CICIND

MANUAL FOR EXPANSION JOINTS AND CHIMNEY SEALS

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Note: Figures are included at the back of the Manual rather than in the text to allow bigger, clearer diagrams.

FOREWORD

This document has been prepared by the CICIND expansion joint and chimney seal committee. The committee members consist of:

Mr. Bill Evans	(Great Britain) Chairman
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In addition many valuable contributions were made by members of CICIND.

Note: All dimensions quoted in this manual use the metric system for consistency. The basic unit of measurement is therefore the millimetre (mm) and metric bolt sizes are quoted. Where other units systems are employed, equivalent or similar sizes providing the same degree of strength and durability may be used.

INTRODUCTION

Prior to this publication, CICIND has published information on expansion joints and chimney seals within several Model Codes and in numerous conference papers. This Manual is the first CICIND publication dedicated to the subject of expansion joints and seals within chimneys and their connecting ductwork.

This Manual covers all chimney expansion joints and seals, both within steel and brick chimney liners and also those associated with steel, concrete or brick chimney windshields. Connections of all chimneys via inlet ducts and/or breechings are also covered.

Expansion joints and seals require careful design and selection of materials in order to contain flue gases or air and to accommodate the temperatures, pressures, movements, chemical loading, moisture vibration and abrasion to which they are subjected.

Good design of expansion joints and seals can make a significant contribution to extending the chimney maintenance interval and therefore the total cost of chimney ownership.

SCOPE

Expansion joints and chimney seals include the following:

- Expansion joints in ductwork adjacent to the chimney or within the chimney windshield
- Expansion joints in steel chimney liners
- Expansion joints between lifts of brickwork in brick chimney liners, including flexible membranes and corbel seals
- Chimney cap details to provide a seal or to exclude rainwater between a chimney liner and the roof or windshield at the top of a chimney
- Weather seals around duct openings in chimney windshields
- Seals to access doors, test ports and inspection ports between both chimney liners and windshields

This Manual covers the design of movement expansion joints and seals for all types of industrial chimneys.

The Manual describes the actions to which expansion joints and seals may be subjected, provides details of typical compensator and seal configurations and describes the materials that may be used. The Manual includes sections on fixings and tolerances. It also covers the inspection and maintenance of seals and expansion joints.

1. DESIGN CRITERIA

The materials comprising the expansion joint or seal should be capable of withstanding the normal and abnormal operating temperatures of the flue gas.

The expansion joint or seal should be designed to accommodate the maximum range of thermal movements, wind loading, pressure, earthquake, etc. in all directions associated with normal and abnormal operating conditions. These designs should accommodate the number of cycles of each range of movement expected during the design life of the expansion joint or seal.

The expansion joint and/or seal should withstand both positive and negative pressures associated with plant operation, including start-up conditions and possible fluctuations between positive and negative pressure. Pressure waves, such as those produced by sudden closure of a damper, should be considered.

All materials in the expansion joint and seal should be able to withstand the chemical loading applied to them throughout their design life, without excessive corrosion or degradation under normal operating conditions.

The expansion joint and seal should resist abrasion from particulate matter in the gas stream. They should not suffer damage by abrasion due to the designed thermal movements of the chimney or inlet duct or their supports.

In the design of the expansion joint and seal, care should be taken to limit the entrapment of particulate matter or condensation from the gas stream.

Any part of the expansion joint or seal exposed to daylight should not be adversely affected by ultraviolet light or ozone. In cases where this is not possible, the design life will possibly be reduced.

Consideration should be given to the effects of vibration induced by the gas stream or the structure to which the expansion joint or seal is attached.

2. TYPICAL DESIGN CONFIGURATIONS

2.1 Preamble

2.2 Ductwork expansion joint to chimney

2.3 Duct entrance expansion joint seal at windshield

2.4 Ductwork to linear seal

2.5 Corbel seal

2.6 Rain cap / hat seal

2.7 Test port or instrumental seal

2.8 Weather hood seal

2.9 Flange gasket seal

2.10 FRP liner seals

2.11 High temperature gas seals

Refer to Section 4 for fixing details

2.1 PREAMBLE

There are various sealing areas, and thus configurations, within and about the chimney area. Often, initial design begins with the ductwork from the induced draft fans to the chimney entrance at the windshield. This area represents the start of the design for many chimney builders and includes expansion joints local to both the inlet and outlet sides of the fans. As the ductwork passes through the windshield, terminology changes and expansion joints become more commonly referred to as "seals".

Chimneys with positive pressure between the liner and the windshield often require a "positive pressure seal" (sure seal) at the point where the ductwork passes through the windshield, while other chimneys may simply require a blockage, using inexpensive materials, to prevent birds or inclement weather from passing into the enclosed area.

Seals within the chimney, located on the internal duct flue, at the chimney elbow, and on the corbels themselves, have become much more sophisticated in recent years. At these locations, where accessibility is often a problem and an increasing service life is now demanded, seals made from proven elastomers and/or fluoropolymer materials supplant previous materials to withstand the rigors of elevated temperatures and operating within highly acidic conditions.

Hat seals (Rain Cap Seals), designed in metallic materials in the past, are also following the trend towards the use of elastomers and fluoropolymer base materials, which yield greater flexibility against vibration and thermal movements and also compensate better for initial misalignments during the erection stage.

Test Port Seals provide a sure seal, which prevents ambient air, rain and snow from entering the windshield/ flue area or internal pressurized air from leaking into the atmosphere. These seals are often concentric in configuration and can be installed after test probes or test port extensions are in position.

Weather Hoods involve overlapping bent metal plates to form an enclosure which can be sealed by an elastomeric or a fluoropolymer seal.

Although much of the emphasis within Section 2.0 is on steel, concrete and brick chimneys, not to be forgotten are fibre reinforced plastic (FRP) chimneys. Design parameters, though simpler in FRP applications, employ the same basic designs and configurations referenced herein.

Recognized by all is the fact that variations do exist and the design configurations and details within this section place emphasis on arrangements, materials and configurations with proven track records. The materials presented represent a consensus on components and materials, yet still allow for alternate designs and future innovation. Utilisation of the ideas presented, and their overall effectiveness, depends greatly on the individual design and the conditions particular to any situation.

2.2 DUCTWORK COMPENSATOR TO CHIMNEY

2.2.1 Typical flue duct expansion joints (metallic arrangement)

This configuration (Figure 1) details a convoluted metal compensator. The metallic compensator should be designed to the exact number of convolutions required to absorb the thermal or wind deflection movements anticipated. Care should be taken when specifying the exact configuration to consider all axial and lateral movements and any foreseen torsional movement. Selection criteria should include an evaluation of vibration which may reduce life as a result of vibration fatigue to the metal frame or bellows.

Although metal compensators absorb straight axial movements well, lateral movement absorption is limited. If lateral movements are excessive, metal compensators may require a double tandem configuration, which provides a pivot arrangement to absorb this multidirectional shear. However, tandem designs require not only considerable expense but also increased length.

The configuration of the bellows can vary in shape, width and height, all dependant upon the design. All metallic models may be either welded to the ductwork flanges or bolted (with gaskets) into position. Metal internal liners (baffles) may have to be utilised in order to prevent abrasive wear. Pins, guides and/or slots are frequently installed to control duct movement and direction. Wind loading should be considered in the compensator's design.

2.2.2 Typical flue duct expansion joints (non-metallic arrangement)

This configuration (Figure 2) details a non-metallic (fabric) compensator in a “U-type” (flanged) design.

Effective materials include elastomers and/or fluoropolymer coated fabrics as the base material. Also used as non-metallic compensators are multiple composite fabric designs; although care should be taken when specifying these, as composites are susceptible to moisture that, on a continuing basis, may reduce the expected service life.

U-type designs minimise the amount of set back from the inside of ductwork thus reducing the amount of ash accumulation at the compensator. The design in Figure 2 simply bolts into the flanges of the ductwork. Metal retaining rings (backing bars) are always used to clamp the non-metallic compensator into position on the steel frame.

No flange gaskets are required on elastomeric models. Fluoropolymer designs, due to the thin gauge and lack of compressibility, require gaskets between the steel frames and the non-metallic compensator to ensure a good seal. Steel flange heights of 75mm are common.

Elastomers normally do not require internal liners as they handle abrasive flow conditions extremely well, unlike fluoropolymers that normally do employ liners.

Elastomers are flexible, absorb vibration extremely well, and handle elevated temperatures with a wide chemical resistance range. Fluoropolymers offer outstanding temperature and acid resistance but are not sturdy in high vibration situations where flutter is present and extreme flexibility is required.

Both the elastomers and fluoropolymer styles are lightweight, easy to install and can be simply repaired. Metallic, fibreglass or similar synthetic fibre reinforcement imbedded within both elastomeric and the fluoropolymer designs offer a substrate which provides most designers the optimum choice for high tensile strength (flexing and pressure) and acid resistance.

2.3 DUCT ENTRANCE EXPANSION JOINT SEAL AT WINDSHIELD

2.3.1 Duct entrance to chimney (basic windshield arrangement)

Historically, dual bent metal plates which are affixed to the outside of the duct and secondly to the windshield itself (Figure 3), have been the norm in satisfying a sealing area in chimneys which are not under a positive pressure. Typically, these designs are not a sure seal; yet a complete seal is required within this design criterion. Packing and insulation are sometimes stuffed in the open area between the bent plates as a simple means to limit weathering and/or birds from entering the chimney. Also used, to prevent bird access, are wire mesh screens anchored to either of the plates.

2.3.2 Duct entrance to chimney seal at windshield (non-metallic seal arrangement)

This configuration (Figure 4) details a non-metallic elastomeric expansion joint which is a seal to the system and is commonly used in positive pressure applications. The elastomer seal is “picture frame” in configuration and is specially manufactured (including specially manufactured corners) to accommodate the size differential from the different dimensional points where it is fixed (one side to the outside of the ductwork and the opposite side to the windshield itself). Flexible, easy to install and with the ability to handle large thermal and wind movements, this expansion joint represents a long term solution to the chimney entrance.

2.4 DUCTWORK TO LINER SEAL

2.4.1 Chimney elbow seal

Detail A within Figure 5 connects the end piece of the flue to the first corbel and is referred to as the “Chimney Elbow Seal” The seal, manufactured from elastomers or fluoropolymerr materials, is a belt style configuration normally supplied in a wide face in order to span the distance between the openings. Often, when the two connecting sections have different inside dimensions, the seal is fabricated in a conical configuration.

