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(54) **MONOBORE RELEASE FOR TUBING  
CONVEYED PERFORATING**

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(57) **ABSTRACT**

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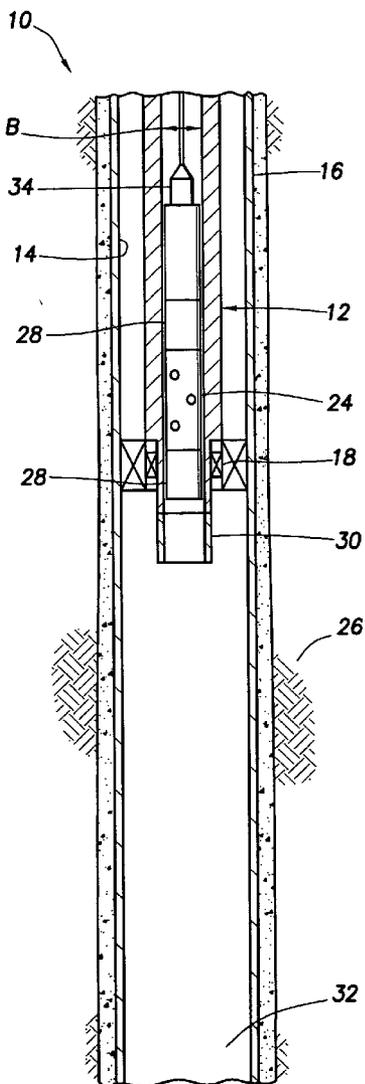
A monobore release for tubing conveyed perforating in a subterranean well. In a described embodiment, a well perforating system includes a release assembly interconnected in a tubular string. At least one perforating gun is releasably secured to the tubular string by the release assembly while the tubular string is conveyed into the well. The release assembly permits the perforating gun to be retrieved from the well through the tubular string, and also permits the perforating gun to be separated from the tubular string in the well.

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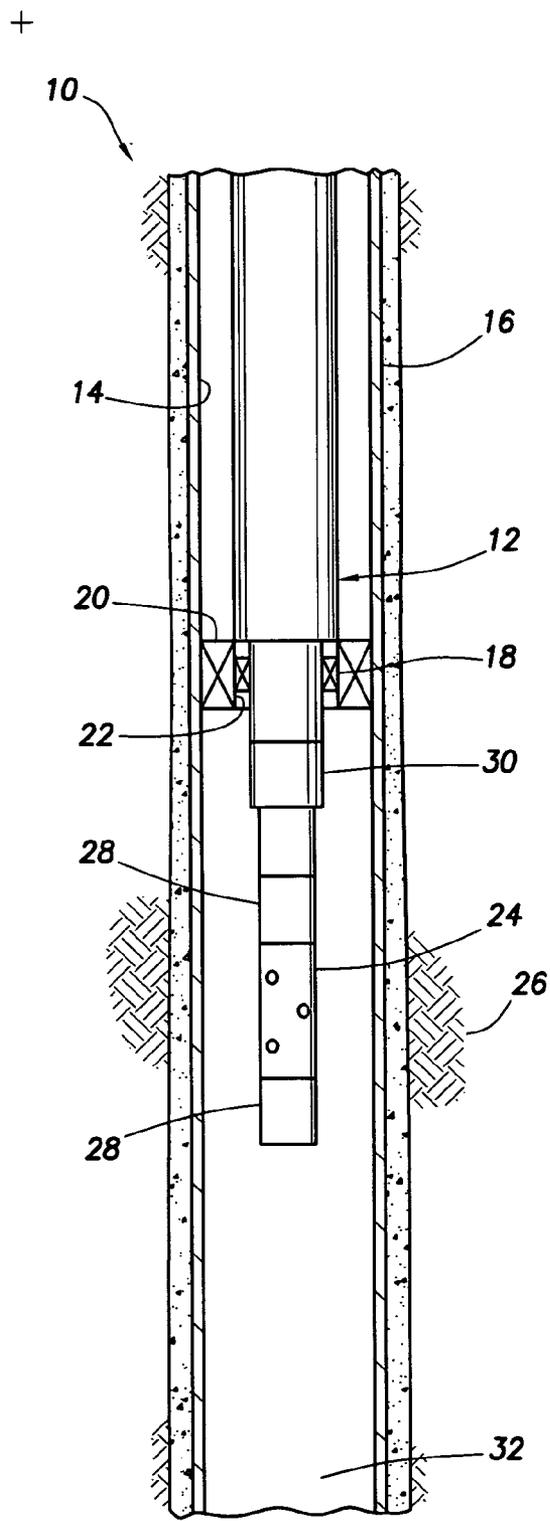


