Aug. 16, 1966 W. W. WORD, JR., ET AL 3,266,823

WELLHEAD EQUIPMENT WITH ABUTTING SLIPS

Original Filed Dec. 16, 1960 2 Sheets-Sheet 1

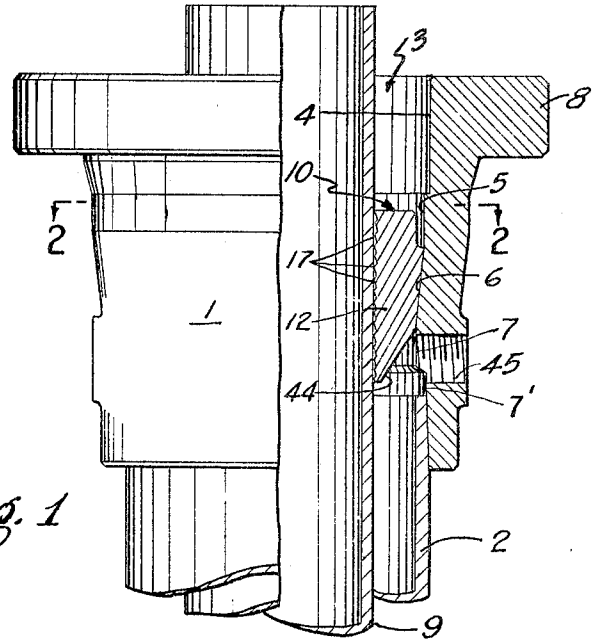


Fig. 1

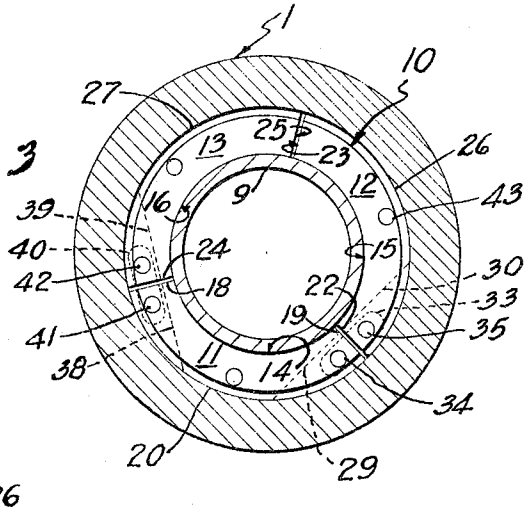
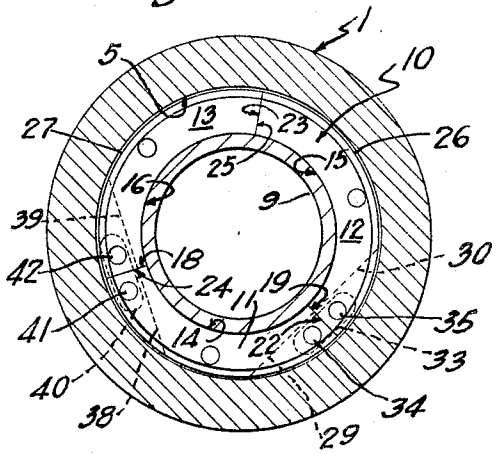


Fig. 3

Fig. 2



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WELLHEAD EQUIPMENT WITH ABUTTING SLIPS

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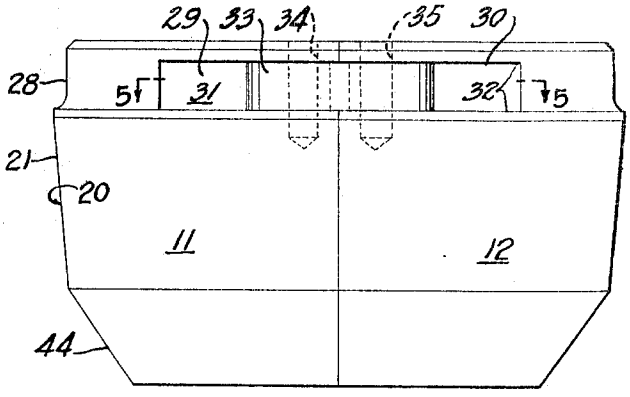
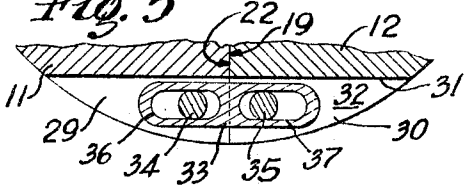