2.4.2 Ductwork to metallic liner seal

Detail A within Figure 6 connects the end piece of the flue to the metallic liner. The seal, manufactured from elastomer or fluoropolymer materials, is a belt style configuration. It is normally supplied in a wide face in order to span the distance between openings.

2.5 CORBEL SEALS

2.5.1 Corbel seals

Non-metallic corbel seals (Figure 7) connect the corbel sections and maintain the seal to the system in negative or positive pressure chimneys. Corbel seals are supplied in a flat belt construction and must be made conical in form when the two connection areas have different inside dimensions. Mastic sealants are often utilised between the rough brick surface and the expansion joint to ensure a perfect gas seal.

2.5.2 Corbel seals / packing seal arrangement

Historically and before the advent of advanced non-metallic seals, negatively pressurized chimneys utilised packing ropes which are wedged into a cavity area formed where the corbels overlap (Figure 8). Inexpensive to purchase and install, sealing ropes do not provide a sure seal and may show susceptibility to acid attack over a relatively short service life. The least expensive and least effective measures involve configurations utilising loose fibreglass or ceramic needle mats while ropes, if utilised, are often furnished top coated in elastomers in an effort to extended acid resistance and service life.

2.6 RAINCAP / HAT SEAL

2.6.1 Rain cap / hat seals
(non-metallic arrangement)

Non-metallic rain caps (Figure 9) are manufactured from elastomers or fluoropolymers in order to connect the outer chimney shell to the inner liner at the top of the chimney. Often used in connection with sealing ropes which serve as a spacer and a secondary seal, rain cap seals are a flat belt configuration and fabricated in a concentric form if the two connecting sections do not line-up in a relatively parallel position.

2.6.2 Rain cap / hat seals
(metallic arrangement)

Metallic rain caps (Figure 10) are manufactured to connect with the outer chimney shell and overlap the interior liner. The arrangement does not provide an absolute seal but does keep most weathering from entering the cavity between the windshield and the liner.

2.7 TEST PORT OR INSTRUMENT SEAL

2.7.1 Test Port Seals Fixed At Liner

The opening in the windshield, which is larger than the test or instrument port to allow for differential movement between the windshield and the liner, must be scaled off to prevent moisture from entering or internal gases from escaping. Figure 11 demonstrates elastomeric concentric seals fixed at one end to the port's outer surface with the opposite side attached to the windshield. The seals are supplied open ended and are spliced on site after being installed. The outer sealing area on the windshield is often not spliced but supplied with a zip, or similar means of closure.

Figures 12 and 13 show test port seals fixed at the windshield and for metal chimneys respectively.

2.8 WEATHER HOOD SEAL

Weather hoods, formed from bent plates (Figure 14), prevent weather and birds from entering the chimney cap. The arrangement does not provide an absolute sealing area but does keep most weathering from entering the cavity between the windshield and the liner.

2.9 FLANGE GASKET SEAL

Flange gaskets are used to seal surfaces where metal to metal connections meet and are bolted together (Figure 15). Access doors also employ gaskets to ensure a good seal when closed. Elastomeric seals, normally manufactured from FKM, are supplied in sponge form in a +44 durometer hardness which ensures sealability and low compression set. Alternate designs include fibreglass tapes often coated with Teflon 0 to improve acid resistance. Pure Teflon 0 ropes are also specified particularly on fluoropolymer designs providing sealability, acid resistance and easy installation. Mastics, or pure Teflon 0 ropes, are used in compensator and seal areas to create a smooth sealing surface. Coated fibreglass gaskets and ropes are used in areas of high temperature.

2.10 FRP LINER SEALS

Seals that connect the two ends of FRP liners are often subjected to large thermal movements and aggressive gases. Care should be taken when selecting a material for this application (Figure 16) to ensure that it can comply with the design conditions specified and also ensure that an adequate seal can be achieved in the fixing area.

2.11 HIGH TEMPERATURE GAS SEALS

The seal in this configuration (Figure 17) should be designed to withstand the full gas temperature and not rely on the insulation pillow.

The sleeve is designed to point against the gas flow to prevent particulates from being trapped behind it.

3 MATERIALS

The selection of materials must be based on functional and structural requirements, chemical and corrosion resistance, as well as high temperature capability. Systems at or below the dew point can result in highly corrosive condensates. New materials and grades are continually being developed so suppliers should be consulted at all times to ensure that the most suitable products are specified

3.1 STRUCTURAL MATERIALS

Mild steel to high grade alloys may be specified depending on the corrosion resistance required. The following are an indication of typical materials:

Carbon steel	With coating such as galvanizing, zinc plating or fluoroelastomer (FKM) coating; Lined with stainless steel, nickel alloy or titanium
Stainless Steels	ASTM 304L,309,316L,317,321, DIN 1.4306,1.4435, 1.4571, 1.4539
Nickel Alloys	Alloy C22*,59**,C276,625 or 686***
Titanium	Grade 2

For details of metallic materials performance see CICIND Metallic Materials Manual.

The metal supplier should be consulted to ensure that a specific alloy is the optimum material for the service conditions.

In the case of hat seals cast iron, stainless steel, nickel base alloy, FKM or acid resistant glass reinforced plastic may be used.

Acid resistant ceramic blocks may be used as backing plates for corbel expansion joints, duct seals and other expansion joints.

*Product of Haynes International

**Product of Krupp-VDM

***Product of International Nickel Alloys

3.2 NON—METALLIC FLEXIBLE ELEMENTS

Most chimney seals or expansion joints are usually constructed from non-metallic materials.

Appendix A defines the capabilities of elastomers and fluoropolymers commonly used in chimney and flue duct expansion joints.

The elastomers used in these applications should be specifically compounded to perform adequately with regard to the service conditions including tensile properties, abrasion, environmental, heat and chemical resistance.

Where flexible element materials are used in areas with a continuous operating temperature above the maximum continuous temperature rating for any of the constituent materials they must be protected with suitable insulation (see paragraph 3.3) to ensure adequate service life.

Table 1 shows the maximum continuous temperature rating and acceptable time limits for short term excursions at high temperatures. All excursions at temperatures higher than the maximum continuous temperature rating will have a detrimental effect on the useful life of the expansion joint.

Where abrasive particles are present in the flue gases the expansion joint should be set back out of the gas stream. If the joint contains insulation or is protected by an insulation pillow it is advisable to protect it with a suitable metal liner or sleeve.

Elastomeric materials for expansion joints should always be used with a reinforcement. Typical reinforcing materials are glass fibre, aramid fibre or corrosion resistant alloy wire.

Table 2 defines the capabilities of suitable fibre and fabric reinforcing materials. Particular regard must be shown to corrosion, chemical and heat resistance requirements especially where an uncoated fabric is used.

3.3 THERMAL INSULATION

In case gas temperatures exceed the upper service limit of the sealing materials, insulating materials are used to reduce interface temperatures. Glass fibre blankets are suitable up to 540℃ (1000℉) and ceramic fibre blankets may be used between 540℃ and 980℃ (1800℉) but may have mechanical and chemical limitations.

3.4 SEALANTS, ADHESIVES AND PACKING MATERIALS

To ensure a gas tight seal between an elastomeric expansion joint and an irregular surface, e.g. a brick or concrete wall, a flexible elastomeric sealant should be used. Again attention must be paid to the chemical and heat resistant properties of the sealant.

Adhesives must be compatible with the substrates to be bonded and the process conditions involved at that location.

Braided glass coated in PTFE or a suitable elastomer may be used as dry packings or gaskets. PTFE rope may be used as a seal between an expansion joint and an uneven substrate or backing place.

Fibre-based sheet materials may be used as gaskets in areas which are within the manufacturer's service limits.

Materials should only be applied in accordance with the manufacturers' recommendations

	Elastomers						Fluoroplastics	
	Neoprene	Hypalon[4]	EPDM	Chlorobutyl	Fluoroelastomer[1]	Silicone	Poly Tetrafluoro Ethylene	Fluoro Ethylene Propylene
ASTM Designations	CR	CSM	EPDM	CIIR	FKM	SL	PTFE	FEP
Material Temperature	All Temperatures °F							
I. Minimum (Low temp brittle point)	-40°	-40°	-60°	-40°	-40°	-60°	-110°	-110°
Continuous operating	180°	225°	300°	300°	400°	450°	500°	400°
Intermittent operating temperature[2] / Accumulative, hrs	250° 168	250° 2600	350° 200	350° 150	550° 240	/	700° 75	500° 100
		350° 70			600° 48			
					650° 16			
					700° 4			
					750° 2			
II Chemical resistance								
H_2O_4 acid, hot (+) less than 50% concentration	B – C	A	A	A	A	C	A	A
H_2O_4 acid hot over 50% concentration	C	B	B – C	B – C	A	C	A	A
HCl acid hot less than 20% concentration	C	B	B	B	A	C	A	A
HCl acid hot over 20% concentration	C	C	C	C	A – B	C	A	A
Anhydrous Ammonia	A	B	A	A	C	C		
NaOH less than 20% concentration	A	A	A	A	A	A	A	A
NaOH over 20% concentration	A	A	A	A	B	B	A	A
III. Abrasion Resistance	A	A	A	A	A	C	C	C
IV. Environmental resistance								
Ozone	B	A	A	A	A	A	A	A
Oxidation	B	A	A	A	A	A	A	A
Sunlight	B	A	A	A	A	A	A	A
Radiation[3]	A	A	A	C	B	B	C	C

1 *Fluoroelastomers when reinforced with non-reactive materials have an intermittent temperature capability of 4hrs @ 700°F and 2hrs @ 750°F*

2 *Excursions at high temperatures will have a detrimental effect on useful life*

3 *Any nuclear application should be referred to expansion joint manufacturer for a specific recommendation*

4 *Viton and Hypalon are registered trademarks of DuPont Dow Elastomers for its fluoroelastomer and chlorosulphonated polyethylene elastomer products*

Rating Code

A = Little or no effect

B = Minor to moderate effect

C = Severe effect

Table 1 - Chemical resistance of elastomers

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Reinforcing materials	Aramid	Fibreglass	Corrosion resistant alloy wire	Polyester	Ceramic
* Temperature Capability	450°F	700-1000°F	2500°F	250°F	1800°F
Chemical resistance					
Dilute H_2SO_4	B	B	A	B	A
Concentrated H_2SO_4	C	C	B	C	A
SO_2 and SO_3	B	B	A	B	A
Caustic	B	B	B	B	C

Rating Code

A = Little or no effect

B = Minor to moderate effect

C = Severe effect

Table 2 - Properties of reinforcement materials

	Fabric Joints						Elastomeric Expansion Joints					
Bolt Size	**Width of Bar**						**Width of Bar**					
	30mm	**40mm**	**50mm**	**60mm**	**70mm**	**80mm**	**30mm**	**40mm**	**50mm**	**60mm**	**70mm**	**80mm**
M8	20 Nm	-	-	-	-	-	20 Nm	-	-	-	-	-
M10	30 Nm	40 Nm	-	-	-	-	30 Nm	30 Nm	-	-	-	-
M12	-	50 Nm	60 Nm	-	-	-	-	40 Nm	50 Nm	-	-	-
M16	-	65 Nm	80 Nm	100 Nm	115 Nm	130 Nm	-	50 Nm	65 Nm	75 Nm	90 Nm	100 Nm
M20	-	-	100 Nm	120 Nm	140 Nm	160 Nm	-	-	75 Nm	90 Nm	110 Nm	125 Nm
M24	-	-	115 Nm	140 Nm	165 Nm	190 Nm	-	-	85 Nm	105 Nm	125 Nm	145 Nm
M27	-	-	120 Nm	150 Nm	180 Nm	210 Nm	-	-	95 Nm	115 Nm	140 Nm	160 Nm
M30	-	-	-	165 Nm	195 Nm	225 Nm	-	-	-	125 Nm	150 Nm	175 Nm
M33	-	-	-	175 Nm	210 Nm	240 Nm	-	-	-	135 Nm	160 Nm	190 Nm

Values valid for MoS_2 lubricated bolting

Table 3 - Guidelines for bolted expansion joints (courtesy of the RAL)

4 FIXINGS

Refer to Section 2 for configuration details.

