

## EROSION RESISTANT FLOW CONDUIT

### FIELD

The disclosed embodiment relates to apparatus for fluid flow conduits for accommodating erosion prevalent in changes of direction of particulate-laden flow streams, and more particularly to an erosion resistant pipe bend insert supported within a pressure housing providing structure support of the insert and failure detection.

### BACKGROUND

Gas and oil wells often produce fluids containing particulates which cause premature failures in piping. A wellhead conducts a fluid flow stream through equipment including chokes and metering apparatus. Particulates such as sand can be produced from the gas or oil formation itself or, in many cases, or introduced sand such as fracturing sand being recovered after stimulation operations. If desanding apparatus is not used, or not used long enough, upon initiating production, the sand concentration through downstream production piping causes accelerated degradation. The placement and orientation of various equipment can result in the occasional bend, including right angle or 90 degree elbows. The elbows result in a change in direction and marked increase in the erosive effect of contained particulates. When flow direction is changed in the bend, the particulates do not parallel the fluid flow, but resist a trajectory change and move against the outside of the turn, eroding the contact points. The erosions patterns in bends, tees, and blind

1 tee connections can be complex, the ultimate point of failure from erosion being  
2 somewhat un-predictable.

3 Internal erosion of the piping is not readily detected until failure and  
4 failure can be catastrophic, the fluid flow such as gas being under pressure,  
5 flammable and often containing H<sub>2</sub>S which is fatal in even low concentrations. This  
6 establishes the need for a effective device.

7 One prior art early warning device is that disclosed in US 7,246,25,  
8 which provides an elbow in a block having a main fluid passageway. The block  
9 further contains a matrix of passageways, separated from the main passageway by  
10 sufficient wall material that expected erosion to destruction will occur only over a  
11 reasonable operations period. The matrix of passageways is maintained at a low  
12 and differential pressure to that of the main flow stream. Erosion eventually breaks  
13 through the wall material, connecting the flow with the matrix of passageways. The  
14 matrix pressure is monitored and when the differential pressure climbs to the  
15 pressure in the process stream, breakthrough is detected and an orderly turnaround  
16 can be scheduled for replacement of the block. The matrix is rated for the process  
17 pressure. One shortcoming is that the matrix of holes have to intersect the area that  
18 was being eroded, being an uncertain science. The matrix cannot provide 100%  
19 coverage as the holes are inside the pressure boundary.

20 Another form of prior art apparatus includes ceramic lined pipes and  
21 machined ceramic elbows.

22 The ceramic material of the elbow forms part of the pressure boundary  
23 and is therefore required to have sufficient tensile strength to meet the pressure

1 requirements. This requires special ceramics or overly thick material. As well, some  
2 regulatory codes would require special exemptions to use this material.

#### 3 4 SUMMARY

5 Generally, a particulate-accommodating fluid conduit and failure  
6 detection apparatus is disclosed herein. In an embodiment, the conduit is a flow  
7 directing insert and failure detection is provided by locating the insert wholly within a  
8 failure detection housing serving as a pressure boundary; failure at any location  
9 therealong being detectable by means associated with the housing. The conduit or  
10 flow directing insert can be manufactured of erosion resistant materials, including  
11 non-ductile and ceramics not normally permitted by regulatory codes for pressure  
12 applications. The flow directing insert is wholly supported and contained within a  
13 pressure chamber of the failure detection housing. The pressure chamber and  
14 housing form a surrounding pressure boundary manufactured from conventional  
15 materials and authorized under appropriate regulatory codes for apparatus and  
16 operations under pressure. Within the pressure chamber, an intermediate fluid pad  
17 is formed about a substantial length of the flow directing insert, between the insert  
18 and the housing. The insert is sealed to the housing at an inlet and a discharge to  
19 separate the fluid flow from the fluid pad.

20 The fluid flow directing insert can be used in wellhead piping, typically  
21 conveying particulates and which is particularly susceptible to erosion.