FIG. 1

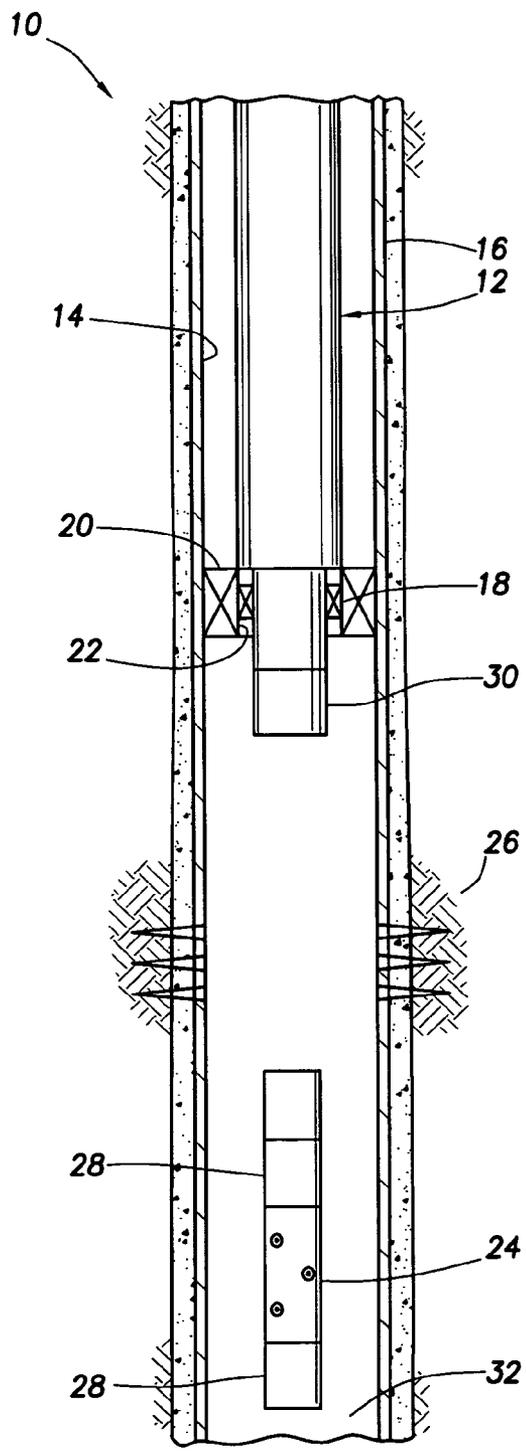


FIG. 2



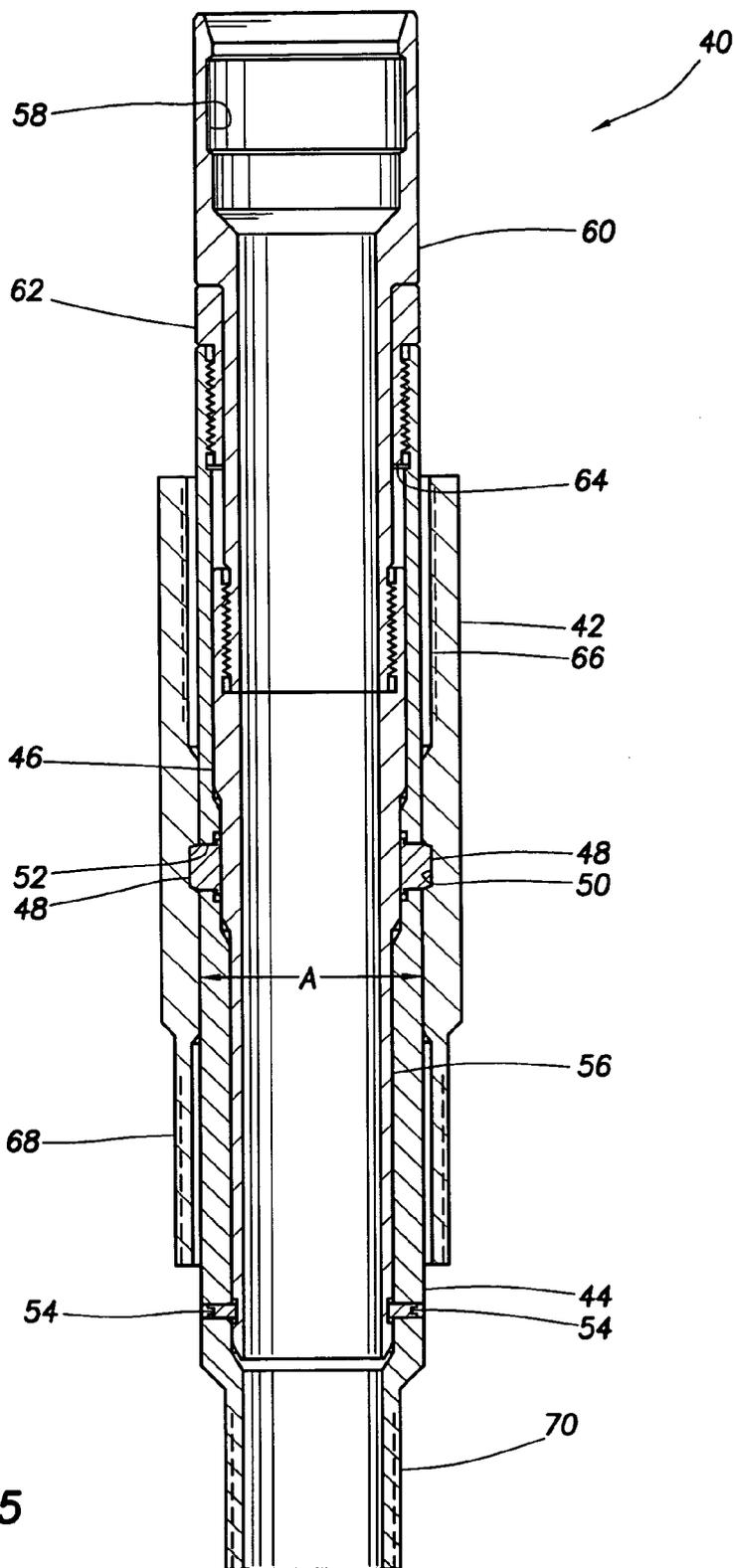


FIG.5

## MONOBORE RELEASE FOR TUBING CONVEYED PERFORATING

### BACKGROUND

[0001] The present invention relates generally to operations performed and equipment utilized in conjunction with a subterranean well and, in an embodiment described herein, more particularly provides a monobore release for tubing conveyed perforating.

[0002] It is well known in the art to release a perforating gun from a tubing string either before or after the perforating gun is fired. For this purpose, a disconnect or release apparatus is typically used to releasably secure the perforating gun to the tubing string.

[0003] However, conventional disconnect or release apparatus do not permit the perforating gun to be retrieved from a well through the tubing string. This is due, at least in part, to internal restrictions in the apparatus which do not permit the perforating gun to be displaced upwardly through the apparatus.

