Claims

1. A seal assembly for sealing in a seal pocket between inner and outer tubular members of a subsea wellhead assembly, comprising:

a metal-to- metal primary seal ring having an axis;

a secondary seal ring secured to and spaced axially from the primary seal ring; and

the primary and secondary seal rings being energized from a run-in to a set position by applying an energizing force to the seal assembly, which causes the secondary seal ring to move to the set position before the primary seal ring moves to the set position.

2.The seal assembly according to claim 1, wherein the primary seal ring comprises:

annular inner and outer legs separated from each other by an annular slot having a run-in radial width;

an energizing ring having a radial thickness greater than the run-in radial width and carried in a run-in position with an end engaging an entrance of the annular slot; and

wherein the energizing force is an axially-directed force applied to the energizing ring.

3. The seal assembly according to claim 1, further comprising:

a plurality of annular channels on an inner side surface of the primary seal ring;

an inlay of a metal softer than the metal of the primary seal ring located within the channels; wherein

the primary seal ring has an annular force transferring leg extending from the channels, the force transferring leg having an end in operative engagement with the secondary seal ring; and

the energizing force is an axially directed and applied to the primary seal ring.

4. The seal assembly according to claim 1, wherein the primary seal ring comprises:

an upper portion that provides sealing engagement with the inner and outer tubular members when the primary seal ring is moved to the set position;

an annular force transferring leg extending downward from the upper portion, the force transferring leg having a lower end in operative engagement with the secondary seal ring; and

the energizing force is downward directed and applied through the force transferring leg before the primary seal ring moves to the set position, thereby causing the secondary seal ring to move to the set position first.

5. The seal assembly according to claim 4, wherein the secondary seal ring comprises:

a lower portion that provides sealing engagement with the inner and outer tubular members when the secondary seal ring is moved to the set position;

an annular neck protruding upward from the lower portion alongside a side surface of the force transferring leg; and

a coupling device between the side surface of the force transferring leg and a side surface of the neck for securing the secondary seal ring to the primary seal ring.

6. The seal assembly according to claim 5, wherein the end of the force transferring leg transfers the energizing force imposed on the force transferring leg to the lower portion of the secondary seal ring, bypassing the coupling device.

7. The seal assembly according to claim 5, wherein a combined radial width of the neck and the force transferring leg is no greater than a radial width of the upper portion of the primary seal ring measured in the run-in position.

8. The seal assembly according to claim 5, wherein:

the upper portion of the primary seal ring has a downward facing shoulder on a lower end of the upper portion; and

the neck has an upper end that is in abutment with the downward facing shoulder when the secondary seal ring is in the set position.

9. The seal assembly according to claim 1, wherein:

the outer tubular member comprises an outer wellhead housing having a bore;

the inner tubular member comprises a casing hanger landed within the bore, the casing hanger having an external shoulder that defines a lower end of the pocket;

the secondary seal ring is carried below the primary seal ring, is at least partially elastomeric, and lands on the shoulder of the casing hanger;

the primary and secondary seal rings are movable from the run-in position to the set position by applying a downward force, the downward force required to move the secondary seal ring to the set position being less than the downward force required to move the primary seal ring to the set position; and

wherein a downward force applied to the primary seal ring after the secondary seal ring has landed on the shoulder transfers to the secondary seal ring to cause the secondary seal ring to move to the set position before the primary seal ring moves to the set position.

10. The seal assembly according to claim 9, wherein the primary seal ring comprises:

annular inner and outer legs separated from each other by an annular slot having a run-in radial width;

an energizing ring having a radial thickness greater than the run-in radial width and carried in a run-in position with a lower end engaging an upper end of the annular slot;

wherein a downward force applied to the energizing ring after the secondary seal ring has landed on the shoulder initially transfers through the primary seal ring to the secondary seal ring to cause the secondary seal ring to move to the set position; and

an additional downward force applied to the energizing ring after the secondary seal ring is in the set position moves the energizing ring into the slot to move the primary seal ring to the set position.

11. The seal assembly according to claim 9, wherein the primary seal ring comprises:

an upper portion that seals between the casing hanger and the wellhead housing when the primary seal ring is moved to the set position; and

an annular force transferring leg extending downward from the upper portion, the force transferring leg having a lower end that transfers to the secondary seal ring a downward force applied to the primary seal ring.

12. The seal assembly according to claim 11, wherein the secondary seal ring comprises:

a lower portion that provides sealing engagement with the casing hanger and the wellhead housing when the secondary seal ring is moved to the set position;

an annular neck protruding upward from the lower portion alongside a side surface of the force transferring leg;

a coupling device between the side surface of the force transferring leg and a side surface of the neck for securing the secondary seal ring to the primary seal ring during run-in; and

wherein the lower end of the force transferring leg transfers a downward force imposed on the force transferring leg to the lower portion of the secondary seal ring, bypassing the coupling device.

13. The seal assembly according to claim 9, wherein:

the secondary seal ring has an elastomeric portion and a metal portion such that while in the set position, the metal portion and the elastomeric portion of the secondary seal ring sealingly engage a sidewall of the casing hanger and a sidewall of the bore.

14. A method of sealing between inner and outer tubular members of a subsea wellhead assembly, comprising:

(a) providing a metal-to-metal primary seal ring of a type that expands radially inward and outward, relative to an axis of the primary seal ring, in response to an axially directed primary setting force relative to an axis of the primary seal ring;

(b) providing a secondary seal ring that expands radially inward and outward in response to an axially directed secondary setting force that is less than the primary setting force;

(c) securing the secondary seal ring to the primary seal ring to define a seal assembly;

(d) lowering the seal assembly between the inner and outer tubular members;

(e) applying a first axially directed force to the primary seal ring that is at least equal to the secondary setting force, causing the secondary seal ring to radially expand inward and outward to sealingly engage the inner and outer tubular members; then

(f) applying a second axially directed force to the primary seal ring that is at least equal to the primary setting force, causing the primary seal ring to radially expand inward and outward to sealingly engage the inner and outer tubular members.

