

THAT CLAIMED IS:

1. A method of locking down an annulus seal (22) disposed within an annulus (16) between outer and inner wellhead members (12, 13), the method comprising the steps of providing a seal assembly (21) including an annulus seal (22), an annular lockdown ring (25), and an energizing ring (24); positioning the seal assembly (21) in the annulus (16) between outer and inner wellhead members (12, 13); and axially translating a distal end portion (41) of the energizing ring (24) into an annular channel (30) of the annulus seal (22), the distal end portion (41) of the energizing ring (24) radially compressing substantial portions of a first annular member (29) of the annulus seal (22) into engagement with an outer diameter surface (14) of the inner wellhead member (13) and radially compressing substantial portions of a second annular member (26) of the annulus seal (22) into engagement with an inner diameter surface (15) of the outer wellhead member (12) responsive to the axial translation of the energizing ring (24), the method being characterized by:

outer diameter surface portions (35) of a proximal end portion (37) of the energizing ring (24) radially compressing substantial portions of the lockdown ring (25) responsive to axially translating the energizing ring (24); substantial portions of the outer diameter surface (31) of the lockdown ring (25) plastically deforming onto a plurality of annular grooves (32) of a set of annular grooves (32) defining a set of wickers (32) located on portions of the inner diameter surface (15) of the outer wellhead member (12).

2. A method as defined in claim 1, wherein the inner wellhead member (13) is a casing hanger (13); wherein the outer wellhead member (12) is a high-pressure wellhead housing (12); and wherein

the annular lockdown ring (25) comprises an outer diameter surface (31) configured to engage adjacent portions of the inner diameter surface (15) of the high-pressure wellhead housing (12) having the set of wickers (32) when operationally positioned therein, an inner diameter surface (33) for engaging the outer diameter surface portions (35) of the proximal end portion (37) of the energizing ring (24), and a tapered surface (39) tapered to facilitate axial

movement of the outer diameter surface (35) of the proximal end portion (37) of the energizing ring (24) into engagement with substantial portions of the inner diameter surface (33) of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22).

3. A method as defined in claim 2, wherein the energizing ring (24) is dimensioned to radially compress substantial portions of the outer diameter surface (31) of the lockdown ring (25) into corresponding portions of the inner diameter surface (15) of the high-pressure wellhead housing (12) and to energize the annulus seal (22), the energizing ring (24) including:

the proximal end portion (37) having the outer diameter surface (35) sized to engage substantial portions of the inner diameter surface (33) of the annular lockdown ring (25), an adjacent tapered surface (49) complementing the tapered surface (39) of the lockdown ring (25) and tapered to facilitate axial movement of the outer diameter surface (35) of the proximal end portion (37) of the energizing ring (24) into engagement with the substantial portions of the inner diameter surface (33) of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22);

the distal end portion (41) sized to simultaneously engage the first annular member (29) and the second annular member (26) of the annulus seal (22) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22); and

a medial portion (51) having an outer surface diameter that is less than the outer surface diameter of the proximal end portion (37) of the energizing ring (24) to accommodate the lockdown ring (25) prior to axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22).

4. A method as defined in claim 3,

wherein the inner diameter surface portions (15) of the high-pressure wellhead housing (12) engaging the outer diameter surface portions (31) of the lockdown ring (25) and the inner diameter surface portions (15) of the high-pressure wellhead housing (12) engaging outer

surface portions of the second annular member (26) of the annulus seal (22) when the annulus seal (22) is energized, have an at least substantially same inner surface diameter;

wherein the energizing ring (24) is axially translated downward to simultaneously energize the first and the second annular members (29, 26) of the annulus seal (22) and outwardly radially compress the substantial portions (31) of the lockdown ring (25) into contact with the inner diameter surface (15) of the outer wellhead member (12);

wherein the distal end portion (41) of the energizing ring (24) has an outer surface diameter that is greater than the diameter of outer diameter surface of the medial portion (51) of the energizing ring (24) to form a shoulder (61) for engaging a retaining nut (23) during removal of the seal assembly (21); and

wherein the method is further characterized by: removing the energizing ring (24) from compressive engagement with the lockdown ring (25) so that the lockdown ring (25) and annulus seal (22) simultaneously disengage from the inner diameter surface (15) of the high-pressure wellhead housing (12) to thereby remove the annulus seal (22) from the annulus (16).

