

ELECTRICALLY ISOLATING, FIRE-SAFE SEALING ELEMENT

BACKGROUND

5 Gasket devices positioned between joined pieces or pipes are used to create a seal between the joined pieces and to prevent leakage of material from the joined pieces at the joint. Moreover, in addition to providing a seal for the joint, in some situations it is also desirable to electrically isolate the joint pieces. One example of corrosion resistance for pipelines is cathodic protection. This type of corrosion
10 protection typically requires sealing joints by providing electrical isolation. Another example is when two sides of the joint are made of different metals in which the electrical potential difference between the two metals can create a galvanic corrosion cell if the two sides are not electrically isolated. In other situations it may also be desirable to maintain a seal for the joint during a fire.
15 Fires are dangerous to pipeline workers but the fires can become even more dangerous and deadly if the seal between joints is not capable of containing the material in the pipes during a fire.

 Gasket devices have been developed to effectively do one of sealing, electrical isolation, or fire safety. Therefore, multiple gaskets must be used to
20 combat situations where all of these concerns are present which can lead to increased costs as well as compatibility and size issues. Other problems exist when multiple gaskets are used, for example, one gasket device that effectively seals a joint may melt at high temperatures, such as during a fire, so that the seal between flanges is no longer effective and possibly may leak. Leakage of material such as
25 petroleum or gas can be extremely dangerous and can increase the likelihood of fire. As another example, some materials that are resistive to deformation also conduct electricity. Thus there remains a need for improvement in the field of electrically isolated, fire-safe, effective sealing systems.

SUMMARY

The invention is defined in the independent claims. Some optional features of the invention are defined in the dependent claims.

5 The disclosed arrangements of an isolation, fire-safe gasket may provide electrical isolation as well as the reliability of defending against a fire while maintaining a competent seal either during a fire or everyday application.

One example of an isolation gasket for use between facing flanges of two flow conduit sections for fluid passage therethrough includes a flat metal core ring having an upper face opposing a lower face and an opening formed therein to allow fluid
10 passage therethrough, wherein the flat metal core ring has a serrated ring positioned between an inner ring and an outer ring. The serrated ring having a plurality of serrations along the upper face and the lower face. The isolation gasket includes a first non-conductive layer on the upper face and the lower face of the inner ring to provide a dielectric barrier for the inner ring, a non-conductive coating on the plurality of
15 serrations along the upper face and the lower face of the serrated ring to provide a dielectric barrier for the serrated ring, and a second non-conductive layer on the upper face and the lower face of the outer ring to provide a dielectric barrier for the outer ring. The isolation gasket also includes a fire resistant layer on the non-conductive coating that is positioned on the serrated ring, wherein the fire resistant layer spans
20 from an outer edge of the serrated ring to a mid-region of the serrated ring and a third non-conductive layer on the non-conductive coating that is positioned on the serrated ring, wherein the third non-conductive layer spans from an inner edge of the serrated ring to the mid-region of the serrated ring, wherein the fire resistant layer abuts against the third non-conductive layer. In one arrangement, the fire resistant layer abuts
25 against the third non-conductive layer at a mid-point between the inner edge and the outer edge of the serrated ring.

Exemplary materials for the isolation gasket include the non-conductive coating being made of polytetrafluoroethylene, the fire resistant layer being made of mica or aluminosilicate, the third non-conductive layer being made of biaxially-
30 oriented filled polytetrafluoroethylene that may be used alone or in combination with one another.

In a first arrangement, the plurality of serrations have a corresponding plurality of alternating peaks and grooves, wherein each of the peaks has a first

axial width dimension and each of the grooves has a second axial width dimension, the first axial width dimension being substantially the same for each of the peaks, and the second axial width dimension being substantially the same for each of the grooves. In a second alternative arrangement, the plurality of serrations have a corresponding

5 plurality of alternating peaks and grooves, wherein each of the peaks has a first axial width dimension that is substantially the same for each of the peaks, and wherein the plurality of grooves includes five groups that are orderly arranged across a width of the serrated ring, wherein the outer two groups of the plurality of grooves have a

10 a third axial width dimension, the middle two groups of the plurality of grooves have a fourth axial dimension, wherein the fourth axial width dimension is larger than the third axial width dimension, and the third axial width dimension is larger than the second axial width dimension. In the second arrangement, the fourth axial width dimension, the third axial width dimension, and the second axial width dimension

15 generally form a convex profile that spans across the width of the serrated ring.

In another example arrangement, a pair of joined flow conduit sections which are constructed and arranged with facing flanges, each flow conduit section having a through bore in combination with an isolation gasket for use between the facing flanges. The isolation gasket includes a flat metal core ring having an upper face

20 opposing a lower face and an opening formed therein to allow fluid passage therethrough, wherein the flat metal core ring has a serrated ring positioned between an inner ring and an outer ring and the serrated ring has a plurality of serrations along the upper face and the lower face. The isolation gasket includes a first non-conductive layer on the upper and the lower faces of the inner ring, a non-conductive coating on

25 the upper and the lower faces of the serrated ring, a second non-conductive layer on the upper and the lower faces of the outer ring, a fire resistant layer on the non-conductive coating that is positioned on the serrated ring, and a third non-conductive layer on the non-conductive coating that is positioned on the serrated ring, wherein the

30 fire resistant layer spans from an outside diameter of the serrated ring to a middle diameter of the serrated ring, and wherein the third

non-conductive layer spans from the middle diameter to an inside diameter of the serrated ring.

In one arrangement the combination further includes at least one isolating sleeve positioned in an aligned bore formed in each of the facing flanges, the isolating sleeve having a length that is substantially equal to a distance between an outer face of each of the flanges with the isolation gasket positioned between the facing flanges, at least one elongate metal fastener having opposing ends, the fastener received in the isolating sleeve for connecting the flanges to one another with the isolation gasket interposed therebetween, and an isolating washer positioned on each of the at least one elongate metal fastener abutting the outer face of the flange. In a first arrangement, the isolating washer includes a metal washer having opposing side surfaces with a sheet of dielectric material laminated to one of the opposing side surfaces and wherein the dielectric material abuts at least the outer face of the flange. In another arrangement, the isolating washer includes a metal core coated with a dielectric material. In one form, the isolating sleeve includes a sleeve made of one of glass reinforced polymer material, epoxy material, phenolic material, and meta-aramid material. In another form, the metal fastener includes a metal shaft threaded to receive a nut on at least one of the opposing ends.

In a first arrangement, the plurality of serrations have a corresponding plurality of alternating peaks and grooves, wherein each of the peaks has a first axial width dimension and each of the grooves has a second axial width dimension, the first axial width dimension being substantially the same for each of the peaks, and the second axial width dimension being substantially the same for each of the grooves.

In a second arrangement, the plurality of serrations have a corresponding plurality of alternating peaks and grooves, wherein each of the peaks has a first axial width dimension that is substantially the same for each of the peaks, and wherein the plurality of grooves includes five groups that are orderly arranged across a width of the serrated ring, wherein the outer two groups of the plurality of grooves have a second axial width dimension, the middle two groups of the plurality of grooves have a third axial width dimension, and the center group of the

plurality of grooves has a fourth axial dimension, wherein the fourth axial width dimension is larger than the third axial width dimension, and the third axial width dimension is larger than the second axial width dimension. In one form, the fourth axial width dimension, the third axial width dimension, and the second axial width dimension generally form a convex profile that spans across the width of the serrated ring.

In another example arrangement of an isolation gasket for use between facing flanges of two flow conduit sections for fluid passage therethrough, the isolation gasket includes a flat metal core ring having an upper face opposing a lower face and an opening formed therein to allow fluid passage therethrough. The flat metal core ring has a serrated ring positioned between an inner ring and an outer ring wherein the serrated ring having a plurality of serrations along the upper face and the lower face. A first non-conductive layer is positioned on the upper face and the lower face of the inner ring to provide a dielectric barrier for the inner ring, a second non-conductive layer on the upper face and the lower face of the outer ring to provide a dielectric barrier for the outer ring, and a non-conductive coating is applied on the plurality of serrations of the upper face and the lower face of the serrated ring to provide a dielectric barrier for the serrated ring. A fire resistant layer and a third non-conductive layer are arranged in a side by side orientation on the non-conductive coating applied on the plurality of serrations of the serrated ring, wherein each of the fire resistant layer and the third non-conductive layer covers approximately half of the serrated ring. In one arrangement, the fire resistant layer spans from an outer edge of the serrated ring to a mid-region of the serrated ring, and the third non-conductive layer spans from an inner edge of the serrated ring to the mid-region of the serrated ring such that the fire resistant layer and the third non-conductive layer do not overlap.

In a first arrangement of the isolation gasket, the plurality of serrations have a corresponding plurality of alternating peaks and grooves, wherein each of the peaks has a first axial width dimension and each of the grooves has a second axial width dimension, the first axial width dimension being substantially the same for each of the peaks, and the second axial width dimension being substantially the same for each of the grooves. In a second arrangement of the isolation gasket, the

plurality of serrations have a corresponding plurality of alternating peaks and grooves, wherein each of the peaks has a first axial width dimension that is substantially the same for each of the peaks, and wherein the plurality of grooves includes five groups that are orderly arranged across a width of the serrated ring, wherein the outer two
5 groups of the plurality of grooves have a second axial width dimension, the middle two groups of the plurality of grooves have a third axial width dimension, and the center group of the plurality of grooves has a fourth axial dimension, wherein the fourth axial width dimension is larger than the third axial width dimension, and the third axial width dimension is larger than the second axial width dimension. In the
10 second arrangement of the isolation gasket, the fourth axial width dimension, the third axial width dimension, and the second axial width dimension generally form a convex profile that spans across the width of the serrated ring.

Further forms, objects, features, aspects, benefits, advantages, and embodiments of the present invention will become apparent from a detailed
15 description and drawings provided herewith. Non-limiting embodiments of the invention will now be described, by way of example only, and with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a top view of a first embodiment of an isolation gasket.

FIG. 2 illustrates a cross sectional view of the isolation gasket in the FIG. 1 embodiment.

5 FIG. 3 illustrates a partial, enlarged view of a non-conductive coating on a serrated ring in the FIG. 1 embodiment.

FIG. 4 illustrates a cross sectional view of the flat metal core ring from the isolation gasket in the FIG. 1 embodiment.

FIG. 5 illustrates a top view of a second embodiment of an isolation gasket.

10 FIG. 6 illustrates a cross sectional view of a serrated ring from the isolation gasket in the FIG. 5 embodiment.

FIG. 7 illustrates the cross sectional view of the serrated ring from the FIG. 6 embodiment.

15 FIG. 8 illustrates a side view and a partial cross sectional view of the isolation gasket in the FIG. 1 embodiment.

FIG. 9 illustrates a side view and a partial cross sectional view of the isolation gasket in the FIG. 1 embodiment.

DETAILED DESCRIPTION

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiment illustrated in the drawings and specific language will be used to describe the same. It will
5 nevertheless be understood that no limitation of the scope of the invention is thereby intended, and alterations and modifications in the illustrated device, and further applications of the principles of the invention as illustrated therein are herein contemplated as would normally occur to one skilled in the art to which the invention relates. One embodiment of the invention is shown in great detail,
10 although it will be apparent to those skilled in the relevant art that some features not relevant to the present invention may not be shown for the sake of clarity.

In order to help with an understanding of the exemplary embodiment, a representative isolation gasket 20 is disclosed and illustrated in FIGS. 1, 2, 3, and 4. The isolation gasket 20 is configured for use between facing flanges of two flow
15 conduit sections for fluid passage therethrough. Some types of fluid that could pass through flow conduit sections include oil, petroleum, natural gas, other flammable materials, and many other types of fluid. As can be appreciated, fluid leakage of any of these fluids could be extremely dangerous and toxic. The isolation gasket 20 includes a flat metal core ring 22 that has an upper face 24 opposite a lower face 26
20 and an opening 28 formed therein to allow fluid passage therethrough when the isolation gasket 20 is assembled with the fluid flow conduit sections as described in more detail below. The isolation gasket 20 includes a first non-conductive layer 70, a second non-conductive layer 72, a non-conductive coating 74, a fire resistant layer 76, and a third non-conductive layer 78 that in combination create a fire
25 resistant and electrically isolating seal. Each of these elements of the isolation gasket 20 will be described next.