Fig. 4

Fig. 5



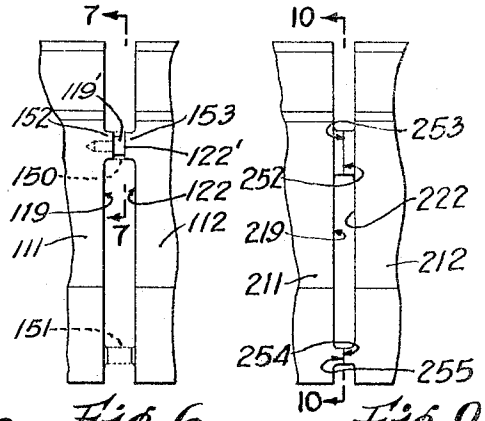


Fig. 8

Fig. 6

Fig. 9

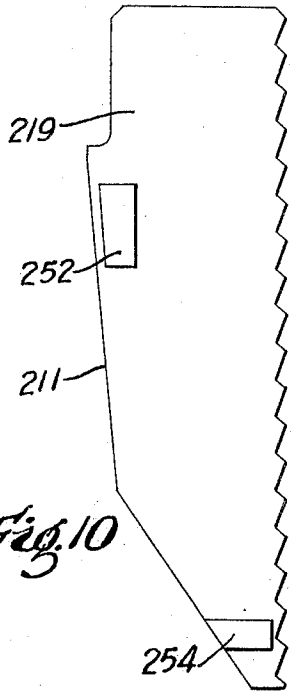
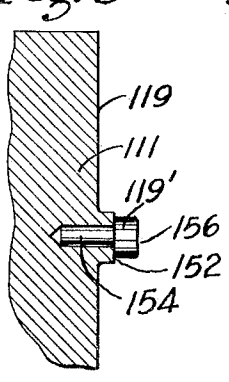


Fig. 10



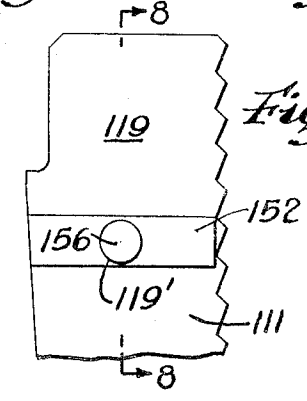


Fig. 7

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WELLHEAD EQUIPMENT WITH ABUTTING SLIPS

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Continuation of application Ser. No. 76,350, Dec. 16, 1960. This application June 21, 1965, Ser. No. 473,546
8 Claims. (Cl. 285—144)

This application is a continuation of our copending application Serial No. 76,350, filed December 16, 1960, now abandoned.

This invention relates to well head equipment and the like and particularly to an improved slip assembly for axially supporting pipe, such as casing and tubing employed in oil and gas wells, and to well head constructions embodying such slip assemblies.

It has long been common practice to suspend casing, tubing and like strings of pipe from well heads by means of a plurality of segmental, downwardly and inwardly tapered wedges, the individual wedges being known as slip segments and the several slip segments combining to form a circularly extending slip assembly. Each slip segment is provided with wickers or the like adapted to penetrate the wall of the pipe for establishing a good supporting engagement between the slip segments and the pipe. The inner faces of the slip segments are arcuate and of such configuration that, in the slip assembly, these faces combine to provide the slip assembly with an inner face of substantially circular transverse cross-section. The outer faces of the slip segments are the downwardly and inwardly tapered surfaces thereof and these are disposed in engagement with a frusto-conical supporting surface, such as a portion of the inner surface of the bowl of a head member. Accordingly, the weight of the pipe causes the slip segments to be wedged between the frusto-conical supporting surface and the outer surface of the pipe so that the wickered inner faces of the slip segments are jammed tightly against the pipe.

In recent years, the strings of casing, tubing and the like necessary for operational use in oil and gas wells have become longer and longer due to the increase in depth of the wells being drilled. Accordingly, the loads which must be supported by the slip assemblies have increased. This trend has required those designing well head equipment to employ slip segments of such configuration and arrangement that the very large loads which must now be carried will not result in excessive downward movement of the slip segments and resultant excessive inward deformation of the pipe being supported. In this regard, it will be understood that, when the pipe is supported by the slip assembly, the slip segments can slide along the frusto-conical supporting surface and, in doing so, will apply increasing radial forces to the pipe so that, if the forces are allowed to become great enough, the wall of the pipe will be excessively deformed inwardly to such a degree that, at the particular point involved, the inner diameter of the pipe will not pass the gage commonly referred to as the "drift" nor the required packers or bottom hole tools and therefore is no longer adequate for its intended purpose.

