the direction of the flow in order to prevent the area between the compensator and the pass tube from filling with dust or condensation, etc. When the pass tube is placed against the direction for the flow, a pass tube plate should be placed at a short distance from the open end of the pass tube, see below. 2.2.1.3.1.

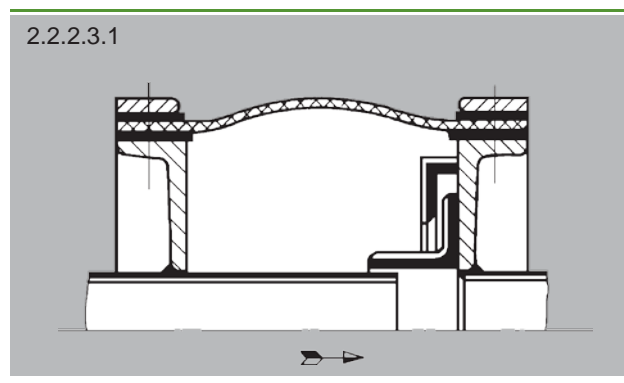


#### 2.2.2 Protective devices and constructive measures for high dust incidence

Kempchen recommends the use of pass tubes as a general rule. However, in some cases it may be advantageous to refrain from using a pass tube. One such situation is a high incidence of dust that may accumulate as a result of humidity and/or temperature. Given the movement to be executed by the compensator in an axial or lateral direction, the compensator would be destroyed by the presence of a pass tube and the accumulation of dust. It is better to omit the inclusion of a pass tube so that the accumulated dust or mud formed can be released by the movement of the compensator unit itself. For dry dust, for instance that which can be found in cement factories, metallurgical plants or lime industry, a packing box with coarse packing cord is used for predominantly axial movement, as in Figure 2.2.2.2.1.



A design with a sash frame as shown in Fig. 2.2.2.3.1 has proven suitable for the absorption of both axial and lateral movements. The sash frame should sit with as little slackness as possible between the ducting flange and the pass tube so that it can be moved both in the axial and lateral movement direction.



## Fabric compensators

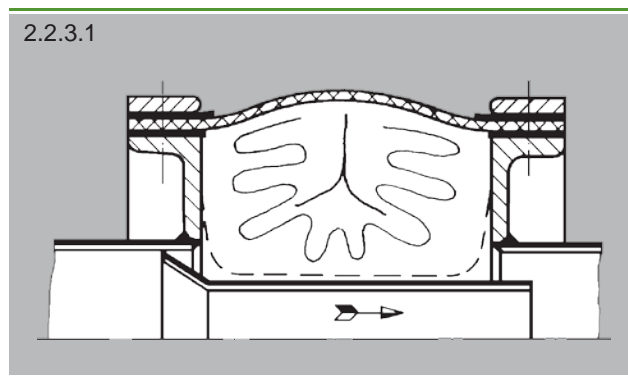
Although sealing using sash frames does not yield a dust-tight seal, it will serve as a major barrier to the rapid penetration of dust into the space between the pass tube and the compensator.

It may occasionally be necessary to remove part of the compensator to remove any dust that has penetrated.

### 2.2.3 Pre-insulation

High temperatures may necessitate that the space between the compensator and pass tube be used for housing pre-insulation, provided that there is sufficient room. In the event of high movement absorption, mineral fibre mats or quartz fabric mats may be wrapped in high-grade steel wire fabric for pre-insulation. Several such pre-insulation packs can be relocatably positioned so as to inhibit radiation exchange and partially prevent convective heat transfer.

A U-shaped folded insulation mat suffices for lesser movement absorption.



Proper design of the pre-insulation (including the parallel case design, see 3.4.6) is particularly essential in high temperatures. Another advantage of the aforementioned parallel case design is that the actual gap between the end of the ducts is only slightly larger than is necessitated by axial movement. In the operating state, this gap is closed save for a small safety distance. The pre-insulation housed in the space resulting from the staggered compensator connector flanges can be properly led and can absorb relatively large movements. Gas flows that are highly dust-laden require pre-insulation less for thermotechnical reasons than for preventing or at least reducing the penetration of dust by padding the space between the

compensator and the pass tube. In the event of a very high incidence of dust, a proper pre-compensator may be necessary.

### 2.2.4 Outer protective grating, outer insulation

The customer may wish to use a protective grating or plate to protect the soft-material compensator against mechanical damages from falling parts – especially during installation – or from rain, snow- or sandstorms or other detrimental effects. When adding such protective mechanisms, a measure which is often taken retroactively, the potential effects on the insulation must be taken into consideration alongside the intended protective effects. Protective shields made from aluminium, for example, may alter the radiation exchange between the compensator's surface and the environment, an effect which must be taken into account. Even if spacers are used to ensure adequate convection, a non-allowable heating of the compensator's surface may occur.

The same applies to protective grating or rain hoods, particularly if they are affixed too tightly, thus preventing the necessary corrective cooling of the compensator's surfaces.

Soft-material compensators may only be insulated from the outside if the media temperature roughly corresponds to the highest allowable temperature of the sealing layers. For compensators equipped with sealing layers made from silicon rubber or silicon-coated fabric, this means a temperature limit of 150 °C or 200 °C (see 2.1.2.4). For those equipped with sealing layers made from PTFE or glass weave, for instance, the temperature limit is 260 °C (see 2.1.2.4).

In the event of media temperatures in excess of these limits, the soft-material compensators may not be insulated from the outside, coated with paint, etc.

### 2.2.5 Protective devices and constructive measures for high condensation incidence, for FGD plants

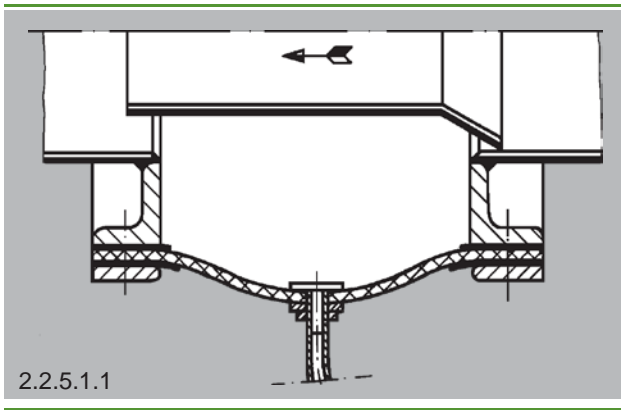
At flue gas desulphurisation plants – and at other types of plants in all sectors of industry – condensation may occur in sufficiently large amounts as to require special measures. In horizontal ducting systems, the fluid may collect inside the compensator on the lower side of the duct and be released in the flange area. In order to prevent this undesirable occurrence, Kempchen has developed special outlet nozzles made of PTFE as shown in Figure 2.2.5.1.1.



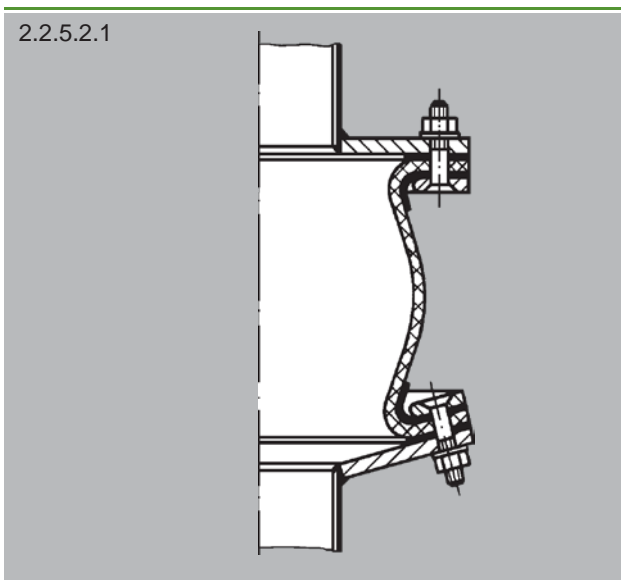
## Fabric compensators

Using plastic piping strainlessly affixed at all direction levels, the fluid can be led away without any problem.

In the event of low pressure, please confer with us regarding the appropriate constructive measures.



In order to avoid fluid accumulation in vertical ducts, Kempchen recommends setting the lower duct reinforcement, which generally also serves as a compensator flange, at an incline, as shown in Figure 2.2.5.2.1. The fluid can thus be led away from the clamping area.



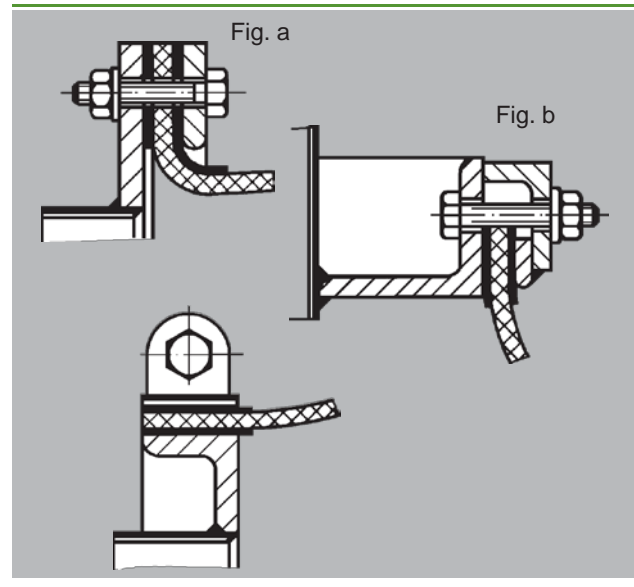
### 2.3 Compensator connection design

Fastening of the compensator can be achieved in the following ways:

- 1) using a through bolt and a screwed counterflange, Fig. a

- 2) without a through bolt, using a strap clamp, Fig. b

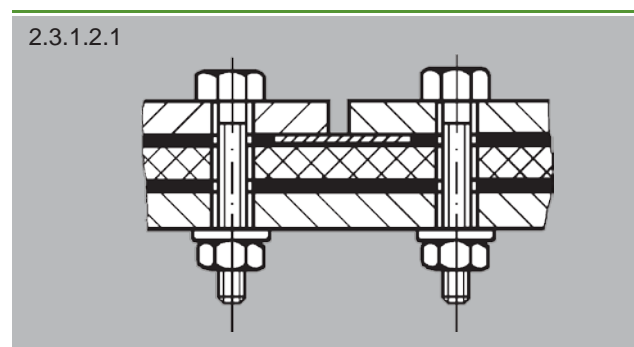
- 3) with band clamps, Fig. c



#### 2.3.1 Screwed counterflanges

Through bolts are typically used for screwed flanges. The duct flange and compensator flange are equipped with through bolt holes for this purpose. In the event of greater pressure and installation lengths, which may be necessitated by greater movement absorption, screwed flanges are advantageous. One disadvantage of screwed flanges is the possibility that they may complicate the sealing process in the flange area. Further details on this topic can be found in Chapter 6.0.

