

1. A seal assembly for sealing an annulus between inner and outer wellhead members, the seal assembly comprising:

an energizer ring formed of a high strength elastic material having inner and outer legs and a central axis;

an annular inner recess formed on an inward facing surface of the inner leg, the inner recess having grooves on a base of the inner recess;

an inner diameter seal ring formed of an inelastic material, the inner diameter seal ring engaging the grooves of the inner recess;

an annular outer recess formed on an outward facing surface of the outer leg, the outer recess having grooves on a base of the outer recess;

an outer diameter seal ring formed of an inelastic material, the outer diameter seal ring engaging the grooves of the outer recess; and

wherein, when the energizer ring is coaxially inserted in the annulus, the inner diameter seal ring is compressively and permanently deformed into sealing contact with the inner wellhead member, and the outer diameter seal ring is compressively and permanently deformed into sealing contact with the outer wellhead member.

2. The seal assembly of claim 1, wherein:

each of the inner and outer legs has a base end and a free end;

each of the inner and outer legs has an enlarged portion proximate to the free end with a radial width greater than the radial width of the leg proximate to the base end; and

the inner recess and the outer recess are formed in the enlarged portions.

3. The seal assembly of claim 1, wherein one leg is a longer leg and the other leg is a shorter leg such that the longer leg has an axial length that is greater than an axial length of the shorter leg.

4. The seal assembly of claim 1, wherein:

each of the inner and outer legs has a base end and a free end;

each of the inner and outer legs has an exterior surface that faces away from the other leg;

each of the inner and outer legs has an enlarged portion proximate to the free end with a radial width greater than the radial width of the leg proximate to the base end; and

the exterior surface of at least one leg tapers gradually to the enlarged portion.

5. The assembly of claim 1, wherein:

each of the inner and outer legs has a base end and a free end;

each of the inner and outer legs has an exterior surface that faces away from the other leg;

each of the inner and outer legs has an enlarged portion proximate to the free end with a radial width greater than the radial width of the leg proximate to the base end; and

the exterior surface of at least one leg has an undercut recess adjacent to the enlarged portion.

6. The seal assembly of claim 1, wherein:

each of the inner and outer legs has a base end and a free end;

each of the inner and outer legs has an exterior surface that faces away from the other leg;

and

the exterior surface of at least one leg has a large radius of curvature extending from the free towards the recess.

7. The seal assembly of claim 1, wherein:

each of the inner and outer legs has an interior surface that faces towards the other leg;

and

the interior surface of each of the inner and outer legs comprises two planar surfaces.

8. The seal assembly of claim 1 wherein :

each of the inner and outer legs has a base end and a free end;

each of the inner and outer legs has an interior surface that faces towards the other leg;

and

the interior surface of each of the inner and outer legs comprises a cylindrical surface proximate the base end that is coaxial with the axis and a conical surface proximate the free end.

9. The seal assembly of claim 1, wherein:

each of the inner and outer legs has a base end and a free end; and

a largest radial width of at least one of the legs is less than the axial distance between the free end and the recess.

10. The seal assembly of claim 1, wherein the inner diameter seal ring and the outer diameter seal ring are formed of an inelastic material selected from a group consisting of lead, tin, or silver.

11. A wellhead assembly comprising:

an outer wellhead member having a bore and an axis;

an inner wellhead member located in the bore and defining an annulus between the inner and outer wellhead members;

an energizer ring formed of an elastic material and comprising a base, and inner and outer legs extending axially from the base to a free end that bias in opposing radial directions respectively against the inner and outer wellhead members;

the inner leg having an inward facing surface with an annular inner band located on and protruding inward from the inward facing surface of the inner leg;

an annular inner recess formed in the inner band, the inner recess having grooves on a base of the inner recess;

an annular inner diameter seal ring formed of an inelastic material located in the inner recess, the inner diameter seal ring engaging the grooves of the inner recess;

the outer leg having an outward facing surface with an annular outer band located on and protruding outward from the outward facing surface of the outer leg;

an annular outer recess formed in the outer band, the outer recess having grooves on a base of the outer recess;

an annular outer diameter seal ring formed of an inelastic material located in the outer recess, the outer diameter seal ring engaging the grooves of the outer recess; and

an open slot between the legs.