Prior art workers have proposed various ways for solving the problem of preventing the slips from applying excessive radial forces to the pipe being supported. Thus, U.S. Patent 2,887,754, issued May 26, 1959, to C. F. Johnson, discloses the provision of teeth or wickers on the outer faces of the slip segments in such fashion as to bite into the frusto-conical surrounding surface which supports the slip assembly. Such additional teeth or wickers tend to limit the downward axial movement of the slip segments and therefore also tend to prevent over-wedging. Also, U.S. Patent 2,874,436, issued February 24, 1959, to Herbert Allen, discloses a particular form of slip segment having a roughened outer face for special engagement with the frusto-conical supporting surface. While proposals of this general type have met with considerable success, there is obviously an upper limit on the axial loads which can be applied to such slip assemblies since, once the axial load becomes great enough, even slips with outer wickers or the like will travel along the frusto-conical supporting surface and allow over-wedging. Further, teeth or wickers on the outer face of the slip segments will tend to dig into and mar the frusto-conical supporting surface which surrounds the slip segments. The resulting damage to the frusto-conical surface makes it difficult to reset the slips, an operation which is frequently required in oil field practice.

It is accordingly a general object of the invention to provide slip means capable of controlling, within practical limits, the magnitude of the deformation of pipe or the like supported by the slip means, which deformation is the result of the wedging action of the slip segments.

Another object is to provide an improved slip assembly capable of axially supporting greater lengths of pipe and the like without excessively deforming the same.

A further object is to devise an improved well head construction wherein great lengths of pipe, such as casing and tubing, are adequately and positively supported but the danger of excessive deformation of the pipe is eliminated.

Yet another object is to provide a slip assembly of such nature that, as the weight of the pipe supported thereby increases, the slips will be positively stopped against further axial movement and over-wedging therefore prevented.

A still further object is to provide a slip means including a plurality of slip segments which are so constructed and arranged with respect to each other that, when in operative position, the inherent turning moment heretofore always applied to the slip segments by the weight of the pipe being supported is completely eliminated.

In order that the manner in which these and other objects are attained in accordance with the invention can be understood in detail, reference is had to the accompanying drawings, which form a part of this specification, and wherein:

FIG. 1 is a view, partly in vertical section and partly in elevation, of a casing head construction in accordance with one embodiment of the invention;

FIG. 2 is a sectional view on line 2—2, FIG. 1, illustrating the slip segments of the apparatus of FIG. 1 in one position, in which further downward axial movement thereof cannot occur;

FIG. 3 is a view similar to FIG. 2 but illustrating the slip segments in a position such that further downward axial movement thereof is still possible;

FIG. 4 is an elevational view of the slip assembly employed in the apparatus of FIG. 1;

FIG. 5 is a fragmentary transverse sectional view taken on line 5—5, FIG. 4;

FIG. 6 is a fragmentary elevational view of a portion of a slip assembly constructed in accordance with another embodiment of the invention;

FIG. 7 is a side elevational view of one of the slip segments employed in the assembly of FIG. 6, the view being taken on line 7—7;

FIG. 8 is a fragmentary sectional view taken on line 8—8, FIG. 7;

FIG. 9 is a fragmentary elevational view, similar to FIG. 6, of a slip assembly constructed in accordance with still another embodiment of the invention, and

FIG. 10 is a side elevational view of a slip segment of the assembly shown in FIG. 9, the view being taken on line 10—10, FIG. 9.

Stated broadly, the present invention achieves the aforementioned objects by means of a construction and arrangement of slip segments such that the weight of the pipe supported thereby can, as the length of the string of pipe is increased, become effective to bring the slip segments to a position in which all of the slip segments abut in edgewise contact. Such contact prevents further downward movement of the slip segments and thereby precludes further reduction of the inner diameter of the slip assembly so that no further increase in the radial gripping pressure applied to the pipe by the slip segments can occur. The slip assembly thus can be said to have a minimum effective internal diameter, occurring when the slip segments have moved into abutting contact with each other and etablished by reason of accurately spaced side abutment faces on each segment, this internal diameter being selected to provide adequate supporting engagement of the slip segments with the pipe when the pipe has the minimum permissible outside diameter for the size of pipe with which the slip assembly is intended for use.

In the drawings, FIG. 1 illustrates in simplified fashion a portion of a wellhead construction in accordance with one embodiment of the invention. Here, casing head member **1** is of conventional construction, being secured to the usual length of outer or supporting casing **2** and comprising a vertical passage **3** extending through the casing head member. Passage **3** includes an upper plain cylindrical portion **4**, a second plain cylindrical portion **5** of slightly smaller diameter located immediately therebelow, the usual smooth downwardly and inwardly tapering intermediate frusto-conical portion **6**, and lower plain cylindrical portions **7** and **7'**. The casing head member is provided with the usual top flange **8** upon which the next head member (not shown) is mounted.

The casing **9** to be supported from head member **1** extends coaxially through member **1** and is engaged and anchored by the slip assembly indicated generally at **10**. As will be clear from FIGS. 1–4, slip assembly **10** comprises three metal slip segments **11**, **12** and **13** which are identical save for the manner in which provision is made for attachment of hinges and handling cords. The slip segments each have an inner face in the form of a segment of a cylinder, as indicated respectively at **14**, **15** and **16**, for engagement with the outer surface of casing **9**, the faces **14–16** being made irregular for gripping engagement with the casing. Thus, the faces **14–16** can be provided with teeth or wickers, indicated at **17**, FIG. 1, in any of various fashions well known to those skilled in the art. At least the irregular inner faces of the slip segments are heat treated or otherwise made harder than the metal of casing **9** so that the irregularities of faces **14–16** will penetrate the casing wall to effect sufficient indenture of the pipe to assure a supporting engagement therewith.