As shown in Fig. 2.3.1.2.1, a partitioned execution is often chosen for counterflange frames. The gaps are bridged by placing thin sheets (0.5 mm thick) underneath. Particularly for smaller dimensions, however, non-partitioned frames are also common.



## Fabric compensators

It is important to note that the radii will decrease by approx. 25% due to the compressability of the soft-material compensator flange, when the screws are tightened into place. Given a thickness of 16 mm for the soft-material compensator flange, and a compressability of 25%, the circumference of a quarter circle changes corresponding to the change in radius of

$$\Delta U = \Delta r \cdot \frac{\pi}{2} = 6,28 \text{ mm}$$

In terms of the flanging radii, long slots in the steel clamping flange are therefore necessary for band compensators due to the change in thickness. The constructing engineer must take this into account when constructing the flanges. Therefore it is necessary to determine the design of the soft-material compensator, and with it, the compressability of the soft-material compensator flanges. If the cross-section of the pipes is round, sufficient slackness for the screw can be achieved in the screw hole by partitioning the entire flange into a sufficient number of sections.

The thickness of the screwed counterflange is calculated according to the following table, which assumes a required surface pressure of 5 N/mm<sup>2</sup>. The second criterion is the allowable deflexion of the counterflange, which is assumed to be a through beam with a distributed load. For flanges or counterflanges with an angle profile instead of the basic square profile, a narrower flange thickness may be chosen that corresponds to the greater moment of inertia.

Information on the required torque and determination of thickness for the counterflanges

- 1) Compensator and edge reinforcement made from elastomers (FKM, EPDM)
- 2) Fabric compensator with edge reinforcement made from FKM, EPDM
- 3) Fabric compensator with edge reinforcement made from fabric

M 10	1 2 3	7 11 18	9 13 21	4,8 7,2 12,0	$l \leq \frac{2370}{b}$	$l \leq 3,7 \cdot h \cdot^3 b$	30	80	8
M 12	1 2 3	12 18 30	14 21 35	7,2 10,8 17,6	$l \leq \frac{3460}{b}$	$l \leq 3,3 \cdot h \cdot^3 b$	40	90	10
(M 14)	1 2 3	19 29 48	22 34 56	9,6 14,4 24,0	$l \leq \frac{4760}{b}$	$l \leq 3,0 \cdot h \cdot^3 b$	40	120	12
M 16	1 2 3	29 44 73	34 51 85	13,0 19,5 32,5	$l \leq \frac{6540}{b}$	$l \leq 2,7 \cdot h \cdot^3 b$	50	130	15
(M 18)	1 2 3	40 60 100	48 72 120	16,0 24,0 40,0	$l \leq \frac{7940}{b}$	$l \leq 2,5 \cdot h \cdot^3 b$	50	160	18
M 20	1 2 3	56 84 140	66 99 165	21,0 31,5 51,5	$l \leq \frac{10220}{b}$	$l \leq 2,3 \cdot h \cdot^3 b$	60	175	20
(M 22)	1 2 3	74 111 185	88 132 220	25,2 37,8 63,0	$l \leq \frac{12760}{b}$	$l \leq 2,2 \cdot h \cdot^3 b$	60	210	25
M 24	1 2 3	96 144 240	114 172 285	28,8 43,2 72,0	$l \leq \frac{14720}{b}$	$l \leq 2,1 \cdot h \cdot^3 b$	60	240	30

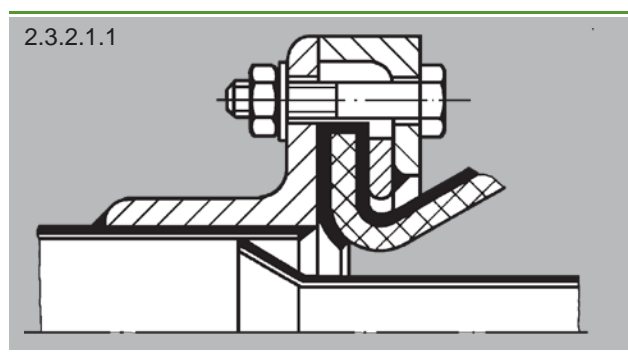
\* The lower torque is to be used with well-lubricated screws, the higher with screws with poor lubrication. The indicated torques may be exceeded by a maximum of 50%.

\*\* The bolt forces indicated are based on the adjacent flange width and screw distance as well as the surface pressure required for the material

## Fabric compensators

### 2.3.2 Clamping flanges

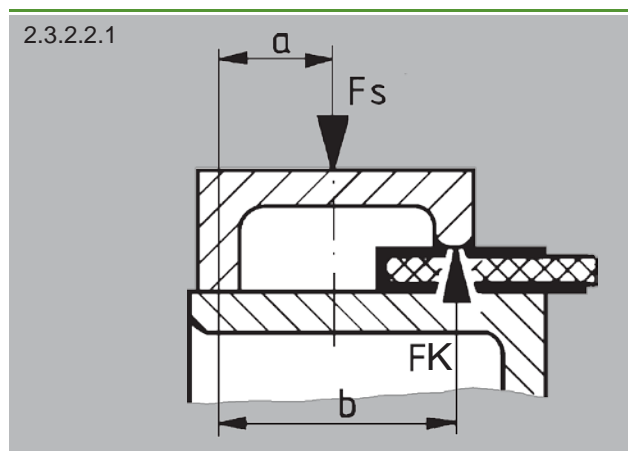
For certain areas of application – for instance, in the presence of poisonous or combustible gases - the use of flanges with strap clamps are recommended instead of screwed flanges with through holes, as the former provide for a more air-tight seal. See also the typical design illustrated in Fig. 2.3.2.1.1. However, this special design is only advantageous for ducts with square cross-sections. In the case of round cross-sections, the strap clamps would need to be partitioned into numerous individual pieces to produce an evenly distributed clamping effect.



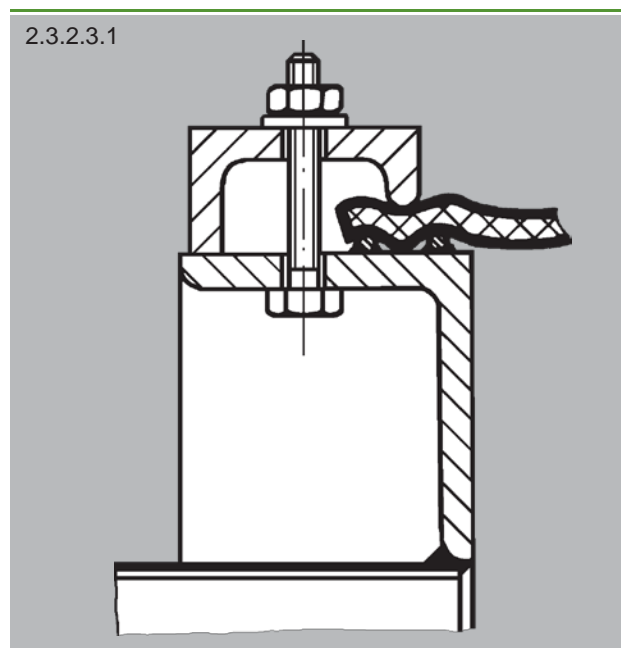
Although this type of connection has many advantages, including improved sealing possibilities, it cannot be used universally: due to its one-armed lever design, it requires more than twice as much bolt force than an ordinary through bolt to achieve the required surface pressure of 5 N/mm<sup>2</sup> in the soft-material compensator region.

As is shown in Fig. 2.3.2.2.1, the required bolt force  $a \cdot F_s = b \cdot F_k$  is calculated based on the relationship as follows:

$$F_s = \frac{b}{a} \cdot F_k$$

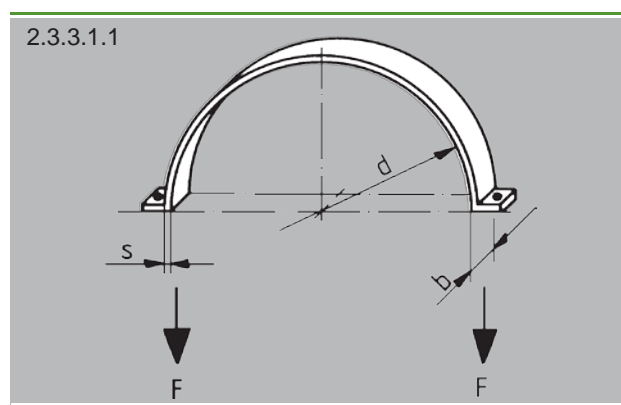


An additional disadvantage of this design is its low retention force, even when measures are taken to increase the clamping force, for instance by soldering round wires onto the flange surfaces, as is shown in Figure 2.3.2.3.1.



### 2.3.3 The band clamps

In certain limited situations, it may be advantageous to use band clamps to affix round compensators having a Type 120 hose connection or Type 110 elbow connection. Two factors determine the limitations for use: first, the fact that any band clamps used must be thin in order to function properly, as they are predominantly meant to transmit tensile stress rather than shear stress. Second, the clamping force is limited by the stability of the band clamps' material. A diameter of 800 mm yields a surface pressure of under 5 N/mm<sup>2</sup>, or the amount of pressure required for screwed flanges (see Fig. 2.3.3.1.1).



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An ordinary band clamp gauge of  $s = 1,5 \text{ mm}$  and a allowable band stress of  $\sigma_{zul} = 400 \text{ N/mm}^2$  result in a maximum diameter of only  $d = 400 \text{ mm}$  if a surface pressure of  $\sigma_D = 3 \text{ N/mm}^2$  is to be achieved. Greater diameters and band clamps with less resistance – or clamping screws not adequately tightened in relation to the resistance of the band clamp – therefore yield surface pressures significantly less  $5 \text{ N/mm}^2$  and the proper impermeability is thus not achieved.

$$d \cdot b \cdot \sigma_D = 2F$$

$$b \cdot s \cdot \sigma_{zul} \geq F$$

$$d \leq \frac{2 \cdot b \cdot s \cdot \sigma_{zul}}{b \cdot \sigma_D} = 2 \cdot s \cdot \frac{\sigma_{zul}}{\sigma_D}$$

Example:  $\sigma_{zul} = 400 \text{ N/mm}^2$

$s = 1,5 \text{ mm}$

$d = 800 \text{ mm}$

$$\sigma_D \leq \frac{2 \cdot 1,5 \cdot 400}{800} = 1,5 \text{ N/mm}^2$$

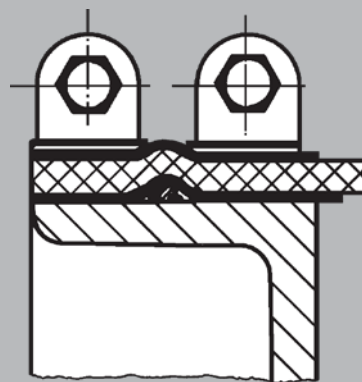
Another disadvantage of band clamps are the problems that arise from their use on flanges at higher temperatures. Because the flange of the soft-material compensator is a poor conductor of heat, a considerable temperature differential may arise between the band clamp and the duct flange. This will lead to either an overextension of the band clamp or an unallowable compression of the compensator flange, leading to a loss of impermeability after one or more instances of temperature change.