Refer to Table 3 for bolt torque settings and Table 4 for clamp bar details

Figure 1

Typically, the flange is bolted with M16 to M20 hexagon headed bolt using two washers and a gasket. Bolts are spaced at centres of 100mm to 150mm. Flanges are often seal welded, both internally and externally to avoid long term leakage.

Figure 2

The expansion joint is usually installed using M12 or M16 hexagon headed bolt or countersunk bolts. The head of the bolt is always to the inside of the expansion joint. A gasket is required between the duct flange and internal sleeve, but not between the sleeve and expansion joint. Bolt spaced between 100 rounded edges to avoid damaging the expansion joint.

Figure 3

The fixing on the windshield incorporates M10 to M12 expanding anchors at 200 to 250 mm centres.

Figure 4

The fixing on the windshield uses a clamping bar of 40 x 6 to 50 x 10 using M10 to M12 expanding anchors. The fixing on flue duct incorporates M10 to M16 studs or bolts welded into position. Spacing of the top and bottom fixings is at 200 to 250 mm centres.

Figure 5 Detail A

The attachment of the bottom expansion joint to the flue duct uses M10 to M12 hexagon headed bolts, studs or tapered holes. Clamping bars can be either round edge flat bar (40 x 6 to 50 x 10) or special ceramic fixing blocks. Bolts are spaced at 100 to 150mm centres.

The attachment of the top of expansion joint can be achieved using expanding anchors or by setting a stud in the brick with acid resistant mortar. With new installations it is worth noting that bricks can be manufactured with holes installed ready to accommodate anchors or studs.

Attachment of the top of the expansion joint to the acid resistant concrete or brick liner is achieved using M10 to M12 expanding anchors spaced at 100 to 150 mm centres. Care must be taken to ensure that the material to be drilled can accommodate an anchor without cracking. A mastic is required between the compensator and a brick or concrete surface to ensure a gas tight seal.

To achieve a uniform distance between bolt centres, holes can be drilled in the gap between bricks when joints are filled with potassium silicate mortar. Liner materials, especially those in older chimneys, must be checked to ensure the suitability of the fixing method.

The bottom of the joint can be fixed to the metal liner by studs welded to the surface or by drilling holes and fixing with bolts and nuts, with the bolt head positioned in the gas stream. This bottom fixing must be installed before the top fixing is attempted.

Care must be taken to ensure that all fixings exposed to the gas are suitably chemically resistant.

Figure 6

Normally the fixing for this expansion joint is not exposed to the flue gas and on small diameters can be achieved by band clamps with a suitable tightening mechanism. However, for larger diameters studs and backing bars at 150 centres must be used.

Figure 7

As per drawing Figure 5 detail A for attachment to a concrete or brick liner.

Figure 8

No fixing required as packing/seal is pushed into position

Figure 9

As per Figure 8

Figure 10

Fixing is achieved by using M10 to M16 expanding anchors. Care must be taken to ensure that the liner can accommodate the expanding anchors.

Width	30	40	50	60	70	80	90	100	mm
Thickness	6/8	8/10	8/10	10/12	10/12	12	12	12/15	mm
Bolt spacing	60	80	100	100	120	120	120	120	mm
Bolt size	8/10	10/12	10/12	12/16	12/16	16	16	16/20	mm

The above values are to be used guide only.
Consult the expansion joint manufacturer for specific details.

Table 4 - Guidelines for the Dimensioning of Clamp Bars

Figures 11 and 12

Attachment to the concrete and brick is achieved by using M8 to M10 expanding anchors at 150 mm centres. Clamping bars 30 x 6 to 40 x 10.

Internal fixings should be chemically resistant to gases but external fixings should be suitable for normal ambient conditions.

Figure 13

Band clamps with suitable tightening mechanism.

Figure 14

The fixing on the windshield uses a clamping bar of 40 x 6 to 50 x 10 and M10 to M12 expanding anchors. The fixing on the flue duct incorporates M10 to M16 studs or bolts welded into position. The spacing of the top and bottom fixings is at 200 to 250 mm centres.

Figure 15

M12 to M16 bolts on centres of 100 to 150 mm.

Figure 16

The seal is installed with a tight fit against the outer wall of the FRP liner. It is held in position by M8 self-tapping screws, installed through the joint and into the liner and ensuring that the liner is not pierced. These screws should be positioned every 250 mm. The seal should be mounted with a landing area of approximately 250 mm on each side of the liner.

The FRP fixing strip is then bonded to the outside of the seal and the liner wall.

Figure 17

The expansion joint is usually installed using M12 to M16 bolts spaced from 100 to 150 mm centres.

The clamping bar should have a radius in the corner to avoid damaging the seal. A gasket is not required between the joint and the mounting metal flanges.

5 TOLERANCES

The tolerance values used in the design and construction of compensators and seals should be compatible with those appropriate to the parts of the chimney to which the seal is attached. Tolerance values for chimney components are given in the following CICIND Model Codes:

- Model Code for Concrete Chimneys Part A: The Shell
- Commentaries for the Model Code for Concrete Chimneys Part A: The Shell
- Model Code for Concrete Chimneys Part B: Brickwork Linings Including Commentaries 1-6
- Model Code for Steel Chimneys
- Commentaries for the Model Code for Steel Chimneys
- Manual for Inspection & Maintenance of Brickwork & Concrete Chimneys

6 TRANSPORTATION, STORAGE & HANDLING FOR INSTALLATION

6.1 TRANSPORT

Expansion joints are packed for transit according to their size, the method and duration of transportation, the final shipping destination and the anticipated duration of storage. Damage should not occur during normal transportation.

Cardboard boxes on pallets, wooden boxes and containers are designed/suitable for handling by fork lift trucks and cranes as appropriate. Cardboard boxes on pallets must not be stored on top of each other. The maximum bearing capacity (supporting capacity) must be respected.

Unpacked expansion joints should be moved with extreme care. Please note the following items :

- Unpacked expansion joints must be placed on a secure base (e.g. pallet) and must be protected temporarily during transportation (including on site).
- The attachment points for the lifting equipment must be on the base (pallet).
- Where appropriate, always use several persons for carrying.
- Do not drag expansion joints along the ground or edges.
- Respect decreased bending properties at low temperatures.

6.2 STORAGE

The condition and the duration of storage have an influence on the condition of the expansion joint.

- Store expansion joints in their original packaging
- Store expansion joints under dry conditions. Avoid high humidity.
- Protect expansion joints from direct weather influence e.g. direct sunlight, rain etc.
- If possible store expansion joints inside buildings.
- Recommended temperature for storage is +10℃ to +20℃
- Do not store other equipment on top of the expansion joints
- Ozone penetration, chemical influence and aggressive environmental conditions must be avoided for storage longer then 6 months.

6.2.1 Short term storage before installation.

The following additional conditions are recommended :

- Store expansion joints in weatherproof container e.g. overseas container
- During short term storage outside, the expansion joint must be covered with an appropriate weather proof cover and should be protected against dampness from the ground.
- At low ambient temperatures, expansion joints have an increased resistance to bending. Under these conditions, it is recommended that the expansion joint should be stored inside a warmer environment immediately prior to installation

6.3 HANDLING FOR INSTALLATION

To preserve the working life and reliability of the expansion joint, please observe the following precautions:

- Large/heavy expansion joints must be supported fully during installation with crane or pulleys
- Expansion joints must not be lifted by attaching the lifting device directly to the fabric. The fabric expansion joint should rest on a supporting base, to which lifting tackle can be attached.
- Expansion joints which have been pre-assembled by the manufacturer must be lifted by the lifting points and not by their shipping straps (unless the manufacturer has combined the two).
- Any protective cover and/or shipping bars must not be removed until installation is completed, but must be removed immediately prior to start up.
- Protect the expansion joint from welding sparks and sharp objects where appropriate.
- Do not walk on or place scaffolding on the expansion joints.
- All clamp bars, including their bolts and nuts, must be in place and hand tight before tightening further.
- Required bolt loading will vary, dependant upon the type of expansion joint, bolt dimensions, bolt lubrication, bolt distance etc. Please see the chart in the appendix for bolting guidelines for bolted expansion joints.

7 INSPECTION AND MAINTENANCE

7.1 GENERAL

Like any other component in an industrial plant, an expansion joint requires supervision to ensure maximum reliability. Expansion joints should be regarded as wearing parts, meaning those parts which need to be replaced at regular intervals. Costly shutdowns and emergency situations can be often be avoided by replacing wearing parts in a timely fashion.

Although, in general, expansion joints and seals do not require actual maintenance, they should be inspected regularly for signs of damage. The first sign of damage will be visible on the surface. The coating may start to discolour or peel, depending on the type of damage (thermal or chemical). If any of these signs appear, contact the expansion joint manufacturer immediately.

The inspection and maintenance of expansion joints and seals should be included in the overall maintenance plan for the chimney. When expansion joints and seals are detailed, consideration should be given to providing access to the expansion joint and areas "behind" the expansion joint for inspection. The need for demolition or expensive dismantling to enable inspection should be avoided if possible. Every opportunity should be taken to assist replacement of elements of the expansion joint that may need frequent replacement.