22 In an embodiment, failure of an insert can be detected by monitoring  
23 changes in the pressure between the fluid stream and the fluid pad. Accordingly,

1 should the flow directing insert fail at any location therealong, the fluid pad is  
2 exposed to the fluid flow and pressures equilibrate, signalling failure and need for  
3 replacement.

4 In other embodiments, similar inserts and housings can be provided for  
5 other challenging erosive flow arrangements including blinded tee's, reducers, and  
6 headers. Accordingly, the term flow directing insert includes a range of piping from  
7 straight runs through 90 degree elbows, a reducer also being contemplated and  
8 included herein, the fluid flow within the reducer being guided from one flow regime  
9 to another and resulting in enhanced risk of erosion.

10 In one aspect, flow directing apparatus is provided for conveying a fluid  
11 flow comprising a housing forming a pressure boundary, and a flow directing insert  
12 within the housing. The flow directing insert is fit sealably within the housing for  
13 forming a pressure chamber about the insert and between the insert and the  
14 housing, the insert having an inlet end for receiving the fluid flow and a discharge  
15 end for discharging the fluid flow. The insert can cause a trajectory change in the  
16 fluid flow such as a bend in the piping. The insert can be replaceable.

17 In another aspect, the fluid flow contains particulates and the insert is a  
18 wear resistant material, such as a non-ductile material like ceramic, resistive to  
19 erosion from the particulates.

20 In another aspect directed to insert failure detection, the flow directing  
21 apparatus further comprises a pressure monitor connected to the pressure chamber  
22 for detecting a pressure change in the pad pressure being indicative of failure of the  
23 insert. The process and pad pressure can be maintained at a pressure differential,

1 the pressure differential being maintained by a make-up pressure source and may  
2 also include a regulator for introducing make-up pressure as necessary to maintain  
3 the differential pressure between the fluid flow and the pressure chamber.

4 In another aspect, the disclosed flow directing apparatus can be  
5 employed in wellhead piping as a flow bend, such as a 90 degree elbow.

#### 6 7 BRIEF DESCRIPTION OF THE DRAWINGS

8 Figure 1A is a cross-sectional view of one embodiment of a flow  
9 directing insert and pressure boundary housing fit into wellhead piping and having  
10 flanged connections to wellhead piping, the fasteners in this figure and others being  
11 omitted for simplicity of view;

12 Figure 1B is an enlarged view of an inside bend of an insert fit with a  
13 bleed port for equilibrating supportive pressures between the fluid flow and the fluid  
14 pad;

15 Figure 2A is a view of one embodiment of the flow directing insert fit to  
16 a pressure boundary housing and having a pressure sensing system;

17 Figure 2B is a view of one embodiment of the flow directing insert fit to  
18 a pressure boundary housing and having a pressure sensing and differential  
19 pressure maintenance system;

20 Figure 3A is a cross-sectional view of a liquid accumulator located in  
21 the pressure housing for pressure maintenance against a fluid pad for a liquid-filled  
22 pressure chamber for the pressure boundary housing;

1                Figure 3B is a cross-sectional view of an optional liquid accumulator as  
2 a device separate from the pressure housing;

3                Figure 4 is a cross-sectional view of a pressure-differential reduction  
4 piston loop for automatic pressure maintenance of the fluid pad for a liquid-filled  
5 pressure chamber;

6                Figure 5 is an exploded view of one methodology for installation of an  
7 insert for replacement or upon initial installation;

8                Figure 5A through 5C are various views of an embodiment of an insert  
9 retainer ring, Fig. 5A illustrating a plan view of a retainer ring of two half-circular and  
10 overlapping rings, Fig. 5B illustrating a side view of assembled rings of Fig. 5A, and  
11 Fig. 5C illustrating yet another embodiment of a four-segmented retainer ring; and

12                Figure 6 is a partial cross-section view of the connection of one end of  
13 the insert to the pressure boundary housing.