The flat metal core ring 22 has a serrated ring 30 positioned between an inner ring 32 and an outer ring 34. The inner ring 32 has an inside diameter 36 that corresponds to the diameter of the opening 28. In one embodiment, the inside
30 diameter 36 matches the inner diameter of the flow sections of pipe into which it is placed. In other words, the inner diameter 36 is substantially the same size as the inner diameter of the bore which has been found to reduce potential corrosion. The

inner ring 32 has an outside diameter 38 that corresponds to the interface between the inner ring 32 and the serrated ring 30. The inner ring 32 has a width 37 that spans between the inside diameter 36 and the outside diameter 38. The inner ring 32 also has an upper face 40 opposite a lower face 42 with a depth or thickness 44 that spans between the upper and the lower faces 40 and 42, respectively. The depth 44 of the inner ring 32 is greater than a depth 66 of the outer ring 34 which has been found to beneficially reduce potential corrosion. In one embodiment, the upper and the lower faces 40 and 42 have a 0.125 microinches surface finish to improve adhesion of the first non-conductive layer 70.

10 The serrated ring 30 has an inside diameter that corresponds to the outside diameter 38 of the inner ring 32 to form an interface therebetween. The serrated ring 30 has an outside diameter 46 that corresponds to the interface between the serrated ring 30 and the outer ring 34. The serrated ring 30 has a width 47 that spans between the inside diameter and the outside diameter 46. The serrated ring 15 30 includes a mid-region or middle diameter that is measured from half-way between the inside diameter and the outside diameter 46 of the serrated ring 30. The serrated ring 30 also has an upper face 48 opposite a lower face 50 with a depth or thickness 52 that spans between the upper and the lower faces 48 and 50. The depth 52 of the serrated ring 30 is greater than either depth 44 of the inner ring 20 32 or depth 66 of the outer ring 34. The serrated ring 30 has a plurality of serrations 54 that span along the upper face 48 and the lower face 50. The plurality of serrations 54 have a corresponding plurality of alternating peaks 56 and grooves 58, wherein each of the peaks 56 has a first axial width dimension and each of the grooves 58 has a second axial width dimension. The first axial width dimension is 25 substantially the same for each of the peaks 56, and the second axial width dimension is substantially the same for each of the grooves 58. In other words, there is no variance in size between the first axial width dimension of all of the peaks 56 and similarly there is no variance in size between the second axial width dimension of all of the grooves 58.

30 The outer ring 34 has an inside diameter that corresponds to the outside diameter 46 of the serrated ring 30. The outer ring 34 also has an outside diameter 60 that spans across the width of the flat metal core ring 22. The outer ring 34 has a

width 61 that spans between the inside diameter and the outside diameter 60. The outer ring 34 also has an upper face 62 opposite a lower face 64 with a depth or thickness 66 that spans between the upper and the lower faces 62 and 64, respectively. In one embodiment, the upper and the lower faces 62 and 64 have a
5 0.125 microinches surface finish to improve adhesion of the second non-conductive layer 72.

The flat metal core ring 22 is made of metal, including stainless steel, 316 stainless steel, high nickel alloys, or other metal that is appropriate for the flow conduit sections and the material therein. In some embodiments, the metal core
10 ring 22 is made of particular materials such as Inconel® austenitic nickel-chromium-based superalloys, Hastelloy® highly corrosion-resistant metal alloys, and Duplex stainless steel to name a few. Typically the size of inner ring 32, serrated ring 30, and the outer ring 34 correspond to the size of the conduit flow sections into which the rings will be placed when in use. One example includes
15 conduit flow sections sized according to ANSI B16.5 Flange Code and the inner ring 32, serrated ring 30, and the outer ring 34 sized accordingly and as noted above. One benefit for flat metal core ring 22 sized for use with ANSI B16.5 Flange Code enables the outside diameter 60 of the outer ring 34 to self align the isolation gasket 20 with within the bolt circle of the facing flanges. Another
20 benefit for the flat metal core ring 22 sized for use with ANSI B16.5 Flange Code is the inner diameter 36 of inner ring 32 would match the ANSI B16.5 Flange Bore exactly thereby allowing for minimum flange face exposure and allowing for pipe cleaning devices or commonly referred in the industry as “pigs” to pass through the isolation gasket 20 and the flanges when assembled. Yet another benefit is the
25 serrated ring 30 is configured for use with both Ring Type Joints and Raised Face ANSI B16.5 flanges.

The isolation gasket 20 also includes a first non-conductive layer 70 that is placed on the upper face 40 and the lower face 42 of the inner ring 32 to provide a dielectric barrier and electrical isolation for the inner ring 32 as illustrated in FIGS.
30 1 and 2. The first non-conductive layer 70 spans across the width 37 of the inner ring 32. In one form, the first non-conductive layer 70 also covers the depth 44 of the inside face of the inner ring 32. Suitable materials for the first non-conductive

layer 70 include G10 laminated sheet, G11 laminated sheet, electrical glass cloth that is impregnated with epoxy resin under high pressure and high heat, polymer based non-conductive coatings, phenolic resin based material, epoxy based non-conductive coatings, or other suitable dielectric material. There are many techniques to apply the first non-conductive layer 70 to the inner ring 32. One technique is to apply the first non-conductive layer 70 as a coating which is applied via a spray gun to the correct thickness using a thickness gauge. A second technique to apply the first non-conductive layer 70 as a different material is with adhesive or glue. The first non-conductive layer 70 has characteristics of high temperature resistance, high mechanical properties and dielectric properties, and good heat resistance. For example, the material chosen for the first non-conductive layer 70 show allow for a temperature of at least 300 degrees Farenheit, at least 25,000psi compressive strength, and at least 400V/mill. for dielectric. A typical range of thickness for the first non-conductive layer 70 is between about 0.2 millimeters to about 80 millimeters.

The isolation gasket 20 also includes a second non-conductive layer 72 that is placed on the upper face 62 and the lower face 64 of the outer ring 34 to provide a dielectric barrier and electrical isolation for the outer ring 34 as illustrated in FIGS. 1 and 2. The second non-conductive layer 72 spans across the width 61 of the outer ring 34. In one form, the second non-conductive layer 72 also covers the depth 66 of the outside face of the outer ring 34. Suitable materials for the second non-conductive layer 72 include G10 laminated sheet, G11 laminated sheet, electrical glass cloth that is impregnated with epoxy resin under high pressure and high heat, polymer based non-conductive coatings, phenolic resin based material, epoxy based non-conductive coatings, or other suitable dielectric material. There are many techniques to apply the second non-conductive layer 72 to the outer ring 34. One technique is to apply the second non-conductive layer 72 as a coating which is applied via a spray gun to the correct thickness using a thickness gauge. A second technique to apply the second non-conductive layer 72 as a different material is with adhesive or glue. The second non-conductive layer 72 has characteristics of high temperature resistance, high mechanical properties and dielectric properties, and good heat resistance. For example, the material chosen

for the second non-conductive layer 72 allows for a temperature of at least 300 degrees Fahrenheit, at least 25,000psi compressive strength, and at least 400V/mill. for dielectric. A typical range of thickness for the first non-conductive layer 70 is between about 0.2 millimeters to about 80 millimeters. The second non-

5 conductive layer 72 can be made of the same material as the first non-conductive layer 70 or a different material depending on the requirements for the isolation gasket 20 in a particular setting. A typical range of thickness for the second non-conductive layer 72 is between about 0.2 millimeters to about 80 millimeters.

The isolation gasket 20 also includes a non-conductive coating 74 that is

10 placed on the serrations 54 including the peaks 56 and the grooves 58 to fully cover the upper face 48 and the lower face 50 of the serrated ring 30 to provide electrical isolation. The non-conductive coating 74 is also placed on an exposed outside face of the serrated ring 30 that spans the depth 52 less either of the depth 44 of the inner ring 32 or the depth 66 of the outer ring 34. Suitable materials for

15 the non-conductive coating 74 include polytetrafluoroethylene (PTFE), any non-conductive polymer, Halar® ECTFE, a copolymer of ethylene and chlorotrifluoroethylene, epoxy based coatings, other variations of PTFE coatings including but not limited to Xylan® 1200 series or Xylan® 1400 series, or other suitable dielectric material. One embodiment of the non-conductive coating 74

20 includes a PTFE coating about 3 to 5 mils thick that is sprayed on the serrations 54 to cover the peaks 56 and the grooves 58.

The isolation gasket 20 also includes a fire resistant layer 76 placed on the non-conductive coating 74 that is positioned on the upper face 48 and the lower face 50 of the serrated ring 30. The fire resistant layer 76 does not cover all of the

25 non-conductive coating 74 but instead spans from an outer edge of the serrated ring 30 to the mid-region of the serrated ring 30 to thereby cover an outer radial portion of the non-conductive coating 74. Suitable materials for the fire resistant layer 76 include a mica sheet with a silicon binder, mica-based laminate sheets, aluminosilicate, ceramic fiber, and ceramic impregnated materials, to name a few

30 materials. In one embodiment, in the event of a fire, the fire resistant layer 76 made of a mica sheet protects the non-conductive coating 74 and resists melting up

to about 1000°C (1832°F). In one embodiment, the fire resistant layer 76 is attached to the non-conductive coating 74 on the serrations 54 via adhesive.

The isolation gasket 20 includes a third non-conductive layer 78 placed on the non-conductive coating 74 wherein the third non-conductive layer 78 spans from an inner edge of the serrated ring 30 to the mid-region of the serrated ring 30 to provide electrical isolation and a seal for the isolation gasket 20. The third non-conductive layer 78 does not cover all of the non-conductive coating 74 but instead spans from an inner edge of the serrated ring 30 to the mid-region of the serrated ring 30 to thereby cover an inner radial portion of the non-conductive coating 74.

10 The fire resistant layer 76 and the third non-conductive layer 78 form a boundary 80 therebetween such that the fire resistant layer 76 does not overlap the third non-conductive layer 78. In other words, the fire resistant layer 76 and the third non-conductive layer 78 are arranged in a side by side orientation on the non-conductive coating 74. Some suitable materials for the third non-conductive layer

15 78 include a chemically inert, biaxially-oriented filled polytetrafluoroethylene (PTFE) or a biaxially-oriented high quality silica-filled PTFE sheet. The biaxial orientation of the PTFE particles creates a unique strength where both the longitudinal and transverse directions of the sheet are equally as strong. This biaxial orientation and addition of fillers such as silica enables the PTFE sheet to

20 resist creep and cold flow when subjected to load. However other embodiments may include different materials that also provide electrical isolation of the serrated ring 30. Other materials for the third non-conductive layer 78 include other PTFE based sheet material, Viton® fluoroelastomer, nitrile, EPDM or ethylene propylene diene monomer (M-class) rubber, and any other compressed sheet non-conducting

25 material.

There are many benefits or advantages to the combination of the fire resistant layer 76, the third non-conductive layer 78, and the non-conductive coating 74. Beneficially the combination of the fire resistant layer 76 and the third non-conductive layer 78 for facings on the non-conductive coating 74 provide the

30 unique benefits of a superior seal, high thermoresistive properties, and electrical isolation. Moreover, the unique placement of the fire resistant layer 76 adjacent the third non-conductive layer 78 enables the fire resistant layer 76 to protect the third

non-conductive layer 78 in the event of a fire and thereby maintain the seal. The third non-conductive layer 78 forms a seal when the isolation gasket 20 is assembled between two flow conduit sections. The fire resistant layer 76 is typically not as strong as third non-conductive layer 78 such that the third non-conductive layer 78 is able to withstand higher pressures. Therefore the third non-conductive layer 78 is placed closer to the inner edge of the serrated ring 30 and the fire resistant layer 76 is placed closer to the outer edge of the serrated ring 30 in a side by side orientation. Also beneficially the non-conductive coating 74 on the serrations 54 maintains a dielectric barrier in the possible situation that if the bolts are overstressed such that the loads on the bolts are too high causing the serrations 54 to cut through the fire resistant layer 76 and the third non-conductive layer 78 there is no metal to metal contact resulting in conductivity. Also beneficially the first non-conductive layer 70, second non-conductive layer 72, and non-conductive coating 74 on the gasket 20 provide electrical isolation.