Slip segment **11** has flat side or edge faces **18**, **19**, FIGS. 2–4, which extend radially and longitudinally relative to inner face **14**, and is also provided with an outer face **20** including an intermediate frusto-conical portion **21**, FIG. 4, dimensioned to be capable of lying in flush engagement with the frusto-conical portion **6** of the passage **3** through casing head member **1**. Slip segments **12** and **13** have flat side or edge faces **22**, **23** and **24**, **25**, respectively, identical with the side or edge faces of slip segment **11**. Slip segments **12** and **13** also have outer faces **26** and **27**, respectively, identical with outer face **20** of slip **11**. Thus, each face **26**, **27** includes an intermediate frusto-conical portion identical with portion **21** of face **20** and therefore capable of lying in flush engagement with portion **6** of passage **3**. As seen in FIG. 4, the intermediate frusto-conical portions of the outer faces of segments **11–13** are smooth, being free of teeth, wickers or other substantial irregularities of the type employed in prior-art devices such as that shown in the aforementioned Patent 2,887,754.

Each outer face **20**, **26** and **27** includes an upper plain cylindrical portion, as indicated at **28** in FIGS. 1 and 4, of reduced diameter.

Slip segments **11** and **12** are provided with slots **29** and **30**, respectively, which, as seen in FIGS. 2–5, are aligned in chordwise fashion with respect to the circular slip assembly. Slots **29** and **30** open outwardly of their respective slip segments and are identical, each being of U-shaped transverse cross-section and having a flat bottom face **31** and flat side faces **32**, FIG. 5. Slip segments **11** and **12** are hinged together by means of a hinge block **33** and hinge pins **34** and **35**. As will be clear from FIGS. 4 and 5, block **33** is provided with a pair of spaced openings **36** and **37** which respectively accommodate the pins **34** and **35**, the pins extending completely through the block and the openings **36** and **37** being elongated lengthwise of the block to allow the pins to shift relative to the block during opening and closing of the slip assembly. As illustrated in FIG. 4, the dimension of hinge block **33**, in a direction axially of the slip assembly, is such that the hinge block at least substantially completely fills the chordwise aligned slots **29** and **30**, preventing the slip segments from shifting axially one with respect to the other. The hinge pins **34** and **35** can be secured in any suitable fashion, as by being threaded into matching bores in the respective slip segments, these bores extending transversely of their respective slots **29**, **30**, in such fashion that each pin can project through both walls defining the slot with which that pin is associated.

Slip segments **11** and **13** are similarly provided with outwardly opening slots **38** and **39**, respectively, which are aligned cordwise with respect to the slip assembly. Slots **38** and **39** accommodate a hinge block **40**, FIG. 3, which is identical to block **33**, hereinbefore described. The hinge connection between slip segments **11** and **13** is completed by hinge pins **41** and **42** in the same manner hereinbefore described with reference to the hinge structure shown in FIG. 5. Again, the dimension of block **40**, in a direction axially of the slip assembly is such as to at least substantially completely fill slots **38** and **30**, so that axial shifting of slip segments **11** and **13**, one with respect to the other, is prevented. It will thus be apparent that the hinge connections between the three segments are such as to allow the slip assembly to be opened and closed about the pipe to be supported, but still prevent material axial shifting of the slip segments. With the slip assembly closed, the hinge connections assure that like portions of all the segments will be aligned in a common plane transverse to the axis of the assembly.

The slip segments are also each provided with an upwardly opening bore **43**, FIG. 3, to accommodate a suitable fastener (not shown), for attachment of the usual handling cords.

At their bottom ends, portions of outer faces **20**, **26** and **27** slant sharply toward the inner faces of the slip segments, as indicated at **44**, FIGS. 1 and 4, so as to clear the lateral ports **45** in member **1** communicating with the annular space between casing **9** and the supporting or outer casing **2**.

In assembled relation, slip segments **11–13** of this embodiment combine to define an annular assembly with inner faces **14–16** either precisely or approximately defining a plain cylindrical surface (ignoring wickers **17**), depending upon whether or not the slip segments abut each other. Outer faces **20**, **26** and **27** are disposed in sliding engagement with the surrounding frusto-conical surface provided by portion **6** of passage **3** in head member **1**. The slip segments are thus disposed in wedging relation between the frusto-conical surface **6** and casing **9**. As is well known in the art, such wedging relationship causes wickers **17** to penetrate casing **9**, sufficient indenture resulting to cause casing **9** to be supported via the wickers.

