

DOWNHOLE APPARATUS, SYSTEM AND METHOD

BACKGROUND

[0001] The present invention relates to apparatus for use in generating a fluid pressure pulse downhole comprising a tubular housing defining an internal fluid flow passage and a device for selectively generating a fluid pressure pulse located in a wall of the housing. The present invention also relates to a downhole data acquisition and telemetry system comprising such an apparatus, and at least one sensor. The present invention also relates to a method of measuring at least one parameter downhole in a wellbore and of transmitting data relating to the at least one parameter to surface.

[0002] In the oil and gas exploration and production industry, a wellbore is drilled from surface utilizing a string of tubing carrying a drill bit. Drilling fluid known as drilling 'mud' is circulated down through the drill string to the bit, and serves various functions. These include cooling the drill bit and returning drill cuttings to surface along an annulus formed between the drill string and the drilled rock formations.

[0003] It is well known that the efficiency of oil and gas well drilling operations can be significantly improved by monitoring various parameters pertinent to the process. For example, information about the location of the borehole is utilized in order to reach desired geographic targets. Additionally, parameters relating to the rock formation can help determine the location of the drilling equipment relative to the local geology, and thus correct positioning of subsequent wellbore-lining tubing. Drilling parameters such as Weight on Bit (WOB) and Torque on Bit (TOB) can also be used to optimize rates of penetration.

[0004] For a number of years, measurement-while-drilling (MWD) has been practiced using a variety of equipment that employs different methods to generate pressure pulses in the mud flowing through the drill string. These pressure pulses are utilized to transmit data relating to parameters that are measured downhole, using suitable sensors, to surface. Systems exist to generate 'negative' pulses and 'positive' pulses.

[0005] Many previous methods have involved placing some, or all, of the apparatus in a probe, and locating the probe down the center of the drill-pipe. This leads to inevitable wear and tear on the apparatus, primarily through the processes of erosion, and also often through excessive vibration experienced during the drilling operation. The cost of operating MWD equipment is therefore often determined by the required flow rates and types of mud employed during the drilling process. Furthermore, as the pipe is obstructed by the MWD equipment, it is impossible to pass through other equipment such as is often required for a variety of purposes. Examples of this include logging tools for the method commonly referred to as 'through bit logging'. Other examples such as diverting valves can be activated by dropping activation devices through the thru bore MWD equipment (these activation devices are commonly balls of a variety of diameters).

[0006] Apparatus has been developed for generating a fluid pressure pulse downhole in which a pulse generating device is located at least partly in a space provided in a wall of an elongate, generally tubular housing. Apparatus of this type is disclosed in the Applicant's International Patent Publication No. WO-2011/004180. The apparatus disclosed in WO-2011/004180 offers significant advantages over prior apparatus and methods, in that locating the pulse generating device in the space in the wall of the tubular housing reduces exposure of the device to fluid flowing through the housing, and thereby erosion of components of the apparatus, particularly the pulse generating device. Additionally, location of the device in the space facilitates the passage of fluid or other downhole objects (such as downhole tools, or actuating devices such as balls or darts) along the fluid flow passage defined by the housing.

[0007] There is a desire to further improve upon the apparatus disclosed in WO-2011/004180. In particular, the device disclosed in WO-2011/004180 typically requires that the wall of the tubular housing be of greater thickness than uphole/downhole portions of the housing, in order to provide a sufficiently large space to receive the device. In one instance this can be achieved by forming an 'upset' or shoulder, which typically either extends outwardly from an external surface of the housing, or inwardly into the internal tubing bore (or possibly both). In another instance this can be achieved by mounting the apparatus in a constant

external diameter tubular (or 'slick OD' tubular) of sufficient wall thickness, such as a drill collar.

[0008] It is preferable to form an upset on the external surface of the housing, so as to avoid restricting the internal tubing bore. However, this requires that the downhole tubing (or wellbore) into which the apparatus is deployed be of sufficiently large diameter all the way down to the placement point for the apparatus. This diameter might be larger than would otherwise be dictated by the overall well design, or features of other components deployed into the well. Furthermore, in certain scenarios, such as where a restriction exists in the wellbore uphole of the desired placement point for the apparatus, it may not be possible to provide the required clearance.

[0009] As a result, an internal upset is employed, extending into the internal tubing bore. Following completion of a downhole procedure involving the measuring of a downhole parameter or parameters, and the transmission of data to surface employing the pulse generating device, there is a desire to provide full bore access through the tubular member. The full bore might be required for the passage of tools or equipment to a position downhole of the apparatus, and for improving fluid flow.

[0010] One proposal is to mill away the components of the apparatus protruding into the internal bore, and so: the upset; at least part of the pulse generating device; and associated control/power equipment. This is undesirable for various reasons, including: the milling operation can take time as the pulse generating device comprises components made from relatively hard materials; the debris from the milling operation can cause problems downhole; and milling batteries in the device (typically lithium based) may not be acceptable either from an environmental or safety perspective. Indeed, for safety reasons it is advisable that the batteries be mounted beyond the milling path.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The following figures are included to illustrate certain aspects of the present disclosure, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations,

combinations, and equivalents in form and function, without departing from the scope of this disclosure.

[0012] Fig. 1 is a schematic longitudinal sectional view of a downhole assembly, comprising apparatus for generating a fluid pressure pulse downhole, in accordance with an embodiment of the present invention, the apparatus shown in use during the completion of a well in preparation for the production of well fluids;

[0013] Fig. 2 is an enlarged, perspective view of the apparatus shown in Fig. 1;

[0014] Fig. 3 is a longitudinal cross-sectional view of the apparatus of Fig. 2, taken in the direction B-B;

[0015] Fig. 4 is an enlarged, highly schematic view of parts of the apparatus of Fig. 2, taken in the direction A-A;

[0016] Fig. 5 is a detailed longitudinal sectional view of the apparatus of Fig. 2, showing a pulse generating device of the apparatus in more detail;

[0017] Fig. 6 is a further enlarged view of part of the device shown in Fig. 5;

[0018] Fig. 7 is a further enlarged view of part of the device shown in Fig. 5;

[0019] Fig. 8 is a further enlarged perspective view of part of the apparatus shown in Fig. 5, with certain internal components shown in ghost outline;

[0020] Fig. 9 is an enlarged view of part of a wellbore of the well shown in Fig. 1, which has been underreamed, showing the apparatus located in the underreamed section;

[0021] Fig. 10 is a sectional view through part of an apparatus for generating a fluid pressure pulse downhole in accordance with another embodiment of the present invention, with a device of the apparatus shown in a retracted position;

[0022] Fig. 11 is a further enlarged view of part of the apparatus shown in Fig. 10; and

[0023] Fig. 12 is a view of the apparatus of Fig. 10, with the device shown in a radially extended position.