14

#### 15                BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

16                As shown in Fig. 1A, an erosion resistant conduit 10 and a pressure  
17 boundary housing 20 is disclosed herein. The housing 20 supports the conduit 10  
18 and enables detection of failure thereof. The conduit directs the flow of fluid and is  
19 exposed to the action of erosion, such as by erosive particulates contained in a  
20 process stream or fluid flow F conducted therethrough. Conduits including bends  
21 are particularly subject to accelerated erosion including aggravating factors such as  
22 the particulates impacting the bend wall, undergoing a change in momentum and the  
23 boundary layer is breached.

1           An extensive analysis of erosive wear in piping systems can be found  
2   in "Recommended Practice RP O501 Erosive Wear In Piping Systems", Rev. 4.2 –  
3   2007 by Det Norske Veritas.

4           Herein, at least a flow directing or bend portion 12 of the conduit 10 is  
5   manufactured as a flow directing insert 14 formed of erosion resistant materials,  
6   including those not normally permitted by regulations for pressure applications.  
7   Such materials include non-ductile or brittle materials.

8           As shown in Figs. 1A, 2A through 5, the arrangement of the housing 20  
9   accommodates the form of insert 14. The example flow directing insert 14 has a 90  
10   degree bend and the housing 20 is provided with inlet and outlet ports at 90  
11   degrees. A housing for a reducer insert would have aligned inlet and outlet ports,  
12   the housing for a 45 degree elbow having inlet and outlets oriented at 45 degrees  
13   and so on.

14           Such materials are firstly and generally unacceptable under regulatory  
15   codes for the instances as forming a pressure boundary to the environment, and  
16   secondly and related thereto, a failure of such materials can be catastrophic, the  
17   insert 14 is wholly supported and contained within a pressure chamber 22 of the  
18   failure detection housing 20 forming a surrounding pressure boundary that can be  
19   manufactured from conventional materials authorized under appropriate codes for  
20   pressure operations. In one aspect, pressure P1 of fluid flow F in the insert and  
21   pressure P2 of the pressure boundary can be controlled to an acceptable pressure  
22   differential  $dp$  ( $|P1-P2|$ ) for controlling the magnitude of pressure-induced stresses in  
23   the insert 14. Further, in another aspect, fluid release due to failure of the insert 14

1 is constrained by the housing 20. As the housing 20 need not be designed for  
2 sustained fluid flow conditions, detection of a failure of the insert 14 can provided for  
3 an orderly shutdown and replacement thereof.

4           Responsive to both above-identified aspects, within the pressure  
5 chamber 22, an intermediate fluid pad B can be formed about a substantial length of  
6 the flow directing insert, between the insert 14 and the housing 20. The fluid pad B  
7 is maintained at a threshold pressure  $P_2$  selected to be related to, and in one  
8 embodiment, different that the fluid flow pressure  $P_1$ . The insert 14 is sealed to the  
9 housing 20 at an insert inlet end 24 and an insert discharge end 26 to separate the  
10 fluid flow F from the fluid pad B. Accordingly, should the flow directing insert 14 fail  
11 at any location therealong, the fluid pad B is exposed to the fluid flow F and  
12 pressures therebetween equilibrate, signalling failure and need for replacement of  
13 the insert 14.

14           Pressure sensors and pressure differentials can be monitored for  
15 signalling failure and, in one embodiment, for initiating closure of an emergency  
16 shutdown (ESD) valve located in the piping upstream of the insert 14, such as that in  
17 wellhead piping between the wellhead and the housing 20. In other embodiments,  
18 an alarm can alert an operator of the need for remedial action.

19           In an embodiment, one suitable material for the flow directing insert 14  
20 is a highly erosion resistant material such as that selected from the ceramics. Such  
21 materials are typically brittle and unsuitable for use as the pressure boundary in  
22 pressure applications according to applicable codes. One material that is usable  
23 includes silicon nitrile which is conventionally cost prohibitive when forming the

1 entirely of a commercial structure. Other lower cost ceramics are quite brittle and  
2 are not listed in the various codes for pressure containment including NACE, ASME,  
3 CSA. As a consequence, use of such materials usually requires special applications  
4 and permission before use in a pressurized environment.