7.2 INSPECTION FREQUENCY

Inspection of expansion joints and seals should take place at every chimney inspection but at maximum intervals of two years. If the expansion joints or seals are accessible while the chimney is in service, annual inspections are recommended.

Excursions from design operating conditions may occur infrequently. These excursions or upset conditions may include:

- High temperature or fire
- Low temperature
- Excessive pressure or explosion
- Low pressure
- Chemical carry over
- Physical damage through, accident, lightning, etc.
- Prolonged shutdown periods

The magnitude and effect of these excursions on the expansion joints and seals should be evaluated and additional inspection and repairs carried out as deemed necessary.

7.3 INSPECTION IMPORTANCE

The anticipated frequency of failure of the expansion joints and seals shall be determined together with an evaluation of the consequential effects of failure. This will then enable inspection criteria and methods of inspection to be predetermined. The time a chimney is out of service to allow inspection and repairs may be a consequential loss in its own right.

7.3.1 Low Consequential Losses

If the consequences of expansion joint and seal failure are low and the fault will not cause hazard or damage; low cost materials and infrequent inspection will suffice.

7.3.2 Medium Consequential Losses

If failure does not cause an immediate hazard but deterioration of the support structures is likely to occur, then planned regular inspection should be carried out at a frequency consistent with reducing damage to acceptable limits. Economic evaluation should be made as to the choice of expansion joint details and materials.

7.3.3 High Consequential Losses

If failure would create immediate hazards, expensive decommissioning, rapid deterioration and/or high cost damage to support structures and adjacent equipment, special precautions need to be taken which may include:

- using the most durable materials available;
- redundancy in the design of the expansion joint/ seal;
- constant inspection of expansion joints or seals by monitoring gas quality or temperature;
- visual monitoring daily;
- provision for rapid replacement of expansion joint/ seal.

7.4 ROUTINE INSPECTIONS & MAINTENANCE

7.4.1 Metallic Cap

The following should be inspected:

- Protective coating on cap, if applicable
- Expansion joints between segments
- Glasscloth seal
- Glasswool packing

Maintenance should include cleaning, painting and removal of damaged elements. Renewal of seals and cleaning of cap packing shall be done in conjunction with lining repairs.

7.4.2 Fabric Rain Cap

The following should be inspected:

- Fabric material
- Fixings

Maintenance should include renewal of damaged elements.

7.4.3 Brickwork Opening

- Fabric seals
- Fixings
- Steel plates

Maintenance should include cleaning of steelwork and replacement of damaged elements.

7.4.4 Corbel Seals

The following should be inspected

- Flexible membrane

- Scaling cloth
- Glasswool packing

Maintenance should include removal of deposits and replacements of damaged elements. Replacements of glasswool cloth can only be done in conjunction with lining repairs and fixing of the cloth may require modification of the existing seal.

7.4.5 Flue Duct Seals

The following should be inspected:

- Steel plates
- Glasswool cloth
- Packing
- Sealer
- Fixings

Maintenance should include cleaning of steelwork and replacement of damaged elements.

7.4.6 Duct Plates

- Fabric seals
- Steel plates and angels
- Fixings

Maintenance should include cleaning of steelwork and replacement of damaged elements.

7.4.7 Test Port Seals

The following should be inspected:

- Fabric seals
- Steel tubes, flanges and plates
- Fixings

Maintenance should include removal of deposits, cleaning of steelwork and replacement of damaged elements.

In the case of non-metallic expansion joints, splicing and/ or repair, field service technicians, or purchasing kits are available as situations warrant.

8 NOTATIONS & DEFINITIONS

ACTIVE LENGTH (LIVE LENGTH)

The exposed portion of the flexible part of the compensator that is free to move.

AXIAL COMPRESSION

The dimensional shortening of a compensator parallel to its longitudinal axis.

AXIAL EXTENSION

The dimensional lengthening of a compensator parallel to its longitudinal axis

ABNORMAL OPERATIONAL TEMPERATURES

High flue gas temperatures due to unusual or emergency operation of the plant. Includes breakdown of sections of the plant such as heat recovery equipment. Prolonged shutdown of the plant may also be included.

BACKING BARS

Metal bars used for the purpose of clamping the compensator to the frame.

BAFFLE

See "Liner"

BELT TYPE COMPENSATOR

A compensator in which the flexible bellows portion of the compensator is like a flat belt and is bolted or clamped to metal adaptor flanges or frame.

BOLT HOLE PATTERNS OR DRILL PATTERN

The systematic location of bolt holes in the duct flanges and the compensator flanges.

BRAIDED / PACKING SEALS

Woven threads of fiberglass, Kevlar, ceramic or the like, braided together to form a square or round rope. Sometimes coated with Teflon or elastomers for added protection. Used between the gap of two components as a static seal to contain flue gases, air or liquids.

BREACH OPENING OR DUCT FACE-TO-FACE LENGTH

The length between the duct or chimney components where the compensator is to be installed.

CHIMNEY ENTRANCE SEALS

Compensators or packing seals used to close off open areas of ductwork entering chimney and the windshield.

CLAMP BARS

Same as backing bars

COLD PRESET

Term used when a compensator is expanded, compressed or laterally offset in the cold installed position.

COMPENSATORS

Metallic or non-metallic materials forming a component used to absorb axial and transverse movements due to thermal expansion or vibration of ductwork and chimney liners. Same as an expansion joint.

COMPOSITE COMPENSATOR

A compensator in which plies of different materials are not bonded together. Normally comprised of an inner liner, thermal insulating barrier, gas barrier and/or an outer cover. Other special plies can be included.

COMPRESSION SET

The permanent distortion of a compensator seen when the compensator is removed from its installed position. The compensator has taken a permanent style that closely resembles the shape seen when in the operational position.

CONCURRENT MOVEMENTS

Combination of two or more types (axial or lateral) of movements occurring simultaneously.

CONTINUOUS TEMPERATURE RATING

Continuous temperature at which a compensator or seal can be operated

CORBEL SEAL

Flexible element at a chimney brickwork liner corbel to withstand differential pressure.

DESIGN TEMPERATURE

The maximum temperature expected during normal operation.

DESIGN PRESSURE

The maximum positive or negative pressure conditions that exist during normal operation

DEW POINT

The temperature at which a particular flue gas starts to form condensation. Acid dew point varies with gas composition and is a higher temperature than the moisture dew point.

DUCT INSIDE DIMENSION

The inside dimension of the ductwork measured from the duct wall prior to any coating.

EMERGENCY OPERATIONAL TEMPERATURE

Temperature/pressure not quantified in specification. These may include a fire or explosion in the chimney or conditions resulting from a catastrophic failure of plant.

EPDM

The generally used short name for ethylene propylene rubber which can be cured with sulphur.

EPR

The generally used short name for ethylene propylene rubber which cannot be cured with sulphur and is usually cured with peroxide.

EXCURSION TEMPERATURE

The temperature the system reaches during a system equipment failure or upset condition. Excursion temperature should be defined as a peak temperature and a maximum duration of excursion set.

EXPANSION JOINTS

See “Compensators”

FIELD ASSEMBLY

A compensator that is assembled at the job site due to its size (too large to ship) or the location of the breach opening make it more practical to install in sections.

FIXINGS

The mechanical system for holding the seal or compensator in position and creating a seal between the sealing mechanism and the structure.

FKM

A.S.T.M. designation for fluoroelastomer, used in the USA

FLEXIBLE MEMBRANE

The item that flexes under thermal growth or movement and prevents gases escaping.

FLUE GAS DUCT

Duct which connects the flue gas to the chimney.

FLUOROPOLYMER

Used as a generic term for fluoroplastics.

FLUTTER

Vibration of the joint caused by the turbulence in the gas stream or equipment

FPM

A.S.T.M. designation for fluoroelastomer used in Europe.

FRP

Fiberglass reinforced plastic.

HAT SEALS

See “Rain Cap Seals”

HYPALON®

Is a registered trademark of DuPont Dow elastomers for chlorosulfonated polyethylene

LATERAL DEFLECTION OR LATERAL MOVEMENT

The displacement of the compensator in a direction perpendicular to the compensator’s longitudinal axis.

LEAD SEALS

Pressure seal formed by encasing a layer of sheet lead between the bricks of the windshield and liner. Old method of forming a seal, which is less often used now.

LIFE CYCLES

Number of times the compensators is operated from the cold to hot position and then back to the cold position

LINER

An internal shield which prevents abrasive particles from directly contacting the compensator

MANUFACTURED FACE TO FACE WIDTH OF COMPENSATOR

The manufactured width of the compensator measured from compensator flange face to flange face. The compensator may be set into a breach opening that is less than manufactured F/F of the compensator to allow for axial extension.

MAXIMUM DESIGN TEMPERATURE

The maximum temperature that the system may reach during normal operating conditions. Not to be confused with excursion temperature.

MISALIGNMENT

The out of line condition that exists between the adjacent faces of the breach or duct flanges during ductwork assembly.

MOVEMENTS

The dimensional changes which the compensator is required to absorb, such as those resulting from thermal expansion or contraction.

NORMAL OPERATIONAL TEMPERATURE

Includes part or full load operation of the plant, or operation with some plant shutdown.

OUTER COVER

The external component of a composite or elastomeric type compensator

PICTURE FRAME

Compensator that seals a rectangular opening in a chimney windshield

PTFE

Polytetrafluoroethylene.

RAIN CAP SEALS

Compensator seals used to seal off area between a chimney windshield and the inner chimney liner. Alternative name for Chimney Cap Seal or hat seal.

RESULTANT MOVEMENT

The net effect of concurrent movements

SEAL GASKETS

A gasket that is placed between two adjacent metal parts to make a gas-tight seal.

SEALANT

Sealant that can be applied in a semi-liquid state that will partially solidify when exposed to ambient conditions.

SERVICE LIFE

Length of time that is estimated the compensator will operate without the need to be replaced or maintained

SILICONE RUBBER

An elastomer which is based on a silicone polymer backbone rather than the more common carbon backbone.

SPLICES

Procedure for making a seal, gasket or compensator endless after being supplied from open ended material. Splicing may be accomplished by one or more of the following : cementing, bonding, heat sealing, stitching, vulcanizing, or mechanical fasteners; usually takes place after installation.

THERMAL BARRIER

Insulating material in a composite compensator designed to reduce the surface temperature of adjacent plies.

THERMAL INSULATION PILLOW

Insulating material encased in a flexible fabric designed to reduce the surface temperature to the inner surface of a flexible element.

