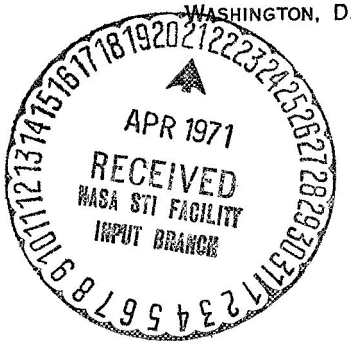
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546



REPLY TO
ATTN OF: GP

March 27, 1971

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,331,255

Corporate Source : Goddard Space Flight Center

Supplementary
Corporate Source :

NASA Patent Case No.: XGS-02422

Gayle Parker

Enclosure:
Copy of Patent

FACILITY FORM 602

N71-21529 (ACCESSION NUMBER) (THRU)

17 (PAGES) 00 (CODE)

(NASA CR OR TMX OR AD NUMBER) 15 (CATEGORY)

NASA-HQ

N71-21529

July 18, 1967 J. P. BAUERNSCHUB, JR 3,331,255

NON-MAGNETIC, EXPLOSIVE ACTUATED INDEXING DEVICE

Filed Oct. 7, 1965 3 Sheets-Sheet 1

Fig. 1

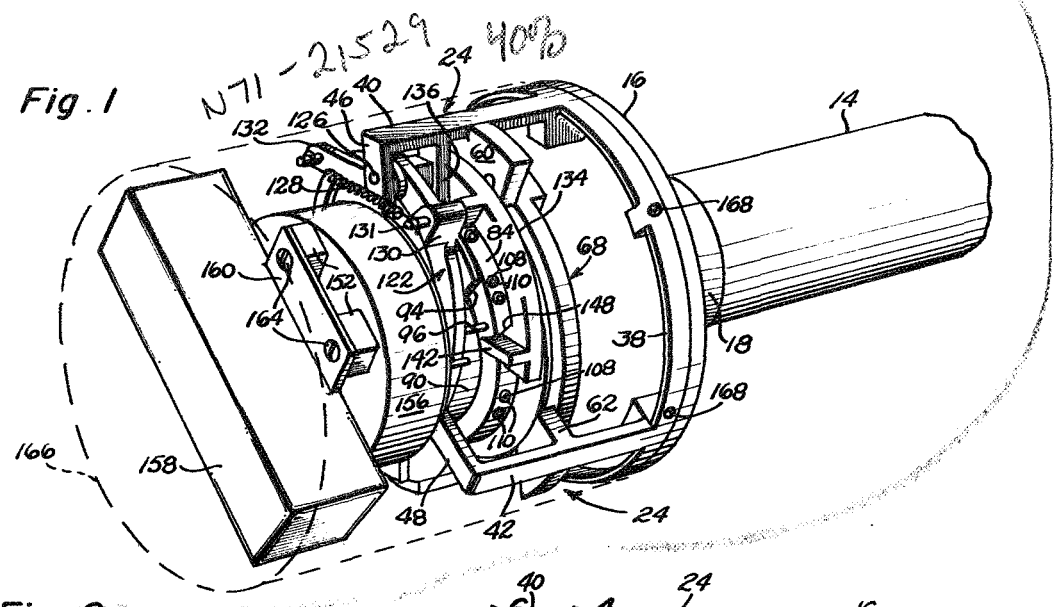


Fig. 2

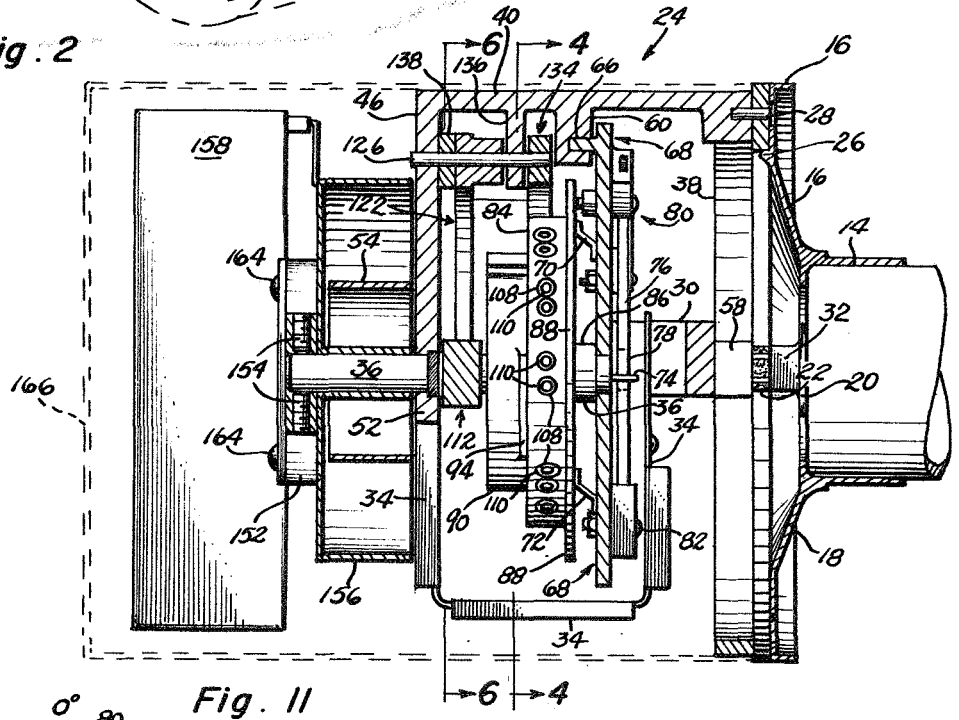
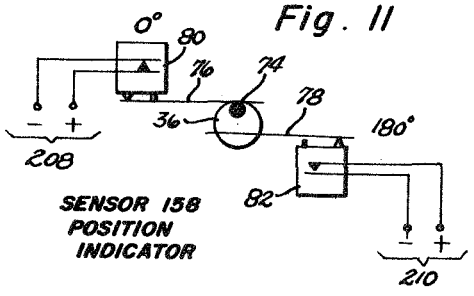


Fig. 11



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July 18, 1967 J. P. BAUERNSCHUB, JR 3,331,255