5. A method as defined in any of claims 1-4,

wherein a proximal end portion (37) of the energizing ring (24) comprises an annular radial extension (45) extending the outer diameter surface (35) of the proximal end portion (37) of the energizing ring (24) so that adjacent outer diameter surface portions of a medial portion (51) of the energizing ring (24) have an outer surface diameter that is substantially less than the outer surface diameter of the proximal end portion (37) of the energizing ring (24),

the annular radial extension (45) enhancing compression of the substantial portions of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), and

the reduced diameter of the outer diameter surface of the medial portion (51) accommodating the lockdown ring (25) prior to axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22).

6. A method as defined in any of claims 1-5,

wherein the seal assembly (21) includes a retaining nut (23) having a tapered surface complementing the tapered surface (49) of the energizing ring (24) and tapered so that when the distal end portion (41) of the energizing ring (24) is fully operationally inserted between the first and the second annular members (29, 26) of the annulus seal (22), the tapered surface (49) of the energizing ring (24) engages the tapered surface (59) of the retaining nut (23); and

wherein the second annular member (26) comprises an annular extension (27), a proximal end of the annular extension (27) configured to engage complementary portions of the retaining nut (23).

7. A method as defined in any of claims 1-6,

wherein the set of wickers (32) at least non-continuously extend between an outer diameter surface of at least a medial portion of the second annular member (26) and a proximal portion of the outer diameter surface (31) of the annular lockdown ring (25) when the annulus seal (22) is energized to thereby enhance retention of the seal assembly (21).

8. A seal assembly (21) for locking down an annulus seal (22) disposed within an annulus (16) between outer and inner wellhead members (12, 13), the seal assembly (21) comprising an annulus seal (22) having a first annular member (29) configured to engage an outer diameter surface (14) of an inner wellhead member (13), a second annular member (26) configured to engage an inner diameter surface (15) of an outer wellhead member (12), and an annular channel (30) extending therebetween to receive an energizing member (24, 41), the seal assembly (21) being characterized by:

an annular lockdown ring (25) having an outer diameter surface (31) configured to engage adjacent portions of the inner diameter surface (15) of the outer wellhead member (12) having a plurality of shallow annular grooves (32) defining a set of wickers (32) when operationally positioned therein, an inner diameter surface (33) to engage an outer diameter surface (35) of an energizing ring (24), and a tapered surface (39) tapered to facilitate axial movement of the outer diameter surface (35) of the energizing ring (24) into engagement with substantial portions of the inner diameter surface (33) of the lockdown ring (25) when axially

translating a distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22); and

the energizing ring (24) dimensioned to radially compress substantial portions of the outer diameter surface (31) of the lockdown ring (25) into corresponding portions of the inner diameter surface (15) of the outer wellhead member (12) and to energize the annulus seal (22), the energizing ring (24) including a proximal end portion (37) having an outer diameter surface (35) sized to engage substantial portions of the inner diameter surface (33) of the annular lockdown ring (25) to radially outwardly compress portions of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), an adjacent tapered surface (49) complementing the tapered surface (39) of the lockdown ring (25) and tapered to facilitate axial movement of the outer diameter surface (35) of the proximal end portion (37) of the energizing ring (24) into engagement with the substantial portions of the inner diameter surface (33) of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), the distal end portion (41) sized to simultaneously engage the first annular member (29) and the second annular member (26) of the annulus seal (22) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), and a medial portion (51) having an outer surface diameter that is less than the outer surface diameter of the proximal end portion (37) of the energizing ring (24) to accommodate the lockdown ring (25) prior to axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22).

9. A seal assembly (21) as defined in claim 8, wherein the inner wellhead member (13) is a casing hanger (13); wherein the outer wellhead member (12) is a high-pressure wellhead housing (12); and wherein

the lockdown ring (25) is further configured so that when the energizing ring (24) is fully axially translated to energize the annulus seal (22), portions of the outer diameter surface (31) of the lockdown ring (25) plastically deform onto a plurality of wickers (32) of the set of wickers

(32) located on portions of the inner diameter surface (15) of the high-pressure wellhead housing (12).