12. The wellhead assembly of claim 11, wherein an axial length of the band on the inner leg and on the outer leg have a cylindrical end surface concentric with the axis.

13. The wellhead assembly of claim 11, wherein the inner leg has an axial length that is shorter than an axial length of the outer leg.

14. The wellhead assembly of claim 11, wherein the inward facing surface of the inner leg tapers gradually to the inner band.

15. The wellhead assembly of claim 11, wherein the outward facing surface of the outer leg has an undercut recess at a junction of the outward facing surface and the outer band.

16. The wellhead assembly of claim 11, wherein an outer surface of the outer band has a large radius of curvature extending from the free end towards the recess.

17. The wellhead assembly of claim 11, wherein an outer surface of both the outer band and the inner band has a large radius of curvature extending from the free end towards the recess.

18. A method for sealing an annulus between inner and outer wellhead members, the method comprising the steps of:

(a) providing a seal assembly that comprises an energizer ring formed of a high strength elastic material having inner and outer legs and a central axis, an annular inner recess formed on an inward facing surface of the inner leg having grooves on a base of the inner recess, an inner diameter seal ring formed of an inelastic material engaging the grooves of the inner recess, an annular outer recess formed on an outward facing surface of the outer leg having grooves on a base of the outer recess, and an outer diameter seal ring formed of an inelastic material engaging the grooves of the outer recess; and

(b) inserting the seal assembly into the annulus so that the seal rings contact inner and outer surfaces of the annulus, plastically deforming the seal rings into sealing engagement between the legs and the inner and outer surfaces by a spring force in the legs.

19. The method of claim 18, wherein each of the inner and outer legs has an exterior surface that faces away from the other leg, each of the inner and outer legs has an enlarged portion proximate to the free end with a radial width greater than the radial width of the leg proximate to the base end, the exterior surface of one leg tapering gradually to the enlarged portion and the exterior surface of the other leg having a large radius of curvature extending from a free end of the leg towards the recess, wherein the step of inserting the seal assembly into the annulus includes:

slidingly engaging the gradual taper with a surface of one of the wellhead members; and

slidingly engaging the large radius of curvature with the other of the wellhead members.

20. The method of claim 18, wherein each of the inner and outer legs has an exterior surface that faces away from the other leg, the exterior surface of both the inner and outer legs having a large radius of curvature extending from a free end of the leg towards the recess, wherein the step of inserting the seal assembly into the annulus includes:

slidingly engaging the large radius of curvature of the outer leg with the outer wellhead member; and

slidingly engaging the large radius of curvature of the inner leg with the inner wellhead member.

CLAIMS

1. A seal assembly for sealing an annulus between inner and outer wellhead members, the seal assembly comprising:

a U-shaped energizer ring formed of a high strength elastic metal material having inner and outer legs joined by a base at a lower end of the energizer ring, the energizer ring having a central axis;

an annular inner recess formed on an inward facing surface of the inner leg;

an inner diameter seal ring formed of an inelastic metal material, the inner diameter seal ring having an interior surface mounted to the inner recess;

an annular outer recess formed on an outward facing surface of the outer leg;

an outer diameter seal ring formed of an inelastic metal material, the outer diameter seal ring having an interior surface mounted to the outer recess; wherein

prior to insertion into the annulus, each of the seal rings has a radial width between the interior surface and an exterior surface of each of the seal rings that is less than an axial dimension from an upper edge to a lower edge of each of the seal rings;

each of the inner and outer legs has a lower base end that joins the base and an upper free end;

each of the inner and outer legs has an interior surface that faces towards the other leg and an exterior surface that faces away from the other leg;

the exterior surface of one of the inner and outer legs has a base portion that extends axially upward from proximate the base end, and a transition portion that extends axially downward from a location axially below a lower end of one of the seal rings to the base portion, the base portion being a cylindrical surface concentric with the axis and the transition portion being a conical surface; and

wherein, when the energizer ring is coaxially inserted in the annulus, the free ends of the inner and outer legs elastically deflect toward each other, causing the inner diameter seal ring to be compressively and permanently deformed into sealing contact with the inner wellhead member, and causing the outer diameter seal ring to be compressively and permanently deformed into sealing contact with the outer wellhead member.

