

STABILIZED CENTER-SHOULDER-SEALED TUBULAR CONNECTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to tubular connections of the kind commonly used in the oil industry. In particular, the tubular connection of the present invention comprises a stabilized center-shoulder seal, wherein stabilization is provided by specialized thread constructions adjacent the center-shoulder seal. The invention also pertains to a specialized center-shoulder seal design. Further, the invention pertains to a thread profile which provides a self-centering function upon makeup of the tubular connection. This thread profile can be used with the stabilized center-shoulder seal connection as well as other connection designs known in the art.

2. Background Art

The present invention is applicable broadly for use in joining pipes, couplings and the like, and has particularly been developed for use in oil industry tubular connections, since these connections experience more severe and demanding conditions than those observed for other industries and applications. In particular, the trend in the oilfield is to minimize pipe diameter and to conserve borehole diameter. The smaller the diameter of the borehole for the well, the greater the conservation of energy and reduction of drilling costs. However, in utilizing smaller diameter pipe, it is important that the connections between adjacent tubular pipes be transparent in geometry and performance characteristics, i.e. the geometry and performance characteristics of the connection be substantially the same as that of the tubular pipe itself. Preferably, the pipe string should behave as if the pipe connections were not there. The ideal connection would have the same geometry as the pipe, such as the same inside and outside diameters, and would have the same performance characteristics such as tension rating, compression rating, internal and external pressure ratings, torsion resistance, and bending resistance, for example.

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1 Two types of oilfield connections, namely flush joints and slim line connections,
2 have been utilized to conserve hole diameter. The outer diameter of a flush joint
3 connection is generally the same as the outside diameter of the tubular pipe. The outside
4 diameter of a slim line connection is generally 2 to 3.5% greater than that of the pipe.
5 Although the objective of such prior art pipe has been to achieve total geometric and
6 performance characteristic transparency, such has not been possible. Often, the
7 performance characteristics of prior art pipe have been sacrificed to achieve greater
8 geometric transparency.

9 Various standards have been set for evaluating the efficiency of a pipe connection.
10 One such efficiency is determined by the load capacity of the pipe and pipe connection
11 in the axial direction. This tension efficiency is calculated by comparing the fracture
12 strength of the connection with the fracture strength of the tubular pipe. Most prior art
13 flush joint and slim line connections achieve an efficiency in the range of 65% to 75%,
14 respectively. This efficiency, of course, varies with the type of connection, the pipe
15 diameter and thickness, and the method of manufacture of the connection.

16 Prior art connections include the basic elements of threads, shoulders, and seals.
17 The following prior art patents describe various features which have been used to produce
18 flush and slim-line connections.

19 U.S. Patent No. 671,274 to W.C. Fischer, issued April 2, 1901, shows a dovetail-
20 shaped thread design which can be applied to the outside of one tubular and the inside
21 of another tubular to be connected together.

22 U.S. Patent No. 1,474,375 to J.J. Moore, issued September 20, 1923 shows what
23 applicant has described as single hook thread design. The thread is used to fasten the
24 forward end of the after-body of a torpedo to an air flask body.

25 U.S. Patent No. 1,927,656, issued September 19, 1933 to G.M. Eaton et al.,
26 describes a pipe joint for fastening together the consecutive pipe lengths of a pipe string
27 in a manner to obtain strength at the joint without increasing the wall thickness (or with
28 a minimum increase thereof) in the portion of the pipe in which the screw threads are cut.
29 One of the two pipes to be joined is machined on the outside surface of the pin and the
30 other is machined on the inside surface of the box so the two pipes can be screwed
31 together to provide what would today be called a slim line connection. The threaded
32 portion of each pipe is machined on a taper with the depth of the turns of the threads



1 being the greatest at the center of the threaded portion and decreasing gradually in both
2 directions to vanishing points at the ends of the threaded portions.

3 U.S. Patent No. 2,062,407, issued December 1, 1936 to G.M. Eaton et al.,
4 discloses a preferred form of pipe joint wherein the height of the threads in the threaded
5 portion of the joint is at a maximum in the central area of the threaded portion of the
6 joint and decreases gradually in both directions to vanishing points, somewhat similar to
7 the joint described above. However, the thread design differs in that the vanishing of the
8 threads corresponds with the intersection of thread fabrication lines which are not only
9 based on a taper relative to the pipe longitudinal axis but also a line which is cylindrical
10 or parallel to the pipe longitudinal axis. Specifically, the root of the thread at the pipe
11 exterior edge position of the pin is located along a line parallel with the pipe longitudinal
12 axis while the crest of the thread at the same location is located along a line at a constant
13 taper with the pipe longitudinal axis. The root of the thread at a position more interior
14 from the edge of the pipe is located along a line at a constant taper with the pipe
15 longitudinal axis, while the crest of the thread at the same location is located on a line
16 of parallel taper to the root for a distance. Finally, at the most interior thread location
17 on the pin, the thread root continues on a taper with the pipe longitudinal axis while the
18 crest of the thread is constructed along a line parallel with the pipe longitudinal axis.
19 Thus, at both the exterior and interior edges of the threaded connection, the thread
20 disappears where thread root and thread crest intersect. The thread construction of the
21 box is complimentary to that of the pin so the two threaded members can be
22 interengaged.

23 U.S. Patent No. 2,207,005 to R.D. Haas, issued July 9, 1940, pertains to a single
24 hook thread form (as defined herein) wherein the pin member load flank is undercut to
25 provide a cam action under pressure to draw the connection members together and
26 establish a sealing-off function. The thread form is constructed on a taper to the
27 longitudinal axis of the connection.

28 U.S. Patent No. 2,488,566 to R.S. Sperry, issued November 22, 1949 described
29 a tapered thread structure having a lead on one flank of the helical thread which differs
30 from the lead on the other flank of the helical thread, to provide a constantly increasing
31 thread width from one end of the thread structure to the opposite end. This variable
32 width thread structure is said to enable easy disassembly of a rod or pin from a socket,



1 permitting separation of pin from socket without the need to completely unscrew the
2 parts, while providing a wedge-like, snug interfit between the threads of the parts when
3 coupled together. The preferred embodiment for use of the variable width thread
4 structure is on the surface of a pull rod used in combination with a tubular work piece
5 to be formed.

6 U.S. Patent No. 3,109,672, issued November 5, 1963 to William F. Franz
7 describes a threaded pipe joint comprising a pipe member having a cylindrical outer
8 surface and a tapered buttress thread at the end thereof vanishing along the outer
9 cylindrical surface, providing a length of fully formed and a length of vanishing threads.
10 The complementary coupling member having thread machined on the internal surface
11 thereof exhibits a full height tapered thread throughout the entire length thereof. The
12 complementary threads on each member have following flanks in bearing relationship and
13 substantially normal to the longitudinal axis of the joint and leading flanks in bearing
14 relationship, which leading flanks have a larger flank angle than the following flanks.
15 Crests and roots are truncated to provide flat crests and roots which are parallel to the
16 longitudinal axis of the joint. Crest truncations of fully formed threads exceed root
17 truncations to provide a predetermined amount of void between the crests and roots of
18 the complementary threads throughout the length of the joint when the pipe and coupling
19 are in hand tight engagement. After power make-up, the crests of the coupling threads
20 engage the roots of the vanishing pipe threads, but voids still remain between crests and
21 roots of the fully formed threads, thus preventing the development of deleterious hoop
22 stresses at the end of the coupling during power make-up.

23 U.S. Patent No. 3,989,284, issued November 2, 1976 to Thomas L. Blose (see
24 also Re. 30,647, issued June 16, 1981) describes a tubular connection (pipe joint)
25 designed to produce hoop tension in the pin member and hoop compression in the box
26 member, the connection exhibits threads having a dove-tail interfit. To achieve the dove-
27 tail interfit, the angles formed between the thread flanks and the root wall of the thread
28 are less than about 85° . In another described embodiment, the load flank of the thread
29 exhibits an angularity from the direction of the connection on axis of less than about 85°
30 while with the stab flank extends radially, in axial radial planes. The pin thread stab
31 flank is the thread flank which is on the leading edge as the pin is telescoped (stabbed)
32 into the box. The load flank is the trailing flank of the thread. In all cases, the threads



1 are designed with clearances such that there is a "dove-tail interfit" between pin and box
2 drawing the pin wall outwardly and the box wall inwardly to produce hoop tension in the
3 pin member and hoop compression in the box member in a made up connection, i.e.
4 there is a wedging interfit of threads in the made up joint.

5 Each thread member is disclosed in the '284 Blose patent as having progressively
6 changing axial width along substantially the entire helical length thereof. Although the
7 preferred embodiment appears to have the threads constructed on a line parallel to the
8 pipe longitudinal axis, the possibility is disclosed of having the threads constructed on a
9 line having constant taper from the pipe longitudinal axis. Also described is the use of
10 an inner shoulder seal between threaded sections of the connection. In one embodiment,
11 the inner shoulder seal is placed between two thread sections which fall on two different
12 lines, each parallel to the pipe longitudinal axis, creating a multiple-step thread with an
13 inner shoulder seal. The inner shoulder seal is shown and described as having a major
14 mating (sealing) surface which is parallel to the pipe longitudinal axis or a major mating
15 (sealing) surface which is at an axial taper.

16 U.S. Patent 4,009,893, issued March 1, 1977 to Schatton et al., discloses box and
17 pin members having two axially spaced thread sections being separated by a radial step
18 zone which includes, for one member, eg. the pin member, an annulus having an axial
19 undercut, a frusto-conical end face and a radially outward bulging peripheral surface,
20 which sealingly engages a slightly contoured surface of the box member in the step zone,
21 while the end face of the annulus bears against a complementary, slightly contoured face
22 in the step zone of the box member. These stop faces supplement complementary thread
23 stop faces respectively at the end of the pin member and box member. It is advised that
24 a flat annulus having good sliding properties, such as teflon, be interposed between the
25 pin member annulus end face and the complementary bearing face of the box member.
26 In one embodiment, there is a space between the pin member annulus end face and the
27 complementary bearing face of the box member, and a sealing sleeve is interposed to fill
28 this space and the undercut space of the pin member annulus.

29 U.S. Patent No. 4,076,436 to D.T. Slatoret al., issued February 28, 1979,
30 describes specially designed stress relief grooves for threaded end portions of tools and
31 for collars on reciprocating or rotating drill string mounted tools.



1 U.S. Patent No. 4,161,332, issued July 17, 1979 to Thomas L. Blose describes
2 a pipe joint including pin and box members having interengaged two-step threads and
3 interengaged annular shoulders. One of the annular shoulders of the connection is located
4 axially between the first and second pair of threads. This shoulder is constructed so that
5 the pin member stab flank of the shoulder is at a negative angle to the pipe longitudinal
6 axis (preferably at about 5 degrees) to provide a semi-dovetail interfit of the shoulder on
7 makeup of the joint. The pin member threads in general exhibit a negative angle load
8 flank (preferably about 15 degrees) and a negative stab flank angle (typically about 30
9 degrees), to provide a semi-dovetail interfit with corresponding box threads; the pin
10 member stab flank is typically not engaged, there being about 0.020 inches clearance with
11 the corresponding box threads on normal make-up.

12 U.S. Patent No. 4,224,607 to T.L. Blose, issued July 17, 1979, discloses a
13 cylindrical threaded connector having a small amount of taper to produce a controlled
14 radial interference to prevent inadvertent thread disengagement.

15 U.S. Patent No. 4,373,754 to C.A. Bollfrass, et al., issued February 15, 1983,
16 describes a threaded connector having multi-stepped, non-tapered thread sections. The
17 thread profile has at least one "hooked" flank to provide improved tensile strength. The
18 wall thickness of the female or box member of the connector is controlled to improve
19 thread loading and to enable inwardly radial movement with the male or pin member to
20 prevent "pulling out" of the threads under axial tensile loading. The outer thread step
21 of the pin member may only partially engage the threads of the box member such that the
22 critical reduction of the tube wall thickness at the thread roots is a minimum.

23 U.S. Patent No. 4,384,737 to H.E. Reusser, issued May 24, 1983 discloses a
24 tubular connection including a coupling or integral socket into which pipe sections are
25 threaded. The outer surface of the pipe sections includes an unthreaded nose portion at
26 the outer end of the threaded portion. The nose portion terminates with an annular
27 surface and includes a plurality of convex surfaces of revolution extending
28 circumferentially of the nose portion, all of which surfaces are adapted to engage the
29 unthreaded portion of the coupling or socket to establish a fluid-tight seal. The present
30 invention does not utilize such a pin nose design. Another feature of the Reusser
31 invention (which is present in all claims which do not pertain specifically to the above-
32 described pin nose design) is that surface-to-surface thread contact exists between either



1 the minor diameter flat portions of thread on each member or between the major diameter
2 flat portions of thread on each member, but that there not be contact between both the
3 minor and major diameter flat portions. The present invention does not use this method
4 of controlling stresses created during make-up of the connection. The connection of the
5 present invention exhibits surface-to-surface thread contact between the crests and roots
6 of successive threads for all full height threads and the majority (but not all) partial height
7 threads.

8 U.S. Patent No. 4,398,756, issued August 16, 1983 to Duret et al., describes a
9 cylindro-conical pipe joint wherein approximately 15% to 25% of the joint is threaded
10 upon a continuous construction line which is at a taper to the longitudinal axis of the
11 pipe, with the remaining approximately 75% to 85% of the threaded portion of the joint
12 being threaded upon a continuous construction line parallel to the longitudinal axis of the
13 pipe. The position of the threading which is on a taper to the pipe longitudinal axis is
14 that which forms the entry to the connection when the pin and box are initially being
15 telescoped together. Thus, clearance is provided by the taper of the box entry to permit
16 ease in initial telescoping of the pin into the box, prior to actual engagement of the
17 threads. Another feature of the Duret et al. invention is that the female (box) member
18 has an internal shoulder against which the end face of the male (pin) member seals. The
19 connection of the present invention relies on other sealing surfaces within the central
20 structure of the connection, permitting the end face of the pin member to extend openly
21 at the edge of the connection.

22 U.S. Patent No. 4,570,982 to T. L. Blose, issued February 18, 1986, describes
23 a tubular connection including pin and box members having a two step thread profile with
24 the leading thread step of the pin member being a smaller diameter than the second thread
25 step. The thread profile of the members has a negative angle load flank and the thread
26 steps are axially separated from one another by a reverse angle torque shoulder having
27 one or two adjacent conical surfaces. The negative load flank angle of the threads and
28 the reverse shoulder angle combine to lock the members together and prevent differential
29 radial separation of the engaged conical sealing surfaces.

30 U.S. Patent No. 4,591,195 issued May 27, 1986 to Chelette et al. discloses a
31 center shoulder seal located between two threaded portions of a pipe joint, wherein the
32 threaded portions are stepped threads constructed on a line parallel to the longitudinal axis



1 of the pipe. The center shoulder seal is fabricated so the pin portion of the seal contains
2 an undercut groove which can be used in combination with a sealing ring of rigid plastic
3 or rubber material to provide a seal capable of retaining hot gases or liquids.

4 U.S. Patent No. 4,603, 889 to J.W. Welsh, issued August 8, 1986, discloses a
5 threaded fastener having an axis adapted to thread connect to two bodies. The fastener
6 is threaded on the inside and the two bodies are threaded on the outside. The threading
7 has first and second load flanks which face axially oppositely. The first flank defines a
8 second pitch, said pitches being different and characterized in that when the fastener is
9 screwed onto body threads the first flank tightens against one body thread when the
10 second flank tightens against the other body thread.

11 U.S. Patent No. 4,671,544, issued June 9, 1987 to Donald J. Ortloff discloses a
12 threaded pipe connection having two portions of tapered threads with tapered sealing
13 surfaces located between the threaded portions. The tapered sealing surfaces engage a
14 resilient seal member located in a groove about midway between the ends of one of the
15 seal member surfaces; when the joint is made up, the sealing surfaces form independent
16 metal-to-metal seals on both sides of the resilient seal member. In a preferred
17 embodiment, the threaded portions are in the form of two steps, one on each side of the
18 center sealing surface described above; the threads are wedge-shaped threads that increase
19 in width progressively in one direction within each step of threads.

20 U.S. Patent No. 4,676,529, issued June 30, 1987 to Patrick E. McDonald
21 describes a pipe joint wherein the pin and box members have two stepped portions of
22 threads, each constructed on a line parallel with the longitudinal axis of the pipe, and
23 having metal-to-metal sealing surfaces located between the threaded portions. The sealing
24 surfaces provide three engaging shoulders between the pin and box; the two sets of outer
25 shoulders have space between them at the time the set of inner shoulders is in contact.
26 Between the set of inner shoulders and each set of outer shoulders, there is a groove; in
27 one location the groove is in the box portion of the connection and in the other location
28 the groove is in the pin portion of the connection. When the connection make-up torque
29 is beyond the yield point of the metal of the set of inner shoulders, the metal extrudes
30 into the grooves in the box and pin members to form interlocking surfaces which hold
31 the box and pin from relative rotation.

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1 U.S. Patent No. 4,696,498 to K.L. Church, issued September 29, 1987,
2 describes a tubular connection having two members, one threaded on the inside (box) and
3 one threaded on the outside (pin). Each member has a double set of steep tapered hook
4 threads, two internal pressure seals including a compressible primary metal-to-metal seal
5 and a supplementary seal made up of a resilient corrosion resistant material.
6 Additionally, the connection has a primary resilient corrosion resistant external pressure
7 seal, and a reverse shoulder engagement between the end of the pin member and a
8 shoulder on the box member to hold the primary metal sealing surfaces in sealing
9 engagement.

10 U.S. Patent No. 4,703,954, issued November 3, 1987 to Ortloff et al. describes
11 a threaded pipe connection comprising a box having tapered internal threads and a pin
12 having tapered external threads, wherein the threads are dovetail shaped in cross section
13 (wedge shaped thread) and increase in width in one direction on the box and in the other
14 direction on the pin. This design is improved over that described in U.S. Patent No.
15 3,989,284 (Re. 30,647) in that high stress concentrations are avoided in the box between
16 the first thread and the end of the box by making the length of the box between the first
17 thread and the end of the box equal to or greater than 5% of the pipe diameter and by
18 providing clearance between the crest of the first full thread on the box and the root of
19 the last thread on the pin and between the crest of the last full thread on the pin and the
20 root of the first full thread on the box.

21 U.S. Patent No. 4,703,959 to E.E. Reeves et al., issued November 3, 1987
22 discloses a threaded pipe connection with compressible seal ring. The connection
23 comprises a pin member threaded on the outside and a box member threaded on the
24 inside. The members have threading which is tapered, with generally dovetail-shaped
25 threads that increase in width in one direction on the pin and in the opposite direction on
26 the box so that the pin and box threads engage to form thread seals between the flanks
27 of the threads and between the roots and crests of the threads. The improvement is said
28 to comprise an annular groove intermediate the ends of the threads on one of the box and
29 pin to form a cavity between the groove and the threads on the other of the box and pin
30 and a ring-shaped seal member of compressible material located in the annular groove.

31 U.S. Patent No. 4,753,460, issued June 28, 1988 to Lawrence Y. Tung, discloses
32 a tubular connection having a small diameter thread set and a large diameter thread set,



1 the small thread set having a lesser number of threads than the large set. A primary
2 torque shoulder is located between the thread sets and a secondary torque shoulder is
3 located behind the large thread set. In the preferred embodiment, the initial partial thread
4 on the pin of both sets and the last partial thread of the small set on the box has a
5 cylindrical root contour (the root contour is constructed on a line parallel with the
6 longitudinal axis of the pipe), whereas the remainder of threads exhibit a tapered root
7 contour. The longitudinal taper angle of the pin thread sets are dissimilar to the box
8 thread sets, there being a maximum separation of the sets near the center of the
9 connection. At the center, a seal is provided; the last threads adjacent to the center
10 shoulder on the threaded sets are hooked (the angle of the pin load flank is negative with
11 respect to the pipe longitudinal axis). In all embodiments described, the threads exhibit
12 a negative load flank and a positive stab flank. The center shoulder area of the pin
13 exhibits two flanks, one of which is positive (near the small diameter step of threads) and
14 one of which is negative (near the center of the shoulder and about midway between the
15 two steps of threads).

16 U.S. Patent No. 4,822,081 to T.L. Blose, issued April 18, 1989, describes a
17 driveable two-member tubular connection, and in particular a thread form for the
18 connection. The thread form utilizes converging, trapped thread flanks and mating
19 shoulders and end faces with dissimilar angles. A two step thread design is illustrated,
20 wherein variable width "trapped" threads are present on each step of threads. The thread
21 crests and roots are described as making contact before the thread flanks are touching.
22 This Blose et al. invention is concerned with the benefit of the thread stab flanks in
23 assisting the shoulders/end faces in resisting axial compressive loading and with the
24 different angles between mating shoulders and end faces to reduce deformation of the
25 shoulders upon axial compressive loading.

26 U.S. Patent No. 4,893,844 to K.D. Chelette et al., issued January 16, 1990,
27 discloses a tubular connection with ventable seal. A deforming seal member is disposed
28 between two surfaces such that a space is provided to at least one side of the sealing
29 member. The connection comprises box and pin members having hooked threads, a stop
30 shoulder between the two members and various seal means.

31 U.S. Patent No. 4,917,409, issued April 17, 1990 to Doyle E. Reeves describes
32 a threaded connection employing a tapered, wedge shaped thread. The threads increase



1 in width in one direction on the box and in the other direction on the pin. The
2 improvement over the prior art appears to be in the ability of the thread design to be used
3 with pipe thread lubricants; to accommodate such lubricants, the thread is designed to
4 eliminate the radial clearance between the thread roots and crests so that the possibility
5 of creating an expansible chamber upon connection make-up that can entrap the liquid or
6 paste-like thread lubricant therein, to produce a false torque reading is greatly minimized,
7 if not entirely reduced. The wedge-shaped thread can be a dove-tail or semi-dovetail
8 thread profile. A variable width thread construction (wherein thread width increases
9 progressively in a given direction) is used in combination with the dovetail or semi-
10 dovetail thread profile (as in the Blose patent 3,989,284). The specification and original
11 claims of Reeves discloses that the load and stab flanks of the thread fully engage "at
12 substantially the same time upon rotational make-up of the threaded connection" Col. 4,
13 lines 43-48. Although only continuation applications were filed during prosecution (no
14 continuation-in-part applications which would permit the introduction of new matter), the
15 claims were amended in a subsequent continuation application to contain the limitation
16 that the thread flanks did not fully engage at substantially the same time.

17 Another concept disclosed and dependently claimed in Reeves is that it is desirable
18 to increase the thread width at the widest portion in the range of approximately four times
19 the thread width at the narrowest portion at the same thread location. There is no
20 discussion as to why this provides an advantage over prior art (which is said to show less
21 of an increase in thread width).

22 U.S. Patent No. 4, 944, 538 to S.R. Read, issued July 31, 1990, describes a
23 threaded pipe joint having improved seal ring entrapment.

24 U.S. Patent No. 4,958,862 to C. Capelli et al., issued September 25, 1990,
25 discloses a tubular connection comprising a pin member having at least one external
26 tapered thread and a box member with complementary internal threads. An end part of
27 the pin member beyond each thread has a conical seal surface and the box member has
28 a conical seal surface with the same taper as that of the pin member, so that upon
29 tightening of the joint a seal is created between pin and box at the forward end region of
30 the pin member.

31 U. S. Patent No. 5,029,906 to K.D. Chelette et al., issued July 9, 1991, pertains
32 to a deformable sealing member used to provide a pressure vent for mating tubular

1 members. A typical threaded coupling comprises pin and box members each having a
2 stepped thread design of hooked configuration on at least one side of a stop shoulder.

3 U.K. Patent Specification 137,777 of W. Pickard, published in 1920, shows a
4 variety of thread designs which can be used to connect two or more parts or objects
5 laterally or which, on entering a material, will become anchored therein and resist
6 separation in all directions at right angles to the longitudinal axis of the connection. Fig.
7 8 of the disclosure shows a single hook thread profile. Fig. 10 shows a double hook
8 thread profile.

9 U.K. Patent Application of K. Maruyama, published November 4, 1981, describes
10 a fluid tight thread joint for oil or gas well pipes. The joint comprises box and pin
11 members; the thread on the pin starts from the pin end as a rounded triangular thread and
12 becomes a buttress thread; the thread on the box member is formed in a corresponding
13 manner.

14 DEFINITIONS

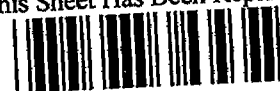
15 For convenience and accuracy of description, the following definitions have been
16 adapted for use in describing the connection of the present invention.

17 The "pin member" of a connection is understood to mean the male portion of a
18 tubular member which is threaded on its external surface to be interengaged with threads
19 on a box member to provide a connection.

20 The "box member" of the connection is understood to mean the female portion
21 of a tubular member which is threaded on its internal surface to be interengaged with
22 threads on a pin member to provide a connection.

23 A connection having a "two-step thread" is understood to mean a connection
24 having two threaded portions wherein one threaded portion has a greater radius from the
25 longitudinal axis of the pipe than the other threaded portion.

26 A "center shoulder seal" is understood to mean a section of a connection disposed
27 between at least two threaded portions, which section exhibits directly contacting surfaces
28 between the pin and box members, or between the pin and box members and a third
29 component such as an annular sealing sleeve, so that the section provides a seal for
30 preventing the passage of fluid through (across the threads of) the assembled connection.



1 A center shoulder seal configuration comprising "a locked double shoulder"
2 configuration is understood to mean a center seal design having interlocking elements,
3 a portion of which are extended from each connection member. In a lengthwise cross-
4 sectional view of the locked double shoulder connection, with the cross section cut along
5 the longitudinal axis of the connection, the locked double shoulder configuration has the
6 appearance of a reverse block S having extended tails on the S. The center bar of the
7 reverse S, which extends lengthwise in the general direction of the connection
8 longitudinal centerline, can be parallel to such centerline or can be at an angle with
9 respect to the centerline. The angle with the connection longitudinal centerline is
10 preferably less than about 45 degrees. More preferably, the angle of the center bar of
11 the reverse block S with respect to the connection longitudinal centerline is less than
12 about 25 degrees.

13 A "thread root" is understood to mean the thread location at which the wall of the
14 tubular member has been machined away to its maximum depth. The thread root defines
15 the major diameter of a box thread and the minor diameter of a pin thread.

16 A "thread crest" is understood to mean the thread location at which the wall of
17 the tubular member has been machined to its minimum depth (in some cases, none of the
18 wall will have been machined away at the crest of the thread). The thread crest defines
19 the major diameter of a pin thread and the minor diameter of a box thread.

20 A "run-out thread" is understood to mean a portion of thread having its roots
21 machined on a taper with respect to the longitudinal axis of the tubular member, but
22 having its crests machined parallel to the longitudinal axis of the tubular member;
23 gradually the construction (machining) lines of the crests and roots of the thread intersect
24 and the thread disappears. In an assembled tubular connection, a run-out thread on a pin
25 member or box member typically corresponds with a run-in thread on the corresponding
26 box member or pin member, respectively.

27 A "run-in thread" is understood to mean a portion of thread having its roots
28 machined parallel to the longitudinal axis of the tubular member, but having its crests
29 machined on a taper with respect to the longitudinal axis of the tubular member; from an
30 initial point, the construction lines of the crests and roots of the threads diverge,
31 ultimately achieving a full height thread. In an assembled tubular connection, a run-in

1 thread on a pin member or box member typically corresponds with a run-out thread on
2 the corresponding box member or pin member, respectively.

3 A "thread stab flank" is understood to mean the more forward or leading flank of
4 the thread when the pin is telescoped into the box.

5 The "thread load flank" is understood to mean the trailing flank of a thread upon
6 telescoping of the pin into the box.

7 A thread "flank angle" is understood to mean the angle formed between the thread
8 flank and a line constructed at the root of the thread flank, which line is perpendicular
9 to the longitudinal axis of the connection (tubular). For ease in understanding, flank
10 angles are defined in geometric terminology. For example, for a connection member
11 cross-sectional drawing showing the connection member with its leading, threaded end
12 toward the right hand side and its trailing threaded end (typically followed by extended
13 tubular) toward the left hand side, a positive flank angle is one wherein rotation of the
14 perpendicular line toward the thread flank is in a clockwise direction, and a negative
15 flank angle is one wherein rotation of the perpendicular line toward the thread flank is
16 in a counter-clockwise direction. In the connection drawings illustrated throughout this
17 application the connection pin member is shown at the bottom of the drawings with its
18 leading edge on the right hand side while the connection box member is shown at the top
19 of the drawing with its leading edge on the left hand side. Thus, the box member
20 drawing can be reoriented to have its leading edge on the right hand side for purposes of
21 viewing the direction of rotation of the line constructed perpendicular to the connection
22 longitudinal axis at the root of the thread flank. As described previously, the stab flank
23 of the thread of each connection member is the thread flank which is leading or most
24 forward as the connection members are telescoped together.

25 A "corresponding connection member portion" is understood to mean the portion
26 of a connection member in contact with the member being discussed, upon assembly of
27 the connection. For example, when a portion of the pin member of the connection is
28 discussed, its corresponding connection member portion is the portion of the box member
29 which will be in contact with that portion of the pin member upon assembly of the
30 connection.

31 "Complementary engagement" is understood to mean the interengagement of
32 corresponding members wherein both corresponding members are threaded in sections

1 having essentially equal thread section length on each member, and wherein the entire
2 height of thread on at least one member per threaded section is completely encompassed
3 within the thread height of the other corresponding member threaded section.

4 A "lead-in thread" is understood to mean a starting portion of full-height or nearly
5 full height threads which are machined on a taper to the longitudinal axis of the tubular
6 member and beginning adjacent to the center shoulder seal configuration.. In an
7 assembled tubular connection, a lead-in thread on a pin member or box member
8 corresponds with a run-out thread on the corresponding box member or pin member,
9 respectively.

10 SUMMARY OF THE INVENTION

11 In accordance with the present invention, a tubular connection comprising at least
12 two connection members and a center shoulder seal has been developed in a manner
13 which provides stabilization of the center shoulder seal and improved efficiency (strength
14 of connection/strength of tubular) of the connection.

15 Also in accordance with the present invention, a center shoulder seal design which
16 provides multiple metal-to-metal sealing surfaces is described. This seal design
17 comprises a locked double shoulder configuration.

18 In addition, the invention pertains to a thread profile which provides a self-
19 centering function during make-up (assembly) of the connection.

20 Although the present invention can be applied to connections comprising tubulars
21 and couplings, the most frequent use of the invention will be in the form of a tubular
22 connection comprising two connection members, and thus the invention is described in
23 this form below.

24 With reference to a tubular connection comprising two connection members,
25 namely a pin member and a box member, the stabilization of the center shoulder seal is
26 achieved using at least one run-out section of thread adjacent to the center shoulder
27 configuration of each connection member. Typically, the at least one run-out section of
28 thread is located adjacent the center shoulder configuration on that portion of the
29 connection member at which the wall thickness is less. The run-out section of thread is
30 typically used in combination with a run-in section of thread on the corresponding



1 connection member. However, a run-out section of thread can be used in combination
2 with a full height lead-in thread on the corresponding connection member.

3 Preferably, a run-out section of thread and a run-in section of thread are used
4 together on the same connection member, with the center shoulder configuration located
5 between the two sections of thread. The corresponding connection member will also
6 comprise the corresponding sections of run-in and run-out threads, respectively, so there
7 is one set of run-in and run-out threads adjacent the center shoulder seal. Even more
8 preferably, in addition to the connection having one set of run-out and run-in thread
9 sections adjacent to the center shoulder seal, the connection has a second set of run-out
10 and run-in threads adjacent to the terminal ends of the connection. Such a double set of
11 run-in, run-out thread sections stabilizes the center shoulder seal and the entire
12 connection. The double set of run-in, run-out sections of threads also provides the most
13 efficient connection.

14 When a connection member exhibits a single run-out thread adjacent to one side
15 of the center shoulder configuration and a full height lead-in thread adjacent to the other
16 side of the center shoulder configuration (with corresponding thread sections on the other
17 connection member), a relief groove may be disposed between the center shoulder
18 configuration and the full height thread. The relief groove permits proper
19 interengagement of the threads upon assembly of the connection and facilitates machining
20 of the full height lead-in thread. When a single set of run-out, run-in threads is used,
21 with the center shoulder seal located between them, or when a double set of run-out, run-
22 in threads is used, it is typically not necessary to use such a relief groove.

23 The most preferred center shoulder seal design is a "locked double shoulder" seal
24 which provides an interlocking design, wherein a longitudinal cross section of the
25 assembled pin and box contacting surfaces (in the center shoulder area) exhibits a reverse
26 block S shape having extended tails on the S. Typically the assembled locked double
27 shoulder configuration cross-section is two to three times as "high" in the radial direction
28 (perpendicular to the tubular longitudinal axis) as it is "wide" in the axial direction
29 (parallel to the connection longitudinal axis). In addition, the height is typically 1/4 to
30 1/3 of the pipe body wall thickness. The center bar of the reverse "S", which extends
31 lengthwise in the general direction of the connection longitudinal centerline, can be
32 parallel to such centerline or can be at an angle with the centerline. The angle with the



1 connection longitudinal centerline is preferably less than about 45 degrees, more
2 preferably less than about 25 degrees, and typically less than about 15 degrees. This seal
3 design provides up to 3 metal on metal sealing surfaces and up to three (3) zero
4 clearance, close tolerance sealing surfaces which can be plugged with thread compound,
5 on normal assembly.

6 Although the locked double shoulder center seal is preferred, other center shoulder
7 designs which are known in the art can also be stabilized using the run-out, run-in thread
8 constructions described above adjacent to the center shoulder. Examples of other
9 shoulder designs which can be stabilized include, not by way of limitation, square
10 shoulder; hook shoulders (wherein the shoulder exhibits at least one negative angle
11 relative to the connection longitudinal axis; square shoulders with a frustrum seal; annular
12 shoulders (shoulder on a taper with the connection longitudinal axis); shoulders
13 comprising grooves or an annulus having an axial undercut which employ a sealing
14 sleeve, ring or annulus; and shoulders designed to extrude a portion of their mass
15 laterally into adjacent grooves upon assembly of the connection. The profile of
16 the individual thread which can be used to make up the run-out, run-in thread sections
17 is preferably selected from the group comprising double hook thread and single hook
18 thread; although other thread profiles standard in the industry can be used.

19 The double hook thread profile is preferred in terms of mechanical performance.
20 The double hook thread exhibits a negative load flank angle and a positive stab flank
21 angle. A double hook thread profile in which the absolute sum of the load and stab flank
22 angles (independent of the sign of the load and stab flank angles) totals less than about
23 20 degrees will function well in the present invention. Preferably, the negative load flank
24 angle does not exceed about 8 degrees and the positive stab flank angle does not exceed
25 about 5 degrees. More preferably, the negative load flank angle ranges from about zero
26 degrees to less than 5 degrees and the positive stab flank angle ranges from about zero
27 degrees to less than 2 degrees, with the absolute sum of the angles being less than 5
28 degrees.

29 The single hook thread comprises a negative load flank angle ranging from about
30 zero degrees to about 15 degrees and a stab flank angle ranging from zero degrees to a
31 negative angle of about 35 degrees. Preferably the negative load flank angle is less than
32 8 degrees and the negative stab flank angle is less than 20 degrees. More preferably, the



1 negative load flank angle ranges from about zero degrees to less than about 8 degrees,
2 while the stab flank angle ranges from about zero degrees to a positive angle of less than
3 about 8 degrees. Most preferably, the negative load flank angle ranges from about zero
4 degrees to less than about 8 degrees, while the stab flank angle ranges from zero degrees
5 to a positive angle of less than 5 degrees.

6 The double hook and single hook thread profiles described above are preferably
7 used in combination with a variable width thread, wherein the thread on each member
8 changes progressively in axial width, with the thread width of the pin member
9 progressively increasing from the leading or forward end toward the following or trailing
10 end of each step of threads, and the thread width of the box member increasing in the
11 opposite direction.

12 The make-up of the connection having single hook or double hook threads is
13 greatly improved by providing a chamfer on the stab flank of the thread profile. This
14 chamfer provides a self-centering function during telescoping of the pin member into the
15 box member. In addition, the chamfer provides increased surface contact area between
16 the members at the time of telescoping, reducing the overall load at any particular contact
17 point and reducing damage to the connection on make-up. The axial distance of travel
18 or width of the chamfer is preferably about 0.005 inches or less, with the degree of the
19 chamfer being a function of the thread pitch and taper. The degree of chamfer is such
20 that the radial height of the chamfer (perpendicular to the connection longitudinal axis)
21 is approximately equal to the step height between the chamfered stab flank and the
22 preceding load flank. The height of the stab flank minus the height of the preceding
23 thread load flank is typically called the step height.

24 BRIEF DESCRIPTION OF THE DRAWINGS

25 Figure 1A shows a schematic of a longitudinal cross-sectional view of one
26 embodiment of the assembled connection of the present invention, wherein the connection
27 comprises a locked double shoulder center-shoulder seal, a single run-out thread section
28 on the pin member adjacent one side of the center shoulder seal and a full height lead-in



1 thread section on the pin member adjacent the other side of the center shoulder seal, with
2 corresponding thread configurations on the box member.

3 Figure 1B shows a schematic of a longitudinal cross-sectional view of the pin
4 member shown in Figure 1A.

5 Figure 1C shows a schematic of a longitudinal cross-sectional view of the box
6 member shown in Figure 1A.

7 Figure 2A shows a schematic of a longitudinal cross-sectional view of a second
8 embodiment of the assembled connection of the present invention wherein the connection
9 comprises a locked double shoulder configuration forming the center-shoulder seal and
10 a set of run-out and run-in thread sections on each side of the center shoulder seal.

11 Figure 2B shows a schematic of a longitudinal cross-sectional view of the pin
12 member shown in Figure 2A.

13 Figure 2C shows a schematic of a longitudinal cross-sectional view of the box
14 member shown in Figure 2A.

15 Figure 3A shows a schematic of a longitudinal cross-sectional view of a third
16 embodiment of the assembled connection of the present invention, wherein the connection
17 comprises a locked double shoulder center-shoulder seal and a double set of run-out and
18 run-in thread sections, with one set being adjacent to the center-shoulder seal and the
19 other set being disposed at the terminal ends of the pin and box members.

20 Figure 3B shows a schematic of a longitudinal cross-sectional view of the pin
21 member shown in Figure 3A.

22 Figure 3C shows a schematic of a longitudinal cross-sectional view of the box
23 member shown in Figure 3A.



1 **Figure 4A** shows a schematic of a longitudinal cross-sectional view of a fourth
2 and most preferred embodiment of the assembled connection, wherein the connection
3 comprises a locked double shoulder center-shoulder seal, a double set of run-out and run-
4 in thread sections, and the preferred thread profile (a single hook, variable-width thread
5 having chamfered stab flanks).

6 **Figure 4B** shows a schematic of a longitudinal cross-sectional view of the pin
7 member shown in **Figure 4A**.

8 **Figure 4C** shows a schematic of a longitudinal cross-sectional view of the box
9 member shown in **Figure 4A**.

10 **Figure 5A** shows a schematic of an enlarged view of the longitudinal cross-section
11 of one embodiment of the locked double shoulder center-shoulder seal, in the form of the
12 assembled connection shown in **Figure 1A**.

13 **Figure 5B** shows a schematic of a longitudinal cross-sectional view of the pin
14 member of **Figure 5A**.

15 **Figure 5C** shows a schematic of a longitudinal cross-sectional view of the box
16 member shown in **Figure 5A**.

17 **Figure 6A** shows a schematic of a longitudinal cross-sectional view of a portion
18 of a section of double hook thread profile of the present invention having a negative load
19 flank angle and a positive stab flank angle.

20 **Figure 6B** shows a schematic of a longitudinal cross-sectional view of a single
21 hook thread profile of the present invention having a negative load flank angle and zero
22 degree (right angle) stab flank.



1 **Figure 6C** shows a schematic of a longitudinal cross-sectional view of a
2 conventional single hook thread profile of the present invention having a negative load
3 flank angle and a negative stab flank angle.

4 **Figure 6D** shows a schematic of a longitudinal cross-sectional view of a preferred
5 double hook thread profile of the present invention having a negative load flank angle and
6 a stab flank angle which is slightly positive, approaching zero degrees.

7 **Figure 7** shows a schematic of a longitudinal cross-sectional view of a preferred
8 single hook thread profile of the present invention having a negative load flank angle, a
9 zero degree (right angle) stab flank and a chamfered stab flank. Most preferably this
10 thread profile would be a variable width thread, wherein the thread on each member
11 changes progressively in axial width.

12 **Figure 8A** shows a schematic of a longitudinal cross-sectional view of the
13 assembled connection of Figure 2, but with the thread having the double hook thread
14 profile shown in Figure 5A, and having different leads in the load and stab flanks,
15 thereby producing a variable thread crest/root width on each thread.

16 **Figure 8B** shows a schematic of a longitudinal cross-sectional view of a portion
17 of the double hook threaded profile of the pin and box members shown in Figure 8A.

18 **Figure 9A** shows a schematic of a longitudinal cross-sectional view of the
19 assembled connection of Figure 3, but with the thread having the single hook thread
20 profile.

21 **Figure 9B-9D** show a schematic of a longitudinal cross-sectional area of a portion
22 of the single hook thread profile of the pin and box members shown in Figure 9A.



1 Figure 10A shows a schematic of an enlarged view of the longitudinal cross-
2 section of the more preferred embodiment of the locked double shoulder center-shoulder
3 seal as used in the assembled connection shown in FIG. 4A.

