MAGNETIC PIPELINE PIGS

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ABSTRACT

A pig or traveller for use in a pipeline contains a magnetic device having poles disposed close to, but out of contact with, the inside walls of the pipe so as to be capable of magnetically saturating the walls and creating a magnetic field outside the pipe which can readily be detected, e.g., by means of a sensitive magnetometer. Pole pieces in the form of radial flanges may be used with an axially extending magnet assembly. Alternatively, the magnetic device may be rotatably mounted in the pig and provided with an impeller which employs pipeline pressure to rotate the magnetic device, and so creates a rotating magnetic field, if the pig becomes stuck. By establishing detector stations at intervals along the pipeline, the progress of the pig can be monitored.

7 Claims, 10 Drawing Figures
MAGNETIC PIPELINE PIGS

When a pipeline has been constructed it is usually necessary to clean, test or gauge the line, and for this purpose it is well known to use a so-called "pig." The pig is designed to fit closely within the pipe and is caused to travel along the pipe by admitting fluid under pressure behind the pig. Pigs are also used in operation of a pipeline to separate different fluids delivered in succession. The pigs are of various designs, the more common type being of spool shape with annular sealing members around the two flanges of the spool. Other pigs are of generally cylindrical shape, formed of resilient material such as foam rubber, to a common practice to utilize spherical pigs, either of a solid resilient material, or inflated or inflatable.

Whatever type of pig is used there is always a risk that the pig may become jammed in the pipe and this presents serious problems particularly if the pipeline section is buried and is of great length. If the pig cannot be removed by applying pressure or other means at the end of the pig it is necessary to uncover the pipe and extract the pig, but to do so it is first necessary to locate the pig accurately. It could also be of considerable value to have means for monitoring the passage of a pig through a pipeline, so that its location at any given moment would be known with a fair degree of accuracy.

Several previous attempts have been made to provide means for locating a pig in a pipeline, but all known methods suffer from disadvantages of one type or another. If the pipeline is buried the difficulties are very considerable since acoustic testing methods cannot be applied. Methods based on the use of radioactive isotopes have obvious attendant risks and disadvantages. Attempts to locate the position of the pig by metering the quantity of pressure fluid admitted to the pipeline require expensive control equipment and highly trained operators, and tend furthermore to be inaccurate. A magnetic go-devil or traveller has also been proposed but it was not found easy to detect its magnetic field from outside the pipeline. The difficulties are further increased by the fact that the pipeline frequently traverses broken ground inaccessible to vehicles, and therefore to heavy equipment, and in other cases the line of the pipe may pass below cultivated ground which preferably should not be disturbed.

Accordingly it is an object of the invention to provide an improved apparatus and method for cleaning, testing, gauging or operating a pipeline, especially a buried pipeline, which will at least partly overcome some of the disadvantages of previous systems.

According to the invention, a traveller for use in cleaning, testing, gauging or operating a pipeline and adapted to fit closely within it, comprises a magnetic device having pole pieces which extend into proximity to the outer circumference of the traveller, and a non-magnetic element disposed radially outwardly of the pole pieces so as to prevent the pole pieces from contacting the internal surface of the pipeline.

With a traveller according to the invention, it is possible to arrange that the pipeline wall is magnetically saturated so that the magnetic field extends well outside the wall and can readily be detected with a sensitive magnetometer.

The magnetic device preferably comprises at least one permanent magnet. In one construction, the magnetic device comprises an externally cylindrical magnet assembly having pole pieces each of which extends from a respective end of the magnet assembly in the form of a radial flange. The non-magnetic element may then comprise a pair of resilient cup-shaped sealing elements, one of which is secured to each pole piece.

In another construction, in which the traveller has an axis which in use coincides with the pipeline axis, the magnetic device, or a part thereof, is rotatable about the said axis. In this construction, the traveller may comprise a fluid-operated impeller drivenly connected to the magnetic device, passages for the pipeline fluid being provided in the traveller and so arranged that the impeller is subject to the fluid. A valve is preferably provided in one of the passages to control the flow of fluid and hence the speed of rotation of the impeller and the magnetic device.