If in such cases there are particular reasons that require the use of band clamps rather than more advisable types of connections using screwed counterflanges, the use of clamp screws with disk spring sets of corresponding strength is strongly recommended.

When using band clamps, one must also take into account the fact that the clamping force of the turnbuckle will only yield the required surface pressure when in the immediate vicinity of the latter depending on the embrace friction. For this reason, band clamps have a maximum length of 1000 to 1500 mm. In the event of a greater diameter, two or more band clamps must be affixed consecutively. In such cases, the turnbuckles are to be moved accordingly, depending on the number of bands.

For safety reasons, it may be necessary to place two narrow band clamps (see Fig. 2.3.3.4.1) next to each other on the angle flange, so that in the event of failure of one band clamp – e.g. due to corrosion – the compensator is at least held in place by an additional band.

2.3.3.4.1



It can be said in summary that band clamps can be used only in relatively cool pipes (media temperature  $t < 200 \text{ °C}$ ) with a relatively small diameter ( $d \leq 1000 \text{ mm}$ ) at relatively low pressure. (medium pressure  $p \leq 0,1 \text{ bar}$ )

## Fabric compensators

### 3.0 Compensator Models

Because of their universal utilisability and multi-dimensional movement absorption, soft-material compensators are not differentiated according to axial, lateral and angular capacities, as is the case with metal or rubber compensators. Rather, they are defined according to their degree of movement absorption and their type of connection, as is shown in the table below.



3.1 Overview table

	Type	Description	Movement absorption <sup>1)</sup>	Comments Recommended LE dimensions
	110	U-shaped compensator	$\Delta l$ axial (0,1 to 0,3) LE $\Delta l$ lateral (0,05 to 0,2) LE	U-shaped and band compensators are the best value standard units for the majority of applications in circular and rectangular ducting. Type 110: LE = 150 to 400 mm Type 120: LE = 100 to 400 mm
	120	Band compensator		
	211	U-shaped compensator for overpressure	$\Delta l$ axial (0,2 to 0,5) LE $\Delta l$ lateral (0,1 to 0,2) LE	Particularly suitable for ducting with square or rectangular cross-section as a special corner construction if possible Type 211: LE = 200 to 400 mm Type 212: LE = 150 to 400 mm
	212	U-shaped compensator for low vacuum	$\Delta l$ axial (0,2 to 0,5) LE $\Delta l$ lateral (0,15 to 0,2) LE	
	221	Band compensator for overpressure	$\Delta l$ axial (0,2 to 0,5) LE $\Delta l$ lateral (0,1 to 0,2) LE	With rectangular compensators, the corners should be shaped by the height of the angular profile. LE = 150 to 400 mm
	222	Band compensator for low vacuum		

1) The movement values indicated are temperature-dependent. Our technical consultants can provide further information.

## Fabric compensators

Type	Description	Movement absorption <sup>1)</sup>	Comments Recommended LE dimensions
310	Pleat compensator with flange connection	$\Delta l$ axial (0,4 to 0,7) LE $\Delta l$ lateral (0,1 bis 0,2) LE	Pleat compensators are particularly suitable for circular duct cross-section in the smaller sizes (up to about 2,000 mm diameter). With larger diameters only low pressures possible. LE = 200 to 800 mm
320	Pleat compensator with band ends		
412	Multiple shaped compensator with intermediate flanges and hinged trellis support. Also in single u-shaped design possible.	$\Delta l$ axial (0,4 to 0,7) LE $\Delta l$ lateral (0,1 to 0,3) LE	Multiple shaped compensators can be applied to large rectangular or circular duct cross-sections and are particularly suitable for large axial movement. The intermediate flanges can be supported by hinged trellis guides or special suspension systems. LE = 200 to 450 mm per u-turn
120 GT	Parallel case design	$\Delta l$ axial (0,1 to 0,3) LE $\Delta l$ lateral (0,05 to 0,2) LE	The parallel case design was developed for rapidly increasing high temperatures, as among others common in gas turbines. See also 3.4.6.
510	Membrane compensator	$\Delta l$ axial (0,4 to 0,7) LE $\Delta l$ lateral (0,1 to 0,2) LE	Membrane compensators are particularly suitable for large diameters, large axial movements and high temperatures. Compensators of this type require supporting or suspension systems. LE-dimension by agreement
621	Tuck up band compensator for overpressure	$\Delta l$ axial (0,6 to 0,8) LE $\Delta l$ lateral (0,1 to 0,2) LE	Tuck up band compensators have proved particularly useful in conjunction with steel chimney liners, as they can absorb very large axial and lateral movements. LE-dimension by agreement
622	Tuck up band compensator for low vacuum		

1) The movement values indicated are temperature-dependent. Our technical consultants can provide further information.



## Fabric compensators

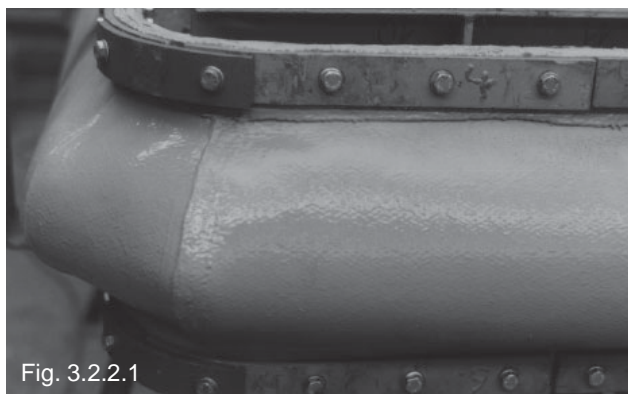
### 3.2 Explanation of overview table

#### 3.2.1

Types 110 and 120 are suitable for the absorption of small changes in length, as they are designed without bulges and thus without a special corner construction. They are therefore inexpensive to produce and can perform in a large range of applications.

#### 3.2.2

Types 211, 212, 221 and 222 have a built-in bulge which doubles their capacity for axial and lateral movement absorption. The corner can be constructed as a mitre with a joint in the supporting layer or as a segment corner with two joints, see Fig. 3.2.2.1.



#### 3.2.3

The pleat compensator (type 310 and 320) or the multiple shaped compensator with intermediate flanges (type 412) absorb larger movements, particularly axial movements. Pleat compensators are specially designed for ducting with a round cross-section and smaller dimensions under approx. 2000 mm in diameter. Larger diameters are only allowable at low pressures.

Instead of the support wires ordinarily found in round pleat compensators, rectangular designs require flat iron support frames.

#### 3.2.4

The type 412 multiple compensator in particular provides interesting possibilities for application, as long as the intermediate flanges required for types 412 and 510 can be suspended

or supported. Kempchen's hinged trellis supports for vertical and horizontal pipelines were developed for this purpose. See Figs. 4.3.1.1 and 4.3.1.2.

#### 3.2.5

Tuck up band compensators can be designed for over pressure (type 621) or low vacuum (type 622). They are particularly suited for steel chimney liners. Tuck up band compensators are the preferred choice for use with large diameters. They absorb large axial and radial movements as may arise in conjunction with thermal striping in collector chimneys. They are connected via angle flange or hose connections.

#### 3.2.6

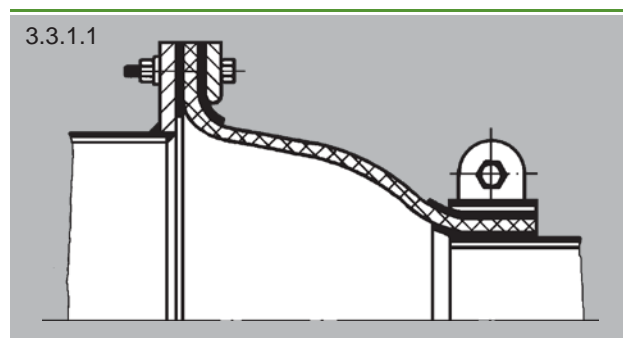
The LE-dimension must be met during assembly, with the following tolerance: + 0 / - 10 mm.

The lateral of the connector ends alignment must not exceed 10 mm during assembly.

### 3.3 Special models

Because of the diversity of demands placed on soft-material compensators, Kempchen has developed a series of special models in addition to the standard models depicted in overview table 3.1. These special models include:

#### 3.3.1 Compensators with different types of connections on each side - Fig. 3.3.1.1



#### 3.3.2 Conical and truncated conical compensators

#### 3.3.3 Compensators for wall ducts

## Fabric compensators

### 3.3.4 Special compensators for rotary air pre-heaters

### 3.3.5 Special compensators for diesel engines, exhaust systems, Fig. 3.3.5.1



Fig. 3.3.5.1

### 3.3.6

These special models of our vulcanised rubber fabric compensators for flue gas purification plants (FGD) can be found in our special brochure on REA (meaning: FGD flue gas desulphurisation plant) compensators. Please see pages 211/212 for a thorough description of our solutions for sealing of lining joints in chimneys.

## 3.4 Notes on selecting and dimensioning a soft-material compensator.

### 3.4.1

We recommend selecting a compensator from the overview table if possible because of the price advantage of these standard models.

The maximum allowable movement absorption can be found in overview table 3.1. Please note that the smaller number applies in higher temperatures due to the thicker construction, while the larger number characterises the movement absorption of a thinner construction.

The dimensions for movement absorption presuppose that axial compression and lateral movement take place simultaneously. If this is not the case, it is important that you make mention of this when enquiring.

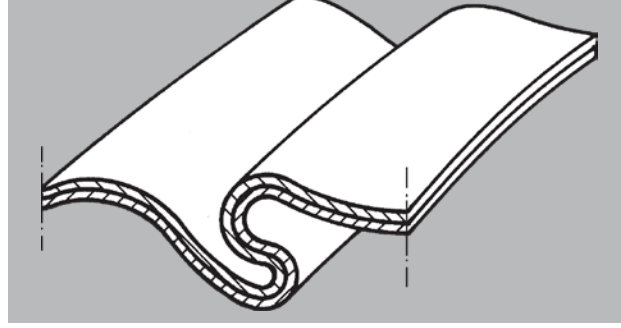
Reference values for the temperature-based elongation of attached duct cross-sections

Temperature °C	50	100	150	200	250	300	350	400	500	600
ferritic steel	0,32	0,89	1,51	2,18	2,87	3,61	4,35	5,12	6,66	-
austenitic steel	-	1,34	2,08	2,97	3,76	4,75	5,69	6,64	8,62	11,2

### 3.4.2

It is important that the soft-material compensator's parallel construction of its insulating layer, sealing layer, wire layer and protective layer remain intact during the anticipated movement, no matter what kind of compensator is chosen. Puckering and buckling are to be avoided, particularly in the outer skin, as this may lead to overheating due to an obstruction of heat output. See Fig. 3.4.2.1.