DETAILED DESCRIPTION

[0024] According to a first aspect of the present invention, there is provided apparatus for use in generating a fluid pressure pulse downhole, the apparatus comprising:

5 **[0025]** a tubular housing defining an internal fluid flow passage, the housing having a housing wall; and

[0026] a device for selectively generating a fluid pressure pulse, the device mounted in a space in the wall of the tubular housing for movement between:

[0027] a retracted position; and

10 **[0028]** a radially extended position.

[0029] Mounting the pulse generating device for movement between such retracted and extended positions provides the advantage that a maximum width dimension (e.g. diameter) described by the apparatus can be arranged to be less when the device is in the retracted position, facilitating deployment of the apparatus along a wellbore to a desired placement point. Following location at the desired placement point, the device can be moved to the radially extended position. Advantageously therefore, the invention provides the ability to open up access through the tubular housing (and so through the apparatus) when the device is in the extended position.

20 **[0030]** The retracted position may be an operating position of the device, in which the device can be employed to generate fluid pressure pulses representative of at least one parameter measured downhole in the well. The device may be moved to the extended position following operation to generate such fluid pressure pulses. However, it will be understood that the device may be
25 equally (or alternatively) capable of generating fluid pressure pulses when in the extended position. In the extended position, an outer surface of the device may be disposed beyond the external surface of the housing.

[0031] In the radially extended position, at least part of the device may extend beyond an external surface of the housing. The tubular housing may have
30 an internal surface and an external surface, and the space may be defined by an aperture in the wall of the housing extending between the internal surface and the external surface. The aperture may have an opening in the internal surface of the

tubular housing, and an opening in the external surface of the tubular housing which communicates with the opening in the internal surface. The openings may be of similar or different dimensions, profile and/or shape. The aperture may communicate with the internal passage, and may open on to the passage.

5 **[0032]** In the retracted position, the pulse generating device may not extend beyond the external surface of the tubular housing. The device may therefore be retracted into the space, and may not protrude beyond the external surface out of the space. Advantageously therefore, the invention provides the ability to navigate a wellbore without requiring that the wellbore be larger than
10 might otherwise be the case, to accommodate the apparatus. In the retracted position, the device may extend a first distance beyond the external surface of the tubular housing; and in the extended position, the device may extend a second distance beyond the external surface of the tubular housing which is greater than said first distance.

15 **[0033]** In the retracted position, the pulse generating device may extend beyond the internal surface of the tubular housing and into the internal fluid flow passage. In the extended position, the device may not extend beyond the internal surface of the tubular housing and so may not extend into the internal fluid flow passage. Advantageously therefore, the invention provides the ability to open full
20 bore access through the tubular housing (and so through the apparatus) when the device is in the extended position. In the retracted position, the device may extend a first distance beyond the internal surface of the tubular housing and into the internal fluid flow passage; and in the extended position, the device may extend a second distance beyond the internal surface of the tubular housing and into the
25 internal fluid flow passage, said second distance being smaller than said first distance.

[0034] The pulse generating device may be releasably mounted to the tubular housing in the space.

30 **[0035]** The apparatus may comprise a mounting member (such as a mounting block) which receives the device, the mounting member mounted for movement between the retracted and extended positions. Mounting of the device in the mounting member may thus facilitate movement of the device between its

retracted and extended positions. The device may comprise or may take the form of a cartridge which can be: a) releasably movably mounted in the space; or b) releasably mounted in the mounting member. The mounting member may be a floating mounting member (and may in particular be a floating block), mounted for floating movement in the space under applied fluid pressure. In the extended position, part of the mounting member may extend beyond the external surface of the housing. In particular, an outer surface of the mounting member may be disposed beyond the external surface of the housing.

[0036] The device may be initially restrained in the retracted position. The device may be initially restrained by at least one latch element, which may be a dog or pin. Said latch element may be actuable to release the device for movement to the extended position. Said latch element may be movable between an engaging position where it restrains the device and a release position where the device is released for movement to the extended position. Said latch element may be shearable or breakable to release the device for movement to the extended position. Where the apparatus comprises a mounting member for the device, said latch element may cooperate with the mounting member for restraining the device.

[0037] The apparatus may be arranged so that the device can be restrained in the extended position. The apparatus may be arranged to automatically restrain the device in the extended position following movement to said position. The device may be restrained by at least one latch element, which may be a dog or pin. Said latch element may be actuable to restrain the device in the extended position. Said latch element may be movable between: a release position, in which movement of the device to the extended position is permitted; and an engaging position where it restrains the device in the extended position. Said latch element may be shearable or breakable to permit release of the device for movement from the extended position back to the retracted position. Where the apparatus comprises a mounting member for the device, said latch element may cooperate with the mounting member for restraining the device.

[0038] Said latch elements may be provided in the tubular housing, in the device (such as in the mounting member), or optionally latch elements may be provided in both the housing and the device. Actuation options for the latch

elements described above may include mechanical, electrical, electromechanical, hydraulic and combinations thereof.

5 **[0039]** The device may be mounted in the space in such a way that movement of the device within or relative to the tubular housing, in particular the space, is restricted. The space may be a recess or pocket defined in the wall of the housing. The apparatus may be configured so that the device is movable from the retracted position to the radially extended position by imparting an expansion force on the tubular housing, in particular on a part of the tubular housing defining the space. Movement to the extended position may therefore be achieved by
10 expansion of the tubular housing (or part thereof).

