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United States Patent Application Publication	20250257628
Kind Code	A1
Publication Date	August 14, 2025
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Surge Pressure Reduction Apparatus with Convertible Diverter Device and Integrity Verification Device

Abstract

An apparatus for use in the oil and gas industry for installation of drilling and production liners and sub-sea casing strings into a borehole through a drilling fluid on a workstring using a running tool with the benefits of surge pressure reduction is disclosed. In an embodiment, a convertible diverter device has a housing with diverting flow path which diverts fluid from its axial passageway to the annular space outside the convertible diverter device, and a closing sleeve, residing within the housing, the closing sleeve having a diverting position and a closed position. In the diverting position, the diverting flow path is not blocked by the closing sleeve, and in the closed position the closing sleeve sealingly blocks the diverting flow path, so only the axial passageway through the housing is accessible for passage of fluid and tools. The closing sleeve is shifted by use of a frangible activation seat, in combination with an activation plug, whereby the frangible activation seat is pulverized after the closing sleeve converts to the closed position. Thereby, the axial passageway is left with an effective internal diameter that may be equal to the internal diameter of the closing sleeve, which may ensure safe passage of fluids and cementing plugs through the converted diverter during casing cementing operations.

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Appl. No.:	**18/859921**
Filed (or PCT Filed):	**August 23, 2024**
PCT No.:	**PCT/US2024/043666**

Related U.S. Application Data

Publication Classification

Int. Cl.: **E21B33/12** (20060101); **E21B34/14** (20060101)

U.S. Cl.:

CPC **E21B33/1208** (20130101); **E21B34/142** (20200501);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a non-provisional application that claims the benefit of U.S. Application Ser. No. 63/534,178 filed on Aug. 23, 2023, which is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION
Field of the Invention
[0002] This invention relates to a downhole surge pressure reducing apparatus for use in the oil and gas industry. More particularly, the apparatus of the present invention provides surge pressure reduction functionality for installing a drilling/production liner, or sub-sea casing down a borehole, by utilizing a frangible activation seat, which results in an unrestricted passageway through the apparatus for subsequent cementing of the drilling/production liner, or sub-sea casing.
Background of the Invention
[0003] Current techniques for reducing surge pressures during installation of casing, or a liner, in an oil and/or gas well typically utilize activation plug and activation seat configurations. These techniques may incorporate a flow port that diverts fluid from the inside of the casing and workstring to the annular space outside of the workstring, which reduces the surge pressure imparted on the open formation caused by lowering the casing and workstring into the well. Upon landing of the casing at the desired depth, it is often desired to block the flow port, so that cement can be pumped down the inside of the workstring and casing, exiting the shoe, or bottom, of the casing, ultimately placing the cement into the annular space outside of the casing and inside the borehole. These techniques leave a restriction in the work string that has proven difficult for the passage of other tools during cementing operations, or wireline operations, following the activation of the surge pressure reducing tools. The no-go diameter of the workstring wiper plugs used to follow the cement, and providing a barrier between the drilling fluid and cement, are typically bigger in diameter than the activation plug of the surge pressure reducing tool, which may be because the activation plug may fall through any casing wiper plugs that are activated by the workstring wiper plug. If the activation plug is larger than the no-go diameter of the workstring wiper plug, then the activation plug can become lodged in the downhole casing wiper plug, so the casing wiper plug cannot accept the workstring wiper plug.
[0004] If care is not taken to test every conceivable configuration of the workstring wiper plug that must pass through the surge pressure reducing tools, then a workstring wiper plug, or other type of tool, may become lodged in the work string at the activation seat, causing severe damage to the wellbore.
[0005] Furthermore, current techniques may employ an integrity verification device positioned downhole of the surge pressure reducing tool, which is used for confirming proper activation of the surge pressure reducing tool. Currently, some integrity testing devices incorporate test seats that further restrict the work string, in the same manner as the surge pressure reduction device.

BRIEF SUMMARY OF SOME OF THE PREFERRED EMBODIMENTS

[0006] This invention overcomes drawbacks to conventional techniques by the use of a frangible activation seat, which is pulverized upon activation of the surge pressure reduction tool. Such technique having a frangible activation seat that may leave the axial passageway of the surge pressure reducing tool with no activation seat restriction, so that the axial passageway, in the area of the previously pulverized activation seat, has the same, or larger, diameter than the smallest inner diameter of the workstring.