15. The method according to claim 14, wherein:

step (c) connecting the secondary seal ring and the primary seal ring with a coupling device; and

steps (d) and (e) comprise transferring the first and second axially directed forces to the secondary seal ring without any portion of the first and second axially directed forces passing through the coupling device.

CLAIMS

The invention claimed is:

1. A seal assembly for sealing in a seal pocket between inner and outer tubular members of a subsea wellhead assembly, comprising:

a metal-to- metal primary seal ring having an axis , the primary seal ring having an upper portion for sealing between the inner and outer tubular members and an annular force transferring leg extending downward from the upper portion;

a secondary seal ring having an upward extending neck extending alongside and secured to the leg, the secondary seal ring having elastomeric and metal sealing surfaces and an upward facing shoulder that is engaged by a lower end of the leg; and

the primary and secondary seal rings being energized from a run-in to a set position by applying a downward directed energizing force to the seal assembly, which causes the secondary seal ring to move to the set position before the primary seal ring moves to the set position; and wherein the energizing force has a load path from the lower end of the leg through the upward facing shoulder of the secondary seal ring, bypassing the neck.

2. The seal assembly according to claim 1, wherein the primary seal ring comprises:

annular inner and outer legs separated from each other by an annular slot having a run-in radial width;

an energizing ring having a radial thickness greater than the run-in radial width and carried in a run-in position with an end engaging an entrance of the annular slot; and

wherein the energizing force is applied to the energizing ring.

3. The seal assembly according to claim 1, wherein:

the neck and the leg are cylindrical and concentric walls connected to each other by a coupling device that is bypassed by the load path.

4. The seal assembly according to claim 1, wherein the secondary seal ring further comprises:

a metal, resilient spring element through which the load path passes.

5. The seal assembly according to claim 4, wherein the spring element is located above the portion of the secondary seal containing the elastomeric and metal seal surfaces.

6. The seal assembly according to claim 4, wherein the spring element comprises a cylinder having circumferentially extending inner slits formed on an inner diameter and circumferentially extending outer slits formed on an outer diameter of the cylinders, the inner slits alternating with the outer slits in an axial direction.

7. The seal assembly according to claim 1, wherein a combined radial width of the neck and the force transferring leg is no greater than a radial width of the upper portion of the primary seal ring measured in the run-in position.

8. The seal assembly according to claim 1, wherein:

the upper portion of the primary seal ring has a downward facing shoulder on a lower end of the upper portion; and

the neck has an upper end that is in abutment with the downward facing shoulder when the secondary seal ring is in the set position.

9. A subsea wellhead assembly, comprising:

an outer wellhead housing having a bore;

a casing hanger landed within the bore, defining an annular pocket between a sidewall of the casing hanger and a sidewall of the bore, the casing hanger having an external shoulder that defines a lower end of the pocket;

a seal assembly that is lowered into the pocket while in a run-in position, the seal assembly having elastomeric and metal seal surfaces that are deformed into sealing engagement with the casing hanger and the sidewall of the bore when the seal assembly is in a set position;

the seal assembly being movable from a run-in position to the set position by applying a downward force;

a resilient, metal spring element that exerts an axial force on the seal assembly after the seal assembly position; and wherein:

the spring element comprises a cylinder having circumferentially extending inner slits formed on an inner diameter and circumferentially extending outer slits formed on an outer diameter of the cylinder, the inner slits alternating with the outer slits in an axial direction.

10. A method of sealing between inner and outer tubular members of a subsea wellhead assembly, comprising:

(a) providing a metal-to-metal primary seal ring of a type that expands radially inward and outward, relative to an axis of the primary seal ring, in response to an axially directed primary setting force relative to an axis of the primary seal ring, and providing the primary seal ring with a downward extending leg;

(b) providing a secondary seal ring having metal and elastomeric sealing surfaces that expand radially inward and outward in response to an axially directed secondary setting force that is less than the primary setting force, and providing the secondary seal ring with an upward extending neck that extends alongside the leg;

(c) securing the neck of the secondary seal ring to the leg of the primary seal ring to define a seal assembly;

(d) lowering the seal assembly between the inner and outer tubular members;

(e) applying a first axially directed force to the primary seal ring that is at least equal to the secondary setting force, causing the secondary seal ring to radially expand inward and outward to sealingly engage the inner and outer tubular members, the first axially directed force extending down the leg to the elastomeric and metal sealing surface portion of the secondary seal, bypassing the neck; then

(f) applying a second axially directed force to the primary seal ring that is at least equal to the primary setting force, causing the primary seal ring to radially expand inward and outward to sealingly engage the inner and outer tubular members.

11. The method according to claim 10, wherein:

step (c) comprises employing a coupling device to connect the neck of the secondary seal ring to the leg of the primary seal ring; and

steps (d) and (e) comprise transferring the first and second axially directed forces to the secondary seal ring without any portion of the first and second axially directed forces passing through the coupling device.

12. The method according to claim 10, wherein:

a set of wickers is located on at least one of the tubular members;

during step (e), the secondary seal ring engages the inner and outer tubular members at an area below the set of wickers; and

the primary seal ring engages the set of wickers during step (f).

13. The method according to claim 10, wherein step (c) further comprises positioning a metal, resilient spring element against an end of the secondary seal ring; and the method further comprises:

in step (e) contracting the spring element in response to the first axially directed force; and

exerting an axially directed spring force from the spring element to the secondary seal ring after the secondary seal ring has been set.