4 Figure 10B shows a schematic of a longitudinal cross-sectional view of the pin
5 member of Figure 10A.

6 Figure 10C shows a schematic of a longitudinal cross-sectional view of the box
7 member of Figure 10A.

8 DESCRIPTION OF THE PREFERRED EMBODIMENTS

9 The tubular connection of the present invention is applicable broadly for use in
10 joining pipes, couplings and the like, but will be described in terms of oil industry tubular
11 connections, since this is one of the highest value uses for the invention. In particular
12 the invention is most typically used in flush joint or slim line tubular connections, where
13 it is desired to minimize any variation in the outside and inside diameter dimensions
14 between the connections and the assembled tubular members. The two major uses for
15 the connection of the present invention are as a flush joint liner, typically having a flush
16 outside diameter, and a liner tie-back, typically a formed connection having a maximum
17 of +3.5% variation in outside diameter.

18 The tubular connection of the present invention utilizes a center seal (between at
19 least two threaded sections of connection) to prevent fluids (liquids or gases) from passing
20 through (across the threads of) the connection. The preferred embodiments of the
21 invention will be described as having a locked double shoulder center shoulder seal,
22 which will be described in detail subsequently. However, other center seal designs such
23 as, for example, square shoulder, hook shoulder, square shoulder with frustrum seal, and
24 annular shoulder can be used in the stabilized center-shoulder-sealed tubular connection
25 of the present invention.

26 In accordance with the present invention, the center shoulder seal is stabilized so
27 that it can withstand various forces placed on the assembled length of tubulars without
28 significant damage to and/or leakage through the seal. The stabilization is provided by

1 using various combinations of thread sections adjacent to the center shoulder seal. In
2 particular, stabilization of the center shoulder seal is achieved using at least one run-out
3 section of thread adjacent to the center shoulder seal configuration of each connection
4 member. The run-out section of thread on one connection member is typically used in
5 combination with a run-in section of thread on the corresponding connection member.
6 However, a run-out section of thread on one connection member can be used in
7 combination with a full height lead-in thread on the corresponding connection member.

8 Figures 1 through 4 illustrate four different preferred embodiments of the
9 connection of the present invention. Each of the four preferred connections illustrated
10 in Figures 1-4, have certain common features which will now be described with respect
11 to embodiment one of Figure 1. Referring now to Figures 1A, 1B and 1C, the pipe joint
12 or threaded connection of the present invention, generally designated 100 in Figure 1A,
13 includes a pin member 102 formed on the end of tubular member 103 and a box member
14 106 formed on the end of another tubular member 107. Either one or both of the tubular
15 members 103, 107 define a longitudinal axis 14 (see Figures 8A or 9A) which is the
16 longitudinal centerline of the connection 100. The box member 106 has an internal
17 thread structure formed therein and is adapted to interengage a complementary external
18 thread structure formed on pin member 102, for mechanically connecting tubular
19 members 103 and 107 which form a part of a string of tubular pipe (not shown).
20 Connection 100 further includes a center shoulder seal 104 located at approximately the
21 longitudinal mid-point of connection 100. The external thread structure of the pin
22 member 102 extends from its pin nose or leading terminal end 105 to a location 109
23 adjacent first center shoulder configuration 119 and then continues on the other side 111
24 of first center shoulder configuration 119 to the end of the external threads at the trailing
25 terminal end 113 of connection 100. The complementary internal thread structure of the
26 box member 106 extends from the box leading terminal end 115 to a location 117
27 adjacent second center shoulder configuration 108 and then continues at the other side
28 121 of second center shoulder configuration 108 to the end of the internal threads at
29 trailing terminal end 123 of connection 100.

30 The center shoulder seal shown on connection 100 at 104, disposed between
31 matched sets of connection threaded sections, prevents fluids (liquids or gases) from
32 passing through (across the threads of) the connection. The preferred embodiments of

1 the invention will be described as having a locked double shoulder center-shoulder seal,
2 which will be described in detail subsequently. However, other center seal designs such
3 as, for example, square shoulder, hook shoulder, square shoulder with frustrum seal, and
4 annular shoulder can be used in the stabilized center-shoulder-sealed tubular connection
5 of the present invention.

6 Referring again to Figure 1, which illustrates embodiment one of the present
7 invention, tubular connection 100, the center shoulder seal 104 is a locked double
8 shoulder made up from a first center shoulder configuration 119 on pin member 102 and
9 a second center shoulder configuration 108 on box member 106. The center-shoulder-
10 seal-stabilizing thread sections (run-out thread sections) on each connection member are
11 located on pin member 102 at 110 and on box member 106 at 114. With reference to
12 pin member 102, run-out thread section 110, adjacent shoulder seal configuration 119,
13 extends from position 109 adjacent seal configuration 119 to intersect full height tapered
14 thread section 126 which extends to pin 102 leading terminal end 105. With reference
15 to box member 106, run out thread section 114, adjacent shoulder seal configuration 108,
16 extends from position 117 adjacent seal configuration 108 to intersect full height tapered
17 thread section 128 which extends to box 106 leading terminal end 115. The
18 complementary thread section which interengages run-out thread section 110 on pin
19 member 102 is full height lead-in thread section 112 on box member 106. The
20 complementary thread section which interengages run-out thread section 114 on box
21 member 106 is full height lead-in thread section 116 on pin member 102. The full height
22 lead-in thread sections 112 and 116 on box member 106 and pin member 102,
23 respectively extend as full height thread sections 124 and 122, respectively,, providing
24 full height tapered threads to the end of these threaded sections at 123 and 113,
25 respectively. The taper on threaded sections extending from leading terminal ends 105
26 and 115 of pin 102 and box 106, respectively, is slightly greater than the taper on
27 threaded sections 112-124 and 116-122, which extend toward the trailing terminal ends
28 123 and 113 of box 106 and pin 102, respectively.

29 Upon assembly of connection 100, run-out thread section 110 of pin member 102
30 is interengaged with full height lead-in thread section 112 of box member 106 and full
31 height thread section 126 of pin member 102 is interengaged with the full height thread
32 section 124 of box member 106. Upon assembly of connection 100, run-out thread



1 section 114 of box member 106 is interengaged with full height lead-in thread section 116
2 of pin member 102 and full height thread sections 128 of box member 106 interengage
3 with full height thread section 122 of pin member 102.

4 Pin member 102 comprises a thread relief groove 118 between full height lead-in
5 thread section 116 and first center-shoulder configuration 119. Corresponding box
6 member 106 comprises a thread relief groove 120 between full lead-in thread section 112
7 and second center-shoulder configuration 108. The thread relief groove facilitates
8 machining the full height lead-in threads 116, 122 on pin member 102 and 112, 124 on
9 box member 106, and enables complete complementary engagement of any corresponding
10 thread profile. Relief grooves 118, 120 also provide a depository for thread compound
11 and ensure that there is no hydraulic lockup of the thread.

12 Helical full height thread sections 112-124 and 116-122 are machined on a
13 constant taper relative to the longitudinal axis of connection 100. Helical full height
14 thread sections 126 and 128 are also machined on a constant taper relative to longitudinal
15 axis 14 of connection 100. However, the taper of these latter thread sections is greater
16 than the taper of their corresponding member thread sections 112-124 and 116-122,
17 respectively, to provide reduced stress at the terminal ends of connection 100 upon
18 assembly. Thread sections 110 and 114 are run-out thread sections which are machined
19 having thread crest construction lines parallel to longitudinal axis 14 of connection 100
20 and having thread root construction lines machined on the constant taper with respect to
21 the longitudinal axis. However, individual crest surfaces and individual root surfaces
22 typically are machined parallel to the connection longitudinal axis. It is possible to leave
23 individual run-in truncated thread crests on a taper, but preferred to machine them to be
24 parallel to the connection longitudinal axis.

25 Upon assembly, the interengaged connection 100 exhibits complete complementary
26 engagement of run-out thread sections 110 and 114, each located on that side of center-
27 shoulder seal 104 at which each connection member wall thickness is less, namely thin
28 wall sections 130, 132, respectively. In addition, a slight interference fit is provided in
29 the threads to assure maximized interengagement of the threads. In an interference fit,
30 at corresponding engagement points on the pin and box members 102 and 106, the pin
31 member 102 is machined slightly larger than the box member 106. Interference fit
32 tapered threads are well established in the art. Complete complementary engagement of



1 the run-out thread section provides a more efficient connection by completely using the
2 available thread flank bearing surfaces, while simultaneously providing limitation of the
3 stresses generated at the thin wall sections 130 on pin member 102 and 132 on box
4 member 106. In addition, the run out thread sections at these locations on the pin and
5 box members permit maintenance of maximum connection wall thickness in the areas,
6 adjacent center shoulder 104, thereby providing a more efficient connection.

7 For purposes of illustration, embodiment one of the invention has been shown in
8 Figure 1 with a single hook thread profile having a negative load flank angle and a
9 negative stab flank angle; the crests and roots of individual, threads are parallel to the
10 connection longitudinal axis. Thread profiles other than a single hook can be used as
11 well, as hereinafter described.

12 For purposes of comparison with the prior art, embodiment one of the present
13 invention, in the structure of a +3 percent over pipe body diameter, formed-box slim line
14 connection, exhibits an efficiency (strength of connection (joint)/strength of pipe) of about
15 85%, compared with the best known +3 percent formed box connection in the industry,
16 which exhibits an efficiency of only about 75%. When the structure is a flush-joint
17 connection, embodiment one of the present invention provides an efficiency of about 75%
18 compared with the best known-in-the industry flush-joint connection efficiency of 65%.

19 Referring now to Figure 2A, which illustrates embodiment two of the present
20 invention connection, tubular connection 200 is made up from pin member 202 machined
21 on the exterior end of tubular 203 and from box member 206 machined on the interior
22 end of tubular 207. The center shoulder seal 204 of tubular connection 200 is a locked
23 double shoulder configuration, formed from a first center shoulder configuration 219 on
24 pin member 202 and from second center shoulder configuration 208 on box member 206.

25 Figure 2B, which shows pin member 202, comprises run-out thread section 210
26 which extends from a location 209 adjacent first center shoulder configuration 219 on the
27 thin-walled portion 230 of pin member 202 to thread section 226 of full height tapered
28 thread which extends to leading end 205 of pin member 202. Pin member 202 also
29 comprises run-in thread section 216 which extends from a location 211 adjacent first
30 center shoulder configuration 219 on the thick-walled portion of pin member 202 to



1 thread section 212 of full height tapered thread which extends to trailing end 213 of pin
2 member 202.

3 Figure 2C, which shows box member 206, comprises run-out thread section 214
4 which extends from a location 217 adjacent second center shoulder configuration 208 on
5 the thin-walled portion 232 of box member 206 to thread section 228 of full height
6 tapered thread which extends to leading end 215 of box member 206. Box member 206
7 also comprises run-in thread section 222 which extends from a location 221 adjacent
8 second center shoulder configuration 208 on the thick-walled portion of box member 206
9 to thread section 224 of full height tapered thread which extends to trailing end 223 of
10 box member 206.

11 Upon assembly of connection 200, run-out thread section 210 of pin member 202
12 interengages run-in thread section 222 of box member 206 and full height threads 226 of
13 pin member 202 interengage full height threads 224 of box member 206. In addition,
14 run-out thread section 214 of box member 206 interengages run-in thread section 216 of
15 pin member 202 and full height thread section 228 of box member 206 interengages full
16 height thread section 212 of pin member 202.

17 Helical full height thread sections 212 and 226 on pin member 202 and full height
18 thread sections 224 and 228 on box member 206 are machined on a constant taper with
19 respect to the longitudinal axis of connection 200, but having the individual surfaces of
20 their roots and crests parallel to the longitudinal axis of connection 200. Run-out thread
21 section 210 on pin member 202 has its minor diameter (roots) machined on a continuation
22 of the constant taper of the minor diameter of adjacent full height thread section 226,
23 while its major diameter (crests) is machined parallel to the connection 200 longitudinal
24 axis. Run-in thread section 216 on pin member 202 has its minor diameter (roots)
25 machined parallel to the connection 200 longitudinal axis, while its major diameter
26 (crests) is machined as a continuation of the constant taper of the major diameter of
27 adjacent full height thread section 212. Corresponding run-out and run-in thread sections
28 of box member 206 are constructed in like manner, with the roots forming the major
29 diameter and the crests forming the minor diameter.

30 Although sequential thread crests and roots are machined as described above,
31 individual crest and root surfaces are typically machined parallel to the longitudinal axis
32 of the connection. The exception to this is run-in thread sections, wherein the individual



1 crest surfaces can be machined as a continuation of the constant taper of the major
2 diameter of adjacent full height threads or can be machined parallel to the connection
3 longitudinal axis. Individual crest surfaces machined parallel to the connection
4 longitudinal axis are preferred. As with connection 100 shown in Figure 1, the tapers
5 of full height threaded sections 226 of pin 202 and 228 of box 206 are greater than the
6 tapers of corresponding full height thread sections 224 of box 206 and 212 of pin 202,
7 respectively.

8 Also, for purposes of illustration, embodiment two of the invention has been
9 shown in Figure 2 with a single hook thread profile having a negative load flank angle
10 and a zero degree stab flank angle; however, other thread profiles can be used as well
11 as hereinafter described.

12 In embodiment two, wherein a set of run-out, run-in thread sections is used
13 adjacent each side of the center-shoulder seal 204, there is minimal unused (nonengaged)
14 thread surface in the assembled thread sections. The connection 200 exhibits complete
15 complementary engagement of the corresponding run-out and run-in thread section pairs,
16 making these tapered threads highly efficient and providing even greater stabilization of
17 the center-shoulder seal 204 than that provided in embodiment one shown in Figure 1.

18 For comparison purposes with the prior art, embodiment two of the present
19 invention shows approximately the same improvement in efficiency over the known prior
20 art as that exhibited by embodiment one shown in Figure 1.

21 Referring now to Figure 3A, which illustrates embodiment three of the present
22 invention connection, tubular connection 300 is made up from pin member 302 machined
23 on the exterior end of tubular 303 and from box member 306 machined on the interior
24 end of tubular 307. The center shoulder seal 304 of tubular connection 300 is a locked
25 double shoulder configuration, formed from first center shoulder configuration 319 on
26 pin member 302 and from second center shoulder configuration 308 on box member 306.

27 Figure 3B, which shows pin member 302 comprises run-out thread section 310
28 which extends from a location 309 adjacent first center shoulder configuration 319 on the
29 thin-walled portion 330 of pin member 302 to thread section 326 of full height tapered
30 thread, which extends to run-in thread section 334 which extends to leading end 305 of
31 pin member 302. Pin member 302 also comprises run-in thread section 316 which
32 extends from a location 311 adjacent first center shoulder configuration 319 on the thick-



1 walled portion of pin member 302 to thread section 312 of full height tapered thread,
2 which extends to run-out thread section 336 which extends to trailing end 313 of pin
3 member 302.

4 Figure 3C, which shows box member 306, comprises run-out thread section 314
5 which extends from a location 317 adjacent second center shoulder configuration 308 on
6 the thin-walled portion 332 of box member 306 to thread section 328 of full height
7 tapered threads, which extends to run-in thread section 338 which extends to leading end
8 315 of box member 306. Box member 306 also comprises run-in thread section 322
9 which extends from a location 321 adjacent second center shoulder configuration 308 on
10 the thick-walled portion of box member 306 to thread section 324 of full height tapered
11 thread, which extends to run-out thread section 340 which extends to trailing end 323 of
12 box member 306.

13 Upon assembly of connection 300, run-out thread section 310 of pin member 302,
14 interengages run-in thread section 322 of box member 301, full height thread section 326
15 of pin member 302 interengages full height thread section 324 of box member 306, and
16 run-in thread section 334 of pin member 302 interengages run-out thread section 340 of
17 box member 306. In addition, run-out thread section 314 of box member 306
18 interengages run-in thread section 316 of pin member 302, full height thread section 328
19 of box member 306 interengages full height thread section 312 of pin member 302, and
20 run-in thread section 338 of box member 306 interengages run-out thread section 336 of
21 pin member 302.

22 Helical full height thread sections 312 and 326 on pin member 302 and 324 and
23 328 on box member 306 are on a constant taper with respect to the longitudinal axis of
24 connection 300, but having the individual surfaces of their roots and crests parallel to the
25 longitudinal axis of connection 300. Run-out thread sections 310 and 336 on pin member
26 302 and run-out thread sections 314 and 340 on box member 306 have their roots
27 machined on a continuation of the constant taper of the adjacent full height thread
28 sections. Run-out thread sections 310 and 336 on pin member 302 and run-out thread
29 sections 314 and 340 on box member 306 have their crests machined parallel to the
30 longitudinal axis of connection 300. Run-in thread sections 316 and 334 on pin member
31 302 and run-in thread sections 322 and 338 on box member 306 have their roots
32 machined parallel to the longitudinal axis of connection 300, while their crests are



1 machined on a continuation of the constant taper of the respective major or minor
2 diameter of the adjacent full height thread sections.

3 Embodiment three of the invention shown in Figure 3 exhibits a double hook
4 thread profile; however, other thread profiles can be used as well, as hereinafter
5 described.

6 This double set of run-out and run-in threads (one set adjacent the center-shoulder
7 seal 304 and a second set at the terminal ends of connection 300) provides maximum joint
8 efficiency and maximum stability for center-shoulder seal 304 of the connection 300.
9 The double set of run-out and run-in threads also provides the smoothest load transfer
10 between pin and box members 302, 306, respectively, thereby not only increasing the
11 connection's rated load capacity but also its overload capacity (i.e., safety factor).

12 For comparison purposes with the prior art, embodiment three of the present
13 invention, in the structure of a +3.5 percent over pipe body diameter, formed box slim
14 line connection exhibits an efficiency (strength of connection (joint)/strength of pipe) of
15 about 95%. When the structure is a 3 percent formed box connection, the efficiency
16 decreases to about 90%. The best known-in-the-industry +3 percent formed box
17 connection provides only a 75% efficiency.

18 Regarding the above-described embodiment three of the present invention, in the
19 structure of a flush outside diameter connection, the efficiency provided is about 77%.
20 The best known-in-the-industry flush connection provides only a 65% efficiency.

21 Referring now to Figure 4A, which illustrates embodiment four of the present
22 invention connection, tubular connection 400 is made up from pin member 402 machined
23 on the exterior end of tubular 403 and from box member 406 machined on the interior
24 end of tubular 407. The center shoulder seal 404 of tubular connection 400 is a locked
25 double shoulder configuration, formed from first center shoulder configuration 419 on
26 pin member 402 and from second center shoulder configuration 408 on box member 406.

27 Figure 4B, which shows pin member 402 comprises run-out thread section 410
28 which extends from a location 409 adjacent first center shoulder configuration 419 on the
29 thin-walled portion 430 of pin member 402 to thread section 426 of full height tapered
30 thread, which extends to run-in thread section 434 which extends to leading end 405 of
31 pin member 402. Pin member 402 also comprises run-in thread section 416 which
32 extends from a location 411 adjacent first center shoulder configuration 419 on the thick-



1 walled portion of pin member 402 to thread section 412 of full height tapered thread,
2 which extends to run-out thread section 436 which extends to trailing end 413 of pin
3 member 402.

4 Figure 4C, which shows box member 406, comprises run-out thread section 414
5 which extends from a location 417 adjacent second center shoulder configuration 408 on
6 the thin-walled portion 432 of box member 406 to thread section 428 of full height
7 tapered threads, which extends to run-in thread section 438 which extends to leading end
8 415 of box member 406. Box member 406 also comprises run-in thread section 422
9 which extends from a location 421 adjacent second center shoulder configuration 408 on
10 the thick-walled portion of box member 406 to thread section 424 of full height tapered
11 thread, which extends to run-out thread section 440 which extends to trailing end 423 of
12 box member 406.

13 The principal difference between this fourth embodiment of the invention and the
14 third embodiment illustrated in Fig. 3 lies in the thread profile. The thread profile of this
15 fourth embodiment is a specialized self-centering thread profile wherein the stab flank of
16 all full-height threads is chamfered, as shown in Fig. 7 and described in detail
17 subsequently with reference to Fig. 7. Thus, each stab flank of full-height thread sections
18 412 and 426 of pin member 402 and each stab flank of full-height thread sections 424 and
19 428 of box member 406 is chamfered. The chamfer width (axial distance) is preferably
20 about 0.005 inches or less and the chamfer height (perpendicular to the connection or
21 member longitudinal axis) is approximately equal to the step height (height of the stab
22 flank minus the height of the preceding thread load flank). Presence of this chamfer on
23 the stab flank of all full-height threads on both pin member 402 and box member 406
24 results in a self-centering action upon assembly of connection 400; in particular, the self-
25 centering action occurs during the initial telescoping (stabbing) of pin member 402 into
26 box member 406.

27 Upon initial assembly of connection 400, after initial telescoping, the stab flanks
28 of pin member 402 threads come to rest on the stab flanks of box member 406 with the
29 chamfered portion of the stab flanks providing the self-centering action described above.
30 Upon completion of assembly, to power tight position, run-out thread section 410 of pin
31 member 402, interengages run-in thread section 422 of box member 401, full height
32 thread section 426 of pin member 402 interengages full height thread section 424 of box



1 member 406, and run-in thread section 434 of pin member 402 interengages run-out
2 thread section 440 of box member 406. In addition, run-out thread section 414 of box
3 member 406 interengages run-in thread section 416 of pin member 402, full height thread
4 section 428 of box member 406 interengages full height thread section 412 of pin member
5 402, and run-in thread section 438 of box member 406 interengages run-out thread
6 section 436 of pin member 402. At power tight position, the load flanks, roots and crests
7 of full-height threads of each member are in sufficient contact to provide sealing
8 engagement, while the stab flanks of these threads exhibit a slight clearance (typically
9 about 0.002 inches).

10 Helical full height thread sections 412 and 426 on pin member 402 and 424 and
11 428 on box member 406 are machined on a constant taper with respect to the longitudinal
12 axis of connection 400, but having the individual surfaces of their roots and crests
13 parallel to the longitudinal axis of connection 400. Run-out thread sections 410 and 436
14 on pin member 402 and run-out thread sections 414 and 440 on box member 406 have
15 their sequential roots machined on a continuation of the constant taper of the adjacent full
16 height thread sections. Run-out thread sections 410 and 436 on pin member 402 and run-
17 out thread sections 414 and 440 on box member 406 have their sequential crests
18 machined parallel to the longitudinal axis of connection 400. The individual root and
19 crest surfaces of run-out thread sections are machined parallel to the connection
20 longitudinal axis. Run-in thread sections 416 and 434 on pin member 402 and run-in
21 thread sections 422 and 438 on box member 406 have their sequential roots machined
22 parallel to the longitudinal axis of connection 400, while their sequential crests are
23 machined on a continuation of the constant taper of the respective major or minor
24 diameter of the adjacent full height thread sections. Although the individual root surfaces
25 of these run-in thread sections are machined parallel to the connection (connection
26 member) longitudinal axis, the individual crests can be machined either on a taper or
27 parallel to the connection longitudinal axis, as previously discussed with reference to run-
28 in thread sections.

29 Embodiment four of the invention, shown in Figure 4 exhibits a thread profile
30 having a chamfered stab flank with a positive stab flank angle of less than about 2
31 degrees, with reference to a line perpendicular to the preceding individual thread root
32 (and the connection longitudinal axis). The load flank angle is a negative angle of about



3 degrees or less. In the most preferred embodiment of the invention, the stab flank angle is zero degrees and the load flank angle is a negative angle of about 3 degrees.

The efficiency of the connection illustrated in Figure 4 is essentially the same as that of the connection illustrated in Figure 3.

Figure 5A is an enlarged view of a center-shoulder seal 500 which is shown in embodiment one of Figure 1. Assembled center shoulder seal 500 is a locked double shoulder seal made up from first center shoulder configuration 510 on pin member 514 and from second center shoulder configuration 530 on box member 534. Thread relief groove 512 on pin member 514 and thread relief grooves 532 on box member 534 are made necessary by the use of full height lead-in threads 526 on pin member 514 and full height lead in threads 546 on box member 534, respectively. When full height lead-in threads are not used, for example in embodiments two, three or four (as illustrated by connections 200, 300 and 400), use of thread relief grooves is optional. The thread profile shown in Figure 5A is a preferred double hook of the kind shown in Figure 6D.

Figures 5B and 5C show first center shoulder configuration 510 of pin member 514 and second center shoulder configuration 530 of box member 534, respectively. Each connection member comprises a ramp, 516 on pin 514 and 536 on box 534. Connection pin member 514 center shoulder configuration 510 comprises shoulder 520 having first undercut surface 528, first sealing surface 518 and fourth sealing surface 522. Connection box member 534 center shoulder configuration 530 comprises shoulder 540 having second undercut surface 548, second sealing surface 542 and third sealing surface 538.

Upon assembly of center shoulder seal 500, first sealing surface 518 on shoulder 520 of pin configuration 510 is lined up by and guided into position on corresponding first ramp 536 of box center shoulder configuration 530. Simultaneously, second sealing surface 542 on shoulder 540 of box center shoulder configuration 530 is lined up by and guided into position on corresponding second ramp 516 of pin center shoulder configuration 510. As the assembly progresses, a metal-to-metal seal is created as first sealing surface 518 on shoulder 520 moves into place against third sealing surface 538 on box center shoulder configuration 530. Simultaneously, a metal-to-metal seal is created as second sealing surface 542 on shoulder 540 moves into place against fourth sealing surface 522 on pin center shoulder configuration 510. As shoulders 520 and 540

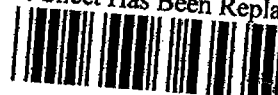


1 move into position, typically they begin to bend slightly, closing the gap between surface
2 524 on first center shoulder configuration 510 and surface 544 on second center shoulder
3 configuration 530, thereby producing a zero clearance or metal-to-metal surface seal
4 between at least a portion of surfaces 524 and 544. This latter zero clearance or metal-
5 to-metal seal will not occur if there is substantial (greater than 0.005 in.) clearance
6 between surface 524 and surface 544 prior to the above-described bending action.

7 Upon final power tightening (torquing) of the assembled connection, the leading
8 surface of shoulder 520 contacts first undercut surface 548 on box center shoulder
9 configuration 530, while the leading surface of shoulder 540 contacts second undercut
10 surface 528 on pin center shoulder configuration 510, thereby creating two additional
11 zero clearance sealing surfaces.

12 Thus, a combined total of at least two (2) and possibly three (3) metal-to-metal
13 zero clearance seals are created during assembly (make-up) of the connection: two metal-
14 to-metal seals at the exterior beveled edges of the locked double shoulder seal 500 where
15 sealing surfaces 518 and 538 are in contact and where sealing surfaces 522 and 542 are
16 in contact; and, a metal to metal sealing surface at the interior of the locked double
17 shoulder seal 500, one at the wall surface where sealing surfaces 524 and 544 contact.
18 Zero clearance seals are obtained where the face surface of pin shoulder 520 contacts box
19 undercut surface 548, and where the face surface of box shoulder 540 contacts pin
20 undercut surface 528. Thus, center-shoulder seal 500 forms multiple metal-to-metal
21 seals, having mating metal-to-metal sealing surfaces which allow a build-up of stored
22 energy within the seal upon power tightening of the assembled connection, such that upon
23 the application of various loads on the pipe and also the connection, the seal will continue
24 to perform and maintain sealing engagement. Further, several zero clearance seals are
25 provided, which combined with the metal to metal seals further prevents leakage under
26 the various conditions of loading to which the connection may be subjected.

27 Typically a thread compound will be used on the surfaces of the threaded
28 connection and this thread compound will bridge any surface defects and clearances less
29 than about 0.005 inches, to provide an improved sealing capability. Such a thread
30 compound will assist the intended metal-to-metal, zero clearance seals described above
31 should surface defects or machining tolerances result in a clearance between metal
32 surfaces of less than about 0.005 inches. A thread compound can also provide a



1 hydraulic seal between surfaces which do not exhibit zero clearance after power tight
2 make-up of the connection. For example, hydraulic seals can be provided between
3 surfaces 529 of pin 514 and 537 of box 534 as well as between surfaces 517 of pin 514
4 and 549 of box 534 using thread compound. Additional hydraulic seals can be provided
5 for each step of connection threads, since the thread surfaces which do not exhibit metal-
6 to-metal contact are close fit surfaces which can be bridged using thread compound.

7 A description of the location and dimensions of the present invention locked
8 double shoulder center seal relative to the cross-sectional area of the connection follows.
9 It is desirable to balance the cross-sectional areas of the tubular walls which make up the
10 connection in the area of the locked double shoulder seal, thus providing a more efficient
11 connection. The formula which follows permits calculation of the preferred diameter of
12 a circle formed by the radial center of the locked double shoulder seal (radial center
13 relative to the longitudinal axis of the connection). This preferred diameter is essentially
14 equal to the connection outside diameter squared plus the connection inside diameter
15 squared minus the constant k , all divided by two, with the square root being taken of the
16 result. The constant k is equal to two times the squared height of interlocked shoulders
17 520 and 540. As shown on Figure 5A, the radial center of the locked double shoulder
18 seal is located at contacting surfaces 524 and 544 of shoulder 520 and shoulder 540,
19 respectively. The height of interlocked shoulders 520 and 540 is dimension 552. The
20 minimum height 552 of interlocked shoulders 520 and 540 is a function of the wall
21 thickness of the tubular (pipe) used to form the connection. Typically the radial height
22 552 of interlocked shoulders 520 and 540 is two to three times the longitudinal width,
23 dimension 554 on Figure 5A, of shoulders 520 and 540. In addition, the height 552 of
24 the cross section of interlocking shoulders 520 and 540 is typically 1/4 to 1/3 of the
25 tubular member (pipe) wall thickness.

26 The connection of the present invention establishes a constant bearing force on the
27 various seals provided by the center-shoulder seal 500. Not only do the curving edges
28 of locked double shoulder seal 500 at 518, 538 and 522, 542 interferingly engage to form
29 a metal-to-metal seal, but upon power tightening of the connection, the facing surface of
30 shoulder 520 in contact with undercut surface 548 and the facing surface of shoulder 540
31 in contact with undercut surface 528 are loaded and the annular contact between surfaces
32 524 and 544 typically establishes a seal due to a bending reaction on the shoulders from



1 the seal 518 contacting seal 538 and seal 542 contacting seal 522 and from the Poisson's
2 effect of the metal upon final power tightening.

3 A more preferred locked double shoulder configuration than that shown in FIGS.
4 5A-5C is described subsequently with reference to FIGS. 10A-10C.

5 Other center shoulder designs which are known in the art can also be stabilized
6 using the adjacent run-out, run-in thread section constructions described above.
7 Examples of other center seal designs which can be stabilized include, not by way of
8 limitation, square shoulders; hook shoulders (wherein the shoulder exhibits at least one
9 negative angle relative to the connection longitudinal axis); square shoulders with a
10 frustrum seal; annular shoulders (shoulder on a taper with the connection longitudinal
11 axis); shoulders comprising grooves or an annulus having an axial undercut which employ
12 a sealing sleeve, ring or annulus; and shoulders designed to extrude a portion of their
13 mass laterally into adjacent grooves upon assembly of the connection.

14 Figures 6A through 6D illustrate four preferred thread profiles for use in
15 combination with the other features of connections of the present invention.

16 For convenience and accuracy of description, the following geometric conventions
17 will be used in describing the angles of the load and stab flanks of the threads of the
18 present invention. The angle α represents the stab flank angle and the angle β represents
19 the load flank angle of the threads. These angles are defined in geometric terminology
20 with reference to a line constructed perpendicular to the longitudinal axis of the
21 connection (tubular) and at the root of the thread flank. A degree of a negative flank
22 angle is the rotation, in degrees, of the perpendicular line in the counterclockwise
23 direction to meet the thread flank. A degree of positive flank angle is the rotation in
24 degrees of the perpendicular line in the clockwise direction to meet the thread flank.
25 These conventions for defining stab and load flank angles do not necessarily comport with
26 the general conventions used in machining pipe threads.

27 Figure 6A illustrates corresponding pin 610 and box 630 cross-sectional profiles
28 for a portion of full height double hook thread 600A. The double hook thread exhibits
29 a negative load flank angle β and a positive stab flank angle α . The thread profile of full
30 height threads from a portion of pin member 610 is shown as it would appear within a
31 threaded tubular section of the present invention. Stab flank 612 forms a positive stab
32 flank angle α with respect to a line perpendicular to root wall 616, which is parallel to



the connection longitudinal axis 14, and load flank 614 forms a negative load flank angle β with respect to a line perpendicular to root wall 618, which is parallel to the connection longitudinal axis.

The thread profile of full height double hook threads from a portion of box member 630 is shown as it would appear within a threaded tubular section of the present invention. For example, in a manner similar to the pin thread, stab flank 632 forms a positive angle α with respect to a line perpendicular to root wall 636, and load flank 634 forms a negative angle β with respect to a line perpendicular to root wall 636. To permit interengagement of the double hook threads of pin member 610 with the double hook threads of box member 630, it is necessary that the thread width be constantly increasing from the leading edge (edge initially telescoped into the box member) of pin member 610, and that the thread width be constantly decreasing (the root width be constantly increasing) from the corresponding edge of box member 630, as shown in Figure 6A. Thus, the thread profile crest widths 620 of pin member 610 are progressively lengthened, while the thread root widths 622 are progressively narrowed, with the reverse occurring on box member 630. One method of producing threads with such dimensions is to machine the thread stab flanks with a slightly greater (longer) lead than the load flanks. The amount of lead increase (ΔL) required to permit the threads to mesh (interengage) upon telescoping (stabbing) is a function of the thread taper (T) and the stab and load flank angles (α and β , respectively), and can be calculated according to the following formula:

$$\Delta L = 1/2 T (\tan | \alpha | + \tan | \beta |)$$

When there is more than one step of threads in the connection (for example, a two step thread wherein one section of threads is followed by a center-shoulder seal, followed by a second section of threads located at a greater axial distance from the longitudinal axis of the connection), the thread width can be constantly increasing from the leading edge of the pin member all of the way to the end of the connection; or, alternatively and preferably, the thread width is increased progressively within each step of threads, beginning with the minimum width thread at the pin leading edge step of threads and the minimum width thread beginning again at the forward edge of the second step of pin threads.

1 The preferred double hook thread, in terms of mechanical performance, exhibits
2 a positive stab flank angle and a negative load flank angle, the absolute sum of which
3 (without regard to sign on the angle) ranges from about 5 degrees to about 20 degrees.
4 Typically, the negative load flank angle does not exceed about 8 degrees and the positive
5 stab flank angle does not exceed about 4 degrees. However, in terms of ease of
6 machining and minimizing the lead adjustments, ΔL , the absolute sum of the positive stab
7 flank angle and negative load flank angle should range from slightly greater than 0
8 degrees to less than 5 degrees, with the negative load flank angle ranging from about 1
9 degree to about 4 degrees. When this reduced absolute sum of load and stab flank
10 angles is used, it is not necessary to use constantly increasing thread width to permit
11 interengagement of connection member threads. Preferably the load flank angle is a
12 larger (greater) absolute angle than the stab flank angle, since for thread profiles having
13 crests and roots which are parallel to the connection longitudinal axis, the load flank
14 length is less than the stab flank length, as can be observed in viewing load flank 614 and
15 stab flank 612. Also, when the connection is operating under the most severe service
16 conditions, the thread load flanks experience a greater applied force than the stab flanks.

17 Figure 6B illustrates corresponding pin 660 and box 670 cross-sectional profiles
18 of one embodiment of single hook thread, 600B. The thread profile of full height threads
19 from a portion of pin member 650 is shown as it would appear within the threaded
20 tubular section of the present invention. The distinguishing feature of this embodiment
21 of single hook thread is that its stab flank 652 exhibits a zero degree angle α with respect
22 to a line perpendicular to both the connection longitudinal axis and the thread root wall,
23 while its load flank 654 exhibits a negative angle β with respect to a line perpendicular
24 to both the connection longitudinal axis and the thread root wall. For example,
25 referencing the thread profile of pin member 650, stab flank 652 forms a right angle with
26 reference to the connection longitudinal axis, or zero degree angle α with respect to a line
27 perpendicular to root wall 656, while load flank 654 forms negative angle β with respect
28 to a line perpendicular to root wall 658. In a corresponding manner, referencing the
29 thread profile of box member 670, stab flank 672 forms a zero degree angle α with a line
30 perpendicular to root wall 676, while load flank 674 forms a negative angle β with a line
31 perpendicular to root wall 676.

1 The single hook thread exhibits a negative stab flank angle which ranges from
2 zero (0) degrees to about 45 degrees, and exhibits a negative load flank angle which
3 ranges from greater than 0 degrees to about 15 degrees. If the load flank angle is a large
4 negative angle, and the stab flank angle is less than the load flank angle, thereby
5 producing thread crests wider than adjacent thread roots, the use of a constantly
6 increasing thread width from the leading edge of the pin, as described above for a double
7 hook thread, may be necessary to permit proper interengagement of the pin and box
8 members of the connection upon initial telescoping (stabbing).

9 A more preferred single hook thread profile, due to ease of machining, is the
10 profile wherein the negative load flank angle ranges from greater than 0 degrees to less
11 than 5 degrees and the negative stab flank angle ranges from zero degrees to about 2
12 degrees, with the absolute sum of the angles being less than 5 degrees. When these
13 reduced negative load flank and stab flank angles are used, it is not necessary to use
14 constantly increasing thread width to permit interengagement of connection member
15 threads. The necessary clearance is provided by making the thread crests narrower than
16 the thread roots.

17 Figure 6C illustrates another thread profile embodiment 600C suitable for use in
18 the connection of the present invention. This thread profile is particularly suitable for
19 a connection having a center-shoulder seal (such as the locked double shoulder) in
20 combination with a single run-out thread and full height lead-in thread on the
21 corresponding member, on each side of the center-shoulder seal. The thread profile of
22 full height threads from a portion of the pin member 690 is another embodiment of a
23 single hook thread as it would appear within the threaded tubular section of the present
24 invention. This particular embodiment of a single hook thread features a load flank 694
25 of pin member 690 thread which exhibits a large negative angle β and a stab flank 692
26 which exhibits a large negative angle α . Generally, angle α is greater than angle β , and
27 consequently, dimensions can be formulated with flank to flank (load to stab) bearing
28 threads, having clearance between thread roots and crests, for example, with clearance
29 between root 696 of pin member 690 and crest 699 of box member 698. This is in
30 contrast with the double hook thread of Figure 6A and the single hook thread of 6B,
31 which are more suitable in a form wherein the thread roots and crests provide bearing
32 surfaces with clearances between corresponding stab and load flanks. Flank to flank



1 bearing threads of the kind shown in Figure 6C can be used to modify the interference
2 in the run-out section of threads.

3 The angles of the single hook thread profile shown in 6C typically are such that
4 the negative load flank angle ranges from about 5 degrees to about 15 degrees and the
5 negative stab flank angle ranges from about 5 degrees to about 35 degrees, with the stab
6 flank angle being larger than the load flank angle by about 10 to 15 degrees.

7 Figure 6D illustrates cross sectional profiles of a preferred double hook thread
8 600D. The preferred double hook thread exhibits a positive stab flank angle α ranging
9 from nearly a zero degree angle to an angle of less than 2 degrees, and a load flank angle
10 β which has been reduced to a small negative angle, ranging from nearly a zero degree
11 angle to an angle of less than 5 degrees, with the absolute sum of the flank angles being
12 less than 5 degrees. The thread profile of full height threads from a portion of pin
13 member 680 is shown as it would appear within a threaded tubular section of the present
14 invention. The distinguishing feature of the preferred double hook thread is that both its
15 positive angle stab flank 682 and its negative angle load flank 684 exhibit a nearly zero
16 degree angle with respect to a line perpendicular to the connection longitudinal axis and
17 the thread root wall. For example, stab flank 682 forms an angle α which ranges from
18 a right angle with reference to the connection longitudinal axis, up to a positive angle of
19 less than 2 degrees with a line perpendicular to root wall 686; and, load flank 684 forms
20 an angle β which ranges from a near right angle with reference to the connection
21 longitudinal axis, up to a negative angle of less than 5 degrees with a line perpendicular
22 to root wall 688. Corresponding box member 689 thread exhibits the same ranges of stab
23 flank angle and load flank angle ranges as those just described. It is not necessary to use
24 progressively increasing thread width to permit connection member thread
25 interengagement (proper meshing after stabbing) when a preferred double hook thread
26 profile of the kind shown in Figure 6D is used. This thread profile is essentially a
27 modified square thread.

28 The most preferred thread profile for use in the present invention is one having
29 a negative load flank angle and a zero degree or positive stab flank angle with a
30 chamfered stab flank, which provides self-centering action upon initial telescoping of
31 connection members. Typically a single hook thread profile (to which this thread profile
32 is similar) requires a variable width thread to permit proper interengagement of the



1 threads. Figures 7A-7C illustrate a thread profile having a negative load flank angle and
2 a zero degree, chamfered stab flank in combination with a variable width thread. The
3 thread profile of pin member 750 comprises a load flank 754 having a negative angle, β ,
4 and a chamfered stab flank 702 having a zero degree angle, α ; the chamfer 756 exhibits
5 a width, ω , and a chamfer degree, η , is a function of thread pitch and taper. The height
6 758 of chamfer 756 is approximately equal to or less than the height of stab flank 752
7 minus the height of the preceding load flank 754, or the "step height." The thread profile
8 of box member 770 comprises a load flank 774 having a negative angle, β , and a
9 chamfered stab flank 772 having a zero degree angle, α ; the chamfer 776 exhibits a
10 width, ω , and a chamfer degree, η , with a chamfer height which is the same as the
11 chamfer height of pin member 750. Box member 770 chamfer width, degree, and height
12 are determined in the manner described for the corresponding pin member 750, with the
13 chamfer degree being a function of thread width and taper and the resulting chamfer
14 height being approximately equal to or less than the step height. An increased chamfer
15 height provides increased self-centering action and is preferred; however, a chamfer
16 height greater than the step height provides no advantage. A chamfer width, ω , of less
17 than 0.005 inches is preferred.