Assuming that the length of casing **9** is not so great that the axial force applied by the casing to the slip seg-

ments exceeds a predetermined value, the slip assembly can occupy any of various axial positions along the surface provided by portion **6** of passage **3**, in all of which positions further downward movement of the slips is possible because the sides or edges of the slip segments do not abut each other. However, when the load applied to the slip segments by casing **9** reaches said predetermined value, sufficient downward movement of the slip segments is assured to bring face **18** into engagement with face **24**, face **19** into engagement with face **22** and face **23** into engagement with face **25**. Since the side faces of each adjacent pair of slip segments now abut each other, as seen in FIG. 2, and since the outer faces of the slips engage portion **6** of passage **3**, no further downward movement of the slip segments, and therefore no further increase in radial gripping pressure applied to the casing by the slip segments, is possible.

As seen in FIG. 2, inner faces **14–16** define a plain cylindrical surface (ignoring wickers **17**) of definite diameter when the corresponding side faces of the slip segments are in contact with each other. It is obvious that, in theory, casing **9** could have an outer diameter so large that the casing would be excessively deformed under the conditions of FIG. 2 or so small that an inadequate gripping action would occur under the conditions of FIG. 2. In actual practice, however, wellhead constructions are designed for specific sizes of standard casing, tubing, etc. Thus, for example, the casing head construction illustrated in the drawings could, under present commercial practice, be designed for casing available to the trade as having an outer diameter of 7 inches. With present standard mill tolerances, the customer is assured that any piece of casing purchased as having a given nominal outer diameter will in fact have an outer diameter within plus or minus ¾% of the nominal size specified and that the wall thickness throughout the length of the piece will be substantially constant. Thus, assuming that the casing head illustrated in FIG. 1 is intended for supporting casing having a nominal outer diameter of 7 inches, the casing head must be operative to support casing having any outer diameter in the range of from 6.947 inches to 7.053 inches (7 inches plus or minus ¾% of 7 inches). Surprisingly, we have found that, employing a slip assembly constructed as hereinbefore described, the casing head structure of the invention is capable of supporting casing of the largest possible outer diameter (7.053 inches) in the range just mentioned without causing inward deformation of the casing to a degree sufficient to prohibit passage of the required packers or other bottom hole tools, and also will provide adequate gripping action to support casing of the smallest possible outer diameter (6.947 inches) in that range, and that this is so even for the maximum pipe loads required by the great depth of wells now being drilled.

From the foregoing, it will be understood that the side or edge faces **18, 19, 22, 23, 24,** and **25** of the slip segments must be formed with considerable accuracy because these faces determine the arcuate dimensions of the slip segments and, therefore, the effective internal diameter of the slip assembly when the slip segments occupy the mutually abutting positions illustrated in FIG. 2. In the embodiment illustrated in FIGS. 1–5, the side or edge faces of each of the slip segments are machined, following which the segments are assembled in side or edge face abutting relationship prior to turning or boring the outer and inner faces, respectively, so that their accurate formation requires a relatively higher manufacturing cost than is usually contemplated in the design of slips.

FIGS. 6–8 illustrate one manner in which the advantages of the embodiment of FIGS. 1–5 can be attained with a lower manufacturing cost. As is an accepted practice in the art, all of the segments of the slip assembly are made from a unitary casting or forging, the individual slip segments being jointed by connecting bridges indicated by dotted lines at **150** and **151** of FIG. 6. Thus the segments **111** and **112** of FIG. 6, joined by bridges **150** and **151**, can be machined as a unit when forming the prescribed inner and outer faces of the slip assembly, after which an accurate axial cut of substantial width is made through the bridge **150** to form the individual slip segments. The bridge **150**, located adjacent the top of the frusto-conical portion of the slip segments **111** and **112**, extends completely across the faces **119** and **122** in a direction radially of the assembly but is only of limited extent axially of the slip assembly. The bridge **151** is located adjacent the bottom of the slip segment and serves only to facilitate the machining of the outer and inner segment faces, and its dimensions are not critical since this bridge is removed and rendered inoperative before the slip segments are completed. The adjacent faces **119** and **122** of the slip segments **111** and **112**, respectively, are thus spaced apart by a material distance, the two slip segments engaging each other only via abutting means comprising a contact button **119′**, carried by slip segment **112**. A bore **154**, extending at right angles to face portion **152** and centered with respect to that face portion, is now formed in slip segment **111**. The contact button **119′** has a stem **155** so dimensioned that the contact button can be fixed in bore **154** simply by driving the stem **155** into the bore until the head of the button seats on face portion **152**. The head of the contact button **119′** has an accurately controlled length so that the exposed face **156** thereof is spaced from face portion **152** of the slip segment by an accurately predetermined distance.

While that portion of bridge **150** which is removed must be removed by making an accurate cut through the semi-finished slip assembly, all or substantially all of the lower bridge **151** is simply and economically removed in any expedient fashion.