The rotating magnetic field produced by this construction is even more readily detected. Normally, the valve is so adjusted that little, if any, rotation occurs during normal travel, but if the traveller becomes stuck in the pipeline the magnetic device rotates at a controlled speed, which is usually selected to produce a frequency of between 2 and 20 cycles per second (preferably about 8 cycles per second) which is readily distinguishable from any stray fields due to leakage from electrical mains supplies which operate at 50 or 60 cycles per second. The frequency is given by multiplying the revolutions per minute of the magnetic device by half the number of pole pieces.

According to another aspect of the invention, we provide a pipeline traveller comprising a pair of spaced magnetically permeable circular disc-like pole pieces, a hollow structural casing of smaller diameter rigidly connected to the pole pieces to provide positive location therefor, a resilient sealing ring mounted at or adjacent the periphery of each pole piece, and an elongated permanent magnet assembly mounted within the casing and in contact with the pole pieces.

According to a further aspect of the invention, we provide a method of testing, cleaning, gauging, or operating a metallic pipe line, in which a traveller is inserted in the pipeline and caused to travel along the pipeline by fluid therein, the traveller incorporating magnetic means for creating a magnetic field which will substantially saturate the wall of the pipeline and create a magnetic field externally of the pipeline, and the position of said traveller is located by means of an external magnetometer.

The invention may be carried out in various ways and several embodiments will now be described by way of example and with reference to the accompanying drawings, in which:

FIG. 1 is a sectional side elevation through a pipeline "pig," or traveller according to the invention,

FIG. 2 is a cross-section on a reduced scale on the line II—II in FIG. 1,

FIG. 3 is a side elevation of a similar pig with brushes for cleaning the inside of a pipeline,

FIG. 4 is a similar view of a "batching" pig for separating two different streams of fluid flowing along a pipeline,

FIG. 5 is a similar side elevation of another form of cleaning pig having scraper blades to engage the walls of the pipeline,

FIG. 6 is a longitudinal section through another form of pig including a rotary magnetic device,

FIG. 7 is an end elevation of the pig of FIG. 6,

FIG. 8 is a section through another form of spherical magnetic pig according to invention, and

FIGS. 9 and 10 illustrate diagrammatically the external fields produced by such magnetic pigs travelling along buried pipelines.

The pig illustrated in FIGS. 1 and 2 consists basically of a pair of circular pole pieces 14, 15, rigidly secured at opposite ends of a cylindrical non-magnetic casing 20. A set of three powerful annular permanent magnets 10, 11, 12 are mounted upon a brass supporting rod 13 extending along the axis of the pig and through apertures in the pole pieces, to which the rod is attached by nuts 16, 17. The magnetically permeable pole pieces 14, 15 extend radially outwardly in the form of flanges, being rigidly located relative to one another by the structural casing 20 and the rod 13. The pole pieces are in contact with the adjacent annular magnets 10, 12 but no excessive stress is exerted on the magnets, which may be formed of a brittle material. It is important that the flux path from the ends of the magnets to the periphery of each pole piece should not be constricted since excessive flux density may reduce the total flux available at the pole pieces. Accordingly the two pole pieces are formed with bosses or rings 18, 19 in which effect provide flux guides at the re-entrant corners between the magnets and the pole flanges, and effective increase the available cross-section of the flux path at these points. It will be noted that the flux guides bosses lie inside the non-magnetic structural casing 20. The casing 20 not only acts as a structural connection between the pole flanges but also protects the magnets 10, 11, 12 from dirt, impact or abrasion, and it will be noted
that the casing is of considerably smaller diameter than the pole flanges, thus allowing the traveller to negotiate bends in the pipeline.

