CONVENTION APPLICATION BY A COMPANY

FORM 8 – REGULATION 12 (2)

AUSTRALIA
PATENTS ACT 1952

DECLARATION IN SUPPORT OF A CONVENTION APPLICATION FOR A PATENT

(a) Here insert (in full) Name of Company.

In support of the Convention Application made by (a) FAILURE ANALYSIS ASSOCIATES, Inc., 149 Commonwealth Drive, Menlo Park, California 94025, United States of America.
(hereinafter referred to as "Applicant") for a patent for an invention entitled:

(b) Here insert Title of Invention.

(b) SURFACE SAMPLING DEVICE

(c) and (d) Here insert Full Name and Address of Company Official authorised to make declaration.

I, (c) David W. Mercaldi
of (d) 383 Lowell Road, Concord, MA 01742, United States of America.

do solemnly and sincerely declare as follows:

1. I am authorised by Applicant to make this declaration on its behalf.

(e) Here insert Basic Country followed by date of Basic Application.

(f) Here insert Full Name(s) of Applicant(s) in Basic Country.

2. The basic Application(s) as defined by section 141 of the Act was / were made
in (e) U.S.A. on the 24th day of February 1987
by (f) David W. Mercaldi
in ..... on the ..... day of 19
by .....
in ..... on the ..... day of 19
by .....
in ..... on the ..... day of 19
by David W. Mercaldi

(g) Here insert (in full) Name and Address of actual Inventor or Inventors.

3. (g) David W. Mercaldi, 383 Lowell Road, Concord, MA 01742, United States of America.
..... is/are
the actual Inventor(s) of the invention and the facts upon which Applicant is entitled to make the Application are as follows:

See reverse side of this form for guidance in completing this part.

Applicant is the assignee of the said inventor

4. The basic Application(s) referred to in paragraph 2 of this Declaration was/were the first Application(s) made in a Convention country in respect of the invention, the subject of the Application.

DECLARED at WESTBOROUGH, MASSACHUSETTS, USA
this 14th day of SEPTEMBER 1990

(h) Personal Signature of Declarant (c) (no seal, witness or legalisation).

(h) David W Mercaldi
(Signature of Declarant)

To THE COMMISSIONER OF PATENTS

(12) PATENT ABRIDGMENT (11) Document No. AU-B-14232/88
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 609114

(54) Title
SURFACE SAMPLING DEVICE

International Patent Classification(s)
(51)[4] G01N 001/04 B23D 019/08 B24B 019/00 B26D 001/44

(21) Application No. : 14232/88 (22) Application Date : 16.02.88

(87) WIPO Number : WO88/06722

(30) Priority Data

(31) Number (32) Date (33) Country
017632 24.02.87 US UNITED STATES OF AMERICA

(43) Publication Date : 26.09.88

(44) Publication Date of Accepted Application : 26.04.91

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(56) Prior Art Documents
US 4220201
US 4106561
US 3159952

(57) Claim

1. A device for obtaining a sample of a substrate and surface from a workpiece comprising:

means for positioning the device relative to the workpiece;

cutting means for separating said sample from said substrate, said cutting means including a blade of generally semi-spherical shape, having an axis of rotation generally concentric with the center of said blade,

first drive means connected to said blade for rotating said cutter about said axis

second drive means connected to said blade for articulating said cutting means whereby said blade can separate said sample from said substrate by following an arcuate path, and

means for retrieving said sample when separated from said substrate.

.../2

42. A method of cutting from a workpiece to be sampled a relatively small, preselected portion of the surface or surface and substrate of said workpiece and for retrieving said preselected portion for analysis apart from said workpiece without creating any substantial increase in stress in said workpiece whereby insufficient damage is caused to said workpiece to be detrimental to its continued use, the steps comprising:

locating a cutting means adjacent said preselected portion of the surface or surface and substrate of said workpiece to be sampled,

driving said cutting means so as to enable it to cut said workpiece when brought into contact therewith,

articulating said cutting means into contact with said workpiece,

cutting said relatively small, preselected portion of the surface or surface and substrate from said workpiece by driving said cutting means while articulating said cutting means through a single arcuate path, thereby creating a relatively shallow, smooth depression in said workpiece, and

retrieving said preselected portion for analysis after said cutting means separates said preselected portion from said workpiece.

AU-AI-14232/88

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

609114

(51) International Patent Classification 4 : G01N 1/04, B26D 1/44, B23D 19/08, B24B 19/00

A1

(11) International Publication Number: WO 88/ 06722

(43) International Publication Date: 7 September 1988 (07.09.88)

(21) International Application Number: PCT/US88/00472

(22) International Filing Date: 16 February 1988 (16.02.88)

(31) Priority Application Number: 017,632

(32) Priority Date: 24 February 1987 (24.02.87)

(33) Priority Country: US

(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK, FI, FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), NO, SE (European patent).

Published
With international search report.

AUSTRALIAN Sec 34(4) PATENT OFFICE

(71) SECTION 34(4)(a) DIRECTION SEE FOLIO 7
NAME DIRECTED The Failure Group, Inc.
2225 Bayshore Road, P.O. Box 51470 Palo Alto California United States of America

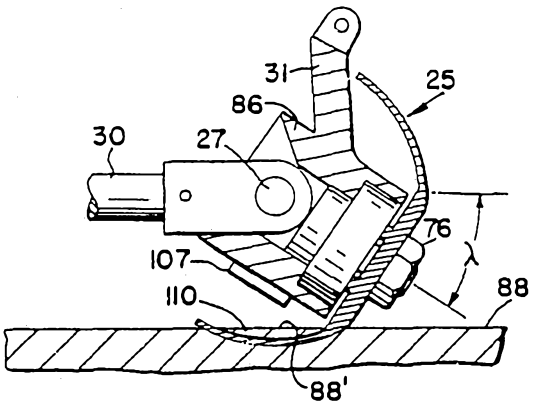
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AUSTRALIAN
26 SEP 1988
PATENT OFFICE

This document contains the amendments made under Section 49 and is correct for printing.

(54) Title: SURFACE SAMPLING DEVICE



(57) Abstract

A device, utilizing a unique hemispherical cutter (25) to remove a sample of material and to retain the sample of material for retrieval. The cutter (25) is mounted on a chassis which can travel along the interior or exterior of the device to be sampled. The carriage can be maintained in a fixed position relative to the structure being sampled. After positioning of the cutter carrying carriage the cutter blade (25) is pivoted to engagement with the surface (88). The blade penetrates the surface and removes a sample (110) in a single continuous cut, leaving a shallow dimple. The sample is then retrieved through the return of the cutter (25) and carriage from the device being sampled.

SURFACE SAMPLING DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to devices for obtaining and retrieving a sample of material for analysis. More particularly, the present invention relates to sampling devices which detach and retrieve a portion of the surface of a material for analysis of surface features and of the underlying material, such as, for example, of the inner portions of pipes found in electric generating "power" plants.

It is often necessary to test or examine material which has been subjected to a somewhat hostile operating environment. In order to accurately, quantitatively, determine the properties of a material, a sample must be obtained from the material for testing. Further, any detailed metallurgical examination requires a sample of material for laboratory analysis. The need for testing or examination of structural materials in remote locations can arise in a number of situations, including the interior of a pipe or conduit which transports material at temperatures and pressures which can cause changes in the mechanical properties of the material composing the pipe over its service life. Also, other equipment which is subjected to stress, and thermal, radiation, chemical, or other environmental conditions may need to be sampled and tested to determine the damaging effects caused by such conditions.

