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[54] **CASING SEAL TESTER FOR SUBSEA COMPLETIONS**

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[52] **U.S. Cl.** ..... **73/40.5 R,** 73/46, 73/151
[51] **Int. Cl.** **G01m 3/36,** G01m 3/14
[58] **Field of Search** ..... 73/40.5 R, 46, 49.1, 49.5, 73/49.6, 155, 151; 33/141 G

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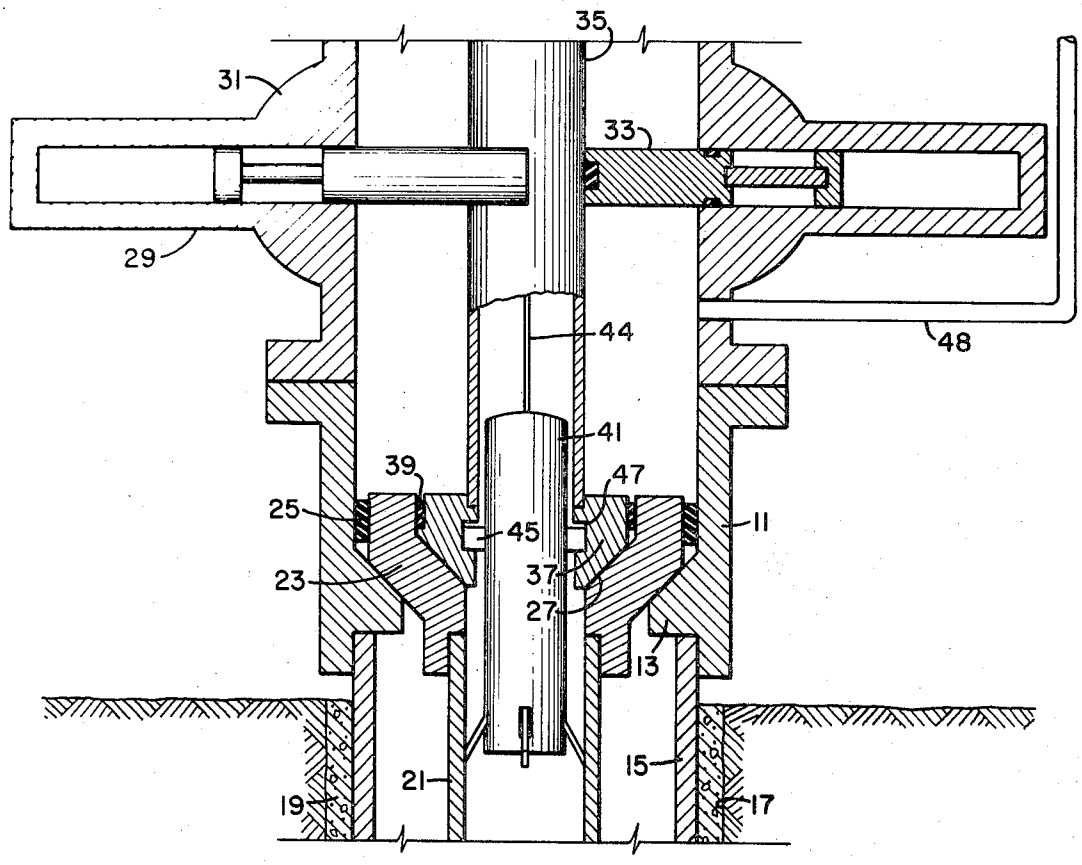
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Attorney, Agent, or Firm—James E. Gilchrist

[57] **ABSTRACT**

Method and apparatus are disclosed for testing annular seal assemblies of the type positioned between the upper exterior of a tubular member and a subsea wellhead or similar assembly from which the tubular member is suspended. The inner bore of the tubular member is isolated from the space directly above the seal. Then pressure is applied above the seal to create a differential pressure across it. A physical property of the tubular member is monitored as pressure is increased to detect any change in the monitored property indicative of a change in external pressure on the portion of the tubular member situated below the seal.