#### 3.4.2.1

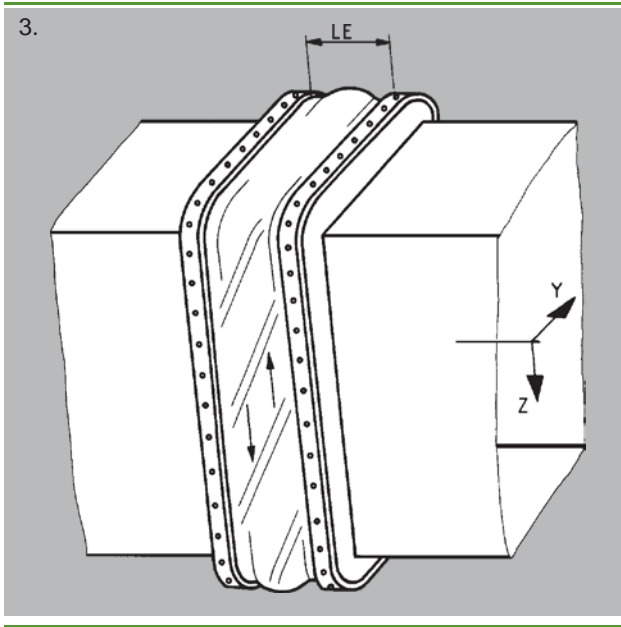


### 3.4.3

Lateral movement absorption is determined not only by the installation length LE of the flange distance, but also by the length of the side in which the lateral movement takes place. As shown in Fig. 3.4.3.1, a smaller lateral movement is possible in direction Z as in direction Y.

long side  $\Delta$  smaller lateral movement absorption  
short side  $\Delta$  larger lateral movement absorption

## Fabric compensators



### 3.4.6 Parallel case design for reduction of compensator flange temperatures

The flange construction in Fig. 3.4.6.1 demonstrates that the hot ducting sections (1) and the cold ducting sections (2) are separated by ducting sections (3), which are made from thin ferritic / austenitic steel with a thickness of only 1.5 to 3 mm.

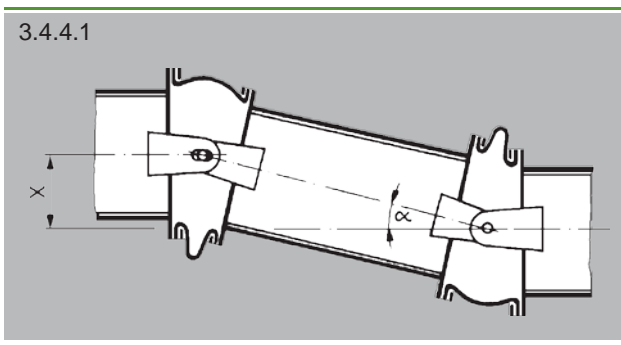
Gas turbine plants have been designed with a daily start-stop cycle and thermal strain of approx. 600 °C, rising and falling in 6 minutes.

Other parallel case constructions have been designed in accordance with Fig. 3.4.6.2. The parallel case design is available as a screw-in unit or weld-in unit.

The advantage of these designs is the considerably lower temperature of the connection and compensator flange as well as the near closure of the gap between the ducting ends in operating condition.

### 3.4.4

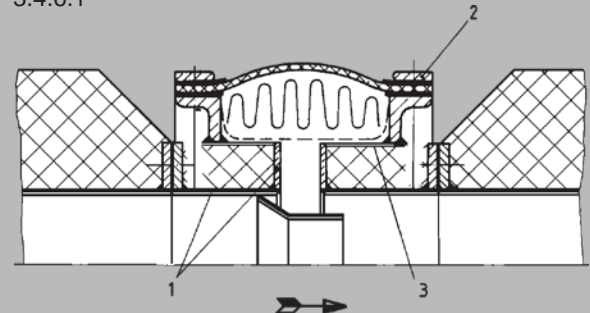
Constructive measures can be taken for particularly large lateral movements. A flexibly suspended section of ducting is one possible solution. The compensators are then loaded as shown in Fig. 3.4.4.1 and function as angular compensators.



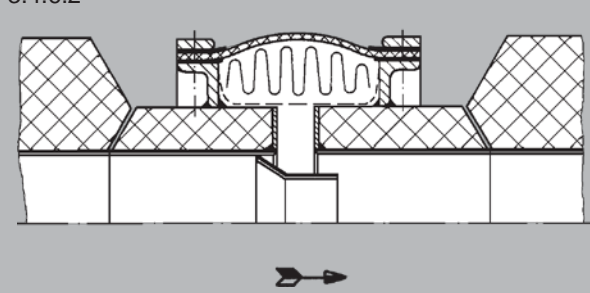
### 3.4.5

Soft-material compensators intended for use as angular compensators must be equipped with a built-in bulge. They should be somewhat pre-loaded so that absorption of not only compression movement but also expansion can take place without the compensator becoming overloaded.

#### 3.4.6.1



#### 3.4.6.2



## Fabric compensators

### 4.0 Connection options

The following descriptions of types of connections are intended to demonstrate the options available and their limits.

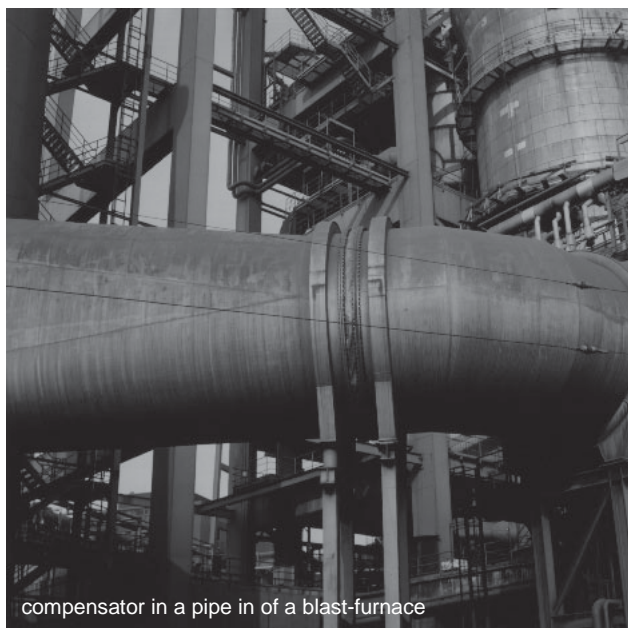
The temperature restrictions given depend to a large extent on the construction of the compensator. As an example, please keep in mind that these limits are approximately 100°C lower for use on silicon or viton-coated fabrics than on fabrics coated with PTFE. PTFE-coated fabric can be used for sustained temperature ranges up to 260 °C, while silicon- and viton-coated fabrics can only be exposed to sustained temperatures of up to 150 °C to 180 °C..

The options for attaching soft-material compensators are given in point 2.3.

Only flanges with a flat face should be used as welding flanges or welding neck flanges, such as DIN 2526 Form B or DIN 28032 DIN 28034 Form D.

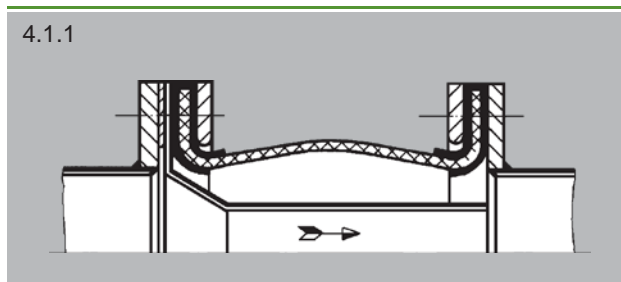
#### 4.1 Flange connection design

Pipelines and ducting are often have angle steel or flat steel frame reinforcement, so that a flange connection already exists for the compensator. This very simple type of connection is possible at media temperatures between 350 °C and 400 °C, see Fig. 4.1.1. This connection also produces an optimal seal.



compensator in a pipe in of a blast-furnace

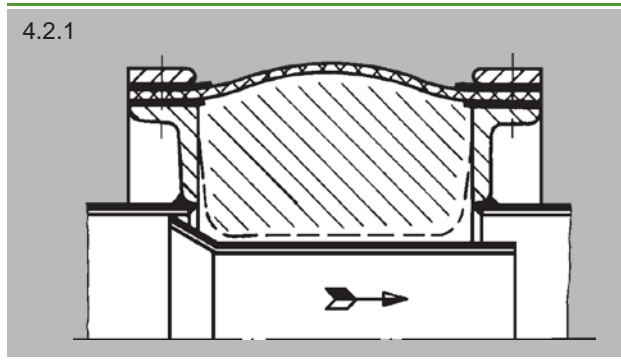
4.1.1



#### 4.2 Designs for hose compensator connections

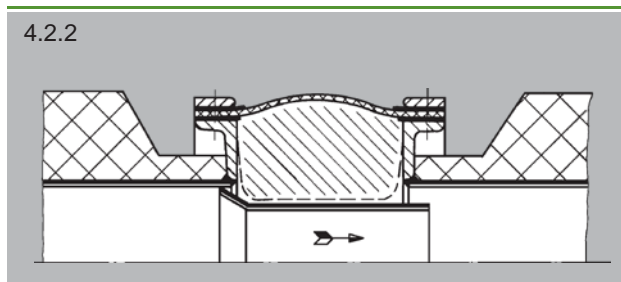
For media temperatures of approx. 400 °C and above, a reinforcement of the ducting ends using an angle or U-profile is recommended, so that compensators can be mounted with a hose connection (see Fig. 4.2.1).

4.2.1

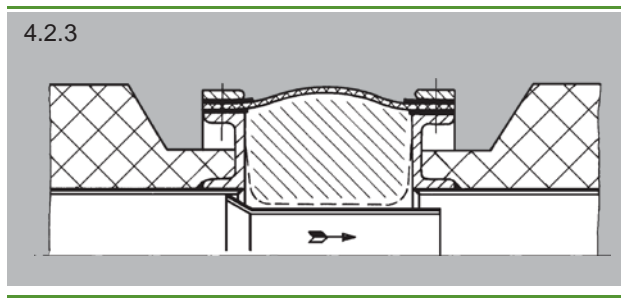


By selecting one of the designs shown in Figs. 4.2.2 and 4.2.3, and setting back the insulation somewhat in the flange connection area, flange temperatures can be reached that are approximately 100 °C than would otherwise be attained.