The effects of exposure to hostile environments, and mechanical and thermal stress can produce severe problems in many situations and with many types of equipment. Notably, an acute problem has developed in aging power plants which have been in service for long periods of time. The turbines which are utilized to

generate power from steam are subjected to thermal, mechanical and corrosive stresses. These stresses can cause failure of all or part of a turbine. If no data is available as to the condition of the materials which compose the components of the turbine then an uninformed decision has to be made as to whether to continue to run the turbines without knowing their true condition; thus presenting the undesirable dilemma of either incurring a significant risk of failure or replacing, prematurely, the turbines prior to the expiration of their useful life. Continuing to run a turbine which has unknowingly become unreliable can, of course, result in catastrophic failure. In addition to the potential tragedy of human injury, there is the enormous expense, in such a situation of having to replace the entire turbine, simply because one component failed.

For the above reasons, at least, there is a great need for a means for determining the condition of the material components of turbines and similar mechanical structures which undergo stress over a prolonged period of time. There is in this respect, a great need to be able to predict the remaining useful life of these machines and their material components. Unfortunately, prior to the advent of the present invention, it was often not possible to accurately measure the present condition of materials subjected to long term stress without destroying or significantly deforming the material components of the mechanism to be tested or completely dissembling the mechanism to be inspected. Under certain prior art sampling techniques, for example, great expense and time was necessary to repair the damage done through the sampling process.

Many techniques have been developed in the prior art for obtaining a sample for analysis, in an attempt to

mitigate the above problems. None has been truly successful in permitting sample removal from remote locations with minimal structural consequences. One technique, for example, makes two cuts into a surface to form a V-shaped groove in the piece of material to be tested. The cuts are made along the entire length of the material in order for the triangular shaped section of material to be removed from the main portion of the material. If the cuts are not along the entire length, two further cuts are needed at either end in order to release the triangular sample, or, the two cuts may be made by a slightly cupped grinding wheel, yielding a sample shape which is typically described as a "boat sample". These processes require a large sample to be taken from the underlying material, and each leaves a sharp hole which needs later repair. This repair of the underlying material is often time consuming and expensive and will generally result in a weakened structure. Further, performing such an operation remotely is not practical.

Another prior art technique which permits obtaining some information about the material while causing little or no damage to the component is referred to as "replication". In this technique, the surface of the material is replicated by application of a coating, generally after some mechanical polishing and chemical etching of the surface has been performed. The coating is applied in liquid form and allowed to harden and is then peeled off to reveal a mirror image of the surface features of the underlying material. This technique only allows for examination of surface features and does not allow for analysis of the underlying material. Also, it is typically not possible to perform this technique in remote locations. The lack of an actual, physical sample

of the underlying material is obviously a significant drawback when attempting to evaluate the condition of certain power plant/turbine components.

As alluded to above, it is also possible to analyze underlying material structures by partial or complete dismantling of the mechanism involved. It may then be possible to examine or sample material components of the mechanism by conventional techniques, followed by replacement of the worn out or damaged parts and reassembly. This often necessitates lengthy shut down periods and requires a large amount of time and expense in the disassembly and reassembly of complicated machinery.

In view of the above, it is apparent that there exists a need in the art for a sampling device which at least overcomes the above-described problems.

SUMMARY OF THE INVENTION

It is an object of the present invention to substantially ameliorate at least some of the disadvantages of the prior art.

Broadly, the present invention is comprised of a device and method for obtaining a sample of a substrate and surface comprising cutting means for separating said sample from said substrate, said cutting means including a generally hemispherically-shaped blade having an axis of rotation generally concentric with the center of said blade, first drive means connected to said blade for rotating said cutter about said axis, second drive means connected to said blade for articulating said cutting means whereby said blade is capable of separating said sample from said substrate by following an arcuate path, and means for retrieving said sample when separated from said substrate.

The present invention creates minimal disruption of the structure from which the sample is taken. A small semi-spherical depression is left in the underlying

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material in the location from which the sample was removed. The cutter of the present invention allows for a single pass in order to separate the sample from the remainder of the material. The single cut, made from one direction is smooth and continuous and therefore leaves no sharp edges.

The teachings of the present invention illustrate that sharp edge or discontinuities need to be ---------

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avoided to minimize stress concentration around the sample taken. The depression formed in the underlying material is spherical and shallow thereby presenting the minimal distortion profile attainable.

In certain preferred embodiments, the depth of the cut can be controlled by the relative positioning of the carrier and the structure from which the sample is taken. A very accurate sample can therefore be obtained which maintains the sample surface intact for analysis. The blade in such an embodiment may be designed for minimum abrasive grinding by generation of a thin kerf for passage of the hemispherical blade.

The hemispherical cutter contemplated in certain further embodiments of the present invention may be of a mechanical cutting type, electrical discharge machining type or any other type cutter which can be configured to form a hemispherical cut line creating a minimal thickness kerf for travel of the blade.

A further advantage of the single pass cut of the present invention is that samples can be taken near junctures of differing planes within the mechanism. A cut near such a corner can be made because all drive and support means can be located on one side of the cutter, permitting placement of the cutter itself deep into the corner from one side as opposed to some previously described sampling methods requiring two cuts from opposing directions.

This invention will now be described with respect to certain embodiments as illustrated in the following drawings:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a side view of a preferred

embodiment of the present invention.

Figure 2 is a top view of a preferred embodiment of the present invention.

Figure 3 is a cross-sectional side view of the hemispherical blade of a preferred embodiment of the present invention.

Figure 4 is a perspective view of a preferred embodiment of the hemispherical cutting blade of the present invention.

Figure 5 is an assembly view of the rotational-to-linear motion translation assembly.

Figure 6 is a back end view of a preferred embodiment of the present invention.

Figure 7 is a front end view of a preferred embodiment of the present invention.

Figure 8 is a cross sectional view taken along line 8-8 of Figures 1 and 2.

Figure 9 is a cross sectional view taken along line 9-9 of Figures 1 and 2.

Figure 10 is a cross sectional view taken along line 10-10 of Figures 1 and 2.

Figure 11 is a cross sectional view taken along line 11-11 of Figures 1 and 2.

Figure 12 is a cross sectional view taken along line 12-12 of Figures 1 and 2 of the present invention.

Figures 13A-E are simplified, partially schematized, views illustrating the present invention in use taking a sample from a surface.

Figure 14 is a top view of a horizontal cross-section of the cutting head taken at the cutter centerline.

DETAILED DESCRIPTION OF A PREFERRED EXEMPLARY EMBODIMENT

Figures 1 and 2 illustrate an embodiment of the present invention, wherein a wheeled carriage is utilized to transport the cutting blade and its associated drive mechanisms to the desired sampling site. As illustrated hemispherical cutter 25 is located towards the forward end of the carriage. The opposite end of the carriage is defined by backend bulkhead 22, upon which is mounted bracket 67 for attachment of positioning handle 98 which is utilized to position the carriage by rolling on wheels 35 and 36. The front end of the carriage is supported by spring-biased front skid 75 (illustrated more completely in Figure 11) which is biased by spring 78 to extend beyond the cutter 25 to protect the blade 48 from contacting the surface when the carriage is not secured in position. Front skid 75 is protected against over-extension by spring retainer 77, mounted to backplate 79.

The backend bulkhead 22, as illustrated in Figure 6, is bolted to the stepper motor housing 86 by bolts 65 which thread into holes 65' (as better illustrated in Figure 8). Backend bulkhead 22 also has electrical connector 60 mounted thereon for receiving the electrical connector which carries the appropriate control signals for stepper motor 24 and drive motor 26. Bulkhead 22 has further openings for provision of coolant and vacuum lines 63 and 64 which extend the length of the carriage to provide coolant to the cutter 25 and the sampling area, and remove spent coolant from the region. Coolant access paths 63 and 64 extend throughout the length of the carriage, as can be seen in Figures 2 and 8-12.

Stepper motor housing 87 is in turn bolted to

the two drive motor housing members 70 and 71, illustrated in Figure 10. Bolts 20 are utilized to secure the stepper motor housing 87 to the threaded holes 20' of the drive motor housing halves 70 and 71. As further illustrated in Figure 8, stepper motor 24 is associated with toothed gear 83 and drive screw support bearing housing 23 is associated with drive screw toothed gear 82. Stepper belt 81 is utilized to link gears 82 and 83. The drive screw 32 is directly coupled to gear 82. As can be seen, Gear 83 is turned in controlled steps by controlled activitation of stepper motor 24. Drive screw 32 is therefore rotated in precise discrete amounts through controlled actuation of stepper motor 24.