TEST / INSTRUMENT PORT SEALS

Test probes are devices which extend through the concrete, brick or steel wall, through the liner. Test ports can be, but are not limited to testing tubes, sensors, or similar devices to sample flue gas. Test port seals protect test probes and equipment from rain, ozone, sunlight ultraviolet, and other weathering or outside damage. Test port seals are utilised on both the outer shell and as the probe passes through the liner.

U – TYPE SEALS

Compensator that is designed to have flanges. Cross-sectional view indicates the compensator to have an elongated “U” Shape.

WINDSHIELD

The outer shell of a chimney.

9 REFERENCES

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- “Why and How to Specify the Right Materials of Construction for Non – Metallic Flue Duct Expansion Joints” – J.G.Bauerle – E I DuPont de Nemours
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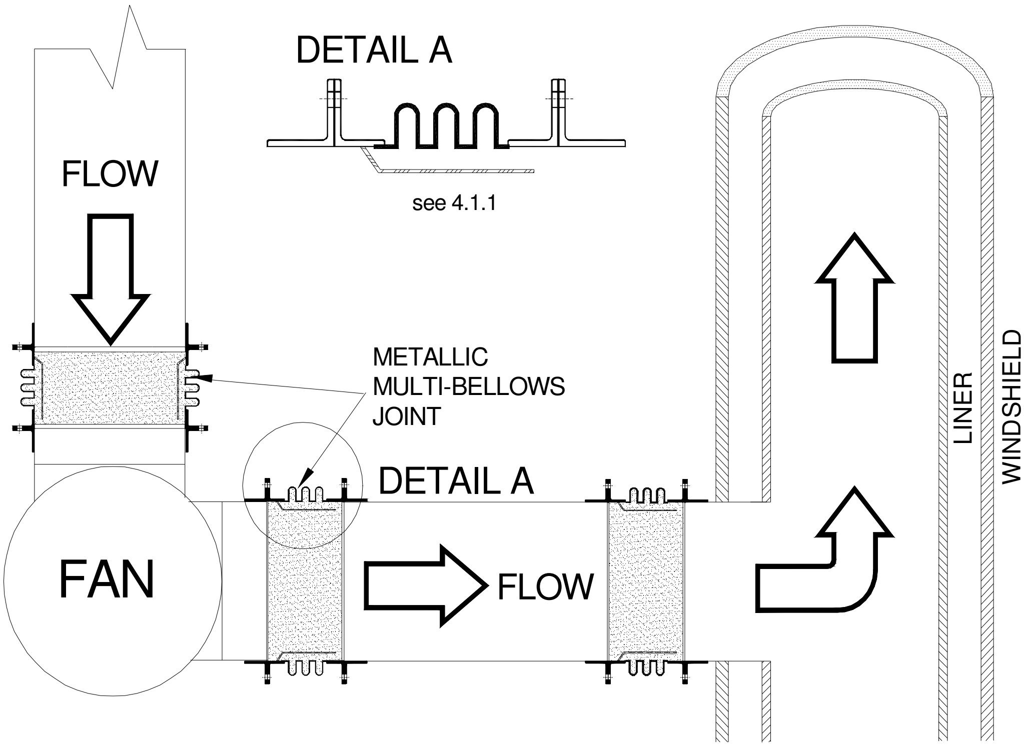