A second embodiment of an isolation gasket 120 is disclosed and illustrated in FIGS. 5, 6, and 7. The isolation gasket 120 is configured for use between facing flanges of two flow conduit sections for fluid passage therethrough. The isolation gasket 120 is similar in all aspects to the isolation gasket 20, except a serrated ring 130 is configured differently from serrated ring 30. Therefore for the sake of brevity similar features for isolation gasket 120 and isolation gasket 20 will not be described. The isolation gasket 120 includes a flat metal core ring that has an upper face opposite a lower face and an opening 128 formed therein to allow fluid passage therethrough when the isolation gasket 120 is assembled with the fluid flow conduit sections as described in more detail below. The isolation gasket 120 also includes a first non-conductive layer, a second non-conductive layer, a non-conductive coating, a fire resistant layer, and a third non-conductive layer (collectively not illustrated) that in combination create a fire resistant and electrically isolating seal similar in all aspects to isolation gasket 20.

The flat metal core ring of isolation gasket 120 has a serrated ring 130 positioned between an inner ring 132 and an outer ring 134. Similar to serrated ring 30, the serrated ring 130 has an inside diameter that corresponds to an outside diameter 138 of the inner ring 132 to form an interface therebetween. The serrated

ring 130 has an outside diameter 146 that corresponds to the interface between the serrated ring 130 and the outer ring 134. The serrated ring 130 has a width 147 that spans between the inside diameter and the outside diameter 146. The serrated ring 130 also has an upper face 148 opposite a lower face 150 with a depth or thickness
5 152 that spans between the upper and the lower faces 148 and 150, respectively.

The serrated ring 130 has a plurality of serrations 154 that span along the upper face 148 and the lower face 150. The plurality of serrations 154 have a corresponding plurality of alternating peaks 156 and grooves 158, wherein each of the peaks 156 has a first axial width dimension, X, and each of the grooves 158 has
10 a corresponding axial width dimension as described next. As illustrated in FIGS. 6 and 7, the first axial width dimension X is substantially the same for each of the peaks 156, however the axial width dimension can vary for each of the grooves 158. In the particular embodiment illustrated in FIGS. 6 and 7, the width 147 is broken into five sections A, B, C, B, and A. Other embodiments can include
15 additional sections within the same size width as width 147. Both sections A have the same overall width and the same number of grooves 158. Similarly both sections B have the same overall width and the same number of grooves 158. Each of the grooves 158 in section A has a second axial width dimension R wherein dimension R is the same size for all of the corresponding grooves 158 in section A.
20 Similarly, each of the grooves 158 in section B has a third axial width dimension S wherein dimension S is the same size for all of the corresponding grooves 158 in section B. Each of the grooves 158 in section C has a fourth axial width dimension T wherein dimension T is the same size for all of the corresponding grooves 158 in section C. Generally, the fourth axial width dimension T is larger than the third
25 axial width dimension S. The third axial width dimension S is larger than the second axial width dimension R. As such, the second axial width dimension R, the third axial width dimension S, and the fourth axial width dimension T collectively form a generally convex profile as indicated by the dashed lines in FIG. 6.

In the illustrated embodiment, the plurality of grooves 158 includes five
30 groups or sections A, B, C, B, and A that are orderly arranged across the width 147 of the serrated ring 130. The outer two groups A and A of the plurality of grooves 158 have the second axial width dimension R, the middle two groups B and B of

the plurality of grooves 158 have the third axial width dimension S, and the center group C of the plurality of grooves 158 has the fourth axial width dimension T, wherein the fourth axial width dimension T is larger than the third axial width dimension S, and the third axial width dimension S is larger than the second axial width dimension R. As such, the fourth axial width dimension T, the third axial width dimension S, and the second axial width dimension R generally form a convex profile or convex sealing plane that spans across the width 147 of the serrated ring 130.

In one embodiment, the first axial width dimension X of the peaks 156 is about 0.125 inches. In this embodiment, the difference between the first axial width dimension X and the fourth axial width dimension T is between 0.012 inches and 0.014 inches. The difference between the first axial width dimension X and the third axial width dimension S is between 0.019 inches and 0.021 inches. The difference between the first axial width dimension X and the second axial width dimension R is between 0.024 inches and 0.026 inches. Moreover, in this embodiment, the five separate sections A, B, C, B, and A, are evenly spaced and distributed across the width 147 of the serrated ring 130.

Beneficially, the serrated ring 130 of the flat metal core ring of isolation gasket 120 provides increased performance in seal-ability and adds more robustness with regard to flange rotation, flange mis-alignment, and over-bolting which are problems in the flange industry. The convex sealing plane also compensates for flange irregularities for which the fire resistant layer 76 and the third non-conductive layer 78 flow into.

In evaluating the pressure-containing capabilities and properties of isolation gasket 20 and similarly isolation gasket 120, a fire test was completed per API standard 6FB (Third Edition, Nov. 1998, Non-bending, On-shore or Open-Offshore Fire Test). Although only isolation gasket 20 was tested, the isolation gasket 120 would behave similarly since the serrated ring 130 would not affect the fire safety rating of isolation gasket 120. The isolation gasket 20 having an outer diameter of about 6 inches was tested. The test involved affixing the isolation gasket 20 between two flanges and fitting the flanges to a test setup at United Valve Inc. of Houston, Texas, USA. The isolation gasket 20 was then subject to

burn cycle at an average flame temperature between 1400° and 1800°F for 30 minutes while maintaining 555 psi. Upon completion of the burn, the pressure was then held during a 30 minute cool down to a temperature below 212°F. The isolation gasket 20 was depressurized and then pressurized back to 555 psi and held for an additional 5 minutes.

The objective of the test was to monitor the total leakage during the duration of the burn/cool down cycle, along with the repressurization cycle with accordance to API 6FB standards. Leakage was determined by the total water level drop through a visual sight gauge during the burn/cool down cycles, and then by manually catching the water in a calibrated container during the repressurization cycle.

The results concluded that the isolation gasket 20 was able to maintain its fire safe characteristics throughout the entirety of the test. During the 30 minute burn and 30 minute cool down period, the measured leakage was only 0 ml/min versus the allowable rate of 22.765 ml/min. The leakage rate during the repressurization cycle was 5 ml/min versus the allowable rate of 22.765 ml/min. The conclusion was that the isolation gasket 20 satisfies the requirements of the API 6FB test protocol.

Below is a summary of the test setup and protocol performed during the gasket fire test with accordance to API 6FB standards:

1. Install the isolation gasket 20 between two CS flanges.
2. Bolt the flanges together using the supplied B7 Studs, 2H Nuts Dielectric Sleeves, and Coated Steel Washers.
3. Apply non-conductive PTFE lubricant to studs/bolts and torque to 225 ft.-lbs.
4. Thread NPT pipe fittings into flanges and affix the flange package in the test setup.
5. Connect all pressure and temperature monitoring equipment in their correct positions. The equipment consisted of 2 flame thermocouples, 3 thermocouples and 3 calorimeter cubes space 120° apart around the circumference of the flange (respectively), and a 4th calorimeter/thermocouple cube place furthest away from the flame sources.

6. Hydrotest the assembly to 555 psi to check all fittings/connections for leaks prior to testing.
7. Confirm pressure and ignite the burners under the flange assembly and start the burn cycle clock.
- 5 8. Per the test protocol, the average temperature of the flame thermocouples must reach 1400°F within 2 minutes of ignition, and maintain an average temperature between 1400°F- 1800°F with no reading less than 1300°F until the average calorimeter temperature reaches 1200°F.
9. The average temperature between the 4 calorimeter cubes must reach 1200°F within 15 minutes of the burner ignition.
- 10 10. Conduct the burn cycle for at least 30 minutes.
11. Upon completion of the burn cycle, cool the valve below 212°F.
12. Depressurize the system.
13. Repressurize the system to 555 psi and hold for 5 minutes.
- 15 14. Determine the allowable leakage rates:

$$AL = SD * \pi = 7.25 * \pi = 22.765 \text{ in}$$

Where: AL= Allowable Leakage

SD= Mean Gasket Seal Diameter

15. Compare the actual leakage rates vs. the allowable rate.

20

During the test, data was sampled every 30 seconds. Data collection consisted of: pressure, calorimeter block temperatures (4), thermocouple temperatures (4), and flame thermocouple temperatures (2). Water levels were also visually monitored through a sight gauge on the pressure vessel. A summary of the main data results is outlined below in Table A and the full data results is outlined below in Table B.

25

Table A

Variable	Data Recorded
Average System Pressure	550.59 PSI
Average Flame Temperature	1722.72°F
Time to reach flame temperature of	1 min 30 seconds

1,400 °F	
Average Calorimeter Temperature	1329.4°F
Time to reach average calorimeter temperature of 1,200 °F	10 min 30 seconds
Total Burn Time	30 min
Total Cool Down Time	30 min
Total Repressurization Hold Time	5 min
Average System Pressure during Repressurization	556.71 PSI