NON-MAGNETIC, EXPLOSIVE ACTUATED INDEXING DEVICE

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Fig. 12

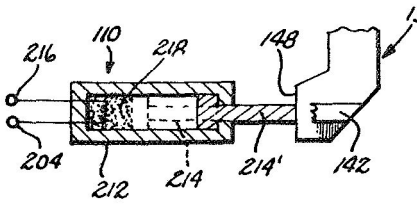

Fig. 3

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NON-MAGNETIC, EXPLOSIVE ACTUATED INDEXING DEVICE

Filed Oct. 7, 1965 3 Sheets-Sheet 3

Fig. 4

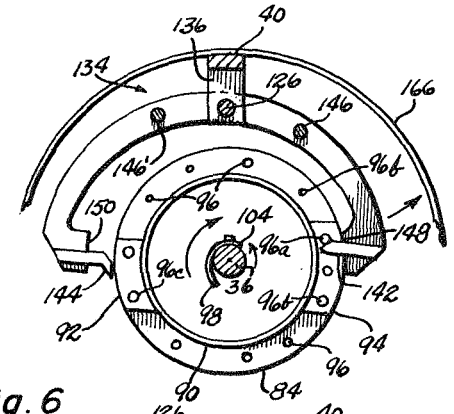


Fig. 5

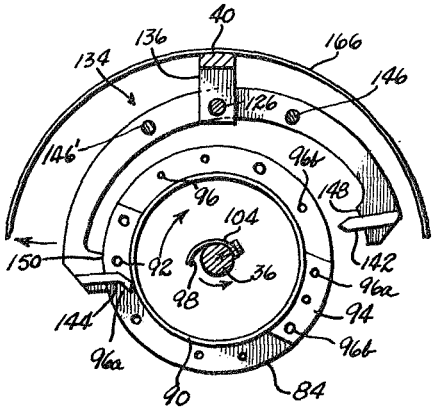


Fig. 6

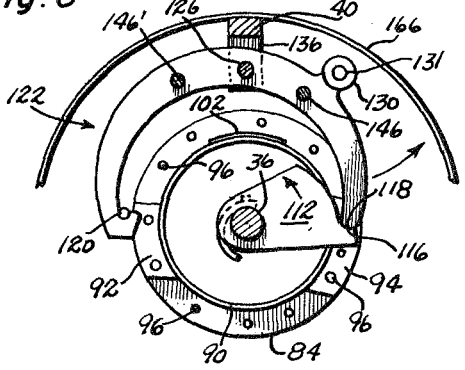


Fig. 7

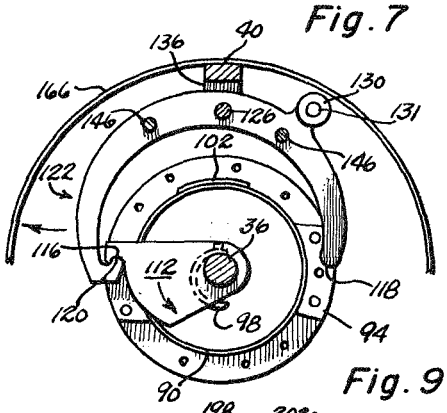


Fig. 8

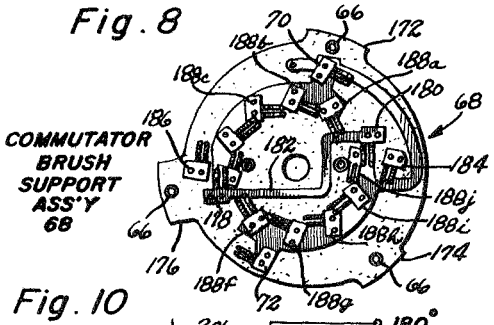
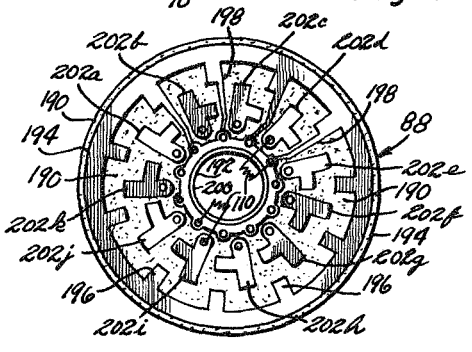
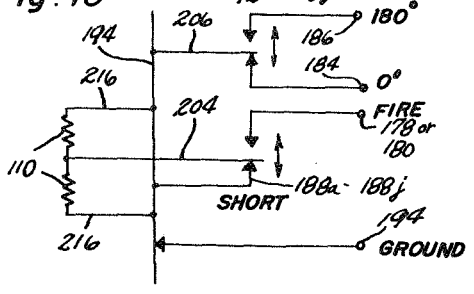


Fig. 9



COMMUTATOR 88

Fig. 10



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United States Patent Office

3,331,255
Patented July 18, 1967

3,331,255
NON-MAGNETIC, EXPLOSIVE ACTUATED INDEXING DEVICE

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Filed Oct. 7, 1965, Ser. No. 493,943
27 Claims. (Cl. 74—126)

ABSTRACT OF THE DISCLOSURE

An indexing device with positionable means having at least first and second stable positions, a ratchet arm, a ratchet coupled to the positionable means and engageable with the ratchet for retaining the positionable means in one stable position, and explosive means for actuating the ratchet arm to momentarily release the ratchet and permit the positionable means to assume another stable position.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to a non-magnetic indexing device and more specifically to an apparatus and method for orienting a magnetic flux sensing instrument in a magnetic field without the generation of detrimental magnetic fields.

A conventional method for indexing a shaft (and any apparatus or device coupled to the shaft) is through the actuation of the stepper motor or a solenoid actuated device.

The actuation of the motor or the solenoid requires a flow of current and it is well known that parts of these devices must be magnetic and that a magnetic field is formed about current carrying conductors or elements. In many applications, the generation of the magnetic field due to the current flow through an actuating device produces no harmful effects and is rarely taken into consideration. In other environments and applications, the magnetic field so generated can be tolerated only to a degree so that certain types of shielding may be satisfactory in reducing the intensity of the field to a tolerable level. However, since a magnetic field exists in space about the earth, and perhaps about other planets and celestial bodies, the measurement of the intensity, direction, etc. of these magnetic fields is a natural exercise of man's eternal quest for knowledge.

The magnetic field intensity about the earth and other bodies is very small. Accordingly, if this field is to be measured, the measuring instrument must be highly sensitive and one must be able to selectively position the instrument for calibration purposes. In certain types of magnetometers, the accepted manner for deriving absolute values of the magnetic fields is through a reversal of the axis of the measuring instrument. For example, values are recorded with the instrument in a first position and are again recorded with the instrument in a second position, substantially 180° removed from the first position.

It will be intuitively clear that if a minute magnetic field is to be measured by a highly sensitive instrument, and, further, that the instrument must be rotated upon its axis at certain intervals, then the conventional means of stepping motors or solenoid actuated devices cannot be employed since each of these devices have a magnetic field that cannot be tolerated by the magnetic flux sensing instrument. Understandably, if conventional means were employed to orient the sensing instrument, then the values of the magnetic field intensity or direction recorded would

be of little value since one would not know whether the recorded value included the measurement of the desired field or the measurement of the desired field including a spuriously generated and unwanted field.

In the present invention, the apparatus for orienting or indexing the magnetic flux sensor is actuated through the detonation of a small explosive charge which is non-magnetic by nature and has no magnetic influence upon the magnetic flux sensing instrument.

Accordingly, it is the principal object of the present invention to improve indexing or shaft orientation apparatus.

It is a further object of the present invention to improve indexing apparatus of the non-magnetic type.

It is a further object of the present invention to provide an instrument indexing apparatus which employs the force created through the detonation of an explosive charge to index the apparatus.