4.2.2



4.2.3





## Fabric compensators

Using band clamps for attachment (see 2.3.3) at diameters up to 1000 mm offers the advantage of avoiding screw holes. An additional advantage is the excellence of the seal attained. At diameters over 1000, screwed counterflanges are the preferred option. These offer a satisfactory sealing capacity.

### 4.3 Hingend trellis support / bar guides

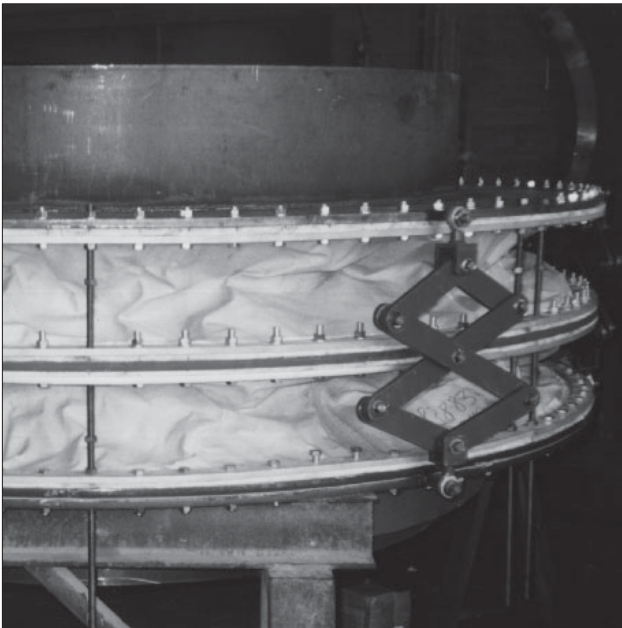


Fig. 4.3.1.1

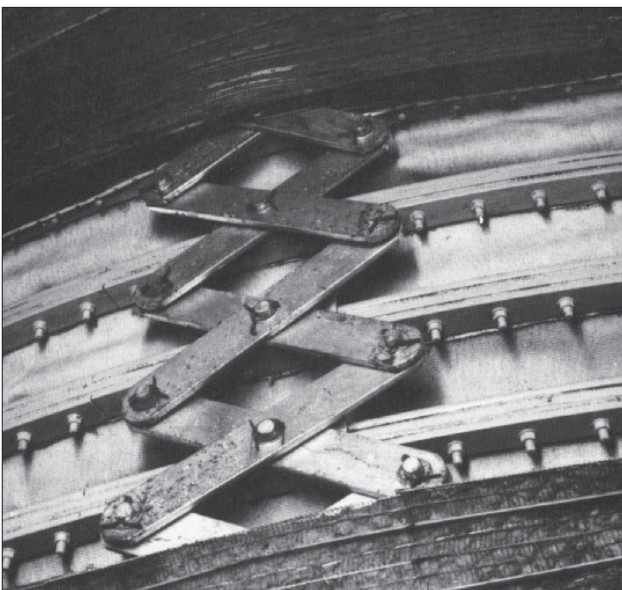


Fig. 4.3.1.2  
Compensator in the chimney of a coal power plant

As indicated in 3.2.4., the multiple shaped compensator can be used with an intermediate flange and hinged trellis support on large ducting cross sections and large axial movements in vertical and horizontal conductings.

The number of compensators and intermediate flanges necessary is determined by the size of the large axial movements to be absorbed. In order to avoid sagging or drooping in a horizontal or vertical direction, Kempchen has developed a hinged trellis support for this purpose (Figs. 4.3.1.1 and 4.3.1.2). The intermediate flanges are supported by hinged trellis and an even distribution of axial movement is carried over the entire multiple shaped compensator, without lateral step aside. Bar guides have proven suitable for use in pleat compensators without intermediate flanges (Fig.4.3.1.3).

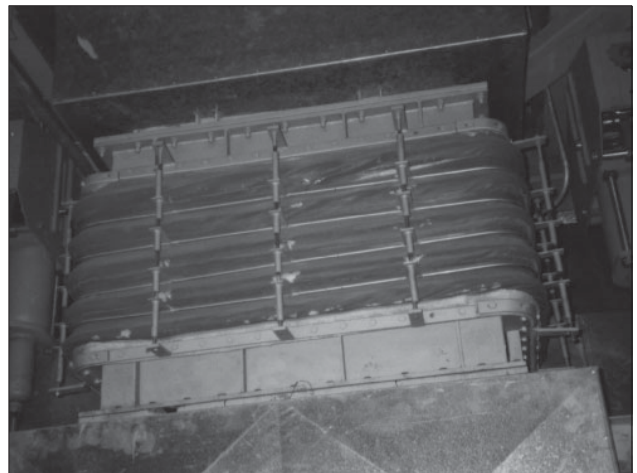


Fig. 4.3.1.3



Compensators at the entrance to a heat recirculation pipe at a sintering plant

## Fabric compensators

### 5.0 Thermal calculation of compensator construction

The foils shown in Table 2.1.2.4 are used as sealing layers.

The highest allowable sustained temperature in the foil(s) or outer coating installed as a sealing layer represents the critical point in the temperature-dependent construction of the compensator. For this reason, these sealing layers serve as the thermal calculation criteria for the compensator's construction.

There are two main areas which must be distinguished: the free area between the two flanges and the loaded area of the compensator between the flange and the counter flange.

#### 5.1

Constructive design of the soft-material compensator for ducting with round, square or other types of cross sections results in different behaviours for heat conduction and heat transfer.

In practice, there may be parallel layers in the free clamping area, to which the theoretical approach and simplifying assumptions (Point 5.3) may apply very well. However, in the pleat area there may be complicated ratios which are not easy to detect by calculation.

Heat transfer takes place through convection or radiation. However, heat transfer is to a large degree dependent on the temperature level and the temperature differential of the ambient air for convection, and on the surfaces standing in the radiation exchange.

Flow ratios also play a major role in heat transfer both inside the compensator and on its external protective layer.

Thus there is considerable variation among the outer surface temperatures of the protective layers of compensators in horizontal ducting. The highest outer surface temperatures occur as a result of thermally determined flow ratios in the middle of the underside and topside of the compensator. These areas are thus particularly vulnerable.

#### 5.2

As is it nearly impossible to detect all of these operating conditions and limiting terms, the following simplifying assumptions are made:

1. We assume the soft-material compensator to be constructed from plane parallel heat insulation layers which allow heat to flow vertically to the two adjacent surfaces.
2. We consider the stationary condition to be that which is reached after a certain amount of time.
3. We assume that the temperature differential that causes the heat output from the surface into the ambient air via convection to be same as the temperature differential that causes heat transfer via radiation.

The following assumptions are made:

1. That the capacity for heat conduction depends on the temperature.
2. That the plane-parallel layer is thinner in the clamping area than in the free area.
3. That when stationary, the heat flow of the compensator through the individual layers may be assumed to be constant, allowing for computation of the temperatures on the parts of the soft-material compensator's individual layers in question.

#### 5.3

The following are two typical temperature diagrams of standard superstructural parts.

In example 5.3.1., the critical point, which serves as the basis for thermal computation, is the external silicon layer 6.

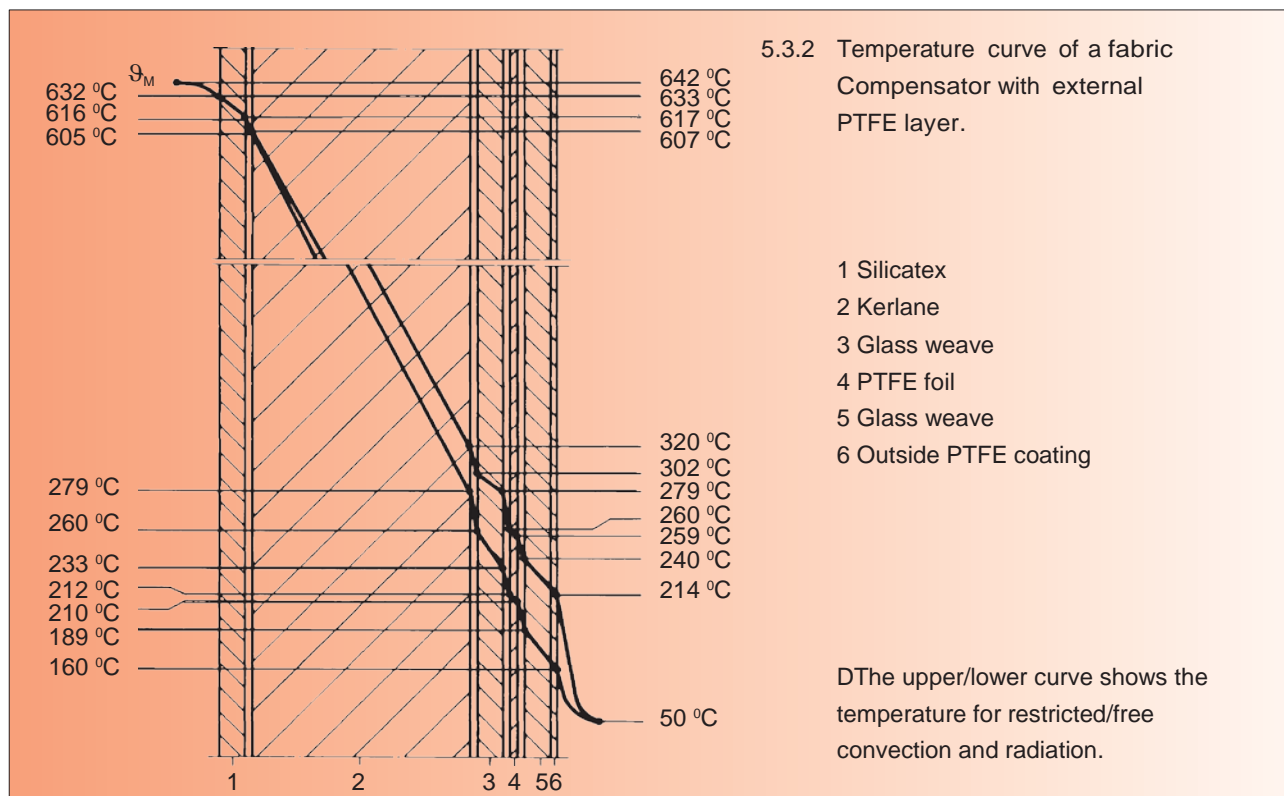
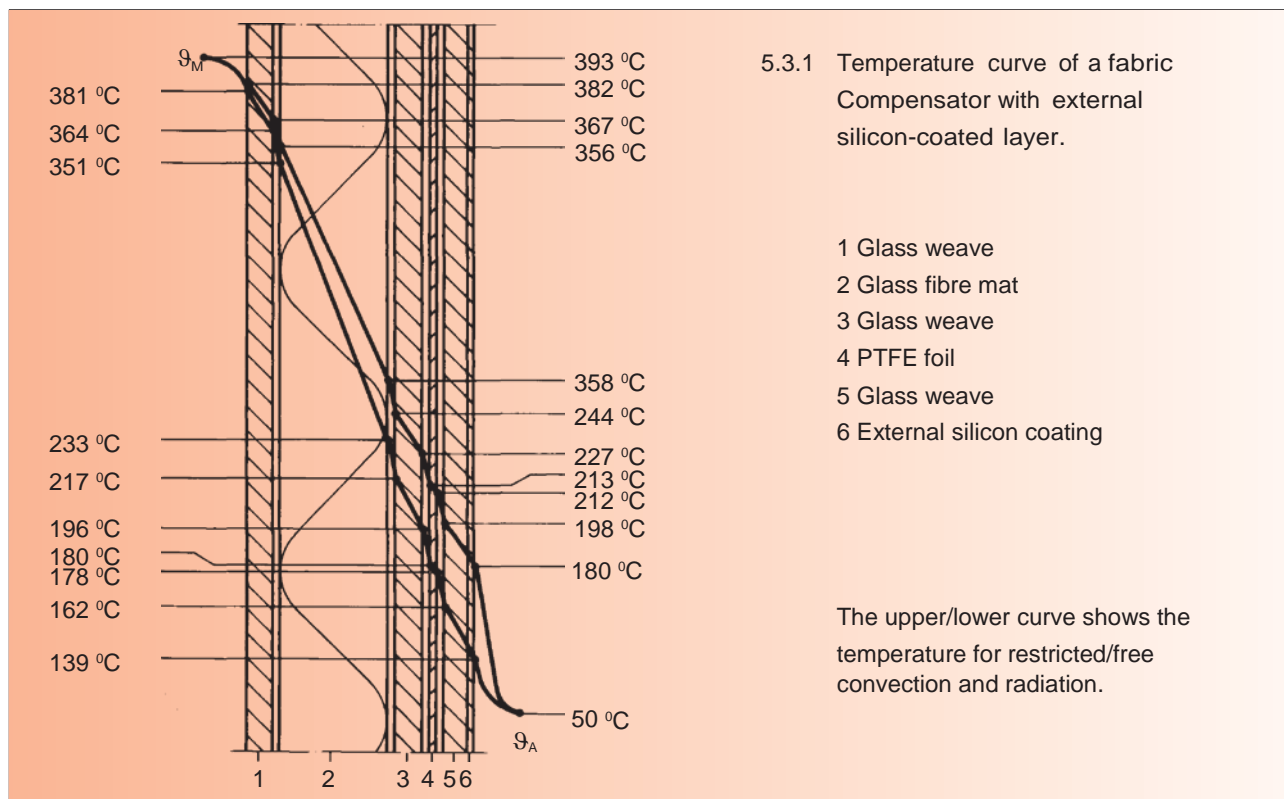
In example 5.3.2., the critical point, which serves as the basis for thermal computation, is the PTFE foil 4.