18 In sizing the connection of the present invention, the location of the radial
19 centerline of the center-shoulder seal is determined with reference to the outside and
20 inside diameters of the pipe. The fade out point of the connection thread sections is
21 determined by the minimum required wall thickness at the terminal ends of the
22 connection. The length of a thread section is a function of the angle of taper of the
23 threads and the change in diameter of the thread. Since the thread sections on each side
24 of the center-shoulder seal should bear approximately one-half of the load on the
25 connection, the amount of engaged thread length may be calculated to ensure that the
26 threads do not shear off under load. Knowing these parameters, one skilled in the art can
27 then determine the thread taper.

28 Figure 8A illustrates an assembled tubular connection 800A of the present
29 invention. Connection 800A includes a set of run-out, run-in threads, set 802 and set
30 804, on each side of a center-shoulder seal 810, which is shown as a locked double
31 shoulder configuration. The thread profile shown is a double hook which is shown
32 enlarged on a portion of pin member 820 and box member 830 in Figure 8B. Double



hook threads having a positive stab flank angle α and a negative load flank angle β , the absolute sum of which is greater than about 8 degrees, require variable, constantly increasing thread crest width (i.e., a lead adjustment between the stab and load flanks) for proper meshing of the flanks, after the threads are telescoped, during hand tight make up. The use of variable width threads permits clearances between flanks in an assembled connection to be kept at a minimum (typically no more than about 0.003 inches). Thus, when a thread compound containing particulate matter is used during assembly of the connection, an additional seal can be formed between thread flanks due to the bridging action of the particles between flank clearances. Generally, such a seal can be formed only if the flank clearances are less than about 0.005 inches.

Figure 8B shows portions of pin member 820 and box member 830, respectively. Stab flank 822 of pin member 820 exhibits a positive angle α of about 5 degrees, for example, and load flank 824 exhibits a negative angle β of about 8 degrees, for example. The variable width full height thread profile shown on the portion of pin member 820 exhibits increasing crest width 825 which corresponds with the variable decreasing width thread on box member 830, which exhibits increasing root width 828.

When double hook threads having constant width crests and roots (not shown) are used in the connection of the present invention, a greater flank clearance (above 0.005 inches, depending on the design) is required, making sealing at the thread flanks uncertain. This creates a potential for fluid leakage across the threads. Consequently, either the preferred double hook thread profile wherein the absolute sum of the flank angles is less than 8 degrees or a conventional single hook thread profile must be used to achieve thread sealing when the thread profile exhibits constant width crests and roots.

Figure 9 illustrates another embodiment of an assembled tubular connection 900A of the present invention. Connection 900A includes a double set of run-out, run-in threads, set 902 and set 904, adjacent center-shoulder seal 910 combined with a second set of run-out, run-in threads, set 906 and set 908, adjacent the terminal ends of the connection. Preferably center-shoulder seal 910 is a locked double shoulder configuration. Connection 900A is shown with a single hook thread profile, having a chamfered stab flank.

As shown in Figure 9B-9D the thread profile of a portion of pin member 950 includes a single hook thread having a stab flank 952 exhibiting a right angle with



1 reference connection 900A longitudinal axis 14 (or a 0 degree angle α with reference to
2 a line perpendicular to the longitudinal axis and to and root wall 966, and having a load
3 flank 954 exhibiting a negative angle β with respect to a line perpendicular to the
4 connection longitudinal axis 14 and thread root wall 968. The negative load flank angle
5 β is preferably in the range from about 1 degree to about 10 degrees. The thread profile
6 of box member 970 is complementary to that of pin member 950.

7 The most preferred embodiment of the present invention is connection 900A
8 shown in Figures 9A-9D which utilizes a double set of run-out, run-in thread sections and
9 a locked double shoulder center seal, but having a variable width thread with a single
10 hook thread profile including a chamfered stab flank, as shown in Figures 9B-9D. This
11 embodiment provides the smoothest flow of forces between the pin member 950 and box
12 member 970; provides high tension efficiency; and, also provides excellent sealing
13 engagement for preventing fluid penetration into the threads and through (across the
14 threads of) the connection. The negative load flank of the single hook thread causes the
15 two thread zones on each side of the center-shoulder seal move as a unit, and the
16 chamfered stab flank provides self-centering action during initial telescoping of the pin
17 member 950 into the box member 970.

18 The run-out, run-in thread sections of the present invention fade in the thread load
19 gradually and then fade out the thread load gradually. Full height threads like those
20 typically used in the prior art cause the thread load to abruptly increase; thereby
21 transferring a large force abruptly, which in turn caused undesirable bending moments
22 within the connection.

23 The tension efficiency of a connection depends upon the extent to which the pin
24 and box member are formed. Generally, the more forming, the greater the efficiency
25 which can be achieved. Thus, greater efficiencies may be achieved in slim line
26 connections which may have up to a 3.5% greater outside diameter than that of the
27 tubular pipe than can be achieved in flush joint connections which have the same outside
28 diameter as the pipe.

29 The double set of run-in, run-out threads of connection 900A is preferred since
30 this provides maximum utilization of available pipe wall without the waste of space in the
31 form of clearances and gaps in the threads for which there is no complementary
32 engagement. Further, it is desirable not to have wasted space in the form of relief



1 grooves, cut-outs, or other metal reduction. However, the relief grooves of the kind
2 shown at 118 and 120 of connection 100 are not critical because they are located in the
3 larger cross-sectional areas of pin 102 and box 106. Thus, they do not become critical
4 in the overall efficiency of the connection.

5 With the single hook thread profile, as shown in Figs. 9A-9D and recommended
6 for use in connection 900A, an interference between the major and minor thread
7 diameters, i.e. thread crests 964 of pin 950 and thread roots 984 of box 970, can be
8 developed on power tight make up. Furthermore, interference between adjacent load
9 flanks and minimal clearance between adjacent stab flanks can be provided on power tight
10 make up. Any interferences of the roots and crests of the threads causes a hoop stress
11 in the pin and box members 650 and 670, respectively. Consequently, upon power tight
12 make-up, if any interference is present, the thread metal tends to move due to Poisson's
13 effect causing the load flanks to butt up and engage. The interference will vary
14 depending upon the pipe diameters and the grade of the pipe. With reference to Figure
15 9A, preferably, the diametrical interference is maximized at thread sections 902 and 904
16 adjacent center-shoulder seal 910 and is gradually reduced to a minimum at thread
17 sections 906 and 908 at the terminal ends of connection 900A. This gradual reduction
18 in diametrical interference is designed to protect the thin walled member thread sections
19 such as 934 of pin member 950 at the terminal ends of the connection. The larger cross-
20 sectional areas adjacent the center-shoulder seal 900A are more rigid and therefore can
21 have greater diametrical interference and absorb greater hoop stress. The cross-sectional
22 areas of both pin member 950 small step and the box member 970 large step adjacent
23 each side of the center shoulder seal 910 are designed to be approximately equal. The
24 inner diametrical interference between the thread crests and roots is controlled to achieve
25 linear stresses in the greater cross-sectional area of the box and pin members as well as
26 achieve linear stresses at the thinner cross-sectional areas of the pin and box members
27 adjacent their terminal ends. A certain amount of diametrical interference is required to
28 achieve a tight interengaging fit of the threads. The general rule is that the interference
29 will vary between .001 and .002 inches per inch of diameter, with less interference at the
30 terminal ends of the connection than adjacent the center-shoulder seal.

31 The preferred center seal is one that is isolated to the loads placed on the pipe
32 string. In other words, center shoulder seal 910 of connection 900A should remain stable



1 and insensitive to varying loads placed on the connection. The locked double shoulder
2 seal shown at 910 of connection 900A includes redundant sealing systems, i.e. a
3 multiplicity of metal-to-metal seals, to achieve an effective sealing engagement such that
4 the seal does not deactivate upon the application of various loads to the connection such
5 as internal and external pressure, axial tension or compression, and torsional and bending
6 moments.

7 Figure 10A is an enlarged view of a center shoulder seal 1000 which is shown in
8 the embodiment of the overall connection of the present invention illustrated in Figure
9 4. Assembled center shoulder seal 1000 is a locked double shoulder seal made up from
10 first center shoulder configuration 1010 on pin member 1014 and from second center
11 shoulder configuration 1030 on box member 1034.

12 Figures 10B and 10C show first center shoulder configuration 1010 of pin member
13 1014 and second shoulder configuration of 1030 of box member 1034, respectively.
14 Each connection member comprises a ramp, 1016 on pin 1014 and 1036 on box 1034.
15 The center shoulder configuration 1010 of connection pin member 1014 comprises
16 shoulder 1020 having first undercut surface 1028, first metal-to-metal sealing surface
17 1018, second metal-to-metal sealing surface 1022 and third metal-to-metal sealing surface
18 1024. The center shoulder configuration 1030 of connection box member 1034 comprises
19 shoulder 1040 having second undercut surface 1048, fourth metal-to-metal sealing surface
20 1038, fifth metal-to-metal sealing surface 1042 and sixth metal-to-metal sealing surface
21 1044.

22 Upon assembly of center shoulder seal 1000, first sealing surface 1018 on center
23 shoulder configuration 1010 of pin configuration 1014 is lined up and guided into position
24 on corresponding first ramp 1036 of box center shoulder configuration 1030.
25 Simultaneously, fifth sealing surface 1042 on box member center shoulder configuration
26 1030 is lined up and guided into position on corresponding second ramp 1016 of pin
27 member center shoulder configuration 1010. As the assembly progresses, a metal-to-
28 metal seal is created at three locations: between first sealing surface 1018 of pin center
29 shoulder configuration 1010 and fourth sealing surface 1038 of pin center shoulder
30 configuration 1030; between second sealing surface 1022 of pin center shoulder
31 configuration 1010 and fifth sealing surface 1042 of box center shoulder configuration



1 1030; and, between third sealing surface 1024 of pin center shoulder configuration 1010
2 and sixth sealing surface 1044 of box center shoulder configuration 1030.

3 Upon final power tightening (torquing) of the assembled connection, the leading
4 surface of shoulder 1020 contacts with first undercut surface 1048 on box member center
5 shoulder configuration 1030, while the leading surface of shoulder 1040 contacts second
6 undercut surface 1028 of pin member center shoulder configuration 1010, thereby
7 creating two additional zero clearance sealing surfaces.

8 Thus, a total of three metal-to-metal seals and two zero clearance seals are created
9 during assembly (make up) of the connection.

10 Typically a thread compound will be used on the threaded surfaces of the
11 connection, as previously described, to bridge any surface defects and clearances less
12 than about 0.005 inches.

13 The preferred embodiments of the present invention, as described above and
14 shown in the Figures are not intended to limit the scope of the present invention, as
15 demonstrated by the claims which follow, since one skilled in the art can, with minimal
16 experimentation, extend the scope of the embodiments to match that of the claims.

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CLAIMS

What is claimed is:

1. A tubular connection comprising at least two members, wherein each member comprises at least two threaded sections having a center seal configuration disposed between said at least two threaded sections, said connection also comprising: at least one stabilizing thread section present on each connection member adjacent said center seal configuration, said stabilizing thread section comprising a run-out thread.

2. The tubular connection of Claim 1, wherein said connection comprises two tubular members, each member having said run-out thread located adjacent said center shoulder seal configuration on that portion of the connection member at which the tubular wall thickness is less.

3. The tubular connection of Claim 1 or Claim 2, wherein the tubular member corresponding with the member having said run-out thread section includes full-height lead-in thread at its location corresponding with said run-out thread.

4. The tubular connection of Claim 3, wherein each connection member includes a thread relief groove located between said center-shoulder seal and said full height lead-in thread section.

5. The tubular connection of Claim 1 or Claim 2, wherein the tubular member corresponding with the member having said run-out thread section includes a run-in thread section at its location corresponding with said run-out thread section.

6. The tubular connection of Claim 1 or Claim 2, wherein each member's at least two threaded sections having a center seal configuration disposed between them are comprised of a two step thread.

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1 7. The tubular connection of Claim 3, comprising at least one additional
2 stabilizing run-out thread section at an exterior edge of each connection member.

1 8. The tubular connection of Claim 4, comprising at least one additional
2 stabilizing run-out thread section at an exterior edge of each connection member.

1 9. The tubular connection of Claim 5, comprising at least one additional
2 stabilizing run-out thread section at an exterior edge of each connection member.

1 10. The tubular connection of Claim 1 or Claim 2 wherein said center-shoulder
2 seal comprises a locked double shoulder configuration.

1 11. The tubular connection of Claim 3, wherein said center-shoulder seal
2 comprises a locked double shoulder configuration.

1 12. The tubular connection of Claim 4, wherein said center-shoulder seal
2 comprises a locked double shoulder configuration.

1 13. The tubular connection of Claim 5, wherein said center-shoulder seal
2 comprises a locked double shoulder configuration.

1 14. The tubular connection of Claim 6, wherein said center-shoulder seal
2 comprises a locked double shoulder configuration.

1 15. The tubular connection of Claim 7, wherein said center-shoulder seal
2 comprises a locked double shoulder configuration.

1 16. The tubular connection of Claim 8, wherein said center-shoulder seal
2 comprises a locked double shoulder configuration.





1 17. The tubular connection of Claim 9, wherein said center-shoulder seal
2 comprises a locked double shoulder configuration.

1 18. The tubular connection of Claim 1 or Claim 2, wherein the profile of said
2 threaded sections is double hook or single hook.

1 19. The tubular connection of Claim 7, wherein the profile of said threaded
2 sections is a double hook or a single hook thread profile and wherein the stab flank of
3 full-height threads is chamfered.

1 20. The tubular connection of Claim 9, wherein the profile of said threaded
2 sections is a double hook or a single hook thread profile, and wherein the stab flank of
3 full-height threads is chamfered.

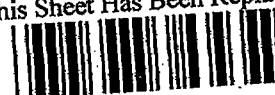
1 21. The tubular connection of Claim 15, wherein the profile of said threaded
2 sections is a double hook or a single hook thread profile, and wherein the stab flank of
3 full-height threads is chamfered.

1 22. The tubular connection of Claim 17, wherein the profile of said threaded
2 sections is a double hook or a single hook thread profile, and wherein the stab flank of
3 full-height threads is chamfered.

1 23. The tubular connection of Claim 1 or Claim 2, wherein the profile of said
2 threaded sections is a double hook, and wherein the absolute sum of the positive stab
3 flank and negative load flank angle is less than 5 degrees.

1 24. The tubular connection of Claim 9, wherein the profile of said threaded
2 sections is a double hook, and wherein the absolute sum of the positive stab flank and
3 negative load flank angle is less than 5 degrees.

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1 25. The tubular connection of Claim 17, wherein the profile of said threaded
2 sections is a double hook, and wherein the absolute sum of the positive stab flank and
3 negative load flank angle is less than 5 degrees.

1 26. The tubular connection of Claim 1 or Claim 2, wherein the profile of said
2 threaded sections is a single hook, wherein the negative load flank angle is less than 15
3 degrees, and wherein the stab flank angle ranges from zero degrees to a negative angle
4 of about 35 degrees.

1 27. The tubular connection of Claim 9, wherein the profile of said threaded
2 sections is a single hook, wherein the negative load flank angle is less than 15 degrees,
3 and wherein the stab flank angle ranges from zero degrees to a negative angle of about
4 35 degrees.

1 28. The tubular connection of Claim 17, wherein the profile of said threaded
2 sections is a single hook, wherein the negative load flank angle is less than 15 degrees,
3 and wherein the stab flank angle ranges from zero degrees to a negative angle of about
4 35 degrees.

1 29. The tubular connection of Claim 27, wherein said negative load flank angle
2 is less than 4 degrees, wherein the absolute sum of said negative load flank angle and
3 said stab flank angle is less than 5 degrees, and wherein said stab flank of full-height
4 threads is chamfered.

1 30. The tubular connection of Claim 28, wherein said negative load flank angle
2 is less than 4 degrees, wherein the absolute sum of said negative load flank angle and
3 said stab flank angle is less than 5 degrees, and wherein said stab flank of full-height
4 thread is chamfered.

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1 31. The tubular connection of Claim 1 or Claim 2 wherein said center-shoulder
2 seal is selected from the group consisting of a locked double shoulder, square shoulder,
3 hook shoulder, square shoulder with a frustrum seal, annular shoulders, shoulder
4 comprising grooves or an annulus having an axial undercut, and shoulders designed to
5 extrude a portion of their mass laterally into adjacent grooves upon assembly of the
6 connection.

1 32. A tubular connection comprising two tubular members, wherein each
2 connection member comprises threaded sections having a center shoulder seal
3 configuration disposed between two of said threaded sections, each tubular member also
4 comprising: a first run-out thread section adjacent said center shoulder seal configuration
5 and located at the more thin-walled portion of said tubular member which is adjacent said
6 center shoulder seal configuration; a second run-out thread section adjacent a terminal end
7 of each tubular member, and located at the more thin-walled terminal end of said tubular
8 member; and, corresponding run-in threaded sections on each tubular member, which
9 run-in threaded sections are located to correspond with run-out threaded sections on the
10 corresponding tubular member.

1 33. The tubular connection of Claim 32, wherein said center shoulder seal
2 configuration comprises a locked double shoulder configuration.

1 34. A tubular connection comprising at least two members, each of which
2 comprises a locked double shoulder configuration.

1 35. A tube and coupling connection wherein at least two members of said
2 connection comprise a locked double shoulder configuration.

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1 36. A method of stabilizing a tubular connection which comprises at least two
2 tubular members, with each member having at least two threaded sections and having a
3 center seal configuration disposed between said at least two threaded sections, said
4 method comprising:

5 utilizing a run-out thread section adjacent said center seal configuration on
6 each connection member, and locating said run-out thread section at the portion of said
7 member, adjacent said center seal where said member wall thickness is less.

1 37. The method of Claim 36, including utilizing an additional run-out thread
2 section near a terminal end of each connection member.

1 38. The method of Claim 36 or Claim 37, including utilizing a run-in thread
2 section on each corresponding member at the location corresponding with said run-out
3 thread section.

1 39. A thread for use in tubular connections, said thread comprising a
2 chamfered stab flank as the stab flank for at least the individual thread members which
3 come into contact upon initial telescoping of a pin member into a box member of said
4 tubular connection.

1 40. The thread of Claim 39, wherein the height of said chamfer is about equal
2 to the step height from the preceding load flank to said stab flank.

1 41. The thread of Claim 39, wherein said load flank angle is a negative angle
2 of less than 15 degrees.

1 42. The thread of Claim 41, wherein said stab flank angle ranges from a
2 negative angle of less than 8 degrees to a positive angle of less than 8 degrees.

1 43. The thread of Claim 42, wherein said stab flank angle ranges from an
2 angle of zero degrees to a positive angle of less than 3 degrees.



1 44. The thread of Claim 43, wherein the absolute sum of said negative load
2 flank angle and said zero degree to positive stab flank angle is less than 5 degrees.

1 45. The thread of Claim 44 wherein said stab flank angle is essentially a zero
2 degree angle.

1 46. The thread of Claim 43, Claim 44 or Claim 45, wherein said thread is a
2 variable width thread having progressively increasing thread width.

1 47. The thread of Claim 46, wherein the height of said stab flank chamfer is
2 about equal to the step height from the preceding load flank to said stab flank.

1 48. A tubular connection member comprising at least two threaded sections and
2 having a center shoulder seal configuration disposed between said at least two threaded
3 sections, said connection member also comprising at least one stabilizing thread section
4 adjacent said center seal configuration, said stabilizing thread section comprising a run-
5 out thread.

1 49. The tubular connection member of Claim 48, wherein said member
2 includes a second run-out thread section at an exterior edge of said connection thread
3 sections.

1 50. The tubular connection member of Claim 48 or Claim 49, wherein said
2 center-shoulder seal configuration comprises a locked double shoulder configuration.

1 51. The tubular connection member of Claim 48 or Claim 49, wherein said
2 threaded sections include a thread profile having a negative load flank angle of less than
3 15 degrees and a stab flank having an angle ranging from a zero degree angle to a
4 positive angle of less than 10 degrees.





1 52. The tubular connection member of Claim 51, wherein at least the full
2 height thread stab flanks which will come into contact upon initial telescoping of a
3 connection pin member into a connection box member are chamfered.

1 53. The tubular connection member of Claim 52, wherein the height of said
2 chamfer is about equal to the step height between the preceding load flank and said
3 chamfered stab flank.

1 54. The tubular connection member of Claim 53, wherein said thread is a
2 variable width thread having progressively increasing width.

1 55. The tubular connection member of Claim 50, wherein said threaded
2 sections include a thread profile having a negative load flank angle of less than 15
3 degrees and a stab flank having an angle ranging from a zero degree angle to a positive
4 angle of less than 8 degrees.

1 56. The tubular connection member of Claim 55, wherein at least the full
2 height thread stab flanks which will come into contact upon initial telescoping of a
3 connection pin member into a connection box member are chamfered.

1 57. The tubular connection member of Claim 56, wherein the height of said
2 chamfer is about equal to the step height between the preceding load flank and said
3 chamfered stab flank.

1 58. The tubular connection member of Claim 57, wherein said thread is a
2 variable width thread having progressively increasing width.



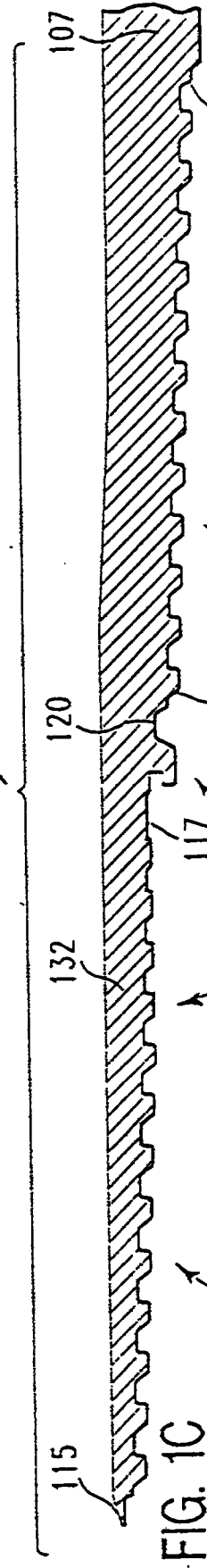
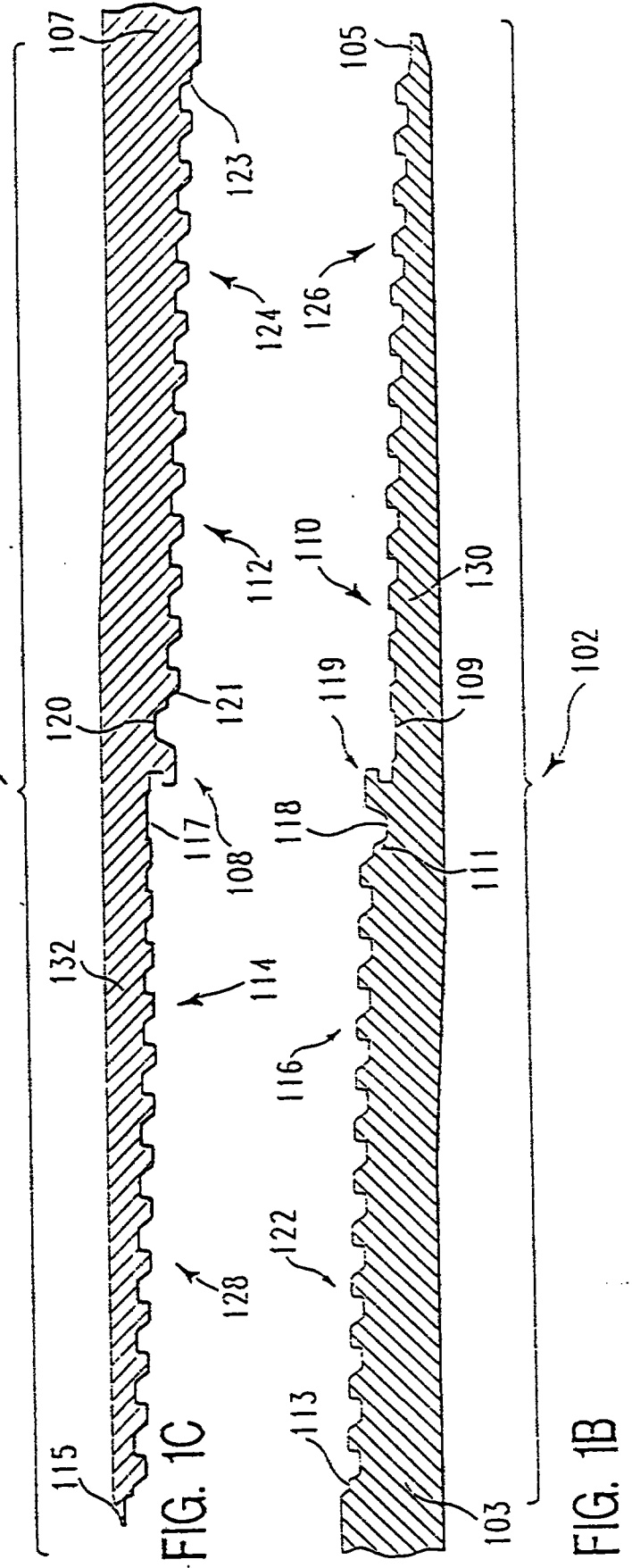
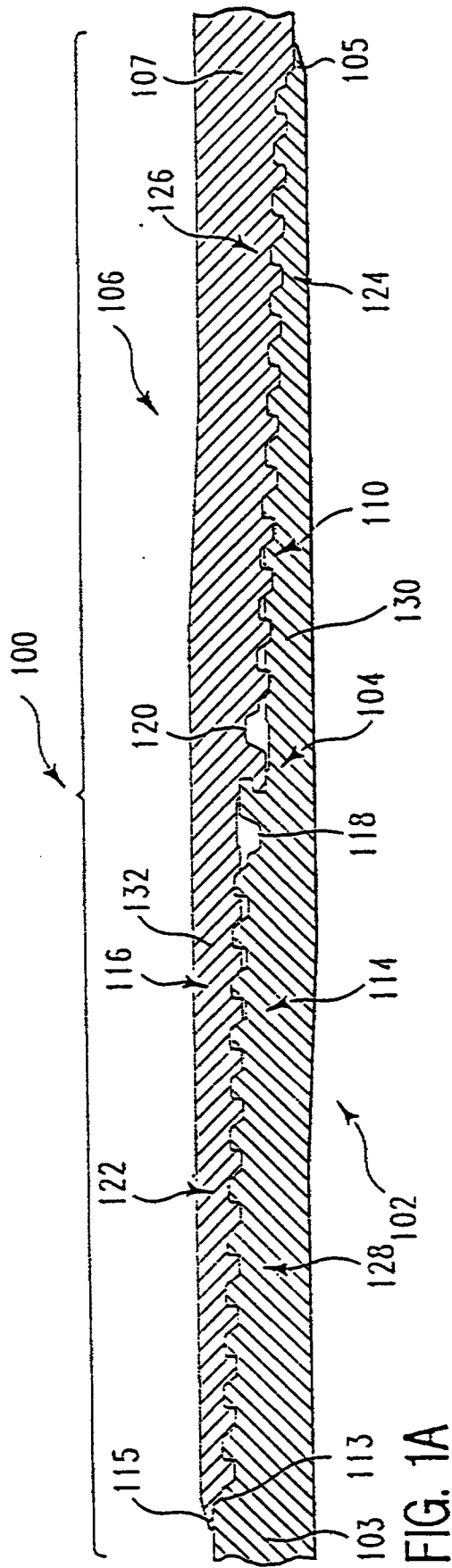
ABSTRACT OF THE DISCLOSURE

The present invention pertains to a tubular connection having a stabilized center-shoulder seal. The stabilization of the center-shoulder seal is achieved using at least one run-out section of thread adjacent to the center-shoulder seal configuration of each connection member. The run-out section of thread is typically used in combination with a run-in section of thread on the corresponding connection member.

Preferably, the center shoulder seal configuration of each connection member is positioned between a run-out thread section and a run-in thread section. (The corresponding connection member will comprise the corresponding sections of run-in and run-out threads, respectively, so there is an interengaging set of run-in and run-out threads). Even more preferably, in addition to the connection having one set of run-out and run-in thread sections adjacent to the center-shoulder seal, the connection has a second set of run-out and run-in threads adjacent to the exterior edges of the connection (A double run-out, run-in stabilization of the center-shoulder seal). The double set of run-out, run-in sections of thread provides the most stable connection.

The most preferred center-shoulder seal design is a "locked double shoulder" design, wherein the cross section of the assembled center-shoulder area exhibits an interlocking double shoulder configuration.

The most preferred thread profile is a single hook thread profile wherein the load flank angle is a negative angle and the stab flank angle is about zero degrees. The preferred thread profile comprises chamfered stab flanks at least at locations which will come into contact upon initial telescoping of a connection pin member into a connection box member. The thread is typically a variable width thread having a progressively increasing thread width throughout a continuous section of thread.



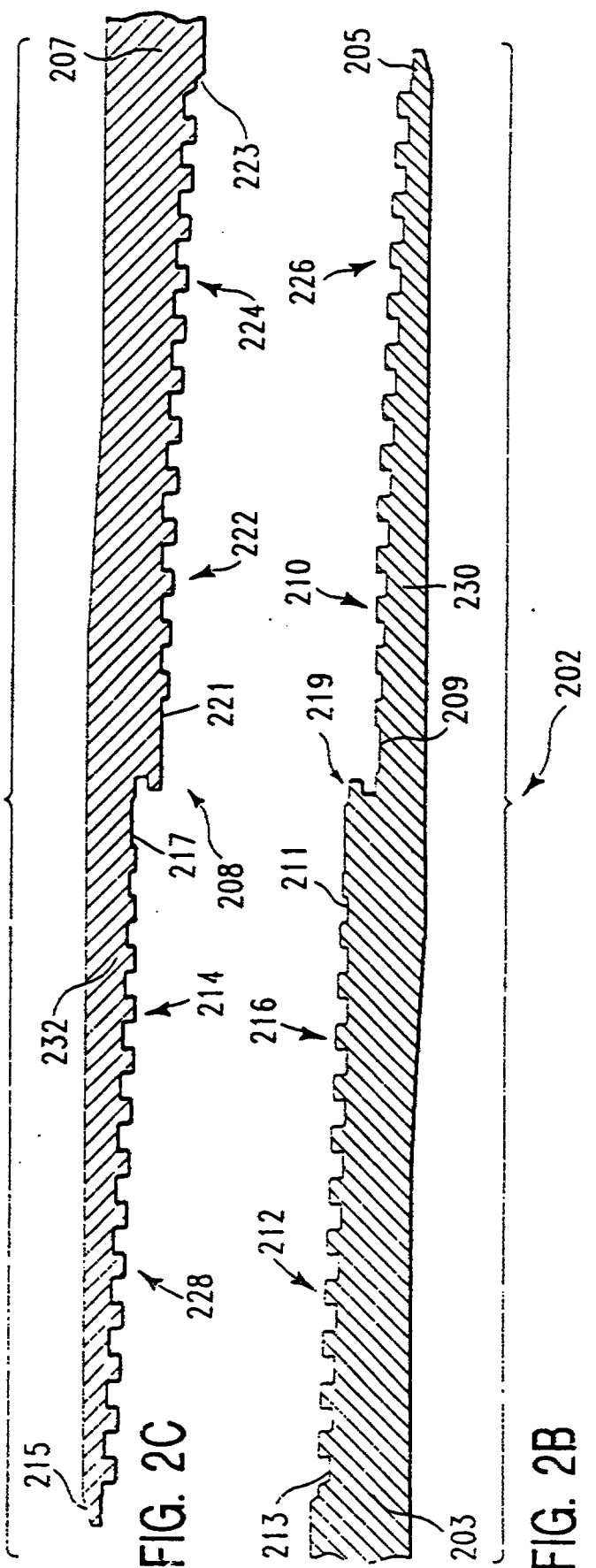
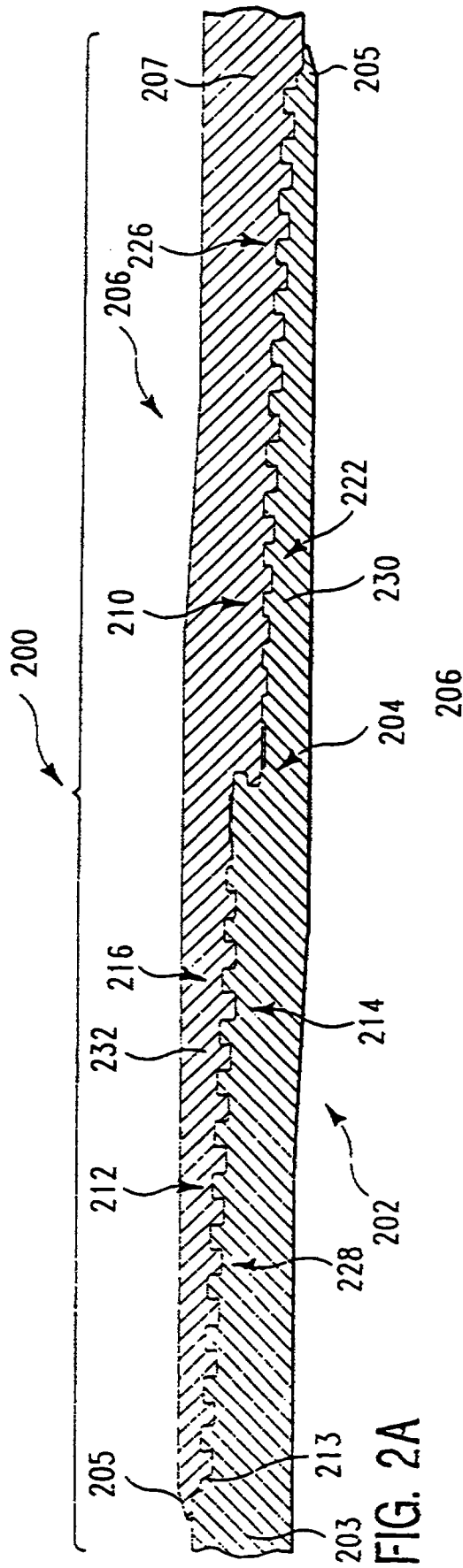


FIG. 2C

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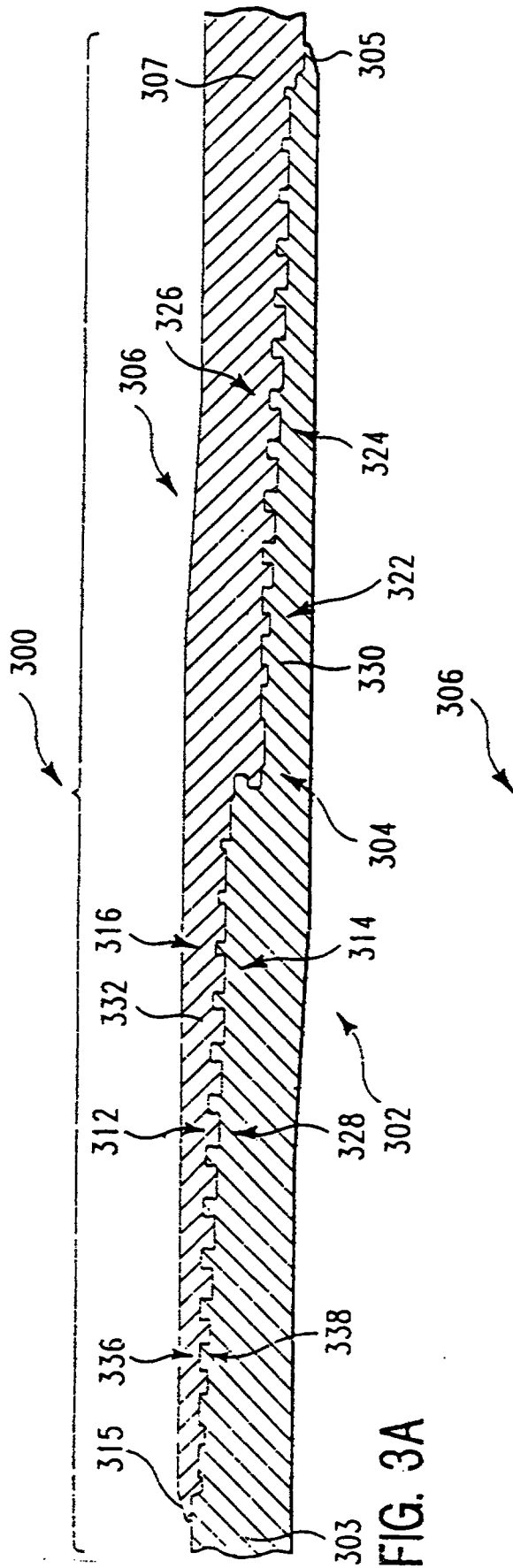
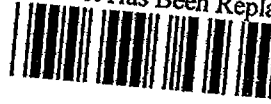


FIG. 3A

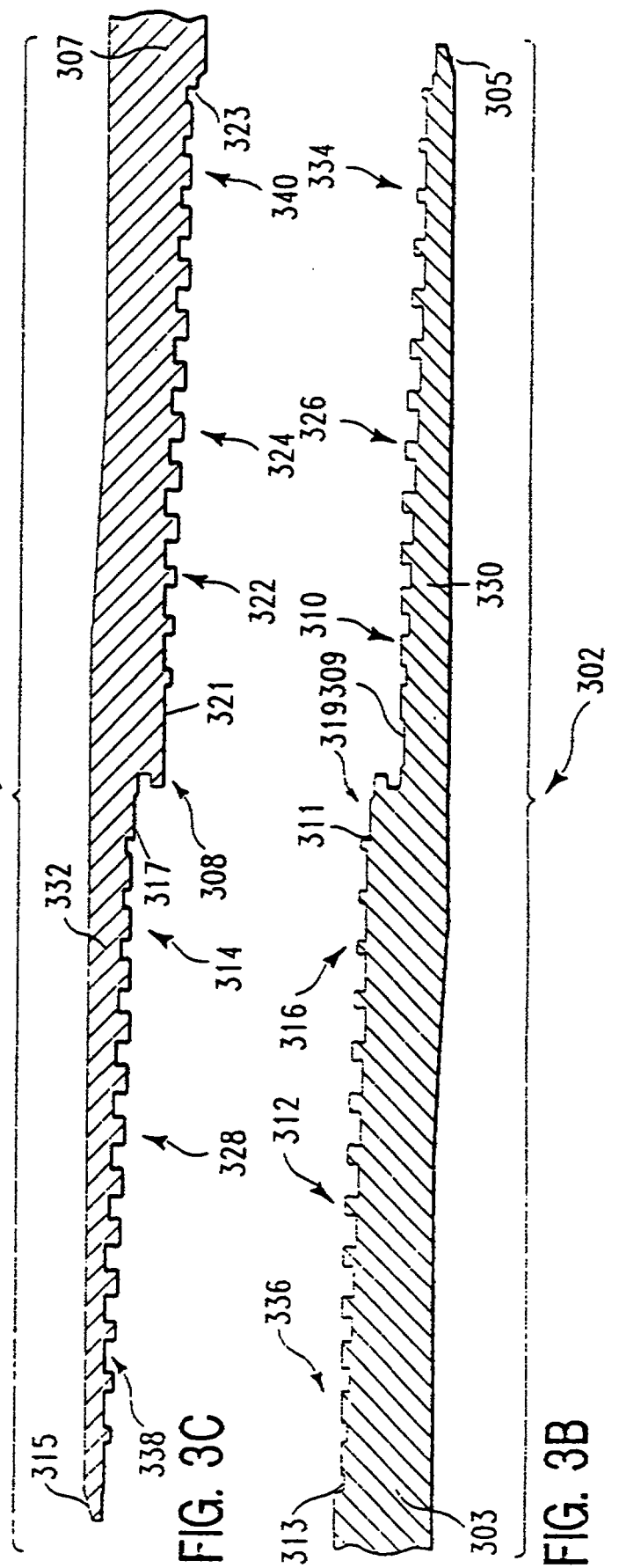
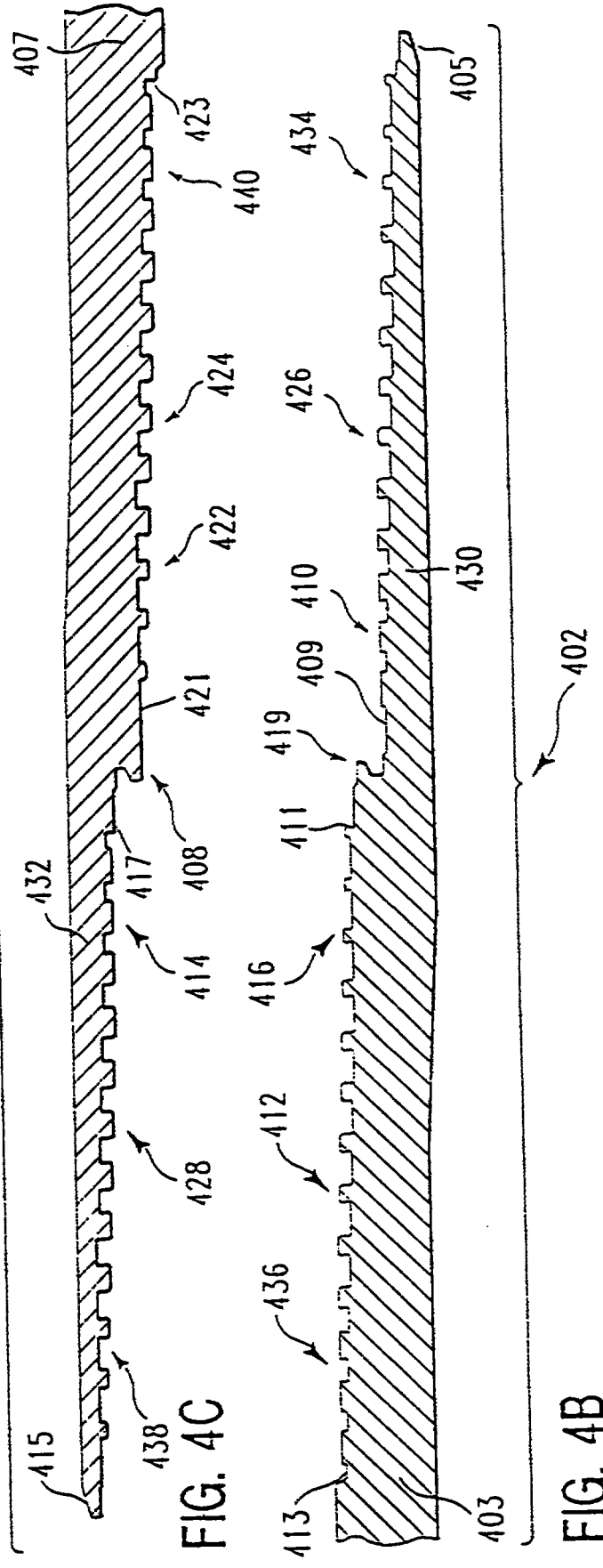
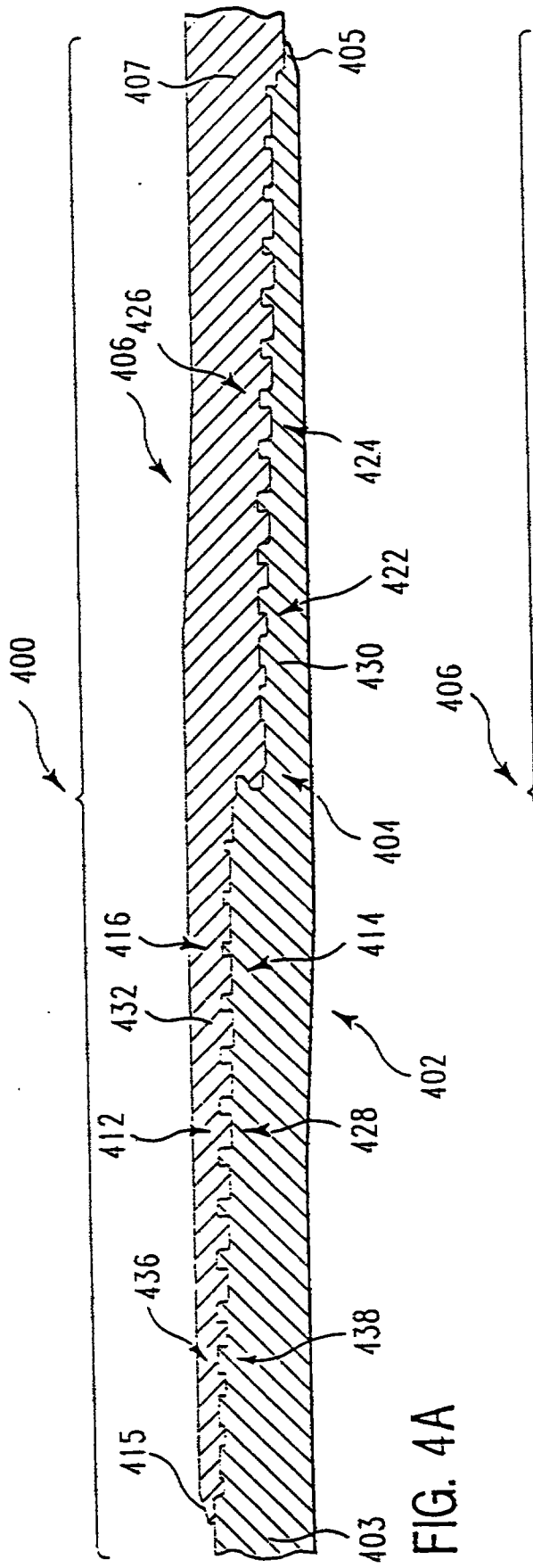
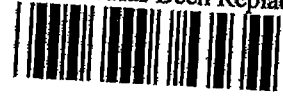