It is a further object of the present invention to provide a magnetometer positioning device of the non-magnetic type for calibrating absolute values of magnetic fields.

It is a further object of the present invention to provide an instrument indexing apparatus employing explosive actuators which may be repeatedly indexed to successive positions to again index the apparatus.

It is a further object of the present invention to provide an instrument indexing apparatus employing explosive actuators which are removed and replenished after each detonation so as to repeatedly index the apparatus to successive positions.

It is a still further object of the present invention to provide a mechanism for supplying precision rotary motion on command for a system requiring only a limited number of operations and where electrical power is limited.

These and other objects of the present invention are accomplished by an indexing apparatus wherein the magnetic flux sensing instrument along with an electrical cable container are positioned upon a rotatable shaft. A ratchet is secured to the shaft and the shaft, being biased for rotation in one direction, is arrested in one of two positions through the engagement of the ratchet with a ratchet arm. Each of the two positions are stable positions and are located approximately 180° removed from each other.

The foregoing ratchet arm is pivotable and is secured to a second ratchet arm which includes a pair of piston surfaces positioned approximately 180° from each other. Within the contour of the second ratchet arm is a piston actuator housing which supports a plurality of piston actuators about its periphery. A commutator bearing a plurality of electrical conductors is secured to the piston actuator housing. A commutator brush support assembly is rigidly positioned and the brushes of the commutator brush support assembly engage the conductors of the commutator as the commutator, being biased for rotation in a direction opposite to the direction of rotation of the magnetic flux sensor, rotates. The entire assembly is supported, as appropriate, from a main structure and a non-magnetic cover is positioned over the entire sensing and indexing apparatus.

To rotate the sensing instrument (to index the device), an electrical pulse is transmitted to the apparatus which causes the detonation of a small explosive charge in a piston actuator positioned in a piston actuator housing. The force of the detonation extends a piston about ⅛ inch. This piston is directed against one of the piston impact surfaces of the second ratchet arm, causing the ratchet arm to pivot outwardly and carry the first ratchet arm along with it. The ratchet, along with its shaft and magnetic flux sensing instrument, disengages the first

ratchet arm, rotates 180°, and reengages the first ratchet arm to then halt in its other position.

Simultaneously, the second ratchet arm will permit approximately a 15° rotation of the piston actuator housing and the commutator coupled thereto. In this manner, an undetonated explosive actuator (actually a pair of actuators) is positioned under the opposite piston impact surface of the second ratchet arm. During the rotation of the commutator upon detonation of the explosive charges, all explosive charges not selected are shorted out so as to prevent their accidental firing. Since the apparatus of the present invention is designed for use in a space vehicle, the electrical output of the magnetic flux measuring instrument in both of its positions would be transmitted through the space vehicle's electronic communication system to a ground station. In addition to the sensing instrument output, a signal is also generated in the apparatus for indicating whether the sensing instrument is in its first position or its second position. It will be readily understood by those skilled in the art that, although the apparatus is described with reference to two stable positions of the sensing instrument, it may be readily adapted for many more different rotational positions than the two set forth by the provision of additional stops to the ratchet engaging ratchet arm. In addition, it will be evident to those skilled in the art that there are other ways of obtaining the same mechanical output from the apparatus. For example, the dual ratchet can be replaced by a single ratchet and a gear train to couple the flux measuring instrument and the piston actuator case. A device incorporating a planetary gear system is also envisioned.

As set forth, one of the particularly salient features of the invention is the manner in which the explosive devices are incorporated to obtain repeated indexing operations. Normally, such explosive devices are only used for one-shot operations because, by their very nature, they can be fired only once and cannot be retracted. The mechanism of the present invention provides for the removal and the replenishment of the explosive actuator for additional successive cycles.

The invention both as to its organization and method of operation together with further objects and advantages thereof will best be understood by reference to the following specification taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a perspective view of the invention and illustrating the encased magnetic flux sensing instrument to the left, the centrally positioned indexing mechanism, and the boom and mounting flange on the right;

FIGURE 2 is an elevational view of the apparatus, partly in section, and emphasizing the piston actuator or explosive charges, and other elements of the invention;

FIGURE 3 is an exploded view of the invention and illustrates the more important elements of the invention while eliminating the showing of such lesser elements as washers, spacers, cable conduits, pins, etc.;

FIGURE 4 is a sectional view taken along the line 4—4 of the FIGURE 2 and showing the piston surfaces bearing ratchet arm which initiates the indexing operation after detonation and also steps the piston actuator housing;

FIGURE 5 is a view similar to the FIGURE 4 but illustrating the piston actuator ratchet arm in its second stable position;

FIGURE 6 is a sectional view taken along the line 6—6 of the FIGURE 2 and illustrating the ratchet engaged by the first ratchet arm which yields a first position of the magnetic flux sensing instrument;

FIGURE 7 is a view similar to the FIGURE 6 except the ratchet and ratchet engaging arm are shown in their other position which produces the second stable position of the sensing instrument which is substantially 180° removed from the first position;

FIGURE 8 is an elevational view of the commutator brush support assembly and illustrating the position of the various brushes of the assembly;

FIGURE 9 is an elevational view of the commutator which is engaged by the commutator brush support assembly of the FIGURE 8;

FIGURE 10 is a diagrammatic electrical schematic illustrating the manner in which the explosive charges or piston actuators are fired or, if not selected for detonation, retained at ground potential so as to eliminate any possibility of accidental firing;

FIGURE 11 is an electrical schematic illustrating the manner in which the position of the magnetic flux sensing instrument is determined; and

FIGURE 12 is a fragmentary view, partly in section, illustrating the position, in dotted outline, of a piston actuator prior to detonation and the position of the piston, in solid outline, after detonation and driving the piston impact surface of the piston ratchet arm outwardly.

Initial reference will be had to the FIGURES 1, 2 and 3. The FIGURES 1 and 2 illustrate the assembled position of the various elements of the indexing device while the FIGURE 3, being an exploded view of the device, succinctly illustrates the configuration of the various elements in their unassembled form.

In order that the invention not be obscured, a number of the minor elements such as spacers, clamps, cable conduits, etc. have been omitted from the exploded view of the FIGURE 3.

With reference to the FIGURES 1, 2 and 3, the indexing apparatus is supported upon a boom **14** which is mounted in and secured to a mounting flange **16**. The mounting flange **16** has a reduced circular portion **18** which receives the boom **14** and is secured thereto by any suitable means. An aperture **20** is centrally positioned along the axis of the mounting flange **16** and receives an electrical connector **22** which connects the electronics of the indexing device with a cable (not shown) communicating with the device through the boom **14**.

A main structure **24** of generally circular configuration and having a plurality of apertures, projecting arms, etc. for receiving the various elements of the indexing mechanism, is secured to the mounting flange **16** and aligned with the mounting flange **16** by the bosses **26**. The main structure **24** may be secured in any suitable manner to the mounting flange **16** such as by a plurality of bolts **28**, one of which is shown in the FIGURE 2. A standoff connector **30** is positioned within the mounting flange **16** at the aperture **20** and engages a pair of bosses **32** and **32'**. A cable conduit **34** of generally square "U" construction is secured to the standoff connector **30** and extends under (according to the position of the device) the indexing apparatus to be hereinafter described, and has its other end supported by a main shaft **36**. Substantially all of the remaining elements are assembled about the main shaft **36**.

