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(54) Titre : DISPOSITIF ENREGISTREUR POUR DES OPERATIONS DE TIR ET PROCEDE POUR SON UTILISATION
(54) Title: LOGGER DEVICE FOR BLASTING OPERATIONS AND METHOD OF USE



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(57) **Abrégé(suite)/Abstract(continued):**

terminals are disposed and configured to be releasably connected to two detonator leg wires of a detonator, the microprocessor is configured to receive an input signal from the two detonator leg wires when a voltage reference is injected into the two detonator leg wires via the two electrical input terminals, and the connector is disposed and configured to be releasably connected to a handheld computer.

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(57) Abstract: An electrical interface apparatus includes two electrical input terminals, a microprocessor disposed in electrical communication with the two electrical input terminals, and a connector disposed in electrical communication with the microprocessor. The two input terminals are disposed and configured to be releasably connected to two detonator leg wires of a detonator, the microprocessor is configured to receive an input signal from the two detonator leg wires when a voltage reference is injected into the two detonator leg wires via the two electrical input terminals, and the connector is disposed and configured to be releasably connected to a handheld computer.

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LOGGER DEVICE FOR BLASTING OPERATIONS AND METHOD OF USE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 61/251,024, filed October 13, 2009, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] The present invention concerns a device and method for determining the location of boreholes by ground positioning satellite ("GPS") and/or other suitable geographic positioning information, and for gathering, evaluating and storing data concerning the condition of electric detonators in the boreholes.

[0003] Patent Cooperation Treaty Publication No. WO 2008/139413 A1, published on 20 November 2008, discloses a system for loading a flowable explosive into blast holes from mobile supply units (trucks). A GPS unit is operable to determine the position of the blast holes and a blast hole identification processor is in communication with the GPS unit to receive from the GPS unit a blast hole coordinate position. The blast hole identification processor identifies the blast hole based on its geographic coordinate position.

[0004] U.S. Patent Application Publication No. US 2005/0263027 A1, published on December 1, 2005, discloses a method for controlling initiation of detonators by measuring the spatial position of the detonator in relation to one or more adjacent detonators and calculating the time of initiation of the detonator based upon its actual spatial position. The spatial position of the detonators is measured using an electronic positioning system, preferably that of an inertial positioning system or a global positioning system.

[0005] U.S. Patent Application Publication No. US 2005/0103219 A1, published on May 19, 2005, discloses a blasting system to facilitate the actuation of a plurality of programmable detonators according to a desired blasting pattern, by downloading to the detonators blasting information which is automatically determined by a portable handheld unit. The portable handheld unit incorporates a positional detecting device such as a GPS device.

SUMMARY OF THE INVENTION

[0006] An embodiment of the invention comprises an apparatus and a method for ascertaining the location of one or more boreholes in which one or more electric detonators are

contained, checking the condition and characteristics of the detonators, and generating an electronic record of the condition of each detonator, including the date and time at which the data was gathered. In the case of more than one detonator in a given borehole, the condition and location within the borehole of each individual detonator is also obtained. Other information, such as the type of detonator, its electrical resistance and continuity of its leg wire circuit are among the data which may be gathered. The resulting database is transmittable from the apparatus of the invention to any suitable electronic or other storage device, such as a remote desktop computer.

[0007] One aspect of the present invention provides that the apparatus comprises a handheld computer which is carried by the operator from borehole to borehole and is removably connected in turn to the leg wires of individual ones of the detonator or detonators in each borehole, in order to record the status of the detonators. Optionally, positional information via a GPS receiver device or the like in the apparatus and/or other borehole specific data may also be recorded and transmitted by the apparatus.

[0008] Another aspect of the present invention provides that the location of the borehole is ascertained by receiving a signal from a global positioning satellite or other positioning devices such as global navigation system satellites.

[0009] Yet another aspect of the present invention provides a galvanometer with suitable firmware incorporated therein so that the galvanometer not only measures the resistance of the detonator to which it is connected, but outputs information to show whether the detonator electrical resistance is within, above or below the desired resistance range.

[0010] The galvanometer may be an integral part of the handheld device or it may be an accessory which is readily connectable to and removable from the handheld device.

[0011] A method aspect of the invention comprises utilizing a handheld computer to ascertain the condition of a plurality of electric detonators respectively dispersed in one or more boreholes by traveling from borehole to borehole and connecting the detonator leg wires to the handheld device to ascertain and record the condition of the detonator and, via GPS or equivalent satellite information, ascertain the position of each borehole. A database is then assembled by the handheld device to include the measured information and the database is transferred to another electronic device for storage and use.

[0012] An embodiment of the invention includes an electrical interface apparatus having two electrical input terminals, a microprocessor disposed in electrical communication

with the two electrical input terminals, and a USB connector disposed in electrical communication with the microprocessor. The two input terminals are disposed and configured to be releasably connected to two detonator leg wires, the microprocessor is configured to receive an input signal from the two detonator leg wires when a voltage reference is injected into the two detonator leg wires via the two electrical input terminals, and the USB connector is disposed and configured to be releasably connected to a handheld computer.

[0013] An embodiment of the invention includes a logger in combination with an electrical interface apparatus for testing seismic borehole shots, where the logger is a handheld computer having an input port and a user interface, and includes logging software loaded thereon, where the combination is a combination of the logger and the above-noted electrical interface apparatus, with the exception that the microprocessor is configured and disposed in direct signal communication with an input port of the handheld computer as opposed to being connected via a USB connector.

[0014] An embodiment of the invention includes a method for checking an electrical characteristic of a borehole detonator having two detonator leg wires using any of the above-noted apparatuses. In an embodiment, the method includes: connecting the above-noted electrical interface apparatus to the above-noted handheld computer; connecting the two electrical input terminals to the two detonator leg wires; injecting a voltage reference into the two detonator leg wires and receiving an input signal from the two detonator leg wires in response to the injected voltage reference; and, displaying a mixed number-and-symbol system on a display of the handheld computer in response to the input signal. In an embodiment, the mixed number-and-symbol system is a numerical value representative of, and in response to, the input signal being representative of a resistance at the two detonator leg wires falling within a pre-defined acceptable range; and, the mixed number-and-symbol system is a string of characters in response to the input signal being representative of a resistance at the two detonator leg wires falling outside the pre-defined acceptable range.