FIG. 3B



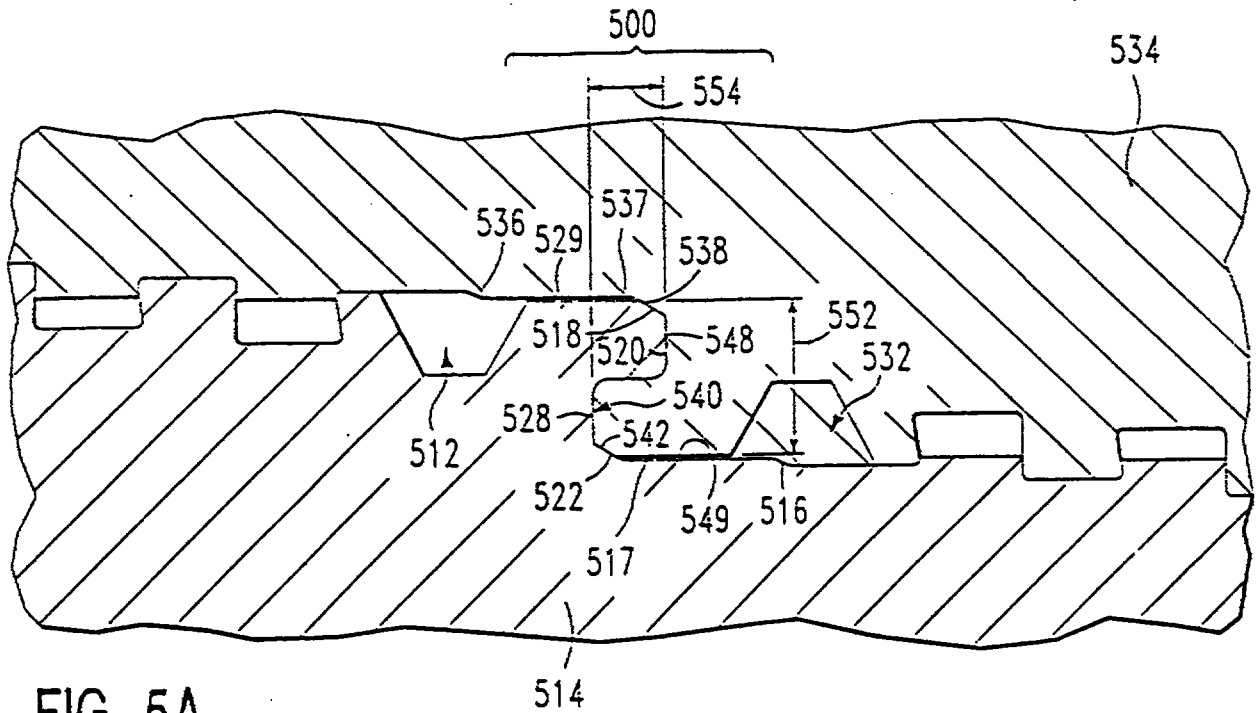
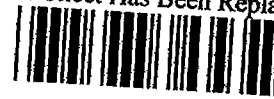


FIG. 5A

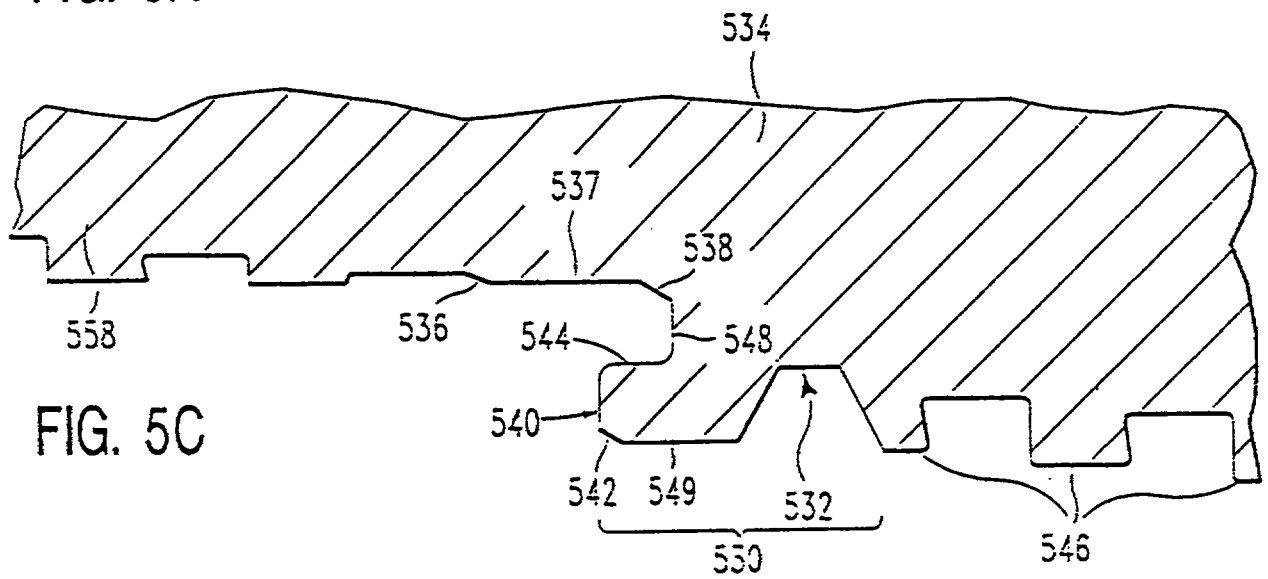


FIG. 5C

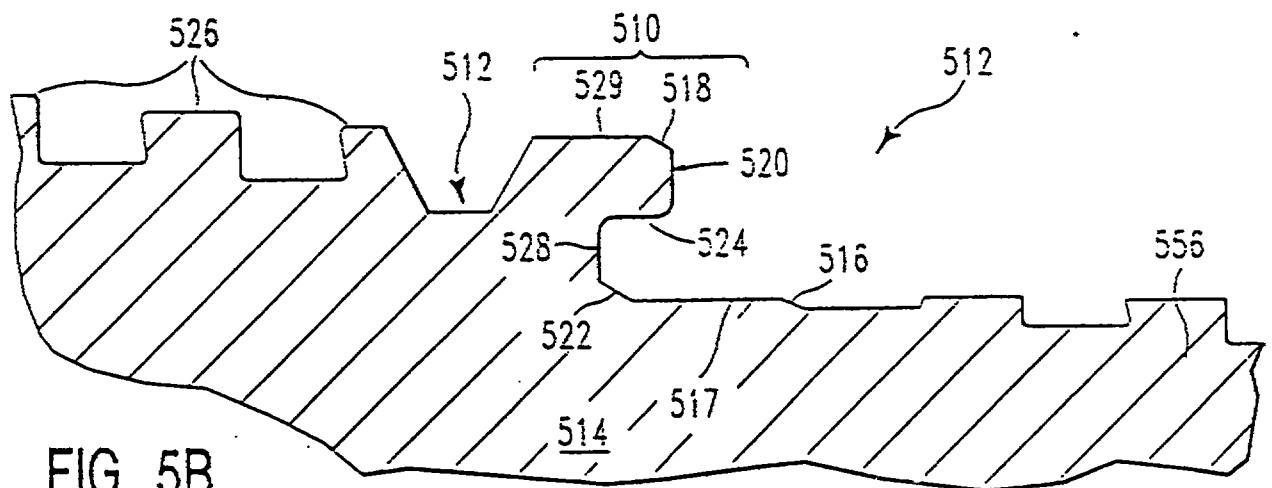


FIG. 5B



FIG. 6A

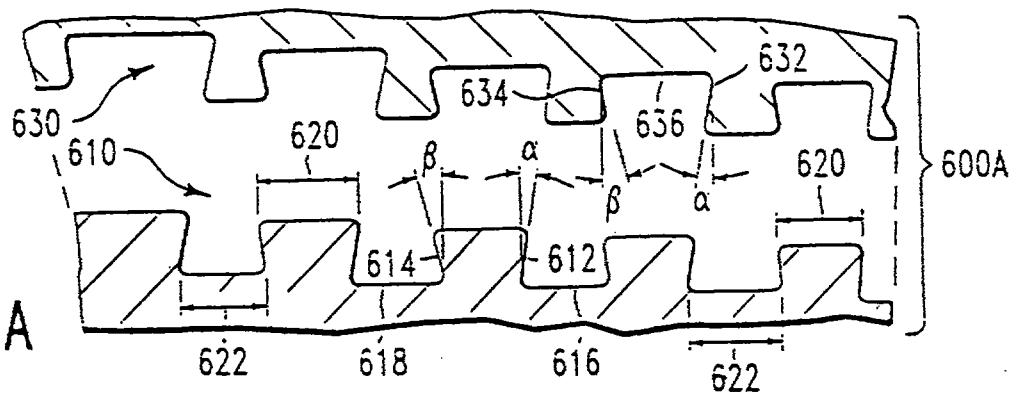


FIG. 6B

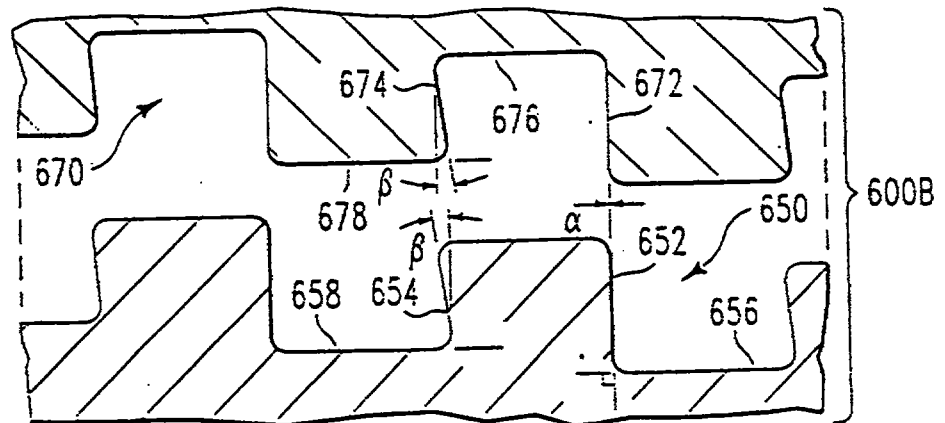


FIG. 6C

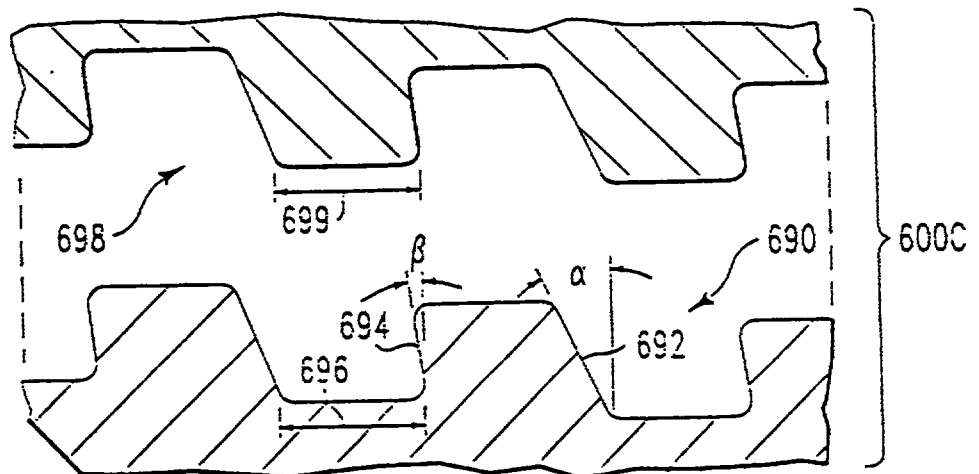
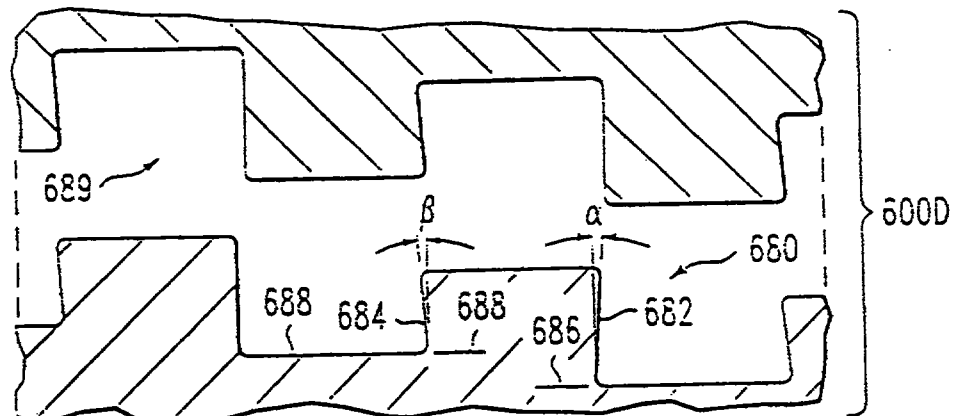


FIG. 6D



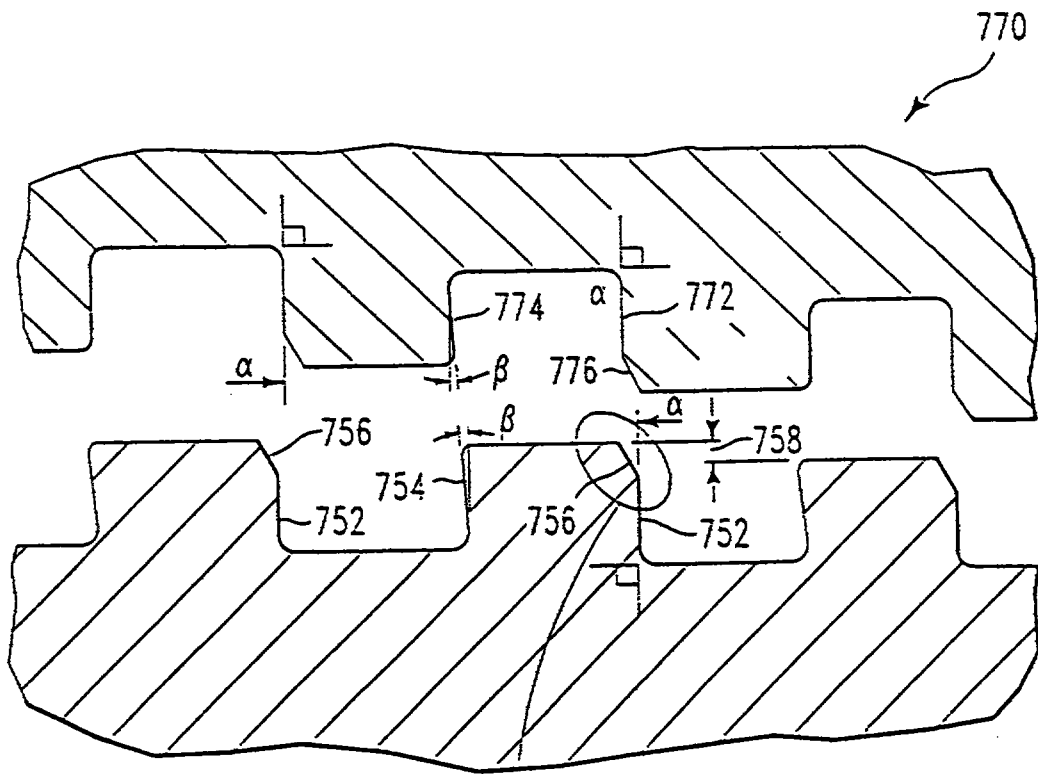
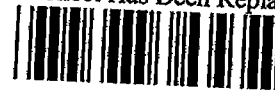


FIG. 7A

FIG. 7B + FIG. 7C

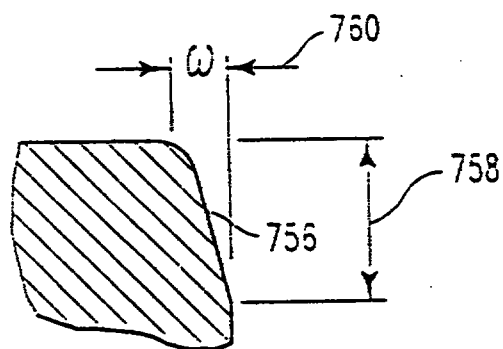


FIG. 7B

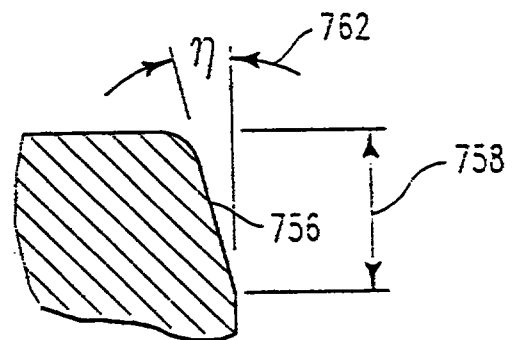


FIG. 7C

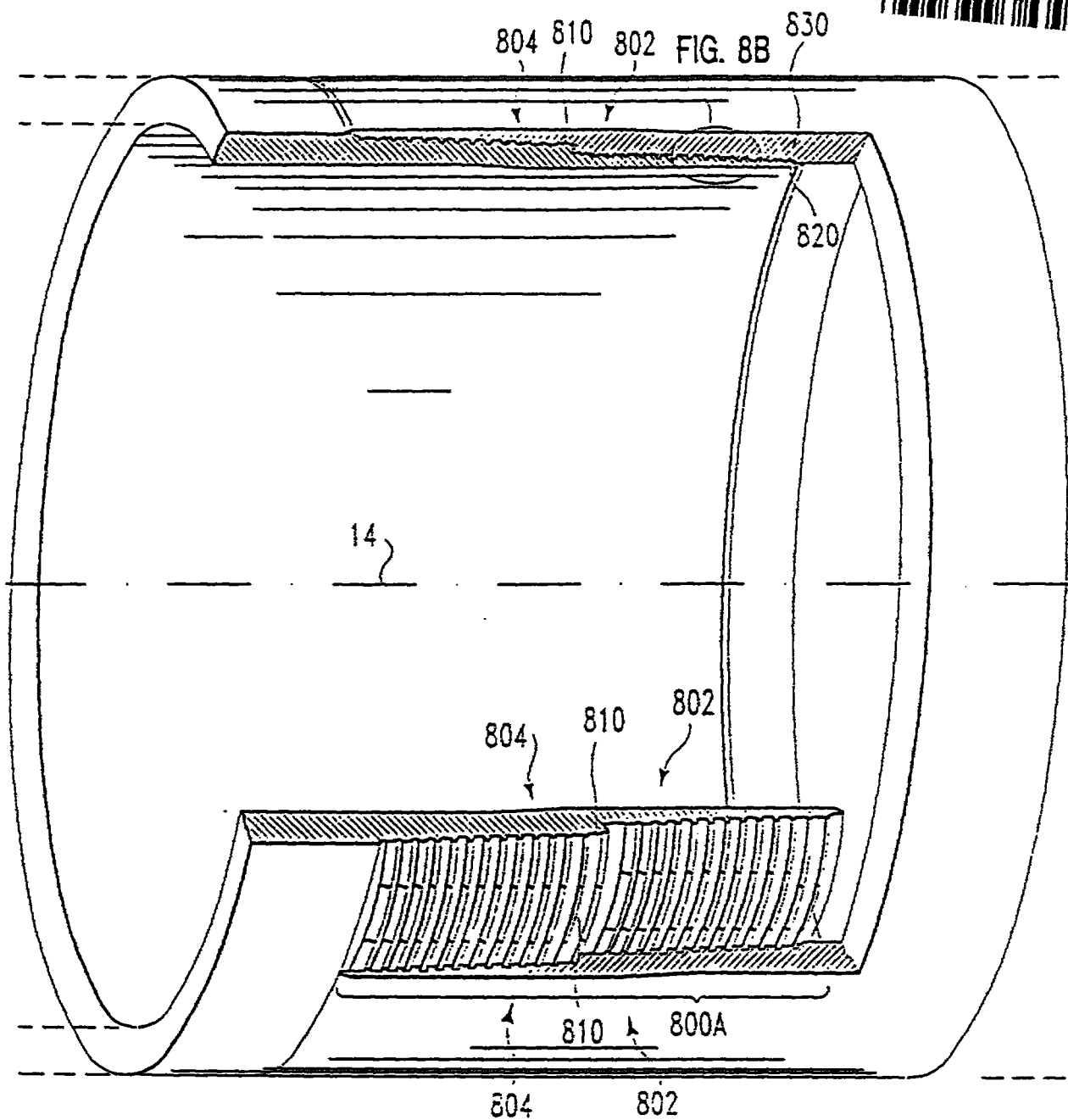
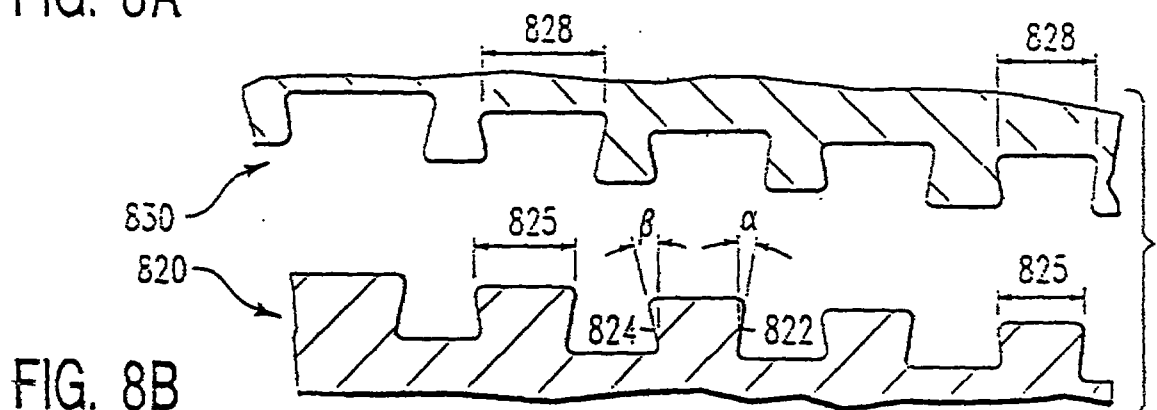


FIG. 8A



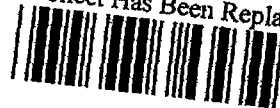


FIG. 9B

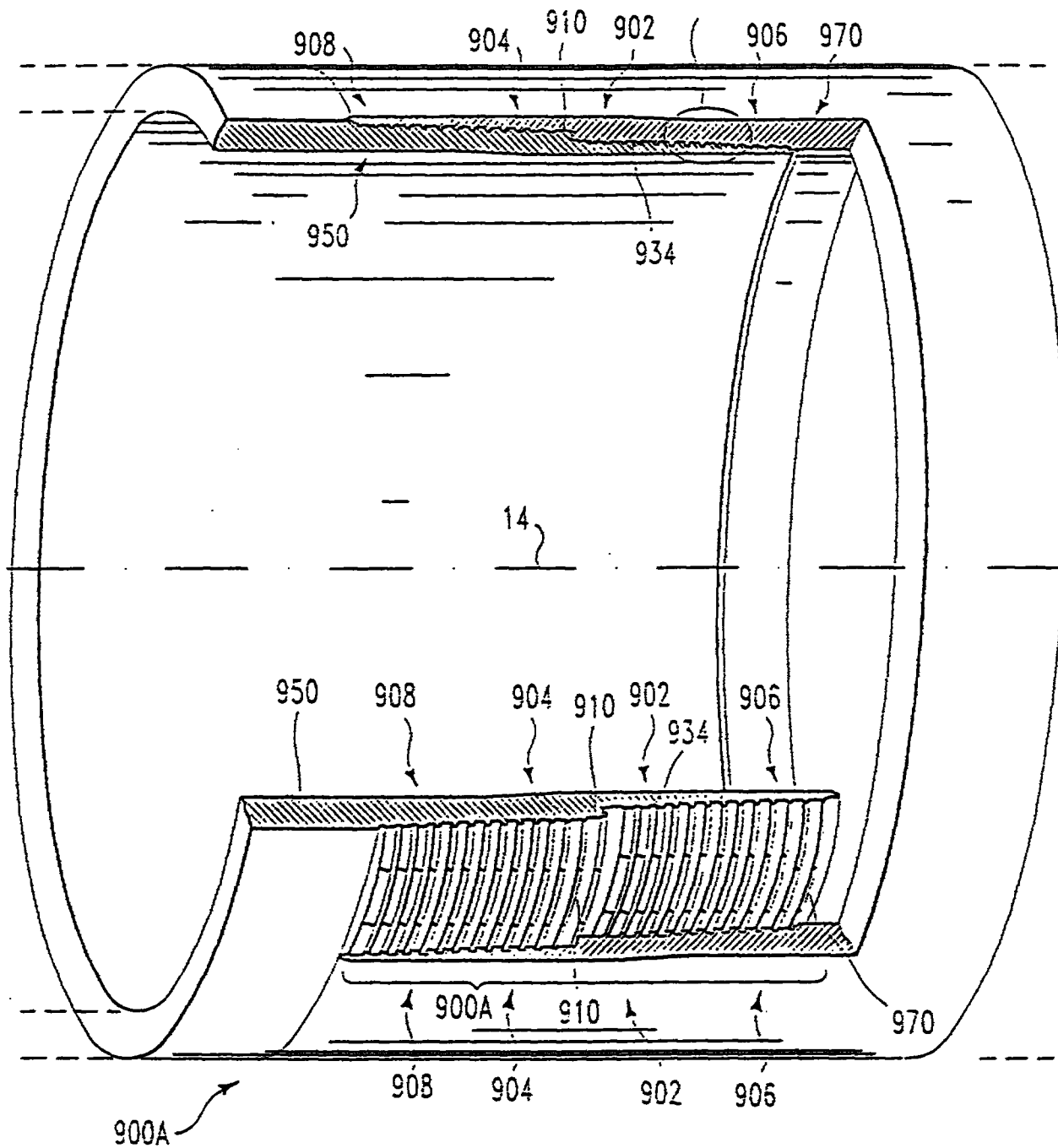


FIG. 9A

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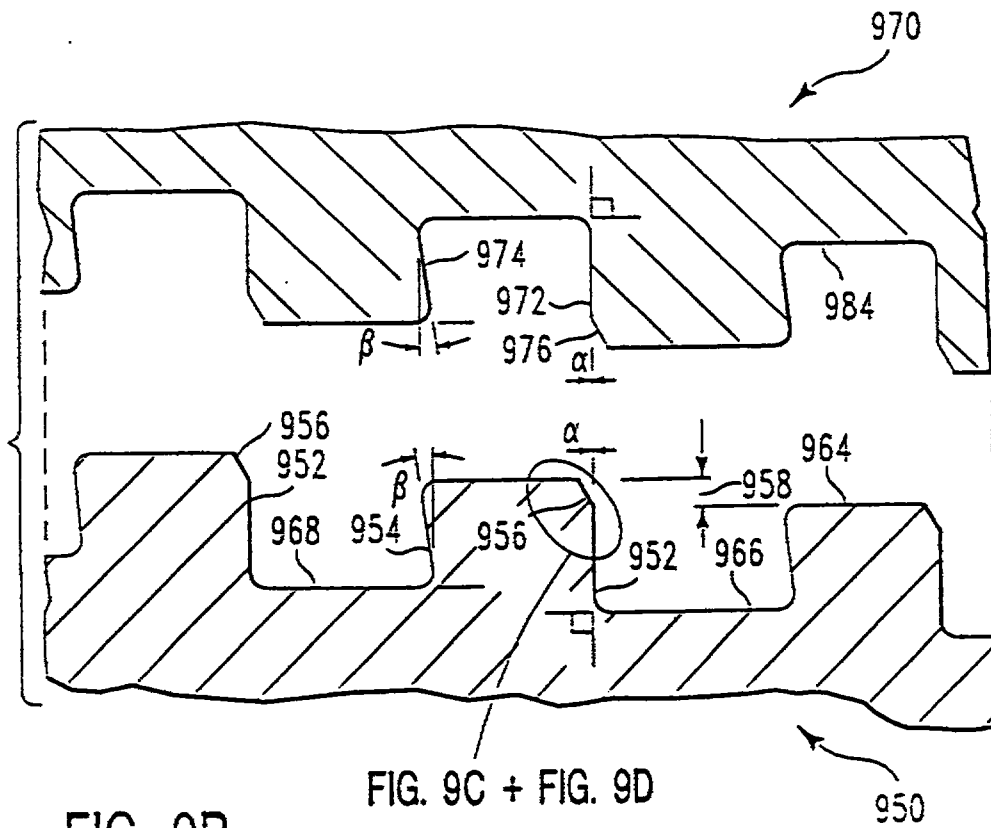
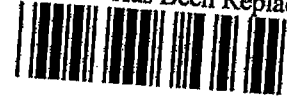
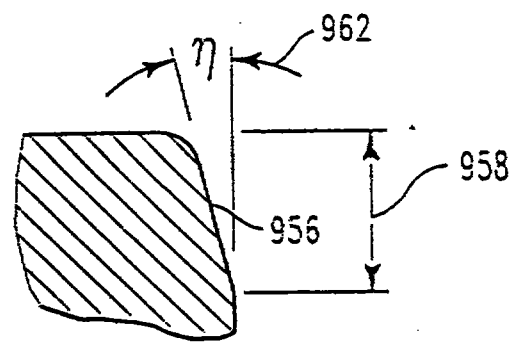
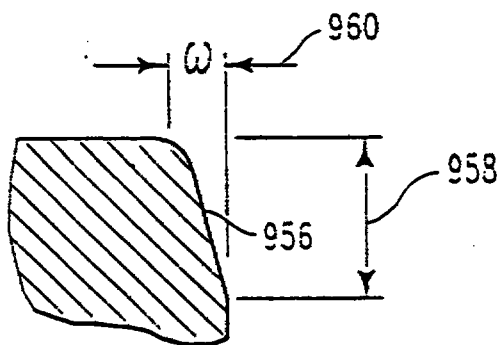
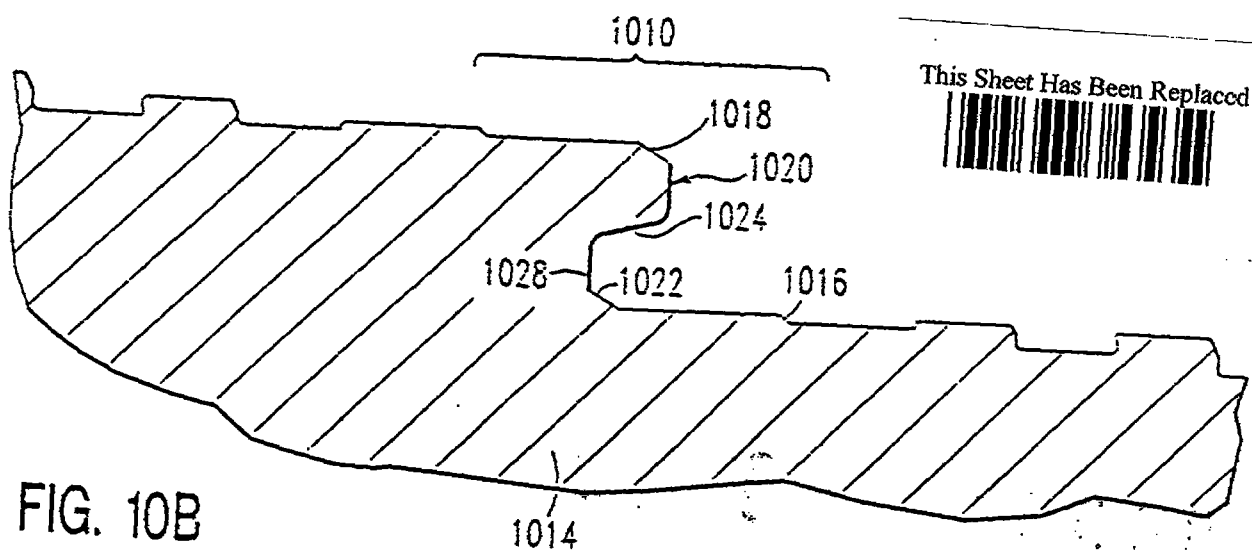
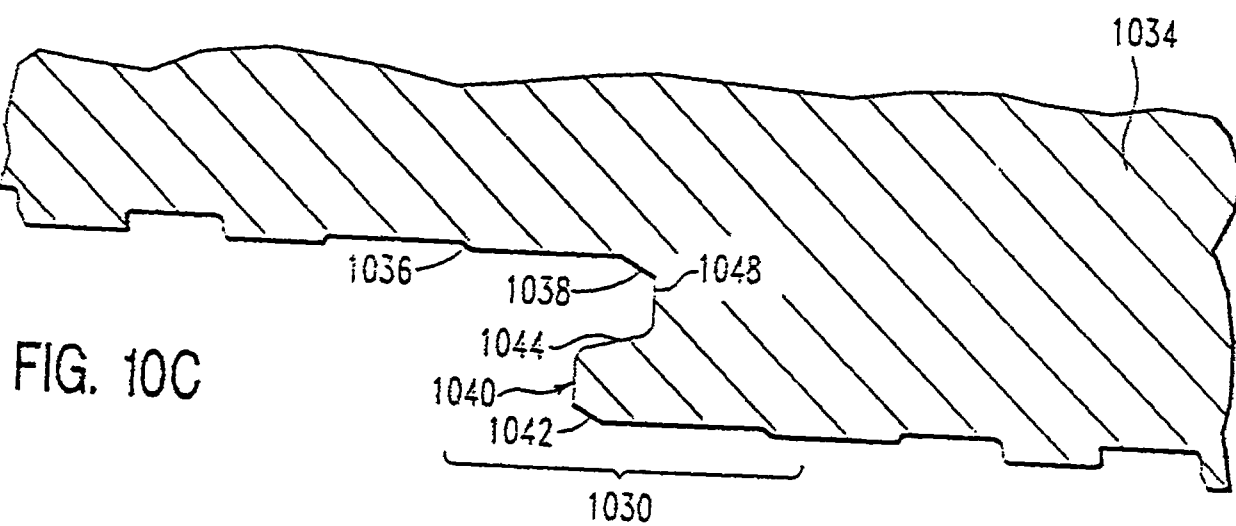
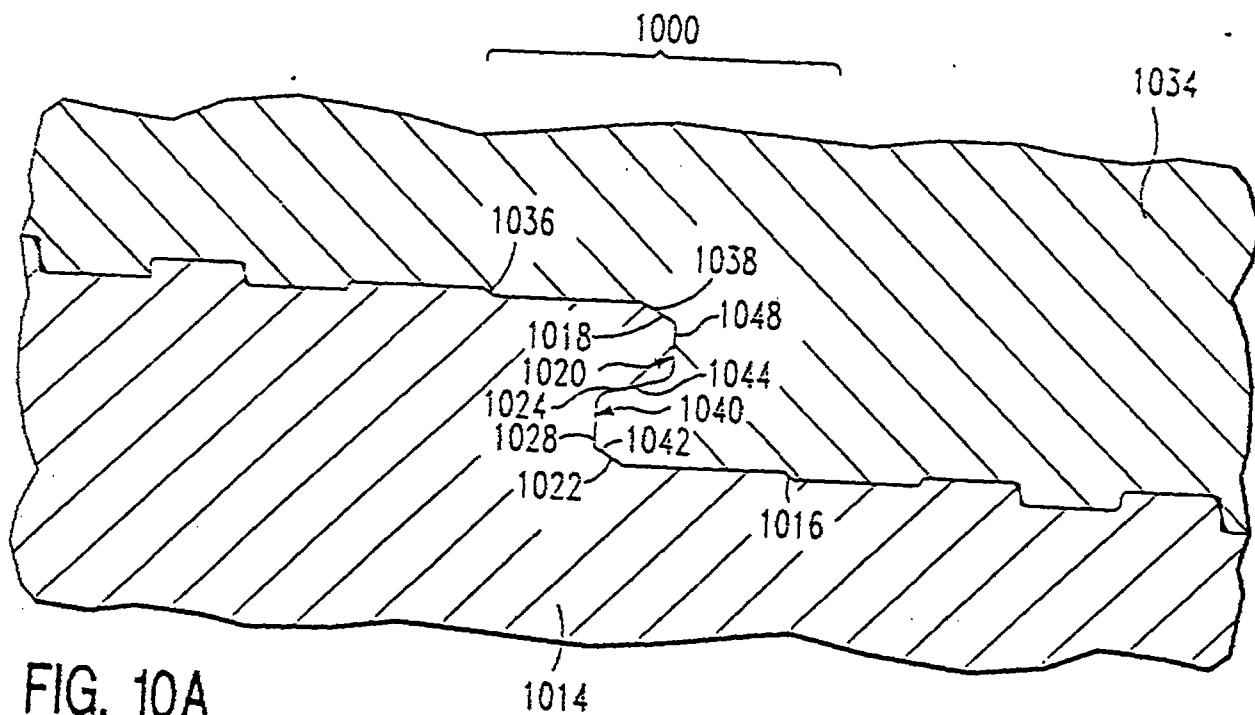


FIG. 9C + FIG. 9D





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REPLACED SHEETS		SG
☒	Description : paged 12, 15, 39 to paged 44	
☒	Claim(s) : paged 47 to paged 54, 56	5A
☐	Drawing(s) : paged to paged	
☒	Abstract : paged 55 to paged 57	
DATE OF RECEIPT		

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STABILIZED CENTER-SHOULDER-SEALED TUBULAR CONNECTION

BACKGROUND OF THE INVENTION

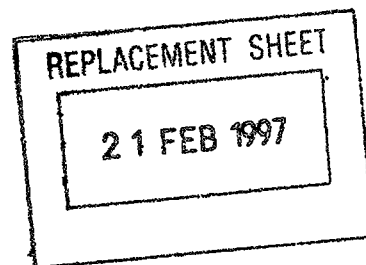
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1. Field of the Invention

The present invention relates to tubular connections of the kind commonly used in the oil industry. In particular, the tubular connection of the present invention comprises a stabilized center-shoulder seal, wherein stabilization is provided by specialized thread constructions adjacent the center-shoulder seal. The invention also pertains to a specialized center-shoulder seal design. Further, the invention pertains to a thread profile which provides a self-centering function upon makeup of the tubular connection. This thread profile can be used with the stabilized center-shoulder seal connection as well as other connection designs known in the art.