[0040] The device may form part of an external surface of the housing, or may be located in a portion of the housing which defines part of the external surface, and which surface part may be moved radially outwardly when the device is moved to the extended position. The tubular housing may be configured so that
15 it is expandable to thereby permit movement of the device to the extended position. The tubular housing may comprise at least one deformation zone which is configured to deform so that the device can move to the extended position. The deformation zone may be provided between a part of the tubular housing which defines the space, and a further part of the tubular housing, which may be a main
20 part or majority of the housing. There may be a zone or zones of deformation bordering the space around an entire perimeter of the space.

[0041] The deformation zone may be a region of the tubular housing which is shaped so that it can deform to permit radially outward movement of the device, to its extended position. The tubular housing may be shaped to define at least one
25 corrugation, fold (or the like) in the deformation zone, said corrugation arranged so that it can be at least partially opened out or extended on exertion of an expansion force, so that the device can move to the extended position. The space may be elongate in a direction along a longitudinal axis of the housing, and there may be at least one of said corrugations bordering lateral sides of the space and extending in
30 a direction along said longitudinal axis.

[0042] The at least one deformation zone may comprise a material having at least one material property which differs from a corresponding property of a

remainder or majority of the housing, and in particular from the part of the housing defining the space. The material property may be yield strength, and the at least one deformation zone may comprise a material having a lower yield strength than the remainder/majority of the housing. This may encourage the tubular housing to
5 deform in the deformation zone on application of an expansion force. The at least one deformation zone may comprise portions which are formed from different materials.

[0043] The apparatus may comprise at least one sensor for measuring a downhole parameter, data relating to the parameter measured by the sensor being
10 transmitted to surface via fluid pressure pulses generated by the pulse generating device. Said sensor may be provided as part of the device, or separately and coupled to the device. Where the apparatus comprises a mounting member for the pulse generating device, the sensor may be provided on or in the mounting member.

[0044] The device may be movable under applied fluid pressure, e.g. by creating a pressure differential between fluid in the internal fluid flow passage relative to fluid externally of the tubular housing. The aperture may define a cylinder which receives the device, and the device may form a piston which is movable within the cylinder by the application of fluid pressure. Suitable seals may
20 be provided between the piston and a wall or walls of the aperture. Where the apparatus comprises a mounting member, the mounting member may define the piston. The tubular housing may be deformable in the at least one deformation zone by applied fluid pressure. The device may be movable from the retracted position to the extended position by applied fluid pressure. The device may be
25 movable from the extended position to the retracted position by applied fluid pressure.

[0045] The device may be movable from the retracted position to the extended position via application of a mechanical force, such as by passing an expansion tool or element through the internal fluid flow passage, the tool
30 imparting a force on: a) the device located in the aperture, to urge it to the extended position; or b) the part of the tubular housing defining the space, to thereby deform the housing in the at least one deformation zone. The device may

be movable from the extended position back to the retracted position via application of mechanical force, such as via contact between the device and a feature in the wellbore. The feature may be a dedicated feature (such as an upset or profile) provided in the wellbore for imparting a force on the device.

5 **[0046]** The apparatus may comprise a plurality of devices for generating a fluid pressure pulse. Each device may be located in a respective space. A plurality of devices may be located in one space. Where the apparatus comprises a mounting member, the mounting member may receive a plurality of pulse generating devices.

10 **[0047]** The tubular housing may define an external upset which forms at least part of the external surface of the housing. The tubular housing may define an internal upset which forms at least part of the internal surface of the housing.

[0048] The apparatus may further comprise an operating unit arranged to operate the device. The operating unit may comprise a source or sources of
15 electrical power (such as a battery), a data acquisition system, sensor(s) and a connector element which serves for electrically coupling the power source(s) to the device and for communicating with the device. The operating unit may be mounted in the or a space. Where the apparatus comprises a mounting member, the operating unit may be mounted on or in the mounting member.

20 **[0049]** The device may be for controlling the flow of fluid along a flow path which communicates with the internal fluid flow passage, to generate a fluid pressure pulse. The device may comprise a valve having a valve element and a valve seat, the valve being actuable to control the flow of fluid along the flow path. This may be achieved by moving the valve element into or out of sealing abutment
25 with the valve seat. The device may comprise an actuator element which is operable to move the valve element to thereby control the flow of fluid through the flow path. The actuator element may be electrically operated (and may for example be a solenoid or motor) and coupled to the source of electrical power in the operating unit. Positive or negative fluid pressure pulses may be generated by
30 the device. Positive pulses may be generated by operating the device to close the respective flow path, and negative pulses by operating the devices to open the flow path. The device may be in the form of a cartridge or insert. The cartridge may

house the valve. The device may define at least part of the flow path. The device may define the outlet. The inlet of each flow path may open on to the internal fluid flow passage. The outlet may open on to an exterior of the housing. The outlet may open on to the internal fluid flow passage at a position which is spaced axially along a length of the housing from the inlet.

[0050] The apparatus may comprise a carrier mounted in the space, and one or more of: the fluid pressure pulse generating device; a source of electrical power (e.g. battery); electronics and sensors or sensor assemblies may be mounted in the carrier.

[0051] According to a second aspect of the present invention, there is provided a downhole data acquisition and telemetry system comprising:

[0052] apparatus for use in generating a fluid pressure pulse downhole according to the first aspect of the invention; and

[0053] at least one sensor for measuring a downhole parameter, data relating to the parameter measured by the sensor being transmitted to surface via fluid pressure pulses generated by the pulse generating device.

[0054] Further features of the apparatus and sensor forming part of the system of the second aspect of the invention are defined above in relation to the first aspect of the invention.