[0015] Other aspects of the present invention will be apparent from the following description and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Figure 1 is an exploded elevation view of a logger in accordance with an embodiment of the invention and comprising a handheld computer and a hood fixture comprising a galvanometer;

[0017] Figure 2A is an exploded assembly view of a logger and a connectable/detachable galvanometer in accordance with an embodiment of the invention;

[0018] Figure 2B is an elevation view of an integrally formed logger/galvanometer combination in accordance with an embodiment of the invention;

[0019] Figure 3 is a schematic plan view of rows of boreholes of a typical blasting set-up, with two of the assemblies of Figure 2 connected to leg wires of respective detonators within selected ones of the boreholes;

[0020] Figure 4 is a schematic flow path showing the general flow of data in accordance with one embodiment of the present invention;

[0021] Figure 4A is a schematic flow path showing more details of the general flow of data;

[0022] Figure 5 is a schematic flow path showing a more detailed flow of data relative to that of Figure 4 and in accordance with an embodiment of the present invention;

[0023] Figure 6A is a chart which lists software specifications and their main functions in accordance with one embodiment of the present invention; and

[0024] Figures 6B through 6H inclusive schematically illustrate some details of the main functions listed in the chart of Figure 6A;

[0025] Figure 6I is a schematic flow chart showing data flow within the handheld computer; and

[0026] Figure 7 is a block diagram schematic of a galvanometer in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0027] An embodiment of the invention includes a handheld computer 10 having or having attached thereto a galvanometer 12 to provide a handheld logger 14 for testing electric or electronic detonators 100 within boreholes 18. Logger 14 is capable of measuring resistance values of electric or electronic detonators 100 in a borehole 18, as well as receiving operator input and geographic position information, such as that provided by a global positioning satellite ("GPS") or the like. The operator may input other data, such as the type and

quantity of explosive in the borehole 18, the explosive type, etc. The resulting database is transferable to an office computer 22 or other storage media, for recording and storing the data. A method in accordance with an embodiment of the invention provides for an operator to move from borehole 18 to borehole 18 and removably connect the handheld logger 14 to the leg wires 20 of each detonator 100 in the borehole 18, to develop a database of the above-described data, and transfer the database as described above. Maps of the borehole locations and other pertinent information may be developed from the database to facilitate planning additional shots, such as seismic survey shots, and to analyze seismic results.

[0028] While the present invention is broadly applicable to blasting operations generally, it is particularly suitable for seismic exploration blasting which is carried out to ascertain the best locations for locating and maximizing the yield of whatever mineral, e.g., oil or gas, is being sought. Typically, a geologist or geophysicist will prepare a macro scale map of a selected survey area covering hundreds or thousands of acres. Surveyor teams are sent to the geologically most promising sites in the mapped area to clear away, if necessary, obstructions such as trees, shrubs, deep grass, etc., and to drive marker stakes into the ground at the selected survey sites. If a selected survey site or a portion of it is not accessible for drilling, for example, it may be at the edge of a cliff, under water, etc., the surveyor team then "skids" the selected site to relocate it into a fully accessible position as close as possible to the originally selected survey site.

[0029] Drill crews then drill boreholes at the staked locations and load suitable explosives, e.g., dynamite, and detonators (blasting caps) into the boreholes. As is typical, the detonator leg wires are positioned to extend upwardly through the borehole to the surface, where they are accessible for connection. The explosive loads in the boreholes are herein referred to as seismic borehole shots.

[0030] Seismic borehole shots often lay idle for a long time ("the idle period"). The idle period may be as much as six months or so, while the rest of the survey site is being prepared. That is, it may be months from the time the detonator and explosive are loaded into a first borehole until all the other boreholes in the survey site are staked, drilled, loaded and otherwise prepared for the blasting.

[0031] Figure 1 is an exploded view and Figure 2 is an assembled view of a logger 14 which is comprised of a handheld computer 10, a display screen 10a and a keypad 10b for inputting information. A stand-alone galvanometer 12 is electronically connectible to com-

puter 10 by a conventional USB cable 16. The galvanometer 12 includes in its resistance circuit of a microprocessor (see block diagram schematic 200 in Figure 7). Electric connector posts 12a and 12b of galvanometer 12 are configured to be releasably connected to detonator leg wires as described below. The galvanometer 12 may be integrated into the circuitry of a suitable handheld computer, or it may be, as illustrated, a separate item which is removably electrically connectable to the handheld computer 10. In either case, the logger 14 is utilized to provide a digital record of borehole locations, electrical resistance of the one or more detonators in the boreholes, and other characteristics such as the type and quantity of explosives in each borehole, all as measured at a specific time and date which is recorded in the data. The microprocessor in the galvanometer resistance circuit preferably also has the feature of calibrating its readings to compensate for ambient temperature variations.

[0032] Figure 3 shows in plan view a series of boreholes 18 arranged in three parallel rows which are arbitrarily labeled as rows A, B and C. In addition to a suitable explosive charge, each borehole 18 contains one or more electric or electronic detonators 100, each of which has a pair of leg wires 20 extending from the detonators through its respective borehole and to the surface. Detonator leg wires 20 are shown as protruding only from the two boreholes being cataloged, but it will be understood that a similar pair of leg wires (represented by reference numeral 20) will extend to the surface from each of the one or more detonators in each of the other boreholes. Loggers 14 are shown as being respectively removably, i.e., temporarily, connected to the leg wires 20 by attaching the leg wires to posts 12a and 12b. These removable connections are made and unmade by hand and the cataloging is carried out by operators. Obviously, any suitable number of loggers 14 may be placed in use at any given time to share the workload among a number of operators.

[0033] The information obtained by the loggers 14 is useful not only for analyzing the layout of a blast site, e.g., a seismic survey site, but for providing a digital record which may be critical for defending against any claims made against the user by third parties, or by the user against a supplier. For example, during the idle period mentioned above, a completed borehole may "slump" due to soil conditions or significant rainfalls and the slumping may break or disconnect one or both of the detonator leg wires. The present invention provides a digital record of the status of the detonator and other conditions in the borehole as of the time loading of the borehole is completed.

[0034] In addition, a map of the planned boreholes can be developed from the data obtained by use of the logger of the present invention and input into a computer or other storage device or media, in order to help locate future borehole placements in the survey site or sites or in future blasting operations generally. A practical advantage is that the driller in the field can enter all needed data electronically, and paper and pencil or pen are not required. The latter is a not inconsiderable advantage in inclement weather.