[0007] Furthermore, a similar frangible test seat can be incorporated in an integrity testing device, which allows for confirmation of proper activation of the surge pressure reduction tool. Following the integrity test of the surge pressure reducing tool, the frangible test seat is pulverized upon reaching a preset activation pressure.

[0008] The workstring is left with no restrictions, caused by an activation seat, or a test seat, which could impede subsequent utilization of workstring wiper plug(s), or other types of equipment, introduced into the axial passageway of the workstring during operations following conversion of the surge pressure reducing tool, and integrity verification.

[0009] These and other needs in the art are addressed by an apparatus for surge pressure reduction for installation of well casing with a convertible diverter device. The apparatus has a housing assembly having an axial internal passageway. The apparatus also has a diverting flow path extending from the axial internal passageway through an outer surface of the housing assembly. In addition, the apparatus includes the housing assembly being connected within a length of a workstring on upper and lower ends of the housing assembly. Further, the apparatus has a closing sleeve releasably connected to the housing assembly. Moreover, the closing sleeve has a first position where its lower end is above the diverting flow path and a second position where the closing sleeve covers the diverting flow path. Seals are engaged within the housing assembly so substantially no fluid passes from the axial internal passageway through the outer surface of the housing assembly. Furthermore, the apparatus includes a frangible activation seat containing an axial hole therethrough, which is configured to catch and seal to an activation plug. The apparatus further includes that the activation plug is conveyed through the workstring to the convertible diverter device. The frangible activation seat is releasably connected to the closing sleeve via a supporting sleeve so that hydraulic pressure applied above the frangible activation seat causes the frangible activation seat, the supporting sleeve, and the closing sleeve to move from the first position to the second position within the housing assembly. The frangible activation seat subsequently releasing from the closing sleeve so the frangible activation seat falls into an impact surface so that the frangible activation seat breaks into small particles and the small particles, along with the activation plug, are moved through the workstring and well casing, thereby leaving the convertible diverter device with an axial passageway that is about equal in diameter to the closing sleeve or the supporting sleeve, whichever is smaller. In embodiments, the frangible activation seat is glass. In further embodiments, the activation plug is a ball. Additional embodiments include where the activation plug has an elastomeric outer layer.

[0010] In a further embodiment, the apparatus includes an integrity verification device positioned below the convertible diverter device. The integrity verification device has a verification housing assembly having an axial internal passageway. In addition, the integrity verification device includes the verification housing assembly being connected within the length of the workstring on upper and lower ends of the verification housing assembly. Further, the integrity verification device has a frangible verification seat containing an axial hole therethrough, which is configured to catch and seal to the activation plug. Moreover, the integrity verification device includes that the frangible verification seat is releasably connected to the verification housing assembly via a verification supporting sleeve so that hydraulic pressure applied above the frangible verification seat causes the frangible verification seat and the verification supporting sleeve to move from a test position to an open position within the verification housing assembly. The frangible verification seat falls into an