[0055] It will be understood that a sensor or sensors may be provided which are capable of measuring a wide range of different parameters in a wellbore, including but not restricted to: pressure (e.g. in the internal bore and/or externally of the tubular housing); temperature; geological features (e.g. rock resistivity, background radiation); density; force (e.g. an axially directed force such as a weight applied to a component in the wellbore, which might be weight on bit (WOB), or a rotationally directed force or torque applied to a component in the wellbore, which might be torque on bit (TOB) or in wellbore tubing); strain; stress; acceleration; and wellbore geometry features (e.g. rotational orientation or 'azimuth', inclination, the depth of a particular component or feature).

[0056] According to a third aspect of the present invention, there is provided a method of measuring at least one parameter downhole in a wellbore and

of transmitting data relating to the at least one parameter to surface, the method comprising the steps of:

[0057] mounting a device for generating a fluid pressure pulse within a space in a wall of a tubular housing which defines an internal fluid flow passage;

5 **[0058]** running the housing into the wellbore with the device in a retracted position, and locating the device at a desired position in the wellbore;

[0059] following location of the device at the desired position, operating the device to generate fluid pressure pulses to transmit data relating to at least one downhole parameter to surface; and

10 **[0060]** moving the pulse generating device from the retracted position to a radially extended position.

[0061] The step of moving the pulse generating device to the extended position may take place following transmission of said data to surface. The step of moving the pulse generating device to the extended position may take place prior
15 to transmission of said data to surface.

[0062] The method may comprise the further step of subsequently moving the device from the extended position back to the retracted position.

[0063] The space may take the form of an aperture extending between an internal surface of the housing and an external surface of the housing, and the
20 method may comprise movably mounting the device within the aperture, and locating the device in a retracted position in the aperture (which is the retracted position defined above). In the radially extended position, at least part of the device may extend beyond an external surface of the housing.

[0064] The device may be moved to the extended position by expansion of
25 the tubular housing, or part thereof, in particular a part defining the space. The device may be moved to the extended position by deforming the tubular housing in a deformation zone or zones.

[0065] The step of moving the device to the extended position may comprise applying fluid pressure to the device to urge it to the extended position.
30 This may involve creating a pressure differential between fluid in the internal fluid flow passage relative to fluid externally of the tubular housing. The method may

comprise the further step of subsequently moving the device from the extended position back to the retracted position by applying fluid pressure to the device.

[0066] The step of moving the device to the extended position may comprise applying a mechanical force to the device to urge it to the extended position. This may involve passing an expansion tool or element through the internal fluid flow passage (which may be actuatable e.g. under fluid pressure), the tool imparting a force on the device to urge it to the extended position. The device may form part of an external surface of the housing, or may be located in a portion of the housing which defines part of the external surface, and which surface part may be moved radially outwardly when the device is moved to the extended position. The method may comprise the further step of subsequently moving the device from the extended position back to the retracted position, by applying a mechanical force to the device. This may involve bringing the device into contact with a feature in the wellbore.

[0067] The method may comprise initially restraining the device in the retracted position. The device may be initially restrained by at least one latch element. Said latch element may be actuated to release the device for movement to the extended position. Said latch element may be sheared or broken to release the device for movement to the extended position, such as via the application of a mechanical force.

[0068] The method may comprise restraining the device in the extended position. The device may be restrained using at least one latch element. Said latch element may be selectively actuated to restrain the device in the extended position. Said latch element may be sheared or broken to permit release of the device for movement from the extended position back to the retracted position.

[0069] Further features of the method of the third aspect of the invention may be derived from or with respect to the text set out above relating to the apparatus and/or system of the first/second aspect of the invention.

[0070] Turning firstly to Fig. 1, there is shown a downhole assembly indicated generally by reference numeral 10, the assembly comprising an apparatus for generating a fluid pressure pulse downhole in accordance with an embodiment of the present invention, and which is indicated generally by reference numeral 12.

As will be described in more detail below, the apparatus 12 has a particular utility in transmitting data relating to one or more parameters measured in a downhole environment to surface.

[0071] In the illustrated embodiment, the assembly 10 takes the form of a tubing string and is shown in use, during the completion of a wellbore or borehole 14. In the drawing, a main portion 16 of the wellbore 14 has been drilled from surface, and lined with wellbore-lining tubing known as casing 18, which comprises lengths or sections of tubing coupled together end-to-end. The casing 18 has been cemented in place at 20, in a known fashion. The wellbore 14 has then been extended, as indicated by numeral 22, by drilling through a section of tubing 24 at the bottom of the wellbore (known as a casing 'shoe') and through a cement plug 26 which surrounds the casing shoe.

[0072] A smaller diameter wellbore-lining tubing known as a liner 28 has then been installed in the extended portion 22 of the wellbore, suspended from the casing 18 by means of a liner hanger 30. The liner 28 is shown prior to cementing in place, cement used to seal the liner (not shown) passing up an annulus 32 defined between a wall 34 of the drilled wellbore and an external surface 36 of the liner. The cement passes up along the annulus 32 and into the casing 24, at a level which is below (i.e. deeper in the well) the liner hanger 30. The liner hanger would then be set by conventional methods. A sealing device known as a packer 38 can then be operated to seal the upper end 40 of the liner 28 (i.e. that which is further uphole towards the surface). The liner 28 is run into the extended portion 22 of the well by means of the tubing string 10 which, in the illustrated embodiment, is a liner running string 10. The running string 10 also provides a pathway for the passage of cement into the liner 28 to seal the annulus 32, and for actuating the liner hanger 30 and packer 38.

[0073] The apparatus 12 of the present invention is incorporated into the string 10, and so run into the wellbore 14 with the liner 28. As will be described below, the apparatus 12 serves for sending data relating to one or more downhole parameter to surface real-time, to facilitate completion of the well (by installing the liner 28), and preparation of the well for production. In the illustrated embodiment, the data which is recovered to surface relates to the orientation of a window 41 in

the liner 28, through which a lateral wellbore (not shown) is to be drilled, extending from the main wellbore 14. As will be understood by persons skilled in the art, data relating to the orientation of the wellbore 14, and indeed other parameters, is vital to ensuring correct drilling and completion of the well shown, for accessing a subterranean formation containing well fluids (oil and/or gas).