[0035] The galvanometer may be a separate item that is readily removably connected to the USB port of any suitable handheld computer. A number of different galvanometers, each customized for testing detonators having different electrical resistance range specifications, may be provided for attachment to the same handheld computer. An alternative design is to utilize an off-the-shelf handheld computer such as the Trimble™ Nomad Handheld Computer (sometimes herein referred to as the "Trimble Computer"), available from Trimble Navigation Limited, Corvallis, Oregon. This handheld computer can utilize software which is well suited for collecting, saving and transmitting field data, e.g., data from cataloging the boreholes of a blasting survey site or other blasting site. The handheld computer 10 also has an integrated GPS receiver 11 to provide the respective geographic locations of the boreholes 18 of Figure 3. The Trimble Computer is, in accordance with one embodiment of the present invention, configured to have a galvanometer 12 removably connected to it to provide a logger 14. Logger 14 is small enough to be readily held in the hand while using it in the field. Further, the Trimble Computer is capable of building, storing and transmitting a database including, by way of example only, borehole location, type of explosive utilized, results of galvanometer tests for the electrical resistance of each detonator in a borehole, etc. Obviously, any other suitable handheld computer fitted with the galvanometer may be used in the apparatus of the invention. As indicated above, different galvanometers may be attached to handheld computer 10, as required in a given case. In an embodiment, the display screen 10a and keypad 10b of handheld computer 10 is configured having a screen layout and keypad layout that are known to one skilled in the art of the Trimble Computer.

[0036] In another embodiment of the present invention, a single integrated logger unit may have the galvanometer circuitry incorporated into the circuitry of a suitable handheld computer. It is usually preferred, however, to couple a stand-alone version of the galvanometer with a suitable off-the-shelf handheld computer, as this approach is simpler and less expensive than developing a customized handheld computer. Further, the ability to change out

galvanometers facilitates customizing the logger for use with detonators of different electrical characteristics. An integrated logger capable of testing different types of detonators would have to include circuitry and operator controls for setting different acceptable ranges of electrical resistance for different types of detonators. This provides an occasion for operator error. Alternatively, a separate integrated logger would have to be provided for each type of detonator. Either alternative is obviously disadvantageous as compared to a handheld computer capable of having different galvanometers attached to it.

[0037] The galvanometer includes firmware (software which cannot be altered by the user) which is programmed to recognize the acceptable range of resistance of the particular electric or electronic detonators being utilized. If the measured resistance exceeds the upper limit of the desired resistance range, a string of plus signs may be displayed on the handheld computer to indicate that the resistance is too high. If the resistance is below the low end of the desired range, a string of minus signs may be displayed to indicate that the resistance is too low. If the resistance falls within the pre-programmed acceptable range, a numerical display of the measured resistance may be shown. A mixed number-and-symbol system is preferred over an all-numerical system because it largely eliminates the danger that the operator will misread a number or mistakenly think that an unacceptable number displayed is within the acceptable range. Obviously, any suitable symbols or indicia and/or audible or visual (lights) indications other than the specific above-described mixed number-and-symbol system may be employed.

[0038] In all cases, the electrical output required to measure the resistance of the detonators is far below the minimum output required to overcome the resistance to initiate the detonators being tested. For example, an electronic detonator sold under the trademark DiPed and available from Dyno Nobel Inc. of Salt Lake City, Utah, has a high electrical resistance range of 44.6 kilo-ohms to 49.5 kilo-ohms.

[0039] The galvanometer 12 may be configured with circuitry and operator controls which enable the adjustment of the acceptable resistance values for the particular type of detonators being utilized. This, however, presents a danger of operator error if the wrong range of acceptable resistance values is mistakenly selected. For that reason, it is preferred to provide customized galvanometers, each of which is configured for one particular acceptable resistance range. Each such customized galvanometer 12 may have a hood-like configuration and be configured to seal the interior of the handheld computer 10 to which the galvanometer

is connected. These "hoods" are configured to removably connect the galvanometer both electrically and physically to the handheld computer, making a water-and weather-tight seal between the hood-shaped galvanometer and the computer. The handheld computer may have a USB port to which the galvanometer is readily connectible. Hoods are advantageously clearly marked to indicate the desired resistance range of the detonators with which that particular hood is to be used. Accordingly, the hoods may be of different colors, etc., so as to reduce the chance of connecting the wrong hood (for the particular type of detonators being interrogated) to the handheld computer. As a practical matter, however, greater assurance that the correct hood is being used is attained by having the blasting supervisor, e.g., the seismic survey supervisor, issue to each driller a tool kit from which the hood or hoods not designed for the particular type of detonators being interrogated have been removed. This leaves in the issued tool kit only the one appropriate hood for the detonators being used in that shot, together with other items such as the handheld computer, batteries, etc.

[0040] After a suitable galvanometer 12 is connected to handheld computer 10 to provide the logger 14, the logger 14 is utilized as schematically illustrated in Figure 3 to collect data pertinent to each borehole 18, and the resulting logger data is fed back to the desktop software application 26. As discussed above, the logger data will typically include information showing whether each detonator has the appropriate desired resistance value range, or one which is above or below the desired range. The position of each borehole is as determined by utilization of the GPS or equivalent signal. Other data may be input by the operator in the field, including the type and amount of explosive in each borehole, and any other pertinent data.

[0041] Figure 4 shows a schematic flow chart in which an office computer 22 (so denominated in order to distinguish it from the handheld computer 10) is shown as receiving and transmitting data between handheld computer 10 and office computer 22. Customer specific data 30, which may include field definitions for example, is input into the desktop software application 26 and is included in the set-up data transmitted to the field software 28 of handheld computer 10. Software 26 accepts and records the data and outputs set-up data to the field software 28 of logger 14. As shown in Figure 4, at this stage, the galvanometer 12 is not connected to handheld computer 10 and so a cap 10c has been inserted into the opening in which galvanometer 12 is inserted, in order to provide a weather- and air-tight seal similar to that provided by galvanometer 12. The desktop software application 26 running on office

computer 22 is also configured to receive post plot survey data 24, which may include hole coordinate information from a GPS for example, and to provide a final shot report 32.