Rotation of drive screw 32 is utilized to pivot cutter 25 into and out of engagement with the surface to be sampled. Drive screw 32 extends from gear 82 and into drive member 50. Figure 5 illustrates the mechanism within drive member 50 for translation of the rotation of drive screw 32 into horizontal motion on push rod 34 to actuate the tilting of cutter 25 by pushing and pulling of arm 31 of the cutter trunnion 86 at pivot point 33. Push rod 34 will flex to accommodate the vertical motion of pivot point 33 that occurs due to its path of rotation. Trunnion 86 exerts force on the cutter shaft 45 through ring bearing 99 disposed between trunnion 86 and the cutter side of universal joint 27, in which shaft 45 is inserted and retained by set screw 100 (Figure 14). The force of trunnion 86 therefore acts to tilt cutter 25 about the axis of trunnion bearings 105 and 106, which axis also passes through the center of action of universal joint 27, and the center of curvature of cutter 25.

The threaded end of drive screw 32 (illustrated in Figure 1), is mated into the threaded hole 97 in one

end of drive member 50. As drive screw 32 is rotated, drive member 50 will travel linearly along the longitudinal axis of drive screw 32. Drive member 50 is prevented from rotation by the engagement of wings 58 and 59 into the slots created between block 51 and drive motor housing member 70 and the block 52 and drive motor housing member 71 illustrated in Figure 10. The wings 58 and 59 of drive member 50 slide along these slots to allow linear motion of drive member 50 while preventing its rotation.

Plunger 95 is threaded securely to the end of push rod 34, which extends through end cap 96. Plunger 95 is then inserted against biasing spring 94 inside the hollow portion of drive member 50. End cap 96 is then secured to the open end of drive member 50. This arrangement allows for compliance in the transmission of force from block 50 to push rod 34, to assure smooth advance of cutter 25 despite the incremental motion of block 50, as driven by stepper motor 24. Spring 94 allows some relative movement of plunger 95 within block 50. This compliance also acts to limit the force applied to pivot cutter 25. Blocks 51 and 52 are held in position by bolts 72.

Wheels 35 and 36 as illustrated in Figure 9, are mounted to an axle attached to spring plate 85. Plate 85 is attached at its opposite end to the stepper motor housing 86, thereby allowing the end to which the wheels 35 and 36 are attached to move upwardly and downwardly freely. Spring member 85 is biased so that wheels 35 and 36 will normally extend downwardly to extend beyond the outer circumference of the carriage, thereby contacting the surface upon which the carriage is riding.

Figure 11 illustrates the drive motor mounting bulkhead 55 to which the drive motor 26 is secured.

Motor mount bulkhead 55 has an elongated slot through which pushrod 34 extends. Pushrod 34 then attaches to arm 31 at pivot 33, as illustrated in Figure 12. Also in Figure 12 the cutter 25 is shown secured to shaft 45 by nut 76. The cutter shaft 45 is linked to the drive motor shaft 30 through universal joint 27, thus allowing free pivoting of the cutter. Cutter support members 68 and 69 are bolted to the motor mount bulkhead 55 by bolts 29 illustrated in Figure 12, which extend through holes 29' illustrated in Figure 11, and are secured into threaded holes in the motor mount bulkhead 55. Similarly the front end bulkhead 21 is secured to the blade support members 68 and 69 by bolts 74, engaged in threaded holes 74'.

Figure 14 illustrates that trunnion bearings 105 and 106 are housed by trunnion support members 56 and 57. Members 56 and 57 are attached to cutter support members 68 and 69 by capscrews 101 through 104.

The air cylinder 94 and pressure foot 92, utilized to lock the carriage in position for sampling, are illustrated in Figure 9. Through proper control of air supply and return lines 61 and 62, air cylinder 94 is actuated to extend pressure foot 92 to engage the interior surface of a tube such as 80. Pressure foot 92 is slotted to permit passage of drive shaft 32.

The entire carriage is first positioned along the length of the tube by use of a rod 98 to push or pull the carriage in the directions indicated by arrow A (Figures 1, 2 and 13A) to the desired location. The carriage rolls along wheels 35 and 36, and slides along front skid 75, which prevents contact of the cutter 25 with the interior surface of the pipe 80. Once the carriage has been located in the desired position, pressure foot 92 is extended through actuation of air

cylinder 94 and is forced into engagement with the upper interior surface of pipe 80. As pressure foot 92 continues to exert force, both front skid 75 and wheels 35 and 36 are forced to retract against their spring-biased mechanisms. The entire carriage will approach surface 88 until support pads 28, 83 and 84 contact the lower surface 88 of the interior of pipe 80. Support pads 28, 83 and 84 are adjusted prior to positioning of the mechanism, so that when the carriage is forced down against the pads, the carriage will rest a predetermined, desired distance off of the surface 88 to be sampled, which will determine the thickness of the sample to be removed.

Once the carriage has been locked in position through force exerted by pressure foot 92 to cause the carriage to rest firmly on support pads 28, 83 and 84, the cutting process illustrated in Figures 13A-D may commence. Arrow A, (Figure 13A) illustrates the horizontal positioning of cutter 25. Prior to being locked in position as described above, cutter 25 was retracted as illustrated in Figure 13B in the direction of Arrow B. The entire carriage carrying cutter 25 is then forced in the direction of Arrow C against support pads 28, 83 and 84 by the clamping mechanism described above. After the positioning and clamping of the assembly, cutter 25 is then rotated in a direction opposite that of Arrow B from its retracted position. This is illustrated in Figure 13C, i.e. a partial cut, and then sequentially in Figure 13D, which is the final cut and separation of the sample to be collected and analyzed. This is accomplished, as aforesaid, through actuation of stepper motor 24 which rotates drive screw 32 to push pushrod 34, thereby tilting trunnion 86 through arm 31. Once the cut is complete, spinning of

the cutter 25 is ceased by deactuation of drive motor 26. Cutter 25 remains in its fully-extended position, (Figure 13D), in order to retain the extracted sample 110. For certain materials, a magnet 107 attached to the underside of trunnion 86 may be used to capture the sample, as indicated by position '110' in Figure 13E. The pressure on pad 92 is relieved by deactuation of air cylinder 94. The carriage then raises up in the direction of Arrow D, (Figure 13E), to ride once again on wheels 35 and 36 and front slide member 75. Cutter 25 is now clear of the interior surface of tube 80 and the carriage may be retrieved in the direction of Arrow E, while cutter 25 is in its fully-extended position (Figure 13E). Sample 110 is supported within the bowl of cutter 25 for retrieval (as illustrated in Figure 13E).

Once extracted, the surface 88' of sample 110 can be analyzed. Also the sample 110 can be analyzed or tested for characteristics of the substrate material, thusly providing a means for analyzing both surface and material characteristics while leaving a minimally-disruptive dimple 109 in the original surface 88.

Blade 25 (as illustrated in Figure 13B) is retractable through angle α wherein the axis of rotation of the blade is preferably about 30 to 32 degrees above horizontal. Similarly, as illustrated in Figures 13D and 13E, blade 25 is preferably designed to travel through angle λ below horizontal to complete the cut which severs sample 110. Angle λ is preferably about 30 to 32 degrees.