5               Herein, the pressure boundary is formed by manufacture of the  
6 housing of conventional fluid pressure containment materials. The housing 20, such  
7 as one manufactured from steel, has an inlet interface 30, shown as an inlet flange  
8 to the upstream fluid piping and a discharge interface 32, shown as a discharge  
9 flange to the downstream fluid stream piping. The flow directing insert 14, possibly  
10 formed from unlisted materials, are wholly within the housing 20. The insert 14 is  
11 sealed to the housing 20 at an inlet seal 34 at the inlet 24 and at a discharge seal 36  
12 at the discharge 26, maintaining separation between the fluid flow F and the fluid  
13 pad B. The fluid flow F then enters the housing at the inlet interface flange 30 and  
14 flows through the flow directing insert 14, sealed from the fluid pad B at the inlet seal  
15 34. Fluid flow exits the flow directing insert 14, sealed from the fluid pad at insert  
16 discharge seal 36. Finally, the fluid flow exits the housing 20, sealed from the  
17 environment at the discharge interface flange 32.

18               Brittle materials are typically unsuitable for pressure operations as they  
19 cannot withstand the tensile stresses resulting from pressure differentials imposed  
20 thereon. By maintaining pressure both within and without the insert, and a  
21 pressures not too dissimilar to one another, stresses are minimized or eliminated.

22               Accordingly, the flow directing insert 14, such as that manufactured of  
23 brittle material, is immersed in the fluid pad B at pad pressure boundary pressures

1 P2 near those at the process flow conditions P1, limiting the pressure differential  
2 (P1-P2) across the insert 14.

3 In one embodiment, and with reference to Fig. 1B, the pad pressure P2  
4 can be balanced to the fluid flow pressure P1 by placing a bleed port 38 in the insert  
5 14 on an erosion-protected area, such as on the inside bend 40, the bleed port  
6 having a restricted flow therethrough. Fluid from the fluid flow F will bleed through  
7 the bleed port 38 into the fluid pad B, balancing the pressure (P1=P2) across the  
8 insert, eliminating differential pressure stresses and minimizing stress overall.

9 With reference to Fig. 2A, so as to enable detection of a failure along  
10 the insert, the pad pressure can be set to a threshold pressure P2, any change  
11 therein, particular that approaching process pressure P1 signaling a failure.

12 Further, and with reference to Fig. 2B, in another embodiment, so as to  
13 enable detection of failure along the insert, the pad pressure P2 can be set to a  
14 threshold pressure that is different from that of the process pressure P1; a  
15 differential pressure  $dP$  ( $dp > 0$ ) of about 100 psi (700 kPa) is deemed sufficient to  
16 detect a breach. Upon failure anywhere therealong, the pad P2 pressure will  
17 equilibrate with the gas process pressure P1 and P1-P2 will be about zero ( $|dp|=0$ ).  
18 A pressure monitor or pressure monitoring devices, such as a pressure transducer  
19 or transducers, can have a set point for differential pressure between process and  
20 pad pressures or for a change in pad pressure.

21 Alternatively, the pad pressure P2 can be controlled using a regulator  
22 50 using the process pressure P1 as a reference pressure, the regulator increasing  
23 the fluid pressure P2 in the pressure chamber as the process pressure P1

1 increases. The process pressure P1 can be tapped into the fluid flow F. As shown,  
2 P1 is monitored at about the inlet interface 30. A differential pressure can be  
3 maintained, such as a lower pad pressure P2 to a higher process pressure P1.  
4 Failure of the insert would cause the pad pressure P2 to rise, signalling failure. A  
5 pressurized source 52 of pad fluid B, or pressure connected to the pad fluid, is  
6 provided to regulate a make-up pressure P3 to the pad pressure. In another  
7 embodiment, the pad fluid is an incompressible fluid such as a liquid.