[0042] A more detailed example of data flow 105 between computer 22 and handheld computer 10 is shown in Figure 4A. Figure 4A is an overview of the workflow between the office (desktop) computer 22 and the handheld computer 10. It is seen that the shot points 110, data dictionary 115, background images 120 are transmitted to the office computer 22 together with files 125 containing the field data 130 from handheld computer 10. The field data is recorded, including the resistance of the detonators, GPS coordinates, a date and time stamp and other attributes as determined by the data dictionary (see Figure 6E for example), created and fed into the office computer 22. Files are transferred between office computer 22 and the handheld computer 10 as required, and handheld computer 10 may be used to navigate to one or more shot points 135. The software 26 of office computer 22 may also be configured and used to perform post-processing of GPS coordinates 140 and to export data 145 such as the final shot report 32 for example.

[0043] Figure 5 shows a detailed software workflow chart 150 wherein the legends in the chart show the flow of information from the office computer 22 software, as the logger is launched. The job specific file 155 is created including defining fixed header fields 160, inputting post-plot coordinates (X,Y) data 165, defining per-day data fields 170, defining per hole shot point data fields 175, then reviewing the fields 180 and saving the file 185. The boxes 190, 191 and 192 to the left-hand side of Figure 5 give examples of specific information and data associated with the first (reference numeral 160), third (reference numeral 170) and fourth (reference numeral 175) steps of the specific file flow chart.

[0044] The right-hand side of Figure 5 shows the application of utilities 300 to upload 305 a job specific file to the handheld computer 10, download 310 the logger files from handheld computer 10, delete 315 extraneous files, if any, from the handheld computer 10, optionally update 320 the handheld software, and then combine 325 the files.

[0045] Figure 6A is a list of the main functions 330 to be performed on the office computer 22, which in an embodiment utilizes the Trimble™ GPS Pathfinder Office software on a Windows™ 2000, XP or Vista™ platform, or any other software platform suitable for the purposes disclosed herein.

[0046] Figure 6B provides a graphical flow chart 340 illustrating one example type of data import as indicated by the first bullet 331 under Main Functions 330 in Figure 6A. The

three steps 341, 342, 343 described in the example of Figure 6B are schematically illustrated by the various computer screens 345, 350, 355, 360 which appear in the order indicated by the arrows 341', 342', 343' interconnecting them. The graphical illustration 345 is representative of a .seg file of the U.S. National Petroleum Reserve from the U.S. Geologic Survey (a .seg file format is known to one skilled in the art). The graphical illustration 350 is representative of the .seg file 345 having been converted into a .dbf (dBase IV) file in Microsoft™ Excel format (a .dbf file format is known to one skilled in the art). The graphical illustration 355 is representative of a screen shot of the import tool available by running the application software on the office computer 22 (the content of screen shot depicted is known to one skilled in the art of Trimble™ GPS Pathfinder Office software). The graphical illustration 360 is representative of a screen shot of a map of the shot point field as provided by the application software on the office computer 22 (the content of screen shot depicted is known to one skilled in the art of Trimble™ GPS Pathfinder Office software).

[0047] Figure 6C shows pertinent computer screens 365, 370, 375 on office computer 22 executing Trimble™ GPS Pathfinder Office software, which are involved in importing background images 380 (see Figure 6D for example) into the program. Background images other than that illustrated in Figure 6D may be imported from a variety of sources. The background image 380 illustrated in Figure 6D may be overlain with a rendition of the location of boreholes on the surface of the terrain, see shot point field 360 in Figure 6B for example. The type of content depicted in screen shots 365, 370, 375, 380 is known to one skilled in the art of Trimble™ GPS Pathfinder Office software.

[0048] Figure 6E shows computer screens 385, 390 of a data dictionary editor with typical attributes which are to be recorded in the field as illustrated in Figure 3. The left-hand screen 385 of Figure 6E shows the "Resistance" (of the detonators), the explosive type used in the borehole, the weight of explosive in the borehole, the depth of the borehole and the shot point. The shot point is the borehole to which the signal to initiate the detonators is sent. The GPS data is used to navigate to the selected shot point. The right-hand screen 390 of Figure 6E shows an edit screen for use in describing the shot point field under consideration. The type of content depicted in screen shots 385, 390 is known to one skilled in the art of Trimble™ GPS Pathfinder Office software.

[0049] Figure 6F illustrates a transfer of files between a computer (e.g., office computer 22) and the handheld logger unit 14 using a data transfer utility. The graphical illustra-

tion of screen shot 395 is representative of a data transfer utility provided by the Trimble™ GPS Pathfinder Office software, and the graphical illustration of screen shot 400 is representative of a data transfer utility provided by Microsoft™ ActiveSync software. The type of content depicted in screen shot 395 is known to one skilled in the art of Trimble™ GPS Pathfinder Office software, and the type of content depicted in screen shot 400 is known to one skilled in the art of Microsoft™ ActiveSync software.

[0050] Figure 6G illustrates computer screens 405, 410 generated in the course of creating loading reports from the field data received from the handheld logger 14. The data may then be exported from the office computer 22 (see export data 145 in Figure 4A for example). The type of content depicted in screen shots 405, 410 is known to one skilled in the art of Trimble™ GPS Pathfinder Office software.

[0051] Figure 6H illustrates computer screens 415, 420 generated when employing data from local fixed GPS sources to improve the accuracy, differential correction, of the location of the boreholes as established by the field GPS, otherwise known as post-processing of GPS coordinates. The type of content depicted in screen shots 415, 420 is known to one skilled in the art of Trimble™ GPS Pathfinder Office software.

[0052] Figure 6I is a schematic flow chart 500 providing a more detailed view of the software workflow of the handheld computer 10. As indicated, the logger handheld software is launched 505, job specific files are loaded 510 together with complete per-day pull down entries 515. An X,Y grid coordinate location 520 and complete per-hole pull-down entries 525 are loaded into the software of the handheld computer 10 which is then connected 530, as illustrated in Figure 3, to the detonator leg wires. If the display screen 10a (Figure 2) of the handheld computer 10 shows that the resistance of the detonator is in specification 535, i.e., is in the desired range, another X,Y grid coordinate is selected and the steps are repeated 540 to log each borehole 18 (Figure 3). If the resistance of the detonator is not within specification, a second try may be made 545 by reconnecting 550 the handheld computer 10 to the detonator and repeating the measurement. If the re-measured resistance is shown to be within specifications, the operator moves on to the next borehole 18 (Figure 3). If the detonator resistance is shown as still outside specification, the resistance measurement failure is acknowledged 555 for that borehole and suitable steps to rectify the matter, e.g., by replacing the out-of-specification detonators, may be taken.