A particularly preferred embodiment of cutter 25 is illustrated in Figures 3 and 4 and is of a hemispherical shape, with a central, threaded hole to accommodate cutter shaft 45. Cutter shaft 45 has a notched end 46 for engagement by set screw 100 within

universal joint 27. The cutter has a thick body portion 47 and a thin curved blade portion 48, which combine to form an essentially bowl-like structure. A thin coating of abrasive grit, which enables the blade to cut, is applied at the outer tip of the blade periphery, along the exterior surface at 42, along the interior at 43 and along the leading edge 49 of the blade. The entire length of the blade 48 is not provided with grit for cutting, so as to provide clearance for the noncutting portion of the blade and to minimize the opportunity for extraneous scratching of the surface of the sample or substrate. The very interior corner where the blade 48 meets the body 47 also contains a thin ring of cutting grit 44. This ring of grit 44 is provided to enable the first edge of a larger sample to be worn away, if necessary, thereby enabling the blade to obtain a deeper sample without jamming of the initial sample edge against the body 47 of the cutter 25.

Cutter 25 need not be precisely hemispherical, but can be comprised of a spherical section larger or smaller than a semi-(half) sphere. The cutter can be comprised of a spherical section greater than a hemisphere if a deeper, larger sample is desired. The cutter can also be comprised of a spherical section of less than hemispherical dimensions if a smaller, shallower sample is desired.

One significant beneficial result of the subject invention is the nature of the sample obtained for analysis. As can be seen in Figures 13C-E, once sample 110 has been cut and retrieved, it can be accurately analyzed, because the original surface 88' of the sample remains undisturbed on the sample's upper surface. Another beneficial result of the subject invention is the nature of the remaining substrate after the sample is cut

from it. As can be seen, the removal of sample 110 leaves a rather small dimple 109 with a fine surface finish in the surface of the sampled substrate which causes minimal disruption and structural weakening of it. By minimizing the kerf left by the blade portion 48 of cutter 25, through utilization of a thin blade, the disruption of material 80 is further minimized. Because cutter 25 is hemispherical in design blade portion 48 can be constructed extremely thin while still providing a very rigid blade. In many embodiments, a kerf of between .020" and .025" may be achieved by using a blade of .010" thickness and fine layer of grit of about .005" in thickness on each side while the structural rigidity necessary to maintain an accurate sampling of steel is still maintained.

Once given the above disclosure many other features, modifications and improvements will become apparent to the skilled artisan. Such features, modifications and improvements are thus to be considered a part of this invention, the scope of which is to be determined by the following claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A device for obtaining a sample of a substrate and surface from a workpiece comprising:

means for positioning the device relative to the workpiece;

cutting means for separating said sample from said substrate, said cutting means including a blade of generally semi-spherical shape, having an axis of rotation generally concentric with the center of said blade,

first drive means connected to said blade for rotating said cutter about said axis

second drive means connected to said blade for articulating said cutting means whereby said blade can separate said sample from said substrate by following an arcuate path, and

means for retrieving said sample when separated from said substrate.

2. The device of claim 1, wherein:

said semi-spherical blade is comprised of a thin, essentially hollow shell having an exposed circular edge.

3. The device of claim 2, further comprising:

a first ring of cutting grit disposed on said circular edge, and extending onto the exterior surface of said shell immediately adjacent to said edge.

4. The device of claim 2 or claim 3, further comprising:

A second ring of cutting grit disposed on the interior surface of said shell, adjacent said circular edge.

5. The device of claim 2 or claim 3, further comprising:

a third ring of cutting grit disposed on the interior surface of said shell, a constant distance from said circular edge, and extending inwardly from said shell.

6. the device of claim 5, wherein:

said third ring of cutting grit is provided to remove a portion of said sample at a sufficient distance from said circular edge to enable said cutter to travel a greater depth into said substrate.

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7. A method for obtaining a sample of a substrate and surface, comprising the steps of:

providing a cutter with a semi-spherical blade,

positioning said cutter adjacent the area of said surface from which said sample is to be taken,

rotating said cutter about a generally central axis,

moving said cutter into engagement with a first portion of said surface,

forming a single continuous cut in said substrate for separating said sample from said substrate by moving said cutter in an arcuate path through said substrate until said cutter emerges from a second portion of said surface,

retaining said sample within said cutter, and retrieving said sample.

8. The method of claim 7, wherein:

said blade is comprised of a thin, essentially hollow spherical section shell having an exposed circular edge.

9. The method of claim 7, wherein:

said semi-spherical cutters further provided with a first ring of cutting grit disposed on said circular edge, and extending onto the exterior surface of said shell immediately adjacent to said edge.

10. The method of claim 7 or claim 8, wherein:

said semi-spherical cutter is further provided with a second ring of cutting grit disposed on the interior surface of said shell adjacent said circular edge.

11. The method of claim 7 or claim 8, wherein:

said semi-spherical cutter is further provided with a third ring of cutting grit disposed on the interior surface of said shell, a constant distance from said circular edge, and extending inwardly from said shell.

12. A sampling device for cutting from a workpiece to be sampled a relatively small, preselected portion of the surface or surface and substrate of said workpiece and for retrieving said preselected portion for analysis apart from said workpiece without creating any substantial increase in stress in said workpiece whereby insufficient

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damage is caused to said workpiece to be detrimental to its continued use comprising:

means for cutting and separating said preselected portion for analysis from said workpiece, said cutting means including a blade means of generally semi-spherical shape having an axis of rotation generally concentric with the center of said blade means,

first drive means connected to said blade means for rotating said blade means about said axis,

second drive means connected to said blade means for articulating said cutting means whereby said blade means is capable of cutting and separating said preselected portion for analysis from said workpiece by following a single arcuate path to create a relatively shallow, smooth depression in said workpiece, and

means for retrieving said preselected portion for analysis when separated from said workpiece.

13. The device of claim 12 wherein:

said semi-spherical blade is comprised of a thin, essentially hollow shell having an exposed circular edge.

14. The device of claim 13, further comprising:

a fist ring of cutting grit disposed on said circular edge, and extending onto the exterior surface of said shell immediately adjacent to said edge.

15. The device of claim 13 or claim 14, further comprising:

a second ring of cutting grit disposed on the interior surface of said shell, adjacent said circular edge.

16. The device of claim 13 or claim 14, further comprising:

a third ring of cutting grit disposed on the interior surface of said shell, a constant distance from said circular edge, and extending inwardly from said shell.

17. The device of claim 16, wherein:

said third ring of cutting grit is provided to remove a portion of said sample at a sufficient distance from

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said circular edge to enable said cutter to travel a greater depth into said substrate.

18. The sampling device of claim 12 wherein said sampling device is capable of cutting and retrieving said preselected portion for analysis without any substantial alteration of said preselected portion.

19. The sampling device of claim 12 which further includes means for positioning said device at a selected position on the surface of said device from which said preselected portion is to be cut and for positioning said cutting means such that when said blade makes its cut by following the aforesaid arcuate path it initiates the cut by entering into the said surface at a first location thereof and finishes the cut by emerging from the same said surface but at a second location thereof.

20. The sampling device of claim 19 which further includes means for securing said cutting means at said selected position.

21. The sampling device of claim 20 wherein said securing means includes a suspension means for carrying and positioning said device, said suspension means normally biasing said device away from said surface and raising said cutting means out of engagement with said surface a sufficient distance to allow retrieval of said device after said cutting and separation of said portion from said surface, and further including means for overcoming said normal bias of said suspension which when actuated lowers said cutting means into cutting relationship with said surface against said normal bias of said suspension means.

22. The sampling device according to claim 21 wherein said means for overcoming the normal bias of said suspension means includes a fluid actuated cylinder means, and said device further includes adjustable means for adjusting the depth of the cut.

23. A sampling device for cutting from a workpiece to be sampled a relatively small, preselected portion of the

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surface or surface and substrate of said workpiece and for retrieving said preselected portion for analysis apart from said workpiece whereby insufficient damage is caused to said workpiece to be detrimental to its continued use comprising:

means for cutting and separating said preselected portion for analysis from said workpiece, said cutting means including a blade of generally semi-spherical shape having an axis of rotation generally concentric with the center of said blade,

first drive means connected to said blade for rotating said cutter about said axis,

second drive means connected to said blade for articulating said cutting means whereby said blade is capable of cutting and separating said preselected portion for analysis from said workpiece by following an arcuate path, and

means for retrieving said preselected portion for analysis when separated from said workpiece, and

wherein said retrieval means comprises said semi-spherical shaped blade.