[0074] To this end and as shown in the enlarged perspective view of Fig. 2 and the longitudinal cross-sectional view of Fig. 3, the apparatus 12 also carries a sensor acquisition system 42 which is provided in an operating unit 44 of the apparatus. The apparatus may include orientation sensors associated with the acquisition system 42, for measuring directional positioning information, and may include suitable strain sensors (not shown) of known types, for measuring the compressive load on the casing 28 having the window 41. As will be described below, the sensors are provided in the sensor acquisition system 42, but may be separate and mounted in an elongate, generally tubular housing 46 of the apparatus 12. The operating unit 44 includes suitable electronics which stores the data, relays the data to the transmitting device 50, and provides power for operation of the apparatus 12. In this way, the data measured by the sensors in the system 42 can be transmitted to surface via the apparatus 12. As will be described below, separate sensors may be provided and coupled to the apparatus 12, for transmitting data relating to various downhole parameters to surface. The sensors may be provided in separate components in the string 10 and coupled to the apparatus 12. The apparatus 12 including the sensor forms a downhole data acquisition and telemetry system according to the invention.

[0075] Parts of the apparatus 12 are also shown in the highly schematic view of Fig. 4. The apparatus 12 is also shown in more detail in the longitudinal sectional view of Fig. 5, and the enlarged views of Figs. 6 and 7. The apparatus 12 comprises the tubular housing 46, which defines an internal fluid flow passage or bore 48. A pulse generating device 50 is mounted in the housing 46, and serves for controlling the flow of fluid along a flow path 52 which communicates with the internal fluid flow passage 48, to generate a fluid pressure pulse.

[0076] In the embodiment of the invention shown in Figs. 2 and 3, the tubular housing 46 has a housing wall 60, an internal surface 61 and an external

surface 63. A space 65 is provided in the wall 60 of the housing 46, and takes the form of an aperture which extends between the internal surface 61 and the external surface 63, and opens on to the internal passage 48. The aperture 65 has internal and external openings which communicate with one another, and which are of similar dimensions. The pulse generating device 50 is mounted in the aperture 65 for movement between a retracted position and a radially extended position. The device 50 is shown in the retracted position in solid outline in Fig. 3, and in the extended position in broken outline. Fig. 5 also shows the device 50 in the extended position. In the extended position, part of the device 50 extends beyond the external surface 63 of the housing. In particular, an external surface 51 of the device 50 is located beyond the housing surface 63.

[0077] Mounting the pulse generating device 50 for movement between such retracted and extended positions provides the advantage that a maximum width dimension (in particular a diameter) described by the apparatus 12 can be arranged to be less when the device 50 is in the retracted position, facilitating deployment of the apparatus 12 along the wellbore 14 to a desired placement point. This may in particular facilitate passage of the apparatus 12 through or past a restriction in the casing 18 (such as upsets or profiles in the casing 18). This may provide the advantage that it is not necessary to make the wellbore 14 larger than might otherwise be the case, to accommodate the apparatus 12. It is of note that it is not uncommon for a wellbore to be enlarged using an underreamer to allow passage of larger tubulars. There may also be a restriction or a restricted bore that the tool needs to pass through such that it can be placed in a hole location that has been enlarged/underreamed, or left conventionally sized consistent with that required to run the original casing into.

[0078] In the illustrated embodiment, the placement point for the device 50 is determined by the required position for the liner 28, as shown in Fig. 1, the apparatus 12 carrying the device 50 being located downhole of the window 41 in the liner. Following location at the desired placement point, the device 50 can be moved to the radially extended position. Advantageously therefore, the invention provides the ability to open up access through the tubular housing 46 (and so through the apparatus 12) when the device 50 is in the extended position. This can

be appreciated from Fig. 1, which shows the device 50 in the retracted position, where it impedes the internal passage 48 of the tubular housing 46. Optionally, the apparatus 12 may be located in a portion of a wellbore which has been underreamed, to provide sufficient clearance for movement of the device 50 to the extended position. This is shown in Fig. 9, where the extended portion 22 of the wellbore has been underreamed, as shown at 23 in the drawing.

[0079] Typically, the retracted position will be an operating position of the device 50, in which the device is employed to generate fluid pressure pulses representative of at least one parameter measured downhole in the well. The device 50 is moved to the extended position following operation to generate fluid pressure pulses to send data to surface. However, it will be understood that the device 50 may be equally be capable of generating fluid pressure pulses when in the extended position. Indeed, an operating position of the device 50 may be the extended position, rather than the retracted position.

[0080] In the retracted position, the pulse generating device 50 does not extend beyond the external surface 63 of the tubular housing 46. The device 50 is therefore retracted into the aperture 65, and does not protrude beyond the external surface out of the aperture. This facilitates passage of the apparatus 12 along the wellbore 14, navigating past any restrictions in the wellbore. In the retracted position, the pulse generating device 50 extends beyond the internal surface 61 of the tubular housing 46 and into the internal fluid flow passage 48. In the extended position, the device 50 does not extend beyond the internal surface 61, and so does not extend into the internal fluid flow passage 48. This may provide the ability to open full bore access through the tubular housing 46 when the device 50 is in the extended position. This may be particularly desirable in order to allow subsequent deployment of tools/equipment into the wellbore downhole of the apparatus 12, and in terms of maximizing fluid flow through the apparatus.

[0081] The apparatus 12 also comprises a mounting member, which takes the form of a mounting block 67, which receives the device 50. The mounting block 67 is mounted for movement between the retracted and extended positions, carrying the device 50, and so serves for moving the device between said positions. The pulse generating device 50 is mounted in the block 67 in such a way that,

when the block is moved to an extended position, at least part of the device 50 protrudes beyond the external surface 63 of the housing 46.

[0082] Effectively, the mounting block 67 forms a floating mounting block or piston which is mounted in the aperture 65, and which is sealed relative to the wall 60 via suitable seals 71. The aperture 65 thereby effectively defines a cylinder in which the mounting block 67 is mounted for movement between the retracted and extended positions, under applied fluid pressure, which will be discussed below. A flange or stop 83 can be provided on the mounting block 67 for restricting outward movement of the block. Following the teachings of WO-2011/004180, the disclosure of which is incorporated herein by way of reference, the pulse generating device 50 takes the form of a cartridge which is releasably mounted in the mounting block 67. The operation of the device 50 will be discussed in more detail below.