10. A seal assembly (21) as defined in claim 9,

wherein the strength rating of the portion (15) of the high-pressure wellhead housing (12) engaging portions of the outer diameter surface (31) of the lockdown ring (25) is between approximately 80 KPsi and 120Kpsi; and

wherein the strength rating of portions of the outer diameter surface (31) of the lockdown ring (25) engaging the portions (15) of the high-pressure wellhead housing (12) is between approximately 30Kpsi and 80 KPsi.

11. A seal assembly (21) as defined in either of claims 9 or 10,

wherein the proximal end portion (37) of the energizing ring (24) comprises an annular radial extension (45) extending the outer diameter surface (35) of the proximal end portion (37) of the energizing ring (24) so that adjacent outer diameter surface portions of a medial portion (51) of the energizing ring (24) have an outer surface diameter that is substantially less than the outer surface diameter of the proximal end portion (37) of the energizing ring (24), the annular radial extension (45) enhancing compression of the substantial portions of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), the reduced diameter of the outer diameter surface of the medial portion (51) accommodating the lockdown ring (25) prior to axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22); and

wherein the distal end portion (41) of the energizing ring (24) has an outer surface diameter that is greater than the diameter of the outer diameter surface of the medial portion (51) of the energizing ring (24) to form a shoulder (61) for engaging a retaining nut (23) during removal of the seal assembly (21).

12. A seal assembly (21) as defined in any of claims 8-11, being further characterized by:

a retaining nut (23) having a tapered surface (59) complementing the tapered surface (49) of the energizing ring (24) and tapered so that when the distal end portion (41) of the energizing ring (24) is fully operationally inserted between the first and second annular members (29, 26) of the annulus seal (22), the tapered surface (49) of the energizing ring (24) engages the tapered surface (59) of the retaining nut (23); and

wherein the second annular member (26) comprises an annular extension (27), a proximal end of the annular extension (27) configured to engage complementary portions of the retaining nut (23).

13. A seal assembly (21) as defined in any of claims 8-12, wherein the tapered surface (49) of the energizing ring (24) is tapered at an angle of approximately between 3° and 15° in relation to a main axis of the outer wellhead member (12).

14. A seal assembly (21) as defined in any of claims 8-13, wherein the set of wickers (32) extend between an outer diameter surface of at least a medial portion of the second annular member (26) and a proximal portion of the outer diameter surface (31) of the annular lockdown ring (25) when the annulus seal (22) is energized to thereby enhance retention of the seal assembly (21).

15. A wellhead assembly (10), comprising: an outer wellhead member (12) adapted to be anchored in a borehole; an inner wellhead member (13) landed within the outer wellhead member (12), a gap between the outer wellhead member (12) and the inner wellhead member (13) defining an annulus (16); a profile on an interior surface of the outer wellhead member (12) comprising a plurality of shallow annular grooves, protuberances, or grooves and protuberances defining a set of wickers (32); and a seal assembly (21) comprising an annulus seal (22) having a first annular member (29) configured to engage an outer diameter surface (14) of the inner wellhead member (13), a second annular member (26) configured to engage an inner diameter surface (15) of the outer wellhead member (12), and an annular channel (30) extending therebetween to receive an energizing member (24, 41), the wellhead assembly (10) being characterized by:

the seal assembly including:

an annular lockdown ring (25) having an outer diameter surface (31) configured to engage adjacent portions of an inner diameter surface (15) of the outer wellhead member (12) having the set of wickers (32) when operationally positioned therein, an inner diameter surface (33) to engage an outer diameter surface (35) of an energizing ring (24), and a tapered surface (39) tapered to facilitate axial movement of the outer diameter surface (35) of the energizing ring (24) into engagement with substantial portions of the inner diameter surface (33) of the lockdown ring (25) when axially translating a distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), and

the energizing ring (24) dimensioned to radially compress substantial portions of the outer diameter surface (31) of the lockdown ring (25) into corresponding portions of the inner diameter surface (15) of the outer wellhead member (12) and to energize the annulus seal (22), the energizing ring (24) including a proximal end portion (37) having an outer diameter surface (35) sized to engage substantial portions of the inner diameter surface (33) of the annular lockdown ring (25) to radially outwardly compress portions (31) of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), an adjacent tapered surface (49) complementing the tapered surface (39) of the lockdown ring (25) and tapered to facilitate axial movement of the outer diameter surface (35) of the proximal end portion (37) of the energizing ring (24) into engagement with the substantial portions of the inner diameter surface (33) of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), the distal end portion (41) sized to simultaneously engage the first annular member (29) and the second annular member (26) of the annulus seal (22) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), and a medial portion (51) having an outer surface diameter that is less than the outer surface diameter of the proximal end portion (37) of the energizing ring (24) to accommodate the lockdown ring (25) prior to axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22).