24. The sampling device of claim 23 wherein said retrieval means further includes a magnet in proximal location to the internal surface of said semi-spherical shaped blade.

25. The sampling device according to claims 12, 18, 23 or 24 wherein said device is capable of cutting, separating and retrieving said preselected portion for analysis from an internal surface or surface and substrate of a generally hollow workpiece at a predetermined location within said workpiece and said retrieval means includes means for moving said device along said internal surface of said workpiece and withdrawing it from said hollow of said workpiece with said preselected portion for analysis confined within the confines of said device.

26. The sampling device of claim 25 wherein said arcuate path is a single arcuate path.

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27. The sampling device of claim 26 wherein said workpiece is the component of a turbine generator system.

28. A sampling device capable of cutting, separating and retrieving a preselected portion of a workpiece to be analyzed, said portion being of a surface or surface and substrate of said workpiece and being located at a relatively confined and inaccessible location, the device comprising:

(a) a housing,

(b) a suspension system on which said housing rests which includes means for moving said housing along a surface to be sampled and means for biasing said moving means to a location external of said housing,

(c) means located within said housing, said means including:

(1) means for cutting and separating said preselected portion from said workpiece, said cutting means including a blade of generally semi-spherical shape having an axis of rotation generally concentric with the center of said blade,

(2) first drive means connected to said blade for rotating said cutter about said axis,

(3) second drive means connected to said blade for articulating said cutting means whereby said blade is capable of cutting and separating said preselected portion from said workpiece by following a generally arcuate path, and

(4) means for retrieving said preselected portion when separated from said workpiece.

29. A sampling device according to claim 28 wherein said suspension system includes a pair of wheels and a spring means associated with said wheels normally biasing said wheels in a direction so as to normally lift said cutting means above said surface a sufficient distance to allow retrieval of said device and said preselected portion after separation from said surface by said blade, and wherein said device further includes expandable and

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retractable fluid operated cylinder means located within said housing and capable of being expanded beyond said housing and being so located that upon expansion beyond said housing into engagement with a surface, continued expansion acts against said spring bias of said wheels thereby securing said device at that location on said surface and lowering said cutting means into cutting relationship with said preselected portion of said surface to be analyzed.

30. A sampling device according to claim 29 wherein said suspension system further includes an expandable and retractable slide member spaced from said wheels and a spring means normally biasing said slide member beyond said housing such that said housing is in part carried by said wheels and in part by said slide member, and such that upon said continued expansion of said fluid operated cylinder means against a surface, said slide member is caused to retract thereby further securing said device and allowing said lowering of said cutting means.

31. A sampling device according to claim 30 wherein said semi-spherical blade is comprised of a thin, essentially hollow shell having an exposed circular edge, said circular edge being provided with a cutting grit and a ring of cutting grit located at a preselected distance on an inner surface of said shell for grinding the forward edge of said portion if the length of said portion exceeds said preselected distance thereby to allow said cut to be completed.

32. A sampling device according to claim 31 further including means for remotely operating said first and second drive means, and means external of said housing for moving said device to its desired location.

33. A sampling device according to claim 18 or 27 wherein said housing is substantially cylindrical in shape and has an opening through which said blade means may be rotated to effect the cutting and separation of said portion to be analyzed.

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34. A sampling device according to claim 33 wherein said device is capable of retrieving said portion for analysis from the internal surface of a pipe.

35. A sampling device according to claim 32 wherein said first drive means comprises in line a stepper motor, a drive screw means, a drive member for translating the rotation of the drive screw into horizontal motion of a pusher rod, and a pusher rod connected to said blade and horizontally operated by said drive member such that controlled actuation of said stepper motor causes said blade to be rotated in precise, predetermined amounts about its axis.

36. A sampling device according to claim 35 wherein said cutting means and second drive means include a drive motor, a shaft actuated by said drive motor and connected to a universal joint located internally of said blade means, said pusher rod being connected by connecting means to said blade internally of said blade such that actuation of said pusher rod causes said blade to rotate about the axis of said universal join and actuation of said drive motor causes said shaft to rotate said blade and universal joint thereby effecting the cutting of a surface contacted by the blade, said connecting means being so arranged as to allow said blade and universal joint to be rotated for cutting without rotation of said connecting means or pusher rod connected thereto.

37. A sampling device according to claim 36 which further includes adjustable means associated with said housing for determining the depth of the cut to be made in the surface being analyzed.

38. A sampling device according to claim 37 capable of cutting, separating and retrieving said portion to be analyzed by initiating the cut at a fist locatio.. on said surface and finishing said cut at a second location on the same said surface.

39. A sampling device according to claim 38 wherein said means for retrieving said preselected portion includes the

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internal surface of said semi-spherical blade.

40. A sampling device according to claim 39 wherein said retrieval means further includes a magnet located within the internal portion of said blade.

41. A sampling device according to claim 39 wherein said retrieval means consists essential of the internal surface of said semi-spherical blade.

42. A method of cutting from a workpiece to be sampled a relatively small, preselected portion of the surface or surface and substrate of said workpiece and for retrieving said preselected portion for analysis apart from said workpiece without creating any substantial increase in stress in said workpiece whereby insufficient damage is caused to said workpiece to be detrimental to its continued use, the steps comprising:

locating a cutting means adjacent said preselected portion of the surface or surface and substrate of said workpiece to be sampled,

driving said cutting means so as to enable it to cut said workpiece when brought into contact therewith,

articulating said cutting means into contact with said workpiece,

cutting said relatively small, preselected portion of the surface or surface and substrate from said workpiece by driving said cutting means while articulating said cutting means through a single arcuate path, thereby creating a relatively shallow, smooth depression in said workpiece, and

retrieving said preselected portion for analysis after said cutting means separates said preselected portion from said workpiece.

43. A method according to claim 42 wherein said step of retrieving the preselected portion includes retaining said preselected portion within said cutting means.

44. A method according to claim 43 wherein said cutting means includes a semi-spherical blade means and said cutting step includes articulating said blade means, while

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rotating said blade means at cutting speed through said arcuate path from a first entrance location on a surface of said workpiece to a second exit location on a surface of said workpiece thereby to form a relatively shallow, non-destructive partial-spherical recess in the surface of said workpiece.

45. A method according to claim 44 wherein said step of retrieving the preselected portion further includes grinding the forwardmost edge of said portion as it is retained in said cutting means, thereby to accommodate it within said semi-spherical blade means for retrieval when said cutting step is completed.

46. A method according to claim 44 wherein said grinding is accomplished by a grinding ring disposed on an internal surface of said semi-spherical blade means.

47. A method according to claim 42 or 44 wherein said step of retrieving said preselected portion for analysis includes the step of attaching said portion to said cutting means by a magnet.

48. A method of sampling a workpiece by cutting from said workpiece to be sampled a relatively small, preselected portion of the surface or surface and substrate of said workpiece and for retrieving said preselected portion for analysis apart from said workpiece whereby insufficient damage is caused to said workpiece to be detrimental to its continued use, the steps comprising:

a cutting means comprised of locating a semi-spherical blade means in proximal cutting relationship to said preselected portion of said workpiece to be sampled,

said blade means having an axis of rotation generally concentric with the center of said blade means and an axis of articulation substantially perpendicular to said axis of rotation,

rotating said blade means about said axis of rotation at a speed capable of cutting said workpiece,

articulating said blade means about said axis of

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articulation and into cutting engagement with said preselected portion of said workpiece,

cutting said relatively small, preselected portion of the surface or surface and substrate from said workpiece by rotating said blade means about said axis of rotation at said cutting speed while articulating said blade means about said axis of articulation through an arcuate path until said preselected portion is separated from said workpiece, and

retrieving said separated preselected portion by steps which include capturing and retaining said preselected portion within the interior portion of said semi-spherical blade means.