Table B

Time	Flame 1	Flame 2	Cal 1	Cal 2	TC1	TC2	Cal 3	TC3	Cal 4	TC4	Avg. Pressure	Vent	Avg. Flame	Avg. Cal	Avg. TC
1:57:00 PM	77.5	77.8	80.8	84.5	80.7	83.8	84	84	87.3	90.7	556.5	557.2	77.65	84.2	84.8
1:57:30 PM	77.5	77.8	80.8	84.5	80.7	83.7	83.8	83.9	87.3	90.5	554.7	555.5	77.65	84.1	84.7
1:58:00 PM	876.3	1676.9	156.2	92.4	217.2	114.9	174.6	315.4	89.3	90.1	552.7	553.8	1276.6	128.1	184.4
1:58:30 PM	1711.8	1792.6	286.1	136.7	324.1	226.6	219.3	425.8	209.2	96.4	551.9	553.2	1752.2	212.8	268.2
1:59:00 PM	1826.6	1802.9	350.4	213.3	379.9	365.2	410.1	593.8	272.8	170	551.5	552	1814.75	311.7	377.2
1:59:30 PM	1838.7	1792.3	463.9	350.1	449.1	493	554.5	709.8	413.7	263.2	551.6	552.5	1815.5	445.6	478.8
2:00:00 PM	1840.2	1785.2	531.5	531.2	503.1	624.5	694.6	831.5	512.7	428.9	551.3	551.8	1812.7	567.5	597.0
2:00:30 PM	1839	1835.1	602.6	677.9	599.2	727.3	802.4	951	587.3	575.5	551	551.9	1837.05	667.6	713.3
2:01:00 PM	1834.9	1777.6	651.1	804.8	605.9	816.3	903	1035	674.2	688.8	550.6	551.2	1806.25	758.3	786.5
2:01:30 PM	1834.3	1825.9	685.8	905.7	644.8	886.5	986.1	1115.3	733.6	797.1	550.3	551.1	1830.1	827.8	860.9
2:02:00 PM	1832.6	1697.2	726.9	990.9	671.5	921.5	1056.5	1145.3	794.9	894.2	550.4	550.6	1764.9	892.3	908.1
2:02:30 PM	1831.2	1697.6	754	1052	688	977.1	1109.5	1199.8	845.7	973.6	550.1	550.9	1764.4	940.3	959.6
2:03:00 PM	1835	1790.4	777.1	1104.7	726	1024.6	1155.1	1263.9	902.3	1044.1	549.3	550.6	1812.7	984.8	1014.7
2:03:30 PM	1834.2	1803.5	803.2	1151.2	742	1060.1	1199.5	1319.6	956.8	1103.7	549.7	550.4	1818.85	1027.7	1056.4
2:04:00 PM	1830.7	1821.5	836.4	1190.3	817.4	1077	1237	1324.4	1000.2	1153.9	550	550.2	1826.1	1066.0	1093.2
2:04:30 PM	1828.7	1823.7	883.3	1224.4	846	1130.1	1267.8	1359.4	1040.2	1196.7	549.6	550.2	1826.2	1103.9	1133.1
2:05:00 PM	1830.8	1823.1	930.5	1252.9	881.9	1135.2	1294.8	1425.6	1075	1222.8	549.5	549.9	1826.95	1138.3	1166.4
2:05:30 PM	1830.6	1832.2	967.3	1277.3	918.4	1149.2	1319.5	1408.1	1086.8	1250	548.7	549.9	1831.4	1162.7	1181.4
2:06:00 PM	1823.3	1804.4	990.9	1297.9	936.7	1165.5	1335.5	1425.8	1113.4	1274.4	549	549.2	1813.85	1184.4	1200.6
2:06:30 PM	1831.4	1827.8	1007.7	1316.1	963.2	1179.4	1348.8	1470.1	1133.9	1292.9	548.8	549.3	1829.6	1201.6	1226.4
2:07:00 PM	1829.2	1712.4	1031	1330.5	968.7	1171.4	1364.7	1428.4	1140.8	1309.3	548.5	549.2	1770.8	1216.8	1219.5
2:07:30 PM	1823.5	1716.8	1054.4	1333.8	972.3	928.9	1374.8	1411.5	1154.3	1324	547.8	549.4	1770.15	1229.3	1159.2
2:08:00 PM	1828.6	1746.4	1061.8	1340.3	975.8	934.7	1380.4	1436.1	1177.6	1333.3	548.8	549.3	1787.5	1240.0	1170.0
2:08:30 PM	1824.6	1697.9	1057.9	1346.1	978.2	1145.7	1380.1	1398.4	1195.5	1342.5	548.7	548.8	1761.25	1244.9	1216.2
2:09:00 PM	1815.8	1686.2	1052	1345.8	979.3	978.3	1373.3	1481.7	1211.6	1349.5	548.2	547.6	1751	1245.7	1197.2
2:09:30 PM	1817.5	1657.6	1050.3	1349.2	982.2	1012.7	1381.8	1449.4	1227.2	1352.1	548.1	545.6	1737.55	1252.1	1199.1
2:10:00 PM	1813.5	1709.7	1045.5	1352.7	973.3	1022.2	1383.1	1428.7	1237.8	1358.8	547.9	548.6	1761.6	1254.8	1195.8
2:10:30 PM	1821.7	1798.2	1053.5	1355.7	982.3	1048.3	1383.2	1471.1	1248.7	1362.8	547.9	548.9	1809.95	1260.3	1216.1
2:11:00 PM	1820.7	1799.9	1070.9	1361.2	1001.7	1050.8	1391.6	1454.8	1260.7	1359.9	547.7	549	1810.3	1271.1	1216.8
2:11:30 PM	1820.7	1776.8	1073.5	1366.4	997.1	1044.7	1396.4	1475.5	1271.1	1357.5	548.1	548.9	1798.75	1276.9	1218.7
2:12:00 PM	1823.3	1739.1	1068.6	1371.5	997.9	1041.6	1402.2	1460.3	1235.8	1348.5	548	548.5	1781.2	1269.5	1212.1
2:12:30 PM	1817.4	1618.9	1059.9	1372.3	994	960	1395.5	1438.3	1282.4	1311.5	548.1	548.3	1718.15	1277.5	1176.0
2:13:00 PM	1825.5	1759.2	1050.6	1370.7	978.1	987.2	1387.6	1487.8	1379.9	1307.3	547.4	548.1	1792.35	1297.2	1190.1
2:13:30 PM	1815.7	1734.1	1055.0	1375.3	982.6	958.1	1400.1	1447.5	1387.4	1313.6	547.1	547.5	1774.90	1304.5	1175.5
2:14:00 PM	1817.8	1704.2	1051.2	1372.9	967.4	968.8	1404.3	1483.1	1385.7	1377.7	546.9	547.2	1761	1303.5	1199.3
2:14:30 PM	1815.9	1782.6	1050.6	1373.9	997.3	1124.8	1408.8	1477.2	1389.8	1427.4	546.3	546.5	1799.25	1305.8	1256.7
2:15:00 PM	1820.3	1751	1056.9	1380.3	991.3	1093.9	1411.8	1480.4	1392.7	1395.4	545.5	546.5	1785.65	1310.4	1240.3
2:15:30 PM	1822.4	1802.8	1068	1381.6	1004.9	1126.9	1421.5	1492.2	1404.8	1400.8	545.4	546.4	1812.6	1319.0	1256.2
2:16:00 PM	1823.5	1787	1083.4	1388.8	1017.1	1135.1	1437.9	1516.3	1405.1	1402.3	545.3	545.9	1805.25	1328.8	1267.7
2:16:30 PM	1817.5	1762.8	1085.3	1395.7	1018	1158.3	1447.1	1516	1409.5	1407.2	544.3	545.7	1790.15	1334.4	1274.9
2:17:00 PM	1818	1799.2	1085.4	1398.9	1018.8	1175.3	1455.7	1562.9	1416.2	1410.1	545	545.7	1808.6	1339.1	1291.8
2:17:30 PM	1822.4	1775.7	1100.6	1407	1036.3	1157	1464.3	1531.1	1422.1	1423.2	544.5	545.3	1799.05	1348.5	1286.9
2:18:00 PM	1817.5	1708.7	1118.2	1406.7	1036.3	1193.9	1464.3	1637.3	1425.6	1422.3	544.7	543.9	1763.1	1353.7	1322.5
2:18:30 PM	1831	1844.1	1123.6	1412.5	1073.8	1181.9	1475.7	1560.8	1426.4	1423.8	544	545.4	1837.55	1359.6	1310.1
2:19:00 PM	1832	1845.4	1139.1	1422.9	1083.4	1195.4	1491.3	1585.7	1425.2	1428.7	544.2	545.1	1838.7	1369.6	1323.3
2:19:30 PM	1825.4	1795.5	1154.8	1429.2	1083.7	1190.1	1493.9	1613.6	1424.7	1425.1	543.7	544.3	1810.45	1375.7	1328.1
2:20:00 PM	1820.6	1770.7	1164.3	1431.7	1085.9	1186.8	1492.3	1592.6	1428.8	1429.2	544.1	544.7	1795.65	1379.3	1323.6
2:20:30 PM	1813.6	1730.3	1163.7	1435.5	1085.9	1196.1	1493.3	1606	1427.8	1475.6	543.6	544.5	1771.95	1380.1	1340.9
2:21:00 PM	1806.7	1604.2	1151.1	1437.1	1061.2	1187.7	1492.3	1542.2	1428.5	1473.9	543.2	544.3	1705.45	1377.3	1316.3
2:21:30 PM	1808.3	1805.7	1142.1	1426	1093.9	1131.8	1486.7	1624.9	1455.8	1469.1	543.1	544.4	1807	1377.7	1329.9
2:22:00 PM	1783.2	1643.8	1141.4	1423.5	1061.7	1154.8	1494.5	1579.5	1453.2	1468.5	543.1	543.7	1713.5	1378.2	1316.1
2:22:30 PM	1795.9	1633.9	1126.2	1420.5	1045.8	1141.1	1483.8	1543.6	1466.3	1471.3	543.1	543.7	1714.9	1374.2	1300.5
2:23:00 PM	1795.4	1765.1	1119.6	1420.6	1054.2	1156.3	1476.7	1582.5	1470.9	1475.9	545.9	545.6	1780.25	1372.0	1317.2
2:23:30 PM	1802.2	1748	1122.4	1424.8	1041.6	1205.9	1490	1625	1472.6	1475.3	553.7	558.5	1775.1	1377.5	1337.0
2:24:00 PM	1761.5	1691.6	1116.5	1427.6	1041.3	1209.1	1494.6	1577.6	1475.3	1478.5	546.8	546.7	1726.55	1378.5	1326.6
2:24:30 PM	1790.4	1801.3	1117.6	1429.4	1059	1163.7	1492.8	1636.2	1480.6	1482.6	557.1	558.1	1795.85	1380.1	1335.4
2:25:00 PM	1791.6	1723.2	1123.1	1436.5	1056.9	1203.9	1501.7	1596.5	1482.7	1484.2	553.1	553.8	1757.4	1386.0	1335.4
2:25:30 PM	1802.9	1754.6	1124.9	1437.2	1051.4	1147.9	1507.8	1564	1489.3	1487.2	549.6	550.3	1778.75	1389.8	1312.6
2:26:00 PM	1796.8	1738.1	1118.6	1435	1034.7	1127.2	1502.6	1526.3	1499.1	1495.3	545.8	546.7	1767.45	1388.8	1295.9
2:26:30 PM	1796.4	1756.6	1114.4	1428.2	1031.3	1121.7	1495.1	1550.3	1498.3	1495.8	542.1	542.6	1776.50	1384.0	1299.8
2:27:00 PM	1802	1732.1	1123.5	1424.9	1048.4	1123	1487.7	1556.1	1493.2	1492.5	555.4	577.5	1767.15	1382.3	1305.0
2:27:30 PM	1785.7	1774.7	1126.7	1425.7	1057.7	1070.2	1484.7	1556.5	1490.6	1487.3	565.7	566.8	1780.2	1381.9	1292.9
2:28:00 PM	1575.4	1272.3	1121.8	1413.9	1015.3	1095.4	1456.2	1346.4	1475.8	1474.9	558.2	559	1423.85	1366.9	1233.0
2:28:30 PM	1065.5	648.1	1080.6	1366	973.2	1065.4	1399.5	1277	1465.8	1460.3	556.1	556.7	856.8	1328.0	1194.0

TABLE B (CONTINUED)