Figure 1 - Metallic compensator arrangement

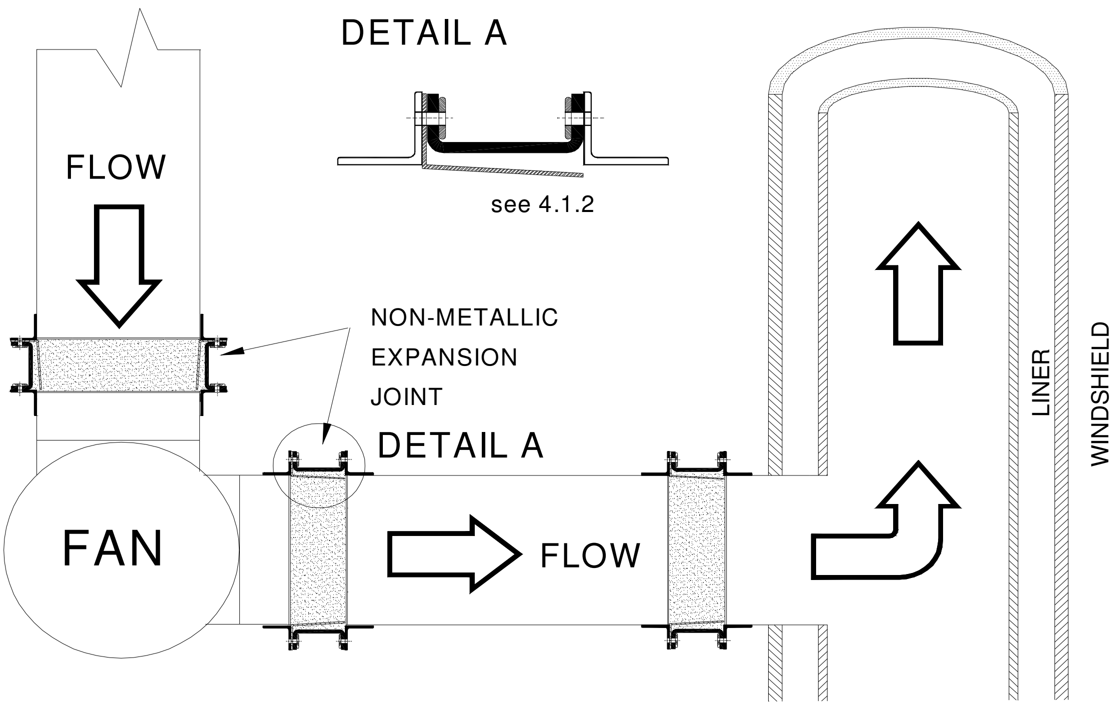

Figure 2 - Non-metallic expansion joint

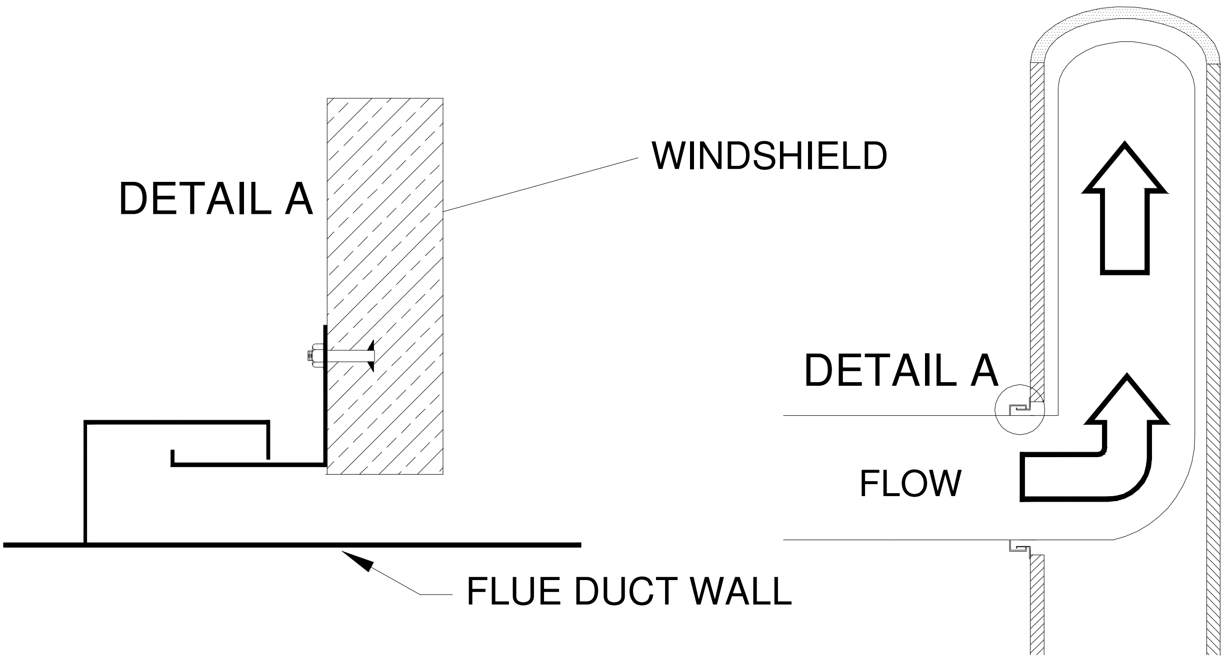

Figure 3 Basic duct entrance seal at windshield

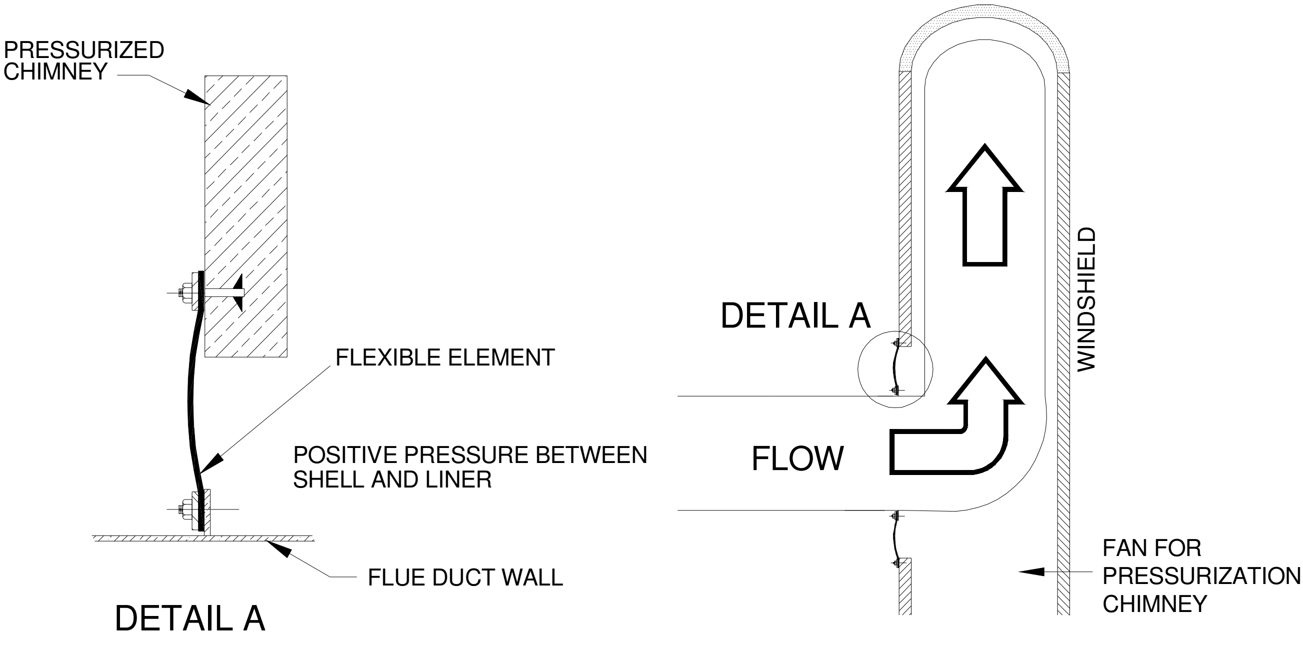

Figure 4 Non-metallic duct entrance seal at windshield

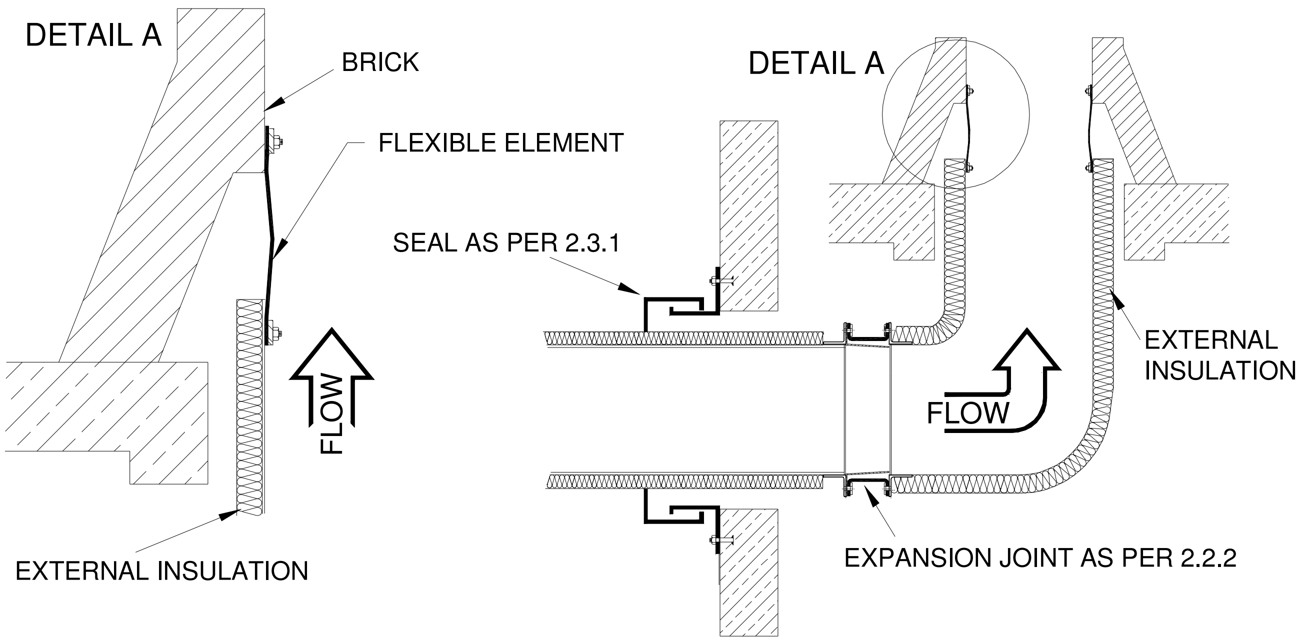

Figure 5 Chimney elbow seal

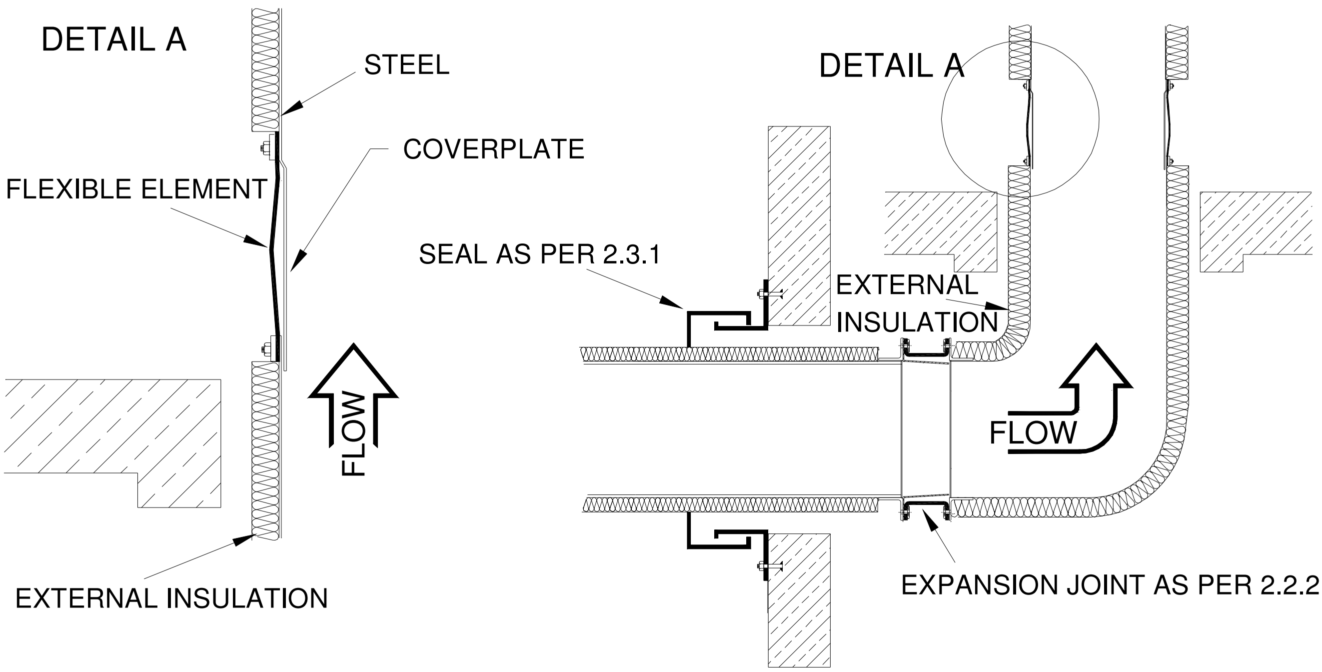