## Fabric compensators

### Temperature Curves

### Example of Design



## Fabric compensators

### 6.0 On Impermeability in soft-material compensators and testing.

The impermeability required of a soft-material compensator varies widely by

- temperature range
- type of compensator
- medium.

Single-layer, compact rubber compensators, fabric compensators with flange sealings made of rubber, and fabric compensators with textile flange sealings can be used in increasingly greater temperatures. The demands for gas-tightness are to be reduced with increasing temperature stress.

#### 6.1 Single-layer rubber compensators

The greatest level of impermeability can be attained with compact rubber compensators made from e.g. EPDM, butyl rubber or fluorelastomer. These compensators have a flange area and compensator bellows made of vulcanised rubber. The compensator bellows is equipped with a vulcanised metallic or non-metallic textile reinforcement. This type of compensator passes the Nekal test at surface pressure of approx. 2 N/mm<sup>2</sup>.

In conformance with the quality and test specifications RAL-GZ 719 Section 2.2.6 "Impermeability", no bubbles may appear in the bellows area or clamping area, as a qualitative demonstration of the Nekal test. Depending on the type of rubber used, rubber compensators can be used at temperatures up to 205°C. Below the dewpoint, these types of compensators are also impermeable when condensation is present.

#### 6.2 Multi-layer fabric compensators with flange sealings made from rubber

For temperatures up to 260 °C we prefer to use fabric compensators with an internally sintered PTFE foil up to 0.5 mm thick. These compensators have been tested and shown to last for many years at both higher temperatures and incidences of greater condensation. They also pass the Nekal test due to the flange sealing, made of fluor rubber or PTFE, which is tightly attached to the PTFE coating

#### 6.3 Multi-layer fabric compensators with textile flange sealings

This type of compensator is used at temperatures over 260 °C. The bellows area can be sealed using gas-tight rubber, plastic or metal foils. In the flange area, however, no gas-tight materials may be used at temperatures over 260 °C. The glass-oder ceramic weave stripes do not pass the Nekal test at high temperatures, but are flue gas tight.

Flue gas tightness refers to impermeability that meets technical standards. In the Nekal test, individual bubbles that appear via diffusion across the heat-insulating flange sealings are allowed in the flange area.

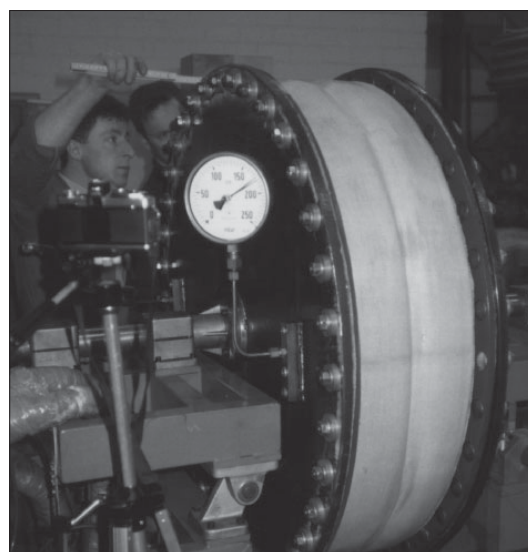
#### 6.4 Conditions for impermeable soft-material compensators

The flange area is the weakest spot of the soft-material compensator. For this reason, the surface pressure and the attainable surface pressure and the actual surface pressure are of great importance during assembly.

Instructions for the proper thickness of the counterflanges depending on the width of the counter flange and the distance between the holes are given in 2.3.1.4. One precondition is that the ducting or piping flange is designed to be rigid, e.g. owing to the choice of an adequate thickness or due to elbowing.

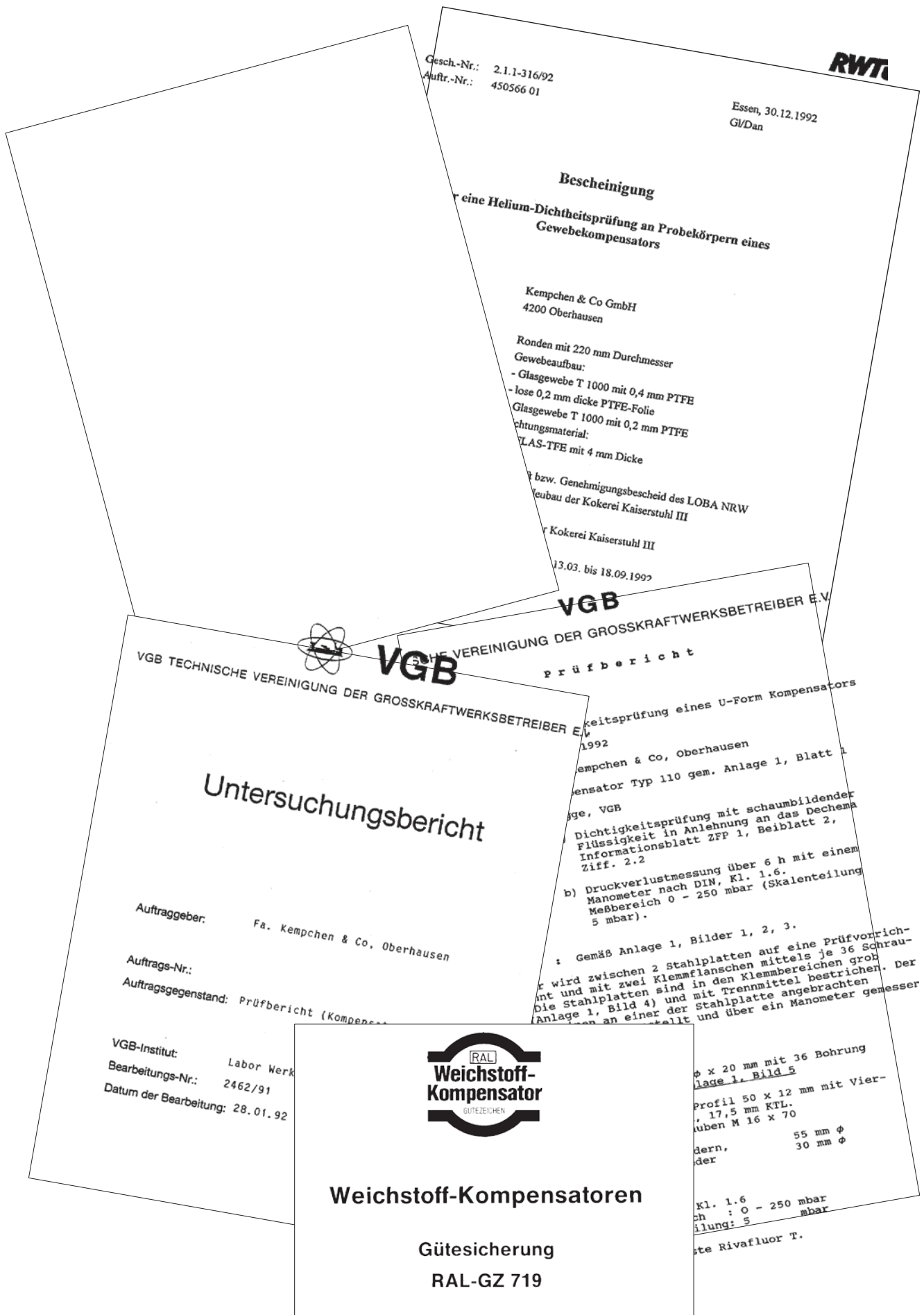
The flange screws are to be tightened in accordance with the capacity and the relaxation properties of the compensator's various superstructural parts. Table 2.3.1.5 also provides instructions for this.

The screws should be re-tightened to the target moment one hour after completion of assembly.