To the outer edge of each of the radial flange pole pieces 14, 15 is secured a resilient cup-shaped sealing element 21, 22 respectively. The sealing elements are readily removable, for replacement purposes, and are held in position by detachable end plates 23, 24 secured by bolts to the pole flanges 14, 15. Each sealing ring has a portion 25 which lies radially outside the periphery of the respective pole flange and acts as a non-magnetic spacer which prevents the pole piece making direct contact with the wall of the pipeline, in which case the magnetic attraction would become excessive. The extreme outer lip of each sealing ring is a narrow flexible skirt. The sealing rings 21, 22 are preferably formed of resilient durable plastics material such as polyurethane, and the material may include a proportion of powdered magnetic material such as ferrite, in order to improve the magnetic permeability of the gap between the pole flanges and the pipeline wall.

One of the end plates 23 has a bracket 27 with an aperture 28 for a ring by which the pig can be lifted.

The embodiment illustrated in FIG. 3 is essentially similar to that of FIGS. 1 and 2 and like parts are indicated by the same reference numerals. In this construction a series of radially extending brush bristles 30 are provided on the casing 20 between the two pole flanges for cleaning the interior surface of the pipeline as the pig travels through it. The internal magnetic structure is identical with FIGS. 1 and 2.

FIG. 4 illustrates another embodiment which is again basically similar to that of FIGS. 1 and 2, and has the same magnetic structure, but in this case the pig is intended for "batching," i.e. to move along the pipeline as a separator between two different fluids, and two extra resilient sealing cups 31, 32, are mounted at opposite ends, beyond the existing seals 21, 22.

The embodiment of FIG. 5 is somewhat similar to that of FIG. 3, and is designed for cleaning purposes, but the brush bristles 30 are replaced by a series of radially extending flexible plastics scraper blades 33 each disposed at a small angle to the longitudinal axis of the pig so as to cause a scraping action on the interior surface of the pipeline while also causing the pig to rotate about its axis as it passes through the pipeline.

In the embodiment of FIGS. 6 and 7, the pig includes a rotatory magnetic system and a fluid impeller for providing the rotatory power. A pair of bar magnets 40, 41 of the same polarity is mounted on a magnetic boss 42 at one end of a shaft 43, and a similar pair of bar magnets 44, 45 with their polarity reversed as compared with magnets 40, 41 is mounted on a similar boss 42 at the other end of the shaft. The shaft 43 is rotatable in bearings 46, 47 in respective end plates 48, 49 which are rigidly connected to one another by a hollow cylindrical structural casing 50, having flanges 51, 52 at each end by which it is bolted to the plates 48, 49. Each of these plates 48, 49 is connected to a light gauge non-magnetic cover 54, 55. The two covers enclose the pairs of magnets 40, 41, 43, 44 and thereby protect them from dirt, impact and abrasion. The end plates 48, 49 and the casings 54, 55 are of non-magnetic material. A fluid operated turbine type impeller 56 is secured to the center of the shaft 43 and pressure fluid from within the pipeline is admitted through an aperture 57 at the rear end of the pig, passes through a filter 58, and further apertures 59, 60 into a space 61 within the casing 50 on the upstream side of the impeller. From the downstream side of the impeller the fluid passes through drillings 62 into a counterbore 63 in the shaft 43. The end of the counterbore 63 is provided with a spring-loaded pressure relief valve 64 which controls the rate of flow of fluid from the counterbore 63, via apertures 65 in a cover plate at the front end of the pig, and so into the pipeline again. The valve is set in relation to the fluid pressure of the fluid to control the rotational speed of the impeller 56 and magnets at a value of between about 400 r.p.m. and 500 r.p.m. This produces a cyclic variation in magnetic flux at a frequency of say 8 c.p.s. (ideally between 2 and 20 c.p.s.) which is readily distinguishable from "mains" frequency effects at 50 c.p.s. or 60 c.p.s.

Resilient cup-shaped sealing elements 66, 67 are secured to the periphery of each cover 54, 55 each sealing ring being detachably positioned by a cover ring and locking bolts. The sealing rings are similar in design to those illustrated in FIG. 1.