It will be understood that the abutment means illustrated in FIG. 6, effective between slip segments **111** and **112**, is duplicated between the third slip segment (not shown), of the assembly and each of slip segments **111** and **112** in precisely the same fashion as has just been described. Accordingly, the minimum effective average internal diameter of the slip assembly is determined by the accurately formed contacting surfaces of the abutment means, which surfaces are of only limited extent and therefore relatively simply and economically manufactured, rather than by the entire side of edge faces of the slip segments.

Alternatively, as illustrated, in FIGS. 9 and 10, slip segments **211** and **212** can be provided with adjacent edge or side faces **219** and **222**, respectively, which are initially connected by two axially spaced bridges when the unitary casting is machined to form the prescribed inner and outer faces of the slip assembly. The two connecting bridges are then accurately severed to provide abutting face portions **252** and **253**, located near the top of the frusto-conical portions of the slip segment sand adjacent the outer faces thereof, and also abutting face portions **254** and **255**, adjacent the bottom of the slip segments. Since the abutting face portions **252, 253** and **254, 255** are of relatively limited extent, it will be understood that the fact that the faces of these portions must be accurately formed does not involve any undue complexity or cost in manufacturing of the slip assembly.

In the embodiment of FIGS. 1–5, the side faces of each slip segment are spaced apart arcuately by an accurately predetermined distance so that, when the slip segments reach their fully-wedged position, as illustrated in FIG. 2, the effective internal diameter of the slip assembly is that which will both provide adequate support for pipes of the smallest possible diameter and assure that, for pipes of the largest possible diameter, excessive inward deformation of the pipe will not occur. Similarly, it will be understood, that, in the embodiment of FIGS. 6–8, the face **156** of button **119′** is arcuately spaced from

the opposite side face of slip segment **111** by an accurately predetermined distance so that the desired result is accomplished. Also, in the embodiment of FIGS. 9 and 10, it will be understood that face portion **252** is arcuately spaced from the effective abutment face at the opposite side of slip segment **211** by an accurately predetermined distance.

Considering the embodiment of FIG. 6 and that of FIG. 9, it will be noted that in each case the adjacent slip segments are provided with abutment means located well above the midpoint of the frusto-conical portion of the slip assembly. Such location of the abutment means is particularly advantageous since it minimizes effective dimensional changes which might otherwise occur as a result of flexing of the slip segments under the heavy loads applied thereon by the long strings of tubular goods supported by the slip assembly.

In all of the embodiments illustrated, interengagement of the several slip segments of the slip assembly, when the segments have wedged to the extent indicated in FIGS. 1 and 2, is effective not only to limit in precise and positive fashion the effective internal diameter of the slip assembly but also to counteract the inherent turning moment which has heretofore been applied to the slip segments of prior-art devices by the supported load. In this regard, it will be understood that, so long as the edges or side faces of the slip segments are spaced from one another, the great weight of the load applied by the pipe supported by the slip segments tends to cause the top portions of the segments to turn inwardly. This tends to collapse the pipe and can, in prior-art devices, result not only in excessive damage to the pipe but also in the pipe being dropped into the well. However, once the slip segments are in engagement with each other, and assuming that the slip assembly is positively supported by the head member, such turning moment is no longer effective.

In all embodiments of the invention, each side of each segment is provided with an abutment face which is sized and shaped to be complementary to the corresponding abutment face of the adjacent side of the adjacent segment. Thus, in the embodiment of FIGS. 1–5, the side face **19** of segment **11** is complementary to the side face **22** of segment **12**. And, in the embodiment of FIGS. 9 and 10, the abutment face **252** of side **219** of segment **211** is complementary to the abutment face **253** of the adjacent side **222** of segment **212**. Further, the abutment faces of each segment are spaced apart circumferentially of the segment by an accurately predetermined arcuate distance, with such distances for all of the segments being measured along arcuate lines of the same radius, and with the arcuate extent of such distances being such that the sum of the arcuate distances for all of the slips is 360°. For example, in the embodiment of FIGS. 1–5, the three segments **11–13** are identical insofar as the arcuate distance between the side faces of the segment is concerned, and for each segment this distance is 120° so that, when the segments are assembled and disposed with the side faces respectively abutting, as seen in FIG. 2, the arcuate distances between the side faces combine to define a full circle.

While, for simplicity of illustration, the slip segments have been shown as provided with internal faces in the form of part of a cylinder, with the inner and outer faces having a common axis when the side or edge faces of the segments abut, the present invention is not limited in these regards. Thus, the slip segments can have inner faces of any form effective to engage the casing or pipe and it is not necessary that the inner and outer faces of the segments have a common axis when in supporting relation. While the side or edge faces of the slip segments have been illustrated as extending radially of the slip assembly when the segments are in mutually abutting relation, the invention is not limited to side faces of this specific nature. Thus, for example, the side or edge faces of the adjacent slip segments can be so made as to abut in a chordal plane, rather than a radial plane, when the segments occupy the mutually abutting positions of FIG. 2.