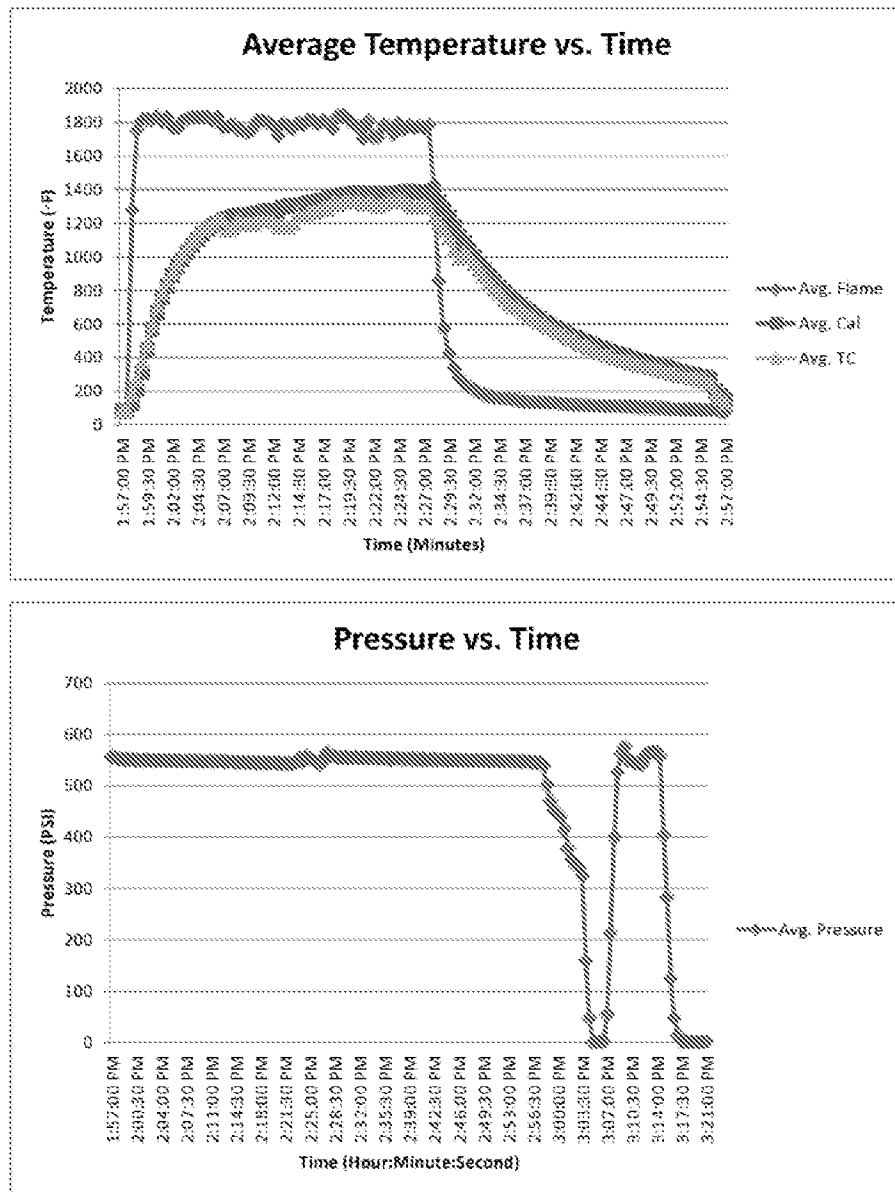
2:29:00 PM	753.3	390.6	1038.2	1319.4	930.7	1044.6	1344.6	1227.9	1421.8	1432.1	555.5	556.5	571.95	1281.0	1158.8
2:29:30 PM	578.8	267.4	997.9	1270.9	889.8	1003.3	1291.2	1189.4	1382.4	1390.1	555.7	556.5	423.1	1235.6	1118.2
2:30:00 PM	457	211.3	958	1224.7	851	826.1	1237.6	1154.7	1300.5	1299.6	555.4	552.9	334.15	1180.2	1032.9
2:30:30 PM	387.1	181.6	848.5	1192.4	815.8	807.2	1191.9	1113.7	1251.3	1231.2	554.8	562.1	284.35	1121.0	992.0
2:31:00 PM	338.4	166.5	813.3	1168	789.3	1076	1175.6	1088.6	1175.3	1152.3	555.3	561	252.45	1083.1	1026.6
2:31:30 PM	299.1	156.7	782.2	1125.4	757.1	1072.5	1135.3	1067.8	1121.3	1099.5	555.2	561.2	227.9	1041.1	999.2
2:32:00 PM	268.5	149	753.6	1081.6	733.2	1029.1	1089.2	1019.2	1078.8	1050.2	554.8	555.3	208.75	1000.8	957.9
2:32:30 PM	242.7	142.3	724.3	1037.5	698.4	989.6	1042.9	976.2	1021.3	1032.6	554.4	547.6	192.5	956.5	924.2
2:33:00 PM	223.3	136.7	697.2	995	677.4	923.7	998.6	940	999.3	1008.3	554.4	556.1	180	922.5	887.4
2:33:30 PM	210.6	134.4	673.2	957.1	653.2	871.8	959.8	895	958.3	961.2	554	550.2	172.5	887.1	845.3
2:34:00 PM	198.3	128.5	649.9	921.8	630.9	834.5	922.5	868.8	921.3	923.5	554.1	559.5	163.4	853.9	814.4
2:34:30 PM	189.6	126.5	627.3	887	610.6	832	886.2	835.9	886.6	873.9	553.6	555.8	158.05	821.8	788.1
2:35:00 PM	184.3	126.5	607.5	856.6	589.5	765.4	854.8	805.2	855.7	843.1	553.6	554.4	155.4	793.7	750.8
2:35:30 PM	181	125.2	588	827.7	571.1	721.1	825.5	780.1	826.6	815.0	553.2	554.4	153.1	767.0	721.8
2:36:00 PM	175.8	122.4	569.2	799.2	554.1	712.3	796.6	750.5	797.9	786.1	553.1	554.1	149.1	740.7	700.7
2:36:30 PM	170.8	120.6	551.5	772.9	537.6	744.7	769.8	728.8	771.35	760.7	552.6	549.9	145.7	716.4	693.0
2:37:00 PM	166	118.5	535.6	747.7	524.2	711.2	745.5	700.7	746.6	735.1	552.6	553.4	142.25	693.9	667.8
2:37:30 PM	161.7	119.4	520	723.9	509.8	679.1	722.3	685.2	723.1	713.6	553	551.5	140.55	672.3	646.9
2:38:00 PM	158.1	113.4	505.4	701.4	491.8	681.9	700.5	662.4	700.95	691.3	552.6	549	135.75	652.1	631.9
2:38:30 PM	155.8	114.9	491.4	680.9	478.5	661.6	678.9	642.7	679.9	670.6	552.6	556.7	135.35	632.8	613.4
2:39:00 PM	153.9	112.7	477.6	661.4	466.2	644.5	659.1	621.6	660.25	650.6	552.3	553.1	133.3	614.6	595.7
2:39:30 PM	152.5	111.7	464.2	642.2	456.2	624.1	640.7	603.7	641.45	632.0	552.1	552.5	132.1	597.1	579.0
2:40:00 PM	150.6	108.6	451.6	625.7	442.4	605	623.4	583.8	624.55	614.4	551.9	552.5	129.6	581.3	561.4
2:40:30 PM	147.4	105	439.1	607.7	426.8	588.7	604.7	568.1	606.2	596.7	551.6	550.8	126.2	564.4	545.1
2:41:00 PM	144.8	105.5	426.9	591.5	417.7	570.9	587.6	552.6	589.55	580.3	551.6	548.7	125.15	548.9	530.4
2:41:30 PM	142.2	105.1	415.8	575.9	406.2	547.3	571.6	535.8	573.75	564.3	551.4	550.2	123.65	534.3	513.4
2:42:00 PM	139.4	103.8	405.4	561.5	397.7	526.7	556.8	525.7	559.15	550.8	551.5	551.8	121.6	520.7	500.2
2:42:30 PM	137	103.6	395.9	548.1	387	495.1	542.9	510.9	545.5	536.9	551.1	547.9	120.3	508.1	482.5
2:43:00 PM	134.6	102	386.1	534.4	377.6	494.3	529	497	531.7	523.0	551.2	552.9	118.3	495.3	473.0
2:43:30 PM	132	100.7	376.1	521.2	368.1	481.6	515	482.8	518.1	509.3	551	555.1	116.35	482.6	460.4
2:44:00 PM	129.9	100.4	367.2	509	360.7	434.8	502.4	470.4	505.7	496.9	550.6	551.9	115.15	471.1	440.7
2:44:30 PM	127.5	99.4	358.2	497.1	351.6	420	489.5	459.1	493.3	484.8	550.5	551.3	113.45	459.5	428.9
2:45:00 PM	126	98.1	349.8	485.9	344.3	407.7	477.6	449.7	481.75	473.7	550.1	548.4	112.05	448.8	418.9
2:45:30 PM	125.9	98.5	342.1	475.2	336	398.5	466.4	439.9	470.8	463.1	550.5	551	112.2	438.6	409.4
2:46:00 PM	125	98.1	334.8	464.4	328	388.3	455.5	427.2	459.95	451.8	550.2	550	111.55	428.7	398.8
2:46:30 PM	122.7	96.2	326.6	453.7	320.2	377.4	444.5	414.9	449.1	440.6	550.2	551.6	109.45	418.5	388.3
2:47:00 PM	120.3	96.2	319.2	443.1	315.2	377	433.1	404.4	438.1	429.7	549.8	549.5	108.25	408.4	381.6
2:47:30 PM	118.5	96.2	312.8	434	307.1	357.8	423.5	398.2	428.75	421.1	549.7	548.9	107.35	399.8	371.1
2:48:00 PM	116.6	93.7	305.2	424.5	298.9	366.5	413.6	385.6	419.05	410.7	549.8	551.1	105.15	390.6	365.4
2:48:30 PM	114.1	92.9	297.9	415.5	293.1	335.9	403.6	375.1	409.55	400.9	549.4	549.1	103.5	381.6	351.3
2:49:00 PM	112.7	93.9	291.8	406.5	287.3	333.8	394.5	371	400.5	393.1	549.6	549.7	103.3	373.3	346.3
2:49:30 PM	111.9	93.4	286.2	398.4	281.4	337.9	386.4	361.1	392.4	384.6	549.2	549.7	102.65	365.9	341.2
2:50:00 PM	112	93.7	280.4	390.5	276.4	334.9	378.2	355.5	384.35	377.1	549	548.9	102.85	358.4	336.0
2:50:30 PM	111.2	92.2	274.7	382.5	269.7	326.1	370.4	348.8	376.45	369.5	549	548.3	101.7	351.0	328.5
2:51:00 PM	108.5	91.7	269.1	374.7	263.8	321.2	361.1	326.6	367.9	357.6	548.9	549.4	100.1	343.2	317.3
2:51:30 PM	103.9	90.4	263.4	365.7	259.3	323.4	349.9	309.2	357.8	345.7	548.5	549.1	97.15	334.2	309.4
2:52:00 PM	100.5	91.3	258	357.2	254.3	314.9	339.2	302.6	348.2	336.8	548.5	548.9	95.9	325.7	302.2
2:52:30 PM	98.5	91.9	253.5	349.8	250.2	308.8	329.7	296.5	339.75	328.9	548.5	549.5	95.2	318.2	296.1
2:53:00 PM	97.2	92.3	248.7	342.2	245.7	309.2	320.5	288.5	331.35	320.6	547.9	547.2	94.75	310.7	291.0
2:53:30 PM	96	92.5	244	335.1	240.2	297	311.4	278.6	323.25	312.1	548	549.4	94.25	303.4	282.0
2:54:00 PM	95	90.8	239.6	328.3	235.4	290.3	302.5	276.6	315.4	305.7	547.6	548.4	92.9	296.5	277.0
2:54:30 PM	93.4	88.8	235	321.7	231.3	275.8	293.8	266.5	307.75	297.4	547.4	548.8	91.1	289.6	267.8
2:55:00 PM	92.4	87.2	230.5	315	226.4	275.1	285.8	262.7	300.4	291.0	547.6	547.9	89.8	282.9	263.8
2:55:30 PM	90.8	87	224.1	308.7	201.6	288.7	278.5	230.8	293.6	277.9	547.3	545.9	88.9	276.2	249.8
2:56:00 PM	91.6	91.1	185.4	289.6	174	265.2	128.8	107.6	209.2	183.8	546.7	546.9	91.35	203.3	182.7
2:56:30 PM	82.2	83.3	160.9	257.7	163.4	217.1	99.5	94.5	178.6	157.6	545.8	546.1	82.75	174.2	158.1
2:57:00 PM	77.6	79.8	148.5	221.5	140.9	190.7	83.1	81.1	152.3	134.5	544.9	545.7	78.7	151.4	136.8
2:57:30 PM	73.8	75.9	137.5	170.1	130.4	164.5	78	78	124.05	112.5	544.7	545.3	74.85	127.4	121.4
2:58:00 PM	69.3	68.7	123.7	153.5	116.4	149.6	76.6	75.6	115.05	105.2	538.5	539.2	69	117.2	111.7
2:58:30 PM	68.4	66.3	116.2	148.7	111.2	144.9	75.3	74.7	112	102.7	500.8	501.4	67.35	113.1	108.4
2:59:00 PM	67.8	65.7	112.8	147.1	108.9	143.1	74.7	73.2	110.9	101.5	470.7	470.8	66.75	111.4	106.7
2:59:30 PM	67.7	64.6	109.9	145	106.9	139.5	73.7	72.9	109.35	100.2	453.9	454.5	66.15	109.5	104.9
3:00:00 PM	68.9	64.2	108.7	143.9	106.5	138.5	73.8	73.1	108.85	99.9	446.4	446.8	66.55	108.8	104.5
3:00:30 PM	69.6	63.7	107.6	142.9	105.4	138.5	73.7	72.4	108.3	99.3	439.4	439.6	66.65	108.1	103.9
3:01:00 PM	70.1	63.6	106.5	141.5	104.6	137.2	73.6	72.3	107.55	98.7	414.8	415.2	66.85	107.3	103.2
3:01:30 PM	70.4	63.5	105.4	140.4	103.8	136.5	73.5	72.3	106.95	98.3	377.6	378	66.95	106.6	102.7
3:02:00 PM	70.9	63.5	104.6	139.6	102.9	136.4	73.4	71.6	106.5	97.8	355.3	355.4	67.2	106.0	102.2

TABLE B (CONTINUED)