16. A wellhead assembly (10) as defined in claim 15, wherein the inner wellhead member (13) is a casing hanger (13); wherein the outer wellhead member (12) is a high-pressure wellhead housing (12); and wherein

the lockdown ring (25) is further configured so that when the energizing ring (24) is fully axially translated to energize the annulus seal (22), portions of the outer diameter surface (31) of the lockdown ring (25) plastically deform onto a plurality of wickers (32) of the set of wickers (32) located on portions of the inner diameter surface (15) of the high-pressure wellhead housing (12).

17. A wellhead assembly (10) as defined in either of claims 15 or 16,

wherein the strength rating of the portion (15) of the high-pressure wellhead housing (12) engaging portions of the outer diameter surface (31) of the lockdown ring (25) is between approximately 80 KPsi and 120Kpsi; and

wherein the strength rating of portions of the outer diameter surface (31) of the lockdown ring (25) engaging the portions of the high-pressure wellhead housing (12) is between approximately 30Kpsi and 80 KPsi.

18. A wellhead assembly (10) as defined in any of claims 15-17,

wherein the proximal end portion (37) of the energizing ring (24) comprises an annular radial extension (45) extending the outer diameter surface (35) of the proximal end portion (37) of the energizing ring (24) so that adjacent outer diameter surface portions of a medial portion (51) of the energizing ring (24) have an outer surface diameter that is substantially less than the outer surface diameter of the proximal end portion (37) of the energizing ring (24), the annular radial extension (45) enhancing compression of the substantial portions of the lockdown ring (25) when axially translating the distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22), the reduced diameter of the outer diameter surface of the medial portion (51) accommodating the lockdown ring (25) prior to axially translating the

distal end portion (41) of the energizing ring (24) into the annular channel (30) of the annulus seal (22); and

wherein the distal end portion (41) of the energizing ring (24) has an outer surface diameter that is greater than the diameter of the outer diameter surface of the medial portion (51) of the energizing ring (24) to form a shoulder (61) for engaging a retaining nut (23) during removal of the seal assembly (21).

19. A wellhead assembly (10) as defined in any of claims 15-18,

wherein the seal assembly (21) includes a retaining nut (23) having a tapered surface (59) complementing the tapered surface (49) of the energizing ring (24) and tapered so that when the distal end portion (41) of the energizing ring (24) is fully operationally inserted between the first and second annular members (29, 26) of the annulus seal (22), the tapered surface (49) of the energizing ring (24) engages the tapered surface (59) of the retaining nut (23); and

wherein the second annular member (26) comprises an annular extension (27), a proximal end of the annular extension (27) configured to engage complementary portions of the retaining nut (23).

20. A wellhead assembly (10) as defined in any of claims 15-19, wherein the tapered surface (49) of the energizing ring (24) is tapered at an angle of approximately between 3° and 15° in relation to a main axis of the outer wellhead member (12).

21. A wellhead assembly (10) as defined in any of claims 15-20, wherein the set of wickers (32) extend between an outer diameter surface of at least a medial portion of the second annular member (26) and a proximal portion of the outer diameter surface (31) of the annular lockdown ring (25) when the annulus seal (22) is energized to thereby enhance retention of the seal assembly (21) within the wellhead assembly (10).

THE INVENTION CLAIMED IS:

1. A method of locking down an annulus seal disposed within an annulus between outer and inner wellhead members, the method comprising the steps of:

providing a seal assembly including an annulus seal, an annular lockdown ring, and an energizing ring, the energizing ring including a proximal end portion, a distal end portion, and a medial portion extending therebetween, the proximal end portion being longitudinally spaced apart from the distal end portion;

positioning the seal assembly in the annulus between outer and inner wellhead members;

axially translating the distal end portion of the energizing ring into an annular channel of the annulus seal, the distal end portion of the energizing ring radially compressing substantial portions of a first annular member of the annulus seal into engagement with an outer diameter surface of the inner wellhead member and radially compressing substantial portions of a second annular member of the annulus seal into engagement with an inner diameter surface of the outer wellhead member responsive to the axial translation of the energizing ring; and

outer diameter surface portions of the proximal end portion of the energizing ring radially compressing substantial portions of the lockdown ring responsive to axially translating the energizing ring, substantial portions of the outer diameter surface of the lockdown ring plastically deforming onto a plurality of annular grooves of a set of annular grooves defining a set of wickers located on portions of the inner diameter surface of the outer wellhead member, the proximal end portion of the energizing ring being spaced apart from the annular channel of the annulus seal when the distal end portion of the energizing ring is operably positioned therein.