2. Background Art

The present invention is applicable broadly for use in joining pipes, couplings and the like, and has particularly been developed for use in oil industry tubular connections, since these connections experience more severe and demanding conditions than those observed for other industries and applications. In particular, the trend in the oilfield is to minimize pipe diameter and to conserve borehole diameter. The smaller the diameter of the borehole for the well, the greater the conservation of energy and reduction of drilling costs. However, in utilizing smaller diameter pipe, it is important that the connections between adjacent tubular pipes be transparent in geometry and performance characteristics, i.e. the geometry and performance characteristics of the connection be substantially the same as that of the tubular pipe itself. Preferably, the pipe string should behave as if the pipe connections were not there. The ideal connection would have the same geometry as the pipe, such as the same inside and outside diameters, and would have the same performance characteristics such as tension rating, compression rating, internal and external pressure ratings, torsion resistance, and bending resistance, for example.



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Two types of oilfield connections, namely flush joints and slim line connections, have been utilized to conserve hole diameter. The outer diameter of a flush joint connection is generally the same as the outside diameter of the tubular pipe. The outside diameter of a slim line connection is generally 2 to 3.5% greater than that of the pipe. Although the objective of such prior art pipe has been to achieve total geometric and performance characteristic transparency, such has not been possible. Often, the performance characteristics of prior art pipe have been sacrificed to achieve greater geometric transparency.

Various standards have been set for evaluating the efficiency of a pipe connection. One such efficiency is determined by the load capacity of the pipe and pipe connection in the axial direction. This tension efficiency is calculated by comparing the fracture strength of the connection with the fracture strength of the tubular pipe. Most prior art flush joint and slim line connections achieve an efficiency in the range of 65% to 75%, respectively. This efficiency, of course, varies with the type of connection, the pipe diameter and thickness, and the method of manufacture of the connection.

Prior art connections include the basic elements of threads, shoulders, and seals. The following prior art patents describe various features which have been used to produce flush and slim-line connections.

U.S. Patent No. 671,274 to W.C. Fischer, issued April 2, 1901, shows a dovetail-shaped thread design which can be applied to the outside of one tubular and the inside of another tubular to be connected together.

U.S. Patent No. 1,474,375 to J.J. Moore, issued September 20, 1923 shows what applicant has described as single hook thread design. The thread is used to fasten the forward end of the after-body of a torpedo to an air flask body.

U.S. Patent No. 1,927,656, issued September 19, 1933 to G.M. Eaton et al., describes a pipe joint for fastening together the consecutive pipe lengths of a pipe string in a manner to obtain strength at the joint without increasing the wall thickness (or with a minimum increase thereof) in the portion of the pipe in which the screw threads are cut. One of the two pipes to be joined is machined on the outside surface of the pin and the other is machined on the inside surface of the box so the two pipes can be screwed together to provide what would today be called a slim line connection. The threaded portion of each pipe is machined on a taper with the depth of the turns of the threads

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being the greatest at the center of the threaded portion and decreasing gradually in both directions to vanishing points at the ends of the threaded portions.

U.S. Patent No. 2,062,407, issued December 1, 1936 to G.M. Eaton et al., discloses a preferred form of pipe joint wherein the height of the threads in the threaded portion of the joint is at a maximum in the central area of the threaded portion of the joint and decreases gradually in both directions to vanishing points, somewhat similar to the joint described above. However, the thread design differs in that the vanishing of the threads corresponds with the intersection of thread fabrication lines which are not only based on a taper relative to the pipe longitudinal axis but also a line which is cylindrical or parallel to the pipe longitudinal axis. Specifically, the root of the thread at the pipe exterior edge position of the pin is located along a line parallel with the pipe longitudinal axis while the crest of the thread at the same location is located along a line at a constant taper with the pipe longitudinal axis. The root of the thread at a position more interior from the edge of the pipe is located along a line at a constant taper with the pipe longitudinal axis, while the crest of the thread at the same location is located on a line of parallel taper to the root for a distance. Finally, at the most interior thread location on the pin, the thread root continues on a taper with the pipe longitudinal axis while the crest of the thread is constructed along a line parallel with the pipe longitudinal axis. Thus, at both the exterior and interior edges of the threaded connection, the thread disappears where thread root and thread crest intersect. The thread construction of the box is complimentary to that of the pin so the two threaded members can be interengaged.

U.S. Patent No. 2,207,005 to R.D. Haas, issued July 9, 1940, pertains to a single hook thread form (as defined herein) wherein the pin member load flank is undercut to provide a cam action under pressure to draw the connection members together and establish a sealing-off function. The thread form is constructed on a taper to the longitudinal axis of the connection.

U.S. Patent No. 2,488,566 to R.S. Sperry, issued November 22, 1949 described a tapered thread structure having a lead on one flank of the helical thread which differs from the lead on the other flank of the helical thread, to provide a constantly increasing thread width from one end of the thread structure to the opposite end. This variable width thread structure is said to enable easy disassembly of a rod or pin from a socket.

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permitting separation of pin from socket without the need to completely unscrew the parts, while providing a wedge-like, snug interfit between the threads of the parts when coupled together. The preferred embodiment for use of the variable width thread structure is on the surface of a pull rod used in combination with a tubular work piece to be formed.

U.S. Patent No. 3,109,672, issued November 5, 1963 to William F. Franz describes a threaded pipe joint comprising a pipe member having a cylindrical outer surface and a tapered buttress thread at the end thereof vanishing along the outer cylindrical surface, providing a length of fully formed and a length of vanishing threads. The complementary coupling member having thread machined on the internal surface thereof exhibits a full height tapered thread throughout the entire length thereof. The complementary threads on each member have following flanks in bearing relationship and substantially normal to the longitudinal axis of the joint and leading flanks in bearing relationship, which leading flanks have a larger flank angle than the following flanks. Crests and roots are truncated to provide flat crests and roots which are parallel to the longitudinal axis of the joint. Crest truncations of fully formed threads exceed root truncations to provide a predetermined amount of void between the crests and roots of the complementary threads throughout the length of the joint when the pipe and coupling are in hand tight engagement. After power make-up, the crests of the coupling threads engage the roots of the vanishing pipe threads, but voids still remain between crests and roots of the fully formed threads, thus preventing the development of deleterious hoop stresses at the end of the coupling during power make-up.

U.S. Patent No. 3,989,284, issued November 2, 1976 to Thomas L. Blose (see also Re. 30,647, issued June 16, 1981) describes a tubular connection (pipe joint) designed to produce hoop tension in the pin member and hoop compression in the box member, the connection exhibits threads having a dove-tail interfit. To achieve the dove-tail interfit, the angles formed between the thread flanks and the root wall of the thread are less than about 85° . In another described embodiment, the load flank of the thread exhibits an angularity from the direction of the connection on axis of less than about 85° while with the stab flank extends radially, in axial radial planes. The pin thread stab flank is the thread flank which is on the leading edge as the pin is telescoped (stabbed) into the box. The load flank is the trailing flank of the thread. In all cases, the threads

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are designed with clearances such that there is a "dove-tail interfit" between pin and box drawing the pin wall outwardly and the box wall inwardly to produce hoop tension in the pin member and hoop compression in the box member in a made up connection, i.e. there is a wedging interfit of threads in the made up joint.

Each thread member is disclosed in the '284 Blose patent as having progressively changing axial width along substantially the entire helical length thereof. Although the preferred embodiment appears to have the threads constructed on a line parallel to the pipe longitudinal axis, the possibility is disclosed of having the threads constructed on a line having constant taper from the pipe longitudinal axis. Also described is the use of an inner shoulder seal between threaded sections of the connection. In one embodiment, the inner shoulder seal is placed between two thread sections which fall on two different lines, each parallel to the pipe longitudinal axis, creating a multiple-step thread with an inner shoulder seal. The inner shoulder seal is shown and described as having a major mating (sealing) surface which is parallel to the pipe longitudinal axis or a major mating (sealing) surface which is at an axial taper.

U.S. Patent 4,009,893, issued March 1, 1977 to Schatton et al., discloses box and pin members having two axially spaced thread sections being separated by a radial step zone which includes, for one member, eg. the pin member, an annulus having an axial undercut, a frusto-conical end face and a radially outward bulging peripheral surface, which sealingly engages a slightly contoured surface of the box member in the step zone, while the end face of the annulus bears against a complementary, slightly contoured face in the step zone of the box member. These stop faces supplement complementary thread stop faces respectively at the end of the pin member and box member. It is advised that a flat annulus having good sliding properties, such as teflon, be interposed between the pin member annulus end face and the complementary bearing face of the box member. In one embodiment, there is a space between the pin member annulus end face and the complementary bearing face of the box member, and a sealing sleeve is interposed to fill this space and the undercut space of the pin member annulus.

U.S. Patent No. 4,076,436 to D.T. Slatoret al., issued February 28, 1979, describes specially designed stress relief grooves for threaded end portions of tools and for collars on reciprocating or rotating drill string mounted tools.

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U.S. Patent No. 4,161,332, issued July 17, 1979 to Thomas L. Blose describes a pipe joint including pin and box members having interengaged two-step threads and interengaged annular shoulders. One of the annular shoulders of the connection is located axially between the first and second pair of threads. This shoulder is constructed so that the pin member stab flank of the shoulder is at a negative angle to the pipe longitudinal axis (preferably at about 5 degrees) to provide a semi-dovetail interfit of the shoulder on makeup of the joint. The pin member threads in general exhibit a negative angle load flank (preferably about 15 degrees) and a negative stab flank angle (typically about 30 degrees), to provide a semi-dovetail interfit with corresponding box threads; the pin member stab flank is typically not engaged, there being about 0.020 inches clearance with the corresponding box threads on normal make-up.

U.S. Patent No. 4,224,607 to T.L. Blose, issued July 17, 1979, discloses a cylindrical threaded connector having a small amount of taper to produce a controlled radial interference to prevent inadvertent thread disengagement.

U.S. Patent No. 4,373,754 to C.A. Bollfrass, et al., issued February 15, 1983, describes a threaded connector having multi-stepped, non-tapered thread sections. The thread profile has at least one "hooked" flank to provide improved tensile strength. The wall thickness of the female or box member of the connector is controlled to improve thread loading and to enable inwardly radial movement with the male or pin member to prevent "pulling out" of the threads under axial tensile loading. The outer thread step of the pin member may only partially engage the threads of the box member such that the critical reduction of the tube wall thickness at the thread roots is a minimum.

U.S. Patent No. 4,384,737 to H.E. Reusser, issued May 24, 1983 discloses a tubular connection including a coupling or integral socket into which pipe sections are threaded. The outer surface of the pipe sections includes an unthreaded nose portion at the outer end of the threaded portion. The nose portion terminates with an annular surface and includes a plurality of convex surfaces of revolution extending circumferentially of the nose portion, all of which surfaces are adapted to engage the unthreaded portion of the coupling or socket to establish a fluid-tight seal. The present invention does not utilize such a pin nose design. Another feature of the Reusser invention (which is present in all claims which do not pertain specifically to the above-described pin nose design) is that surface-to-surface thread contact exists between either

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the minor diameter flat portions of thread on each member or between the major diameter flat portions of thread on each member, but that there not be contact between both the minor and major diameter flat portions. The present invention does not use this method of controlling stresses created during make-up of the connection. The connection of the present invention exhibits surface-to-surface thread contact between the crests and roots of successive threads for all full height threads and the majority (but not all) partial height threads.

U.S. Patent No. 4,398,756, issued August 16, 1983 to Duret et al., describes a cylindro-conical pipe joint wherein approximately 15% to 25% of the joint is threaded upon a continuous construction line which is at a taper to the longitudinal axis of the pipe, with the remaining approximately 75% to 85% of the threaded portion of the joint being threaded upon a continuous construction line parallel to the longitudinal axis of the pipe. The position of the threading which is on a taper to the pipe longitudinal axis is that which forms the entry to the connection when the pin and box are initially being telescoped together. Thus, clearance is provided by the taper of the box entry to permit ease in initial telescoping of the pin into the box, prior to actual engagement of the threads. Another feature of the Duret et al. invention is that the female (box) member has an internal shoulder against which the end face of the male (pin) member seals. The connection of the present invention relies on other sealing surfaces within the central structure of the connection, permitting the end face of the pin member to extend openly at the edge of the connection.

U.S. Patent No. 4,570,982 to T. L. Blose, issued February 18, 1986, describes a tubular connection including pin and box members having a two step thread profile with the leading thread step of the pin member being a smaller diameter than the second thread step. The thread profile of the members has a negative angle load flank and the thread steps are axially separated from one another by a reverse angle torque shoulder having one or two adjacent conical surfaces. The negative load flank angle of the threads and the reverse shoulder angle combine to lock the members together and prevent differential radial separation of the engaged conical sealing surfaces.

U.S. Patent No. 4,591,195 issued May 27, 1986 to Chelette et al. discloses a center shoulder seal located between two threaded portions of a pipe joint, wherein the threaded portions are stepped threads constructed on a line parallel to the longitudinal axis

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of the pipe. The center shoulder seal is fabricated so the pin portion of the seal contains an undercut groove which can be used in combination with a sealing ring of rigid plastic or rubber material to provide a seal capable of retaining hot gases or liquids.

U.S. Patent No. 4,603, 889 to J.W. Welsh, issued August 8, 1986, discloses a threaded fastener having an axis adapted to thread connect to two bodies. The fastener is threaded on the inside and the two bodies are threaded on the outside. The threading has first and second load flanks which face axially oppositely. The first flank defines a second pitch, said pitches being different and characterized in that when the fastener is screwed onto body threads the first flank tightens against one body thread when the second flank tightens against the other body thread.

U.S. Patent No. 4,671,544, issued June 9, 1987 to Donald J. Ortloff discloses a threaded pipe connection having two portions of tapered threads with tapered sealing surfaces located between the threaded portions. The tapered sealing surfaces engage a resilient seal member located in a groove about midway between the ends of one of the seal member surfaces; when the joint is made up, the sealing surfaces form independent metal-to-metal seals on both sides of the resilient seal member. In a preferred embodiment, the threaded portions are in the form of two steps, one on each side of the center sealing surface described above; the threads are wedge-shaped threads that increase in width progressively in one direction within each step of threads.

U.S. Patent No. 4,676,529, issued June 30, 1987 to Patrick E. McDonald describes a pipe joint wherein the pin and box members have two stepped portions of threads, each constructed on a line parallel with the longitudinal axis of the pipe, and having metal-to-metal sealing surfaces located between the threaded portions. The sealing surfaces provide three engaging shoulders between the pin and box; the two sets of outer shoulders have space between them at the time the set of inner shoulders is in contact. Between the set of inner shoulders and each set of outer shoulders, there is a groove; in one location the groove is in the box portion of the connection and in the other location the groove is in the pin portion of the connection. When the connection make-up torque is beyond the yield point of the metal of the set of inner shoulders, the metal extrudes into the grooves in the box and pin members to form interlocking surfaces which hold the box and pin from relative rotation.

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U.S. Patent No. 4,696,498 to K.L. Church, issued September 29, 1987, describes a tubular connection having two members, one threaded on the inside (box) and one threaded on the outside (pin). Each member has a double set of steep tapered hook threads, two internal pressure seals including a compressible primary metal-to-metal seal and a supplementary seal made up of a resilient corrosion resistant material. Additionally, the connection has a primary resilient corrosion resistant external pressure seal, and a reverse shoulder engagement between the end of the pin member and a shoulder on the box member to hold the primary metal sealing surfaces in sealing engagement.

U.S. Patent No. 4,703,954, issued November 3, 1987 to Ortloff et al. describes a threaded pipe connection comprising a box having tapered internal threads and a pin having tapered external threads, wherein the threads are dovetail shaped in cross section (wedge shaped thread) and increase in width in one direction on the box and in the other direction on the pin. This design is improved over that described in U.S. Patent No. 3,989,284 (Re. 30,647) in that high stress concentrations are avoided in the box between the first thread and the end of the box by making the length of the box between the first thread and the end of the box equal to or greater than 5% of the pipe diameter and by providing clearance between the crest of the first full thread on the box and the root of the last thread on the pin and between the crest of the last full thread on the pin and the root of the first full thread on the box.

U.S. Patent No. 4,703,959 to E.E. Reeves et al., issued November 3, 1987 discloses a threaded pipe connection with compressible seal ring. The connection comprises a pin member threaded on the outside and a box member threaded on the inside. The members have threading which is tapered, with generally dovetail-shaped threads that increase in width in one direction on the pin and in the opposite direction on the box so that the pin and box threads engage to form thread seals between the flanks of the threads and between the roots and crests of the threads. The improvement is said to comprise an annular groove intermediate the ends of the threads on one of the box and pin to form a cavity between the groove and the threads on the other of the box and pin and a ring-shaped seal member of compressible material located in the annular groove.

U.S. Patent No. 4,753,460, issued June 28, 1988 to Lawrence Y. Tung, discloses a tubular connection having a small diameter thread set and a large diameter thread set.

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the small thread set having a lesser number of threads than the large set. A primary torque shoulder is located between the thread sets and a secondary torque shoulder is located behind the large thread set. In the preferred embodiment, the initial partial thread on the pin of both sets and the last partial thread of the small set on the box has a cylindrical root contour (the root contour is constructed on a line parallel with the longitudinal axis of the pipe), whereas the remainder of threads exhibit a tapered root contour. The longitudinal taper angle of the pin thread sets are dissimilar to the box thread sets, there being a maximum separation of the sets near the center of the connection. At the center, a seal is provided; the last threads adjacent to the center shoulder on the threaded sets are hooked (the angle of the pin load flank is negative with respect to the pipe longitudinal axis). In all embodiments described, the threads exhibit a negative load flank and a positive stab flank. The center shoulder area of the pin exhibits two flanks, one of which is positive (near the small diameter step of threads) and one of which is negative (near the center of the shoulder and about midway between the two steps of threads).

U.S. Patent No. 4,822,081 to T.L. Blose, issued April 18, 1989, describes a driveable two-member tubular connection, and in particular a thread form for the connection. The thread form utilizes converging, trapped thread flanks and mating shoulders and end faces with dissimilar angles. A two step thread design is illustrated, wherein variable width "trapped" threads are present on each step of threads. The thread crests and roots are described as making contact before the thread flanks are touching. This Blose et al. invention is concerned with the benefit of the thread stab flanks in assisting the shoulders/end faces in resisting axial compressive loading and with the different angles between mating shoulders and end faces to reduce deformation of the shoulders upon axial compressive loading.

U.S. Patent No. 4,893,844 to K.D. Chelette et al., issued January 16, 1990, discloses a tubular connection with ventable seal. A deforming seal member is disposed between two surfaces such that a space is provided to at least one side of the sealing member. The connection comprises box and pin members having hooked threads, a stop shoulder between the two members and various seal means.

U.S. Patent No. 4,917,409, issued April 17, 1990 to Doyle E. Reeves describes a threaded connection employing a tapered, wedge shaped thread. The threads increase

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in width in one direction on the box and in the other direction on the pin. The improvement over the prior art appears to be in the ability of the thread design to be used with pipe thread lubricants; to accommodate such lubricants, the thread is designed to eliminate the radial clearance between the thread roots and crests so that the possibility of creating an expansible chamber upon connection make-up that can entrap the liquid or paste-like thread lubricant therein, to produce a false torque reading is greatly minimized, if not entirely reduced. The wedge-shaped thread can be a dove-tail or semi-dovetail thread profile. A variable width thread construction (wherein thread width increases progressively in a given direction) is used in combination with the dovetail or semi-dovetail thread profile (as in the Blose patent 3,989,284). The specification and original claims of Reeves discloses that the load and stab flanks of the thread fully engage "at substantially the same time upon rotational make-up of the threaded connection" Col. 4, lines 43-48. Although only continuation applications were filed during prosecution (no continuation-in-part applications which would permit the introduction of new matter), the claims were amended in a subsequent continuation application to contain the limitation that the thread flanks did not fully engage at substantially the same time.

Another concept disclosed and dependently claimed in Reeves is that it is desirable to increase the thread width at the widest portion in the range of approximately four times the thread width at the narrowest portion at the same thread location. There is no discussion as to why this provides an advantage over prior art (which is said to show less of an increase in thread width).

U.S. Patent No. 4, 944, 538 to S.R. Read, issued July 31, 1990, describes a threaded pipe joint having improved seal ring entrapment.

U.S. Patent No. 4,958,862 to C. Capelli et al., issued September 25, 1990, discloses a tubular connection comprising a pin member having at least one external tapered thread and a box member with complementary internal threads. An end part of the pin member beyond each thread has a conical seal surface and the box member has a conical seal surface with the same taper as that of the pin member, so that upon tightening of the joint a seal is created between pin and box at the forward end region of the pin member.

U. S. Patent No. 5,029,906 to K.D. Chelette et al., issued July 9, 1991, pertains to a deformable sealing member used to provide a pressure vent for mating tubular

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members. A typical threaded coupling comprises pin and box members each having a stepped thread design of hooked configuration on at least one side of a stop shoulder.

U.K. Patent Specification 137,777 of W. Pickard, published in 1920, shows a variety of thread designs which can be used to connect two or more parts or objects laterally or which, on entering a material, will become anchored therein and resist separation in all directions at right angles to the longitudinal axis of the connection. Fig. 8 of the disclosure shows a single hook thread profile. Fig. 10 shows a double hook thread profile.

U.K. Patent Application of K. Maruyama, published November 4, 1981, describes a fluid tight thread joint for oil or gas well pipes. The joint comprises box and pin members; the thread on the pin starts from the pin end as a rounded triangular thread and becomes a buttress thread; the thread on the box member is formed in a corresponding manner.

DEFINITIONS

For convenience and accuracy of description, the following definitions have been adapted for use in describing the connection of the present invention.

The "pin member" of a connection is understood to mean the male portion of a tubular member which is threaded on its external surface to be interengaged with threads on a box member to provide a connection.

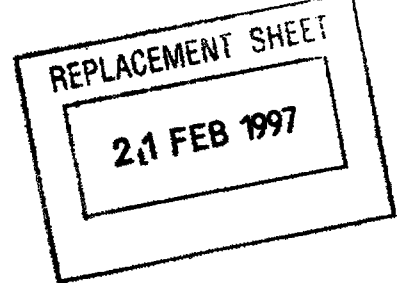
The "box member" of the connection is understood to mean the female portion of a tubular member which is threaded on its internal surface to be interengaged with threads on a pin member to provide a connection.

A connection having a "two-step thread" is understood to mean a connection having two threaded portions wherein one threaded portion has a greater radius from the longitudinal axis of the pipe than the other threaded portion.

A "center shoulder seal" is understood to mean a section of a connection disposed between at least two threaded portions, which section exhibits directly contacting surfaces between the pin and box members, or between the pin and box members and a third component such as an annular sealing sleeve, so that the section provides a seal for preventing the passage of fluid through (across the threads of) the assembled connection.

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A center shoulder seal configuration comprising "a locked double shoulder" configuration is understood to mean a center seal design having interlocking elements, a portion of which are extended from each connection member. In a lengthwise cross-sectional view of the locked double shoulder connection, with the cross section cut along the longitudinal axis of the connection, the locked double shoulder configuration has the appearance of a reverse block S having extended tails on the S. The center bar of the reverse S, which extends lengthwise in the general direction of the connection longitudinal centerline, can be parallel to such centerline or can be at an angle with respect to the centerline. The angle with the connection longitudinal centerline is preferably less than about 45 degrees. More preferably, the angle of the center bar of the reverse block S with respect to the connection longitudinal centerline is less than about 25 degrees.

A "thread root" is understood to mean the thread location at which the wall of the tubular member has been machined away to its maximum depth. The thread root defines the major diameter of a box thread and the minor diameter of a pin thread.

A "thread crest" is understood to mean the thread location at which the wall of the tubular member has been machined to its minimum depth (in some cases, none of the wall will have been machined away at the crest of the thread). The thread crest defines the major diameter of a pin thread and the minor diameter of a box thread.

A "run-out thread" is understood to mean a portion of thread having its roots machined on a taper with respect to the longitudinal axis of the tubular member, but having its crests machined parallel to the longitudinal axis of the tubular member; gradually the construction (machining) lines of the crests and roots of the thread intersect and the thread disappears. In an assembled tubular connection, a run-out thread on a pin member or box member typically corresponds with a run-in thread on the corresponding box member or pin member, respectively.

A "run-in thread" is understood to mean a portion of thread having its roots machined parallel to the longitudinal axis of the tubular member, but having its crests machined on a taper with respect to the longitudinal axis of the tubular member; from an initial point, the construction lines of the crests and roots of the threads diverge, ultimately achieving a full height thread. In an assembled tubular connection, a run-in

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thread on a pin member or box member typically corresponds with a run-out thread on the corresponding box member or pin member, respectively.

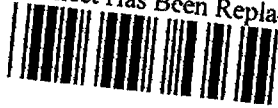
A "thread stab flank" is understood to mean the more forward or leading flank of the thread when the pin is telescoped into the box.

The "thread load flank" is understood to mean the trailing flank of a thread upon telescoping of the pin into the box.

A thread "flank angle" is understood to mean the angle formed between the thread flank and a line constructed at the root of the thread flank, which line is perpendicular to the longitudinal axis of the connection (tubular). For ease in understanding, flank angles are defined in geometric terminology. For example, for a connection member cross-sectional drawing showing the connection member with its leading, threaded end toward the right hand side and its trailing threaded end (typically followed by extended tubular) toward the left hand side, a positive flank angle is one wherein rotation of the perpendicular line toward the thread flank is in a clockwise direction, and a negative flank angle is one wherein rotation of the perpendicular line toward the thread flank is in a counter-clockwise direction. In the connection drawings illustrated throughout this application the connection pin member is shown at the bottom of the drawings with its leading edge on the right hand side while the connection box member is shown at the top of the drawing with its leading edge on the left hand side. Thus, the box member drawing can be reoriented to have its leading edge on the right hand side for purposes of viewing the direction of rotation of the line constructed perpendicular to the connection longitudinal axis at the root of the thread flank. As described previously, the stab flank of the thread of each connection member is the thread flank which is leading or most forward as the connection members are telescoped together.

A "corresponding connection member portion" is understood to mean the portion of a connection member in contact with the member being discussed, upon assembly of the connection. For example, when a portion of the pin member of the connection is discussed, its corresponding connection member portion is the portion of the box member which will be in contact with that portion of the pin member upon assembly of the connection.

"Complementary engagement" is understood to mean the interengagement of corresponding members wherein both corresponding members are threaded in sections



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having essentially equal thread section length on each member, and wherein the entire height of thread on at least one member per threaded section is completely encompassed within the thread height of the other corresponding member threaded section.

A "lead-in thread" is understood to mean a starting portion of full-height or nearly full height threads which are machined on a taper to the longitudinal axis of the tubular member and beginning adjacent to the center shoulder seal configuration.. In an assembled tubular connection, a lead-in thread on a pin member or box member corresponds with a run-out thread on the corresponding box member or pin member, respectively.

SUMMARY OF THE INVENTION

In accordance with the present invention, a tubular connection comprising at least two connection members and a center shoulder seal has been developed in a manner which provides stabilization of the center shoulder seal and improved efficiency (strength of connection/strength of tubular) of the connection.

Also in accordance with the present invention, a center shoulder seal design which provides multiple metal-to-metal sealing surfaces is described. This seal design comprises a locked double shoulder configuration.

In addition, the invention pertains to a thread profile which provides a self-centering function during make-up (assembly) of the connection.

Although the present invention can be applied to connections comprising tubulars and couplings, the most frequent use of the invention will be in the form of a tubular connection comprising two connection members, and thus the invention is described in this form below.

With reference to a tubular connection comprising two connection members, namely a pin member and a box member, the stabilization of the center shoulder seal is achieved using at least one run-out section of thread adjacent to the center shoulder configuration of each connection member. Typically, the at least one run-out section of thread is located adjacent the center shoulder configuration on that portion of the connection member at which the wall thickness is less. The run-out section of thread is typically used in combination with a run-in section of thread on the corresponding

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connection member. However, a run-out section of thread can be used in combination with a full height lead-in thread on the corresponding connection member.

Preferably, a run-out section of thread and a run-in section of thread are used together on the same connection member, with the center shoulder configuration located between the two sections of thread. The corresponding connection member will also comprise the corresponding sections of run-in and run-out threads, respectively, so there is one set of run-in and run-out threads adjacent the center shoulder seal. Even more preferably, in addition to the connection having one set of run-out and run-in thread sections adjacent to the center shoulder seal, the connection has a second set of run-out and run-in threads adjacent to the terminal ends of the connection. Such a double set of run-in, run-out thread sections stabilizes the center shoulder seal and the entire connection. The double set of run-in, run-out sections of threads also provides the most efficient connection.

When a connection member exhibits a single run-out thread adjacent to one side of the center shoulder configuration and a full height lead-in thread adjacent to the other side of the center shoulder configuration (with corresponding thread sections on the other connection member), a relief groove may be disposed between the center shoulder configuration and the full height thread. The relief groove permits proper interengagement of the threads upon assembly of the connection and facilitates machining of the full height lead-in thread. When a single set of run-out, run-in threads is used, with the center shoulder seal located between them, or when a double set of run-out, run-in threads is used, it is typically not necessary to use such a relief groove.

The most preferred center shoulder seal design is a "locked double shoulder" seal which provides an interlocking design, wherein a longitudinal cross section of the assembled pin and box contacting surfaces (in the center shoulder area) exhibits a reverse block S shape having extended tails on the S. Typically the assembled locked double shoulder configuration cross-section is two to three times as "high" in the radial direction (perpendicular to the tubular longitudinal axis) as it is "wide" in the axial direction (parallel to the connection longitudinal axis). In addition, the height is typically 1/4 to 1/3 of the pipe body wall thickness. The center bar of the reverse "S", which extends lengthwise in the general direction of the connection longitudinal centerline, can be parallel to such centerline or can be at an angle with the centerline. The angle with the

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connection longitudinal centerline is preferably less than about 45 degrees, more preferably less than about 25 degrees, and typically less than about 15 degrees. This seal design provides up to 3 metal on metal sealing surfaces and up to three (3) zero clearance, close tolerance sealing surfaces which can be plugged with thread compound, on normal assembly.

Although the locked double shoulder center seal is preferred, other center shoulder designs which are known in the art can also be stabilized using the run-out, run-in thread constructions described above adjacent to the center shoulder. Examples of other shoulder designs which can be stabilized include, not by way of limitation, square shoulder; hook shoulders (wherein the shoulder exhibits at least one negative angle relative to the connection longitudinal axis; square shoulders with a frustrum seal; annular shoulders (shoulder on a taper with the connection longitudinal axis); shoulders comprising grooves or an annulus having an axial undercut which employ a sealing sleeve, ring or annulus; and shoulders designed to extrude a portion of their mass laterally into adjacent grooves upon assembly of the connection. The profile of the individual thread which can be used to make up the run-out, run-in thread sections is preferably selected from the group comprising double hook thread and single hook thread; although other thread profiles standard in the industry can be used.

The double hook thread profile is preferred in terms of mechanical performance. The double hook thread exhibits a negative load flank angle and a positive stab flank angle. A double hook thread profile in which the absolute sum of the load and stab flank angles (independent of the sign of the load and stab flank angles) totals less than about 20 degrees will function well in the present invention. Preferably, the negative load flank angle does not exceed about 8 degrees and the positive stab flank angle does not exceed about 5 degrees. More preferably, the negative load flank angle ranges from about zero degrees to less than 5 degrees and the positive stab flank angle ranges from about zero degrees to less than 2 degrees, with the absolute sum of the angles being less than 5 degrees.

The single hook thread comprises a negative load flank angle ranging from about zero degrees to about 15 degrees and a stab flank angle ranging from zero degrees to a negative angle of about 35 degrees. Preferably the negative load flank angle is less than 8 degrees and the negative stab flank angle is less than 20 degrees. More preferably, the

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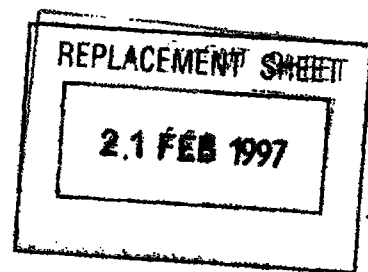
negative load flank angle ranges from about zero degrees to less than about 8 degrees, while the stab flank angle ranges from about zero degrees to a positive angle of less than about 8 degrees. Most preferably, the negative load flank angle ranges from about zero degrees to less than about 8 degrees, while the stab flank angle ranges from zero degrees to a positive angle of less than 5 degrees.

The double hook and single hook thread profiles described above are preferably used in combination with a variable width thread, wherein the thread on each member changes progressively in axial width, with the thread width of the pin member progressively increasing from the leading or forward end toward the following or trailing end of each step of threads, and the thread width of the box member increasing in the opposite direction.

The make-up of the connection having single hook or double hook threads is greatly improved by providing a chamfer on the stab flank of the thread profile. This chamfer provides a self-centering function during telescoping of the pin member into the box member. In addition, the chamfer provides increased surface contact area between the members at the time of telescoping, reducing the overall load at any particular contact point and reducing damage to the connection on make-up. The axial distance of travel or width of the chamfer is preferably about 0.005 inches or less, with the degree of the chamfer being a function of the thread pitch and taper. The degree of chamfer is such that the radial height of the chamfer (perpendicular to the connection longitudinal axis) is approximately equal to the step height between the chamfered stab flank and the preceding load flank. The height of the stab flank minus the height of the preceding thread load flank is typically called the step height.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A shows a schematic of a longitudinal cross-sectional view of one embodiment of the assembled connection of the present invention, wherein the connection comprises a locked double shoulder center-shoulder seal, a single run-out thread section on the pin member adjacent one side of the center shoulder seal and a full height lead-in



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thread section on the pin member adjacent the other side of the center shoulder seal, with corresponding thread configurations on the box member.

Figure 1B shows a schematic of a longitudinal cross-sectional view of the pin member shown in Figure 1A.

Figure 1C shows a schematic of a longitudinal cross-sectional view of the box member shown in Figure 1A.

Figure 2A shows a schematic of a longitudinal cross-sectional view of a second embodiment of the assembled connection of the present invention wherein the connection comprises a locked double shoulder configuration forming the center-shoulder seal and a set of run-out and run-in thread sections on each side of the center shoulder seal.

Figure 2B shows a schematic of a longitudinal cross-sectional view of the pin member shown in Figure 2A.

Figure 2C shows a schematic of a longitudinal cross-sectional view of the box member shown in Figure 2A.

Figure 3A shows a schematic of a longitudinal cross-sectional view of a third embodiment of the assembled connection of the present invention, wherein the connection comprises a locked double shoulder center-shoulder seal and a double set of run-out and run-in thread sections, with one set being adjacent to the center-shoulder seal and the other set being disposed at the terminal ends of the pin and box members.

Figure 3B shows a schematic of a longitudinal cross-sectional view of the pin member shown in Figure 3A.

Figure 3C shows a schematic of a longitudinal cross-sectional view of the box member shown in Figure 3A.

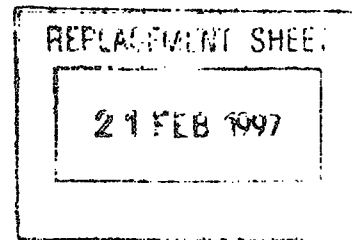


Figure 4A shows a schematic of a longitudinal cross-sectional view of a fourth and most preferred embodiment of the assembled connection, wherein the connection comprises a locked double shoulder center-shoulder seal, a double set of run-out and run-in thread sections, and the preferred thread profile (a single hook, variable-width thread having chamfered stab flanks).

Figure 4B shows a schematic of a longitudinal cross-sectional view of the pin member shown in Figure 4A.

Figure 4C shows a schematic of a longitudinal cross-sectional view of the box member shown in Figure 4A.

Figure 5A shows a schematic of an enlarged view of the longitudinal cross-section of one embodiment of the locked double shoulder center-shoulder seal, in the form of the assembled connection shown in Figure 1A.

Figure 5B shows a schematic of a longitudinal cross-sectional view of the pin member of Figure 5A.

Figure 5C shows a schematic of a longitudinal cross-sectional view of the box member shown in Figure 5A.

Figure 6A shows a schematic of a longitudinal cross-sectional view of a portion of a section of double hook thread profile of the present invention having a negative load flank angle and a positive stab flank angle.

Figure 6B shows a schematic of a longitudinal cross-sectional view of a single hook thread profile of the present invention having a negative load flank angle and zero degree (right angle) stab flank.

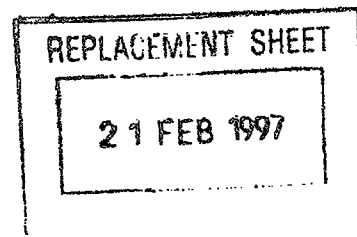


Figure 6C shows a schematic of a longitudinal cross-sectional view of a conventional single hook thread profile of the present invention having a negative load flank angle and a negative stab flank angle.

Figure 6D shows a schematic of a longitudinal cross-sectional view of a preferred double hook thread profile of the present invention having a negative load flank angle and a stab flank angle which is slightly positive, approaching zero degrees.

Figure 7 shows a schematic of a longitudinal cross-sectional view of a preferred single hook thread profile of the present invention having a negative load flank angle, a zero degree (right angle) stab flank and a chamfered stab flank. Most preferably this thread profile would be a variable width thread, wherein the thread on each member changes progressively in axial width.

Figure 8A shows a schematic of a longitudinal cross-sectional view of the assembled connection of Figure 2, but with the thread having the double hook thread profile shown in Figure 5A, and having different leads in the load and stab flanks, thereby producing a variable thread crest/root width on each thread.

Figure 8B shows a schematic of a longitudinal cross-sectional view of a portion of the double hook threaded profile of the pin and box members shown in Figure 8A.

Figure 9A shows a schematic of a longitudinal cross-sectional view of the assembled connection of Figure 3, but with the thread having the single hook thread profile.

Figure 9B-9D show a schematic of a longitudinal cross-sectional area of a portion of the single hook thread profile of the pin and box members shown in Figure 9A.

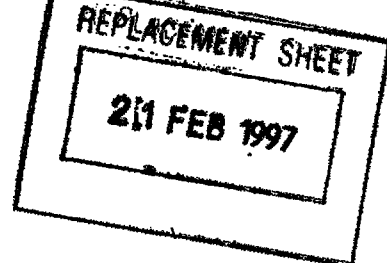


Figure 10A shows a schematic of an enlarged view of the longitudinal cross-section of the more preferred embodiment of the locked double shoulder center-shoulder seal as used in the assembled connection shown in FIG. 4A.

Figure 10B shows a schematic of a longitudinal cross-sectional view of the pin member of Figure 10A.

Figure 10C shows a schematic of a longitudinal cross-sectional view of the box member of Figure 10A.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The tubular connection of the present invention is applicable broadly for use in joining pipes, couplings and the like, but will be described in terms of oil industry tubular connections, since this is one of the highest value uses for the invention. In particular the invention is most typically used in flush joint or slim line tubular connections, where it is desired to minimize any variation in the outside and inside diameter dimensions between the connections and the assembled tubular members. The two major uses for the connection of the present invention are as a flush joint liner, typically having a flush outside diameter, and a liner tie-back, typically a formed connection having a maximum of +3.5% variation in outside diameter.

The tubular connection of the present invention utilizes a center seal (between at least two threaded sections of connection) to prevent fluids (liquids or gases) from passing through (across the threads of) the connection. The preferred embodiments of the invention will be described as having a locked double shoulder center shoulder seal, which will be described in detail subsequently. However, other center seal designs such as, for example, square shoulder, hook shoulder, square shoulder with frustrum seal, and annular shoulder can be used in the stabilized center-shoulder-sealed tubular connection of the present invention.

In accordance with the present invention, the center shoulder seal is stabilized so that it can withstand various forces placed on the assembled length of tubulars without significant damage to and/or leakage through the seal. The stabilization is provided by

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using various combinations of thread sections adjacent to the center shoulder seal. In particular, stabilization of the center shoulder seal is achieved using at least one run-out section of thread adjacent to the center shoulder seal configuration of each connection member. The run-out section of thread on one connection member is typically used in combination with a run-in section of thread on the corresponding connection member. However, a run-out section of thread on one connection member can be used in combination with a full height lead-in thread on the corresponding connection member.

Figures 1 through 4 illustrate four different preferred embodiments of the connection of the present invention. Each of the four preferred connections illustrated in Figures 1-4, have certain common features which will now be described with respect to embodiment one of Figure 1. Referring now to Figures 1A, 1B and 1C, the pipe joint or threaded connection of the present invention, generally designated 100 in Figure 1A, includes a pin member 102 formed on the end of tubular member 103 and a box member 106 formed on the end of another tubular member 107. Either one or both of the tubular members 103, 107 define a longitudinal axis 14 (see Figures 8A or 9A) which is the longitudinal centerline of the connection 100. The box member 106 has an internal thread structure formed therein and is adapted to interengage a complementary external thread structure formed on pin member 102, for mechanically connecting tubular members 103 and 107 which form a part of a string of tubular pipe (not shown). Connection 100 further includes a center shoulder seal 104 located at approximately the longitudinal mid-point of connection 100. The external thread structure of the pin member 102 extends from its pin nose or leading terminal end 105 to a location 109 adjacent first center shoulder configuration 119 and then continues on the other side 111 of first center shoulder configuration 119 to the end of the external threads at the trailing terminal end 113 of connection 100. The complementary internal thread structure of the box member 106 extends from the box leading terminal end 115 to a location 117 adjacent second center shoulder configuration 108 and then continues at the other side 121 of second center shoulder configuration 108 to the end of the internal threads at trailing terminal end 123 of connection 100.