5 Claims, 2 Drawing Figures



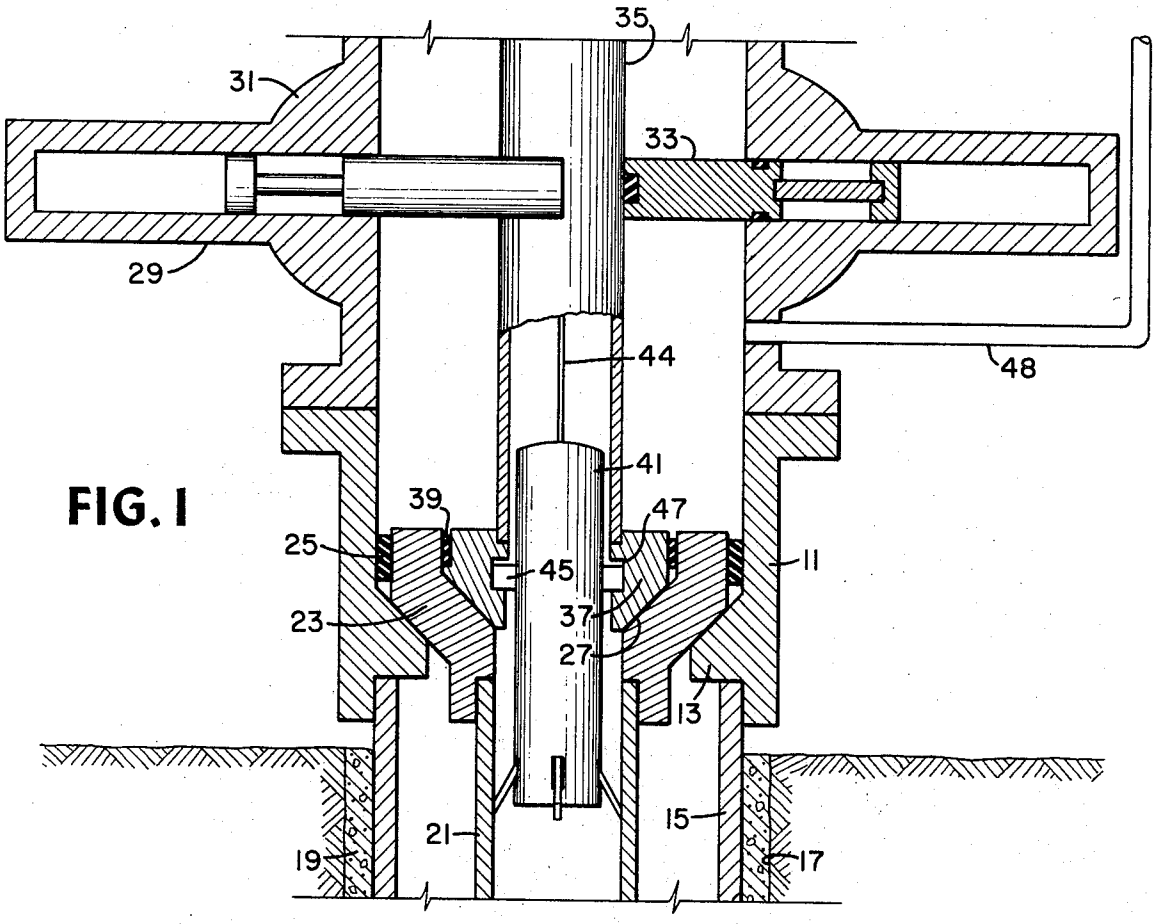

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FIG. 1

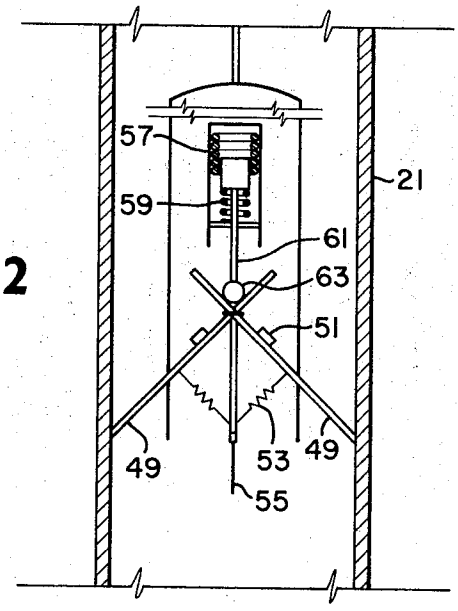

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FIG. 2

CASING SEAL TESTER FOR SUBSEA COMPLETIONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to method and apparatus for testing annular seals of the type positioned between a subsea wellhead and a tubular member landed within it.

2. Description of the Prior Art

Wells drilled offshore for crude oil and natural gas frequently have their wellheads positioned on the sea floor. In such installations, the wellhead is normally installed by mounting it on the upper end of a string of casing which is lowered into a borehole and cemented in place. The wellhead is a generally cylindrical member having a bowl-shaped bore which is adapted to sealably support an inner concentric string of casing. A casing hanger is affixed to the upper end of the inner pipe string prior to lowering and landing it within the bowl of the subsea wellhead. The hanger has an enlarged diameter and is adapted to be received and supported within the bowl. It is provided with a seal assembly around its outer periphery and like the wellhead has a bowl-shaped inner bore adapted to land the next string of casing. In this fashion, a nest of casing hangers may be landed one atop the other within a wellhead, each serving to suspend a successively smaller concentric string of casing.

Seal assemblies are positioned between each bowl and the casing hanger it supports to provide a pressure tight connection. These seals are important to the safety of operations carried out within the well as their integrity is essential to contain well pressure. They must be designed to withstand maximum well pressure since any kick or other pressure abnormality which must be controlled by closing the blowout preventers situated above the wellhead will be exerted across these seals. It therefore is an important aspect of any overall well safety program to pressure test each such seal assembly after its installation.