[0004] It would be very beneficial to be able to retrieve the perforating gun through the tubing string, so that the tubing string would not have to be pulled from the well in order to retrieve the perforating gun. This benefit could be realized whether or not the perforating gun is successfully fired in the well. For example, if the perforating gun is not successfully fired, retrieval of the perforating gun would permit another perforating gun to be conveyed into the well through the tubing string (e.g., conveyed by wireline, coiled tubing, etc.).

[0005] As another example, it may be desirable to displace the perforating gun from a position opposite perforations formed by the gun, in order to prevent sanding up the gun, provide greater flow area, permit gravel packing, etc., but insufficient rathole is available in which to drop the gun. In that case, it would be beneficial to retrieve the gun from the well, without pulling the tubing string.

[0006] It would also be very beneficial to avoid internal restrictions in the tubing string. Therefore, the apparatus used to releasably secure the perforating gun to the tubing string would preferably leave a minimum internal restriction which is at least as great as a minimum internal restriction of the remainder of the tubing string.

[0007] Furthermore, it would be beneficial if the apparatus used to releasably secure the perforating gun to the tubing string would permit both retrieving the perforating gun through the tubing string, and separating the perforating gun from the tubing string (i.e., so that the perforating gun can drop in the well below the tubing string).

### SUMMARY

[0008] In carrying out the principles of the present invention, in accordance with an embodiment thereof, a method, system and apparatus are provided which supply the above-described benefits to the art of well perforating.

[0009] In one aspect of the invention, a method of perforating a well is provided. The method includes the steps of: actuating at least one perforating gun while the perforating gun is secured to a tubular string in the well; and retrieving the perforating gun from the well through the tubular string.

[0010] In another aspect of the invention, a well perforating system includes a release assembly interconnected in a tubular string. At least one perforating gun is releasably secured to the tubular string by the release assembly while the tubular string is conveyed into the well. The release assembly permits the perforating gun to be retrieved from the well through the tubular string, and also permits the perforating gun to be separated from the tubular string in the well.

[0011] In yet another aspect of the invention, a release assembly for use in releasably securing at least one perforating gun to a tubular string positioned in a subterranean well is provided. The release assembly includes an outer housing having upper and lower connections for interconnecting the housing in the tubular string. An inner housing has a lower connection for interconnecting the perforating gun to the inner housing. A mandrel is displaceable between a secured position in which the inner and outer housings are secured relative to each other, and a released position in which relative displacement is permitted between the inner and outer housings.

[0012] These and other features, advantages, benefits and objects of the present invention will become apparent to one of ordinary skill in the art upon careful consideration of the detailed description of representative embodiments of the invention hereinbelow and the accompanying drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1** is a schematic partially cross-sectional view of a system and method embodying principles of the present invention, in which initial steps of the method have been performed;

[0014] **FIG. 2** is a schematic partially cross-sectional view of the system and method of **FIG. 1**, in which further steps of the method have been performed;

[0015] **FIG. 3** is a schematic partially cross-sectional view of the system and method of **FIG. 1**, in which alternate steps of the method have been performed;

[0016] **FIG. 4** is a schematic partially cross-sectional view of the system and method of **FIG. 1**, in which an alternate configuration of the system is illustrated; and

[0017] **FIG. 5** is a cross-sectional view of a release assembly which may be used in the system and method of **FIG. 1**, and which embodies principles of the invention.

### DETAILED DESCRIPTION

[0018] Representatively illustrated in **FIG. 1** is a system **10** and associated method which embody principles of the present invention. In the following description of the system **10** and other apparatus and methods described herein, directional terms, such as "above", "below", "upper", "lower", etc., are used only for convenience in referring to the accompanying drawings. Additionally, it is to be understood that the various embodiments of the present invention described herein may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of the present invention.

[0019] As depicted in **FIG. 1**, a tubular string **12** has been conveyed into and positioned within a wellbore **14** lined

with protective casing 16. As used herein, the term "casing" indicates a tubular structure which lines a wellbore, such as a casing string, liner string or other tubular string.