The main structure **24** includes an annulus **38** which is secured to the mounting flange **16** and three substantially axially parallel arms **40**, **42** and **44** extending from the annulus **38** and equidistant from the axis. At the end of the arms **40**, **42** and **44** opposite to the annulus **38**, three projections **46**, **48** and **50** are joined, respectively, to the arms **40**, **42** and **44** and converge toward an axial ring **52**. The axial ring **52** supports an axial sleeve **54**, as shown. The standoff connector **39** is supported in the area adjacent the aperture **58** and then to the cable conduit **34**, as previously described. Projecting inwardly from each of the arms **40**, **42** and **44** are a pair of ears **60** and **62** which are visible while the third ear projects from the arm **44**. An aperture is formed in each of the ears **60**, **62** and the invisible ear, to receive a bolt **66** (it being understood that there is a bolt received in each of the ears) for securing thereto a commutator brush support assembly **68**. The commutator brush support assembly **68** is rigidly secured to the main structure **24** and supports a plurality of bifurcated contacts, only four of which are shown in the FIGURE 3, whose function and operation will be set forth with reference to the FIGURES 8 and 9. A pair of contacts **70** and **72** are illustrated in the FIG-

URE 2 for reference purposes. The commutator brush support assembly **68** is of a non-conductive or insulating material so as to provide insulation between certain of the contacts.

One end of the shaft **36** is suitably supported within the centrally positioned aperture of the brush support assembly **68**, and an eccentrically mounted pin **74**, secured to the shaft **36** extends through the brush assembly **68** and alternatively engages a pair of switch arms **76** and **78** projecting from, respectively, a pair of sensor position indicating switches **80** and **82**, only the switch **80** being visible in the FIGURE 2. The operation of the switches **80** and **82** will be discussed with subsequent reference to the FIGURE 11.

Continuing leftwardly from the rightward end of the shaft **36** adjacent the eccentrically mounted pin **74**, a piston actuator housing **84** having an axial sleeve **86** is loosely mounted upon the shaft **36** and has a commutator **88** positioned about the axial sleeve **86** and secured to a face of the piston actuator housing **84**. The contacts **70**, **72**, and the remaining contacts of the commutator brush support assembly **68** engage the conductors printed upon the face of the commutator **88**, the commutator **88** being discussed with reference to the FIGURE 9. Secured to the opposite face of the piston actuator housing **84** is a power spring housing **90** which is loosely mounted over the shaft **36**. The power spring housing **90** has a pair of ears **92** and **94** extending therefrom which are provided with a plurality of apertures to receive an equal number of pins or bolts **96** extending from the face of the piston actuator housing **84**. The pins not only secure the power spring housing **90** to the piston actuator housing **84** but also serve as indexing pins which cooperate with a ratchet arm to reposition the piston actuator housing **84** after each detonation of a piston actuator or explosive charge, to be hereinafter described. A power spring **98** is fitted within the power spring housing **90** and has its outer end **100** secured to a lobe **102** of the power spring housing **90** and its inner end **104** secured to the shaft **36** at the aperture **106**. As viewed in the FIGURE 3, the power spring housing **90**, piston actuator housing **84**, and commutator **88** are biased for rotation in a clockwise direction while the main shaft **36** is biased for rotation in a counterclockwise direction.

The piston actuator housing **84** has a plurality of pairs of peripherally located and axially oriented apertures **108** which are adapted to receive a piston actuator **110**, two of which are shown in the FIGURE 3. A piston actuator **110** is positioned in each of the apertures **108** and are arranged in pairs for redundancy. This provides an added feature of positive indexing in the event of the failure of one of the actuators **110** to detonate and it is very unlikely that two detonators in parallel would both fail to detonate. As a result, indexing of the apparatus upon command, is assured. A piston actuator **110** houses an explosive charge, which upon detonation, drives a small piston outwardly to engage a piston impact surface of a ratchet arm. Subsequent reference will be had to FIGURE 12 wherein the actuator **110** and their operation will be fully described.

As best shown in the FIGURE 3, a ratchet or pawl **112** has an aperture **114** which fits about the shaft **36** and is rigidly secured thereto by a roll pin (not shown). The ratchet **112** has a hook **116** formed at its outer end for engaging a first stop **118** and a second stop **120** formed on a sensor ratchet arm **122**. The sensor ratchet arm **122** is pivoted at **124**, and as shown in the FIGURES 1 and 2, is mounted for pivotable movement upon a shaft **126**. A ratchet spring **128** is secured to the sensor ratchet arm **122** by a pin **131** (FIGURES 1, 6 and 7) supported from a projection **130**. The other end of the ratchet spring **128** is pinned to a pin from a projecting member **132** extending substantially perpendicular to the projection **46**. The position of the ratchet spring **128** is such that it has a first off-center position so as to urge the sensor ratchet arm **122** in a clockwise rotational sense to engage the stop **118** and a second off-center position wherein the ratchet **122** is urged in a counterclockwise rotational sense so that the hook **116** of the ratchet **112** will engage the stop **120**.

A second ratchet arm is employed in the practice of the invention and is identified as a piston ratchet arm **134** and is also mounted for limited pivotable movement upon the ratchet shaft **126**. The ratchet shaft **126**, extends between the projection **46** and an inwardly directed projection **136** formed from the inner surface of the arm **40**. As best shown in FIGURE 2, the shaft **126** passes through the projection **46**, a spacer **138**, the pivot **124** of the sensor ratchet arm **122**, the projection **136** from the arm **40**, and a pivot point **140** of the piston ratchet arm **134**. The piston ratchet arm **134** has a pair of opposed inwardly directed dogs **142** and **144** which are adapted to engage the pins **96** secured to the face of the piston actuator housing **84**. A pair of pins **146** and **146'** extend from the piston ratchet arm **134** and are equally spaced from the pivot **140**. The pins **146** and **146'** are adapted to enter the apertures **56** and **58**, respectively, of the sensor ratchet arm **122** and in this manner, the piston ratchet arm **134** and the sensor ratchet arm **122** rock as a unit. Adjacent each of the dogs **142** and **144** is a flat surface or piston impact surface **148** and **150**, respectively, which alternately engage the piston caused by the detonation of the explosive charge in the piston actuators **110**. Through the cooperation of the piston ratchet arm **134**, the dogs **142** and **144**, and the pins **96** projecting from a face of the piston actuator housing **84**, the force of the piston directed against either of the piston impact surface **148** and **150** will cause a type of escapement movement which, due to the unique construction of the ends of the dogs **142** and **144**, causes the piston actuator housing **84** to rotate a sufficient amount as to position a new and undetonated set of piston actuators **110** under one of the piston impact surfaces **148** or **150**. In an embodiment of the invention which was constructed and operated in accordance with the teachings of the present invention, the rotational movement permitted to the piston actuator housing **84** was 15° and the sets of piston actuators **110** were spaced accordingly. The detonation of the piston actuators **110** proceeds from a set of detonators **110** which may act against the piston impact surface **148** to a second set of piston actuators **110** which are substantially 180° removed from the first set of actuators **110** and act against the piston impact surface **150** and then back to a third set, adjacent the first set, which act against the piston impact surface **148**, and so forth. The complete operation of the indexing device will be reserved for discussion in the section on the operation of the device.