impact surface so that the frangible verification seat breaks into small particles and the small particles, along with the activation plug, are moved through the workstring and the well casing. Furthermore, the integrity verification device is left with an axial passageway that is about equal in diameter to the verification housing or the verification supporting sleeve, whichever is smaller.
[0011] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter that form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiments disclosed may be readily utilized as a basis for modifying or designing other embodiments for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent embodiments do not depart from the spirit and scope of the invention as set forth in the appended claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0012] For a detailed description of the preferred embodiments of the invention, reference will now be made to the accompanying drawings in which:
[0013] FIG. **1** is an elevation view of a wellbore depicting a drilling/production liner being installed downhole on a drill pipe using a surge pressure reducing tool string comprising a surge pressure reducing convertible diverting tool and an integrity verification device;
[0014] FIG. **2** is a sectional view of an embodiment of the surge pressure reducing convertible diverter and integrity verification device, in the diverting position;
[0015] FIG. **2**A is an enlarged sectional view of an embodiment of the convertible diverter in the diverting position;
[0016] FIG. **2**B is an enlarged sectional view of an embodiment of the integrity verification device in the test position;
[0017] FIG. **3** is a perspective view of a closing sleeve of the convertible diverter, showing an embodiment of the latch mechanism;
[0018] FIG. **4** is a perspective, cutaway view of the closing sleeve, activation plug, and activation seat in the ready-for-activation position;
[0019] FIG. **4**A is a perspective, cutaway view of the closing sleeve, activation plug, and activation seat in the activated position;
[0020] FIG. **5** is a sectional view of an embodiment of the surge pressure reducing convertible diverter and integrity verification device, in the closed and ready-for-cementing position;
[0021] FIG. **5**A is an enlarged sectional view of the closing sleeve area from FIG. **5**; and
[0022] FIG. **5**B is an enlarged sectional view of the activation area of the integrity verification device from FIG. **5**.
DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS
[0023] In oilfield applications, a “drilling/production liner” and “sub-sea casing” are tubular casing members that are installed on a worksting, or drill pipe. It is to be understood that the term “sub-sea casing” is used with respect to offshore operations, where the upper end of the casing is landed in the wellhead located near the sea floor. For ease of reference in this specification, the present invention is described with respect to a “drilling/production liner.” The term “tubular casing member” is intended to embrace either a “drilling/production liner” or a “sub-sea casing.”
[0024] A description of an embodiment of the present invention is provided to facilitate an understanding of the invention. This description is intended to be illustrative and not limiting of the present invention. Furthermore, while one embodiment of the present invention includes a surge pressure reducing apparatus comprising both a convertible diverter and an integrity verification

device, it should be understood that another embodiment of the present invention includes a convertible diverter device without use of an integrity verification device.

[0025] With reference to FIG. **1**, the general components of a system in which a tool in accordance with the present invention is used are illustrated. Mast M suspends a traveling block TB. The traveling block TB supports a top drive D that moves vertically, upward and downward. An influent drilling line L supplies the top drive D with drilling fluid from a drilling fluid reservoir (not shown). The workstring S comprises a plurality of drill pipe segments that extend down into the borehole BH, and the number of such drill pipe segments may be dependent on the depth of the borehole BH. Additionally, the workstring S comprises a convertible diverter device **100** and, in some embodiments, an integrity verification device **200** in accordance with the present invention, which are operatively connected between drill pipe segments of workstring S and above running tool RT. There may be drill pipe segments positioned between convertible diverter device **100** and integrity verification device **200**, as well as between integrity verification device **200** and running tool RT. In an embodiment, running tool RT is comprised of a releasing device and a casing hanger, the casing hanger permanently connected to casing C, which is the tubular casing member. The lower end of casing C has a guide shoe GS, which may contain a convertible valve. It is to be understood by one of ordinary skill in the art, that the convertible valve is open to flow in both directions in a run-in position. Once the casing C is located at the desired position in the borehole BH, the convertible valves are converted to one-way valves, which only allow fluid flow from inside casing C to borehole BH for cementing operations.

[0026] During the downward movement of installing casing C, casing C and workstring S are displacing drilling fluid, which must go somewhere. This displacement creates surge pressure on formation F. Surge pressure may be undesirable, as it may cause damage to the open formation F, which can result in problems with cementation of casing C within borehole BH.

[0027] Surge pressure reduction is accomplished because guide shoe GS allows for drilling fluid to enter casing C, in a run-in position. The drilling fluid continues to be displaced through the inner passageway of casing C, and into an inner passageway of workstring S, and diverted from the inner passageway of workstring S to the annular space between the inner wall of surface casing SC and the outer wall of workstring S, via convertible diverter device **100**.

[0028] Still with reference to FIG. **1**, solidified cement CE fixes surface casing SC to the surrounding formation F. Surface casing SC contains an opening O in the uppermost region of the surface casing SC. The opening O controls the return of drilling fluid as it travels up the annular space between the workstring S and the surface casing SC.