The center shoulder seal shown on connection 100 at 104, disposed between matched sets of connection threaded sections, prevents fluids (liquids or gases) from passing through (across the threads of) the connection. The preferred embodiments of

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the invention will be described as having a locked double shoulder center-shoulder seal, which will be described in detail subsequently. However, other center seal designs such as, for example, square shoulder, hook shoulder, square shoulder with frustrum seal, and annular shoulder can be used in the stabilized center-shoulder-sealed tubular connection of the present invention.

Referring again to Figure 1, which illustrates embodiment one of the present invention, tubular connection 100, the center shoulder seal 104 is a locked double shoulder made up from a first center shoulder configuration 119 on pin member 102 and a second center shoulder configuration 108 on box member 106. The center-shoulder-seal-stabilizing thread sections (run-out thread sections) on each connection member are located on pin member 102 at 110 and on box member 106 at 114. With reference to pin member 102, run-out thread section 110, adjacent shoulder seal configuration 119, extends from position 109 adjacent seal configuration 119 to intersect full height tapered thread section 126 which extends to pin 102 leading terminal end 105. With reference to box member 106, run out thread section 114, adjacent shoulder seal configuration 108, extends from position 117 adjacent seal configuration 108 to intersect full height tapered thread section 128 which extends to box 106 leading terminal end 115. The complementary thread section which interengages run-out thread section 110 on pin member 102 is full height lead-in thread section 112 on box member 106. The complementary thread section which interengages run-out thread section 114 on box member 106 is full height lead-in thread section 116 on pin member 102. The full height lead-in thread sections 112 and 116 on box member 106 and pin member 102, respectively extend as full height thread sections 124 and 122, respectively,, providing full height tapered threads to the end of these threaded sections at 123 and 113, respectively. The taper on threaded sections extending from leading terminal ends 105 and 115 of pin 102 and box 106, respectively, is slightly greater than the taper on threaded sections 112-124 and 116-122, which extend toward the trailing terminal ends 123 and 113 of box 106 and pin 102, respectively.

Upon assembly of connection 100, run-out thread section 110 of pin member 102 is interengaged with full height lead-in thread section 112 of box member 106 and full height thread section 126 of pin member 102 is interengaged with the full height thread section 124 of box member 106. Upon assembly of connection 100, run-out thread

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section 114 of box member 106 is interengaged with full height lead-in thread section 116 of pin member 102 and full height thread sections 128 of box member 106 interengage with full height thread section 122 of pin member 102.

Pin member 102 comprises a thread relief groove 118 between full height lead-in thread section 116 and first center-shoulder configuration 119. Corresponding box member 106 comprises a thread relief groove 120 between full lead-in thread section 112 and second center-shoulder configuration 108. The thread relief groove facilitates machining the full height lead-in threads 116, 122 on pin member 102 and 112, 124 on box member 106, and enables complete complementary engagement of any corresponding thread profile. Relief grooves 118, 120 also provide a depository for thread compound and ensure that there is no hydraulic lockup of the thread.

Helical full height thread sections 112-124 and 116-122 are machined on a constant taper relative to the longitudinal axis of connection 100. Helical full height thread sections 126 and 128 are also machined on a constant taper relative to longitudinal axis 14 of connection 100. However, the taper of these latter thread sections is greater than the taper of their corresponding member thread sections 112-124 and 116-122, respectively, to provide reduced stress at the terminal ends of connection 100 upon assembly. Thread sections 110 and 114 are run-out thread sections which are machined having thread crest construction lines parallel to longitudinal axis 14 of connection 100 and having thread root construction lines machined on the constant taper with respect to the longitudinal axis. However, individual crest surfaces and individual root surfaces typically are machined parallel to the connection longitudinal axis. It is possible to leave individual run-in truncated thread crests on a taper, but preferred to machine them to be parallel to the connection longitudinal axis.

Upon assembly, the interengaged connection 100 exhibits complete complementary engagement of run-out thread sections 110 and 114, each located on that side of center-shoulder seal 104 at which each connection member wall thickness is less, namely thin wall sections 130, 132, respectively. In addition, a slight interference fit is provided in the threads to assure maximized interengagement of the threads. In an interference fit, at corresponding engagement points on the pin and box members 102 and 106, the pin member 102 is machined slightly larger than the box member 106. Interference fit tapered threads are well established in the art. Complete complementary engagement of

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the run-out thread section provides a more efficient connection by completely using the available thread flank bearing surfaces, while simultaneously providing limitation of the stresses generated at the thin wall sections 130 on pin member 102 and 132 on box member 106. In addition, the run out thread sections at these locations on the pin and box members permit maintenance of maximum connection wall thickness in the areas, adjacent center shoulder 104, thereby providing a more efficient connection.

For purposes of illustration, embodiment one of the invention has been shown in Figure 1 with a single hook thread profile having a negative load flank angle and a negative stab flank angle; the crests and roots of individual, threads are parallel to the connection longitudinal axis. Thread profiles other than a single hook can be used as well, as hereinafter described.

For purposes of comparison with the prior art, embodiment one of the present invention, in the structure of a +3 percent over pipe body diameter, formed-box slim line connection, exhibits an efficiency (strength of connection (joint)/strength of pipe) of about 85 %, compared with the best known +3 percent formed box connection in the industry, which exhibits an efficiency of only about 75 %. When the structure is a flush-joint connection, embodiment one of the present invention provides an efficiency of about 75 % compared with the best known-in-the industry flush-joint connection efficiency of 65 %.

Referring now to Figure 2A, which illustrates embodiment two of the present invention connection, tubular connection 200 is made up from pin member 202 machined on the exterior end of tubular 203 and from box member 206 machined on the interior end of tubular 207. The center shoulder seal 204 of tubular connection 200 is a locked double shoulder configuration, formed from a first center shoulder configuration 219 on pin member 202 and from second center shoulder configuration 208 on box member 206.

Figure 2B, which shows pin member 202, comprises run-out thread section 210 which extends from a location 209 adjacent first center shoulder configuration 219 on the thin-walled portion 230 of pin member 202 to thread section 226 of full height tapered thread which extends to leading end 205 of pin member 202. Pin member 202 also comprises run-in thread section 216 which extends from a location 211 adjacent first center shoulder configuration 219 on the thick-walled portion of pin member 202 to

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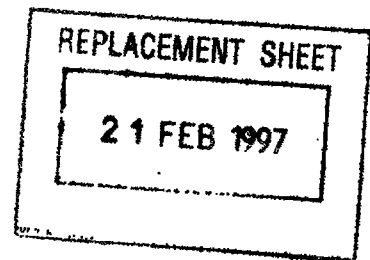
thread section 212 of full height tapered thread which extends to trailing end 213 of pin member 202.

Figure 2C, which shows box member 206, comprises run-out thread section 214 which extends from a location 217 adjacent second center shoulder configuration 208 on the thin-walled portion 232 of box member 206 to thread section 228 of full height tapered thread which extends to leading end 215 of box member 206. Box member 206 also comprises run-in thread section 222 which extends from a location 221 adjacent second center shoulder configuration 208 on the thick-walled portion of box member 206 to thread section 224 of full height tapered thread which extends to trailing end 223 of box member 206.

Upon assembly of connection 200, run-out thread section 210 of pin member 202 interengages run-in thread section 222 of box member 206 and full height threads 226 of pin member 202 interengage full height threads 224 of box member 206. In addition, run-out thread section 214 of box member 206 interengages run-in thread section 216 of pin member 202 and full height thread section 228 of box member 206 interengages full height thread section 212 of pin member 202.

Helical full height thread sections 212 and 226 on pin member 202 and full height thread sections 224 and 228 on box member 206 are machined on a constant taper with respect to the longitudinal axis of connection 200, but having the individual surfaces of their roots and crests parallel to the longitudinal axis of connection 200. Run-out thread section 210 on pin member 202 has its minor diameter (roots) machined on a continuation of the constant taper of the minor diameter of adjacent full height thread section 226, while its major diameter (crests) is machined parallel to the connection 200 longitudinal axis. Run-in thread section 216 on pin member 202 has its minor diameter (roots) machined parallel to the connection 200 longitudinal axis, while its major diameter (crests) is machined as a continuation of the constant taper of the major diameter of adjacent full height thread section 212. Corresponding run-out and run-in thread sections of box member 206 are constructed in like manner, with the roots forming the major diameter and the crests forming the minor diameter.

Although sequential thread crests and roots are machined as described above, individual crest and root surfaces are typically machined parallel to the longitudinal axis of the connection. The exception to this is run-in thread sections, wherein the individual



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crest surfaces can be machined as a continuation of the constant taper of the major diameter of adjacent full height threads or can be machined parallel to the connection longitudinal axis. Individual crest surfaces machined parallel to the connection longitudinal axis are preferred. As with connection 100 shown in Figure 1, the tapers of full height threaded sections 226 of pin 202 and 228 of box 206 are greater than the tapers of corresponding full height thread sections 224 of box 206 and 212 of pin 202, respectively.

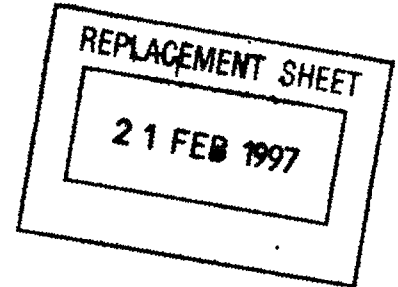
Also, for purposes of illustration, embodiment two of the invention has been shown in Figure 2 with a single hook thread profile having a negative load flank angle and a zero degree stab flank angle; however, other thread profiles can be used as well as hereinafter described.

In embodiment two, wherein a set of run-out, run-in thread sections is used adjacent each side of the center-shoulder seal 204, there is minimal unused (nonengaged) thread surface in the assembled thread sections. The connection 200 exhibits complete complementary engagement of the corresponding run-out and run-in thread section pairs, making these tapered threads highly efficient and providing even greater stabilization of the center-shoulder seal 204 than that provided in embodiment one shown in Figure 1.

For comparison purposes with the prior art, embodiment two of the present invention shows approximately the same improvement in efficiency over the known prior art as that exhibited by embodiment one shown in Figure 1.

Referring now to Figure 3A, which illustrates embodiment three of the present invention connection, tubular connection 300 is made up from pin member 302 machined on the exterior end of tubular 303 and from box member 306 machined on the interior end of tubular 307. The center shoulder seal 304 of tubular connection 300 is a locked double shoulder configuration, formed from first center shoulder configuration 319 on pin member 302 and from second center shoulder configuration 308 on box member 306.

Figure 3B, which shows pin member 302 comprises run-out thread section 310 which extends from a location 309 adjacent first center shoulder configuration 319 on the thin-walled portion 330 of pin member 302 to thread section 326 of full height tapered thread, which extends to run-in thread section 334 which extends to leading end 305 of pin member 302. Pin member 302 also comprises run-in thread section 316 which extends from a location 311 adjacent first center shoulder configuration 319 on the thick-



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walled portion of pin member 302 to thread section 312 of full height tapered thread, which extends to run-out thread section 336 which extends to trailing end 313 of pin member 302.

Figure 3C, which shows box member 306, comprises run-out thread section 314 which extends from a location 317 adjacent second center shoulder configuration 308 on the thin-walled portion 332 of box member 306 to thread section 328 of full height tapered threads, which extends to run-in thread section 338 which extends to leading end 315 of box member 306. Box member 306 also comprises run-in thread section 322 which extends from a location 321 adjacent second center shoulder configuration 308 on the thick-walled portion of box member 306 to thread section 324 of full height tapered thread, which extends to run-out thread section 340 which extends to trailing end 323 of box member 306.

Upon assembly of connection 300, run-out thread section 310 of pin member 302, interengages run-in thread section 322 of box member 301, full height thread section 326 of pin member 302 interengages full height thread section 324 of box member 306, and run-in thread section 334 of pin member 302 interengages run-out thread section 340 of box member 306. In addition, run-out thread section 314 of box member 306 interengages run-in thread section 316 of pin member 302, full height thread section 328 of box member 306 interengages full height thread section 312 of pin member 302, and run-in thread section 338 of box member 306 interengages run-out thread section 336 of pin member 302.

Helical full height thread sections 312 and 326 on pin member 302 and 324 and 328 on box member 306 are on a constant taper with respect to the longitudinal axis of connection 300, but having the individual surfaces of their roots and crests parallel to the longitudinal axis of connection 300. Run-out thread sections 310 and 336 on pin member 302 and run-out thread sections 314 and 340 on box member 306 have their roots machined on a continuation of the constant taper of the adjacent full height thread sections. Run-out thread sections 310 and 336 on pin member 302 and run-out thread sections 314 and 340 on box member 306 have their crests machined parallel to the longitudinal axis of connection 300. Run-in thread sections 316 and 334 on pin member 302 and run-in thread sections 322 and 338 on box member 306 have their roots machined parallel to the longitudinal axis of connection 300, while their crests are

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machined on a continuation of the constant taper of the respective major or minor diameter of the adjacent full height thread sections.

Embodiment three of the invention shown in Figure 3 exhibits a double hook thread profile; however, other thread profiles can be used as well, as hereinafter described.

This double set of run-out and run-in threads (one set adjacent the center-shoulder seal 304 and a second set at the terminal ends of connection 300) provides maximum joint efficiency and maximum stability for center-shoulder seal 304 of the connection 300. The double set of run-out and run-in threads also provides the smoothest load transfer between pin and box members 302, 306, respectively, thereby not only increasing the connection's rated load capacity but also its overload capacity (i.e., safety factor).

For comparison purposes with the prior art, embodiment three of the present invention, in the structure of a +3.5 percent over pipe body diameter, formed box slim line connection exhibits an efficiency (strength of connection (joint)/strength of pipe) of about 95%. When the structure is a 3 percent formed box connection, the efficiency decreases to about 90%. The best known-in-the-industry +3 percent formed box connection provides only a 75% efficiency.

Regarding the above-described embodiment three of the present invention, in the structure of a flush outside diameter connection, the efficiency provided is about 77%. The best known-in-the-industry flush connection provides only a 65% efficiency.

Referring now to Figure 4A, which illustrates embodiment four of the present invention connection, tubular connection 400 is made up from pin member 402 machined on the exterior end of tubular 403 and from box member 406 machined on the interior end of tubular 407. The center shoulder seal 404 of tubular connection 400 is a locked double shoulder configuration, formed from first center shoulder configuration 419 on pin member 402 and from second center shoulder configuration 408 on box member 406.

Figure 4B, which shows pin member 402 comprises run-out thread section 410 which extends from a location 409 adjacent first center shoulder configuration 419 on the thin-walled portion 430 of pin member 402 to thread section 426 of full height tapered thread, which extends to run-in thread section 434 which extends to leading end 405 of pin member 402. Pin member 402 also comprises run-in thread section 416 which extends from a location 411 adjacent first center shoulder configuration 419 on the thick-

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walled portion of pin member 402 to thread section 412 of full height tapered thread, which extends to run-out thread section 436 which extends to trailing end 413 of pin member 402.

Figure 4C, which shows box member 406, comprises run-out thread section 414 which extends from a location 417 adjacent second center shoulder configuration 408 on the thin-walled portion 432 of box member 406 to thread section 428 of full height tapered threads, which extends to run-in thread section 438 which extends to leading end 415 of box member 406. Box member 406 also comprises run-in thread section 422 which extends from a location 421 adjacent second center shoulder configuration 408 on the thick-walled portion of box member 406 to thread section 424 of full height tapered thread, which extends to run-out thread section 440 which extends to trailing end 423 of box member 406.

The principal difference between this fourth embodiment of the invention and the third embodiment illustrated in Fig. 3 lies in the thread profile. The thread profile of this fourth embodiment is a specialized self-centering thread profile wherein the stab flank of all full-height threads is chamfered, as shown in Fig. 7 and described in detail subsequently with reference to Fig. 7. Thus, each stab flank of full-height thread sections 412 and 426 of pin member 402 and each stab flank of full-height thread sections 424 and 428 of box member 406 is chamfered. The chamfer width (axial distance) is preferably about 0.005 inches or less and the chamfer height (perpendicular to the connection or member longitudinal axis) is approximately equal to the step height (height of the stab flank minus the height of the preceding thread load flank). Presence of this chamfer on the stab flank of all full-height threads on both pin member 402 and box member 406 results in a self-centering action upon assembly of connection 400; in particular, the self-centering action occurs during the initial telescoping (stabbing) of pin member 402 into box member 406.

Upon initial assembly of connection 400, after initial telescoping, the stab flanks of pin member 402 threads come to rest on the stab flanks of box member 406 with the chamfered portion of the stab flanks providing the self-centering action described above. Upon completion of assembly, to power tight position, run-out thread section 410 of pin member 402, interengages run-in thread section 422 of box member 401, full height thread section 426 of pin member 402 interengages full height thread section 424 of box

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member 406, and run-in thread section 434 of pin member 402 interengages run-out thread section 440 of box member 406. In addition, run-out thread section 414 of box member 406 interengages run-in thread section 416 of pin member 402, full height thread section 428 of box member 406 interengages full height thread section 412 of pin member 402, and run-in thread section 438 of box member 406 interengages run-out thread section 436 of pin member 402. At power tight position, the load flanks, roots and crests of full-height threads of each member are in sufficient contact to provide sealing engagement, while the stab flanks of these threads exhibit a slight clearance (typically about 0.002 inches).

Helical full height thread sections 412 and 426 on pin member 402 and 424 and 428 on box member 406 are machined on a constant taper with respect to the longitudinal axis of connection 400, but having the individual surfaces of their roots and crests parallel to the longitudinal axis of connection 400. Run-out thread sections 410 and 436 on pin member 402 and run-out thread sections 414 and 440 on box member 406 have their sequential roots machined on a continuation of the constant taper of the adjacent full height thread sections. Run-out thread sections 410 and 436 on pin member 402 and run-out thread sections 414 and 440 on box member 406 have their sequential crests machined parallel to the longitudinal axis of connection 400. The individual root and crest surfaces of run-out thread sections are machined parallel to the connection longitudinal axis. Run-in thread sections 416 and 434 on pin member 402 and run-in thread sections 422 and 438 on box member 406 have their sequential roots machined parallel to the longitudinal axis of connection 400, while their sequential crests are machined on a continuation of the constant taper of the respective major or minor diameter of the adjacent full height thread sections. Although the individual root surfaces of these run-in thread sections are machined parallel to the connection (connection member) longitudinal axis, the individual crests can be machined either on a taper or parallel to the connection longitudinal axis, as previously discussed with reference to run-in thread sections.

Embodiment four of the invention, shown in Figure 4 exhibits a thread profile having a chamfered stab flank with a positive stab flank angle of less than about 2 degrees, with reference to a line perpendicular to the preceding individual thread root (and the connection longitudinal axis). The load flank angle is a negative angle of about

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3 degrees or less. In the most preferred embodiment of the invention, the stab flank angle is zero degrees and the load flank angle is a negative angle of about 3 degrees.

The efficiency of the connection illustrated in Figure 4 is essentially the same as that of the connection illustrated in Figure 3.

Figure 5A is an enlarged view of a center-shoulder seal 500 which is shown in embodiment one of Figure 1. Assembled center shoulder seal 500 is a locked double shoulder seal made up from first center shoulder configuration 510 on pin member 514 and from second center shoulder configuration 530 on box member 534. Thread relief groove 512 on pin member 514 and thread relief grooves 532 on box member 534 are made necessary by the use of full height lead-in threads 526 on pin member 514 and full height lead in threads 546 on box member 534, respectively. When full height lead-in threads are not used, for example in embodiments two, three or four (as illustrated by connections 200, 300 and 400), use of thread relief grooves is optional. The thread profile shown in Figure 5A is a preferred double hook of the kind shown in Figure 6D.

Figures 5B and 5C show first center shoulder configuration 510 of pin member 514 and second center shoulder configuration 530 of box member 534, respectively. Each connection member comprises a ramp, 516 on pin 514 and 536 on box 534. Connection pin member 514 center shoulder configuration 510 comprises shoulder 520 having first undercut surface 528, first sealing surface 518 and fourth sealing surface 522. Connection box member 534 center shoulder configuration 530 comprises shoulder 540 having second undercut surface 548, second sealing surface 542 and third sealing surface 538.

Upon assembly of center shoulder seal 500, first sealing surface 518 on shoulder 520 of pin configuration 510 is lined up by and guided into position on corresponding first ramp 536 of box center shoulder configuration 530. Simultaneously, second sealing surface 542 on shoulder 540 of box center shoulder configuration 530 is lined up by and guided into position on corresponding second ramp 516 of pin center shoulder configuration 510. As the assembly progresses, a metal-to-metal seal is created as first sealing surface 518 on shoulder 520 moves into place against third sealing surface 538 on box center shoulder configuration 530. Simultaneously, a metal-to-metal seal is created as second sealing surface 542 on shoulder 540 moves into place against fourth sealing surface 522 on pin center shoulder configuration 510. As shoulders 520 and 540

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move into position, typically they begin to bend slightly, closing the gap between surface 524 on first center shoulder configuration 510 and surface 544 on second center shoulder configuration 530, thereby producing a zero clearance or metal-to-metal surface seal between at least a portion of surfaces 524 and 544. This latter zero clearance or metal-to-metal seal will not occur if there is substantial (greater than 0.005 in.) clearance between surface 524 and surface 544 prior to the above-described bending action.

Upon final power tightening (torquing) of the assembled connection, the leading surface of shoulder 520 contacts first undercut surface 548 on box center shoulder configuration 530, while the leading surface of shoulder 540 contacts second undercut surface 528 on pin center shoulder configuration 510, thereby creating two additional zero clearance sealing surfaces.

Thus, a combined total of at least two (2) and possibly three (3) metal-to-metal zero clearance seals are created during assembly (make-up) of the connection: two metal-to-metal seals at the exterior beveled edges of the locked double shoulder seal 500 where sealing surfaces 518 and 538 are in contact and where sealing surfaces 522 and 542 are in contact; and, a metal to metal sealing surface at the interior of the locked double shoulder seal 500, one at the wall surface where sealing surfaces 524 and 544 contact. Zero clearance seals are obtained where the face surface of pin shoulder 520 contacts box undercut surface 548, and where the face surface of box shoulder 540 contacts pin undercut surface 528. Thus, center-shoulder seal 500 forms multiple metal-to-metal seals, having mating metal-to-metal sealing surfaces which allow a build-up of stored energy within the seal upon power tightening of the assembled connection, such that upon the application of various loads on the pipe and also the connection, the seal will continue to perform and maintain sealing engagement. Further, several zero clearance seals are provided, which combined with the metal to metal seals further prevents leakage under the various conditions of loading to which the connection may be subjected.

Typically a thread compound will be used on the surfaces of the threaded connection and this thread compound will bridge any surface defects and clearances less than about 0.005 inches, to provide an improved sealing capability. Such a thread compound will assist the intended metal-to-metal, zero clearance seals described above should surface defects or machining tolerances result in a clearance between metal surfaces of less than about 0.005 inches. A thread compound can also provide a

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hydraulic seal between surfaces which do not exhibit zero clearance after power tight make-up of the connection. For example, hydraulic seals can be provided between surfaces 529 of pin 514 and 537 of box 534 as well as between surfaces 517 of pin 514 and 549 of box 534 using thread compound. Additional hydraulic seals can be provided for each step of connection threads, since the thread surfaces which do not exhibit metal-to-metal contact are close fit surfaces which can be bridged using thread compound.

A description of the location and dimensions of the present invention locked double shoulder center seal relative to the cross-sectional area of the connection follows. It is desirable to balance the cross-sectional areas of the tubular walls which make up the connection in the area of the locked double shoulder seal, thus providing a more efficient connection. The formula which follows permits calculation of the preferred diameter of a circle formed by the radial center of the locked double shoulder seal (radial center relative to the longitudinal axis of the connection). This preferred diameter is essentially equal to the connection outside diameter squared plus the connection inside diameter squared minus the constant k , all divided by two, with the square root being taken of the result. The constant k is equal to two times the squared height of interlocked shoulders 520 and 540. As shown on Figure 5A, the radial center of the locked double shoulder seal is located at contacting surfaces 524 and 544 of shoulder 520 and shoulder 540, respectively. The height of interlocked shoulders 520 and 540 is dimension 552. The minimum height 552 of interlocked shoulders 520 and 540 is a function of the wall thickness of the tubular (pipe) used to form the connection. Typically the radial height 552 of interlocked shoulders 520 and 540 is two to three times the longitudinal width, dimension 554 on Figure 5A, of shoulders 520 and 540. In addition, the height 552 of the cross section of interlocking shoulders 520 and 540 is typically 1/4 to 1/3 of the tubular member (pipe) wall thickness.

The connection of the present invention establishes a constant bearing force on the various seals provided by the center-shoulder seal 500. Not only do the curving edges of locked double shoulder seal 500 at 518, 538 and 522, 542 interferingly engage to form a metal-to-metal seal, but upon power tightening of the connection, the facing surface of shoulder 520 in contact with undercut surface 548 and the facing surface of shoulder 540 in contact with undercut surface 528 are loaded and the annular contact between surfaces 524 and 544 typically establishes a seal due to a bending reaction on the shoulders from

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the seal 518 contacting seal 538 and seal 542 contacting seal 522 and from the Poisson's effect of the metal upon final power tightening.

A more preferred locked double shoulder configuration than that shown in FIGS. 5A-5C is described subsequently with reference to FIGS. 10A-10C.

Other center shoulder designs which are known in the art can also be stabilized using the adjacent run-out, run-in thread section constructions described above. Examples of other center seal designs which can be stabilized include, not by way of limitation, square shoulders; hook shoulders (wherein the shoulder exhibits at least one negative angle relative to the connection longitudinal axis); square shoulders with a frustrum seal; annular shoulders (shoulder on a taper with the connection longitudinal axis); shoulders comprising grooves or an annulus having an axial undercut which employ a sealing sleeve, ring or annulus; and shoulders designed to extrude a portion of their mass laterally into adjacent grooves upon assembly of the connection.

Figures 6A through 6D illustrate four preferred thread profiles for use in combination with the other features of connections of the present invention.

For convenience and accuracy of description, the following geometric conventions will be used in describing the angles of the load and stab flanks of the threads of the present invention. The angle α represents the stab flank angle and the angle β represents the load flank angle of the threads. These angles are defined in geometric terminology with reference to a line constructed perpendicular to the longitudinal axis of the connection (tubular) and at the root of the thread flank. A degree of a negative flank angle is the rotation, in degrees, of the perpendicular line in the counterclockwise direction to meet the thread flank. A degree of positive flank angle is the rotation in degrees of the perpendicular line in the clockwise direction to meet the thread flank. These conventions for defining stab and load flank angles do not necessarily comport with the general conventions used in machining pipe threads.

Figure 6A illustrates corresponding pin 610 and box 630 cross-sectional profiles for a portion of full height double hook thread 600A. The double hook thread exhibits a negative load flank angle β and a positive stab flank angle α . The thread profile of full height threads from a portion of pin member 610 is shown as it would appear within a threaded tubular section of the present invention. Stab flank 612 forms a positive stab flank angle α with respect to a line perpendicular to root wall 616, which is parallel to

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the connection longitudinal axis 14, and load flank 614 forms a negative load flank angle β with respect to a line perpendicular to root wall 618, which is parallel to the connection longitudinal axis.

The thread profile of full height double hook threads from a portion of box member 630 is shown as it would appear within a threaded tubular section of the present invention. For example, in a manner similar to the pin thread, stab flank 632 forms a positive angle α with respect to a line perpendicular to root wall 636, and load flank 634 forms a negative angle β with respect to a line perpendicular to root wall 636. To permit interengagement of the double hook threads of pin member 610 with the double hook threads of box member 630, it is necessary that the thread width be constantly increasing from the leading edge (edge initially telescoped into the box member) of pin member 610, and that the thread width be constantly decreasing (the root width be constantly increasing) from the corresponding edge of box member 630, as shown in Figure 6A. Thus, the thread profile crest widths 620 of pin member 610 are progressively lengthened, while the thread root widths 622 are progressively narrowed, with the reverse occurring on box member 630. One method of producing threads with such dimensions is to machine the thread stab flanks with a slightly greater (longer) lead than the load flanks. The amount of lead increase (ΔL) required to permit the threads to mesh (interengage) upon telescoping (stabbing) is a function of the thread taper (T) and the stab and load flank angles (α and β , respectively), and can be calculated according to the following formula:

$$\Delta L = 1/2 T (\tan | \alpha | + \tan | \beta |)$$

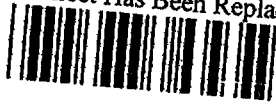
When there is more than one step of threads in the connection (for example, a two step thread wherein one section of threads is followed by a center-shoulder seal, followed by a second section of threads located at a greater axial distance from the longitudinal axis of the connection), the thread width can be constantly increasing from the leading edge of the pin member all of the way to the end of the connection; or, alternatively and preferably, the thread width is increased progressively within each step of threads, beginning with the minimum width thread at the pin leading edge step of threads and the minimum width thread beginning again at the forward edge of the second step of pin threads.

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The preferred double hook thread, in terms of mechanical performance, exhibits a positive stab flank angle and a negative load flank angle, the absolute sum of which (without regard to sign on the angle) ranges from about 5 degrees to about 20 degrees. Typically, the negative load flank angle does not exceed about 8 degrees and the positive stab flank angle does not exceed about 4 degrees. However, in terms of ease of machining and minimizing the lead adjustments, ΔL , the absolute sum of the positive stab flank angle and negative load flank angle should range from slightly greater than 0 degrees to less than 5 degrees, with the negative load flank angle ranging from about 1 degree to about 4 degrees. When this reduced absolute sum of load and stab flank angles is used, it is not necessary to use constantly increasing thread width to permit interengagement of connection member threads. Preferably the load flank angle is a larger (greater) absolute angle than the stab flank angle, since for thread profiles having crests and roots which are parallel to the connection longitudinal axis, the load flank length is less than the stab flank length, as can be observed in viewing load flank 614 and stab flank 612. Also, when the connection is operating under the most severe service conditions, the thread load flanks experience a greater applied force than the stab flanks.

Figure 6B illustrates corresponding pin 660 and box 670 cross-sectional profiles of one embodiment of single hook thread, 600B. The thread profile of full height threads from a portion of pin member 650 is shown as it would appear within the threaded tubular section of the present invention. The distinguishing feature of this embodiment of single hook thread is that its stab flank 652 exhibits a zero degree angle α with respect to a line perpendicular to both the connection longitudinal axis and the thread root wall, while its load flank 654 exhibits a negative angle β with respect to a line perpendicular to both the connection longitudinal axis and the thread root wall. For example, referencing the thread profile of pin member 650, stab flank 652 forms a right angle with reference to the connection longitudinal axis, or zero degree angle α with respect to a line perpendicular to root wall 656, while load flank 654 forms negative angle β with respect to a line perpendicular to root wall 658. In a corresponding manner, referencing the thread profile of box member 670, stab flank 672 forms a zero degree angle α with a line perpendicular to root wall 676, while load flank 674 forms a negative angle β with a line perpendicular to root wall 676.



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The single hook thread exhibits a negative stab flank angle which ranges from zero (0) degrees to about 45 degrees, and exhibits a negative load flank angle which ranges from greater than 0 degrees to about 15 degrees. If the load flank angle is a large negative angle, and the stab flank angle is less than the load flank angle, thereby producing thread crests wider than adjacent thread roots, the use of a constantly increasing thread width from the leading edge of the pin, as described above for a double hook thread, may be necessary to permit proper interengagement of the pin and box members of the connection upon initial telescoping (stabbing).

A more preferred single hook thread profile, due to ease of machining, is the profile wherein the negative load flank angle ranges from greater than 0 degrees to less than 5 degrees and the negative stab flank angle ranges from zero degrees to about 2 degrees, with the absolute sum of the angles being less than 5 degrees. When these reduced negative load flank and stab flank angles are used, it is not necessary to use constantly increasing thread width to permit interengagement of connection member threads. The necessary clearance is provided by making the thread crests narrower than the thread roots.

Figure 6C illustrates another thread profile embodiment 600C suitable for use in the connection of the present invention. This thread profile is particularly suitable for a connection having a center-shoulder seal (such as the locked double shoulder) in combination with a single run-out thread and full height lead-in thread on the corresponding member, on each side of the center-shoulder seal. The thread profile of full height threads from a portion of the pin member 690 is another embodiment of a single hook thread as it would appear within the threaded tubular section of the present invention. This particular embodiment of a single hook thread features a load flank 694 of pin member 690 thread which exhibits a large negative angle β and a stab flank 692 which exhibits a large negative angle α . Generally, angle α is greater than angle β , and consequently, dimensions can be formulated with flank to flank (load to stab) bearing threads, having clearance between thread roots and crests, for example, with clearance between root 696 of pin member 690 and crest 699 of box member 698. This is in contrast with the double hook thread of Figure 6A and the single hook thread of 6B, which are more suitable in a form wherein the thread roots and crests provide bearing surfaces with clearances between corresponding stab and load flanks. Flank to flank

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bearing threads of the kind shown in Figure 6C can be used to modify the interference in the run-out section of threads.

The angles of the single hook thread profile shown in 6C typically are such that the negative load flank angle ranges from about 5 degrees to about 15 degrees and the negative stab flank angle ranges from about 5 degrees to about 35 degrees, with the stab flank angle being larger than the load flank angle by about 10 to 15 degrees.

Figure 6D illustrates cross sectional profiles of a preferred double hook thread 600D. The preferred double hook thread exhibits a positive stab flank angle α ranging from nearly a zero degree angle to an angle of less than 2 degrees, and a load flank angle β which has been reduced to a small negative angle, ranging from nearly a zero degree angle to an angle of less than 5 degrees, with the absolute sum of the flank angles being less than 5 degrees. The thread profile of full height threads from a portion of pin member 680 is shown as it would appear within a threaded tubular section of the present invention. The distinguishing feature of the preferred double hook thread is that both its positive angle stab flank 682 and its negative angle load flank 684 exhibit a nearly zero degree angle with respect to a line perpendicular to the connection longitudinal axis and the thread root wall. For example, stab flank 682 forms an angle α which ranges from a right angle with reference to the connection longitudinal axis, up to a positive angle of less than 2 degrees with a line perpendicular to root wall 686; and, load flank 684 forms an angle β which ranges from a near right angle with reference to the connection longitudinal axis, up to a negative angle of less than 5 degrees with a line perpendicular to root wall 688. Corresponding box member 689 thread exhibits the same ranges of stab flank angle and load flank angle ranges as those just described. It is not necessary to use progressively increasing thread width to permit connection member thread interengagement (proper meshing after stabbing) when a preferred double hook thread profile of the kind shown in Figure 6D is used. This thread profile is essentially a modified square thread.

The most preferred thread profile for use in the present invention is one having a negative load flank angle and a zero degree or positive stab flank angle with a chamfered stab flank, which provides self-centering action upon initial telescoping of connection members. Typically a single hook thread profile (to which this thread profile is similar) requires a variable width thread to permit proper interengagement of the

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threads. Figures 7A-7C illustrate a thread profile having a negative load flank angle and a zero degree, chamfered stab flank in combination with a variable width thread. The thread profile of pin member 750 comprises a load flank 754 having a negative angle, β , and a chamfered stab flank 702 having a zero degree angle, α ; the chamfer 756 exhibits a width, ω , and a chamfer degree, η , is a function of thread pitch and taper. The height 758 of chamfer 756 is approximately equal to or less than the height of stab flank 752 minus the height of the preceding load flank 754, or the "step height." The thread profile of box member 770 comprises a load flank 774 having a negative angle, β , and a chamfered stab flank 772 having a zero degree angle, α ; the chamfer 776 exhibits a width, ω , and a chamfer degree, η , with a chamfer height which is the same as the chamfer height of pin member 750. Box member 770 chamfer width, degree, and height are determined in the manner described for the corresponding pin member 750, with the chamfer degree being a function of thread width and taper and the resulting chamfer height being approximately equal to or less than the step height. An increased chamfer height provides increased self-centering action and is preferred; however, a chamfer height greater than the step height provides no advantage. A chamfer width, ω , of less than 0.005 inches is preferred.

In sizing the connection of the present invention, the location of the radial centerline of the center-shoulder seal is determined with reference to the outside and inside diameters of the pipe. The fade out point of the connection thread sections is determined by the minimum required wall thickness at the terminal ends of the connection. The length of a thread section is a function of the angle of taper of the threads and the change in diameter of the thread. Since the thread sections on each side of the center-shoulder seal should bear approximately one-half of the load on the connection, the amount of engaged thread length may be calculated to ensure that the threads do not shear off under load. Knowing these parameters, one skilled in the art can then determine the thread taper.

Figure 8A illustrates an assembled tubular connection 800A of the present invention. Connection 800A includes a set of run-out, run-in threads, set 802 and set 804, on each side of a center-shoulder seal 810, which is shown as a locked double shoulder configuration. The thread profile shown is a double hook which is shown enlarged on a portion of pin member 820 and box member 830 in Figure 8B. Double

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hook threads having a positive stab flank angle α and a negative load flank angle β , the absolute sum of which is greater than about 8 degrees, require variable, constantly increasing thread crest width (i.e., a lead adjustment between the stab and load flanks) for proper meshing of the flanks, after the threads are telescoped, during hand tight make up. The use of variable width threads permits clearances between flanks in an assembled connection to be kept at a minimum (typically no more than about 0.003 inches). Thus, when a thread compound containing particulate matter is used during assembly of the connection, an additional seal can be formed between thread flanks due to the bridging action of the particles between flank clearances. Generally, such a seal can be formed only if the flank clearances are less than about 0.005 inches.

Figure 8B shows portions of pin member 820 and box member 830, respectively. Stab flank 822 of pin member 820 exhibits a positive angle α of about 5 degrees, for example, and load flank 824 exhibits a negative angle β of about 8 degrees, for example. The variable width full height thread profile shown on the portion of pin member 820 exhibits increasing crest width 825 which corresponds with the variable decreasing width thread on box member 830, which exhibits increasing root width 828.

When double hook threads having constant width crests and roots (not shown) are used in the connection of the present invention, a greater flank clearance (above 0.005 inches, depending on the design) is required, making sealing at the thread flanks uncertain. This creates a potential for fluid leakage across the threads. Consequently, either the preferred double hook thread profile wherein the absolute sum of the flank angles is less than 8 degrees or a conventional single hook thread profile must be used to achieve thread sealing when the thread profile exhibits constant width crests and roots.

Figure 9 illustrates another embodiment of an assembled tubular connection, 900A of the present invention. Connection 900A includes a double set of run-out, run-in threads, set 902 and set 904, adjacent center-shoulder seal 910 combined with a second set of run-out, run-in threads, set 906 and set 908, adjacent the terminal ends of the connection. Preferably center-shoulder seal 910 is a locked double shoulder configuration. Connection 900A is shown with a single hook thread profile, having a chamfered stab flank.

As shown in Figure 9B-9D the thread profile of a portion of pin member 950 includes a single hook thread having a stab flank 952 exhibiting a right angle with

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reference connection 900A longitudinal axis 14 (or a 0 degree angle α with reference to a line perpendicular to the longitudinal axis and to and root wall 966, and having a load flank 954 exhibiting a negative angle β with respect to a line perpendicular to the connection longitudinal axis 14 and thread root wall 968. The negative load flank angle β is preferably in the range from about 1 degree to about 10 degrees. The thread profile of box member 970 is complementary to that of pin member 950.

The most preferred embodiment of the present invention is connection 900A shown in Figures 9A-9D which utilizes a double set of run-out, run-in thread sections and a locked double shoulder center seal, but having a variable width thread with a single hook thread profile including a chamfered stab flank, as shown in Figures 9B-9D. This embodiment provides the smoothest flow of forces between the pin member 950 and box member 970; provides high tension efficiency; and, also provides excellent sealing engagement for preventing fluid penetration into the threads and through (across the threads of) the connection. The negative load flank of the single hook thread causes the two thread zones on each side of the center-shoulder seal move as a unit, and the chamfered stab flank provides self-centering action during initial telescoping of the pin member 950 into the box member 970.

The run-out, run-in thread sections of the present invention fade in the thread load gradually and then fade out the thread load gradually. Full height threads like those typically used in the prior art cause the thread load to abruptly increase, thereby transferring a large force abruptly, which in turn caused undesirable bending moments within the connection.

The tension efficiency of a connection depends upon the extent to which the pin and box member are formed. Generally, the more forming, the greater the efficiency which can be achieved. Thus, greater efficiencies may be achieved in slim line connections which may have up to a 3.5% greater outside diameter than that of the tubular pipe than can be achieved in flush joint connections which have the same outside diameter as the pipe.

The double set of run-in, run-out threads of connection 900A is preferred since this provides maximum utilization of available pipe wall without the waste of space in the form of clearances and gaps in the threads for which there is no complementary engagement. Further, it is desirable not to have wasted space in the form of relief

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grooves, cut-outs, or other metal reduction. However, the relief grooves of the kind shown at 118 and 120 of connection 100 are not critical because they are located in the larger cross-sectional areas of pin 102 and box 106. Thus, they do not become critical in the overall efficiency of the connection.

With the single hook thread profile, as shown in Figs. 9A-9D and recommended for use in connection 900A, an interference between the major and minor thread diameters, i.e. thread crests 964 of pin 950 and thread roots 984 of box 970, can be developed on power tight make up. Furthermore, interference between adjacent load flanks and minimal clearance between adjacent stab flanks can be provided on power tight make up. Any interferences of the roots and crests of the threads causes a hoop stress in the pin and box members 650 and 670, respectively. Consequently, upon power tight make-up, if any interference is present, the thread metal tends to move due to Poisson's effect causing the load flanks to butt up and engage. The interference will vary depending upon the pipe diameters and the grade of the pipe. With reference to Figure 9A, preferably, the diametrical interference is maximized at thread sections 902 and 904 adjacent center-shoulder seal 910 and is gradually reduced to a minimum at thread sections 906 and 908 at the terminal ends of connection 900A. This gradual reduction in diametrical interference is designed to protect the thin walled member thread sections such as 934 of pin member 950 at the terminal ends of the connection. The larger cross-sectional areas adjacent the center-shoulder seal 900A are more rigid and therefore can have greater diametrical interference and absorb greater hoop stress. The cross-sectional areas of both pin member 950 small step and the box member 970 large step adjacent each side of the center shoulder seal 910 are designed to be approximately equal. The inner diametrical interference between the thread crests and roots is controlled to achieve linear stresses in the greater cross-sectional area of the box and pin members as well as achieve linear stresses at the thinner cross-sectional areas of the pin and box members adjacent their terminal ends. A certain amount of diametrical interference is required to achieve a tight interengaging fit of the threads. The general rule is that the interference will vary between .001 and .002 inches per inch of diameter, with less interference at the terminal ends of the connection than adjacent the center-shoulder seal.