49. A method according to claim 48 wherein the step of retaining said preselected portion within the interior portion of said semi-spherical blade means includes the step of magnetically securing said portion to said interior portion of said blade means.

50. A method according to claim 48 wherein said cutting step includes articulating said blade means through said arcuate path from a first entrance location on a surface of said workpiece to a second exit location on a surface of said workpiece thereby to form a relatively shallow, non-destructive, partial-spherical recess in the surface of said workpiece.

51. A method according to claims 42, 48 or 50 wherein said cutting means is retained in a housing provided with means for locating said cutting means in proximal cutting relationship with said preselected portion, and which includes the further step of securing said cutting means to said workpiece once said cutting means is located in said cutting relationship with said preselected portion.

52. A method according to claim 51 wherein said housing includes a suspension means for carrying and positioning said cutting means,

said suspension means normally biasing the housing and cutting means away from the preselected portion of

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said workpiece and raising said cutting means out of engagement with said preselected portion a sufficient distance to allow retrieval of said housing and cutting means after said preselected portion is cut from said workpiece,

said housing further including means for overcoming the normal bias of said suspension means which when actuated lowers said cutting means into cutting relationship with said surface against said normal bias of said suspension means and wherein,

said step of securing said cutting means to said workpiece once said cutting means is located in said cutting relationship with said preselected portion includes engaging a first portion of a surface of said workpiece with said suspension means and thereafter expanding said means for overcoming said normal biasing engagement with a second portion of a surface of said workpiece.

53. A method according to claim 52 wherein said expansion of said means for overcoming the normal bias of said suspension means, overcomes and acts against the normal bias of said suspension means and lowers said cutting means into proximal relationship with said preselected portion of said workpiece, thereby securing said cutting means in cutting relationship with said preselected portion by a combination of the normal bias of said suspension acting against the expanded means for overcoming said normal bias.

54. A method according to claim 53 wherein said means for overcoming the normal bias of said suspension means includes a fluid actuated cylinder means, and said step of expansion includes actuating said fluid actuated cylinder means.

55. A method according to claim 54 which further includes adjusting the cutting means prior to cutting, thereby to adjust the depth of the cut.

56. A method according to claim 55 wherein said

preselected portion of a workpiece is an internal surface of a turbine-generator system.

57. A method of taking a metallurgical sample from a remote, internal surface of a generally inaccesible area within a turbine-generator without disassembling said generator so as to completely expose the area to be sampled, the steps including:

providing a probe of sufficiently small size to be moved through an orifice in said generator to a location for sampling, said probe comprising a housing having there within a cutting means,

moving said probe through said orifice and adjacent the portion of surface to be sampled, such that said cutting means are in proximal relationship to said portion,

securing said probe at said location,

driving said cutting means so as to enable it to cut said portion when brought into contact therewith,

articulating said cutting means into contact with said portion,

cutting from said surface of said turbine-generator a relatively small, non-destructive sample by articulating said driven cutting means through a single arcuate path, thereby creating a relatively shallow, smooth depression in said surface, and

retrieving said sample for analysis after said cutting means separates said sample from said surface.

58. A method according to claim 57 wherein said cutting means comprises a semi-spherical blade means having an axis of rotation generally concentric with the center of said blade means and an axis of articulation substantially perpendicular to said axis of rotation,

said driving step comprising rotating said blade means about said axis of rotation at a speed capable of cutting said surface, and said articulation and cutting steps include articulating said blade means through a single arcuate path from one point on the surface to another, thereby to collect said sample within the

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interior portion of said blade means and create in said surface a non-destructive, relatively shallow, smooth partial-spherical recess, and

retrieving said sample by moving said probe containing said sample within the interior of said blade means from the location of sampling to a point out of said orifice.

59. A sampling device substantially as herein described with reference to the accompanying drawings.

60. A method for obtaining a sample substantially as herein described with reference to the accompanying drawings.

DATED this 17th day of January, 1991

THE FAILURE GROUP, INC.