[0053] In view of the foregoing, and with reference to Figures 1-3 and 7, it will be appreciated that an embodiment of the invention includes an electrical interface apparatus (also herein referred to as a galvanometer) 12 having two electrical input terminals 12a, 12b, a microprocessor 205 disposed in electrical communication with the two electrical input terminals 12a, 12b, and a USB connector 210 disposed in electrical communication with the microprocessor 205. The two input terminals 12a, 12b are disposed and configured to be releasably connected to the two detonator leg wires 20 that are attached to an associated detonator 100. The microprocessor 205 is configured to receive an input signal from the respective two detonator leg wires 20 when a voltage reference 212 from a voltage reference source 215 is injected into the two detonator leg wires 20 via the two electrical input terminals 12a, 12b. The USB connector 210 is disposed and configured to be releasably connected to a handheld computer 10.

[0054] In an embodiment, and with particular reference to Figure 1, the USB connector 210 is disposed at one end of a flexible USB cable 16, and is configured to be releasably connected to the handheld computer 10 via hand manipulation of the flexible USB cable 16. An opposing end of the flexible USB cable 16 is electrically connected to the microprocessor 205.

[0055] In another embodiment, and with particular reference to Figure 2A, the electrical interface apparatus 12 includes a flexible hood 220 disposed on a side of the apparatus 12 opposite that of the two electrical input terminals 12a, 12b, and the USB connector 210 is disposed within the flexible hood 220. Here, the USB connector 210 is releasably connectable to the handheld computer 10 concurrently with the flexible hood 220 being releasably sealable to the handheld computer 10 to form a weather seal between the apparatus 12 and the handheld computer 10 to protect the connections at the USB connector 210 when the apparatus 12 is releasably connected to the handheld computer 10.

[0056] In yet another embodiment, and with reference to Figure 2B, the electrical interface apparatus 12 is integrally arranged with, that is, immovably fixed to, the handheld computer 10, in a combination that forms a logger 14 when appropriate logging software is loaded onto the handheld computer 10. Here, there would be no need for a USB connector per se, as the microprocessor 205 would be configured and disposed in direct signal communication with an input port 225 of the handheld computer 10. The input port 225 is depicted in dashed line fashion in Figure 2B, and in association with the USB connector 210 in Figure

7, for illustrative purposes, but may be disposed within the combination logger 14 in any manner suitable for the purposes disclosed herein.

[0057] While Figures 1, 2A and 2B, depict alternative embodiments, all embodiments of the invention employ the functionality of the block diagram schematic 200 depicted in Figure 7, which is a block diagram schematic of the electrical interface apparatus 12, and which will now be discussed in more detail.

[0058] With reference to Figures 1-3 as well as Figure 7, an embodiment of the electrical interface apparatus 12 includes microprocessor 205 disposed in electrical communication with the two electrical input terminals 12a, 12b via an analog-to-digital (A/D) converter 230, and disposed in electrical communication with the USB connector 210 via a USB-to-serial interface 235, where serial data 240 is communicated between the microprocessor 205 and the USB-to-serial interface 235, and USB data 245 is communicated between the USB-to-serial interface 235 and the USB connector 210. The A/D converter 230 is configured to convert an input analog signal 250 from the two electrical input terminals 12a, 12b to a digital signal 255 to be communicated to the microprocessor 205.

[0059] As mentioned above, a voltage reference source 215 is disposed in electrical communication with the two electrical input terminals 12a, 12b, and is configured to provide voltage reference 212 that is injected into the two detonator leg wires 20 via the two electrical input terminals 12a, 12b. The voltage reference 212 has a value that is below the ignition voltage of the detonator 100 under investigation, but of sufficient value for the firmware programmed into the handheld computer 10 to test for and recognize an acceptable range of resistance of the particular detonator 100, thereby providing indication of the electrical health of the detonator 100 under investigation. In an embodiment, the ignition circuit of each detonator 100 in the bore hole 18 includes a resistor electrically connected across the two detonator leg wires 20, but disposed on the ignition circuit proximate the igniter of the detonator, as described in commonly assigned U.S. Publ. No. 2008/0223241. As a result of this testing, an embodiment of the invention provides a digital record of the status of the detonator 100 and other conditions in the borehole 18.

[0060] With reference still to Figure 7, a power bus 260 is disposed in electrical communication with the USB connector 210, and offers a means for providing operational power, data communications, and grounding, via the USB connector 210 using known USB industry standard specifications, to the voltage reference source 215, the A/D converter 230, the mi-

croprocessor 205, and the USB-to-serial interface 235. While an embodiment is described herein with power bus 260 being a USB-type power bus, it will be appreciated that the invention is not so limited and may employ other power/communications/grounding bus configurations as suitable for the purposes disclosed herein. Consequently, bus configurations other than a USB-type bus are contemplated and considered within the scope of the invention disclosed herein.

[0061] In an embodiment, the voltage reference 212 is provided by the voltage reference source 215 integrally arranged within the electrical interface apparatus 12, as discussed above. However, in an alternative embodiment, the handheld computer 10 provides the voltage reference 212, which is communicated via the USB connector 210, or any other connector suitable for the purposes disclosed herein, and the USB power bus 260, or any other bus suitable for the purposes disclosed herein, to the two electrical input terminals 12a, 12b, as depicted by dashed bus path 265.

[0062] From the foregoing, it will be appreciated that an embodiment of the invention includes the microprocessor 205 being responsive to executable program code which when executed on the microprocessor 205 facilitates display, on the display 10a of the handheld computer 10, of a mixed number-and-symbol system in response to the input signal 250 from the two detonator leg wires 20 when the voltage reference 212 is injected into the two detonator leg wires 20 via the two electrical input terminals 12a, 12b.

[0063] It will also be appreciated that the display of the mixed number-and-symbol system may have more than one form.

[0064] In a first embodiment, the display includes display of a first symbol string, such as a plurality of plus sign characters for example, in response to the input signal 250 being representative of too high of a resistance at the two detonator leg wires 20, display of a second symbol string, such as a plurality of minus sign characters for example, in response to the input signal 250 being representative of too low of a resistance at the two detonator leg wires 20, and display of a numerical value representative of, and in response to, the input signal 250 being representative of a resistance at the two detonator leg wires 20 falling within a pre-defined acceptable range.