Figure 6 Ductwork to metallic liner seal

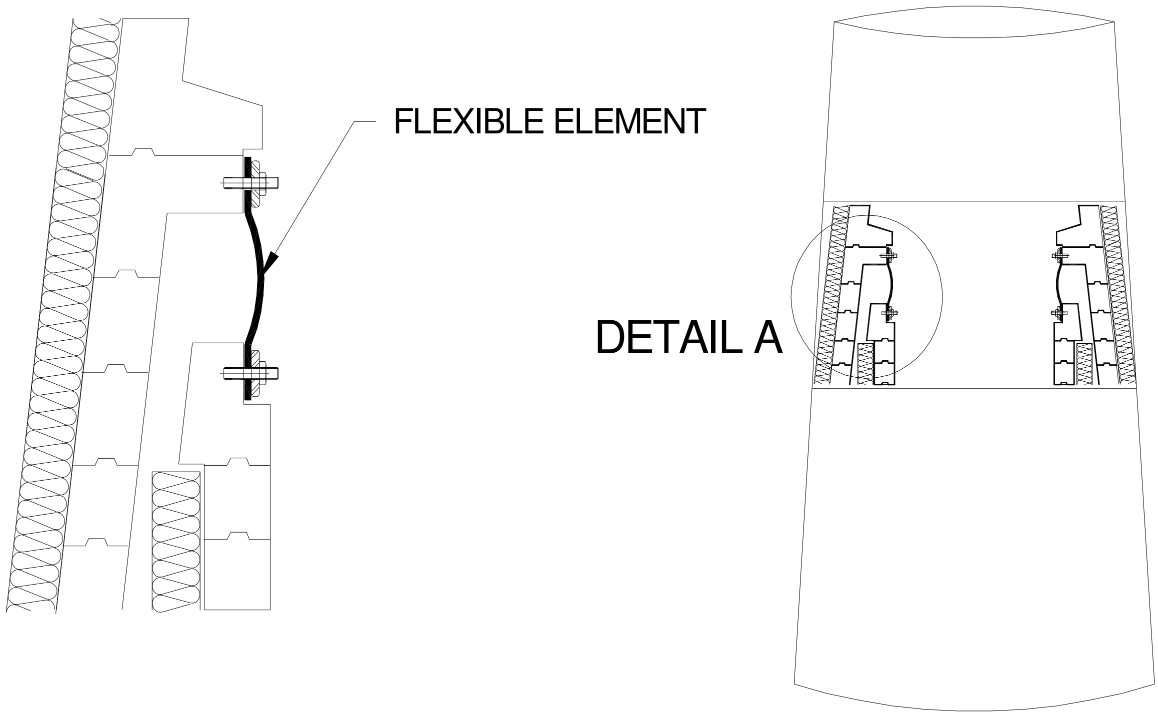

Figure 7 Corbel seal

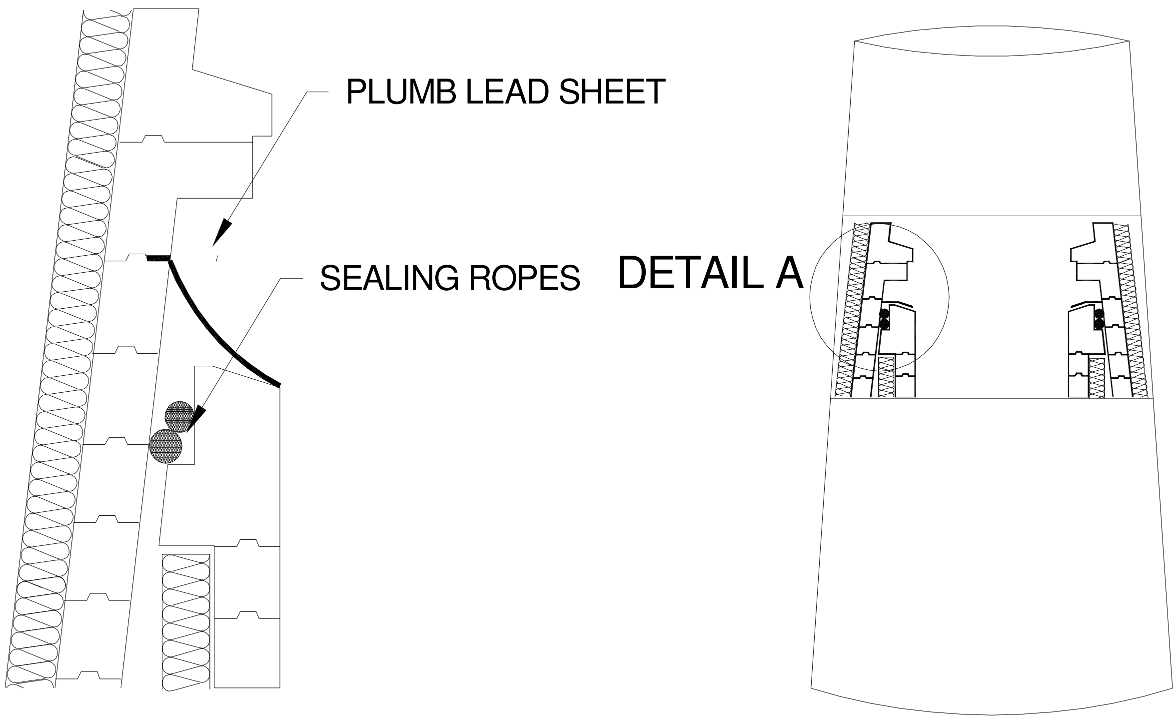

Figure 8 Corbel seal/packing seal arrangement

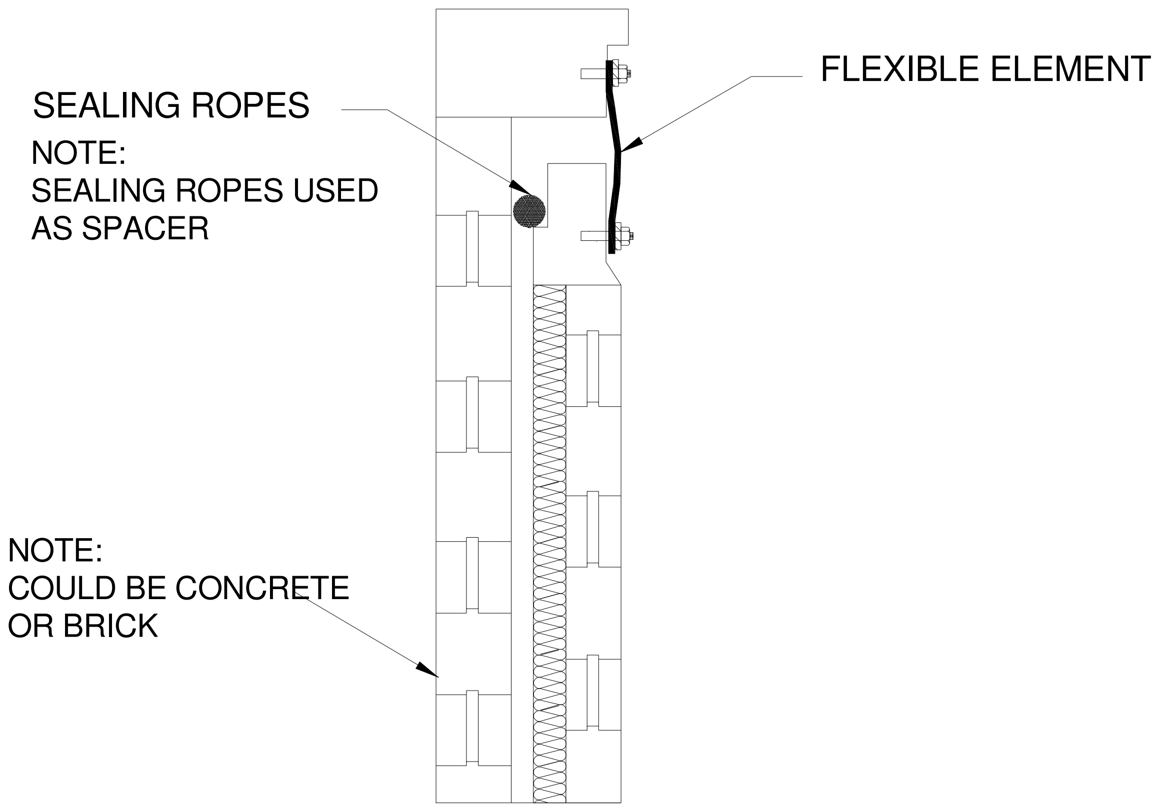

Figure 9 Non-metallic raincap

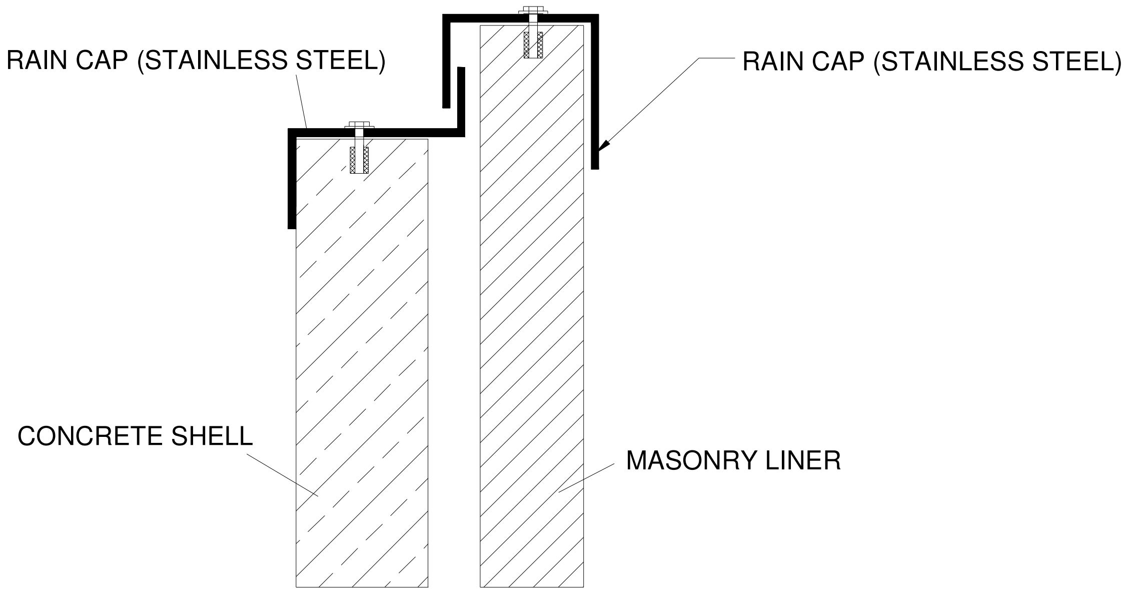

Figure 10 Metallic raincap / hat seal

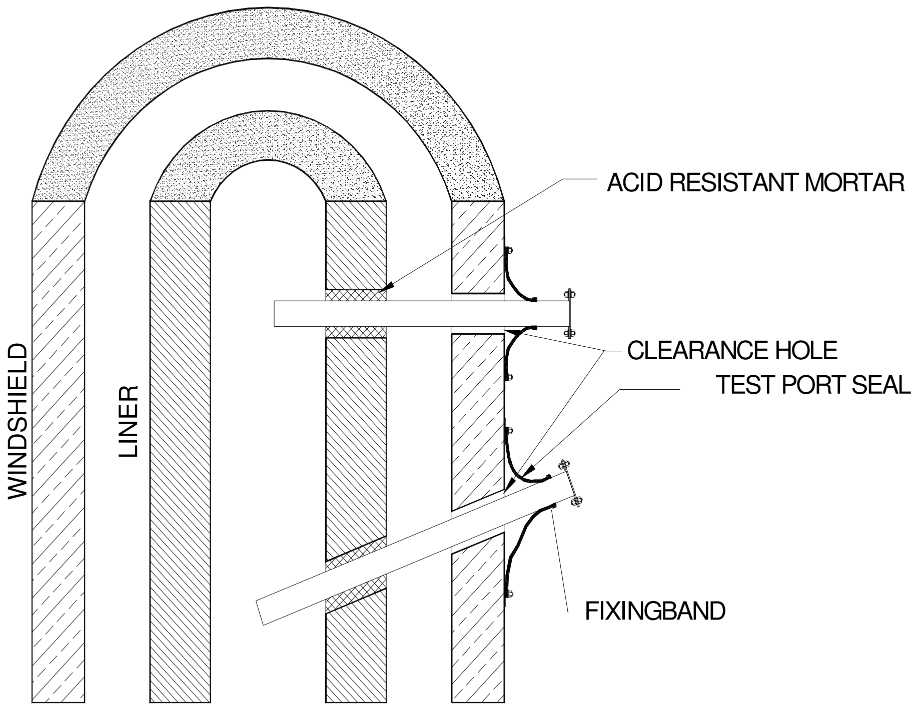

Figure 11 Test port seal, fixed at liner

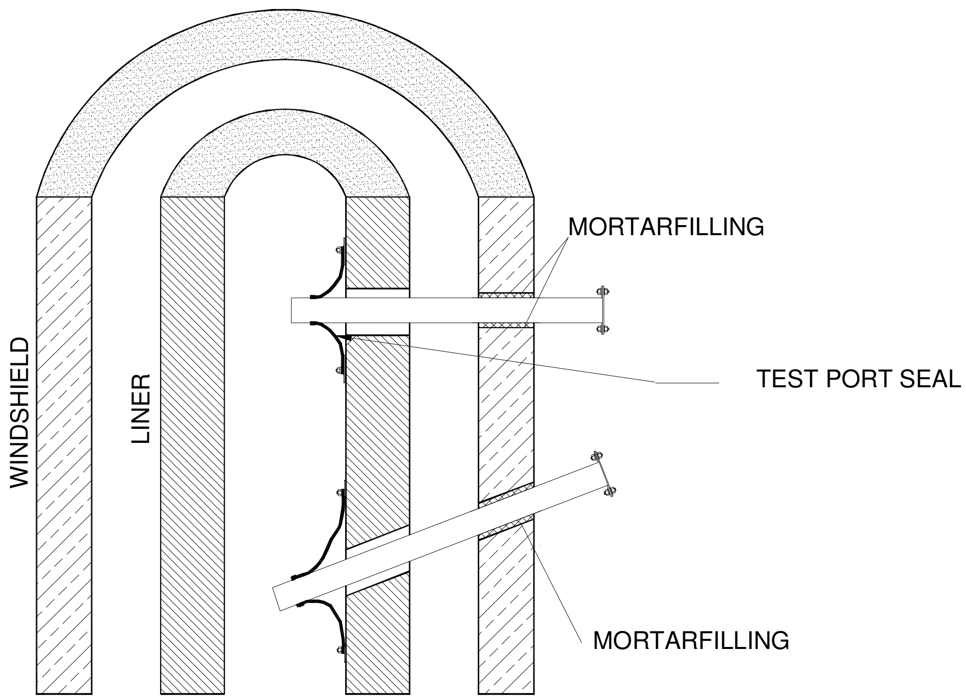