Attorney: WILLIAM S. LLOYD

Fellow Institute of Patent Attorneys of Australia

of SHELSTON WATERS

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Fig.1

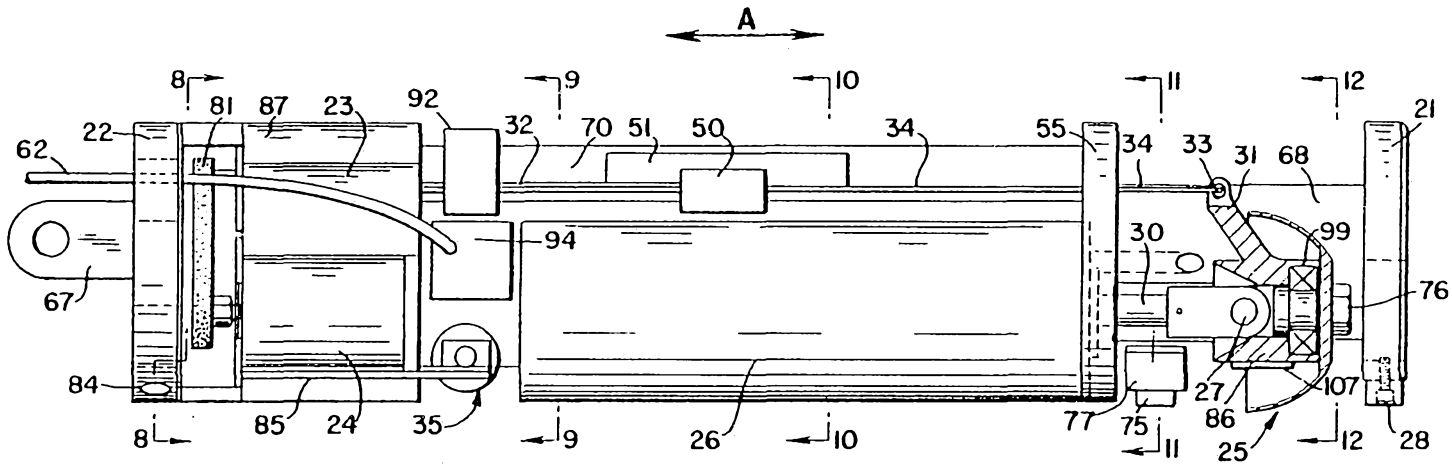

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Fig.2

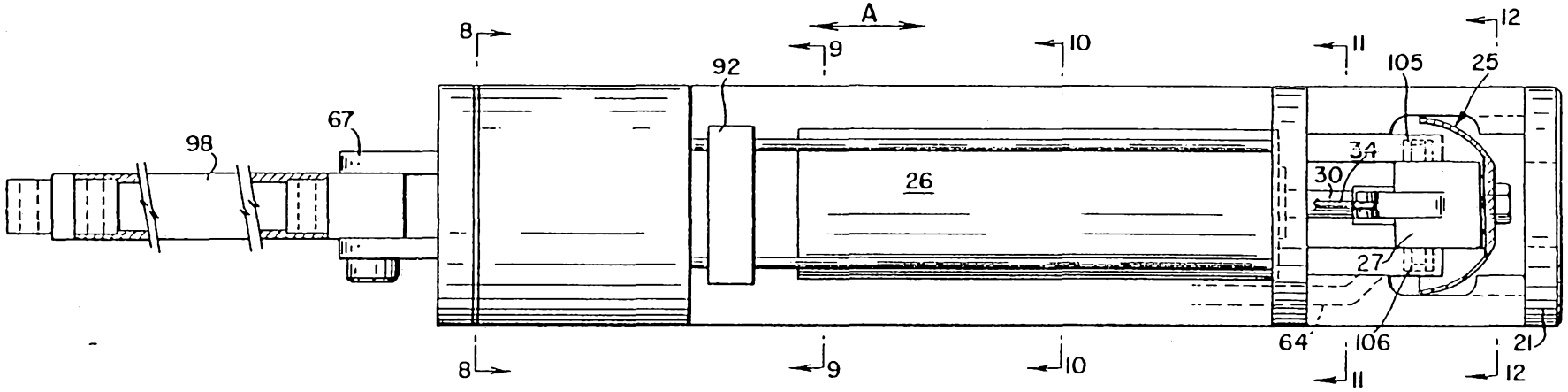

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Fig.3

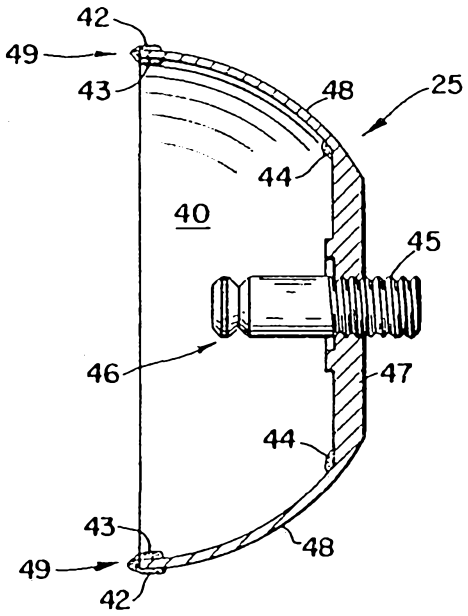


Fig.4

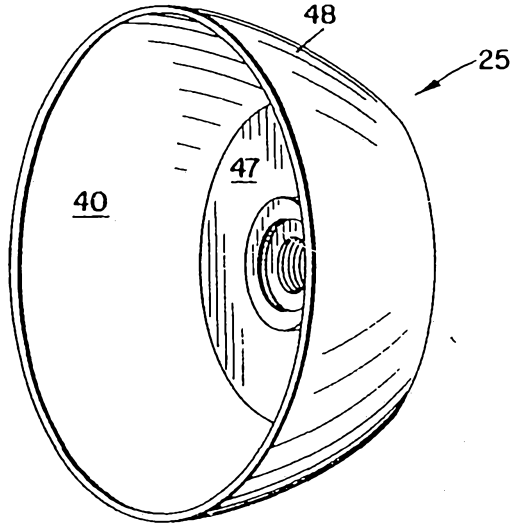


Fig.5

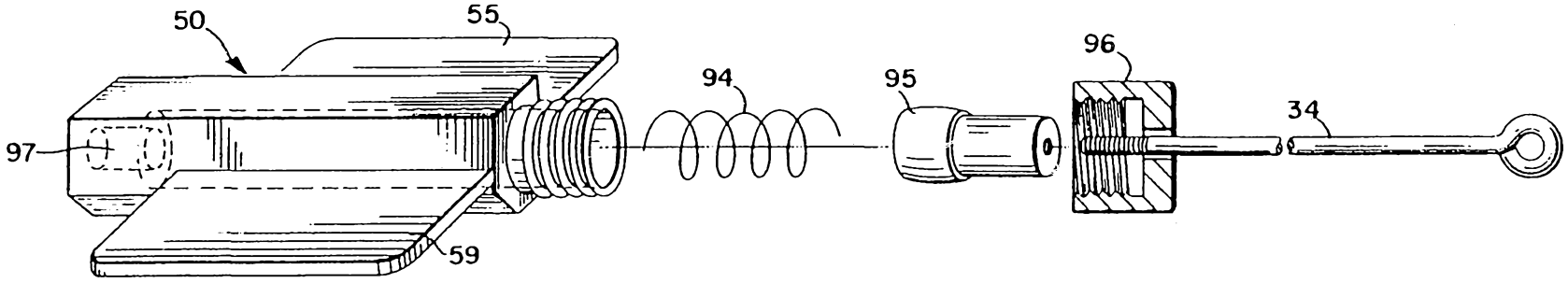


Fig.6

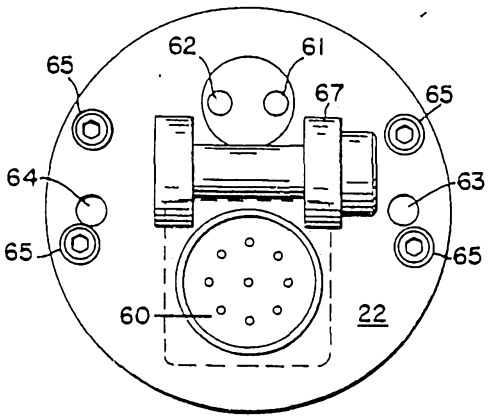


Fig.7

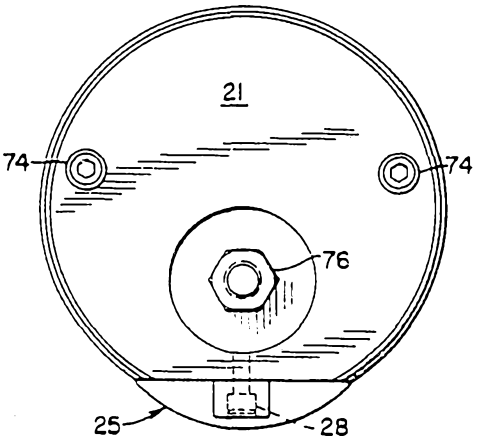


Fig.8

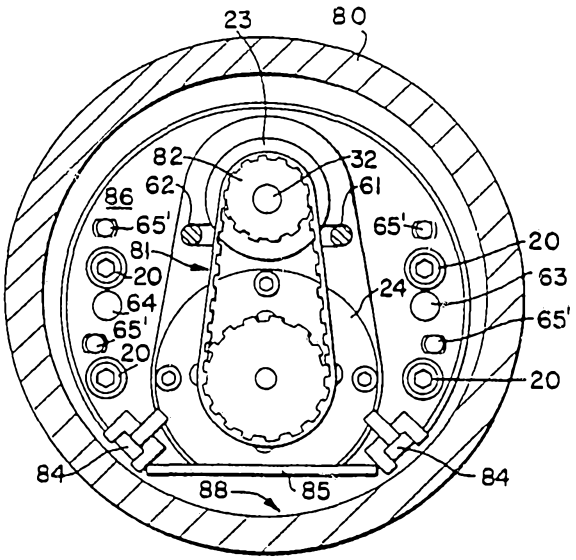


Fig.9

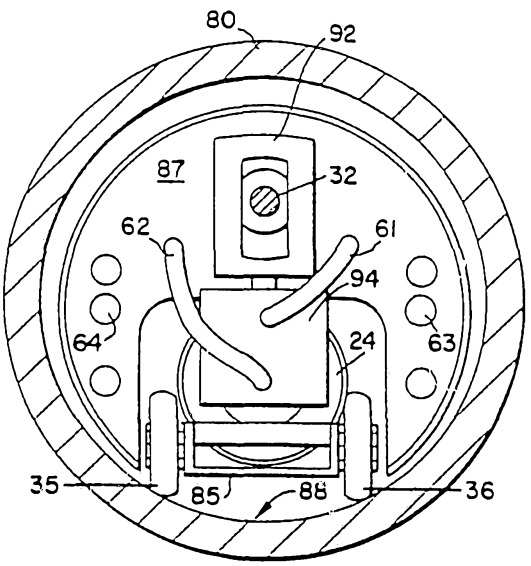


Fig.10

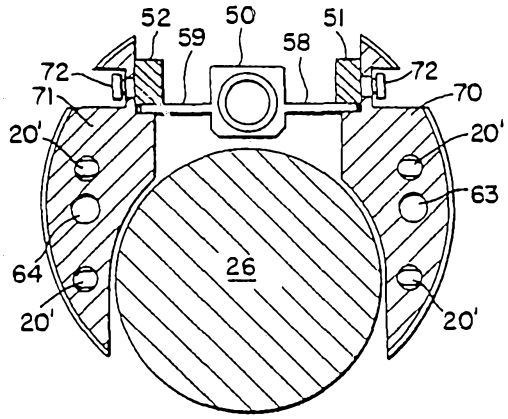


Fig.11

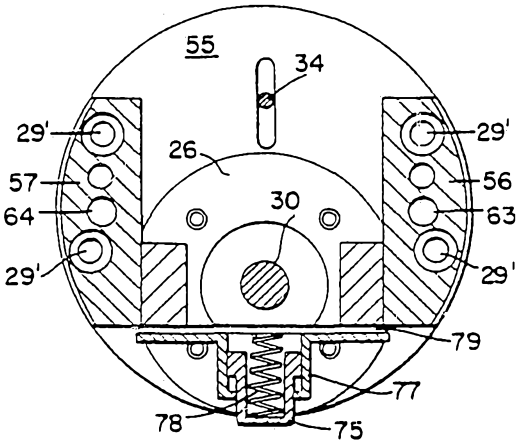


Fig.12

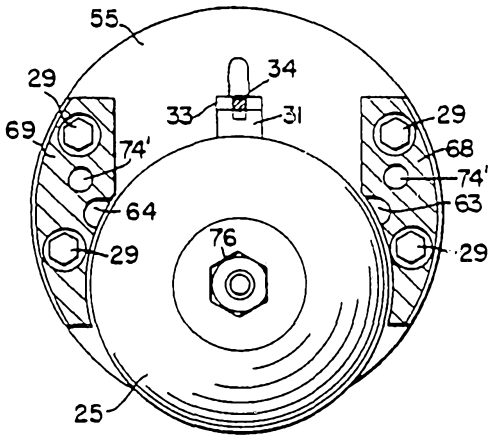


Fig.14

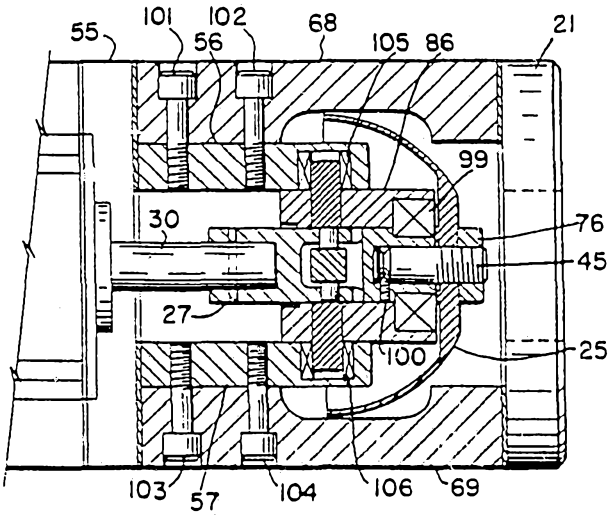


Fig.13A

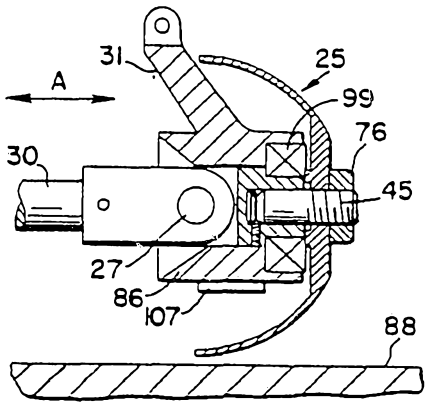


Fig.13B

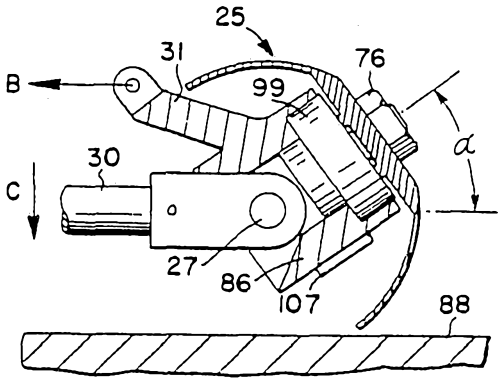


Fig.13C

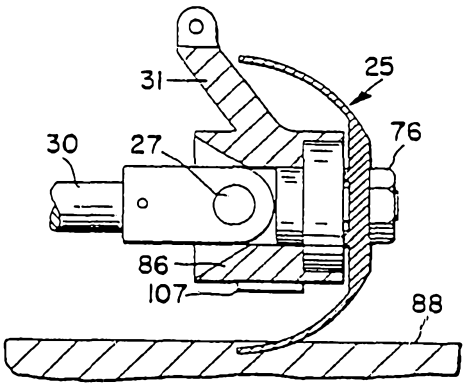


Fig.13D

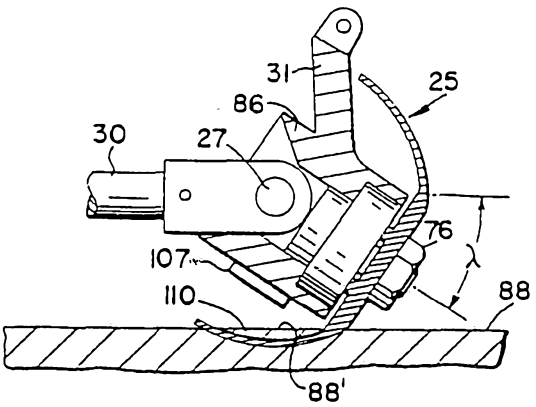
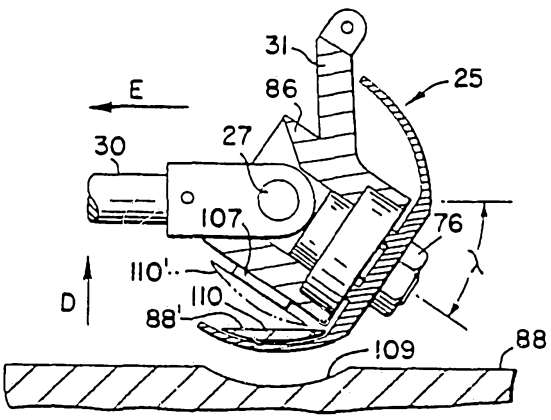


Fig.13E



INTERNATIONAL SEARCH REPORT

International Application No. PCT/US88/00472

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (4):G01N 1/04, B26D 1/44,B23D 19/08, B24B19/00