[0065] In a second embodiment, the display is not so much a display, but an indication, where the mixed number-and-symbol is replaced with a mixed number-and-indication. Here, the microprocessor 205 is responsive to executable program code which when executed

on the microprocessor 205 facilitates presentation of a mixed number-and-indicator system on an audio-visual system (referred to herein with reference to element 10a) of the handheld computer 10 in response to the input signal 250 from the two detonator leg wires 20 when the voltage reference 212 is injected into the two detonator leg wires 20 via the two electrical input terminals 12a, 12b.

[0066] In an embodiment, the presentation of the mixed number-and-indicator system includes audible presentation of a first sound, such as a relatively high frequency for example, in response to the input signal 250 being representative of too high of a resistance at the two detonator leg wires 20, audible presentation of a second sound, such as a relatively low frequency for example, in response to the input signal 250 being representative of too low of a resistance at the two detonator leg wires 20, and display of a numerical value representative of, and in response to, the input signal 250 being representative of a resistance at the two detonator leg wires 20 falling within a pre-defined acceptable range.

[0067] In an alternative embodiment, the presentation of the mixed number-and-indicator system includes visual presentation of a first color, such as green for example, in response to the input signal 250 being representative of too high of a resistance at the two detonator leg wires 20, visual presentation of a second color, such as red for example, in response to the input signal 250 being representative of too low of a resistance at the two detonator leg wires 20, and display of a numerical value representative of, and in response to, the input signal 250 being representative of a resistance at the two detonator leg wires 20 falling within a pre-defined acceptable range.

[0068] In an embodiment, the mixed number-and-symbol system is combined with the mixed number-and-indication system such that both visual display (symbols and/or colors) and audible presentation is provided for too high or too low of a resistance at the two detonator leg wires 20.

[0069] From the foregoing description of structure, it will be appreciated that an embodiment of the invention also includes a method for checking an electrical characteristic, such as but not limited to resistance, of a borehole detonator 100 having two detonator leg wires 20, using an electrical interface apparatus 12 in combination with a handheld computer 10, the structure of such combination being discussed above. In an example embodiment, the method includes connecting the two electrical input terminals 12a, 12b to the two detonator leg wires 20, injecting a voltage reference 212 into the two detonator leg wires 20 and receiv-

ing an input signal 250 from the two detonator leg wires 20 in response to the injected voltage reference 212, and displaying a mixed number-and-symbol system and/or a mixed number-and-indication system on the display and/or an audio-visual system of the handheld computer 10 in response to the input signal 250, where the mixed number-and-symbol system and/or the mixed number-and-indication system is representative of the resistance measured at the two detonator leg wires 20, as discussed above.

[0070] While reference is made herein to a USB connector 210, it will be appreciated that the scope of the invention is not limited to only a USB connector, but may also be practiced using any connector and associated cable suitable for the purposes disclosed herein. All such other connectors and associated cables are contemplated and considered within the scope of the invention disclosed herein.

[0071] An embodiment of the invention may be embodied in the form of computer-implemented processes and apparatuses for practicing those processes. The present invention may also be embodied in the form of a computer program product having computer program code containing instructions embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, USB (universal serial bus) drives, or any other computer readable storage medium, such as random access memory (RAM), read only memory (ROM), erasable programmable read only memory (EPROM), electrically erasable programmable read only memory (EEPROM), or flash memory, for example, wherein, when the computer program code is loaded into and executed by a computer, the computer becomes an apparatus for practicing the invention. The present invention may also be embodied in the form of computer program code, for example, whether stored in a storage medium, loaded into and/or executed by a computer, or transmitted over some transmission medium, such as over electrical wiring or cabling, through fiber optics, or via electromagnetic radiation, wherein when the computer program code is loaded into and executed by a computer, the computer becomes an apparatus for practicing the invention. When implemented on a general-purpose microprocessor, the computer program code segments configure the microprocessor to create specific logic circuits. A technical effect of the executable instructions is to check an electrical characteristic of a borehole detonator.

[0072] While the invention has been described in detail with reference to specific embodiments, it will be appreciated that numerous variations may be made to the described embodiments which variations nonetheless lie within the scope of the present invention.

[0073] While certain combinations of features relating to an electrical interface apparatus and/or detonator test apparatus have been described herein, it will be appreciated that these certain combinations are for illustration purposes only and that any combination of any of these features may be employed, explicitly or equivalently, either individually or in combination with any other of the features disclosed herein, in any combination, and all in accordance with an embodiment of the invention. Any and all such combinations are contemplated herein and are considered within the scope of the invention disclosed.

CLAIMS

What is claimed is:

1. An electrical interface apparatus, comprising:
two electrical input terminals;
a microprocessor disposed in electrical communication with the two electrical input terminals; and
a USB connector disposed in electrical communication with the microprocessor;
wherein the two input terminals are disposed and configured to be releasably connected to two detonator leg wires;
wherein the microprocessor is configured to receive an input signal from the two detonator leg wires when a voltage reference is injected into the two detonator leg wires via the two electrical input terminals; and
wherein the USB connector is disposed and configured to be releasably connected to a handheld computer.
2. The apparatus of Claim 1, wherein:
the USB connector is disposed at one end of a flexible USB cable, and is configured to be releasably connected to the handheld computer via hand manipulation of the flexible USB cable, and wherein an opposing end of the flexible USB cable is electrically connected to the microprocessor.
3. The apparatus of Claim 1, further comprising:
a flexible hood disposed on a side of the apparatus opposite that of the two electrical input terminals;
wherein the USB connector is disposed within the flexible hood;
wherein the USB connector is releasably connectable to the handheld computer concurrently with the flexible hood being releasably sealable to the handheld computer to form a weather seal between the apparatus and the handheld computer to protect the connections at the USB connector when the apparatus is releasably connected to the handheld computer.

4. The apparatus of Claim 1, further comprising:
a voltage reference source disposed in electrical communication with the two electrical input terminals;

wherein the voltage reference source is configured to provide the voltage reference to be injected into the two detonator leg wires via the two electrical input terminals.

5. The apparatus of Claim 1, further comprising:
a USB power bus disposed and configured in electrical communication with the USB connector and the two electrical input terminals;

wherein the USB connector is configured to receive the voltage reference from the handheld computer and communicate the voltage reference to the two electrical input terminals via the USB power bus.