[0020] A seal assembly 18 carried on the tubing string 12 provides sealing engagement between the tubing string and a seal bore 22 associated with a packer 20 previously set in the wellbore 14. The seal bore 22 could be formed in the packer 20, in a polished bore receptacle attached to the packer, or otherwise associated with the packer. Alternatively, the packer 20 could be interconnected in the tubing string 12 and conveyed into the wellbore 14 as part of the tubing string.

[0021] When the seal assembly 18 is engaged with the seal bore 22, a perforating gun 24 carried by the tubing string 12 is positioned opposite a formation or zone 26 intersected by the wellbore 14. Of course, if the packer 20 is interconnected in the tubing string 12, then setting the packer in the wellbore 14 will anchor the perforating gun opposite the zone 26. Only a single perforating gun 24 is depicted in FIG. 1 opposite a single zone 26, but it should be understood that any number of individual perforating guns may be used, and any number of zones may be perforated, in the system 10.

[0022] Firing heads 28 are provided above and below the perforating gun 24. When it is desired to actuate the perforating gun 24, one or both of the firing heads 28 preferably cause explosives in the perforating gun 24 to detonate in a manner well known to those skilled in the art. Although two firing heads 28 are depicted for redundancy in firing the perforating gun 24, any number of firing heads may be used in the system 10. The firing heads 28 may be mechanically, hydraulically, electrically, or otherwise actuated in keeping with the principles of the invention.

[0023] The perforating gun 24 is releasably secured to the tubing string 12 by means of a release assembly 30 interconnected in the tubing string. As depicted in FIG. 1, the release assembly 30 is positioned below the packer 20. Thus, the release assembly 30 is displaced through the packer 20 when the tubing string 12 is positioned in the wellbore 14. As described in more detail below, the release assembly 30 may alternatively be positioned above the packer 20.

[0024] One of the advantages of the system 10 is that the release assembly 30 permits the perforating gun 24 to be separated from the tubing string 12, so that the gun can drop into a rathole 32 below the zone 26. Another advantage of the system 10 is that the release assembly 30 also permits the perforating gun 24 to be retrieved from the wellbore 14 through the tubing string 12. Whichever of these alternatives is chosen, yet another advantage of the system 10 is that, after releasing, the release assembly 30 has a minimum internal restriction which is at least as great as a minimum internal restriction of the remainder of the tubing string 12, so that the release assembly does not present any additional hindrance to flow of fluids or passage of equipment through the tubing string.

[0025] Referring additionally now to FIG. 2, the system 10 is depicted in a configuration in which the zone 26 has been perforated by actuating the perforating gun 24. The release assembly 30 has then been operated to release the perforating gun 24 from the tubing string 12, allowing the perforating gun to separate from the tubing string and drop into the rathole 32.

[0026] Note that it is not necessary for the perforating gun 24 to successfully fire in order to release the perforating gun from the tubing string 12. The perforating gun 24 may unsuccessfully fire (the explosives therein may fail to detonate, etc.), in which case it may be desired to drop the perforating gun into the rathole 32, so that another perforating gun may be conveyed through the tubing string (for example, by wireline, coiled tubing, etc.) to perforate the zone 26.

[0027] Referring additionally now to FIG. 3, the system 10 is depicted in another configuration in which the perforating gun 24 is being retrieved from the wellbore 14 through the tubing string 12. A conventional retrieval tool 34, such as a Model GS pulling tool available from Halliburton Energy Services, Inc. of Houston, Tex., may be conveyed by wireline, slickline, coiled tubing, or other type of conveyance through the tubing string 12 to release the release assembly and retrieve the perforating gun 24.