The preferred center seal is one that is isolated to the loads placed on the pipe string. In other words, center shoulder seal 910 of connection 900A should remain stable

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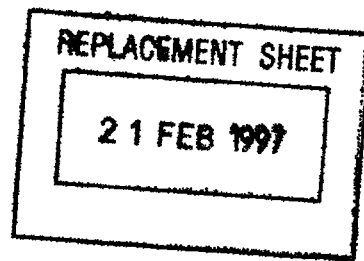
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and insensitive to varying loads placed on the connection. The locked double shoulder seal shown at 910 of connection 900A includes redundant sealing systems, i.e. a multiplicity of metal-to-metal seals, to achieve an effective sealing engagement such that the seal does not deactivate upon the application of various loads to the connection such as internal and external pressure, axial tension or compression, and torsional and bending moments.

Figure 10A is an enlarged view of a center shoulder seal 1000 which is shown in the embodiment of the overall connection of the present invention illustrated in Figure 4. Assembled center shoulder seal 1000 is a locked double shoulder seal made up from first center shoulder configuration 1010 on pin member 1014 and from second center shoulder configuration 1030 on box member 1034.

Figures 10B and 10C show first center shoulder configuration 1010 of pin member 1014 and second shoulder configuration of 1030 of box member 1034, respectively. Each connection member comprises a ramp, 1016 on pin 1014 and 1036 on box 1034. The center shoulder configuration 1010 of connection pin member 1014 comprises shoulder 1020 having first undercut surface 1028, first metal-to-metal sealing surface 1018, second metal-to-metal sealing surface 1022 and third metal-to-metal sealing surface 1024. The center shoulder configuration 1030 of connection box member 1034 comprises shoulder 1040 having second undercut surface 1048, fourth metal-to-metal sealing surface 1038, fifth metal-to-metal sealing surface 1042 and sixth metal-to-metal sealing surface 1044.

Upon assembly of center shoulder seal 1000, first sealing surface 1018 on center shoulder configuration 1010 of pin configuration 1014 is lined up and guided into position on corresponding first ramp 1036 of box center shoulder configuration 1030. Simultaneously, fifth sealing surface 1042 on box member center shoulder configuration 1030 is lined up and guided into position on corresponding second ramp 1016 of pin member center shoulder configuration 1010. As the assembly progresses, a metal-to-metal seal is created at three locations: between first sealing surface 1018 of pin center shoulder configuration 1010 and fourth sealing surface 1038 of pin center shoulder configuration 1030; between second sealing surface 1022 of pin center shoulder configuration 1010 and fifth sealing surface 1042 of box center shoulder configuration



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1030; and, between third sealing surface 1024 of pin center shoulder configuration 1010 and sixth sealing surface 1044 of box center shoulder configuration 1030.

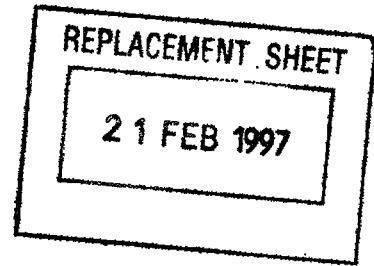
Upon final power tightening (torquing) of the assembled connection, the leading surface of shoulder 1020 contacts with first undercut surface 1048 on box member center shoulder configuration 1030, while the leading surface of shoulder 1040 contacts second undercut surface 1028 of pin member center shoulder configuration 1010, thereby creating two additional zero clearance sealing surfaces.

Thus, a total of three metal-to-metal seals and two zero clearance seals are created during assembly (make up) of the connection.

Typically a thread compound will be used on the threaded surfaces of the connection, as previously described, to bridge any surface defects and clearances less than about 0.005 inches.

The preferred embodiments of the present invention, as described above and shown in the Figures are not intended to limit the scope of the present invention, as demonstrated by the claims which follow, since one skilled in the art can, with minimal experimentation, extend the scope of the embodiments to match that of the claims.

CLAIMS



What is claimed is:

1. A tubular connection comprising at least two members, wherein each member comprises at least two threaded sections having a center seal configuration disposed between said at least two threaded sections, said connection also comprising: at least one stabilizing thread section present on each connection member adjacent said center seal configuration, said stabilizing thread section comprising a run-out thread.
2. The tubular connection of Claim 1, wherein said connection comprises two tubular members, each member having said run-out thread located adjacent said center shoulder seal configuration on that portion of the connection member at which the tubular wall thickness is less.
3. The tubular connection of Claim 1 or Claim 2, wherein the tubular member corresponding with the member having said run-out thread section includes full-height lead-in thread at its location corresponding with said run-out thread.
4. The tubular connection of Claim 3, wherein each connection member includes a thread relief groove located between said center-shoulder seal and said full height lead-in thread section.
5. The tubular connection of Claim 1 or Claim 2, wherein the tubular member corresponding with the member having said run-out thread section includes a run-in thread section at its location corresponding with said run-out thread section.
6. The tubular connection of Claim 1 or Claim 2, wherein each member's at least two threaded sections having a center seal configuration disposed between them are comprised of a two step thread.

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7. The tubular connection of Claim 3, comprising at least one additional stabilizing run-out thread section at an exterior edge of each connection member.

8. The tubular connection of Claim 4, comprising at least one additional stabilizing run-out thread section at an exterior edge of each connection member.

9. The tubular connection of Claim 5, comprising at least one additional stabilizing run-out thread section at an exterior edge of each connection member.

10. The tubular connection of Claim 1 or Claim 2 wherein said center-shoulder seal comprises a locked double shoulder configuration.

11. The tubular connection of Claim 3, wherein said center-shoulder seal comprises a locked double shoulder configuration.

12. The tubular connection of Claim 4, wherein said center-shoulder seal comprises a locked double shoulder configuration.

13. The tubular connection of Claim 5, wherein said center-shoulder seal comprises a locked double shoulder configuration.

14. The tubular connection of Claim 6, wherein said center-shoulder seal comprises a locked double shoulder configuration.

15. The tubular connection of Claim 7, wherein said center-shoulder seal comprises a locked double shoulder configuration.

16. The tubular connection of Claim 8, wherein said center-shoulder seal comprises a locked double shoulder configuration.

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17. The tubular connection of Claim 9, wherein said center-shoulder seal comprises a locked double shoulder configuration.

18. The tubular connection of Claim 1 or Claim 2, wherein the profile of said threaded sections is double hook or single hook.

19. The tubular connection of Claim 7, wherein the profile of said threaded sections is a double hook or a single hook thread profile and wherein the stab flank of full-height threads is chamfered.

20. The tubular connection of Claim 9, wherein the profile of said threaded sections is a double hook or a single hook thread profile, and wherein the stab flank of full-height threads is chamfered.

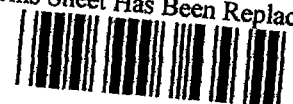
21. The tubular connection of Claim 15, wherein the profile of said threaded sections is a double hook or a single hook thread profile, and wherein the stab flank of full-height threads is chamfered.

22. The tubular connection of Claim 17, wherein the profile of said threaded sections is a double hook or a single hook thread profile, and wherein the stab flank of full-height threads is chamfered.

23. The tubular connection of Claim 1 or Claim 2, wherein the profile of said threaded sections is a double hook, and wherein the absolute sum of the positive stab flank and negative load flank angle is less than 5 degrees.

24. The tubular connection of Claim 9, wherein the profile of said threaded sections is a double hook, and wherein the absolute sum of the positive stab flank and negative load flank angle is less than 5 degrees.

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25. The tubular connection of Claim 17, wherein the profile of said threaded sections is a double hook, and wherein the absolute sum of the positive stab flank and negative load flank angle is less than 5 degrees.

26. The tubular connection of Claim 1 or Claim 2, wherein the profile of said threaded sections is a single hook, wherein the negative load flank angle is less than 15 degrees, and wherein the stab flank angle ranges from zero degrees to a negative angle of about 35 degrees.

27. The tubular connection of Claim 9, wherein the profile of said threaded sections is a single hook, wherein the negative load flank angle is less than 15 degrees, and wherein the stab flank angle ranges from zero degrees to a negative angle of about 35 degrees.

28. The tubular connection of Claim 17, wherein the profile of said threaded sections is a single hook, wherein the negative load flank angle is less than 15 degrees, and wherein the stab flank angle ranges from zero degrees to a negative angle of about 35 degrees.

29. The tubular connection of Claim 27, wherein said negative load flank angle is less than 4 degrees, wherein the absolute sum of said negative load flank angle and said stab flank angle is less than 5 degrees, and wherein said stab flank of full-height threads is chamfered.

30. The tubular connection of Claim 28, wherein said negative load flank angle is less than 4 degrees, wherein the absolute sum of said negative load flank angle and said stab flank angle is less than 5 degrees, and wherein said stab flank of full-height thread is chamfered.

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31. The tubular connection of Claim 1 or Claim 2 wherein said center-shoulder seal is selected from the group consisting of a locked double shoulder, square shoulder, hook shoulder, square shoulder with a frustrum seal, annular shoulders, shoulder comprising grooves or an annulus having an axial undercut, and shoulders designed to extrude a portion of their mass laterally into adjacent grooves upon assembly of the connection.

32. A tubular connection comprising two tubular members, wherein each connection member comprises threaded sections having a center shoulder seal configuration disposed between two of said threaded sections, each tubular member also comprising: a first run-out thread section adjacent said center shoulder seal configuration and located at the more thin-walled portion of said tubular member which is adjacent said center shoulder seal configuration; a second run-out thread section adjacent a terminal end of each tubular member, and located at the more thin-walled terminal end of said tubular member; and, corresponding run-in threaded sections on each tubular member, which run-in threaded sections are located to correspond with run-out threaded sections on the corresponding tubular member.

33. The tubular connection of Claim 32, wherein said center shoulder seal configuration comprises a locked double shoulder configuration.

34. A tubular connection comprising at least two members, each of which comprises a locked double shoulder configuration.

35. A tube and coupling connection wherein at least two members of said connection comprise a locked double shoulder configuration.

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36. A method of stabilizing a tubular connection which comprises at least two tubular members, with each member having at least two threaded sections and having a center seal configuration disposed between said at least two threaded sections, said method comprising:

utilizing a run-out thread section adjacent said center seal configuration on each connection member, and locating said run-out thread section at the portion of said member, adjacent said center seal where said member wall thickness is less.

37. The method of Claim 36, including utilizing an additional run-out thread section near a terminal end of each connection member.

38. The method of Claim 36 or Claim 37, including utilizing a run-in thread section on each corresponding member at the location corresponding with said run-out thread section.

39. A thread for use in tubular connections, said thread comprising a chamfered stab flank as the stab flank for at least the individual thread members which come into contact upon initial telescoping of a pin member into a box member of said tubular connection.

40. The thread of Claim 39, wherein the height of said chamfer is about equal to the step height from the preceding load flank to said stab flank.

41. The thread of Claim 39, wherein said load flank angle is a negative angle of less than 15 degrees.

42. The thread of Claim 41, wherein said stab flank angle ranges from a negative angle of less than 8 degrees to a positive angle of less than 8 degrees.

43. The thread of Claim 42, wherein said stab flank angle ranges from an angle of zero degrees to a positive angle of less than 3 degrees.

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44. The thread of Claim 43, wherein the absolute sum of said negative load flank angle and said zero degree to positive stab flank angle is less than 5 degrees.

45. The thread of Claim 44 wherein said stab flank angle is essentially a zero degree angle.

46. The thread of Claim 43, Claim 44 or Claim 45, wherein said thread is a variable width thread having progressively increasing thread width.

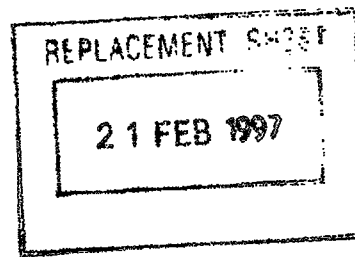
47. The thread of Claim 46, wherein the height of said stab flank chamfer is about equal to the step height from the preceding load flank to said stab flank.

48. A tubular connection member comprising at least two threaded sections and having a center shoulder seal configuration disposed between said at least two threaded sections, said connection member also comprising at least one stabilizing thread section adjacent said center seal configuration, said stabilizing thread section comprising a run-out thread.

49. The tubular connection member of Claim 48, wherein said member includes a second run-out thread section at an exterior edge of said connection thread sections.

50. The tubular connection member of Claim 48 or Claim 49, wherein said center-shoulder seal configuration comprises a locked double shoulder configuration.

51. The tubular connection member of Claim 48 or Claim 49, wherein said threaded sections include a thread profile having a negative load flank angle of less than 15 degrees and a stab flank having an angle ranging from a zero degree angle to a positive angle of less than 10 degrees.



52. The tubular connection member of Claim 51, wherein at least the full height thread stab flanks which will come into contact upon initial telescoping of a connection pin member into a connection box member are chamfered.

53. The tubular connection member of Claim 52, wherein the height of said chamfer is about equal to the step height between the preceding load flank and said chamfered stab flank.

54. The tubular connection member of Claim 53, wherein said thread is a variable width thread having progressively increasing width.

55. The tubular connection member of Claim 50, wherein said threaded sections include a thread profile having a negative load flank angle of less than 15 degrees and a stab flank having an angle ranging from a zero degree angle to a positive angle of less than 8 degrees.

56. The tubular connection member of Claim 55, wherein at least the full height thread stab flanks which will come into contact upon initial telescoping of a connection pin member into a connection box member are chamfered.

57. The tubular connection member of Claim 56, wherein the height of said chamfer is about equal to the step height between the preceding load flank and said chamfered stab flank.

58. The tubular connection member of Claim 57, wherein said thread is a variable width thread having progressively increasing width.

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STABILIZED CENTRE-SHOULDER-SEALED TUBULAR CONNECTIONABSTRACT

The present invention pertains to a tubular connection (100) having a stabilized centre-shoulder seal (104). The stabilization of the centre-shoulder seal is achieved using at least one run-out section (114, 110) of thread adjacent to the centre-shoulder seal configuration of each connection member. The run-out section of thread is typically used in combination with run-in section of thread on the corresponding connection member. Preferably, the centre-shoulder seal configuration of each connection member is positioned between a run-out threads section and a run-in section. (The corresponding connection member will comprise the corresponding sections of run-in and run-out threads, respectively, so there is an interengaging set of run-in and run-out threads). Even more preferably, in addition to the connection having one set of run-out and run-in thread sections adjacent to the centre-shoulder seal, the connection has a second set of run-out and run-in threads adjacent to the exterior edges of the connection (A double run-out, run-in stabilization of the centre-shoulder seal). The double set of run-out, run-in sections of thread provides the most stable connection. The most preferred centre-shoulder seal design is a "locked double shoulder" design (119), wherein the cross section of the assembled centre-shoulder area exhibits an interlocking double shoulder configuration. The most preferred thread profile is a single hook thread profile wherein the load flank angle is a negative angle and the stab flank angle is about zero degrees. The preferred profile chamfered stab flanks at least at locations which will come into contact upon initial telescoping of a connection pin member into a connection box member. The thread is typically a variable width thread having a progressively increasing thread width throughout a continuous section of thread.

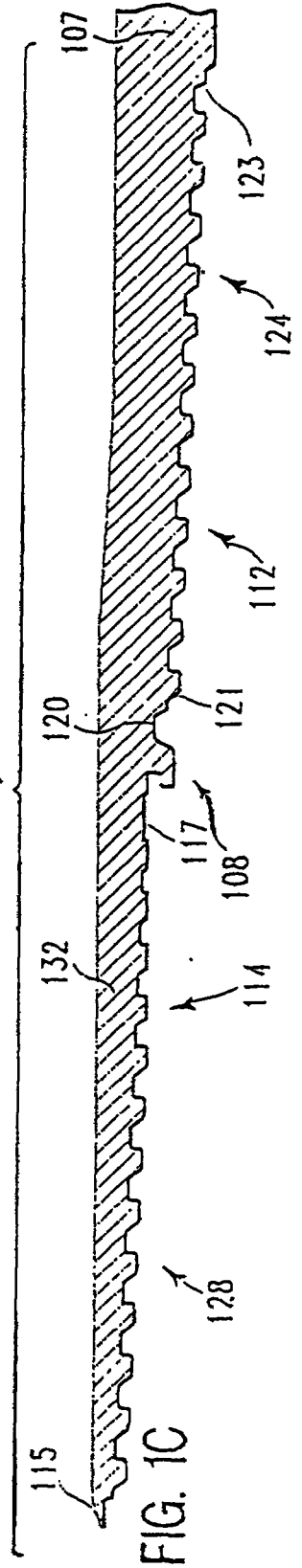
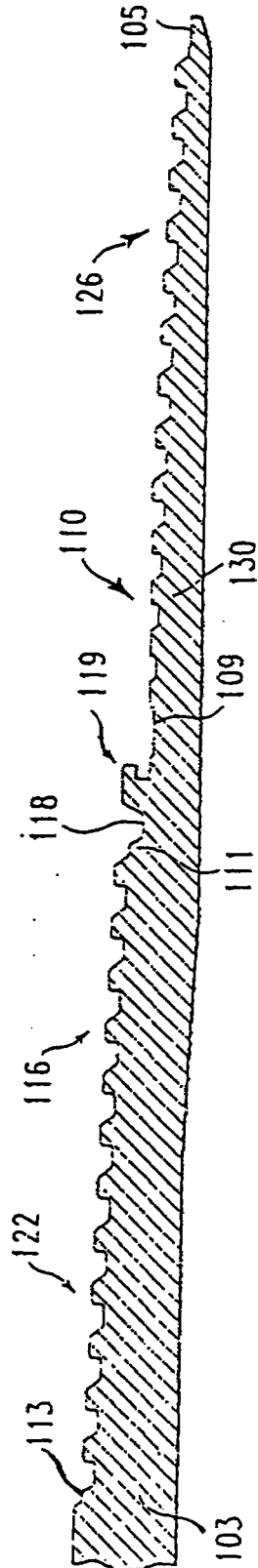
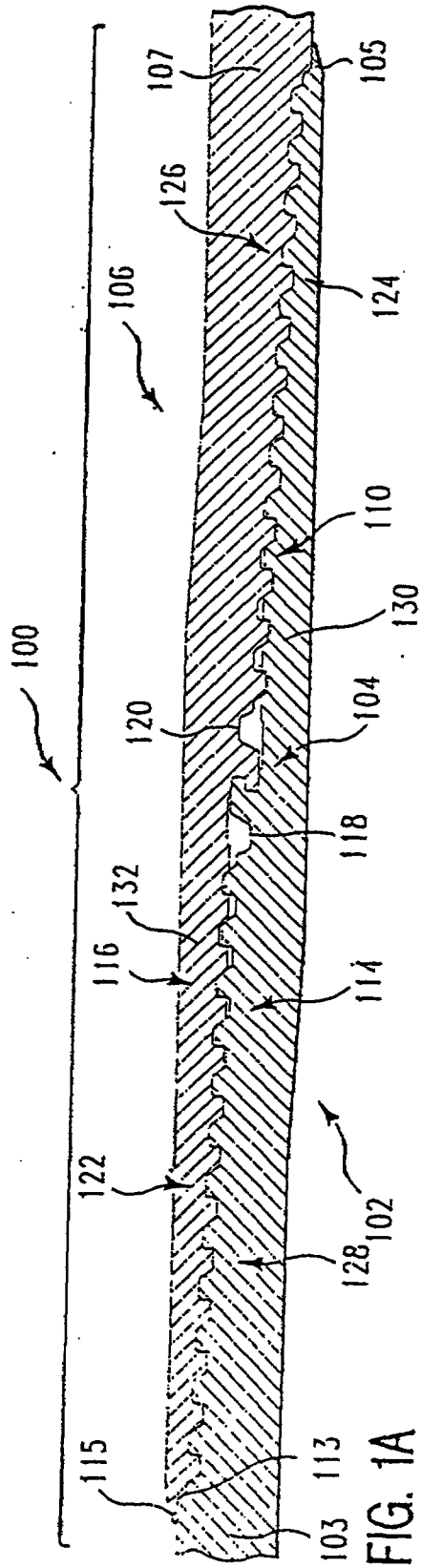
FIGURE 4A, 4B, & 4C

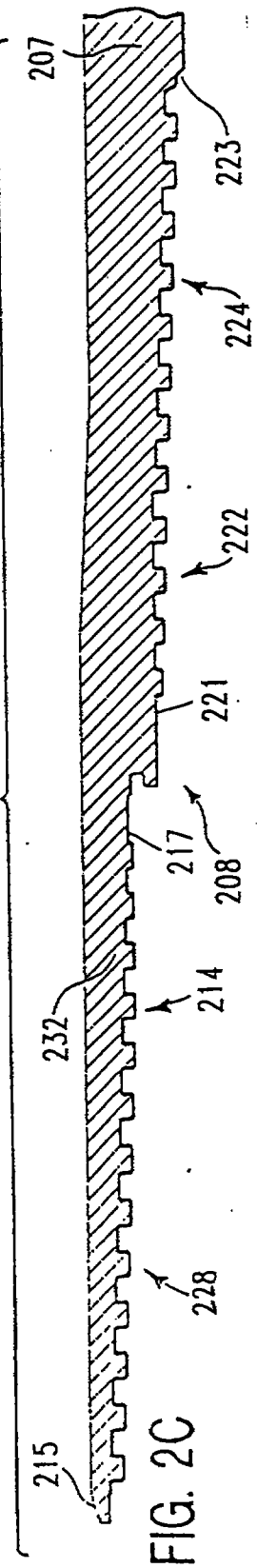
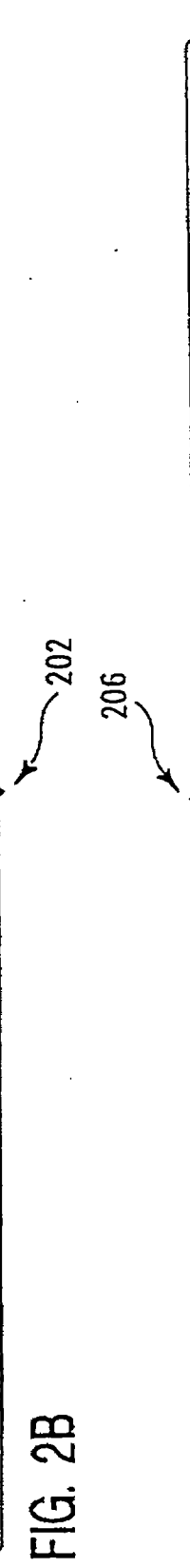
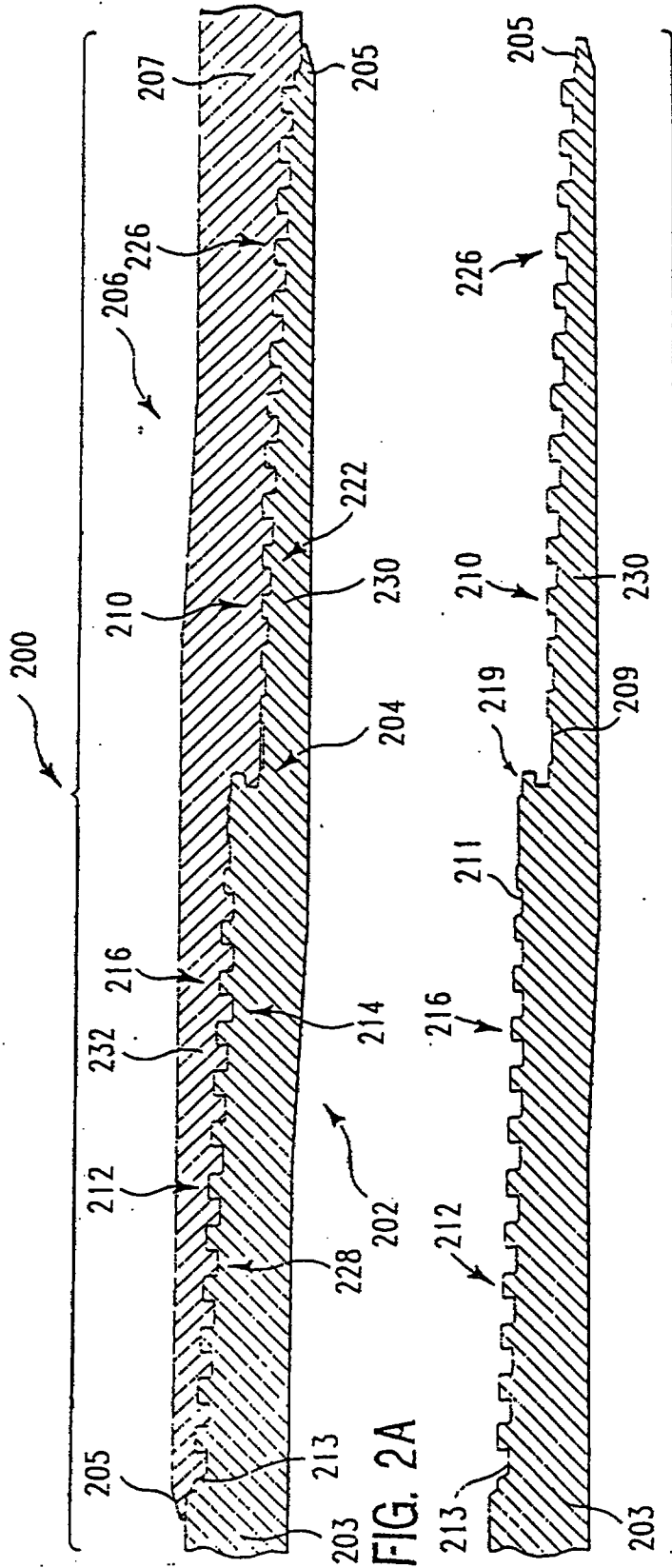
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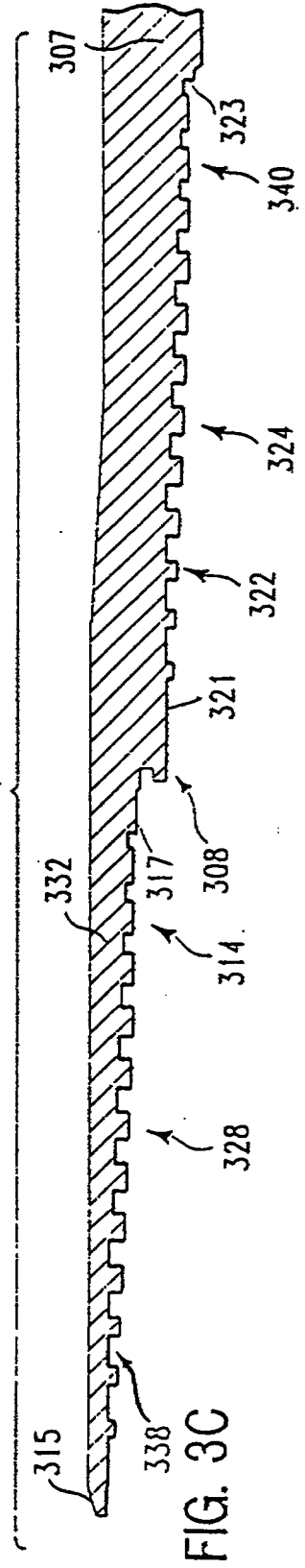
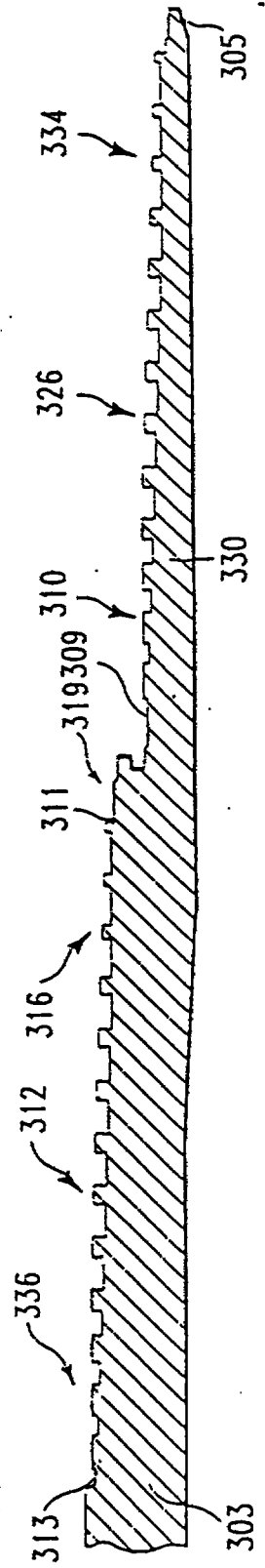
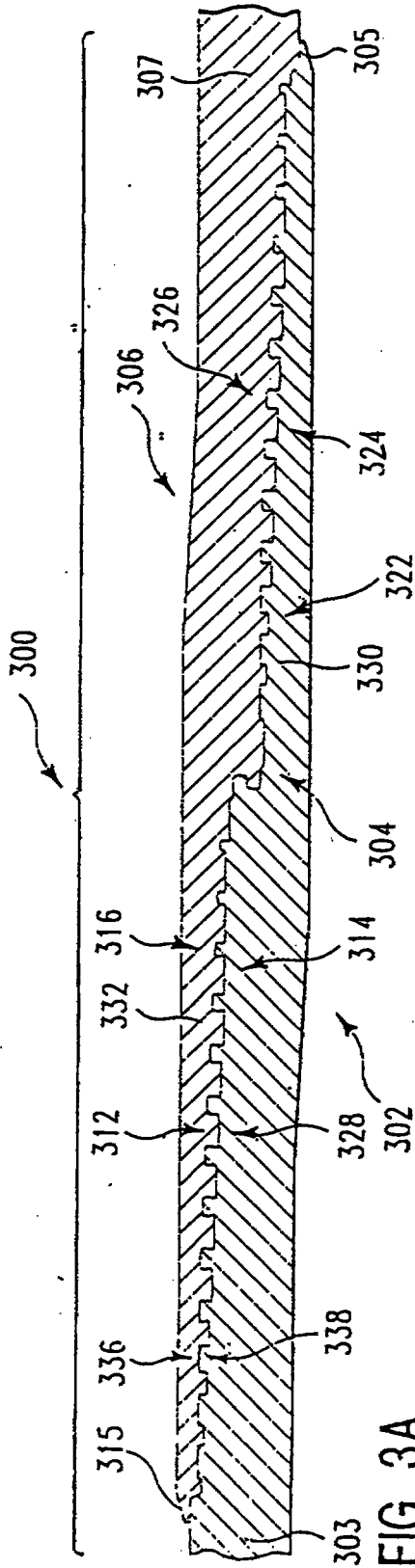


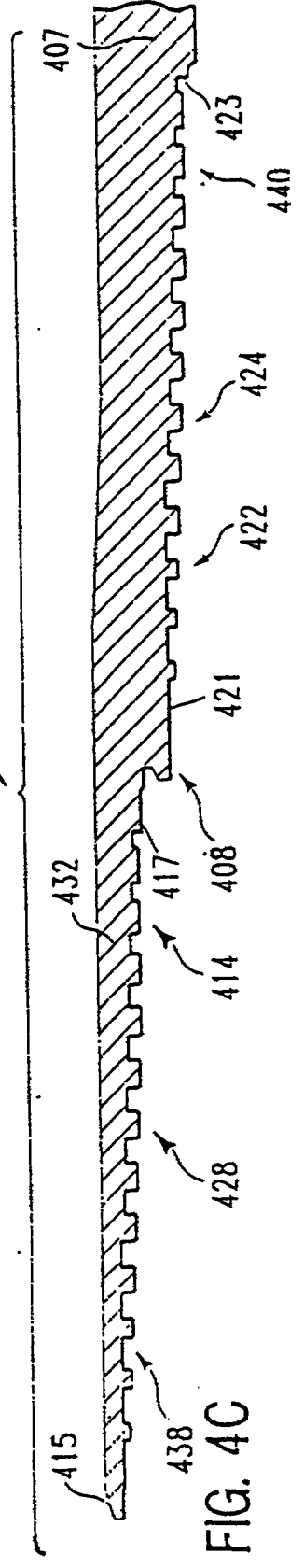
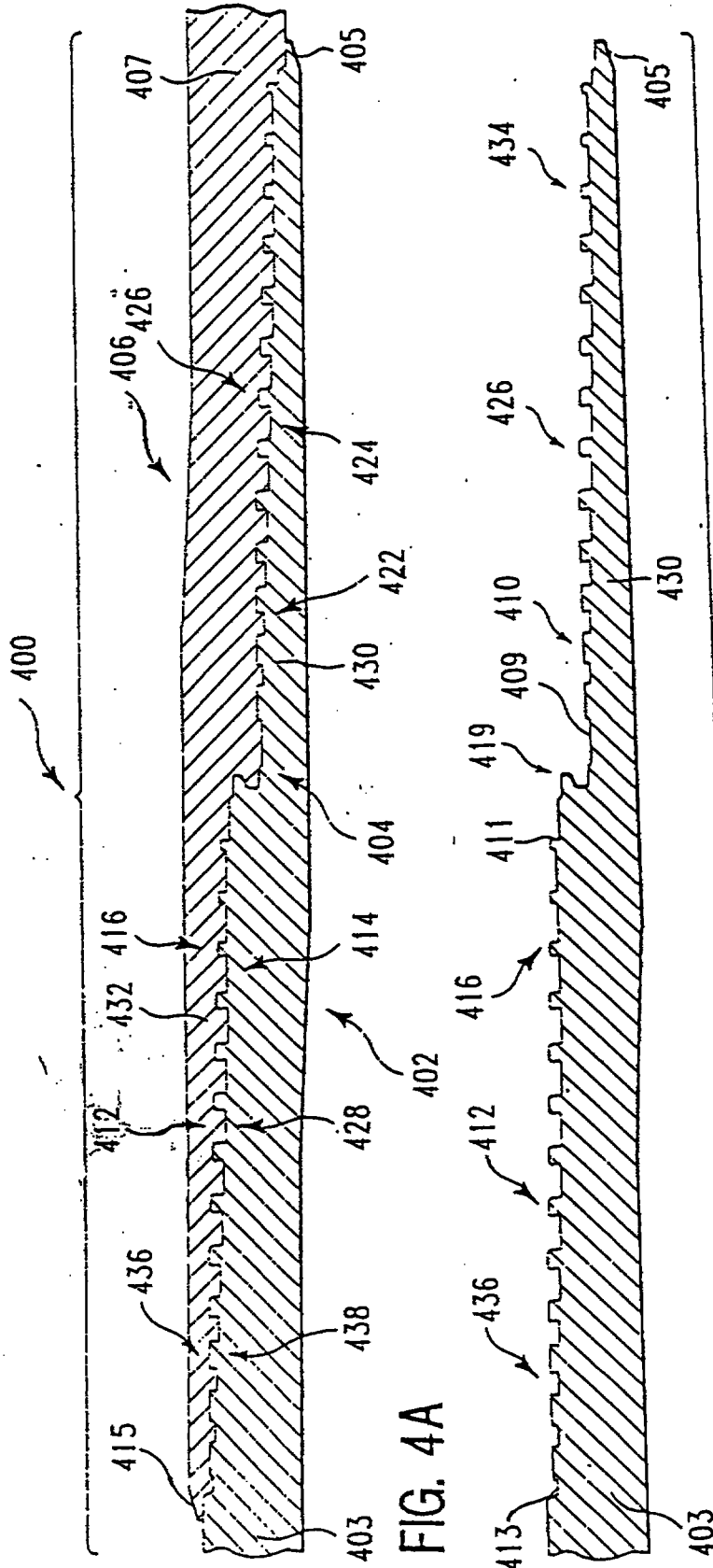
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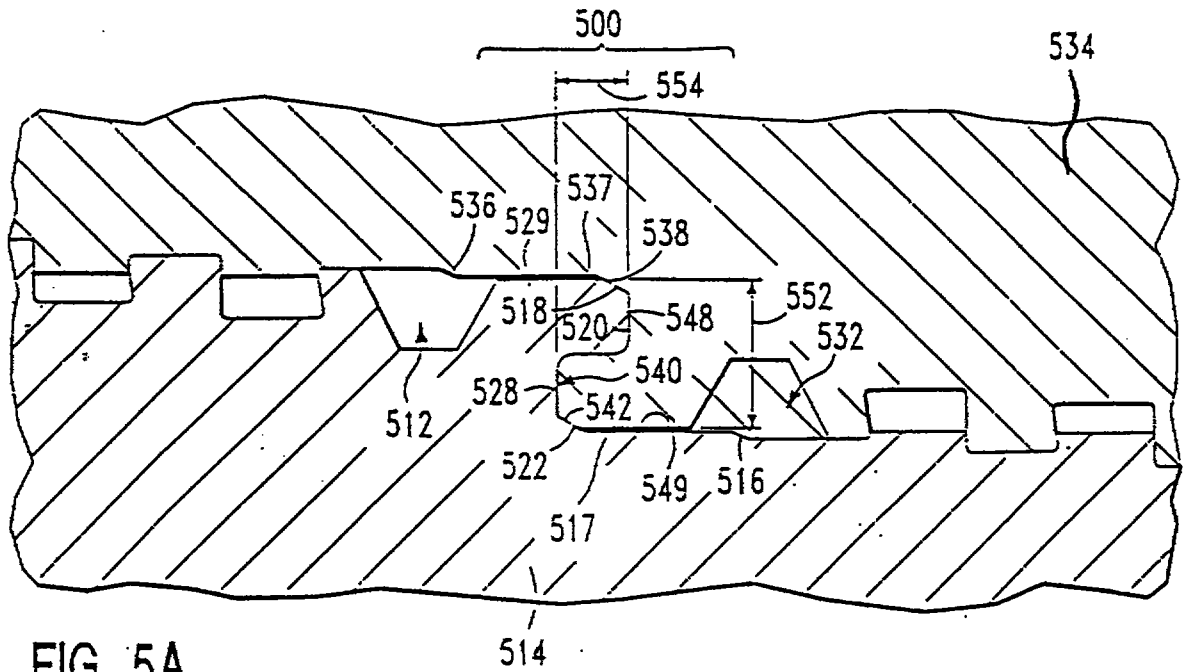