With this embodiment, if the pig becomes stuck in the pipeline, the pipeline fluid pressure will rise fractionally and open the valve 64. Pressure fluid will pass through the apertures 57, 59, 60 through the impeller 56, and thence through passages 62 and the valve 64, finally emerging at the other end of the pig through apertures 65. The fluid flow path thus "by-passes" the obstruction caused by the stuck pig and its sealing rings. The impeller causes rotation of the magnets so creating a rotary magnetic field which can readily be detected from outside the pipeline.

FIG. 8 shows another form of pipeline traveller according to the invention, in the form of a resilient sphere 70 of rubber or other resilient material which can be inflated if desired through an inflator element shown diagrammatically at 71. The sphere 70 contains a cylindrical bar magnet 72 (which may be encased in a structural non-magnetic tube) and a pair of mushroom-shaped pole pieces 73, 74 each of which has a hollow stem or socket as shown at 75, fitting slidably over a respective end of the bar magnet 72, and a spherical head in contact with the inner surface of the sphere 70 as shown at 76. The pole pieces 73, 74 are separated by a magnetic ring 77 surrounding the magnet forces the two pole pieces 73, 74 apart against the inner surface of the sphere 70 but allows them to move towards one another if the sphere has to be compressed, e.g. to pass an obstruction.

The pigs or travellers described above are all designed to produce a powerful magnetic field which is sufficient to saturate the wall of the pipeline. FIG. 9 illustrates diagrammatically a magnetic pig of the type illustrated in FIG. 1 moving along a buried pipe 80. It will be seen that the magnetic field between the pole flanges 21, 22 has saturated the pipe wall and the external magnetic field 81 extends a considerable distance from the pipe and can be detected at ground level by a sensitive magnetometer 82 which is preferably of the fluxgate type, or may be a gradiometer having two spaced sensing heads for detecting a change in the field. The rotating magnetic field produced by the embodiment of FIGS. 6 and 7 is particularly easily detected and distinguished from other extraneous fields. For detection of a spherical traveller as shown in FIG. 8 it may be preferred to use three sensors disposed at equal intervals around the pipeline. FIG. 10 represents an end view of a buried pipeline 80 with a pig of type illustrated in FIGS. 6 and 7 moving therein, and shows the general form of the external magnetic field produced by the rotating magnets 40, 41 which again are designed to saturate the pipeline wall.

Magnetic pigs or detectors can also be used in various ways for cleaning, testing, gauging or operating pipelines. By the use of a series of detectors spaced apart at selected intervals along the pipeline, the progress of a pig through the pipeline can be followed from a remote control station. The detectors are preferably gradiometers of the flux gate type using a pair of parallel electro-magnetic sensors, connected to supply a signal to the remote control station. In addition the magnetic signal produced by the traveller makes it very much easier to locate it if it becomes stuck in the pipeline.

We claim:

1. A pipeline traveller comprising a pair of spaced magnetically permeable circular disc-like pole pieces, a hollow structural casing of smaller diameter rigidly connected to the pole pieces to provide positive location therefor, a resilient sealing ring mounted adjacent the periphery of each pole piece, and an elongated permanent magnet assembly mounted within the casing and in contact with the pole pieces;

2. A traveller according to claim 1, including a non-magnetic element disposed radially outwardly of each of said pole pieces so as to prevent the pole pieces from contacting the internal surface of a pipeline in which the traveller is located.
3. A traveller according to claim 1, wherein annular flux guides are disposed at the junctions between said pole pieces and the external surface of said magnet assembly.

4. A traveller according to claim 1, wherein said magnet assembly comprises a plurality of annular permanent magnets, all polarized axially in the same direction, and disposed on an axially extending non-magnetic support rod, with adjacent faces of said magnets in contact.

5. A traveller according to claim 1, wherein said casing is of non-magnetic material.

6. A traveller according to claim 1, including radially extending brush bristles for cleaning the inside of the pipeline.

7. A traveller according to claim 1, including radially extending scraper blades disposed at a small angle to the longitudinal axis of the traveller.