2. A method as defined in claim 1,
wherein the inner wellhead member is a casing hanger;

wherein the outer wellhead member is a high-pressure wellhead housing; and

wherein the annular lockdown ring comprises an outer diameter surface configured to engage adjacent portions of the inner diameter surface of the high-pressure wellhead housing having the set of wickers when operationally positioned therein, an inner diameter surface for engaging the outer diameter surface portions of the proximal end portion of the energizing ring, and a tapered surface tapered to facilitate axial movement of the outer diameter surface of the proximal end portion of the energizing ring into engagement with substantial portions of the inner diameter

surface of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal.

3. A method as defined in claim 2, wherein the energizing ring is dimensioned to radially compress substantial portions of the outer diameter surface of the lockdown ring into corresponding portions of the inner diameter surface of the high-pressure wellhead housing and to energize the annulus seal, the energizing ring including:

the proximal end portion having the outer diameter surface sized to engage substantial portions of the inner diameter surface of the annular lockdown ring, an adjacent tapered surface complementing the tapered surface of the lockdown ring and tapered to facilitate axial movement of the outer diameter surface of the proximal end portion of the energizing ring into engagement with the substantial portions of the inner diameter surface of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal;

the distal end portion sized to simultaneously engage the first annular member and the second annular member of the annulus seal when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal; and

the medial portion having an outer surface diameter that is less than the outer surface diameter of the proximal end portion of the energizing ring to accommodate the lockdown ring prior to axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal.

4. A method as defined in claim 3,

wherein the inner diameter surface portions of the high-pressure wellhead housing engaging the outer diameter surface portions of the lockdown ring and the inner diameter surface portions of the high-pressure wellhead housing engaging outer surface portions of the second annular member of the annulus seal when the annulus seal is energized, have an at least substantially same inner surface diameter;

wherein the energizing ring is axially translated downward to simultaneously energize the first and the second annular members of the annulus seal and outwardly radially compress the substantial portions of the lockdown ring into contact with the inner diameter surface of the outer wellhead member;

wherein the distal end portion of the energizing ring has an outer surface diameter that is greater than the diameter of outer diameter surface of the medial portion of the energizing ring to form a shoulder for engaging a retaining nut during removal of the seal assembly; and

wherein the method further comprises removing the energizing ring from compressive engagement with the lockdown ring so that the lockdown ring and annulus seal simultaneously disengage from the inner diameter surface of the high-pressure wellhead housing to thereby remove the annulus seal from the annulus.

5. A method as defined in claim 1,

wherein the proximal end portion of the energizing ring comprises an annular radial extension extending the outer diameter surface of the proximal end portion of the energizing ring so that adjacent outer diameter surface portions of the medial portion of the energizing ring have an outer surface diameter that is substantially less than the outer surface diameter of the proximal end portion of the energizing ring,

the annular radial extension enhancing compression of the substantial portions of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, and

the reduced diameter of the outer diameter surface of the medial portion accommodating the lockdown ring prior to axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal.

6. A method as defined in claim 1,

wherein the seal assembly includes a retaining nut having a tapered surface complementing the tapered surface of the energizing ring and tapered so that when the distal end portion of the energizing ring is fully operationally inserted between the first and the second annular members of the annulus seal, the tapered surface of the energizing ring engages the tapered surface of the retaining nut; and

wherein the second annular member comprises an annular extension, a proximal end of the annular extension configured to engage complementary portions of the retaining nut.

7. A method as defined in claim 1,

wherein the set of wickers at least non-continuously extend between an outer diameter surface of at least a medial portion of the second annular member and a proximal portion of the outer diameter surface of the annular lockdown ring when the annulus seal is energized to thereby enhance retention of the seal assembly.