[0029] With reference to FIGS. **2**, **2**A, and **2**B, an embodiment of the present invention includes a convertible diverter device **100** and an integrity verification device **200**, which may, or may not be, separated by operable connections to drill pipe segments. The embodiment of the configuration shown in FIGS. **2**, **2**A, and **2**B is in the diverting position. Diverter upper connection **101** extends above housing assembly **103**, and is used to operatively connect to the lower end of a drill pipe segment used in the workstring S. Diverter lower connection **102** extends below housing assembly **103**, and is for operatively connecting to the upper end of a drill pipe segment, or verification device upper connection **201**. Integrity verification device **200** contains a verification device upper connection **201** and a verification device lower connection **202**. Verification device lower connection **202** is used to operatively connect to the upper end of the running tool RT, or to drill pipe segments, which may extend between integrity verification device **200** and running tool RT.

[0030] In embodiments as shown, housing assembly **103** includes an axial through-bore for passage from the inside of the workstring S to the inside of the casing C, and a diverting flow path **104** formed through the wall of housing assembly **103** for establishing communication between the annular space outside the convertible diverter device **100** and the axial bore of the housing assembly **103**. Therefore, such an embodiment allows the displaced drilling fluid to flow up the annular space, having a larger flow area than the axial passageway of the workstring S, which reduces the surge pressure on the open formation F.

[0031] In further embodiments as shown, closing sleeve **110** is releasably connected to housing assembly **103** by an upper shear mechanism **115**, shown as one, or more, shear screws. The lower end of the closing sleeve **110** is positioned above diverting flow path **104** when in the diverting position. Upper seal **120**A provides a seal between closing sleeve **110** and housing assembly **103**, above diverting flow path **104** and lower seal **120**B positioned within housing assembly **103**, below diverting flow path **104**. Lower seal **120**B is protected in the diverting position, from erosion, movement, debris, and the like by cover sleeve **160**. Cover sleeve **160** is releasably connected to housing assembly **103**, and has an upper end which is positioned below diverting flow path **104**. Cover sleeve **160** is temporarily held in position by lower release mechanism **165**, shown as one or more shear screws.

[0032] In embodiments as illustrated, after casing C is lowered to a desired depth in borehole BH, activation plug **300** is launched from the surface by introduction into the internal axial passageway of the workstring S. Activation plug **300** is designed to sealingly engage activation seat **150**. Activation plug **300** may be allowed to fall, within the internal axial passageway of the workstring S, to the activation seat **150**, or it may be pumped down, with drilling fluid, the internal axial passageway of the workstring S. In the embodiment as illustrated, activation plug **300** is a ball. In some embodiments, it may be desirable for activation plug **300** to have a resilient elastomeric outer layer to prevent damage to activation seat **150** when activation plug **300** lands on activation seat **150**, and subsequently lands on verification seat **250**. It is to be understood that activation plug **300** is not limited to a ball but may include any other configuration suitable to sealingly engage activation seat **150**.

[0033] Activation seat **150** is supported in the run-in position by activation shear sleeve **151**. Activation shear sleeve **151** is releasably connected to closing sleeve **110** by activation shear tab **151**T of activation seat **150**. Activation shear tab **151**T is manufactured to “shear”, or break, at a predetermined force which is provided by hydraulic pressure against activation plug **300** sealing against activation seat **150**. Activation seat **150** is sealingly engaged with closing sleeve **110** via bonded seal **121**. Bonded seal **121** has a resilient elastomeric portion **121**R that is permanently bonded to a rigid substrate of bonded seal **121**. Resilient elastomeric portion **121**R provides a suitable seal between the outer surface of activation seat **150** and an inner surface of closing sleeve **110**. Impact pin **152** is held in place between activation shear sleeve **151** and closing sleeve **110**. Impact pin **152** has an upper end that is configured to rupture frangible activation seat **150**, upon impact. The upper end of impact pin **152** is spaced away from the activation seat **150** while convertible diverter device **100** is in the diverting position. Stop shoulder **110**S, located within closing sleeve **110**, is configured to limit downward movement of activation shear sleeve **151**. It is to be understood by one of ordinary skill in the art, that there may be one, or more impact pins **152**, used to ensure desirable breaking of frangible activation seat **150**.