Current testing procedure employs a blowout preventer test tool which is positioned by lowering it on the drill string. It engages and seats within the bowl of the casing hanger of the innermost casing string and is provided with an annular seal assembly to close off the upper bore of the string. The blowout preventers are then closed around the drill string and fluid is introduced under pressure into the drill string-wellhead annulus beneath the preventers. Pressure is increased until differential pressure across the casing seals reaches the desired test level. Normally, fluid leak-off during this pressure test is interpreted as indicating a faulty seal assembly.

The above technique has the disadvantage that, for it to detect a seal leak, fluid must be free to flow across the faulty seal at detectable rates. If communication between the space beneath the seal being tested and the surrounding formation is impeded, as by the presence of cement, a faulty seal will not permit appreciable volumes of fluid to be pumped through it at test pressures. In addition, the formation itself may be so impermeable that it will only accept fluid at very high pressures. A rapid increase of pressure in response to the pumping of a small volume of fluid is thus not a positive test. An additional difficulty with this procedure is that the outer casing normally has a lower burst rating than the inner string so that, if pressure is rapidly increased and the seal is in fact faulty, the possibility exists that this testing procedure will burst the outer casing.

SUMMARY OF THE INVENTION

The method and apparatus of the present invention provide a positive test for annular seal assemblies of the type employed in subsea wells and greatly alleviate the difficulties outlined above. In accordance with the method of the invention, the seal disposed between a pipe string and the bowl assembly in which the string is landed is tested by isolating the upper bore of the string from the space above the seal and then increasing the pressure above the seal assembly to impose a differential pressure across the seal. As the differential pressure is increased, a physical property of the section of the pipe situated below the seal assembly is monitored to detect any change in the monitored property indicative of a change in external pressure acting on this segment of the pipe in response to the change in differential pressure. Preferably, the diameter of the inner bore of the pipe string is monitored at a point situated below the seal assembly.