The shaft **36** extends through the sleeve **54** of the main structure **24** and is secured to a mounting projection **152** by any suitable means such as the bolts **154**. A cable container **156** is formed from the mounting projection **152** and surrounds the sleeve **54** but at a distance sufficient to permit several turns of electrical cable to surround the sleeve **54**. A magnetic flux sensor **158** has a mounting flange **160** secured thereto which bears a plurality of apertures **162** which mate with apertures in the mounting projection **152** so as to accommodate a plurality of bolts **164**. In this manner, the magnetic flux sensor **158** will follow the excursions of the ratchet **112** and the main shaft **36** coupled thereto. The magnetic flux sensor **158** is oriented in a first position and in a second position substantially 180° removed from the first position. Each time the piston actuators are detonated, the magnetic flux sensor **158** seeks its outer position.

Finally, a cover **166** of a material having suitable nonconducting properties such as fiberglass, is positioned

over the entire mechanism and secured by a plurality of peripheral screws **168** which seat in a plurality of apertures **170** formed on the main structure **24**.

With reference to the FIGURES 4 and 5, the FIGURE 4 illustrates one of the two positions of the piston ratchet arm **134** while the FIGURE 5 illustrates the other position of the piston ratchet arm **134**. The piston ratchet arm **134** oscillates between its two positions and is actuated by the detonation of the piston actuators **110**. The piston actuators **110** selected for detonation alternate from one side of the piston actuator housing **84** to the opposite side or approximately 180° removed from the previously fired or detonated piston actuators **110**. After each detonation, the piston ratchet arm **134** moves to its other stable position.

More specifically, as shown in the FIGURE 4, the dog **142** is shown engaging the pin **96***a* and serves to retain the piston actuator housing **84** in the position shown. It will be recalled that the piston actuator housing **84** is biased in a clockwise direction as viewed in the FIGURE 4. In the position as shown, the piston impact surface **148** (perhaps more appropriately, a piston surface) is resting against a pair of piston actuators **110** (not visible in the FIGURE 4) which are mounted about the periphery of the piston actuator housing **84**. When it is desired to rotate or index the magnetic flux sensor **158**, the electronic circuitry will select the piston actuators **110** immediately under the piston impact surface **148** so that the piston ratchet arm **134** will be driven outwardly about the shaft **126** in the direction of the arrow as indicated in the FIGURE 4. The detonation of the selected piston actuators **110** will not only permit approximately 15° of clockwise rotation of the piston actuator housing **84** but will also permit 180° counterclockwise rotation of the shaft **36** upon which the magnetic flux sensor **158** is mounted. The indexing of the magnetic flux sensor **158** will be subsequently discussed with reference to the FIGURES 6 and 7.

In the FIGURE 5, the position of the piston ratchet arm **134** and the piston actuator housing **84** are shown after detonation of the piston actuators **110** against the piston impact surface **148**. The operation of the device produces a type of escapement movement in that the dog **142** has released the pin **96***a*, thus permitting clockwise rotation of the piston actuator housing **84** and as the dog **144** is driven inwardly toward the axis of rotation of the piston actuator housing **84**, the dog **144** will engage the pin **96***c* and thus halt the rotation of the piston actuator housing **84**. This operation positions a pair of undetonated piston actuators **110** under the piston impact surface **150**. When it is again desired to index the magnetic flux sensor **158**, the piston actuators **110** under the piston impact surface **150** would be detonated thus driving the piston ratchet arm **134** about its pivot shaft **126** with the piston ratchet **134** being moved to a position as indicated by the arrow in the FIGURE 5. The dog **144** will be driven away from its engagement with the pin **96***c* and the dog **142** will engage the pin **96***b* and thus again permit limited rotation of the piston actuator housing **84** so as to position a pair of undetonated piston actuators **110** under the piston impact surface **148**. After the piston actuators **110** under the piston impact surface **150** are detonated, the piston ratchet arm **134** assumes the position shown in the FIGURE 4 except that the dog **142** is now engaging the pin **96***b* rather than the pin **96***a*. In this manner, the piston actuators **110** can be successively fired or detonated until all actuators **110** have been discharged.

The FIGURES 6 and 7 illustrate the two positions of the ratchet **112** and consequently the two positions of the magnetic flux sensor **158**. Each time the piston ratchet arm **134** oscillates, the sensor ratchet arm **122** also pivots since both are secured by a common shaft **126** to the main structure **24** and are coupled through the pins **146** and **146'** to each other. As shown in the FIGURE 6, the stop **118** of the sensor ratchet arm **122** is shown engaging the hook **116** of the ratchet **112**. This is a stable position which retains the shaft **36** and the magnetic flux sensor **158** in one of its two positions. It will be recalled that the shaft **36** is biased counterclockwise, as viewed in the FIGURES 6 and 7 by the power spring **98**.

When the piston ratchet arm **134** is driven outwardly in the direction indicated by the arrow of the FIGURE 4, the sensor ratchet arm **122** of the FIGURE 6 is also pivoted outwardly about the shaft **126** causing the stop **118** to disengage the hook **116** of the ratchet **112**. This pivoting of the sensor ratchet arm **122** now positions the stop **120** in the path of the hook **116** so that the ratchet **112** is halted as shown in the FIGURE 7 when the hook **116** engages the stop **120**. Since the magnetic flux sensor **158** is coupled to the shaft **36**, the sensor **158** has been rotated approximately 180°. It will be recalled that the ratchet **112** is biased counterclockwise as viewed in the FIGURES 6 and 7 due to the power spring **98**, both of which are connected to the shaft **36**.

When it is again desired to rotate the magnetic flux sensor **158**, the piston actuators **110** under the piston impact surface **150** of the FIGURE 5 will be detonated so as to pivot both the piston ratchet arm **134** and the sensor ratchet arm **122** about the shaft **126** and cause the stop **120** to disengage the hook **116**. As the sensor ratchet arm **122** pivots outwardly in the direction of the arrow shown in the FIGURE 7, the stop **118** will be positioned in the path of the hook **116** so that engagement of the hook **116** and the stop **118** takes place. Again, the magnetic flux sensor **158** has been rotated 180° or back to its original position as determined by the position of the elements illustrated in the FIGURES 4 and 6. The ratchet spring **128**, best illustrated in the FIGURE 1, assists in maintaining the sensor ratchet arm **122** and the piston ratchet arm **134** in each of their positions as shown in the FIGURES 4 through 7.