8. A seal assembly for locking down an annulus seal disposed within an annulus between outer and inner wellhead members, the seal assembly comprising:

an annulus seal having a first annular member configured to engage an outer diameter surface of an inner wellhead member, a second annular member configured to engage an inner diameter surface of an outer wellhead member, and an annular channel extending therebetween to receive an energizing member;

an annular lockdown ring having an outer diameter surface configured to engage adjacent portions of the inner diameter surface of the outer wellhead member having a plurality of shallow annular grooves defining a set of wickers when operationally positioned therein, an inner diameter surface to engage an outer diameter surface of an energizing ring, and a tapered surface tapered to facilitate axial movement of the outer diameter surface of the energizing ring into engagement with substantial portions of the inner diameter surface of the lockdown ring when axially translating a distal end portion of the energizing ring into the annular channel of the annulus seal; and

the energizing ring dimensioned to radially compress substantial portions of the outer diameter surface of the lockdown ring into corresponding portions of the inner diameter surface of the outer wellhead member and to energize the annulus seal, the energizing ring including a proximal end portion having an outer diameter surface sized to engage substantial portions of the inner diameter surface of the annular lockdown ring to radially outwardly compress portions of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, an adjacent tapered surface complementing the tapered surface of the lockdown ring and tapered to facilitate axial movement of the outer diameter surface of the proximal end portion of the energizing ring into engagement with the substantial portions of the inner diameter surface of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, the distal end portion sized to simultaneously engage the first annular member and the second annular member of the annulus seal when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, and a medial portion having an outer surface diameter that is less than the outer surface diameter of the proximal end portion of the energizing ring to accommodate the lockdown ring prior to axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal.

9. A seal assembly as defined in claim 8,
wherein the inner wellhead member is a casing hanger;

wherein the outer wellhead member is a high-pressure wellhead housing; and

wherein the lockdown ring is further configured so that when the energizing ring is fully axially translated to energize the annulus seal, portions of the outer diameter surface of the lockdown ring plastically deform onto a plurality of wickers of the set of wickers located on portions of the inner diameter surface of the high-pressure wellhead housing.

10. A seal assembly as defined in claim 9,

wherein the strength rating of the portion of the high-pressure wellhead housing engaging portions of the outer diameter surface of the lockdown ring is between approximately 80 KPsi and 120 Kpsi; and

wherein the strength rating of portions of the outer diameter surface of the lockdown ring engaging the portions of the high-pressure wellhead housing is between approximately 30 Kpsi and 80 KPsi.

11. A seal assembly as defined in claim 9,

wherein the proximal end portion of the energizing ring comprises an annular radial extension extending the outer diameter surface of the proximal end portion of the energizing ring so that adjacent outer diameter surface portions of a medial portion of the energizing ring have an outer surface diameter that is substantially less than the outer surface diameter of the proximal end portion of the energizing ring, the annular radial extension enhancing compression of the substantial portions of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, the reduced diameter of the outer diameter surface of the medial portion accommodating the lockdown ring prior to axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal; and

wherein the distal end portion of the energizing ring has an outer surface diameter that is greater than the diameter of the outer diameter surface of the medial portion of the energizing ring to form a shoulder for engaging a retaining nut during removal of the seal assembly.

12. A seal assembly as defined in claim 8, further comprising:

a retaining nut having a tapered surface complementing the tapered surface of the energizing ring and tapered so that when the distal end portion of the energizing ring is fully operationally inserted between the first and second annular members of the annulus seal, the tapered surface of the energizing ring engages the tapered surface of the retaining nut; and

wherein the second annular member comprises an annular extension, a proximal end of the annular extension configured to engage complementary portions of the retaining nut.

13. A seal assembly as defined in claim 8, wherein the tapered surface of the energizing ring is tapered at an angle of approximately between 3° and 15° in relation to a main axis of the outer wellhead member.

14. A seal assembly as defined in claim 8, wherein the set of wickers extend between an outer diameter surface of at least a medial portion of the second annular member and a proximal portion of the outer diameter surface of the annular lockdown ring when the annulus seal is energized to thereby enhance retention of the seal assembly.