[0028] The perforating gun 24 may be retrieved from the wellbore 14 due to the gun being unsuccessfully fired, in which case retrieval of the gun will permit another perforating gun to be conveyed through the tubing string 12 to perforate the zone 26, without having to pull the tubing string. However, the perforating gun 24 may be retrieved even if it was successfully fired, for example, if it is not desired to leave the gun opposite the zone 26 after perforating, and if there is not sufficient rathole 32 below the zone to receive the perforating gun.

[0029] It will be appreciated that, because the release assembly 30 presents no additional restriction in the tubing string 12 when released, the perforating gun 24 (and associated firing heads 28, etc.) can conveniently pass through the release assembly as well as it can pass through the remainder of the tubing string.

[0030] Referring additionally now to FIG. 4, the system 10 is depicted in an alternate configuration in which the release assembly 30 is positioned above the packer 20, instead of below the packer. One advantage to this configuration is that the release assembly 30 does not pass through the packer 20 when the tubing string 12 is conveyed into the wellbore 14. Thus, the release assembly 30 can have a larger outer dimension, and consequently can have a larger minimum internal restriction to accommodate larger perforating guns, etc. passing therethrough.

[0031] Of course, if the packer 20 is instead interconnected in the tubing string 12 when it is conveyed into the wellbore 14, then the release assembly 30 does not pass through the packer 20. In that case, the outer dimension of the release assembly 30 would not be restricted by the packer 20 bore, and the release assembly having the larger outer dimension could be positioned above or below the packer as desired.

[0032] Referring additionally now to FIG. 5, a release assembly 40 embodying principles of the invention is representatively illustrated. The release assembly 40 may be used for the release assembly 30 in the system 10, or the release assembly 40 may be used in other systems or methods. Furthermore, other types of release assemblies may be used for the release assembly 30 in the system 10. Accordingly, it should be clearly understood that the present invention is not limited to any specific details of the system 10 or release assembly 40 described herein.

[0033] The release assembly 40 as depicted in FIG. 5 includes an outer housing 42, an inner housing 44 and a mandrel 46. The outer and inner housings 42, 44 are secured against displacement relative to each other by engagement of multiple dogs or lugs 48 with an annular recess 50 formed internally in the outer housing 42. The dogs 48 extend through openings 52 formed through a sidewall of the inner housing 44.

[0034] The mandrel 46 maintains the dogs 48 in engagement with the recess 50 by preventing inward displacement of the dogs. However, if shear screws 54 releasably securing the mandrel 46 in position relative to the inner housing 44 are sheared, then the mandrel will be permitted to displace upward. Upward displacement of the mandrel 46 will position a radially reduced portion 56 of the mandrel opposite the dogs 48 and permit the dogs to displace inwardly out of engagement with the recess 50.

[0035] Thus, the inner housing 44 is released for displacement relative to the outer housing 42 by applying a force to the mandrel 56 to shear the screws 54 and upwardly displace the mandrel, thereby permitting the dogs 48 to be disengaged from the recess 50. Of course, the release assembly 40 could be configured so that the mandrel 56 is downwardly displaced to permit the dogs 48 to be disengaged from the recess 50.

[0036] The force is preferably applied to the mandrel 46 by engaging a tool, such as the retrieval tool 34 described above, with an internal profile 58 formed in a mandrel extension 60 attached to the mandrel. The force is then transmitted from the tool 34 to the mandrel extension 60 by pulling upwardly on the tool from the surface.

[0037] The mandrel 46 and extension 60 are reciprocally received in the inner housing 44. As described above, the shear screws 54 initially prevent displacement of the mandrel 46 relative to the inner housing 44. Once the shear screws 54 are sheared, upward displacement of the mandrel 46 relative to the inner housing 44 may be limited by a collar 62 attached to an upper end of the inner housing. The collar 62 has a shoulder 64 formed on a lower end thereof which will contact an upper end of the mandrel 46 and prevent further upward displacement of the mandrel relative to the inner housing 44.