The commutator brush support assembly **68** of the FIGURE 8 and the commutator **88** of the FIGURE 9 serve to supply firing current to the selected piston actuators **110**; to short out the non-selected piston actuators **110**; and, to provide a signal indicating whether the zero degree side or the 180° side of the piston actuator housing **84** is in firing position. The commutator brush support assembly **68** is maintained stationary with respect to the main structure **24** by being bolted thereto by the bolts **66** which extend from a plurality of ears **172**, **174** and **176** equally spaced about the periphery of the support assembly **68**. On the other hand, the commutator **88** rotates along with the piston actuator housing **84** since it is secured thereto so that the contacts, to be hereinafter identified, on the commutator brush support assembly **68** are in wiping engagement with the conductors printed upon the commutator **88**.

The firing contacts of the FIGURE 8 are identified as **178** and **180** which are oppositely disposed upon the support assembly **68** and joined by a printed conductor **182**. Although both the firing contacts **178** and **180** are electrically hot when detonation is desired, only one contact of the pair of contacts **178** and **180** will engage conductors coupled to the explosive charges or piston actuators **110**. It will be noted that the contacts **178** and **180** as well as the remaining contacts of the circuit are bifurcated so that a redundancy of contacts is provided so as to assure detonation of the piston actuators upon command. A zero degree position contact **184** is positioned upon the support assembly **68** and a 180° position contact **186** is disposed approximately 180° from the 0° position contact **184**. The function of the contacts **184** and **186** is to provide a signal indicating which pair of piston actuators **110** are in position for detonation. The ground contacts are indicated at **70** and **72** while the remaining contacts **188***a* through **188***j* serve as grounding contacts for grounding out the non-selected piston actuators **110**. When the selected piston actuators **110** are to be detonated, the conductors of the commutator **88** are so posi-

tioned so as to remove the selected piston actuators **110** from ground and position either the firing contacts **178** or **180** upon their leads so as to be detonated upon command.

The commutator **88** of the FIGURE 9 is made up of a circular insulator **190**, such as a phenolic resin, having a central aperture **192**. Deposited upon the insulator **190**, are a plurality of conductors of the deposited printed circuit type for performing the functions set forth as the commutator **88** rotates due to its connection to the piston actuator housing **84**. More specifically, a generally circular conductor **194** is deposited upon the insulator **190** and includes a plurality of short projections **196** which project into the insulator **190** and longer conductors **198** that extend into the central portion of the insulator **190** and form a ring **200** about the aperture **192**. Symmetrically disposed about the ring conductor **200** are a plurality of T shaped conductors **202***a* through **202***k* which are adapted to engage either one of the ground contacts **188***a* through **188***j* or the firing contacts **178** or **180** of the FIGURE 8. Two of the piston actuators **110** are shown symbolically within the aperture **192** of the FIGURE 9 and are connected between the ring conductor **200** at ground potential and one of the conductors **202***a* through **202***k*. The conductors **202***a* through **202***k* remain at ground potential unless their associated piston actuator **110** has been selected for detonation. In this event, the rotation of the commutator **88** will cause one of the conductors **202***a* through **202***k* to be removed from ground due to the positioning of the contacts **188***a* through **188***k* of the FIGURE 8 and the piston actuator **110** associated with the particular conductor **202***a* through **202***k* which has been selected for firing, will now be fired or detonated upon receipt of a signal to the apparatus.

The functioning of the commutator brush support assembly **68** of the FIGURE 8 and the commutator **88** of the FIGURE 9 is shown symbolically in the FIGURE 10. Since a redundancy is provided with the piston actuators **110**, a pair of piston actuators is shown in the FIGURE 10 wherein one conductor **216** of each of the actuators **110** is connected to the ground conductor **194**. The other conductor of each of the piston actuators **110** is indicated at **204** and is, when not in firing position, shorted to ground by one of the contacts **188***a* through **188***j*. In addition, a conductor **206** is coupled between a pair of contacts **184** and **186** and oscillates between the two contacts so as to indicate whether the piston actuator housing **84** is in the 0° firing position or the 180° firing position. Detonation or firing current is supplied on the contacts **178** or **180** and as shown in the FIGURE 10, the conductors **204** is always at ground potential unless the conductor **204** is that conductor associated with the selected piston actuators **110** to be detonated. In that event, the conductor **204** moves upwardly to engage one of the firing contacts **178** or **180**.

With reference to the FIGURE 11, the circuit provides a means whereby an indication may be derived as to whether the magnetic flux sensor **158** is in its first position which may be termed 0° or in its second position which is 180° removed from its first position. The position of the sensing switches **80** and **82** and the eccentrically mounted pin **74** of the shaft **36** which engages the arms **76** and **78** extending from the switches **80** and **82**, respectively, are partially visible in the FIGURE 2 immediately to the right of the commutator brush support assembly **68**. Again, with reference to the FIGURE 11, as the shaft **36** is indexed, the eccentrically mounted pin **74** will engage the extending arm **76** or **78** on one of the switches **80** or **82** and thus close a circuit to provide an indication of the position of the magnetic flux sensor **158**. In the illustration of the FIGURE 11, the pin **74** is shown engaging the switch arm **76** of the switch **80** and has closed its contacts so that it produces an indication on a pair of terminals **208** that the magnetic flux sensor **168** is in its first or 0° position. It will be readily understood that the use of the term first position and 0° is arbitrarily and is used only to provide an indication of the relative position of the magnetic flux sensor **158**. In the event that three or more positions of the magnetic flux sensor **158** are desired, the apparatus would be modified accordingly and would thus provide three or more indications of the relative position of the magnetic flux sensor **158**.

After another set of piston actuators **110** are detonated, the shaft **36** will rotate approximately 180° and cause the eccentrically mounted pin **74** to open the switch **80** contacts by disengaging the switch arm **76** and will now engage the switch arm **78** of the switch **82** and close the contacts associated with that switch. Accordingly, on a pair of terminals **210**, an indication may be derived as to the present position of the magnetic flux sensor **158**.

The FIGURE 12 illustrates the manner in which the piston actuator **110** engages one of the piston actuator surfaces **148** or **150** to step the device. Each piston actuator **110** includes an outer cylindrical casing **212**. Within the casing **212** is an explosive charge **218** which is detonated by a current supplied to a small heater or detonator by the conductors **204**, **216**, and a movable piston **214** shown in dotted outline. Upon detonation, the piston **214'** in solid outline, is driven outwardly to engage the piston impact surface **148** of the piston ratchet arm **134**, thus rocking the piston ratchet arm **134** and the sensor ratchet arm **122** about the pin **140**.

Operation

Although the operation of the apparatus has previously been set forth, it is believed appropriate to briefly review the indexing apparatus and its functioning as an entity.