8           As shown in Fig. 3A, so as to isolate the source fluid of the make-up  
9 pressure from the pad fluid, the system can further include an intermediate isolation  
10 chamber 54. The pad fluid can be a liquid which is to be separated from a gaseous  
11 pressure maintenance fluid or gas. The chamber 54 and make-up source act as a  
12 form of liquid accumulator. The chamber 54 forms a cylinder that can be  
13 incorporated into the housing 20. Regulated make-up pressure P3 can drive a  
14 piston 56, movable within the chamber 54, to displace pad fluid to and from fluid pad  
15 B and necessarily vary the fluid pad pressure P2 as process pressure P1 varies  
16 inside the flow directing insert 14. The pressurized source of make-up pressure P3  
17 can be supplied by a pressure tank or bottle having pressurized fluid within such as  
18 gaseous nitrogen (N2).

19           As shown in Fig. 3B, the isolation chamber 54 can alternatively be  
20 located external to the housing 20.

21           Turning to the Fig. 4, one can eliminate need for a regulator using a  
22 pressure-differential reduction piston loop 60 comprising a stepped piston 62 and  
23 wherein the intermediate chamber is corresponding stepped cylinder 64. Process

1 pressure P1 of the fluid flow F, through process connection 56 to the fluid flow F, is  
2 in fluid communication with and acts on a first smaller area A1 of stepped piston 62  
3 in stepped cylinder 64 to produce force F. Force F acts on a larger second area A2  
4 of the stepped piston 62, which is in fluid communication with, and producing a fluid  
5 pressure P2 on the fluid pad side, fluidly connected through pad connection 58 to  
6 the pressure chamber 22. Accordingly, the fluid pressure P2 is automatically  
7 maintained at a pressure lower than the process pressure P1. As the process  
8 pressure P1 varies, so does the fluid pad pressure P2, only at a lower, and  
9 differential, pressure dP.

10               With reference to Fig. 5, the insert 14 is removably installable into the  
11 housing 20 and replaceable. The insert 14 is sealed to the housing 20 using end  
12 ring seals 70, 70 between each of the insert's inlet and discharge ends 24,26, and  
13 an inside of the housing. The seals 70,70 seal the insert 14 to the housing and  
14 separate the fluid flow F from the fluid pad B.

15               In an embodiment, the housing's pressure chamber 22 houses the  
16 insert 14 and forms a first annular base to which the inlet end 24 of the insert is fit, a  
17 ring seal 70 being located therebetween. The first annular base is aligned with, and  
18 formed about, the inlet interface 34. A second annular base is provided at the  
19 discharge interface for sealing with the other discharge end 26 of the insert 14. A  
20 second ring seal 70 located therebetween. In this embodiment the inlet and  
21 discharge ends 24,26 of the insert 14 are formed with flanges 71 for corresponding  
22 placement and sandwiching of the ring seal 70 between the insert 14 and the  
23 housing 20.

1           As shown in the exploded view of Fig. 5, for installation of an insert 14  
2 into the housing 20, the housing can be formed in four components, a main body 72,  
3 an inlet body 74, a discharge body 76, and an access closure 78.

4           The insert 14 can be initially fit to the discharge body 76 and installed  
5 through an outlet port 90 of the main body 20. The discharge body 76 is sealed  
6 thereto using conventional flange ring seal 80. The flanged discharge end of the  
7 insert 14 is secured to the discharge body 76 using an insert seal 70 and a retainer  
8 ring 81. That portion of the discharge body 76 within the pressure chamber 22 forms  
9 the discharge interface 36. The retainer ring 81 clamps the insert's flange 71 to the  
10 discharge interface 36 of the discharge body 76. With reference to Figs. 5A, 5B and  
11 5C, the retainer ring 81 can be configured in one of a variety of two or more  
12 sectional pieces 82, as known in the art, so as to be arranged about the insert, yet  
13 form a substantially continuous clamp about the flange 71. Fig. 5A illustrates two  
14 sectional pieces while Fig. 5C shows four sectional pieces. The sectional pieces  
15 overlap and fasteners secure them together and to the underlying structure.