[0034] Latch mechanism **112** is retained in a profile created by the coupling of retention ring **111** and closing sleeve **110**. Retention ring **111** provides retention of activation seat **150** by limiting upward movement of activation seat **150**. Furthermore, retention ring **111** ensures that latch mechanism **112** moves with closing sleeve **110**, from a diverting position to a closed position during activation. Latch mechanism **112** is designed such that it can flex from a radially compressed, or run-in, position, to a machined, or latched, position. FIG. **3** shows latch mechanism **112** in the machined position while residing in the profile created between coupled retention ring **111** and closing sleeve **110**.

[0035] FIG. **4** shows the quarter-sectioned view, in the run-in position, with activation plug **300** seated on activation seat **150** within closing sleeve **110**.

[0036] FIG. **4**A shows the post activation position of the same components shown in FIG. **4**.

[0037] FIGS. **2** and **2**B further show an integrity verification device **200**, which is positioned below convertible diverter device **100**. Integrity verification device **200** has a verification housing assembly **203**, which is operably connected to the workstring S on its upper connection **201** and lower connection **202**. Following closure of convertible diverter device **100**, integrity verification device **200** is used to verify the pressure integrity of seals **120**A and **120**B between closing sleeve **110** and housing assembly **103**. This verification is accomplished by activation plug **300** falling to and sealingly engaging frangible verification seat **250**. Frangible verification seat **250** is supported in the test position by verification shear sleeve **251**, in similar fashion to activation seat **150** being supported by activation shear sleeve **151**. It is to be understood by one of ordinary skill in the art, that there may be one, or more impact pins **252**, used to ensure desirable breaking of frangible verification seat **250**.

[0038] Verification shear tab **251**T may be manufactured to "shear", or break, at a predetermined force, which is provided by hydraulic pressure against activation plug **300** sealingly engaged with verification seat **250**. Verification seat **250** is sealingly engaged with verification housing assembly **203** via verification bonded seal **221**. Verification bonded seal **221** has a resilient elastomeric portion **221**R, which is permanently bonded to a rigid substrate of verification bonded seal **221**. Resilient elastomeric portion **221**R provides a suitable seal between the outer surface of verification seat **250** and an inner surface of verification housing assembly **203**. Impact pin **252** is held in place between activation shear sleeve **251** and verification housing assembly **203**. Impact pin **252** has an upper end that is configured to rupture frangible verification seat **250**, upon impact. The upper end of impact pin **252** is spaced away from verification seat **250** while integrity verification device **200** is in a test position. Verification stop shoulder **203**S, located within verification housing assembly **203**, is configured to limit downward movement of verification shear sleeve **251**.

[0039] With reference to FIGS. **5** and **5**A, convertible diverter device **100** is revealed in its closed position, so that the diverting flow path **104** is blocked and sealed by closing sleeve **110** in concert with seals **120**A and **120**B. The closed position is accomplished by activation plug **300** landing and sealing against activation seat **150**. This closed position allows for hydraulic pressure to be applied above activation seat **150**. The hydraulic pressure creates a force pushing against upper shear mechanism **115**, as well as against activation shear tab **151**T. The applied hydraulic pressure required to shear, or break, upper shear mechanism **115** is significantly lower than the applied hydraulic pressure to shear, or break, activation shear tab **151**T. This may be desired to ensure that closing sleeve **110** is fully shifted to the closed position, before activation seat **150** is pulverized. Once upper shear mechanism **115** breaks, closing sleeve **110**, along with the components that reside inside of or attached to closing sleeve **110**, will shift downward. Upper shear mechanism remnant **115**R is the "broken off" portion of upper shear mechanism **115** following the release of closing sleeve **110** from housing assembly **103**. The lower end of closing sleeve **110** will contact upper end of cover sleeve **160**, and the momentum and/or continued application of hydraulic pressure may cause lower release mechanism **165** to break the connection between cover sleeve **160** and housing assembly **103**. Lower release mechanism remnant **165**R is the "broken off" piece of lower release mechanism **165** following the release of cover sleeve **160** from housing assembly **103**. Closing sleeve **110** may push cover sleeve **160** downward, until it shoulders out in the closed position. In the closed position, latch mechanism **112** has reached a position downhole of locking shoulder **103**S, and latch mechanism **112** has flexed outward radially into its machined position, thereby resisting any upward movement relative to the housing assembly **103**, therefore locking closing sleeve **110** in the closed position.