U.S. Cl. : 51/33.R, 281.R; 73/864.41; 83/919

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	51/33.R, 58,99,126,206.R,209.R,281.R; 73/86,864.41; 83/54,490,491,861,919;125/13.SS; 408/150; 409/143

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	U.S., A, 3,159,952 (Lipkins) 08 December 1964 See column 2, lines 7-24.	1-11
Y	U.S., A, 3,857,425 (Wiklund) 31 December 1974 See column 1, lines 12-23.	1-11
Y	U.S., A, 3,374,586 (Stone) 26 March 1968 See column 2, lines 18-34.	1-6
Y	U.S., A, 122,514 (Bullock) 09 January 1872 See column 2, lines 19-29.	5,6,10,11
Y	U.S., A, 4,372,174 (Cymbalisty et. al.) 08 February 1983. See abstract.	1,7
A	U.S., A, 4,106,561 (Jerome et. al.) 15 August 1978	1,7
A	U.S., A, 4,220,201 (Hauk) 02 September 1980	1,7
A	U.S., A, 4,434,815 (Flaherty et. al.) 06 March 1984	1,7
A	U.S., A, 4,588,119 (Fernandez-Acebal et. al.) 13 May 1986	1,7

(cont'd)

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
25 MAY 1988	23 JUN 1988
International Searching Authority	**Signature of Authorized Officer**
ISA/US	ROBERT P. OLSZEWSKI

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	U.S., A, 4,598,597 (Widner et. al.) 08 July 1986	1,7
PX / PY	Grimsley's House of Tools, Inc. catalogue issued 01 June 1987, "Grimsley's Portable Trepanning Metal Cutting Machine Model, WP-1," see entire document.	1,2,7,8 / 3-6,9-11