[0083] The device 50 is initially restrained in the retracted position, by at least one latch element. In the illustrated embodiment, there are two such latch elements, one of which is shown (Fig. 3) and given the reference numeral 73. The latch element 73 takes the form of a dog or pin, and is actuatable to release the device 50 for movement to the extended position. The dogs 73 are movable between engaging positions, where they restrain the device 50, and a release position, where the device 50 is released for movement to the extended position. The dogs 73 are arranged to engage the mounting block 67 to thereby restrain the device 50.

[0084] The apparatus 12 is also arranged so that the device 50 can be restrained in the extended position, again by means of at least one latch element. In the illustrated embodiment, there are two such latch elements, one of which is shown and indicated by reference numeral 75. The latch element 75 takes the form of a dog or pin, and is actuatable to engage the device 50. The dogs 75 are movable between a release position, so that movement of the device 50 to the extended position is permitted, and an engaging position where they restrain the device 50 in the extended position. The dogs 75 may be shearable or breakable to permit release of the device 50, for movement from the extended position back to the

retracted position. Again, the dogs 75 are arranged to engage the mounting block 67 to thereby restrain the device 50.

[0085] Actuation options for the dogs 73 and 75 include mechanical, electrical, electromechanical, hydraulic and combinations thereof.

5 **[0086]** As mentioned above, the device 50 is movable from its retracted position to its extended position under applied fluid pressure. This is achieved by creating a pressure differential between fluid in the internal fluid flow passage 48 relative to fluid externally of the tubular housing 46, in the annulus 32. For example, the pressure of the fluid in the internal passage 48 may be raised using a
10 pump at surface, so that the fluid pressure force acting on an internal piston face defined by the mounting block 67 is greater than that acting on an external piston face (that resulting from the pressure of fluid in the annulus 32). However, the device 50 may be movable from the retracted position to the extended position via application of a mechanical force, such as by passing an expansion tool or element
15 (not shown) through the internal fluid flow passage 48, the tool imparting a force on the device to urge it to the extended position. The device 50 is similarly movable from the extended position back to the retracted position by applied fluid pressure, in this case by raising the pressure in the annulus 32, or by allowing the pressure of the fluid in the passage 48 to fall.

20 **[0087]** The tubular housing 46 defines an external upset 77 which forms or defines part of the external surface 63 of the housing 46. The tubular housing 46 may, however, be arranged to define an internal upset which forms at least part of the internal surface 61 of the housing 46, and so which may protrude into the internal passage 48 to some extent.

25 **[0088]** Optionally, the apparatus 12 can comprise a plurality of pulse generating devices, and Fig. 4 illustrates an option where the apparatus 12 comprises the device 50, plus a second similar such device 54. Both of the devices 50 and 54 are mounted in the mounting block 67, and so movable between retracted and extended positions in unison. The devices 50 and 54 can be operated
30 in various different ways, and can, for example, be employed to issue separate or combined pressure pulse signals. In a further variation, the apparatus 12 may comprise only a single pulse generating device 50, and associated operating/power

and sensor equipment may be arranged differently from that described above. For example and referring to Fig. 4, a battery or other power source for operating the pulser 50 may be provided in the location indicated by the numeral 54; the sensor assembly 42 may be provided in the location indicated by the numeral 54; or the operating unit 44 may be provided in the location indicated by the numeral 54.

[0089] Operation of the devices 50 and 54 is achieved in a similar fashion, and will now be described.

[0090] The operating unit 44 is arranged to operate the device 50, or both the first and second devices 50 and 54 where provided, simultaneously or individually, as required. The operating unit 44 is shown in more detail in Fig. 8, which is a further enlarged perspective view of part of the apparatus shown in Fig. 5, with certain internal components shown in ghost outline and showing the operating unit during insertion into the mounting block 67. The operating unit 44 includes an electronics section 66 which comprises the sensor acquisition system 42, first and second electrical power sources in the form of batteries 69a and 69b, first and second electrical connector elements 68a, 68b and a suitable data storage device (not shown). The batteries 69a and 69b provide power for actuation of the devices 42, 50 and 54, respectively, although a single battery may be utilized. The connector elements 68a, 68b provide electrical connection with the devices 50 and 54 so that they can be operated to transmit data relating to parameters measured by the sensors in or associated with the sensor acquisition system 42 to surface.

[0091] The first and second devices 50 and 54 each comprise a valve, one of which is shown and given the reference numeral 74. The valves 74 comprise a valve element 76 and a valve seat 78, the valves being actuable to control the flow of fluid along the respective flow paths 52. This is achieved by moving the respective valve elements 76 into or out of sealing abutment with the valve seats 78. The devices 50 and 54 also each include respective actuators 70 coupled to the valve elements 76, to thereby control the flow of fluid through the respective flow paths 52. The actuators 70 are electrically operated, and take the form of solenoids or motors having shaft linkages 81. The actuator shaft linkages 81 are coupled to the valve elements 76 to control their movement, and provide linear or

rotary inputs for operation of the valve elements, the latter being via a suitable rotary to linear converter.

[0092] Power for operation of the actuators 70 is provided by the battery packs 69a, 69b via the connector elements 68a, 68b. As shown in Figs. 6 and 8, the connector elements 68 are located within seal bore assemblies 90 mounted within bores 92 of the devices 50, 54. Ends 98 of the connector elements 68a, 68b make electrical connection with sockets 99, which transmit power to the actuators 70. Operation of the actuators 70 causes the actuator shaft linkage 81 to translate the valve elements 76 out of sealing engagement with the valve seat 78. When it is desired to return the valves 74 to their closed positions, the actuators 70 are deactivated and return springs (not shown) urge the valve elements 76 back into sealing abutment with their valve seats 78.

[0093] The structure and operation of both the valves 74 and actuators 66 are in most respects similar to that disclosed in WO-2011/004180, the disclosure of which is incorporated herein by way of reference. Accordingly, these components will not be described in further detail herein.