The apparatus of the present invention is useful in testing an annular seal disposed between the exterior of a vertical tubular member and a wellhead or similar tubular member within which the tubular member is supported. It includes means for isolating the bore of the inner tubular member from the space directly above the annular seal and means for applying pressure to the top of the annular seal to increase the differential pressure acting across the seal without pressurizing the bore of the inner tubular member. Means extending within the tubular member are also provided for monitoring a physical property of that portion of the inner tubular member situated below the annular seal to detect any changes in the monitored property indicative of an increase in external pressure acting on the inner tubular member in response to an increase in the differential pressure across the seal. In a preferred embodiment a plurality of extensible arms are provided for contacting the inner wall of the tubular member and are adapted to detect any change in the inner diameter of the tubular member.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional elevation view of a subsea wellhead and associated apparatus in combination with the apparatus of the invention.

FIG. 2 is an enlarged elevation view of the apparatus of the invention depicted in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 of the drawings depicts a cross-sectional elevation of a wellhead designated by numeral 11. It will be noted to have a generally cylindrical configuration. Disposed about the inner circumference of its bore is an inward extending beveled shoulder 13 which serves to support an inner string of casing within the wellhead. The wellhead is shown connected to the upper end of a string of casing identified by numeral 15. This connection, may be threaded, welded or any of the other well known connections for joining tubular members for high pressure service. Casing string 15 is shown extending downwardly into a borehole 17 in which it is

anchored by means of cement **19** disposed in the annulus between the casing and borehole.

An inner string of casing **21** is shown in the drawing positioned concentrically within outer casing string **15.** A casing hanger **23** is connected to the upper end of this inner string. The casing hanger is sized to fit within the inner bowl of the wellhead and is beveled around its outer periphery so as to uniformly engage and to be supported by the inwardly extending shoulder identified by numeral **13.** It is provided with a seal assembly **25** disposed about its outer periphery. The upper interior of the hanger forms a bowl similar to that of the interior of the wellhead and is provided with a shoulder extending around the inner periphery designated by numeral **27** which is adapted to support an inner concentric pipe string.

Positioned above the wellhead is a portion of a blowout preventer stack designated generally by numeral **29,** which is typical of those used commercially in floating drilling operations. The BOP stack normally includes several ram-type preventers and a bag-type preventer. The portion shown includes a single ram-type preventer **31.** A section of the drill string **35** is shown extending downward through the inner bore of the BOP stack and preventer **31** is depicted with its rams **33** closed, sealing the annulus between the bore of the BOP and the drill string.

A substantially cylindrical member **37** is shown connected to the lower end of the drill string. A circumferential seal assembly **39** extends around the external periphery of the member. The member is shown positioned within the bowl of hanger **23** connected to the upper end of inner pipe string **21** and supported by inwardly extending shoulder **27** disposed about the inner periphery of the hanger. With cylindrical member **37** seated in the bowl of the hanger, as shown, circumferential seal **39** closes the space between the member and the bowl assembly against flow. The cylindrical member may conveniently be a BOP tester tool of the type commonly used in floating drilling operations. It will be appreciated, however, that other types of members could be used to isolate the bore of the tubular member from the space directly above seal **25.**

Means extending within inner tubular member **21** are provided for monitoring a physical property of that portion of the tubular member situated below annular seal **25** to detect any changes indicative of an increase in external pressure acting on the tubular member during pressure testing of seal **25.** Preferably, the inner diameter of the tubular member is monitored, although it will be appreciated that other properties diagnostic of pressure change could also or alternatively be monitored.

The means depicted includes a detector assembly designated by numeral **41** and shown positioned within the bore of cylindrical member **37** and extending downward therefrom within the bore of inner casing string **21.** A means is provided near the upper end of the detector assembly for anchoring it against the walls of cylindrical member **37.** This means may for example comprise a set of extensible dogs **45** adapted to extend into recesses **47** in the bore of the cylindrical member as is shown in the drawing. An inflatable packer assembly could also be used to anchor the detector device and it can readily be anchored to the wall of casing string **21.** It will be apparent that still other means of anchoring the detector assembly can be employed provided their performance is compatible with the requirements of the means used to monitor changes in the physical characteristics of the pipe string. It will frequently be desirable, for example, to anchor the detector assembly rigidly when changes in pipe diameter are measured by means of strain gages. Other physical characteristics may be more sensitive to vertical displacement, vibration, and the like.