Initially, the apparatus will be assembled as shown in the FIGURES 1 and 2. Although the invention has been set forth with reference to the manner of positioning a magnetic flux sensor **158**, it will be readily evident that the sensor can take many other and varied forms without departing from the spirit and essential characteristics of the invention. The magnetic flux sensor **158** may be encapsulated in a suitable resin, as found convenient. A sufficient amount of flexible electrical cable is threaded from the electrical connector **22**, about the cable conduit **34** and into the cable container **156** so as to permit a number of revolutions of the magnetic flux sensor **158** commensurate with the number of piston actuators or explosive charges **110** carried aboard the indexing device.

With the cover **166** removed, a piston actuator **110** is positioned in each of the apertures **108** of the piston actuator housing **84**. At the same time, the power spring **98** is placed under tension so as to bias the power spring housing **90** and the piston actuator housing **84** in one direction while biasing the main shaft **36**, the ratchet **112**, the cable container **156** and the magnetic flux sensor **158** in the opposite direction. Manipulation of the escapement movement will permit this operation.

With the electrical cables and conductors in place, a piston actuator **110** in each of the apertures **108**, and the power spring **98** under tension, the cover **166** is now placed over the indexing device and secured. The entire apparatus is now ready to perform its mission of measuring values of magnetic fields in outer space. More specifically, the non-magnetic, explosive actuated indexing device of the present invention will supply precision rotary motion on command for a system that requires only a limited number of operations and where electrical power is at a premium. The specific application of the indexing device of the present invention is to rotate a single magnetic flux sensor 180° each time calibration of the instrument is desired. Such reversal of the axis of the magnetic flux sensor **158** is the only way absolute values of magnetic fields can be obtained from certain types of magnetometers such as employed in the present invention.

When rotation of the magnetic flux sensor **158** is re-

quired, a signal will be transmitted to the apparatus which applies a short pulse of firing current to the contacts **178** and **180** and the conductor **182** therebetween (see FIGURE 8). The commutator **88**, best shown in the FIGURE 9, will be so positioned that the firing current on the aforementioned contacts will be applied to one of the conductors **202***a* through **202***k* that is associated with the pair of piston actuators **110** immediately below one of the piston impact surfaces **148** or **150**. For the purposes of explanation, we will assume that the piston **148** is resting against the periphery of the piston actuator housing **84** as shown in the FIGURE 4. Symbolically, the conductor **204** of the FIGURE 10 would be moved upwardly against the contact designated "Fire" which corresponds with the contacts **178** or **180**. As the piston actuators **110** immediately under the piston **148** of the piston ratchet arm **134** are detonated (see the FIGURE 12, also) the piston ratchet arm **134** of the FIGURE 4 would be pivoted in the direction of the arrow and since the piston ratchet arm **134** is coupled to the sensor ratchet arm **122** by the pins **146** and **146'** the sensor ratchet arm **122** would also be carried outwardly so as to disengage the hook **116** of the ratchet **112** from the stop **118** of the sensor ratchet arm **122**. Also, the dog **142** of the piston ratchet arm **134** would disengage the pin **96***a*.

At this instant, the apparatus very quickly assumes its next stable position which is, for the magnetic flux sensor **158**, a position approximately 180° removed from its immediate former position, and for the piston actuator housing **84**, a position so as to locate un-detonated piston actuators **110** under the piston impact surface **150** of the piston ratchet arm **134**.

The foregoing is accomplished and is succinctly set forth in the FIGURES 5 and 7. The dog **144** rocks inwardly so as to engage the pin **96***c* and thus halt the clockwise rotation of the piston actuator housing **84**. Undetonated piston actuators **110** are now positioned under the piston impact surface **150** for subsequent detonation when reorientation of the magnetic flux sensor **158** is desired. Also, the hook **116** of the ratchet **112** has rotated approximately 180° under the urging of the power spring **98** so that the hook **116** now engages the stop **120** of the sensor ratchet arm **122**. In the event that three or more stable positions of the sensing instrument are desired, it will be evident to those skilled in the art that the sensor ratchet arm **122** could be modified accordingly to provide three or more stops such as the stops **118** and **120**.

As the piston actuator housing **84** rotates, it carries along with it the commutator **88** so that one of the firing contacts **178** or **180** are now in engagement with one of the conductors **202***a* through **202***k* which are electrically connected to the next set of piston actuators **110** to be detonated. During the indexing of the commutator **88**, the wipers or contacts **188***a* through **188***j* cause all piston actuators **110** not selected for detonation to be placed at ground potential. In this manner, only the selected piston actuators **110** are detonated and positive action is thereby accomplished. Further, it will be noted that the piston actuators **110** are fired in groups of two so that a redundancy is present in the event one of the piston actuators **110** should fail to fire. That is to say, the device will be indexed if only one piston actuator **110** should detonate and the second piston actuator **110** is provided as a back-up feature since statistically, two piston actuators **110** would rarely fail to fire upon command.

Signals are now available from conductors coupled to the contact **184** or **186** indicating from which side of the piston actuator housing **84** the next detonation will take place. In addition, the position of the magnetic flux sensor **158** would be indicated on one of the pair of terminals **208** or **210** as shown in the FIGURE 11.

Thus, there has been described and illustrated a non-magnetic indexing device for measuring minute magnetic fields. The conventional manner for indexing a shaft coupled to a magnetic flux sensor is to employ a stepper motor or a solenoid actuated device. However, both of these methods, due to current flow, produce a magnetic field which cannot be tolerated since the magnitude of the generated magnetic fields may approach or exceed or interfere with the measurement of the unknown magnetic field. Accordingly, the primary advantage of the indexing device of the present invention is that it is completely non-magnetic but achieves its mission of determining absolute values of unknown magnetic fields such as those found around the earth and in distant space.

A particular novel feature of the present invention is the manner in which the explosive devices or piston actuators are incorporated to obtain repeated operations. Normally, such devices are only used for one-shot operations because, by their very nature, they can only be detonated once and cannot be retracted. However, the present invention has overcome these deficiencies and the present mechanism provides for the removal and replenishment of the explosive actuator for additional cycles of operation.

It will be evident to those skilled in the art that many modifications of the invention are evident. There are a number of different ways of obtaining the same mechanical output from the system of the present invention. For example, the dual ratchet arms can be replaced by a single ratchet arm and a gear train to couple the flux sensor and the piston actuator housing. In addition, a device incorporating a planetary gear system has also been successfully constructed and operated in accordance with the principles of the present invention.

Thus, the present invention may be embodied in other specific forms without departing from the spirit and the essential characteristics of the invention. The present embodiment is, therefore, to be considered in all respects as illustrative and the scope of the invention being indicated by the appended claims rather than the foregoing description, and all changes which come within the meaning and range of the equivalency of the claims are, therefore, intended to be embraced therein.

What is claimed is:

1. An indexing device comprising positionable means having at least a first stable position and a second stable position, a rotatable ratchet coupled to said positionable means and having an engaging surface, an arcuate ratchet arm having at least two mating surfaces for retaining said ratchet in a stable position by engaging said surface, and explosive means for actuating said ratchet arm to release said ratchet from a mating surface for subsequent engagement with another mating surface.