[0038] This engagement between the collar 64 and the mandrel 46 also allows the tool 34 to be used to retrieve the mandrel, extension 60, inner housing 44, collar and dogs 48 from within the outer housing 42. In this manner, only the outer housing 42 remains once these other elements have been retrieved from within the outer housing using the tool 34. The sequence of steps in this operation is as follows: 1) the tool 34 is engaged with the profile 58; 2) an upwardly directed force is applied from the tool to the extension 60 and, thus, to the mandrel 46; 3) the shear screws 54 are sheared by the force; 4) the mandrel 46 is displaced upwardly by the force; 5) the dogs 48 retract out of engagement with the recess 50; 6) the mandrel contacts the shoulder 64 of the collar 60; and 7) the inner housing 44, mandrel, extension, dogs and collar are displaced upwardly out of the outer housing 42.

[0039] When used in the system 10, the outer housing 42 is interconnected in the tubing string 12 via upper and lower connections 66, 68. In this manner, the release assembly 40 becomes part of the tubing string 12. Preferably, the upper connection 66 is internally threaded, and the lower connection is externally threaded, but other configurations may be used, if desired.

[0040] When the inner housing 44, mandrel 46, extension 60, dogs 48 and collar 62 are displaced out of the outer housing 42, only the outer housing remains interconnected in the tubing string 12. Preferably, the outer housing 42 has a minimum internal restriction A which is at least as great as a minimum internal restriction B (see FIG. 3) of the remainder of the tubing string 12. The internal restriction A may be an inner diameter or other dimension of the outer housing 42, and the internal restriction B may be an inner diameter or other dimension of the tubing string 12.

[0041] The inner housing 44 has a lower connection 70 which is used to attach the perforating gun 24 (and firing heads 28 and/or other associated equipment) to the release assembly 40. Preferably, the lower connection 70 is externally threaded. The perforating gun 24 (and associated equipment) is sized so that it will be able to pass through the outer housing 42 (i.e., through the minimum internal restriction A), if it is desired to retrieve the perforating gun from the wellbore through the tubing string 12.

[0042] Note that the lower connection 70 of the inner housing 44 is radially inwardly disposed relative to each of the upper and lower connections 66, 68 of the outer housing 42. In this manner, the inner housing lower connection 70 is positioned within the tubular string 12 when the release assembly 40 is interconnected in the tubular string. Thus, the perforating gun 24 may be connected to the inner housing 44 and retrieved through the outer housing 42, as long as the perforating gun can pass through the minimum internal restriction A.

[0043] In the alternative configuration of the system 10 depicted in FIG. 2, it is instead desired to separate the perforating gun 24 from the tubing string 12. In that case, the collar 62 may be eliminated from the release assembly 40. Thus, when the mandrel 46 and extension 60 are displaced upwardly, the inner housing 44 (with the perforating gun 24 attached thereto) will be free to displace downwardly relative to the outer housing 42, thereby permitting the inner housing, perforating gun and associated equipment to separate from the tubing string and drop into the rathole 32.

[0044] The inner housing 44, perforating gun 24 and associated equipment may still be retrieved from the wellbore 14 through the tubing string 12 (for example, by using a fishing tool to engage these elements), since they can still pass through the outer housing 42 and the remainder of the tubing string.

[0045] The mandrel 46 and extension 60 may be retrieved through the tubing string 12 to the surface with the tool 34. Note, also, that in this case it is not necessary for the perforating gun 24 to pass through the minimum internal restriction A, and so the perforating gun may have a larger outer dimension.

[0046] Therefore, it will be readily appreciated that the system 10 and release assembly 40 provide many benefits to the current state of the well perforating art. When released, the release assembly 40 provides the relatively large minimum internal restriction A which is at least as great as the minimum internal restriction B of the remainder of the tubing string 12. This relatively large internal restriction A permits the perforating gun 24 to be retrieved from the wellbore 14 through the tubing string 12. The perforating gun 24 may be either retrieved through the tubing string 12, or separated from the tubing string and allowed to drop into the rathole 32. The perforating gun 24 may be retrieved or dropped, whether or not the perforating gun has been successfully fired.