Figure 12 Test port seal, fixed at windshield

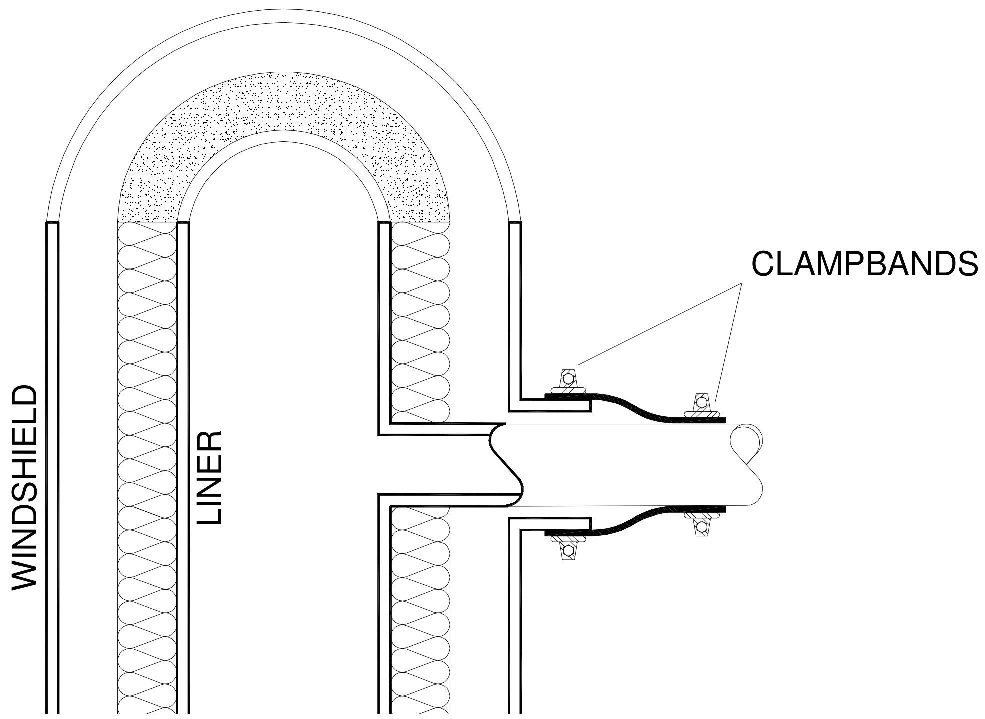

Figure 13 Test port seal for a metal chimney

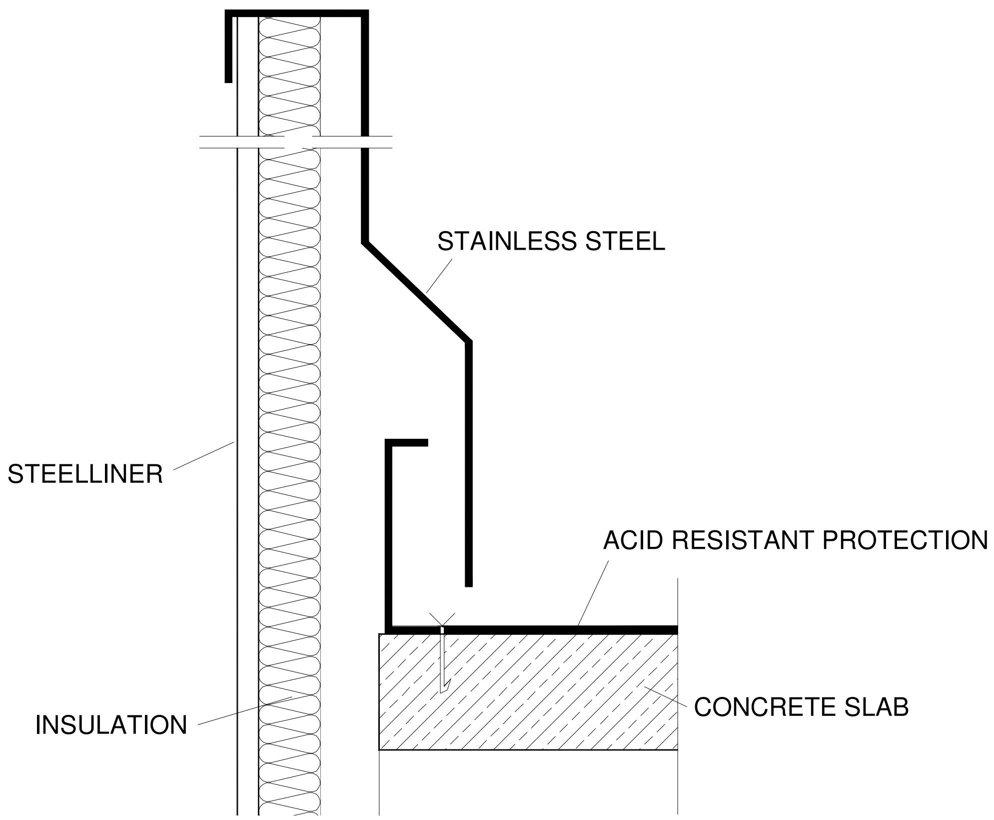

Figure 14 Weather Hood Seal

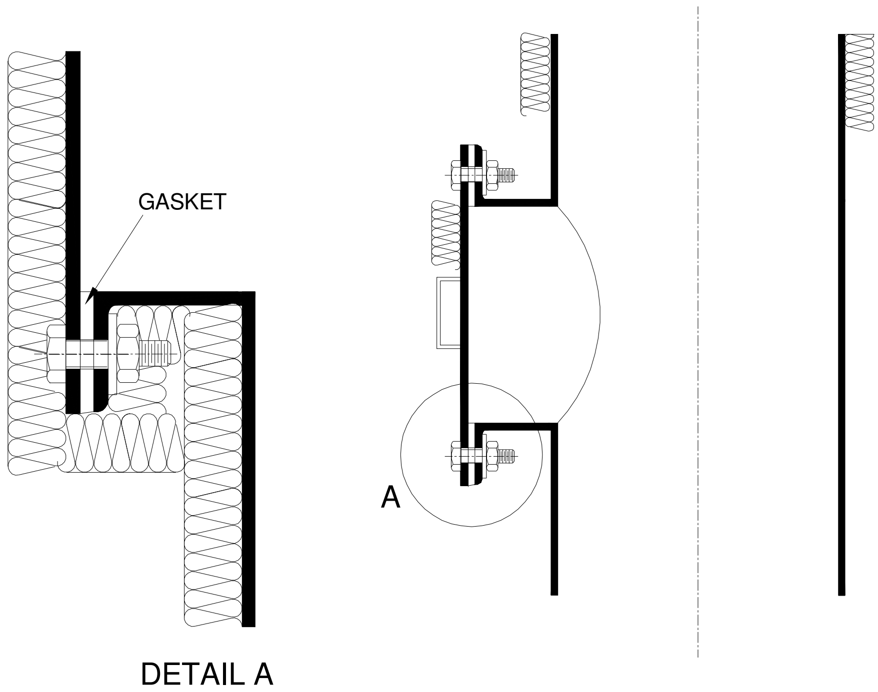

Figure 15 Flange Gasket Seal

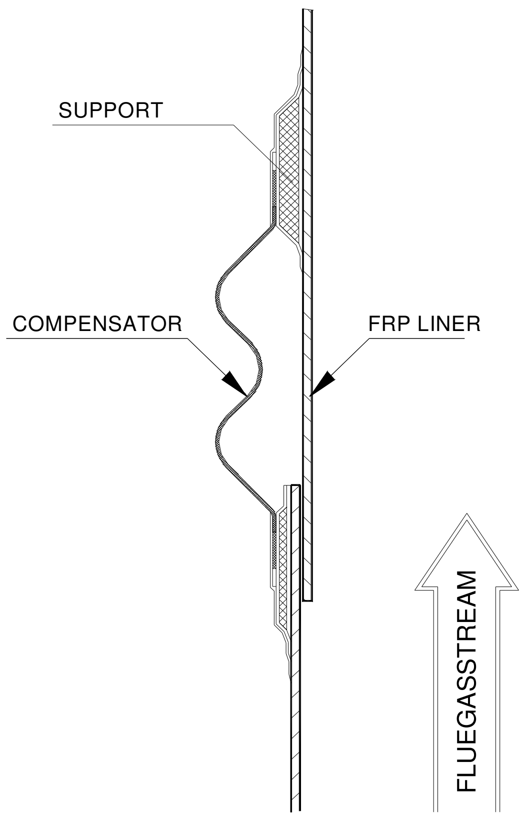

Figure 16 FRP liner seal

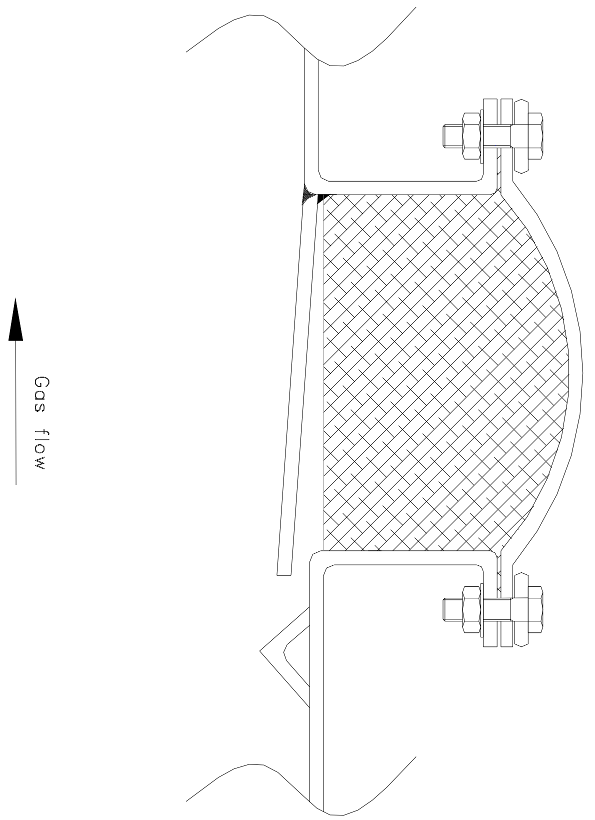

Figure 17 High temperature gas seal