It will be understood that the invention is applicable not only to casing heads but also to tubing heads and other constructions in which pipe is anchored by segmental, wedging slip segments. While wickers **17** have been chosen for illustration, it will be understood that the inner slip segment faces **14–16** can be made irregular in other manners without departing from the scope of the invention. It will also be understood by those skilled in the art that, for simplicity of illustration, various parts of the wellhead construction of FIG. 1 which are not material to the invention have been omitted.

When it is stated in the appended claims that the slip assembly of the present invention is effective to securely support the pipe, with the pipe retaining, within practical tolerances, substantially its original inner diameter in the area of engagement between the pipe and the slip segments, we mean that, even though the pipe is securely supported in the manner defined, the inner diameter thereof remains such that the pipe will still pass its standard "drift" and packers, bottom hole tools, etc., therefore can still be passed freely through the pipe in the area of slip engagement.

What is claimed is:

1. In a well apparatus for supporting pipe of an outer diameter within a definite range established by manufacturing tolerance for a stated size of pipe, the combination of

a wellhead member having an upright passage through which the pipe to be supported can extend, said wellhead member having

an inwardly facing, downwardly and inwardly tapering, frusto-conical, slip-segment-supporting surface defining at least a portion of said passage; and

an annular slip assembly comprising a plurality of slip segments, each of said segments having

an inner, pipe-engaging face,

an outer face which slants downwardly toward the inner face of the segment, said outer face being of such an angle that said segments can be engaged in wedging fashion between said supporting surface and a pipe extending through said passage, and

a pair of sides spaced apart transversely of the segment;

each of said sides being provided with an abutment face and the abutment faces of each of said segments being spaced apart by an accurately predetermined distance, the ones of said abutment faces which are located on adjacent sides of adjacent ones of said segments being so disposed as to face each other when said segments are disposed with said outer faces engaging said supporting surface and like portions of said segments aligned in a common plane transverse to said passage,

said abutment faces being of limited extent axially of said slip assembly and being each located above the midpoint of said outer slanting face of the respective slip segment,

said accurately predetermined distance being such that adjacent ones of said abutment faces are spaced apart when said slip assembly occupies an upper position on said supporting surface, and a predetermined amount of downward movement of said slip assembly along said supporting surface, with attendant inward movement of said segments occurring because of the downwardly and inwardly tapering configuration of said supporting surface, will cause the adjacent pairs of said abutment faces to come into engagement with each other, such engagement then precluding further downward

movement of said slip assembly relative to said support means;

the dimensions of said segments, including said accurately predetermined distance, being such that, when adjacent pairs of said abutment faces are engaged, said inner faces will embrace a pipe of any outer diameter within said range with sufficient indenture of the pipe to effect positive support of the pipe by said slip assembly;

prevention of downward movement of said slip assembly relative to said supporting surface, resulting from engagement of said abutment faces, also serving to preclude further inward movement of said segments, whereby further inward deformation of the pipe is also prevented.

2. An apparatus according to claim 1, wherein said abutment faces are each located adjacent said outer slanting face.

3. An apparatus according to claim 1, wherein each side of each of said segments is provided with at least two of said abutment faces spaced apart axially of said slip assembly.

4. An apparatus according to claim 3, wherein one of said abutment faces at each side of each of said segments is located above the midpoint of the outer slanting face of such segment.

5. In a slip assembly for supporting pipe of an outer diameter within a definite range established by manufacturing tolerance for a stated size of pipe, the combination of

a plurality of slip segments each having

an inner, pipe-engaging face,

an outer face which slants downwardly toward the inner face of the segment, and

a pair of sides spaced apart transversely of the segment; and

retaining means operatively connected to said segments to retain the same in an annular series with like portions of said segments aligned in a common transverse plane,

said retaining means allowing transverse movement of said segments toward and away from each other;

each side of each of said segments being provided with an abutment face,

the abutment faces of each of said segments being spaced apart, transversely of the segment, by an accurately predetermined distance,

the ones of said abutment faces which are located on adjacent sides of adjacent ones of said segments opposing each other whereby, when said segments are moved toward each other, the opposing ones of said abutment faces come into mutual abutting relation and thereby preclude further movement of said segments toward each other,

said abutment faces being of limited extent axially of the slip assembly and each being located above the midpoint of said outer slanting face of the respective slip segment,

said accurately predetermined distance being such that, when said abutment faces are engaged, said inner faces will embrace a pipe of any outer diameter in said range with sufficient indenture of the pipe to effect positive support of the pipe by the slip assembly.