The detector device shown has a wireline cable **44** of a type commonly used in well logging operations attached to its upper end. This cable is used to raise and lower the detector assembly within the bore of the drill string and also to conduct electrical signals. Thus the data monitored by the detector assembly can be transmitted through the wire line to the vessel at the water surface. In addition, signals transmitted through the cable can be used to extend and retract extensible dogs **45** to anchor and release the detector assembly from the cylindrical member. While shown as an independent device, the detector assembly can, alternatively, be made integral with cylindrical member **37** and thus be run in and out on the drill string. Where the two devices are integral the only function of the cable is to carry signals to the surface diagnostic of the physical property being mounted. While use of a cable is preferred, it will be noted that a downhole recorder could be used instead and test results analyzed when the detector and recorder are retrieved from the well.

Means are provided within the detector assembly for contacting the inner wall of pipe **21** and detecting pressure induced changes in the diameter of the pipe. As shown generally in FIG. **1** and in detail in FIG. **2,** a plurality of extensible arms **49** may be employed to engage the walls of pipe string. Changes in the diameter of the pipe may then be monitored by means of one or more strain gage transducers **51** situated on the arms. The exemplary device includes three extensible arms spaced at 120° intervals and pivotally connected to one another near their upper end. Each arm is interconnected by a spring **53** to a centrally located vertical rod **55** so as to bias the arms towards a retracted position away from the inner walls of the pipe string. A solenoid actuated device **57** is mounted in the housing above the arms and includes an extensible rod **61** which is biased by spring **59** towards its retracted position. As shown in the drawings, the solenoid is energized so that rod **61** is in its extended position, having overcome spring **59.** Ball **63** is shown attached to the end of the extensible rod and in contact with the segments of extensible arms **49** which are situated above the pivot. As shown, downward displacement of the ball has forced the arms to overcome restraining springs **53** and to pivot outwardly and into contact with the inner wall of the tubular member **21.** The arms will remain locked in contact with the pipe wall until solenoid **57** is de-energized. Changes in the inner diameter of the pipe will thereafter result in slight deflections in the extensible arms and these deflections are in turn detectable by the strain gage transducers.

It will be appreciated that numerous other mechanical arrangements may be employed to extend and retract the contact arms, the important aspect being that the arms, once in contact with the shoulder remain locked there so that any changes in their dimensions can be attributed to changes in diameter of the tubular member.

To test an annular seal assembly positioned between the upper exterior of a tubular member and a subsea wellhead or similar assembly within which the tubular member is sealably supported, the inner bore of the upper end of the tubular member is initially isolated from the space directly above the seal as, for example, by closing it against flow. This may conveniently be accomplished by running in a cylindrical member provided with a circumferential seal assembly and sized to be received within the upper end of the tubular member. This will preferably be a blowout preventer testing tool such as that designated by numeral **37** of the drawing which can be run on the end of the drill string until it is positioned within the bowl-shaped recess of hanger assembly **23** connected to the top of the inner pipe string. Sufficient weight is then applied to the tool to assure that it seats properly on inward extending shoulder **27** and that seal **39** prevents flow between the two members.

With the bore of inner tubular member **21** isolated from the space directly above seal **25** the blowout preventers are then closed around the drill pipe to localize the area in which pressure is increased to test the integrity of the annular seal. This may involve closing a ram-type preventer, such as **31** shown in FIG. **1**, or by closing a bag preventer. A fluid under pressure, usually drill fluid, is then introduced into the annular space above the seal assembly to be tested, i.e., the drill string-wellhead annulus beneath the BOP. This fluid may conveniently be introduced through choke line **48** which extends down the exterior of the riser pipe, not shown.