3:02:30 PM	70.9	63.2	103.4	138.3	101.7	135.6	73.1	71.5	105.7	97.2	345.5	345.9	67.05	105.1	101.5
3:03:00 PM	71.1	63.2	102.4	137.4	100.8	134.7	73.1	71.6	105.25	96.8	340.4	340.8	67.15	104.5	101.0
3:03:30 PM	71.4	63.5	101.7	136.4	100	133.9	73.4	71.6	104.9	96.6	324.2	324.2	67.45	104.1	100.5
3:04:00 PM	71.5	63.4	100.5	135.5	99	133.1	73.2	71.6	104.35	96.2	159.4	159.9	67.45	103.4	100.0
3:04:30 PM	71.6	63.3	99.8	134.5	98.3	131.8	73.5	71.6	104	95.9	47.5	46.9	67.45	103.0	99.4
3:05:00 PM	71.7	63.3	98.9	133.3	97.5	131	73.6	71.6	103.45	95.5	1	0.8	67.5	102.3	98.9
3:05:30 PM	71.9	63.8	98.2	132.5	96.8	130.2	73.7	71.9	103.1	95.3	1.2	1.1	67.85	101.9	98.6
3:06:00 PM	72.2	62.9	97.8	131.5	95.6	129	73.9	71.6	102.7	94.9	1.3	0.5	67.55	101.5	97.8
3:06:30 PM	72.1	62.6	96.6	130.4	95.2	128	73.9	71.8	102.15	94.6	0.9	0.8	67.35	100.8	97.4
3:07:00 PM	72.1	62.5	95.6	129.3	94.4	127.1	74.2	71.8	101.75	94.3	53.9	53.1	67.3	100.2	96.9
3:07:30 PM	72.3	62.6	94.9	128.2	93.7	126	74.3	71.9	101.25	93.9	214	214.2	67.45	99.7	96.4
3:08:00 PM	72.4	62.6	94	127	92.7	124.9	74.5	71.8	100.75	93.5	399.2	399.8	67.5	99.1	95.7
3:08:30 PM	72.7	62.3	93.3	125.9	92.1	123.6	74.8	72.2	100.35	93.3	526.5	527.3	67.5	98.6	95.3
3:09:00 PM	74.1	64	92.6	125	91.9	122.8	75.1	72.7	100.05	93.2	563.7	564.5	69.05	98.2	95.2
3:09:30 PM	74.1	63.1	92	124	91.1	121.9	75.4	72.5	99.7	92.9	576	576.9	68.6	97.8	94.6
3:10:00 PM	73.5	62.8	91.5	122.9	90.4	120.7	75.5	72.6	99.2	92.6	550.5	551.2	68.15	97.3	94.1
3:10:30 PM	72.8	62.9	90.8	121.9	90.1	119.6	75.5	72.9	98.7	92.3	546.9	547.4	67.85	96.7	93.7
3:11:00 PM	72.5	62.5	90.4	120.9	89.3	118.9	75.6	72.9	98.25	91.9	544.7	545.3	67.5	96.3	93.3
3:11:30 PM	72.5	60.9	88.6	120.2	87.4	118.7	75.5	73.2	97.85	91.7	543.1	544	66.7	95.5	92.7
3:12:00 PM	72.1	61.9	89.1	119.3	88.1	116.9	75.6	73	97.45	91.3	542.4	543.2	67	95.4	92.3
3:12:30 PM	71.3	60.7	87.9	118.3	87.7	114.6	75.4	73.2	96.85	90.9	561.6	562.5	66	94.6	91.6
3:13:00 PM	71.1	63.6	89	117.6	87.2	114.5	76	73.8	96.8	91.1	564.5	565.4	67.35	94.9	91.6
3:13:30 PM	71.4	61.5	87.5	116.2	86.9	112.8	78.7	73	97.45	91.3	564.8	565.6	66.45	95.0	91.0
3:14:00 PM	71.3	62	86.7	115.3	86.1	111.2	75.9	73.2	95.6	90.0	564.8	565.5	66.65	93.4	90.1
3:14:30 PM	71.3	62.1	86.6	114.6	85.8	110.4	76	73.6	95.3	89.9	557.5	558	66.7	93.1	89.9
3:15:00 PM	71.4	62.1	86.4	114	85.5	109.6	76	73.4	95	89.6	402.9	403.4	66.75	92.9	89.5
3:15:30 PM	71.7	62.3	85.4	113.1	85.3	109.3	76.1	73.7	94.6	89.4	283.6	283.8	67	92.3	89.4
3:16:00 PM	71.9	62.5	85.6	112.6	84.9	110	76.3	73.7	94.45	89.3	124.8	124.7	67.2	92.2	89.5
3:16:30 PM	71.9	62	85.2	112	85.1	109.2	76.3	73.8	94.15	89.1	48.4	47.9	66.95	91.9	89.3
3:17:00 PM	71.6	61.5	84.7	110.9	84.8	108.4	76.4	73.5	93.65	88.6	14.2	13.7	66.55	91.4	88.8
3:17:30 PM	71.3	61.7	85.7	110.1	84.1	107.7	76.3	73.4	93.2	88.3	1.9	1.7	66.5	91.3	88.4
3:18:00 PM	70.9	61.3	83.5	109.3	83.5	106.2	76.4	73.2	92.85	87.9	1.1	0.6	66.1	90.5	87.7
3:18:30 PM	70.9	61.1	84.1	108.2	83.1	105.1	76.4	73.2	92.3	87.5	1.3	0.9	66	90.3	87.2
3:19:00 PM	70.5	61.4	84	107.5	83.1	104.6	76.3	73.2	91.9	87.2	1.3	0.8	65.95	89.9	87.0
3:19:30 PM	70.5	61.5	83.3	106.8	82.6	103.8	76.2	73.2	91.5	86.9	0.9	0.8	66	89.5	86.6
3:20:00 PM	70.8	60.6	82.6	105.9	82.7	102.6	76.3	73.2	91.1	86.6	1.1	0.7	65.7	89.0	86.3
3:20:30 PM	70.1	61.4	83.1	105.4	82.8	101.8	76.3	73.5	90.85	86.5	1.2	0.8	65.75	88.9	86.2
3:21:00 PM	70.5	61.7	82.3	103.8	83	100.8	76.4	73.2	90.1	85.9	1.2	0.8	66.1	88.2	85.7

As evident from the tests, the isolation gasket 20 was able to maintain its fire safe characteristics throughout the entirety of the test. During the 30 minute burn and 30 minute cool down period, the measured leakage was 0 ml/min versus
5 the allowable rate of 22.765 ml/min. The leakage rate during the repressurization cycle was 5 ml/min versus the allowable rate of 22.765 ml/min. The conclusion is that the isolation gasket 20 satisfies the requirements of the API 6FB test protocol. The two data curves below depict the time duration of the test across the horizontal axis and the temperature or the pressure along the vertical axis.

Data Curves:



Turning now to the manufacture and assembly of the isolation gasket 20 or isolation gasket 120, typically the flat metal core ring 22 is manufactured from a large sheet of 0.250" thick material that is the core material of choice. One example of material used for flat metal core ring 22 is 316L stainless steel. A water jet is used to cut the inner diameter 36 and the outside diameter 60 of the flat metal core ring 22. Lathes are then used to turn the flat metal core ring 22 while the inner diameter 36, the outside diameter 60, the inner ring 32, the outer ring 34, and the serrated ring 30 are cut with various tools. A water jet or another device is

then used to cut the first non-conductive layer 70, the second non-conductive layer 72, the fire resistant layer 76, and the third non-conductive layer 78 from respective larger pieces of material. Adhesive or glue is then used to adhere the appropriately sized first non-conductive layer 70, the second non-conductive layer 72, the fire resistant layer 76, and the third non-conductive layer 78 to the flat metal core ring 22.

Turning now to application of the isolation gasket 20 or isolation gasket 120, in one embodiment, the isolation gasket 20 or isolation gasket 120 is used between two flanges in a flow line application however the isolation gasket 20 or 120 may be used in other pipe connections. The following example will discuss the isolation gasket 20 in combination with two pipe sections however the example is also applicable for the isolation gasket 120. Illustrated in FIG. 8 is the isolation gasket 20 positioned between two pipe sections 200 in a flow line application such that the inner diameter 36 of the inner ring 32 aligns with the diameter of the pipe sections 200. Each of the pipe sections 200 includes a flange 202 which is placed in a confronting relationship with the isolation gasket 20 positioned therebetween. Flanges 202 include one or more bores 204 which align with one another so that nut and bolt sets 206 may be used to connect the flanges 202.

Beneficially electrical isolation between the flanges 202 is achieved through the connection by various parts as described next. A pair of aligned bores 204 with a sleeve 206 is constructed between the flanges 202. The sleeve 206 can be made of a glass reinforced polymer although other materials, such as epoxy, phenolic, and meta-aramid materials may be used. The sleeve 206 has a length that is about the same as the distance between outer surfaces 208 of flanges 202 with gasket 20 positioned therebetween. Once sleeve 206 has been inserted into the pair of aligned bores 204, isolating washers 210 are placed on either side of bores 204 on outer surfaces 208 of flanges 202. In this embodiment, metal washers 212 are then positioned against washer 210 and bolt 206 is passed through the washers and sleeve 206 after which it is secured by nuts 214. Other embodiments may not include metal washers 212. At each of the aligned bores 204 the same process is repeated and thereafter nuts 214 may be tightened to compress gasket 20 at a desired pressure.

Isolation gasket 20 or 120 in combination with isolating washers 210 and sleeves 206 provide electrical isolation of separate pipe sections 200. Isolating washers 210 are positioned against outer surfaces 208 of flanges 202 and in combination with sleeve 206, provide electrical isolation between the nut and bolt
5 sets 206 and the flanges 202. In one form, the isolating washers 210 are metal core washers that are coated with a dielectric material.

The uses of the terms "a" and "an" and "the" and similar references in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless
10 otherwise indicated herein or clearly contradicted by context. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein.

15 While the invention has been illustrated and described in the foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only certain preferred embodiments have been described and that all changes and modifications that come within the spirit of the invention are desired to be protected. In addition, all references cited herein are
20 indicative of the level of skill in the art and are hereby incorporated by reference in their entirety.

CLAIMS

What is claimed is:

1. An isolation gasket for use between facing flanges of two flow conduit
5 sections for fluid passage therethrough, the isolation gasket comprising:
a flat metal core ring having an upper face opposing a lower face and an
opening formed therein to allow fluid passage therethrough, the flat metal core ring
having a serrated ring positioned between an inner ring and an outer ring, the serrated
ring having a plurality of serrations along the upper face and the lower face, the
10 plurality of serrations include a plurality of alternating peaks and grooves, wherein
each of the peaks has an axial width dimension that is substantially the same for each
of the peaks, and wherein each of the plurality of grooves has an axial width
dimension arranged such that collectively the plurality of grooves forms a convex
profile that spans across a width of the serrated ring;
15 a first non-conductive layer on the upper and the lower faces of the inner ring
to provide a dielectric barrier;
a non-conductive coating on the upper and the lower faces of the serrated ring;
a second non-conductive layer on the upper and the lower faces of the outer
ring to provide a dielectric barrier;
20 a fire resistant layer on the non-conductive coating that is positioned on the
serrated ring; and
a third non-conductive layer on the non-conductive coating that is positioned
on the serrated ring, wherein the third non-conductive layer is adjacent the fire
resistant layer.
25
2. The isolation gasket of any preceding claim, wherein the fire resistant layer
abuts against the third non-conductive layer at a mid-point between an inner edge and
an outer edge of the serrated ring.
- 30 3. The isolation gasket of any preceding claim, wherein the fire resistant layer
spans from an outside diameter of the serrated ring to a middle diameter of the serrated
ring, and wherein the third non-conductive layer spans from the middle diameter to an
inside diameter of the serrated ring.

4. The isolation gasket of any preceding claim, wherein the fire resistant layer and the third non-conductive layer are arranged in a side by side orientation on the non-conductive coating applied on the plurality of serrations of the serrated ring, wherein each of the fire resistant layer and the third non-conductive layer covers
5 approximately half of the serrated ring.

5. The isolation gasket of any preceding claim, wherein the plurality of grooves includes five groups that are orderly arranged across a width of the serrated ring, wherein the outer two groups of the plurality of grooves have a second axial width
10 dimension, the middle two groups of the plurality of grooves have a third axial width dimension, and the center group of the plurality of grooves has a fourth axial dimension, wherein the fourth axial width dimension is larger than the third axial width dimension, and the third axial width dimension is larger than the second axial width dimension.

15

6. The isolation gasket of claim 5, wherein the fourth axial width dimension, the third axial width dimension, and the second axial width dimension generally form a convex profile that spans across the width of the serrated ring.

20

7. The isolation gasket of any one of claims 4, claim 5 or claim 6 when appended directly to claim 1 or claim 2, wherein the fire resistant layer spans from an outside diameter of the serrated ring to a middle diameter of the serrated ring, and wherein the third non-conductive layer spans from the middle diameter to an inside diameter of the
25 serrated ring.