2. The seal assembly of claim 1, wherein:

each of the inner and outer legs has an enlarged portion proximate to the free end with a radial width greater than the radial width of the leg proximate to the base end; and

the inner recess and the outer recess are formed in the enlarged portions.

3. The seal assembly of claim 1, wherein one leg is a longer leg and the other leg is a shorter leg such that the longer leg has an axial length that is greater than an axial length of the shorter leg.

4. The seal assembly of claim 1, wherein:

each of the inner and outer legs has an enlarged portion proximate to the free end with a radial width greater than the radial width of the leg proximate to the base end; and

the exterior surface of at least one leg tapers gradually to the enlarged portion.

5. The seal assembly of claim 1, wherein:

the exterior surface of each of the seal rings is cylindrical prior to insertion of the seal assembly into the annulus.

6. The seal assembly of claim 1, wherein:

the exterior surface of at least one leg has a large radius of curvature extending from the free end towards the recess.

7. The seal assembly of claim 1, wherein:

a largest radial width of at least one of the legs proximate the free end is less than an axial distance between the free end and the recess of the at least one of the legs.

8. The seal assembly of claim 1, wherein the inner diameter seal ring and the outer diameter seal ring are formed of material selected from a group consisting of lead, tin, or silver.

9. The seal assembly of claim 1, wherein:

the inner recess has grooves on a base of the inner recess;

the inner diameter seal ring engages the grooves of the inner recess and protrudes radially outward past the exterior surface of the inner leg;

the outer recess has grooves on a base of the outer recess; and

the outer diameter seal ring engages the grooves of the outer recess and protrudes radially outward past the exterior surface of the outer leg.

10. The seal assembly of claim 1, wherein the interior surface of each of the inner and outer legs has a first portion that extends axially upward from proximate the base end to a location axially below a lower end of the seal ring, and a second portion that extends axially downward from proximate the free end to the first portion, the first portion being a cylindrical surface parallel to the axis and the second portion being a conical surface.

11. A wellhead assembly comprising:

an outer wellhead member having a bore and an axis, the outer wellhead member further having a tapered outer wellhead shoulder defined by a change in inner diameter of the outer wellhead member from a region with a smaller inner diameter to a region with a larger inner diameter;

an inner wellhead member located in the bore and defining an annulus between the inner and outer wellhead members, the inner wellhead member further having a tapered inner wellhead shoulder defined by a change in outer diameter of the inner wellhead member from a region with a smaller inner diameter to a region with a larger inner diameter;

a U-shaped energizer ring formed of an elastic metal material and comprising a base, and inner and outer legs joined by and extending axially from the base to a free end that bias in opposing radial directions respectively against the inner and outer wellhead members;

the inner leg having a base end and a free end, and an inward facing surface with an annular inner band located on and protruding inward from the inward facing surface of the inner leg proximate the free end;

an annular inner recess formed in the inner band;

an annular inner diameter seal ring formed of an inelastic metal material located in the inner recess;

the outer leg having a base end and a free end, and an outward facing surface with an annular outer band located on and protruding outward from the outward facing surface of the outer leg proximate the free end;

an annular outer recess formed in the outer band;

an annular outer diameter seal ring formed of an inelastic metal material located in the outer recess;

an open slot between the legs; wherein

when the energizer ring is coaxially inserted in the annulus, the free ends of the inner and outer legs elastically deflect toward each other, causing the inner diameter seal ring to be compressively and permanently deformed into sealing contact with the inner wellhead member, and causing the outer diameter seal ring to be compressively and permanently deformed into sealing contact with the outer wellhead member; and wherein

the energizer ring is located within the annulus axially between the outer wellhead shoulder and the inner wellhead shoulder.