Pressure is increased so as to build up the differential pressure acting across the seal. This will serve to increase the external pressure acting on the portion of tubular member below the seal if the seal is faulty. At the same time, the physical characteristics of the tubular member are monitored to detect any changes indicative of an increase in external pressure acting on this section of the tubular member. Changes can readily be detected with the strain gage apparatus depicted in FIGS. **1** and **2** of the drawings. The strain gage apparatus contained within housing **41** may be lowered through the drill string and anchored within BOP test tool as shown in the drawings or, alternatively, may form an integral part of the BOP test tool. In either case an electrical cable such as the one depicted by numeral **41** preferably extends between the tool and the earth's surface. This cable can be used to raise and lower the strain gage device in addition to supplying electric power, furnishing control signals and relaying data back to the drilling vessel.

In the exemplary device shown, housing **41** is lowered by means of the cable and when extensible members **45** on the housing are in registry with slots **47** of the BOP test tool an electrical signal is transmitted down the cable to extend the locking dogs so as to anchor the device. Solenoid **57** is then energized so that rod **61** will be extended. This causes ball **63** on the end of the rod to force the extensible arms outward until they come into contact with the inner walls of conduit **21**. The strain gage transducer circuits are then energized and readings are taken to provide an initial level which will correspond to no deformation of the pipe. In the event the seal is leaking, the pressurized fluid contained in the drill pipe wellhead annulus will pressurize the annular area on the opposite side of the seal and cause the pressure acting on the exterior of the tubular member to increase. Any change in external pressure will tend to decrease the diameter of the pipe and will be detected by the strain gage apparatus, giving a rapid and positive indication of the existence of a defective seal assembly.

Upon completion of the test, solenoid **57** is de-energized permitting spring **59** to retract rod **61** and ball **63**. With the ball retracted springs **53** act to withdraw arms **49** from contact with the wall and to fold them toward central rod **55** and within the housing to facilitate withdrawal of the device. Extensible dogs **45** are de-energized to release housing **41** from the BOP test assembly **37** and cable **44** is then withdrawn to retrieve the device to the surface. The BOP rams **33** are then released and the drill string **35** is withdrawn to return the BOP test tool to the surface.

What is claimed is:

1. Apparatus for testing an annular seal disposed between the exterior of a tubular member and a subsea wellhead or similar assembly from which the tubular member is suspended which comprises:

a. means for isolating the bore of the inner tubular member from the space directly above the annular seal;

b. means for applying pressure to the top of the annular seal to increase the differential pressure acting across the seal without pressurizing the bore of the inner tubular member; and

c. means extending within the inner tubular member for monitoring a physical property of that portion of the inner tubular member situated below the annular seal to detect any changes in the monitored property indicative of a change in external pressure acting on the inner tubular member in response to increasing the differential pressure across the seal.

2. The apparatus of claim **1** wherein the monitoring means includes a plurality of extensible and retractable arms for contacting the inner wall of the tubular member in combination with at least one strain gage transducer to permit detection of changes in the inner diameter of the tubular member.

3. The apparatus of claim **2** wherein the isolating means includes a substantially cylindrical body member provided with an annular seal about its outer perimeter and sized to be sealably supported within the upper end of the tubular member.

4. A method of testing an annular seal of the type positioned between the upper exterior of a tubular member and a subsea wellhead or similar assembly from which said tubular member is suspended comprising:

a. isolating the bore of said tubular member from the space directly above the seal to prevent flow therebetween;

b. applying pressure to the top of said annular seal to create a differential pressure across said seal; and

c. monitoring a physical property of the portion of said tubular member situated beneath said annular seal to detect any change indicative of a change in external pressure acting on said portion of said tubular member in response to a change in the differential pressure.

5. The method of claim **4** wherein the inner diameter of the tubular member is monitored to detect any changes resulting from a change in external pressure.

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