FIG. 5A

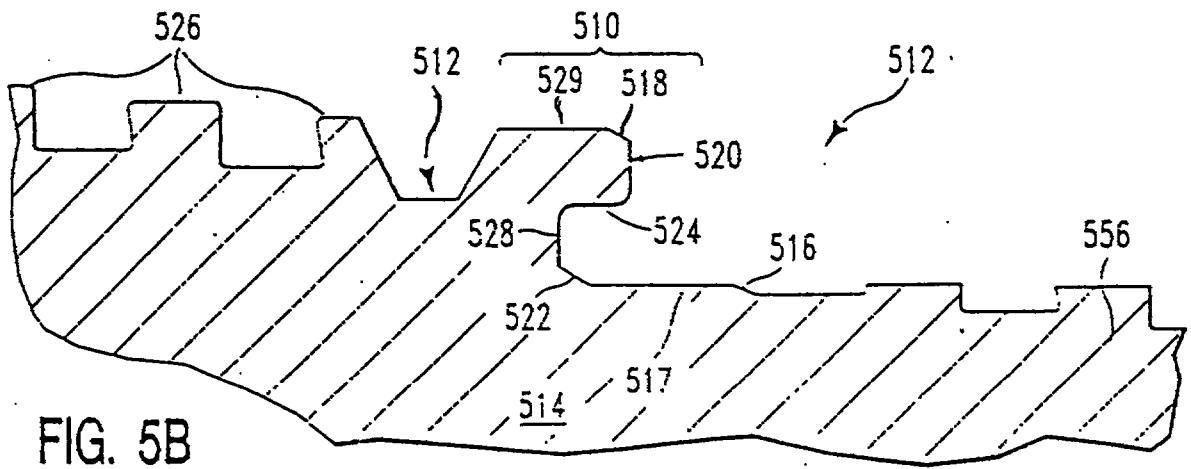


FIG. 5B

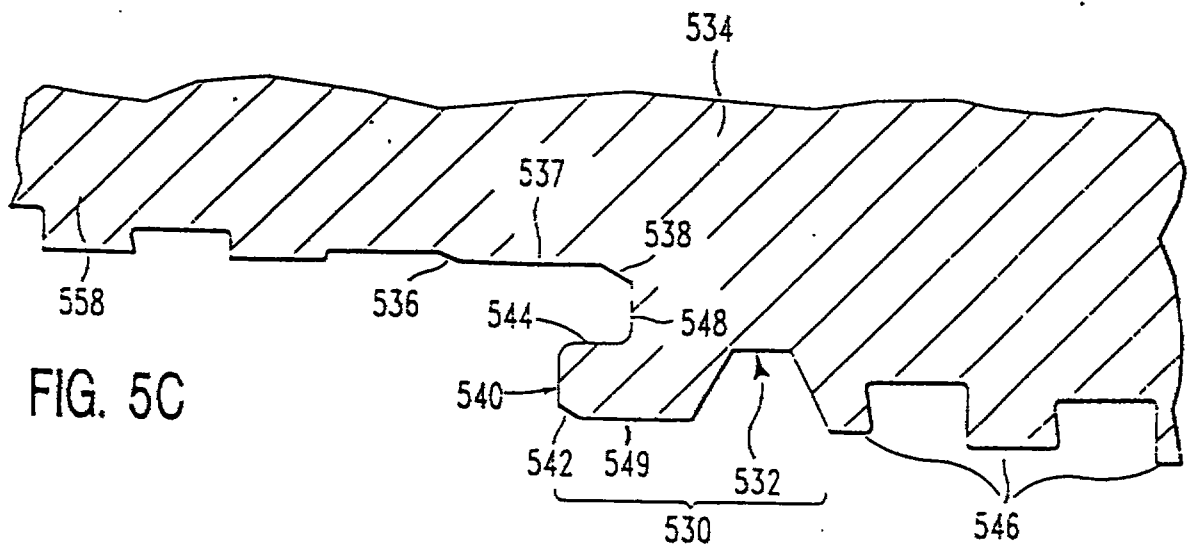


FIG. 5C

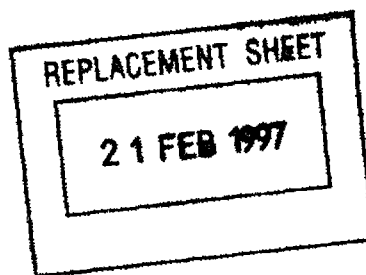


FIG. 6A

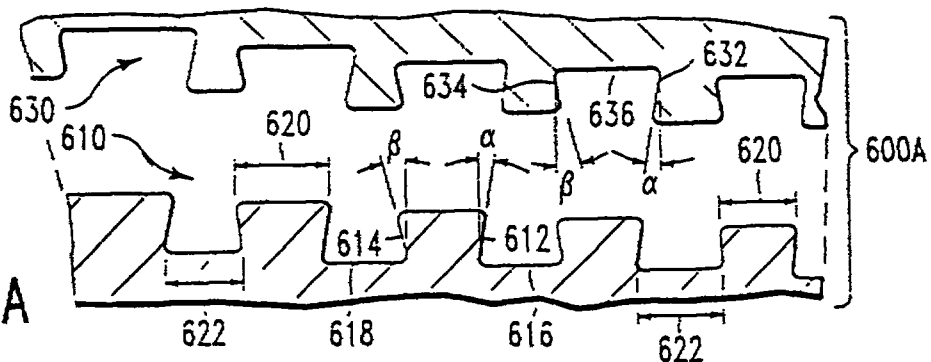


FIG. 6B

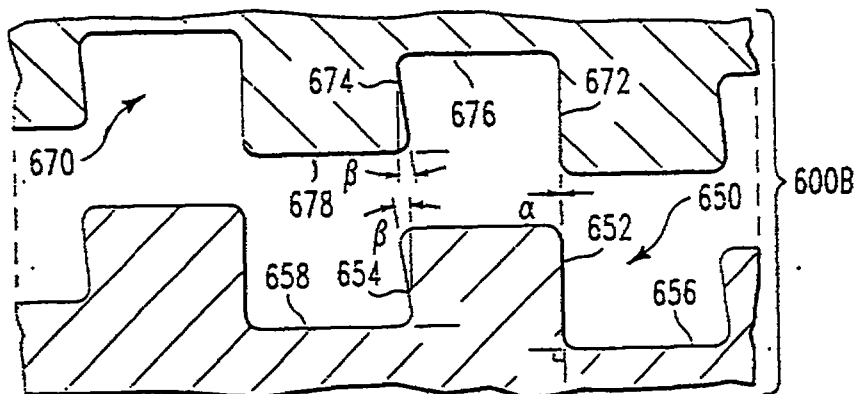


FIG. 6C

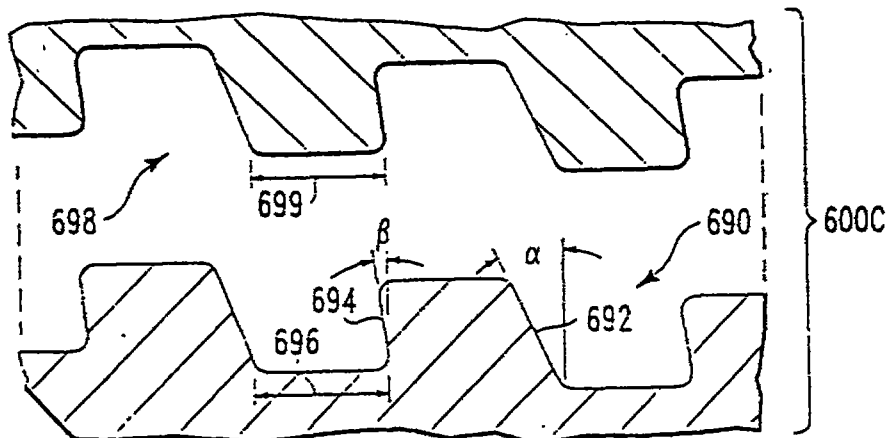
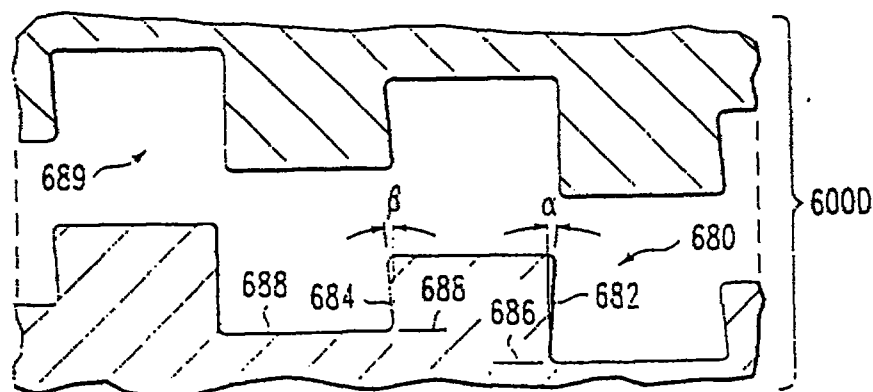
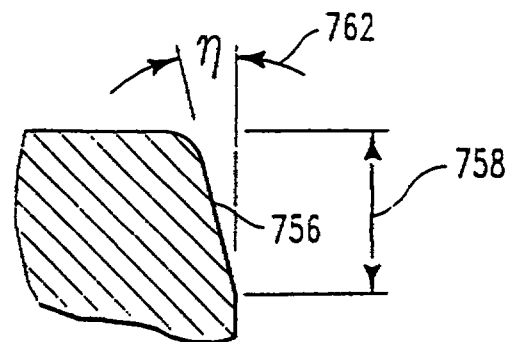
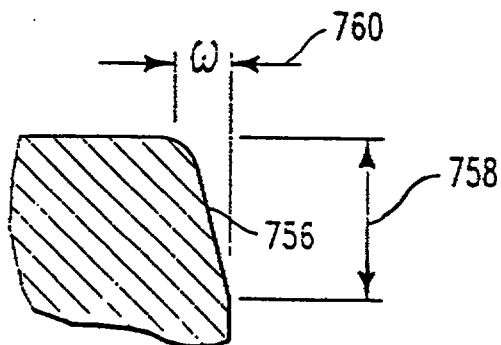
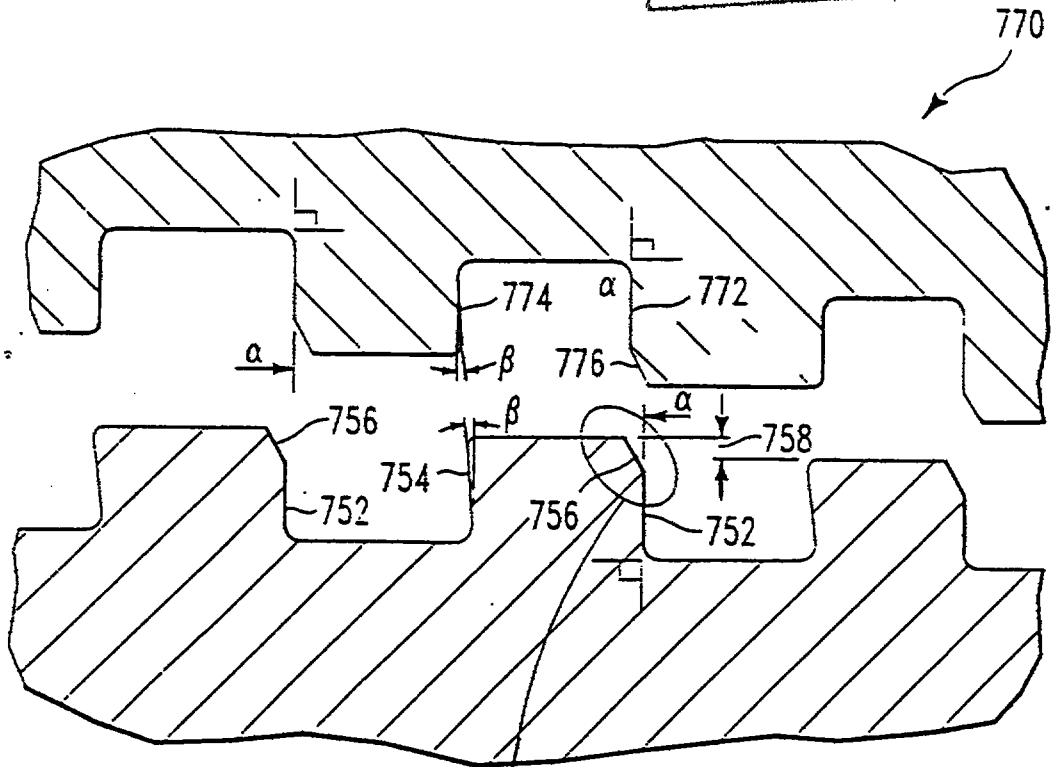
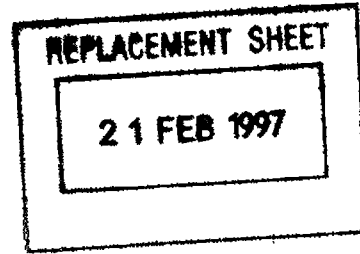


FIG. 6D





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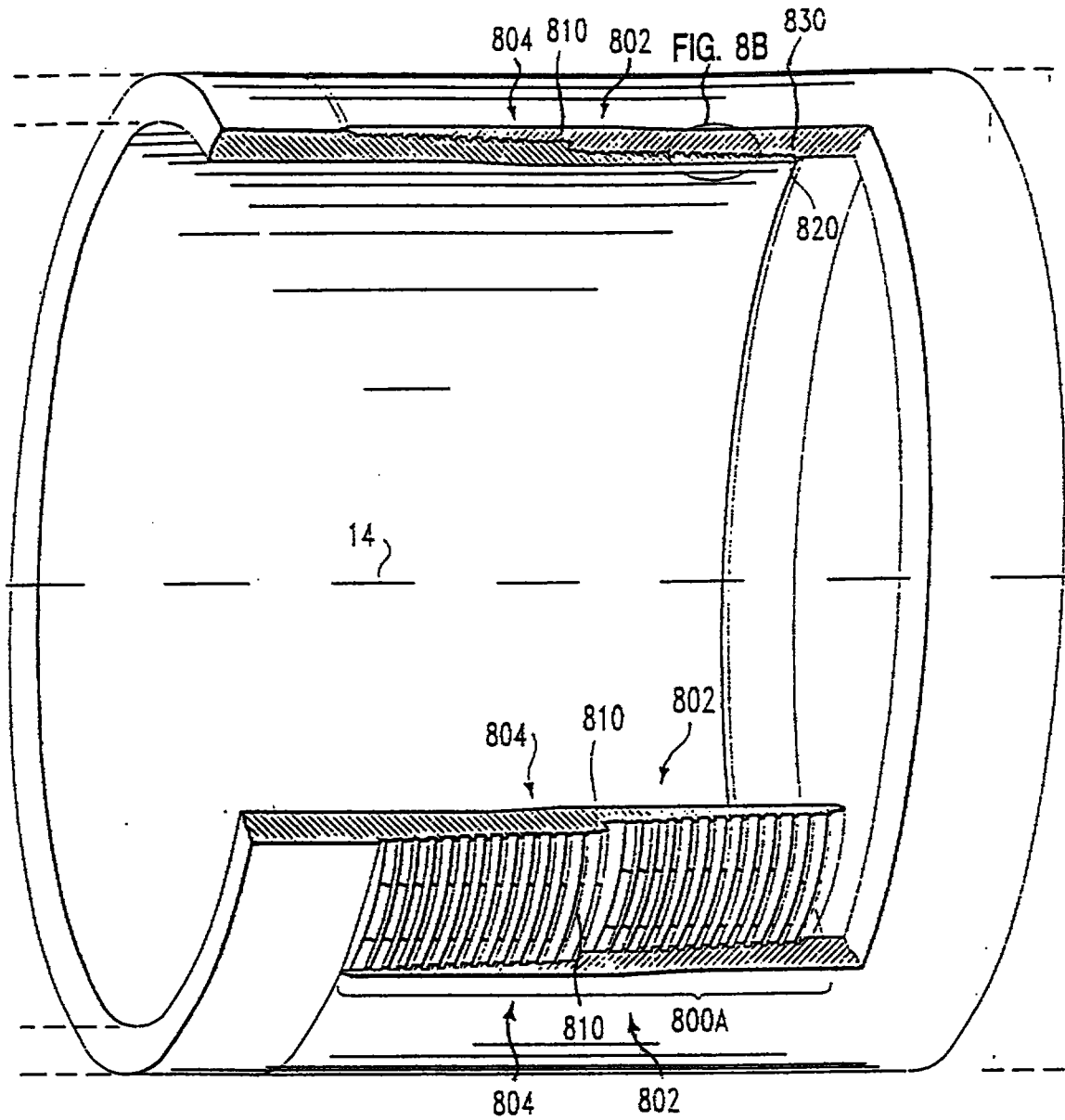
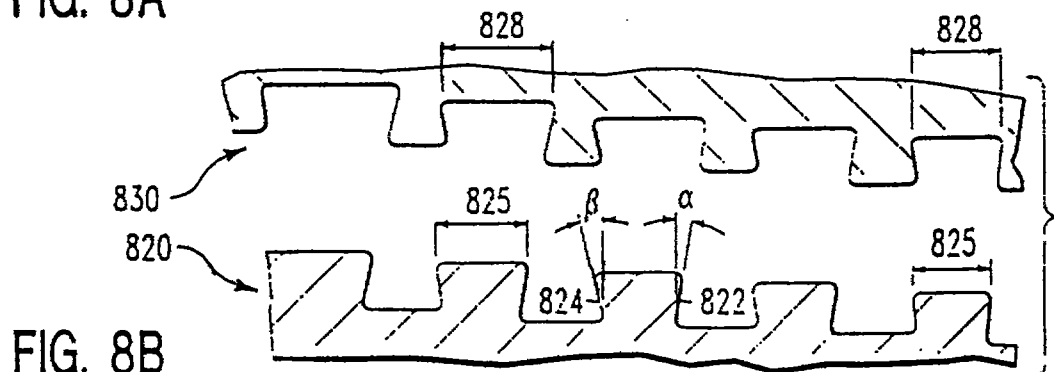


FIG. 8A



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FIG. 9B

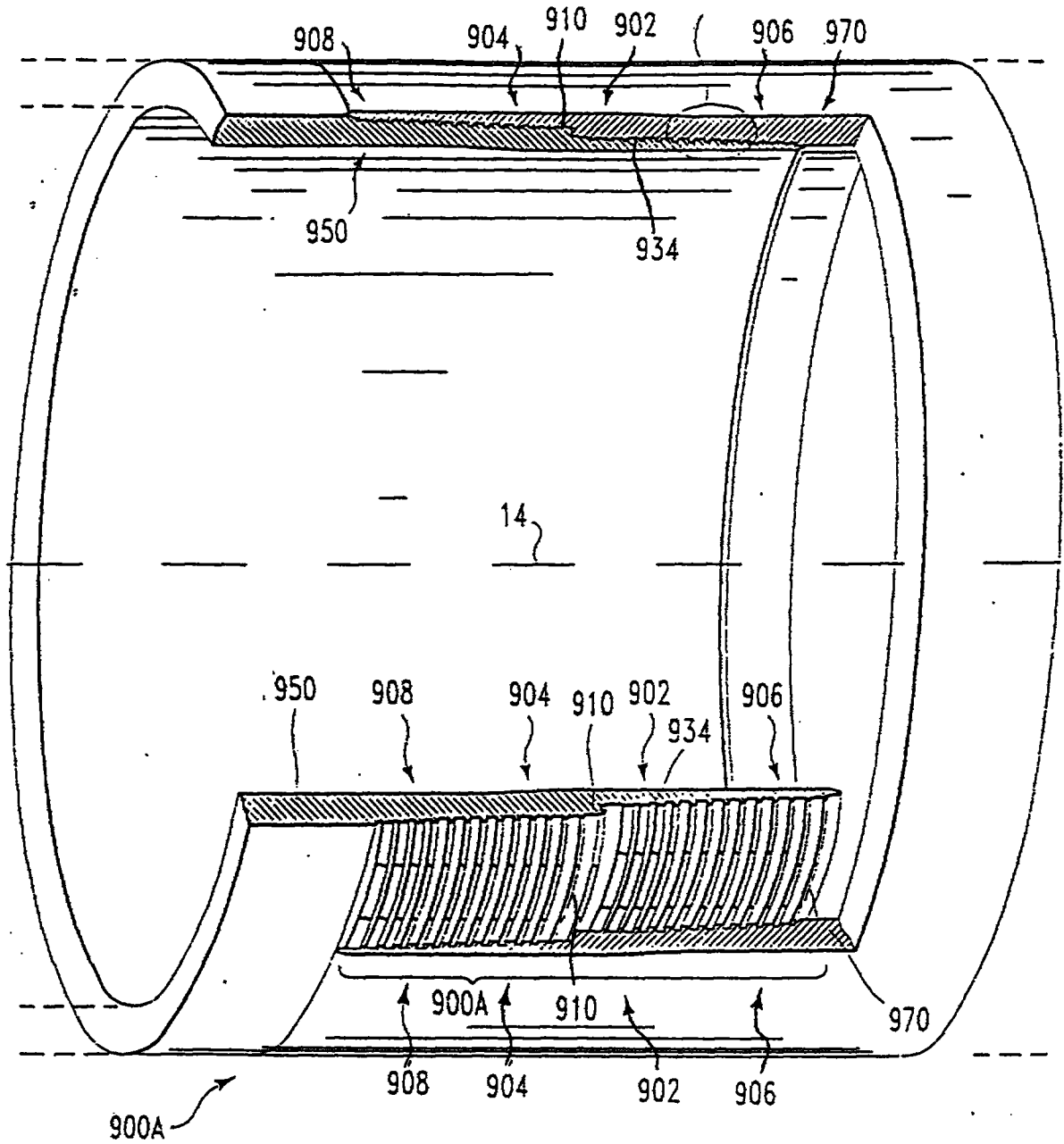
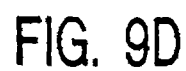
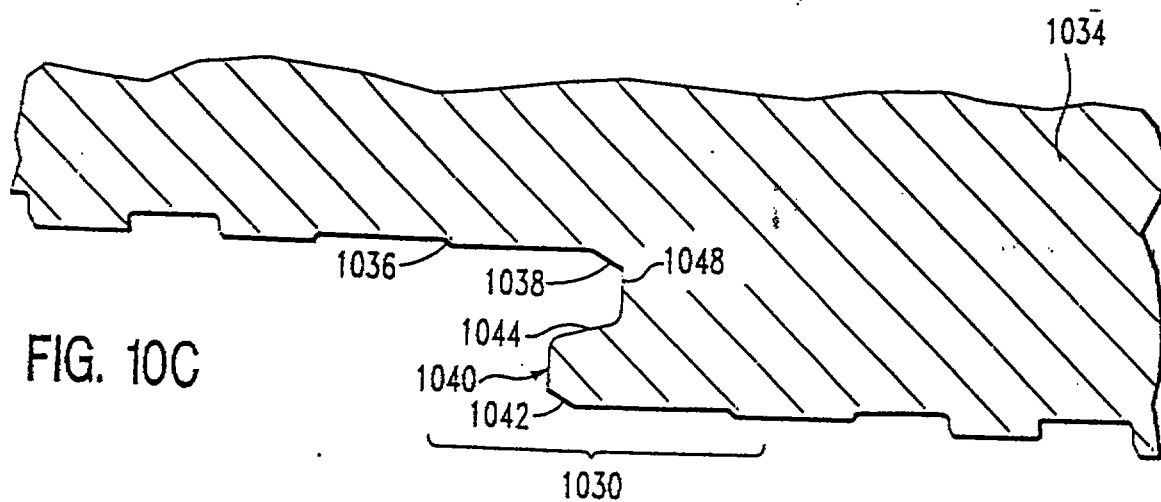
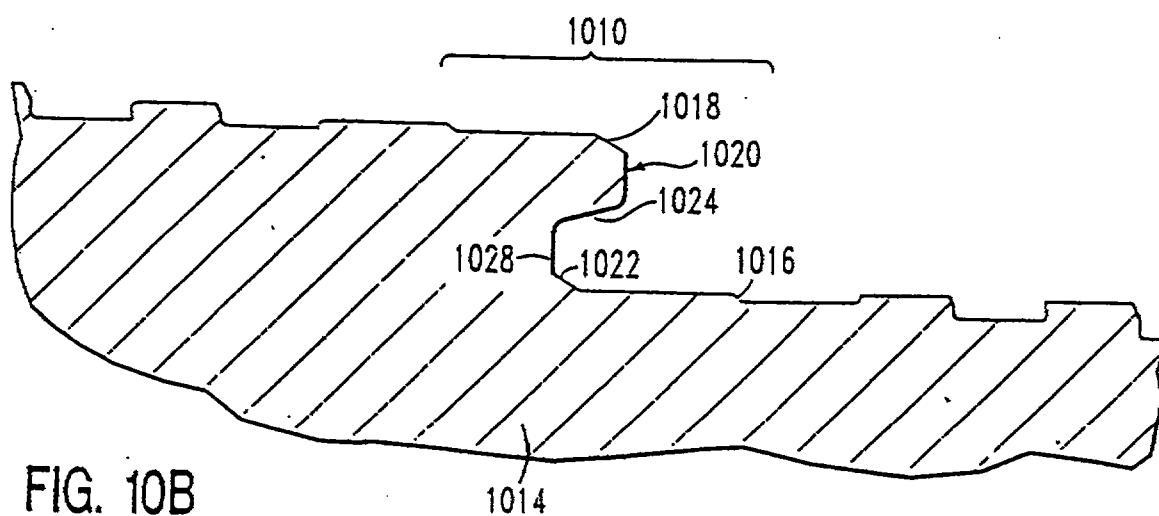
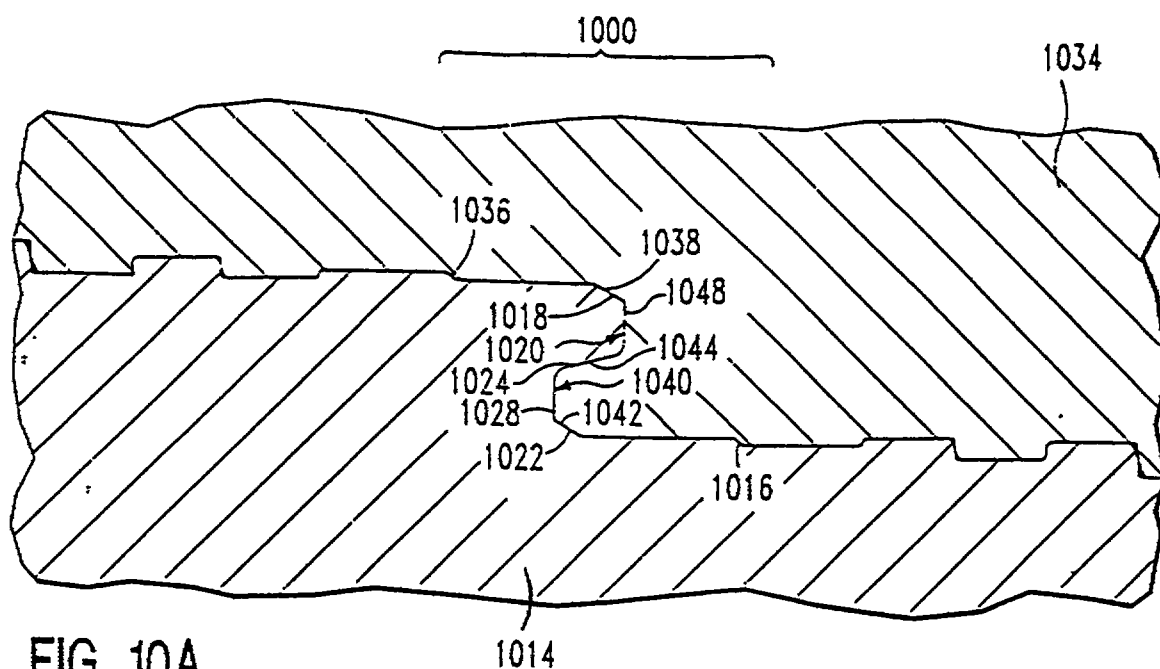


FIG. 9A





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☒ Description	: paged 1 to paged 15	
☒ Claim(s)	: paged 17 to paged 22	
☐ Drawing(s)	: paged 1 to paged 15	
☐ Abstract	: paged 1 to paged 15	
DATE OF RECEIPT		25/7/17

members. A typical threaded coupling comprises pin and box members each having a stepped thread design of hooked configuration on at least one side of a stop shoulder.

U.K. Patent Specification 137,777 of W. Pickard, published in 1920, shows a variety of thread designs which can be used to connect two or more parts or objects laterally or which, on entering a material, will become anchored therein and resist separation in all directions at right angles to the longitudinal axis of the connection. Fig. 8 of the disclosure shows a single hook thread profile. Fig. 10 shows a double hook thread profile.

U.K. Patent Application of K. Maruyama, published November 4, 1981, describes a fluid tight thread joint for oil or gas well pipes. The joint comprises box and pin members; the thread on the pin starts from the pin end as a rounded triangular thread and becomes a buttress thread; the thread on the box member is formed in a corresponding manner.

A tubular connection according to the preamble of claim 1 is disclosed in US-A-4 524 042.

DEFINITIONS

For convenience and accuracy of description, the following definitions have been adapted for use in describing the connection of the present invention.

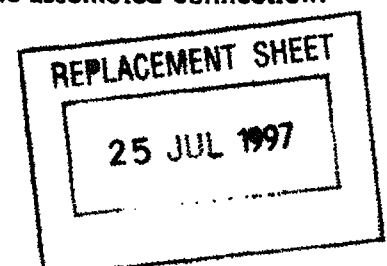
The "pin member" of a connection is understood to mean the male portion of a tubular member which is threaded on its external surface to be interengaged with threads on a box member to provide a connection.

The "box member" of the connection is understood to mean the female portion of a tubular member which is threaded on its internal surface to be interengaged with threads on a pin member to provide a connection.

A connection having a "two-step thread" is understood to mean a connection having two threaded portions wherein one threaded portion has a greater radius from the longitudinal axis of the pipe than the other threaded portion.

A "center shoulder seal" is understood to mean a section of a connection disposed between at least two threaded portions, which section exhibits directly contacting surfaces between the pin and box members, or between the pin and box members and a third component such as an annular sealing sleeve, so that the section provides a seal for preventing the passage of fluid through (across the threads of) the assembled connection.

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having essentially equal thread section length on each member, and wherein the entire height of thread on at least one member per threaded section is completely encompassed within the thread height of the other corresponding member threaded section.

A "lead-in thread" is understood to mean a starting portion of full-height or nearly full height threads which are machined on a taper to the longitudinal axis of the tubular member and beginning adjacent to the center shoulder seal configuration. In an assembled tubular connection, a lead-in thread on a pin member or box member corresponds with a run-out thread on the corresponding box member or pin member, respectively.

In accordance with the present invention, there is provided a tubular connection comprising:

at least two connection members;

each said connection member including at least two threaded sections of threads having stab and load flanks and a centre shoulder disposed between said at least two threaded sections;

said centre shoulders engaging to form a centre shoulder seal configuration; characterised by:

said at least two threaded sections including at least one run-out thread section present on each connection member and engaging threads on the other connection member;

said at least one run-out thread section being adjacent said centre shoulder seal configuration; and

said centre shoulders being arranged to form a centre shoulder seal configuration having a plurality of sealing surfaces.

A tubular connection comprising at least two connection members and a center shoulder seal has been developed in a manner which provides stabilization of the centre shoulder seal and improved efficiency (strength of connection/strength of tubular) of the connection.

Also in accordance with the present invention, there is provided a method of stabilizing a tubular connection

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having at least two connection members, each with a centre shoulder, the method characterised by the steps of:

threading a run-out thread section on one of the connection members located between its centre shoulder and leading terminal end with a thread section on the other connection member;

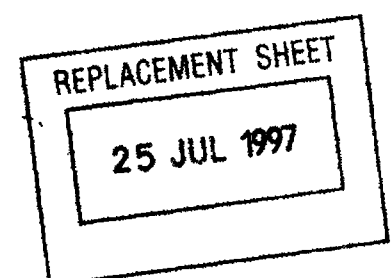
threading a run-out thread section on the other connection member located between its centre shoulder and leading terminal with a thread section on the one of the connection members; and,

engaging the centre shoulders to form a seal between the two connection members, the seal having a plurality of sealing surfaces.

A center shoulder seal design which provides multiple metal-to-metal sealing surfaces is described. This seal design comprises a locked double shoulder configuration.

Although the present invention can be applied to connections comprising tubulars and couplings, the most frequent use of the invention will be in the form of a tubular connection comprising two connection members, and thus the invention is described in this form below.

With reference to a tubular connection comprising two connection members, namely a pin member and a box member, the stabilization of the center shoulder seal is achieved using at least one run-out section of thread adjacent to the center shoulder configuration of each connection member. Typically, the at least one run-out section of thread is located adjacent the center shoulder configuration on that portion of the connection member at which the wall thickness is less. The run-out section of thread is typically used in combination with a run-in section of thread on the corresponding





The single hook thread exhibits a negative stab flank angle which ranges from zero (0) degrees to about 45 degrees, and exhibits a negative load flank angle which ranges from greater than 0 degrees to about 15 degrees. If the load flank angle is a large negative angle, and the stab flank angle is less than the load flank angle, thereby producing thread crests wider than adjacent thread roots, the use of a constantly increasing thread width from the leading edge of the pin, as described above for a double hook thread, may be necessary to permit proper interengagement of the pin and box members of the connection upon initial telescoping (stabbing).

A more preferred single hook thread profile, due to ease of machining, is the profile wherein the negative load flank angle ranges from greater than 0 degrees to less than 5 degrees and the ~~positive~~^{negative} stab flank angle ranges from zero degrees to about 2 degrees, with the absolute sum of the angles being less than 5 degrees. When these reduced negative load flank and stab flank angles are used, it is not necessary to use constantly increasing thread width to permit interengagement of connection member threads. The necessary clearance is provided by making the thread crests narrower than the thread roots.

Figure 6C illustrates another thread profile embodiment 600C suitable for use in the connection of the present invention. This thread profile is particularly suitable for a connection having a center-shoulder seal (such as the locked double shoulder) in combination with a single run-out thread and full height lead-in thread on the corresponding member, on each side of the center-shoulder seal. The thread profile of full height threads from a portion of the pin member 690 is another embodiment of a single hook thread as it would appear within the threaded tubular section of the present invention. This particular embodiment of a single hook thread features a load flank 694 of pin member 690 thread which exhibits a large negative angle β and a stab flank 692 which exhibits a large negative angle α . Generally, angle α is greater than angle β , and consequently, dimensions can be formulated with flank to flank (load to stab) bearing threads, having clearance between thread roots and crests, for example, with clearance between root 696 of pin member 690 and crest 699 of box member 698. This is in contrast with the double hook thread of Figure 6A and the single hook thread of 6B, which are more suitable in a form wherein the thread roots and crests provide bearing surfaces with clearances between corresponding stab and load flanks. Flank to flank



CLAIMS

1. A tubular connection comprising:
at least two connection members;
each said connection member including at least two threaded sections of threads having stab and load flanks and a centre shoulder disposed between said at least two threaded sections;
said centre shoulders engaging to form a centre shoulder seal configuration; characterised by:
said at least two threaded sections including at least one run-out thread section present on each connection member and engaging threads on the other connection member;
said at least one run-out thread section being adjacent said centre shoulder seal configuration; and
said centre shoulders being arranged to form a centre shoulder seal configuration having a plurality of sealing surfaces.
2. A connection according to claim 1, wherein said threads are variable width threads having progressively increasing thread width, and the thread crests of the threads are wider than the adjacent thread roots.
3. A connection according to claim 1, wherein said centre shoulder seal configuration comprises a locked double shoulder configuration.
4. A connection according to claim 1, wherein said centre shoulder seal configuration is a hook shoulder with a frustum seal.
5. A connection according to claim 1, wherein said threads have a negative load flank angle from nearly a zero degree angle to an angle of about 3 degrees and a positive stab flank angle from zero degrees to about 2 degrees.

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6. A connection according to claim 1, further including a chamfered stab flank for centring one connection member with respect to the other connection member.
7. A connection according to claim 1, wherein said at least two threaded sections include full height threads with the stab flank of said full-height threads being chamfered.
8. A connection according to claim 1, wherein each said connection member includes a run-in thread section opposite said run-out thread section on the other connection member.
9. A connection according to claim 1, wherein each said connection member includes a full-height thread section opposite said run-out thread section on the other connection member.
10. A connection according to claim 1, wherein said connection members each have trailing ends and further include at least one additional run-out thread section between said centre shoulder seal configuration and said trailing end of each connection member.
11. A connection according to claim 1, wherein each said connection member includes a leading terminal end and a trailing end, said run-out thread section being a first run-out thread section located between said centre shoulder seal configuration and said leading terminal end, and each said connection member further including a second run-out threaded section adjacent the trailing end of each connection member and run-in threaded sections on each connection member located opposite said first and second run-out threaded sections on the other connection member.
12. A connection according to claim 1, wherein:

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said at least two connection members include a first member having a first centre shoulder and a second member having a second centre shoulder;

said first centre shoulder including a first shoulder and a first undercut surface and said second centre shoulder including a second shoulder and a second undercut surface.

13. A connection according to claim 12, wherein at least one of said first and second shoulders sealingly engages one of said first and second undercut surfaces.

14. A connection according to claim 12, wherein said first shoulder includes a first exterior sealing surface and said first undercut surface includes a first interior sealing surface; said second shoulder includes a second exterior sealing surface and said second undercut surface includes a second interior sealing surface; whereby at least one of said first exterior sealing surfaces forms a metal-to-metal seal with one of said first and second interior sealing surfaces.

15. A connection according to claim 14, wherein said first and second exterior and interior sealing surfaces are formed by bevelled surfaces.

16. A connection according to claim 12, wherein said first and second undercut surfaces each have a portion thereof which interferingly engages said second and first shoulders respectively.

17. A connection according to claim 12, wherein said first shoulder and first undercut surface form a first surface extending therebetween and said second shoulder and second undercut surface form a second surface extending therebetween, and a seal being formed between said first and second surfaces.

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18. A connection according to claim 12, wherein said first member further includes a first interior ramp surface extending from said first undercut surface and a first exterior ramp surface extending from said first shoulder and said second member further includes a second interior ramp surface extending from said second undercut surface and a second exterior ramp surface extending from said second shoulder, at least one of said first and second exterior ramp surfaces interferingly engaging one of said first and second interior ramp surfaces.

19. A connection according to claim 18, wherein said first and second connection members include ramp surfaces for aligning and guiding said first and second exterior ramp surfaces into sealing engagement with said second and first interior ramp surfaces respectively.

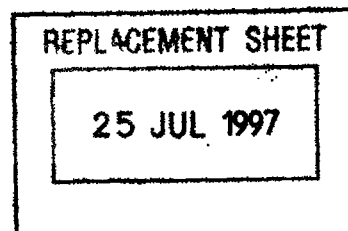
20. A method of stabilizing a tubular connection having at least two connection members, each with a centre shoulder, the method characterised by the steps of:

threading a run-out thread section on one of the connection members located between its centre shoulder and leading terminal end with a thread section on the other connection member;

threading a run-out thread section on the other connection member located between its centre shoulder and leading terminal with a thread section on the one of the connection members; and,

engaging the centre shoulders to form a seal between the two connection members, the seal having a plurality of sealing surfaces.

21. The method of claim 20, wherein the thread sections threading with the run-out thread sections are run-in thread sections.



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members. A typical threaded coupling comprises pin and box members each having a stepped thread design of hooked configuration on at least one side of a stop shoulder.

U.K. Patent Specification 137,777 of W. Pickard, published in 1920, shows a variety of thread designs which can be used to connect two or more parts or objects laterally or which, on entering a material, will become anchored therein and resist separation in all directions at right angles to the longitudinal axis of the connection. Fig. 8 of the disclosure shows a single hook thread profile. Fig. 10 shows a double hook thread profile.

- U.K. Patent Application of K. Maruyama, published November 4, 1981, describes a fluid tight thread joint for oil or gas well pipes. The joint comprises box and pin members; the thread on the pin starts from the pin end as a rounded triangular thread and becomes a buttress thread; the thread on the box member is formed in a corresponding manner.

A tubular connection according to the preamble claim 1 is disclosed in US-A-4 524 042.

DEFINITIONS

For convenience and accuracy of description, the following definitions have been adapted for use in describing the connection of the present invention.

The "pin member" of a connection is understood to mean the male portion of a tubular member which is threaded on its external surface to be interengaged with threads on a box member to provide a connection.

The "box member" of the connection is understood to mean the female portion of a tubular member which is threaded on its internal surface to be interengaged with threads on a pin member to provide a connection.

A connection having a "two-step thread" is understood to mean a connection having two threaded portions wherein one threaded portion has a greater radius from the longitudinal axis of the pipe than the other threaded portion.

A "center shoulder seal" is understood to mean a section of a connection disposed between at least two threaded portions, which section exhibits directly contacting surfaces between the pin and box members, or between the pin and box members and a third component such as an annular sealing sleeve, so that the section provides a seal for preventing the passage of fluid through (across the threads of) the assembled connection.

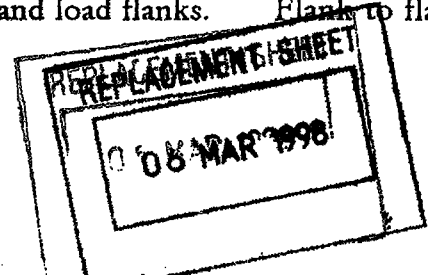
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The single hook thread exhibits a negative stab flank angle which ranges from zero (0) degrees to about 45 degrees, and exhibits a negative load flank angle which ranges from greater than 0 degrees to about 15 degrees. If the load flank angle is a large negative angle, and the stab flank angle is less than the load flank angle, thereby producing thread crests wider than adjacent thread roots, the use of a constantly increasing thread width from the leading edge of the pin, as described above for a double hook thread, may be necessary to permit proper interengagement of the pin and box members of the connection upon initial telescoping (stabbing).

A more preferred single hook thread profile, due to ease of machining, is the profile wherein the negative load flank angle ranges from greater than 0 degrees to less than 5 degrees and the negative stab flank angle ranges from zero degrees to about 2 degrees, with the absolute sum of the angles being less than 5 degrees. When these reduced negative load flank and stab flank angles are used, it is not necessary to use constantly increasing thread width to permit interengagement of connection member threads. The necessary clearance is provided by making the thread crests narrower than the thread roots.

Figure 6C illustrates another thread profile embodiment 600C suitable for use in the connection of the present invention. The thread profile is particularly suitable for a connection having a center-shoulder seal (such as the locked double shoulder) in combination with a single run-out thread and full height lead-in thread on the corresponding member, on each side of the center-shoulder seal. The thread profile of full height threads from a portion of the pin member 690 is another embodiment of a single hook thread as it would appear within the threaded tubular section of the present invention. This particular embodiment of a single hook thread features a load flank 694 of pin member 690 thread which exhibits a large negative angle β and a stab flank 692 which exhibits a large negative angle α . Generally, angle α is greater than angle β , and consequently, dimensions can be formulated with flank to flank (load to stab) bearing thread, having clearance between thread roots and crests, for example, with clearance between root 696 of pin member 690 and crest 699 of box member 698. This is in contrast with the double hook thread of Figure 6A and the single hook thread of 6B, which are more suitable in a form wherein the thread roots and crests provide bearing surfaces with clearances between corresponding stab and load flanks. Flank to flank



STABILIZED CENTRE-SHOULDER-SEALED TUBULAR CONNECTIONABSTRACT

The present invention pertains to a tubular connection (100) having a stabilized centre-shoulder seal (104). The stabilization of the centre-shoulder seal is achieved using at least one run-out section (114, 110) of thread adjacent to the centre-shoulder seal configuration of each connection member. The run-out section of thread is typically used in combination with run-in section of thread on the corresponding connection member. Preferably, the centre-shoulder seal configuration of each connection member is positioned between a run-out threads section and a run-in section. (The corresponding connection member will comprise the corresponding sections of run-in and run-out threads, respectively, so there is an interengaging set of run-in and run-out threads). Even more preferably, in addition to the connection having one set of run-out and run-in thread sections adjacent to the centre-shoulder seal, the connection has a second set of run-out and run-in threads adjacent to the exterior edges of the connection (A double run-out, run-in stabilization of the centre-shoulder seal). The double set of run-out, run-in sections of thread provides the most stable connection. The most preferred centre-shoulder seal design is a "locked double shoulder" design (119), wherein the cross section of the assembled centre-shoulder area exhibits an interlocking double shoulder configuration. The most preferred thread profile is a single hook thread profile wherein the load flank angle is a negative angle and the stab flank angle is about zero degrees. The preferred profile chamfered stab flanks at least at locations which will come into contact upon initial telescoping of a connection pin member into a connection box member. The thread is typically a variable width thread having a progressively increasing thread width throughout a continuous section of thread.

FIGURE 4A, 4B, & 4C

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