6. The apparatus of Claim 1, further comprising:
an analog-to-digital converter disposed in electrical communication between the two electrical input terminals and the microprocessor, and configured to convert an analog signal from the two electrical input terminals to a digital signal to be communicated to the microprocessor.

7. The apparatus of Claim 6, further comprising:
a serial-to-USB interface disposed in electrical communication between the microprocessor and the USB connector, the serial-to-USB interface disposed and configured to convert serial data from/to the microprocessor to USB data to/from the USB connector.

8. The apparatus of Claim 1, wherein:
the microprocessor is responsive to executable program code which when executed on the microprocessor facilitates display of a mixed number-and-symbol system on a display of the handheld computer in response to the input signal from the two detonator leg wires when the voltage reference is injected into the two detonator leg wires via the two electrical input terminals.

9. The apparatus of Claim 8, wherein the display of the mixed number-and-symbol system comprises:

display of a first symbol string in response to the input signal being representative of too high of a resistance at the two detonator leg wires;

display of a second symbol string in response to the input signal being representative of too low of a resistance at the two detonator leg wires; and

display of a numerical value representative of, and in response to, the input signal being representative of a resistance at the two detonator leg wires falling within a pre-defined acceptable range.

10. The apparatus of Claim 9, wherein:

the first symbol string comprises a plurality of plus sign characters; and

the second symbol string comprises a plurality of minus sign characters.

11. The apparatus of Claim 1, wherein:

the microprocessor is responsive to executable program code which when executed on the microprocessor facilitates presentation of a mixed number-and-indicator system on an audio-visual system of the handheld computer in response to the input signal from the two detonator leg wires when the voltage reference is injected into the two detonator leg wires via the two electrical input terminals.

12. The apparatus of Claim 11, wherein the presentation of the mixed number-and-indicator system comprises:

audible presentation of a first sound in response to the input signal being representative of too high of a resistance at the two detonator leg wires;

audible presentation of a second sound in response to the input signal being representative of too low of a resistance at the two detonator leg wires; and

display of a numerical value representative of, and in response to, the input signal being representative of a resistance at the two detonator leg wires falling within a pre-defined acceptable range.

13. The apparatus of Claim 11, wherein the presentation of the mixed number-and-indicator system comprises:

visual presentation of a first color in response to the input signal being representative of too high of a resistance at the two detonator leg wires;

visual presentation of a second color in response to the input signal being representative of too low of a resistance at the two detonator leg wires; and

display of a numerical value representative of, and in response to, the input signal being representative of a resistance at the two detonator leg wires falling within a pre-defined acceptable range.

14. A combination logger and electrical interface apparatus for testing seismic borehole shots, the combination comprising:

a logger comprising a handheld computer having an input port and a user interface;
and

an electrical interface apparatus comprising:

two electrical input terminals; and

a microprocessor disposed in electrical communication with the two electrical input terminals;

wherein the two input terminals are disposed and configured to be releasably connected to two detonator leg wires of the seismic borehole shots;

wherein the microprocessor is configured to receive an input signal from the two detonator leg wires when a voltage reference is injected into the two detonator leg wires via the two electrical input terminals; and

wherein the microprocessor configured and disposed in signal communication with the input port of the handheld computer.

15. The combination of Claim 14, wherein:

the handheld computer is configured to provide a digital record of borehole attributes measured at a specific location, time, and date, at least a portion of the borehole attributes being received from the electrical interface apparatus.

16. The combination of Claim 15, wherein:
the specific location, time, and date are provided by a GPS receiver disposed within the handheld computer.

17. The combination of Claim 15, wherein:
the borehole attributes include at least one of: type of explosive in a respective borehole; quantity of explosive in a respective borehole; weight of explosive in a respective borehole; depth of a respective borehole; type of rock in a respective borehole; and, electrical resistance of a detonator in a respective borehole.

18. A method for checking an electrical characteristic of a borehole detonator having two detonator leg wires, the method comprising:

connecting an electrical interface apparatus to a handheld computer, the electrical interface apparatus comprising:

two electrical input terminals;

a microprocessor disposed in electrical communication with the two electrical input terminals; and

a USB connector disposed in electrical communication with the microprocessor;

wherein the two input terminals are disposed and configured to be releasably connected to the two detonator leg wires;

wherein the microprocessor is configured to receive an input signal from the two detonator leg wires when a voltage reference is injected into the two detonator leg wires via the two electrical input terminals;

wherein the microprocessor is responsive to executable program code which when executed on the microprocessor facilitates display of a mixed number-and-symbol system on a display of the handheld computer in response to the input signal from the two detonator leg wires when the voltage reference is injected into the two detonator leg wires via the two electrical input terminals; and

wherein the USB connector is disposed and configured to be releasably connected to a handheld computer;