Kempchen employees pressure testing a compensator at the Kempchen compensator testing station

Fabric compensators



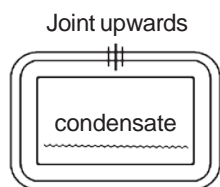
## Fabric compensators

### 7.0 Assembly and repair instructions

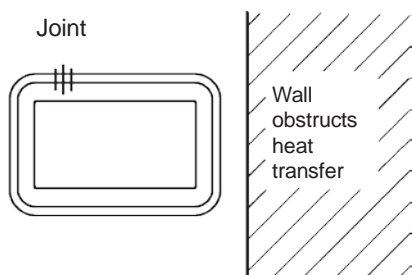
#### 7.1 General instructions for closing a prepared site joint

- Take out the compensator and check which side is the inside. The outside is marked as such.
- Make sure the pass tube has no sharp edges. Any sharp edges must be refinished.
- Because the joint is naturally the weakest spot on the compensator, it should be placed in an area that can be expected to be exposed to low mechanical and thermal stress.

In horizontal piping and ducting at risk for condensation formation, the joint should be placed upwards.

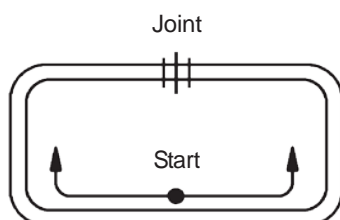


If you anticipate trapped heat because unfavourable arrangement of objects obstructs free convection, or a radiation exchange is taking place, the joint should be placed on the area of the compensator which can be expected to remain coolest.



Check to make sure that the counterflanges are properly rounded.

- Begin assembly a compensator with a joint with screwed flanges in the middle of the compensator on the side across from area where the joint is to be placed, and continue to the open ends.

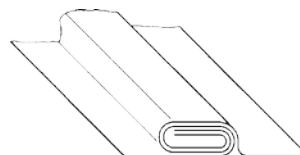


We recommend leaving approx. ½ m unscrewed to allow for proper freedom of movement.

- Now overlap the fabrics alternatingly. Sew the fabrics together, beginning from the inside. Do the same for any wire weave or rock wool layers.

Be especially careful when sewing together the sealing layers.

- a) Glue the PTFE foil with Siemapren 1500 F(N) according to the illustration, fold, and interlock or weld in place

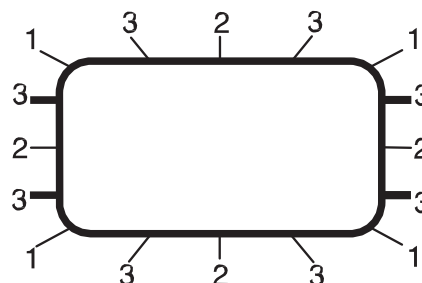


- b) Glass fibres with a sintered PTFE layer and polyester fibres with viton coating are painted with viton solution B and sewn together.

Silicon-coated glass or polyester fibres are painted with silicon paste and sewn together. Finally, all stitches are sealed with viton solution and the compensator is mounted.

When assembly is performed by a Kempchen technician, the PTFE foils are professionally welded, and the sealing layers are welded with sintered PTFE foils using special site joint preparations.

- The continuous band compensator should be mounted according to this sketch:

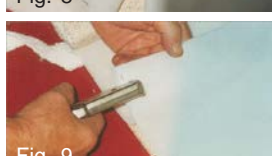
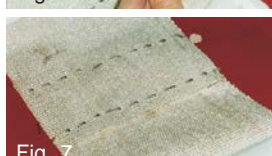
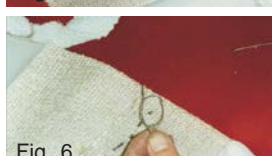


Begin assembly on corners. 1. Tighten one screw in the middle of each corner 2. Then each in the same way 3 etc. This method eliminates small waves or folds.



## Fabric compensators

### 7.2 Special instructions for closing a prepared site joint and repairing the compensator of a type 110 or 120



#### Fibre construction:

- 1 Fibre glass layer with sintered PTFE foil
- 1 PTFE-foil layer, loose
- 1 Fibre glass layer with sintered PTFE foil

#### Inner and outer edge reinforcement, fibre glass strip

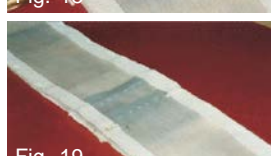
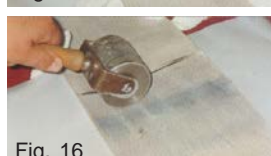
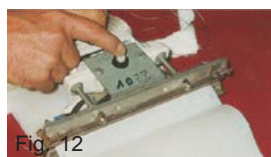
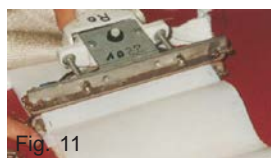
1. Loosen approx. 200 mm of the edge reinforcement. Cut the first inner layer to the proper length, leaving a 100 mm overlap. Apply adhesive to both sides and let dry approx. 4-5 minutes (Figs. 1 + 2). Apply pressure with a hand roller if necessary (Fig. 3).

2. Place a bent needle with thread approx. 20 mm from the edge. Make stitches 20 mm wide 10 mm apart across the entire width. Tie the ends of the thread into knots, create 2 seams (Figs. 4 to 7).

- 3a. Stack the PTFE foils atop one another, staple the end and make multiple folds, approx. 20 mm wide, staple the final fold on both sides to prevent the foil from sliding (Figs. 8 to 10).

- 3b. Weld the foil with a welding apparatus, if a foil welding apparatus is available on site, attach welding film to the ends of the foil (Fig. 11).

Line up the other side without the welding foil precisely and staple. Set the welding tongs to 60 with the control device, press the button wait 20 seconds, release the tongs. Trim



off any remaining welding film. Fold the welded foil once again (Figures 12 + 13).

4. Outer layer: with the outer layer turned away from the inner layer, paint both sides with adhesive and glue like the inner layer (Fig. 14)

Important for the outer seam: A guard or thick PTFE foil or similar material must be inserted between the fabric layer and the PTFE foil to prevent the PTFE foil from being damaged by the needle (Figure 15).

Press over the glued portions with a roller (Fig. 16).

Create seams as in the inner layer. Paint the seams with multiple layers of viton preparation to close the stitch holes of the seam. Make multiple paints until a closed film accumulates (Fig. 17)

Stretch the reinforced edge to its exact length, lay the parts flush against one another and glue approx. 20 mm offset from the fabric seam (Fig. 18).

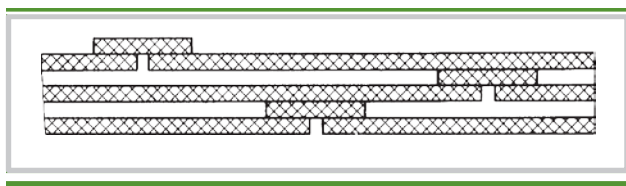
Attach the inner edge reinforcement in the same way. Finished seam connection (Fig. 19).

Control device, welding tongs, required equipment (Fig. 20).

## Fabric compensators

### 7.3 Repairing a compensator by separation and reconnection, if assembly in continuous form is not possible

This is a difficult task, because unlike the prepared joint, the separation point does not allow for easy overlapping. This method should only be used if the pass tube cannot be dismantled or other operating conditions prohibit assembly in a continuous condition. For this reason, one must thoroughly consider whether detaching and switching the pass tube and re-welding after partial assembly of an continuous compensator, for instance, is preferable to separating the fabric compensator. If the decision has been made to separate the compensator, the separation must take place layer by layer. Additional strips of material of the same or higher quality must be placed under respective separation points. Then the separation points must be connected to overlapped joints. Section 7.1 applies to the individual steps of the process.



### 7.4 Repairing mechanical damage or burn holes

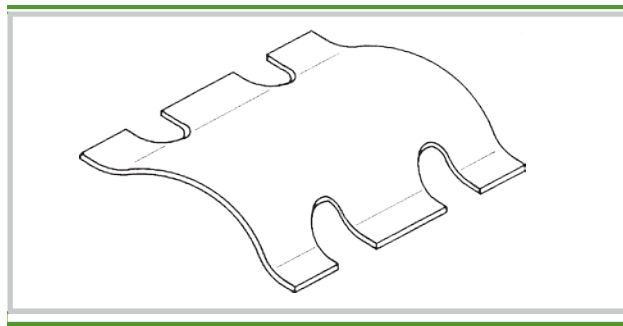
In order for a repair to be successful, the ripped or cutted material aside must have sufficient stability.

- The damaged parts of the fabric are unfolded until the innermost layer is reached. In some circumstances it may be necessary to expand a small tear for this purpose.
- The innermost layer – wire mesh or textile fabric – is sewn with wire or special thread.  
Any insulation is returned to its proper position and covered with a proportionate piece of fabric.
- Next a piece of the fabric layer in equivalent size is placed in front of the sealing layer. The sealing layer is painted with viton adhesive and glued to the piece of fabric, and a proportionate piece of fabric is sewn onto the sealing layer as well. The seams are in turns sealed with Viton.
- Any additional layers of damage are repaired as described above.

### 7.5 Emergency assistance

When damage occurs during operation and high temperatures prohibit the steps described in 7.3, it may be helpful to place a sheet metal strip over the site of the damage, particularly in band- or U-shaped compensators.

Loosen the counterflange and clamp a strip of sheet metal cut according to the illustration below in the screw hole area underneath. Attempt to recreate the shape taken on by the compensator. Seal the area between the metal strip and the compensator's outer skin with viton adhesive or silicon past



This type of repair presupposes that the position of both sections of piping or ducting have changed only slightly. However, this repair will generally allow for continued operation until the next shut-down.

## 8.0 Storage, installation and assembly instructions

### 8.1 Storage

Soft material compensators are sensitive to damage during transport and must therefore be transported properly. Be careful with sharp edges and pointed objects during transport!

Compensators must be properly stored until the time of installation. It is recommended that they be stored in climate-controlled metal trailers, from which they can be transported to the assembly site. The storage area must be heated at outside temperatures below 5 degrees Celsius.

When immediate assembly is not possible and the compensators must be temporarily stored at the assembly site, it is important that the compensators be protected from wet conditions, e.g. covered with a plastic tarp. When on-site, the com-



## Fabric compensators

Compensators must be carefully stored on wooden pallets and protected from damage from assembly work (mechanical protection) or general construction site traffic.

Compensators that have become stiff from storage at low temperatures may not be used in this condition. They must be brought to room temperature in order to regain flexibility.

### 8.2 Installation

After installation, the following factors must be taken into consideration, particularly in the areas above the compensator

- general protective measures during assembly work
- temperature protection (welding work)
- mechanical protection (welding and grinding work)

It is recommended that compensators remain protected if possible until initial operation.

Protective plates placed next to or above the compensator can obstruct heat radiation during operation. Normally, compensators may not be insulated. The same applies to the flanges, as a large portion of heat is transferred over the flanges. (Exceptions: Compensators with heat insulation or weather protective shields specially constructed for this purpose).