[0094] The first and second devices 50 and 54 are mounted in respective spaces 80 and 82 provided in the floating mounting block 67. The operating unit 44 is similarly mounted in a space 84 in the mounting block 67, which is separate from the spaces 80, 82 in which the first and second devices 50, 54 are mounted but which opens on to them. As shown, the devices 50, 54 and the operating unit 44 are mounted entirely within the respective spaces 80, 82 and 84.

[0095] The first and second devices 50, 54 and indeed the operating unit 44 are in the form of cartridges or inserts which can be releasably mounted in the mounting block 67, in the spaces 80, 82 and 84. Whilst shown as pockets or recesses, the spaces 80, 82 and/or 84 could take the form of bored chambers in the mounting block 67.

[0096] The cartridges of the first and second devices 50, 54 and operating unit 44 are shaped so that they are entirely mounted within the respective spaces 80, 82 and 84. The cartridges of the first and second devices 50, 54 house the respective valves 74. The first and second devices 50 and 54 also define part of the respective flow paths 52, the flow paths extending from the inlets 58 in the

housing wall 60, through the valves 74 to outlets 62. Operation of the valves 74 thereby controls the flow of fluid along the flow paths 52 from the inlets 58 to the respective outlets 62 to generate pulses. Positive or negative fluid pressure pulses may be generated by the devices 50, 54. Positive pulses are generated by operating the devices 50, 54 to close the respective flow paths 52, 56, and negative pulses by operating the devices to open the flow paths.

[0097] Turning now to Fig. 10, there is shown a sectional view through part of an apparatus for generating a fluid pressure pulse downhole in accordance with another embodiment of the present invention, the apparatus indicated by reference numeral 12'. Like components of the apparatus 12' with the apparatus 12 of Figs. 1 to 9 share the same reference numerals, with the addition of the suffix '.

[0098] The apparatus 12' is of similar construction to the apparatus 12, and only the significant differences will be described herein. The apparatus 12' is shown in Fig. 10 sectioned transverse to a main longitudinal axis of a housing 46' in the region of a device 50' for generating a fluid pressure pulse. The device 50' is shown in Fig. 10 in a retracted position. Fig. 11 is a further enlarged view of part of the apparatus 12', in particular of part of a wall 60' of the housing 46'. Fig. 12 is a view of the apparatus 12' with the device 50' in a radially extended position.

[0099] In this embodiment, the device 50' is mounted in a space 65' in the wall 60' which takes the form of a recess or pocket. The device 50' is mounted in the space 65' in such a way that movement of the device within the space is restricted. The apparatus 12' is, in this embodiment, configured so that the device 50' is movable from the retracted position to the radially extended position by imparting an expansion force on the tubular housing 46', in particular on the part which defines the space 65'. The tubular housing 46' is therefore configured so that it is expandable to permit movement of the device 50' to the extended position. In this embodiment, the device 50' forms part of an external surface 63' of the housing 46', or is located in a portion of the housing 46' which defines part of the external surface 63', and which surface part is moved radially outwardly when the device 50' is moved to the extended position.

[00100] In the illustrated embodiment, the tubular housing 46' comprises a plurality of deformation zones 102, which are configured to deform so that the device 50' can move to the extended position. The deformation zones 102 are provided between a part 104 of the tubular housing 46' which defines the space 65', and a main part 106 of the housing 46'. The space 65' is elongate in a direction along a longitudinal axis of the housing 46', and the zones 102 border the lateral sides of the space, extending in a direction along the longitudinal axis. Effectively however, there are zones of deformation bordering the space 65' around its entire perimeter, although only two are shown in the drawings. Any suitable number of deformation zones may be provided to permit the desired movement of the device 50'.

[00101] The deformation zones 102 are regions of the tubular housing 46' which are shaped so as to permit the required radially outward movement of the device 50' to its extended position. In the illustrated embodiment, the tubular housing 46' is shaped to define at least one corrugation or fold 108 in the deformation zones 102, the corrugations arranged so that they can be at least partially opened out or extended on exertion of an expansion force, so that the device can move to the extended position. This is shown in Fig. 12.

[00102] The deformation zones 102 comprise a material having at least one material property which differs from a corresponding property of a majority of the housing, and in particular from the part 104 of the housing defining the space 65'. The material property is typically the yield strength, and the deformation zones 102 comprise a portion 112 of a material having a lower yield strength than the remainder of the housing 46'. This may encourage the tubular housing 46' to deform in the deformation zones 102, on application of an expansion force. By way of example, a majority of the housing 46' (in particular the main part 106 and the part 104 defining the space 65') may be of a steel alloy having a higher yield strength than that of the portion 112, so that deformation occurs in the portion 102, which includes the corrugation 108. Deformation may be achieved by applied fluid pressure or mechanical expansion, such as using an expansion tool, following the techniques described above. For example and as shown in Fig. 10, hydraulic

rams 110 may be actuated to impart a force on the portion 104 defining the space 65'.

[00103] Whilst the apparatus of the present invention has been shown and described in the transmission of data to surface relating to compressive load applied to a wellbore-lining tubing, it will be understood that the apparatus has a wide range of uses including in the drilling and production phases, or indeed in an intervention operation (e.g. to perform remedial operations in the well following commencement of production). Accordingly, the apparatus may have a use in transmitting data relating to other parameters pertinent to the drilling, completion or production phases and/or in an intervention. Such may include but are not limited to pressure (e.g. in the internal bore and/or externally of the tubular housing); temperature; geological features (e.g. rock resistivity, background radiation); density; force (e.g. an axially directed force such as a weight applied to a component in the wellbore, which might be weight on bit (WOB), or a rotationally directed force or torque applied to a component in the wellbore, which might be torque on bit (TOB) or in wellbore tubing); strain; stress; acceleration; and wellbore geometry features (e.g. rotational orientation or 'azimuth', inclination, the depth of a particular component or feature). Sensors appropriate for the measurement of the required parameter(s) may be provided.