15. A wellhead assembly, comprising:

an outer wellhead member adapted to be anchored in a borehole;

an inner wellhead member landed within the outer wellhead member, a gap between the outer wellhead member and the inner wellhead member defining an annulus;

a profile on an interior surface of the outer wellhead member comprising a plurality of shallow annular grooves, protuberances, or grooves and protuberances defining a set of wickers; and

a seal assembly comprising:

an annulus seal having a first annular member configured to engage an outer diameter surface of the inner wellhead member, a second annular member configured to engage an inner diameter surface of the outer wellhead member, and an annular channel extending therebetween to receive an energizing member,

an annular lockdown ring having an outer diameter surface configured to engage adjacent portions of an inner diameter surface of the outer wellhead member having the set of wickers when operationally positioned therein, an inner diameter surface to engage an outer diameter surface of an energizing ring, and a tapered surface tapered to facilitate axial movement of the outer diameter surface of the energizing ring into engagement with substantial portions of the inner diameter surface of the lockdown ring when axially translating a distal end portion of the energizing ring into the annular channel of the annulus seal, and

the energizing ring dimensioned to radially compress substantial portions of the outer diameter surface of the lockdown ring into corresponding portions of the inner diameter surface of the outer wellhead member and to energize the annulus seal, the energizing including a proximal end portion having an outer diameter surface sized to engage substantial portions of the inner diameter surface of the annular lockdown ring to radially outwardly compress portions of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, an adjacent tapered surface complementing the tapered surface of the lockdown ring and tapered to facilitate axial movement of the outer diameter surface of the proximal end portion of the energizing ring into engagement with the substantial portions of the inner diameter surface of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, the distal end portion sized to simultaneously engage the first annular member and the second annular member of the annulus seal when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, and a medial portion having an outer surface diameter that is less than the outer surface diameter of the proximal end portion of the energizing ring to accommodate the lockdown ring prior to axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal.

16. A wellhead assembly as defined in claim 15,
wherein the inner wellhead member is a casing hanger;

wherein the outer wellhead member is a high-pressure wellhead housing; and

wherein the lockdown ring is further configured so that when the energizing ring is fully axially translated to energize the annulus seal, portions of the outer diameter surface of the lockdown ring plastically deform onto a plurality of wickers of the set of wickers located on portions of the inner diameter surface of the high-pressure wellhead housing.

17. A wellhead assembly as defined in claim 15,
wherein the strength rating of the portion of the high-pressure wellhead housing engaging portions of the outer diameter surface of the lockdown ring is between approximately 80 KPsi and 120 Kpsi; and

wherein the strength rating of portions of the outer diameter surface of the lockdown ring engaging the portions of the high-pressure wellhead housing is between approximately 30 Kpsi and 80 KPsi.

18. A wellhead assembly as defined in claim 15,

wherein the proximal end portion of the energizing ring comprises an annular radial extension extending the outer diameter surface of the proximal end portion of the energizing ring so that adjacent outer diameter surface portions of a medial portion of the energizing ring have an outer surface diameter that is substantially less than the outer surface diameter of the proximal end portion of the energizing ring, the annular radial extension enhancing compression of the substantial portions of the lockdown ring when axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal, the reduced diameter of the outer diameter surface of the medial portion accommodating the lockdown ring prior to axially translating the distal end portion of the energizing ring into the annular channel of the annulus seal; and

wherein the distal end portion of the energizing ring has an outer surface diameter that is greater than the diameter of the outer diameter surface of the medial portion of the energizing ring to form a shoulder for engaging a retaining nut during removal of the seal assembly.

19. A wellhead assembly as defined in claim 15,

wherein the seal assembly includes a retaining nut having a tapered surface complementing the tapered surface of the energizing ring and tapered so that when the distal end portion of the energizing ring is fully operationally inserted between the first and second annular members of the annulus seal, the tapered surface of the energizing ring engages the tapered surface of the retaining nut; and

wherein the second annular member comprises an annular extension, a proximal end of the annular extension configured to engage complementary portions of the retaining nut.

20. A wellhead assembly as defined in claim 15, wherein the tapered surface of the energizing ring is tapered at an angle of approximately between 3° and 15° in relation to a main axis of the outer wellhead member.

21. A wellhead assembly as defined in claim 15, wherein the set of wickers extend between an outer diameter surface of at least a medial portion of the second annular member and a proximal portion of the outer diameter surface of the annular lockdown ring when the annulus seal is energized to thereby enhance retention of the seal assembly within the wellhead assembly.