[0040] With reference to FIGS. **5** and 5B, integrity verification device **200** is revealed in its post-test position. The post-test position is achieved by applying hydraulic pressure above the sealingly engaged activation plug **300** and frangible verification seat **250**. The hydraulic pressure imparts an axial piston force upon frangible verification seat **250**, which loads into verification shear sleeve **251**. Verification shear sleeve **251** contains the feature of verification shear tab **251**T that may be designed to "shear" or break off of verification shear sleeve **251** at a predetermined force, or pressure. To verify the proper closing of convertible diverter device **100**, hydraulic pressure is applied and held, at a level that is lower than the predetermined force, or pressure, which breaks, or shears, verification shear tab **251**T. After integrity is confirmed, hydraulic pressure is increased to break, or shear, verification shear tab **251**T. Upon breaking, or shearing, of verification shear tab **251**T, the inner portion of verification shear sleeve **251**, along with frangible verification seat **250**, is driven downward so frangible verification seat **250** comes into forceful contact with impact pin **252**. Impact pin **252** is designed to be harder and tougher than verification seat **250**, therefore causing frangible verification seat **250** to be pulverized into small particles, which travel downhole with the flow of the drilling fluid. And, activation plug **300**, no longer supported by the pulverized frangible verification seat **250**, is free to fall and travel downhole through the casing C with the flow of the drilling fluid.

[0041] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations may be made herein without departing from the spirit and scope of the invention as defined by the appended claims.

Claims

1. An apparatus for surge pressure reduction for installation of well casing with a convertible diverter device comprising: a) a housing assembly having an axial internal passageway, and a diverting flow path extending from the axial internal passageway through an outer surface of the housing assembly; b) the housing assembly being connected within a length of a workstring on upper and lower ends of the housing assembly; c) a closing sleeve releasably connected to the housing assembly; d) the closing sleeve having a first position where its lower end is above the diverting flow path and a second position where the closing sleeve covers the diverting flow path, and seals are engaged within the housing assembly so substantially no fluid passes from the axial internal passageway through the outer surface of the housing assembly; e) a frangible activation seat containing an axial hole therethrough, which is configured to catch and seal to an activation plug; f) the activation plug is conveyed through the workstring to the convertible diverter device; g) the frangible activation seat is releasably connected to the closing sleeve via a supporting sleeve so that hydraulic pressure applied above the frangible activation seat causes the frangible activation seat, the supporting sleeve, and the closing sleeve to move from the first position to the second position within the housing assembly; h) the frangible activation seat subsequently releasing from the closing sleeve so the frangible activation seat falls into an impact surface so that the frangible activation seat breaks into small particles and the small particles, along with the activation plug, are moved through the workstring and well casing; and i) leaving the convertible diverter device with an axial passageway that is about equal in diameter to the closing sleeve or the supporting sleeve, whichever is smaller.
2. The apparatus of claim 1, wherein the frangible activation seat is glass.
3. The apparatus of claim 1, wherein the activation plug is a ball.
4. The apparatus of claim 3, wherein the activation plug has an elastomeric outer layer.
5. The apparatus of claim 1, including an integrity verification device positioned below the convertible diverter device, the integrity verification device comprising: a) a verification housing assembly having an axial internal passageway; b) the verification housing assembly being connected within the length of the workstring on upper and lower ends of the verification housing assembly; c) a frangible verification seat containing an axial hole therethrough, which is configured to catch and seal to the activation plug; d) the frangible verification seat is releasably connected to the verification housing assembly via a verification supporting sleeve so that hydraulic pressure applied above the frangible verification seat causes the frangible verification seat and the verification supporting sleeve to move from a test position to an open position within the verification housing assembly; e) the frangible verification seat falls into an impact surface so that

the frangible verification seat breaks into small particles and the small particles, along with the activation plug, are moved through the workstring and the well casing; and f) leaving the integrity verification device with an axial passageway that is about equal in diameter to the verification housing or the verification supporting sleeve, whichever is smaller.