6. In a slip assembly for supporting pipe of an outer diameter within a definite range established by manufacturing tolerance for a stated size of pipe, the combination of

a plurality of slip segments each having

an inner, pipe-engaging face,

an outer face which slants downwardly toward the inner face of the segment, and

a pair of sides spaced apart transversely of the segment; and

retaining means operatively connected to said segments to retain the same in an annular series with like portions of said segments aligned in a common transverse plane,

said retaining means allowing transverse movement of said segments toward and away from each other;

each side of each of said segments being provided with at least two abutment faces spaced apart axially of the slip assembly,

the abutment faces of one of said sides of each of said segments being spaced from the abutment faces of the other of said sides of the segment, transversely of the segment, by an accurately predetermined distance,

the ones of said abutment faces which are located on adjacent sides of adjacent ones of said segments respectively opposing each other whereby, when said segments are moved toward each other, the opposing ones of said abutment faces come into mutual abutting relation and thereby preclude further movement of said segments toward each other,

said accurately predetermined distance being such that, when said abutment faces are engaged, said inner faces will embrace a pipe of any outer diameter in said range with sufficient indenture of the pipe to effect positive support of the pipe by the slip assembly.

7. In a well installation, the combination of

a wellhead member provided with an upright passage defined at least in part by a downwardly and inwardly tapering, frusto-conical, smooth slip-segment-supporting surface;

a string of standard casing including a portion which extends through said passage and has an outer diameter within a definite range established by manufacturing tolerance for a stated size of casing; and

an annular slip assembly engaged with said supporting surface and said portion of said string of casing to support the string of casing from said wellhead member, said slip assembly comprising a plurality of slip segments each having

an arcuate casing-engaging inner face engaged with said portion of said string of casing,

an outer smooth downwardly and inwardly slanting face disposed at the same angle as said supporting surface and in flush engagement therewith, and

a pair of sides spaced apart circumferentially of the segment and extending generally axially of said casing;

each of said sides being provided with an abutment face which is sized and shaped to be complementary to the corresponding abutment face of the adjacent side of the adjacent one of said segments and the abutment faces of each of said segments being spaced apart, circumferentially of the segment, by an accurately predetermined arcuate distance, said arcuate distances being measured along arcuate lines of the same radius and being of such arcuate extent that the sum of said arcuate distances is 360°,

the ones of said abutment faces which are located on adjacent sides of adjacent ones of said segments being in mutual abutting relation, whereby the weight of said string of casing is precluded from causing said segments to move downwardly relative to said wellhead member, said arcuate inner casing-engaging face of each of said segments being provided with a roughened surface adapted to indent the casing by a substantially uniform amount, said roughened surface being so disposed on each of said

segments that uniform radial force is applied to the casing about its entire circumference by said slip assembly;

like portions of said segments being aligned in a common plane transversely of said string of casing, and said arcuate casing-engaging inner faces combining to define a circular surface which embraces said portion of said string of casing with sufficient indenture of the casing to effect support of the string of casing by said slip assembly,

prevention of downward movement of said slip assembly relative to said wellhead member, by reason of the mutual engagement of said abutment faces, also being effective to preclude inward movement of said segments and thereby prevent excessive inward deformation of the casing.

8. In a slip assembly for supporting well casing of an outer diameter within a definite range established by manufacturing tolerance for a stated size of casing, the combination of

a plurality of slip segments each having

an inner, arcuate, pipe-engaging face,

an outer face which slants downwardly toward the inner face of the segment, and

a pair of sides spaced apart transversely of the segment; and

retaining means operatively connected to said segments to retain the same in an annular series with like portions of said segments aligned in a common transverse plane,

said retaining means allowing transverse movement of said segments toward and away from each other;

each side of each of said segments being provided with an abutment face,

the abutment faces of each of said segments being spaced apart, transversely of the segment, by an accurately predetermined distance,

the ones of said abutment faces which are located on adjacent sides of adjacent ones of said segments opposing each other whereby, when said segments are moved toward each other in such fashion as to decrease the overall diameter of said annular series, the opposing ones of said abutment faces come into mutual abutting relation and thereby preclude further movement of said segments toward each other,

said accurately predetermined distance being such that, when said abutment faces are mutually engaged, said arcuate inner faces combine to define a circular surface of accurately predetermined diameter capable of embracing casing of any outer diameter in said range with sufficient indenture of the casing to effect positive support of the casing by the slip assembly,

each of said segments comprising

an integral main body having first and second sides spaced circumferentially of the segment, each of said sides including a side surface which is of limited extent in a direction longitudinally of the segment and which is located above the midpoint of said outer slanting face of the segment,

a separate abutment member rigidly secured to said first side and projecting from the one of said side surfaces included thereby, said abutment member having a surface spaced from said one side surface in a direction transversely of the segment,

the distance between the other of said side surfaces and said surface of said abutment member constituting said accurately predetermined distance, and said other side surface and said surface of said abutment member respectively constituting said abutment faces.

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