16           The inlet body 14 can be fit to an inlet port 79 of the main body 20 and  
17 sealed thereto using conventional flange ring seal 80 for forming a sealed housing  
18 20. That portion of the inlet body within the pressure chamber 22 forms the inlet  
19 interface 34. The inlet end 24 of the insert 14 can be guided through an outlet port  
20 90, aligning the inlet end of the insert with the inlet interface 34.

21           As shown in better detail in Fig. 6, an insert ring seal 70 is arranged  
22 between the inlet end 24 of the insert 14 and the inlet interface 34. A retainer ring

1 81 can be guided through an access port 90 for clamping the insert's flange 71 to  
2 the inlet interface 34.

3               Once the inlet end 24 of the insert 14 is secured, the access closure 78  
4 can be secured to the main body 72 to seal the access port 92 and form the  
5 pressure chamber 22.

6               The housing 20 is now closed to seal and form the fluid pad B. The  
7 housing closure is sealed and re-closable for permitting installation and replacement  
8 of the flow directing insert 14.

9               The arrangement for the inlet and outlet is arbitrary and can be  
10 reversed.

11

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE  
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

1. A flow directing apparatus for conveying a fluid flow comprising:  
a housing forming a pressure boundary; and  
a flow directing insert fit sealably within the housing for forming a pressure chamber about the insert and between the insert and the housing, the insert having an inlet end for receiving the fluid flow and a discharge end for discharging the fluid flow, wherein said fluid flow has a process pressure and the pressure chamber has a pad pressure, and a pressure differential is maintained between the process pressure and the pad pressure.
2. The flow directing apparatus of claim 1 wherein the insert is replaceable.
3. The flow directing apparatus of claim 1 or 2, wherein:  
the inlet end is sealed to the housing at an inlet seal; and  
the discharge end is sealed to the housing at a discharge seal.
4. The flow directing apparatus of claim 1, 2 or 3, wherein:  
the fluid flow contains particulates; and  
the insert is a wear resistant material resistive to erosion from the particulates.

5. The flow directing apparatus of claim 4 wherein the wear resistant material is a non-ductile material.

6. The flow directing apparatus of claim 5 wherein the wear resistant material is a ceramic.

7. The flow directing apparatus of any one of claims 1 to 6 further comprising a pressure monitor connected to the pressure chamber for detecting a pressure change in the pad pressure being indicative of failure of the insert.

8. The flow directing apparatus of claim 7 further comprising:  
a make-up pressure source in fluid communication with the pressure chamber for maintaining the pressure differential between the process pressure and pad pressure.

9. The flow directing apparatus of claim 6 or 7, further comprising:  
a pad pressure maintenance system for maintaining the pad pressure relative to the process pressure.

10. The flow directing apparatus of claim 9 wherein the pad pressure maintenance system further comprises a bleed port formed in the insert for pressure maintenance, with restricted flow therethrough, between the fluid flow and the pressure chamber.

11. The flow directing apparatus of claim 9 or 10, wherein the pad pressure maintenance system further comprises a make-up pressure source and a regulator for introducing make-up pressure as necessary to maintain a differential pressure between the fluid flow and the pressure chamber.

12. The flow directing apparatus of claim 9 wherein the pressure chamber contains a fluid pad of liquid and the pad pressure maintenance system further comprises:

a make-up pressure source of gas at a make-up pressure; and

a isolation chamber forming a cylinder and having a piston movable therein, the piston intermediate the make-up pressure source and the fluid pad.

13. The flow directing apparatus of claim 12, wherein:

the chamber is stepped and the piston is stepped; and

the piston has a first smaller area in fluid communication with the process pressure and a larger second area in fluid communication with the fluid pad for automatically maintaining the pad pressure at a pressure lower than the process pressure.

14. The flow directing apparatus of any one of claims 1 to 11, wherein the pressure chamber contains a fluid pad of liquid.

15. A flow bend in wellhead piping comprising the flow directing apparatus of any one of claims 1 to 14.

16. The flow directing apparatus of any one of claims 1 to 15 wherein the pad pressure is maintained at a threshold pressure, variation therefrom being indicative of insert failure.