2. An indexing device comprising positionable means having at least a first stable position and a second stable position, a rotatable pawl coupled to said positionable means, a pivotable, arcuate ratchet arm having pawl engaging surfaces equal in number to the number of stable positions of said positionable means, and explosive means for pivoting said ratchet arm to release said pawl at a pawl engaging surface to thereafter re-engage said pawl at another pawl engaging surface.

3. An indexing device comprising positionable means having at least a first stable position and a second stable position, a rotatable pawl coupled to said positionable means, a first pivotable, ratchet arm having pawl engaging surfaces equal in number to the number of stable positions to said positionable means; a second pivotable ratchet arm coupled to said first ratchet arm, and explosive means for actuating said second ratchet arm to thereby pivot said first ratchet arm and release said pawl at a pawl engaging surface to thereafter re-engage said pawl at another pawl engaging surface.

4. The combination as defined in claim **3** including means for resiliently maintaining said first and second ratchet arms in a stable position after actuation by said explosive means.

5. An indexing device comprising positionable means having at least a first stable position and a second stable position, a rotatable pawl coupled to said positionable means, a first pivotable, arcuate ratchet arm having pawl engaging surfaces equal in number to the number of stable positions of said positionable means, a second pivotable, arcuate, ratchet arm coupled to said first ratchet arm, a circular housing means positioned within said second ratchet arm, and explosive means positioned within said housing means for causing expanding gases to actuate said second ratchet arm to thereby pivot said first ratchet arm and release said pawl at a pawl engaging surface to thereafter re-engage said pawl at another pawl engaging surface.

6. The combination as defined in claim 5 including means for detonating said explosive means.

7. The combination as defined in claim 5 wherein said housing means includes a plurality of peripheral apertures for receiving a plurality of explosive charges.

8. The combination as defined in claim 7 including means for detonating selected explosive charges and means to index said housing means and thereby expose undetonated charges to said second ratchet means.

9. The combination as defined in claim 7 including means for urging said positionable means in one direction to its stable positions and for urging said housing means bearing explosive charges in the opposite direction.

10. The combination as defined in claim 9 wherein said means is a power spring having one end coupled for urging said positionable means and its other end for urging said housing means.

11. The combination as defined in claim 9 including means on said second ratchet and cooperating with said housing means for defining a plurality of indexable positions of said housing means, each indexable position corresponding to the position of an unused explosive charge.

12. Apparatus for positioning a sensing device alternately from a first position to a second position approximately 180° removed from the first position comprising a shaft for mounting said device, a ratchet secured to said shaft, a first ratchet arm for engaging said ratchet to thereby halt said device in its first and second positions, a housing loosely mounted about said shaft and bearing a plurality of equally spaced peripheral apertures, an explosive charge positioned in each of said apertures, a second ratchet arm coupled to said first arm and having a pair of inner surfaces displaced approximately 180° from each other for receiving the force exerted upon detonation of one of said explosive charges, means for biasing said housing in one direction and said shaft in the opposite direction, and means on said second ratchet arm and cooperating with means on said housing for indexing said housing so as to present an un-detonated charge under said inner surfaces of said second ratchet arm.

13. The combination as defined in claim 12 wherein said means for biasing is a coil spring and further includes a spring housing coupled to and enclosing an end of said spring, said spring housing being secured to said housing loosely mounted about said shaft.

14. The combination as defined in claim 12 wherein said ratchets pivot and oscillate between a first position wherein one of said inner surfaces is next to an explosive charge and said other inner surface is removed from a charge and a second position wherein the position of said inner surfaces are reversed.

15. The combination as defined in claim 14 wherein the charge in said housing nearest one of said inner surfaces is designated the next charge to be detonated and including means for detonating said charge upon command so as to advance said sensing device in its next position.

16. The combination as defined in claim 14 including means for inhibiting the accidental firing of all charges except the selected charge.

17. The combination as defined in claim 14 wherein said means is a commutator brush assembly cooperating with electrical conductors coupled to said charges.

18. The combination as defined in claim 12 including a second group of equally spaced apertures in said housing, said apertures arranged in pairs and housing a redundant explosive charge.

19. The combination as defined in claim 12 including means for detecting whether the sensing device is in its first position or its second position.

20. The combination as defined in claim 19 wherein said means includes an arm for engaging a first switch to indicate the first position and a second switch for indicating the second position.

21. Apparatus for positioning a magnetic flux sensor alternately from a first position to a second position approximately 180° removed from the first position comprising generally arcuate supporting means, a shaft projecting into said supporting means and coupled to said flux sensor, a pawl secured to said shaft, a first ratchet arm pivoted from said supporting means for engaging said pawl to thereby halt said sensor in its first and second positions, a rotatable housing loosely mounted about said shaft and within said supporting means, a plurality of equally spaced peripheral apertures formed in said housing and directed toward said shaft, an explosive charge positioned in each of said apertures, a second ratchet arm coupled to said first arm and pivoted from said supporting means adjacent said charge supporting housing, a pair of piston surfaces formed on the inner surfaces of said second arm approximately 180° removed from each other and adapted to be actuated by the detonation of an explosive charge positioned thereunder, a commutator carried by said housing and bearing electrical conductors for coupling to said explosive charges, means on said second arm and said housing for indexing said housing after each detonation to thereby expose an undetonated charge to one of said piston surfaces, a coil spring for biasing said housing in one direction and said shaft and sensor in the opposite direction, and means for detonating the explosive charge under a piston surface to thereby pivot said second arm and index said housing to expose undetonated charges to a piston surface, and pivot said first arm to thereby momentarily release said panel and permit said sensor to advance to its other position.

22. The combination as defined in claim 21 including means for indicating which position of the first and second positions that said sensor is residing.

23. The combination as defined in claim 21 including means on said commutator for preventing the accidental detonation of unselected charges.

24. Shaft indexing apparatus comprising a pawl coupled to said shaft, a ratchet arm for engaging said pawl and having one or more pawl arresting positions, means for biasing said shaft toward a direction of rotation, a rotatable housing loosely mounted upon said shaft and bearing a plurality of shaft oriented, peripheral apertures, an explosive charge positioned in each aperture, and means for detonating said explosive charge to thereby rock said arm to release said pawl to index said shaft to a new position.

25. Shaft indexing apparatus comprising a pawl coupled to said shaft, a ratchet arm for engaging said pawl and having one or more pawl arresting positions, means for biasing said shaft toward a direction of rotation, a rotatable housing loosely mounted upon said shaft and bearing a plurality of shaft oriented, peripheral apertures, an explosive charge positioned in each aperture, a piston actuator arm connected to said ratchet arm and having piston surfaces positioned over selected ones of said ex-

plosive charges, means to detonate a selected charge, and means to index said housing to thereby expose undetonated charges to a piston surface.

26. The combination as defined in claim 25 wherein said means to index includes a pair of projections extending from said actuator arm which engages pins extending from said housing and a spring coupled to said housing.

27. The combination as defined in claim 25 including

means for preventing the accidental detonation of unselected charges.

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