[00104] Various modifications may be made to the foregoing without departing from the spirit or scope of the present invention.

[00105] In the retracted position, the device may extend a first distance beyond the external surface of the tubular housing; and in the extended position, the device may extend a second distance beyond the external surface of the tubular housing which is greater than said first distance.

[00106] In the retracted position, the device may extend a first distance beyond the internal surface of the tubular housing and into the internal fluid flow passage; and in the extended position, the device may extend a second distance beyond the internal surface of the tubular housing and into the internal fluid flow passage, said second distance being smaller than said first distance.

[00107] The device may comprise or may take the form of a cartridge which can be releasably movably mounted in the aperture.

[00108] Said latch element may be shearable or breakable to release the device for movement to the extended position.

[00109] The latch elements may be provided in the tubular housing, in the device (such as in the mounting member), or optionally in both the housing and the
5 device.

[00110] The device may be movable from the extended position to the retracted position via application of mechanical force, such as via contact between the device and a feature in the wellbore. The feature may be a dedicated feature, such as an upset or profile, provided in the wellbore for imparting a force on the
10 device.

[00111] The apparatus may comprise a plurality of devices for generating a fluid pressure pulse. Each device may be located in a respective aperture. A plurality of devices may be located in one aperture. Where the apparatus comprises a mounting member, the mounting member may receive a plurality of
15 pulse generating devices.

[00112] The aperture openings may be of different dimensions, profile and/or shape.

[00113] The apparatus may be arranged to automatically restrain the device in the extended position following movement to said position. For example,
20 the latch element may be sprung or otherwise biased.

CLAIMS

What is claimed is:

1. An apparatus for generating downhole fluid pressure pulses, comprising:

a tubular housing defining an internal fluid flow passage and providing a housing wall having an internal surface and an external surface; and
a device for selectively generating a fluid pressure pulse, the device being mounted in an aperture defined in the housing wall and being movable between a retracted position, where the device is seated within the aperture, and a radially extended position, where the device extends at least partially beyond the external surface.

2. The apparatus of claim 1, wherein the aperture extends between the internal and external surfaces of the housing wall.

3. The apparatus of claim 1, wherein, when in the retracted position, the device extends at least partially into the internal fluid flow passage and beyond the internal surface.

4. The apparatus of claim 1, further comprising a mounting block movably disposed within the aperture, wherein the device is mounted to the mounting block and the mounting block moves between the retracted and radially extended positions.

5. The apparatus of claim 4, wherein the mounting block is secured in the retracted position using one or more latch elements.

6. The apparatus of claim 4, wherein the mounting block is secured in the radially extended position using one or more latch elements.

7. The apparatus of claim 6, wherein the one or more latch elements are shearable to permit release of the mounting block for movement from the radially extended position back to the retracted position.

8. The apparatus of claim 1, wherein the device is movable from the retracted position to the radially extended position by imparting an expansion force on the tubular housing at or adjacent the aperture.

9. The apparatus of claim 8, wherein the tubular housing comprises at least one deformation zone configured to deform so that the device can move from the retracted position to the radially extended position.

10. The apparatus of claim 9, wherein the at least one deformation zone defines at least one corrugation arranged to be at least partially extended upon assuming the expansion force.

11. The apparatus of claim 1, wherein the device is movable from the retracted position to the radially extended position via at least one of a pressure differential between the internal fluid flow passage and external to the tubular housing, and application of a mechanical force that serves to move the device.

12. The apparatus of claim 1, further comprising at least one sensor communicably coupled to the device for measuring a downhole parameter, wherein data relating to the downhole parameter measured by the at least one sensor is transmitted to a surface location via fluid pressure pulses generated by the device.

13. The apparatus of claim 12, wherein the downhole parameter is selected from the group consisting of pressure, temperature, a geological feature, density, weight on bit, torque on bit, strain, stress, acceleration, and a wellbore geometry feature.

14. A method, comprising:

introducing a downhole assembly into a wellbore, the downhole assembly including a tubular housing defining an internal fluid flow passage and providing a housing wall having an internal surface and an external surface, and a device mounted in an aperture defined in the housing wall;

conveying the downhole assembly within the wellbore on a tubing string with the device being in a retracted position, where the device is seated within the aperture;

locating the device at a desired position in the wellbore;

operating the device to generate fluid pressure pulses to transmit data relating to at least one downhole parameter to a surface location; and

moving the device from the retracted position to a radially extended position, where the device extends at least partially beyond the external surface.

15. The method of claim 14, wherein moving the device from the retracted position to the radially extended position precedes operating the device to generate fluid pressure pulses to transmit data relating to at least one downhole parameter to a surface location.

16. The method of claim 14, wherein the device is arranged within a mounting block movably disposed within the aperture, and wherein moving the device from the retracted position to the radially extended position comprises moving the mounting block from the retracted position to the radially extended position.

17. The method of claim 16, further comprising securing the mounting block in the retracted position using one or more latch elements.

18. The method of claim 16, further comprising securing the mounting block in radially extended position using one or more latch elements.

19. The method of claim 14, wherein moving the device from the retracted position to the radially extended position comprises:

imparting an expansion force on the tubular housing at or adjacent the aperture; and

deforming at least one deformation zone in the tubular housing in response to the expansion force and thereby moving the device from the retracted position to the radially extended position.

20. The method of claim 14, wherein moving the device from the retracted position to the radially extended position comprises introducing a pressure differential between the internal fluid flow passage and external to the tubular housing.

21. The method of claim 14, wherein moving the device from the retracted position to the radially extended position comprises applying a mechanical force to the device.

22. The method of claim 21, wherein the device is arranged within a mounting block movably disposed within the aperture, and wherein applying the

mechanical force to the device comprises applying the mechanical force on the mounting block.

23. The method of claim 14, further comprising measuring the at least one downhole parameter with at least one sensor arranged in the downhole assembly and communicably coupled to the device, the downhole parameter being is selected from the group consisting of pressure, temperature, a geological feature, density, weight on bit, torque on bit, strain, stress, acceleration, and a wellbore geometry feature.