8. The isolation gasket of any preceding claim, further comprising:
at least one isolating sleeve positioned in an aligned bore formed in each of the facing flanges, the isolating sleeve having a length that is substantially equal to a
30 distance between an outer face of each of the flanges with the isolation gasket positioned between the facing flanges;

at least one elongate metal fastener having opposing ends, the fastener received in the isolating sleeve for connecting the flanges to one another with the isolation gasket interposed therebetween; and

5 an isolating washer positioned on each of the at least one elongate metal fastener abutting the outer face of the flange.

9. The isolation gasket of claim 8, wherein the isolating washer includes a metal washer having opposing side surfaces with a sheet of dielectric material laminated to one of the opposing side surfaces and wherein the dielectric material abuts at least the
10 outer face of the flange.

10. The isolation gasket of any one of claims 8 to 9, wherein the isolating washer includes a metal core coated with a dielectric material.

15 11. The isolation gasket of any one of claims 8 to 10, wherein the isolating sleeve includes a sleeve made of one of glass reinforced polymer material, epoxy material, phenolic material, and meta-aramid material.

20 12. The isolation gasket of any one of claims 8 to 11, wherein the metal fastener includes a metal shaft threaded to receive a nut on at least one of the opposing ends.

13. The isolation gasket of any one of claims 7 to 12, wherein the plurality of grooves includes five groups that are orderly arranged across a width of the serrated ring, wherein the outer two groups of the plurality of grooves have a second axial
25 width dimension, the middle two groups of the plurality of grooves have a third axial width dimension, and the center group of the plurality of grooves has a fourth axial dimension, wherein the fourth axial width dimension is larger than the third axial width dimension, and the third axial width dimension is larger than the second axial width dimension.

30

14. The isolation gasket of claim 13, wherein the fourth axial width dimension, the third axial width dimension, and the second axial width dimension generally form a convex profile that spans across the width of the serrated ring.

15. An isolation gasket for use between facing flanges of two flow conduit sections for fluid passage therethrough, the isolation gasket comprising:
- a flat metal core ring having an upper face opposing a lower face and an opening formed therein to allow fluid passage therethrough, the flat metal core ring having a serrated ring positioned between an inner ring and an outer ring, the serrated ring having a plurality of serrations along the upper face and the lower face, wherein the plurality of serrations have a corresponding plurality of alternating peaks and grooves, wherein each of the peaks has a first axial width dimension that is substantially the same for each of the peaks, and wherein the plurality of grooves includes five groups that are orderly arranged across a width of the serrated ring, wherein the outer two groups of the plurality of grooves have a second axial width dimension, the middle two groups of the plurality of grooves have a third axial width dimension, and the center group of the plurality of grooves has a fourth axial dimension, wherein the fourth axial width dimension is larger than the third axial width dimension, and the third axial width dimension is larger than the second axial width dimension;
 - a first non-conductive layer on the upper face and the lower face of the inner ring to provide a dielectric barrier for the inner ring;
 - a second non-conductive layer on the upper face and the lower face of the outer ring to provide a dielectric barrier for the outer ring;
 - a non-conductive coating applied on the plurality of serrations of the upper face and the lower face of the serrated ring to provide a dielectric barrier for the serrated ring;
 - a fire resistant layer and a third non-conductive layer arranged in a side by side orientation on the non-conductive coating applied on the plurality of serrations of the serrated ring, wherein each of the fire resistant layer and the third non-conductive layer covers approximately half of the serrated ring.
16. The isolation gasket of claim 1, wherein the fire resistant layer spans from an outer edge of the serrated ring to a mid-region of the serrated ring, and the third non-conductive layer spans from an inner edge of the serrated ring to the mid-region of the

serrated ring such that the fire resistant layer and the third non-conductive layer do not overlap.

17. The isolation gasket of any preceding claim, wherein the non-conductive
5 coating is made of polytetrafluoroethylene.
18. The isolation gasket of any preceding claim, wherein the fire resistant layer is made of mica or aluminosilicate.
- 10 19. The isolation gasket of any preceding claim, wherein the third non-conductive layer is made of biaxially-oriented filled polytetrafluoroethylene.
20. The isolation gasket of any one of claims 15 to 19, wherein the fourth axial width dimension, the third axial width dimension, and the second axial width
15 dimension generally form a convex profile that spans across the width of the serrated ring.
21. An assembly comprising a pair of joined flow conduit sections which are constructed and arranged with facing flanges, each flow conduit section having a
20 through bore; said pair of joined flow conduit sections having an isolation gasket according to any preceding claim disposed between said facing flanges.

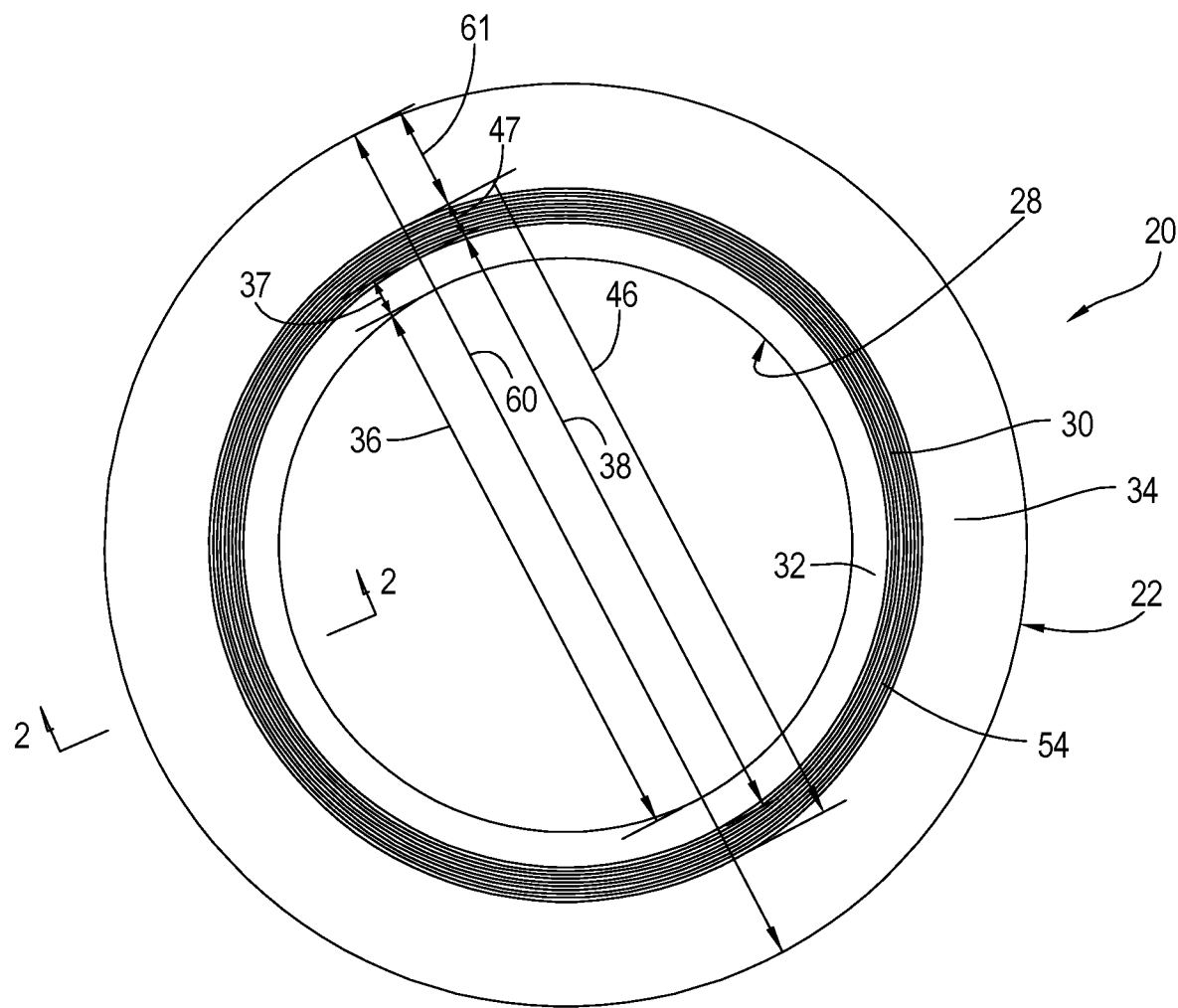
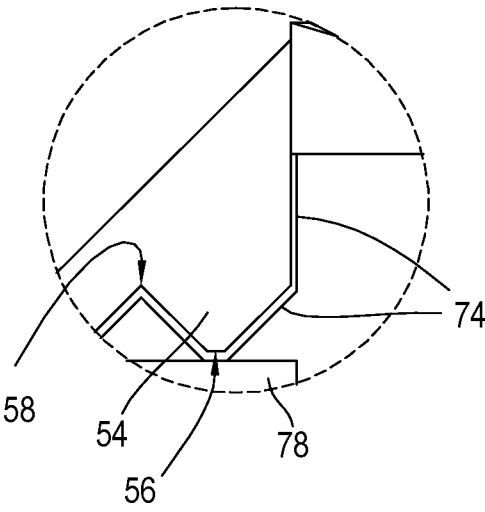
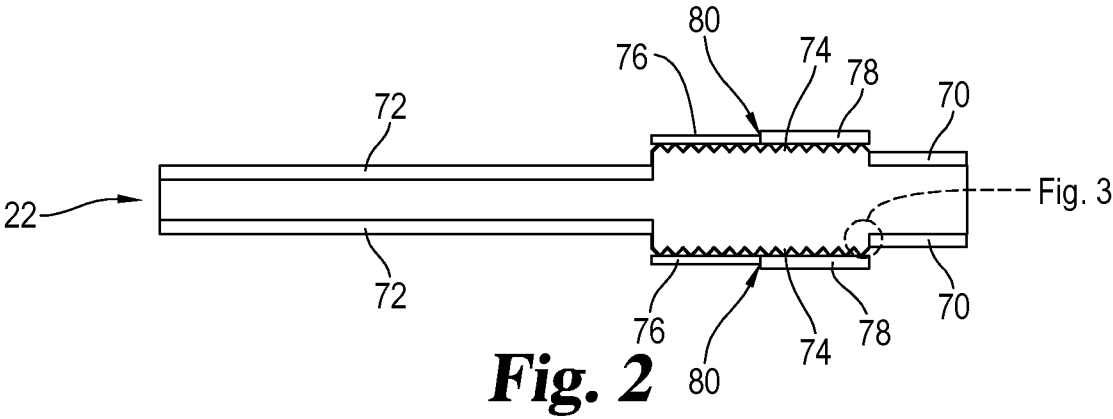