12. The wellhead assembly of claim 11, wherein an axial length of the band on the inner leg and on the outer leg have a cylindrical end surface concentric with the axis.

13. The wellhead assembly of claim 11, wherein the inner leg has an axial length that is shorter than an axial length of the outer leg.

14. The wellhead assembly of claim 11, wherein the inward facing surface of the inner leg tapers gradually to the inner band.

15. The wellhead assembly of claim 11, wherein the outward facing surface of the outer leg has an undercut recess at a junction of the outward facing surface and the outer band.

16. The wellhead assembly of claim 11, wherein an outer surface of the outer band has a large radius of curvature extending from the free end towards the recess.

17. The wellhead assembly of claim 11, wherein an outer surface of both the outer band and the inner band has a large radius of curvature extending from the free end towards the recess.

18. The wellhead assembly of claim 11, wherein:
the inner recess has grooves on a base of the inner recess;
the inner diameter seal ring engages the grooves of the inner recess and protrudes radially outward past the exterior surface of the inner band;
the outer recess has grooves on a base of the outer recess; and
the outer diameter seal ring engages the grooves of the outer recess and protrudes radially outward past the exterior surface of the outer band.

19. The wellhead assembly of claim 11, wherein the inner wellhead shoulder is an upward facing shoulder located axially above the energizer ring and the outer wellhead shoulder is a downward facing shoulder located axially below the energizer ring.

20. A method for sealing an annulus between inner and outer wellhead members, the method comprising the steps of:

(a) providing a seal assembly that comprises a U-shaped energizer ring formed of a high strength elastic metal material having:

a central axis;

inner and outer legs joined by a base at a lower end of the energizer ring and an upper free end;

an annular inner recess formed on an inward facing surface of the inner leg, and an inner diameter seal ring formed of an inelastic metal material mounted to the inner recess;

an annular outer recess formed on an outward facing surface of the outer leg, and an outer diameter seal ring formed of an inelastic metal material mounted to the outer recess,

(b) inserting the seal assembly into the annulus so that the free ends of the inner and outer legs elastically deflect toward each other, causing the seal rings contact inner and outer surfaces of the annulus, plastically deforming the seal rings into sealing engagement between the legs and the inner and outer surfaces by a spring force in the legs; and

(c) landing the energizer ring within the annulus axially between a tapered outer wellhead shoulder and tapered inner wellhead shoulder, the outer wellhead shoulder defined by a change in inner diameter of the outer wellhead member from a region with a smaller inner diameter to a region with a larger diameter, and the inner wellhead shoulder being defined by a change in outer diameter of the inner wellhead member from a region with a smaller inner diameter to a region with a larger inner diameter.

21. The method of claim 20, wherein each of the inner and outer legs has an enlarged portion proximate to the free end with a radial width greater than the radial width of the leg proximate to the base end, the exterior surface of one leg tapering gradually to the enlarged portion and the exterior surface of the other leg having a large radius of curvature extending from a free end of the leg towards the recess, wherein the step of inserting the seal assembly into the annulus includes:

slidingly engaging the gradual taper with a surface of one of the wellhead members; and

slidingly engaging the large radius of curvature with the other of the wellhead members.

22. The method of claim 20, wherein the exterior surface of both the inner and outer legs having a large radius of curvature extending from a free end of the leg towards the recess, wherein the step of inserting the seal assembly into the annulus includes:

slidingly engaging the large radius of curvature of the outer leg with the outer wellhead member; and

slidingly engaging the large radius of curvature of the inner leg with the inner wellhead member.

23. The method of claim 18, wherein the inner wellhead shoulder is an upward facing shoulder located axially above the energizer ring and the outer wellhead shoulder is a downward facing shoulder located axially below the energizer ring, wherein step (b) further comprises engaging at least one of the upward facing shoulder and the downward facing shoulder with a portion of the energizer ring to apply the spring force in the legs.