Fabric compensators may not be coated with paint or varnished. In certain types of compensators, the solvent can attack and destroy the compensator. Also, a varnish layer represents an unallowable insulation. There should be no sharp edges on the pass tube; any sharp edges must be repaired. The counterflanges must also be properly rounded.

### 8.3 Assembly

- The steel flanges are to be inspected for smooth welding seams and rounded edges and any repairs carried out.
- Bolt holes in the steel parts must be free of burrs
- The flange misalignment/the distance between the flanges must lie within the allowable tolerance
- Lay out the compensator and check which side is the inner site. The outside is marked as such!

- With elastomer compensators and fabric compensators, with elastomer edge reinforcement, use the separating agent provided. For directions for use, see the package.

The freedom of movement required for absorption of axial and/or radial movements is built in to the compensator. When installing, make sure that the compensator is pre-compressed so the installation length (LE dimension) is retained.

The joint/seam must be placed on the point of the compensator exposed to the least mechanical or thermal stress! In horizontal pipelines at risk for condensation formation, the inner seam must be placed at the top (12 o'clock) or on the side near the top – 2 or 10 o'clock. Stop assembly if the ambient temperature at the assembly site reaches values below 5 degrees Celsius.

It may be possible to partition off the ducting in the compensator area and heat the inside to temperatures > 5 degrees Celsius. Always check the outside temperature during assembly in the winter!

### 8.4 Notes on screw assembly of closed compensators

With screwed flanges, begin assembly of the compensator by placing one screw on each quarter of the circumference (C:4). The remaining sections are then halved again. The distance of 1 to 4 mm between the clamp frames is to be bridged by a shim of 0.5 mm in width. Then the screws may be tightened at half bolt force.

The full starting torque is to be applied to each screw in the second round of screwing. Important: make sure the intended surface pressures are attained! A precondition for this is that the ducting flange and clamping flange meet the aforementioned requirements.

When closing the ends of the band compensator, it is imperative to follow the instructions provided with the compensator.

The bolt screws are to be mounted with their head to the compensator so the remaining screw protrusion do not damage the compensator. After the initial heat phase, or if no initial heat phase is possible, re-tighten the screws to the required torque after 24 hours.

## Fabric compensators

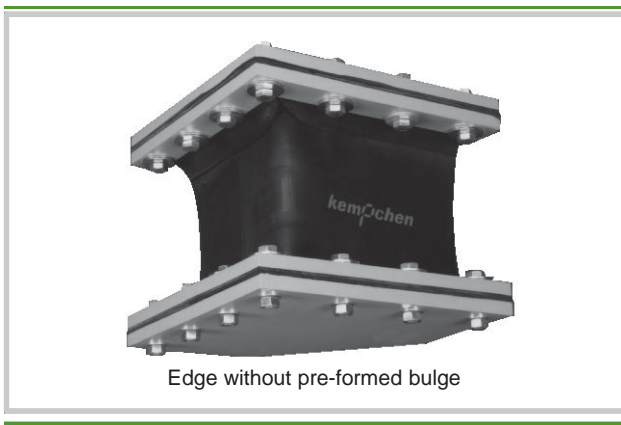
### 9.0 Elastomer, rubber and metal compensators

Elastomer compensators for FGD and FGP plants (see also 3.3.6)

These compensators are used wherever an increased incidence of chemical attack is anticipated. Depending on the elastomer quality, they can be used at up to 200 °C.

They are available for round and square-shaped conduit with or without pre-formed bulge at the edges and upon request with a vulcanised outlet nozzle with or without flange connection.

We produce elastomer compensators using a patented manufacturing technique with and without a pre-formed bulge at the edge area.



#### Rubber compensators

With pressure-proof cord inserts for all sectors of industry to compensate expansions and to reduce noise and vibration transmission - also in a braced version.



#### Metal compensators

For high pressure and temperature loads, also in special steels and all weldable metals; with or without flanges, movement restrainers are supplied on request.

#### Chimney seals

Lining-joint seals made of fluor rubber terpolymer with wire mesh reinforcement made of high-alloy stainless steel are used to seal the expansion joint in chimney lining.

The sealing strip is attached to the lining by means of wall anchors and clamping strips made of high-alloy stainless steel. The clamping strips and wall anchors can also be coated with fluor rubber. Due to its special construction and the materials selected this seal can be subjected to a sustained temperature load of up to 200°C.

Realon cords made of PTFE with a silicate-fibre core for permanent temperatures up to 260°C and short-term peak loads up to 305°C are used in chimneys to additionally safeguard the lining-joint seal.



Kempchen technicians installing a lining-joint seal

## Fabric compensators

## Technical questionnaire for fabric compensators

An

Kempchen Dichtungstechnik

GmbH

Im Waldteich 21

D-46147 Oberhausen

Company Name : \_\_\_\_\_

Street Address : \_\_\_\_\_

Location : \_\_\_\_\_

Authorized Officer : \_\_\_\_\_

Telephone : \_\_\_\_\_ Fax : \_\_\_\_\_

Dated : \_\_\_\_\_ Order No. : \_\_\_\_\_

Please complete this questionnaire, answering as thoroughly as possible so that we may provide you with a professional quotation.

## 1) Medium ...

† Flue gas

† Exhaust

† Air

† Other, please specify : \_\_\_\_\_

Please attach an analysis, if available

Materials burned : \_\_\_\_\_

Dust content : \_\_\_\_\_ mg/m<sup>3</sup> Grain size : \_\_\_\_\_ mm

Dew point : \_\_\_\_\_ °C

## 2) Medium temperature and ambient temperature...

Operating : \_\_\_\_\_ °C Design : \_\_\_\_\_ °C

Interruption : \_\_\_\_\_ °C for a duration of : \_\_\_\_\_ days or

: \_\_\_\_\_ hours or

: \_\_\_\_\_ minutes accumulated over † Life-span

† one year

Ambient temperature : \_\_\_\_\_ °C ( Standard value : 50 °C )

Is radiation being obstructed?

† no

† yes, please specify source and nature of obstruction:

Radiation from other plant components

† no

† yes, please specify source and nature of radiation:

## 3) Medium pressure...

Operating pressure

over pressure

low vacuum

: \_\_\_\_\_ mbar Design : \_\_\_\_\_ mbar

: \_\_\_\_\_ mbar; Alternating pressure load :

† no

† yes, frequency : \_\_\_\_\_ Hz

Pressure impact load :

† no

† yes

Interruption

: \_\_\_\_\_ mbar for a period of : \_\_\_\_\_ days or

: \_\_\_\_\_ hours or

: \_\_\_\_\_ minutes accumulated over † Life-span

† one year

Required seal impermeability :

## 4) Movement absorption...

Axial extension

: \_\_\_\_\_ mm,

Axial compression

: \_\_\_\_\_ mm,

Lateral movement

: \_\_\_\_\_ mm, pre-load

† no

† yes, please specify : \_\_\_\_\_ mm

Angular rotation

: \_\_\_\_\_ °

Vibration † no

† yes, frequency : \_\_\_\_\_ Hz, Amplitude : \_\_\_\_\_ mm

Change of load : \_\_\_\_\_ times per † year or † month or † day or † hour

## 5) Other conditions for use...

Pipe lay on † horizontal

† vertical, flow direction

† upwards

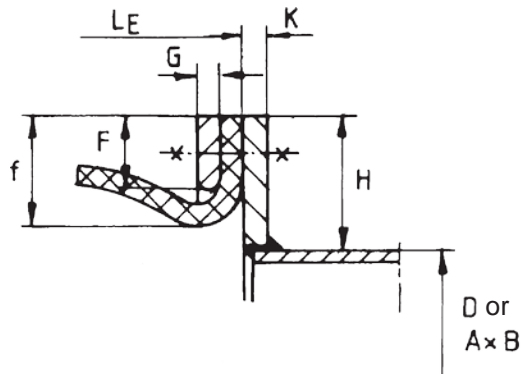
† downwards

## Fabric compensators

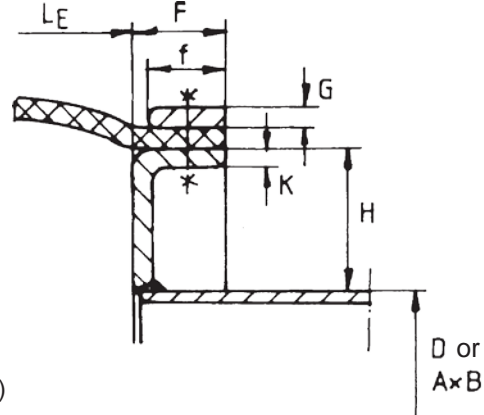
- Usage area
- † outdoors
  - † indoors
  - † Compensator must be insulated from the outside
  - † Pipeline rinsing
- Other (e.g. certificates, pressure tests) :

### 6) Dimensions / type of connection...

† Flange connection (e.g. type 110)



† Band connection (z.B. type 120)



† other type of connection (please provide drawing)

outer diameter D : \_\_\_\_\_ mm or  
ducting dimension A : \_\_\_\_\_ mm , ducting dimension B: \_\_\_\_\_ mm

flange dimension F : \_\_\_\_\_ mm, thickness G : \_\_\_\_\_ mm  
ducting flange H : \_\_\_\_\_ mm, thickness K : \_\_\_\_\_ mm  
Hole diameter d : \_\_\_\_\_ mm, number of holes n : \_\_\_\_\_  
Inside width between the flanges LE : \_\_\_\_\_ mm  
(optional for models such as type 110) flange height f : \_\_\_\_\_ mm

† The dimensions F, f, G, H, K und LE should be determined by Kempchen & Co.

Design :

- † closed or
- † with holes or
- † production based on measurements or
- † other (e.g. one-sided with holes), please specify:
- † open
- † without holes
- † production based on drawing

### 7) Scope of quotation desired and deadlines...

Compensator pre-insulation (where necessary)	† be at hand	† quotation requested
Assembly	† be at hand	† quotation requested
Assembly supervision	† be at hand	† quotation requested
Assembly inspection test	† be at hand	† quotation requested

Backing flanges	† be at hand	† quotation requested, material	: _____
Ducting flange	† be at hand	† quotation requested, material	: _____
Pass tube	† be at hand	† quotation requested, material	: _____
Connection screws	† be at hand	† quotation requested, quality	: _____

For compensators with nuts and washer

or :

Installation parts, pre-assembled  
Surface treatment  
of steel parts provided :

† quotation requested, material : \_\_\_\_\_

† zinc-coated : \_\_\_\_\_  
† Sandblasting : \_\_\_\_\_  
† Primer : \_\_\_\_\_  
† Final coating : \_\_\_\_\_  
† untreated

Quoting deadline: :  
Anticipated delivery deadline :