Fig. 1



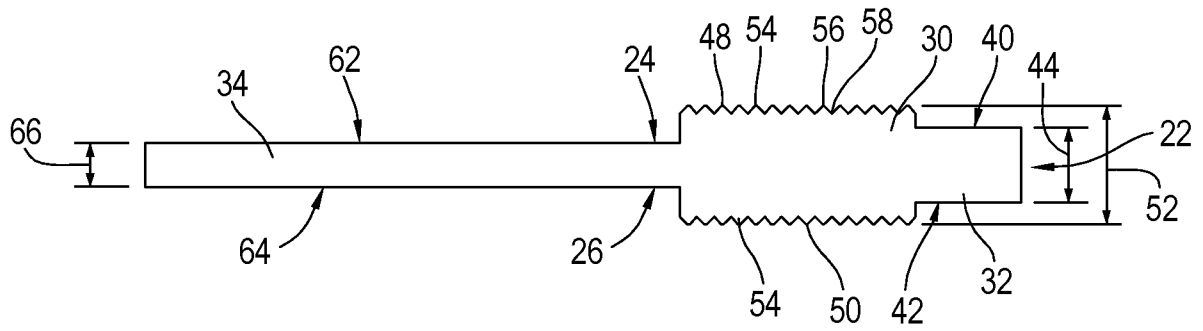


Fig. 4

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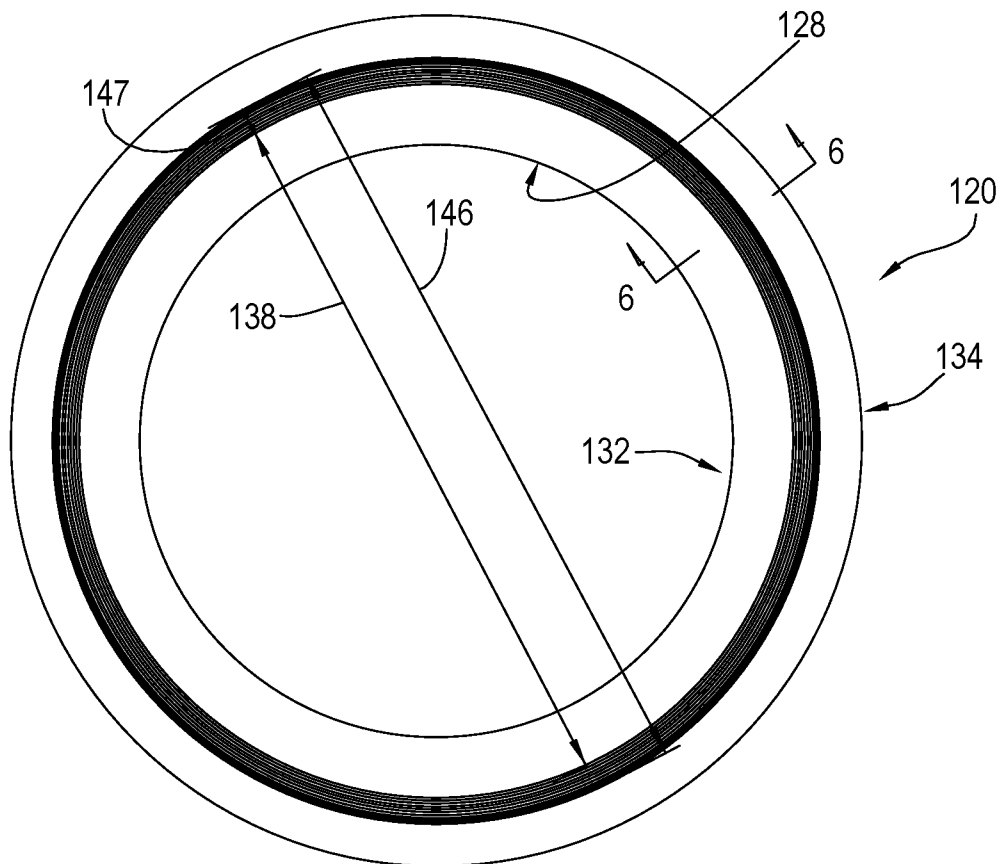
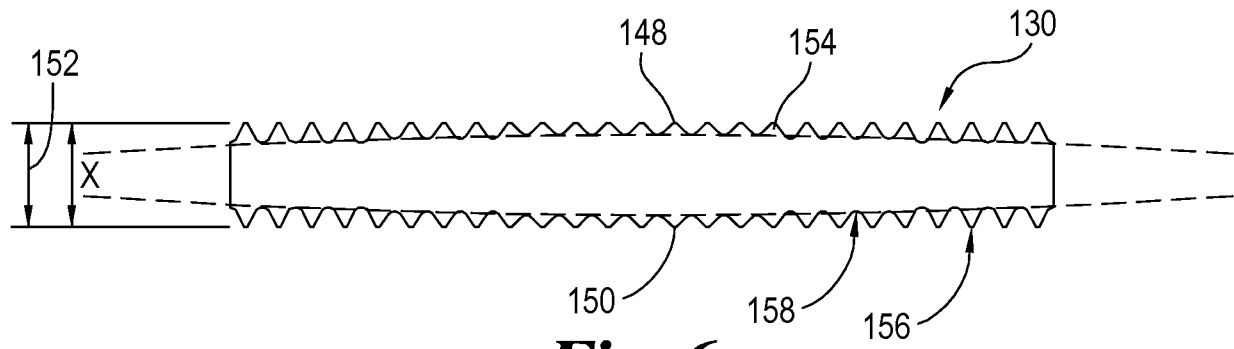
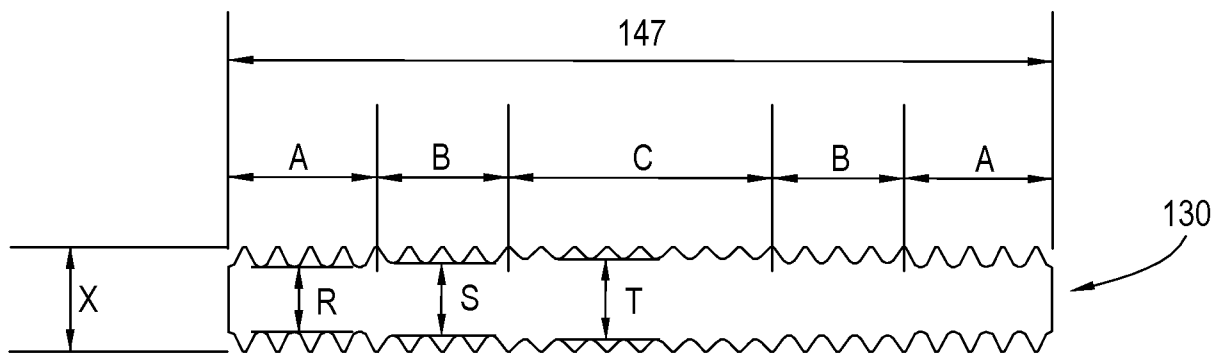
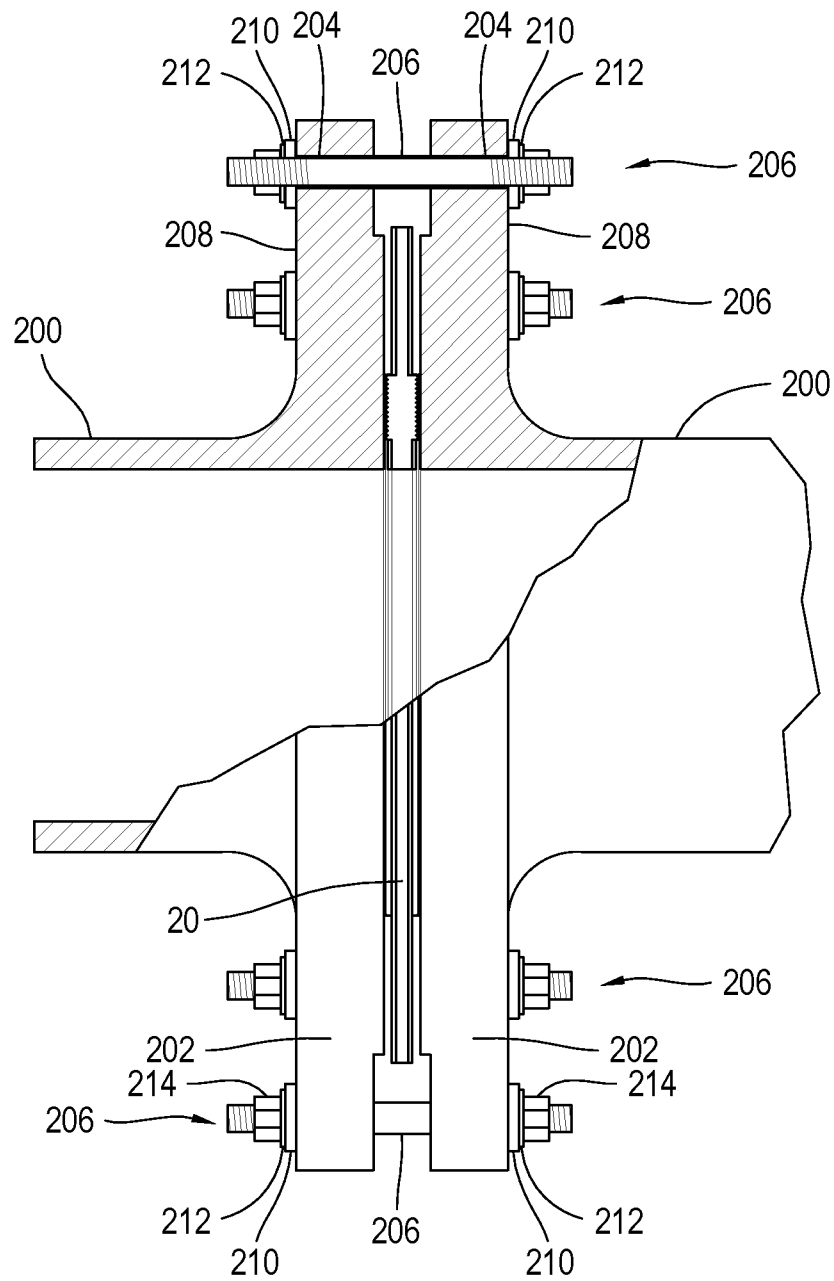
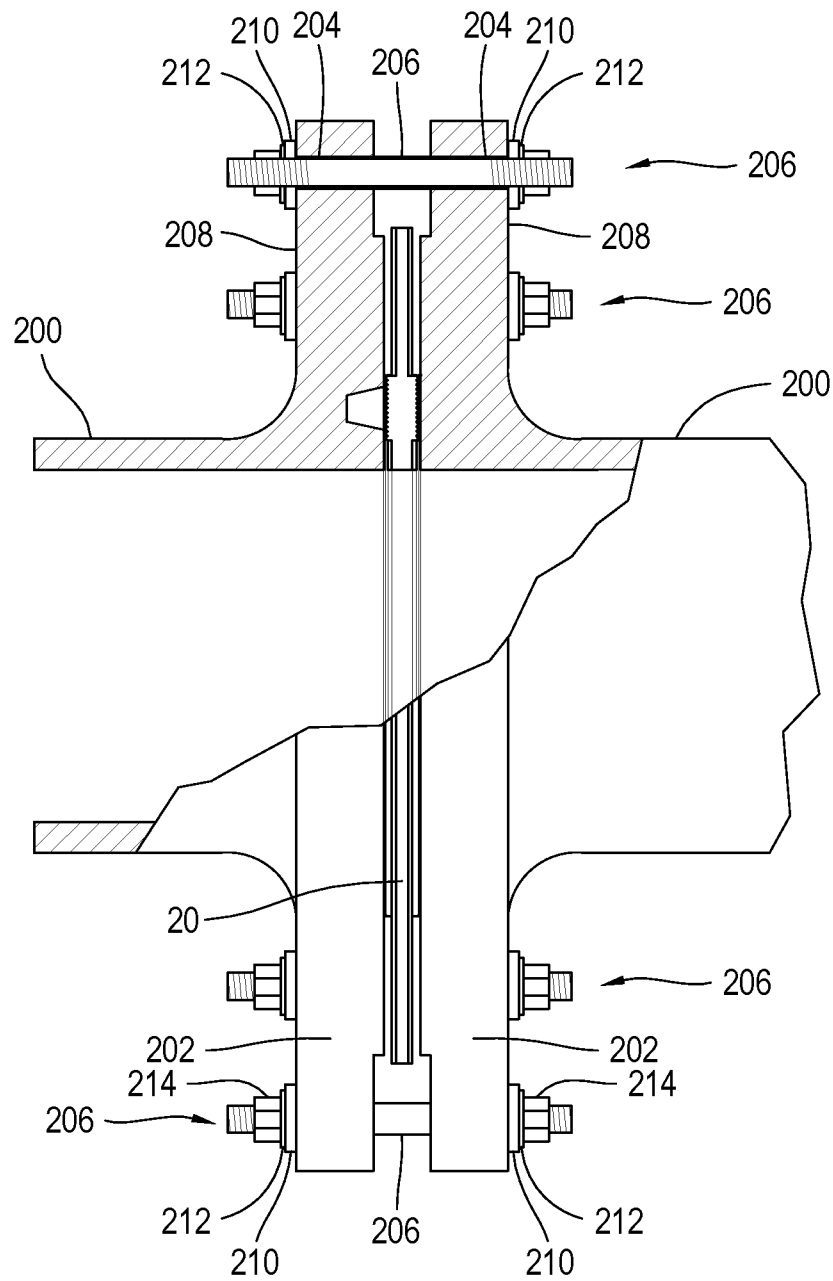


Fig. 5

**Fig. 6****Fig. 7**

**Fig. 8**

**Fig. 9**