[0047] Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments of the invention, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to these specific embodiments, and such changes are contemplated by the principles of the present invention. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the present invention being limited solely by the appended claims and their equivalents.

What is claimed is:

1. A method of perforating a subterranean well, the method comprising the steps of:

actuating at least one perforating gun while the perforating gun is secured to a tubular string in the well; and

retrieving the perforating gun from the well through the tubular string.

2. The method according to claim 1, further comprising the steps of:

securing the perforating gun to the tubular string; and

then positioning the tubular string in the well.

3. The method according to claim 2, wherein the positioning step further comprises positioning the tubular string within casing lining a wellbore of the well.

4. The method according to claim 1, wherein the actuating step further comprises firing the perforating gun.

5. The method according to claim 1, wherein the actuating step further comprises unsuccessfully firing the perforating gun.

6. The method according to claim 1, further comprising the step of releasably securing the perforating gun to the tubular string using a release assembly interconnected in the tubular string.

7. The method according to claim 6, wherein the retrieving step further comprises providing a minimum internal restriction of the release assembly at least as great as a minimum internal restriction of a remainder of the tubular string.

8. The method according to claim 6, further comprising the step of interconnecting the release assembly in the tubular string so that the release assembly is above a packer on the tubular string when the tubular string is positioned in the well.

9. The method according to claim 6, further comprising the step of interconnecting the release assembly in the tubular string so that the release assembly is below a packer on the tubular string when the tubular string is positioned in the well.

10. The method according to claim 6, wherein the retrieving step further comprises engaging a profile of the release assembly with a retrieval tool conveyed through the tubular string.

11. A well perforating system, comprising:

a release assembly interconnected in a tubular string;

at least one perforating gun releasably secured to the tubular string by the release assembly while the tubular string is conveyed into the well; and

the release assembly permitting the perforating gun to be retrieved from the well through the tubular string, and permitting the perforating gun to be separated from the tubular string in the well.

12. The system according to claim 11, wherein the release assembly has a minimum internal restriction which is at least as great as a minimum internal restriction of a remainder of the tubular string when the perforating gun is retrieved from the well.

13. The system according to claim 11, wherein the release assembly has a minimum internal restriction which is at least as great as a minimum internal restriction of a remainder of the tubular string when the perforating gun is separated from the tubular string in the well.

14. The system according to claim 11, wherein the tubular string is positioned within casing lining a wellbore of the well.

15. The system according to claim 11, wherein the release assembly is positioned above a packer in the well.

16. The system according to claim 11, wherein the release assembly is positioned below a packer in the well.

17. The system according to claim 11, wherein the release assembly includes a profile formed therein, and further comprising a tool engaged with the profile to cause the perforating gun to be released from the tubular string.

18. A release assembly for use in releasably securing at least one perforating gun to a tubular string positioned in a subterranean well, the release assembly comprising:

an outer housing having upper and lower connections for interconnecting the housing in the tubular string;

an inner housing having a lower connection for interconnecting the perforating gun to the inner housing; and

a mandrel which is displaceable between a secured position in which the inner and outer housings are secured relative to each other, and a released position in which relative displacement is permitted between the inner and outer housings.

19. The release assembly according to claim 18, wherein the inner housing lower connection is positioned radially inward relative to the outer housing lower connection.

20. The release assembly according to claim 18, wherein the inner housing lower connection is positioned radially inward relative to the outer housing upper connection.

21. The release assembly according to claim 18, wherein the inner housing is displaceable through the outer housing lower connection.

22. The release assembly according to claim 18, wherein the inner housing is displaceable through the outer housing upper connection.

23. The release assembly according to claim 18, wherein the inner housing has a maximum outer dimension which is less than a minimum internal restriction of the outer housing.

24. The release assembly according to claim 18, wherein the inner housing lower connection is positioned within the tubular string when the release assembly is interconnected in the tubular string.

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