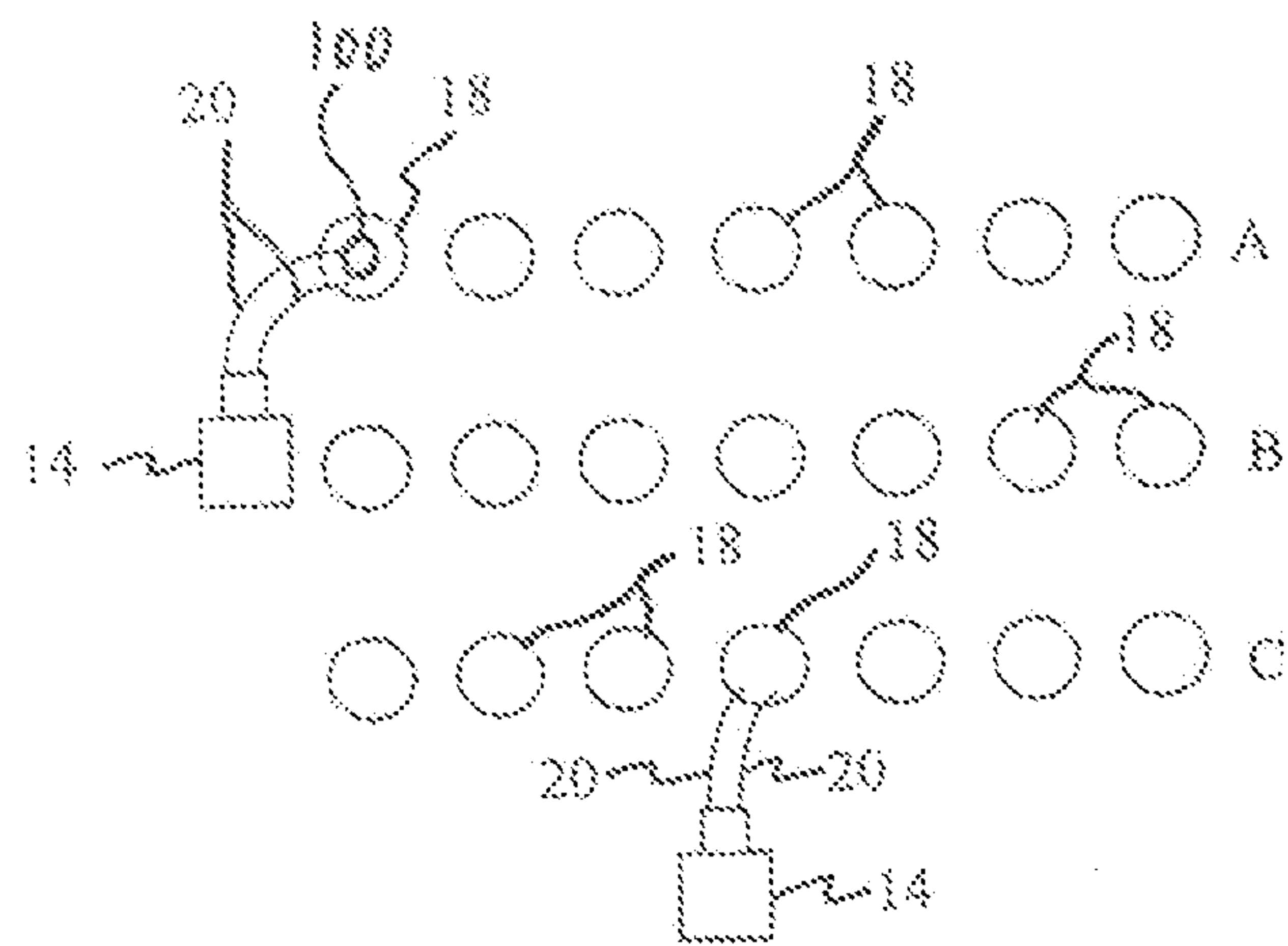
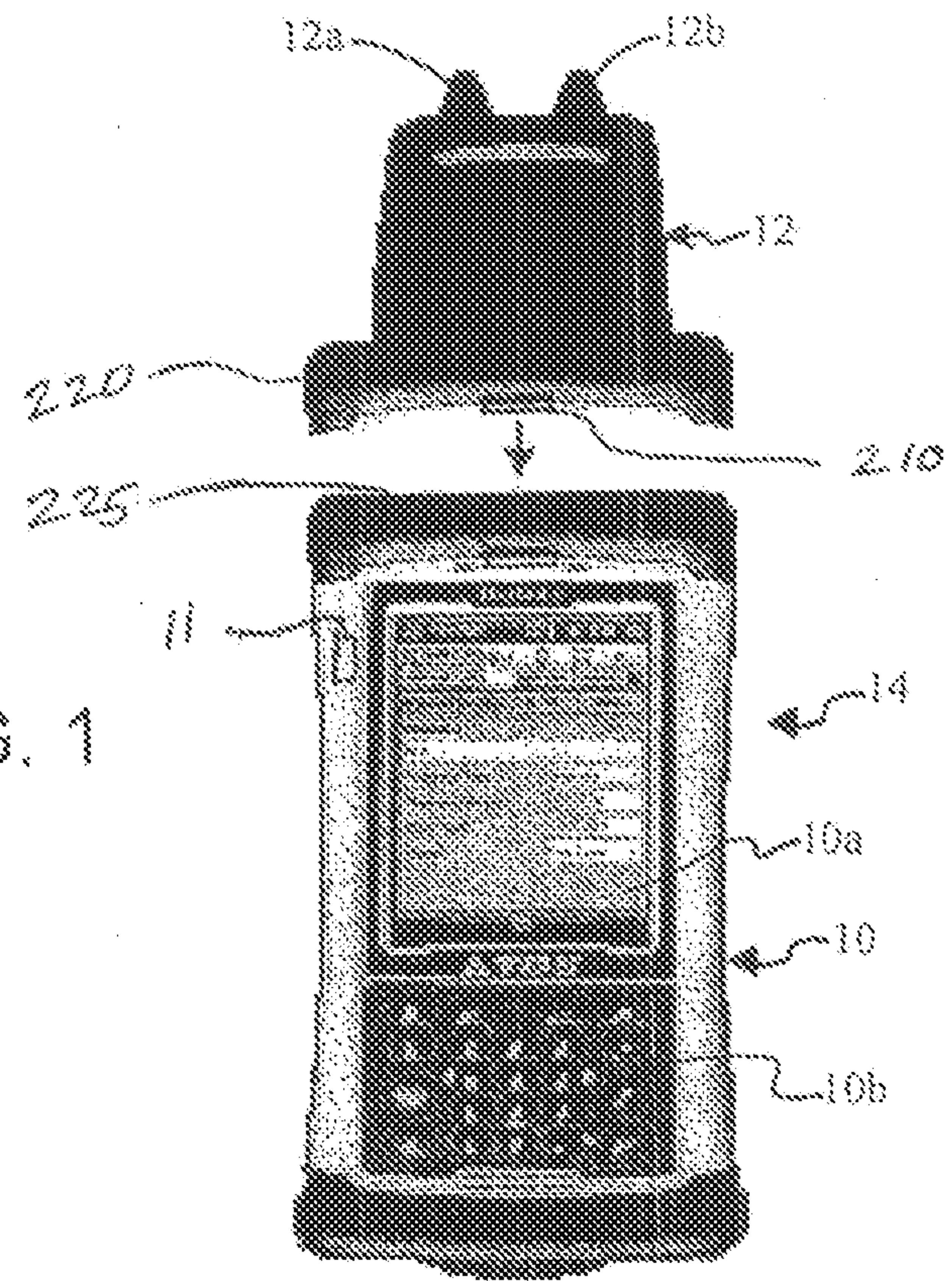
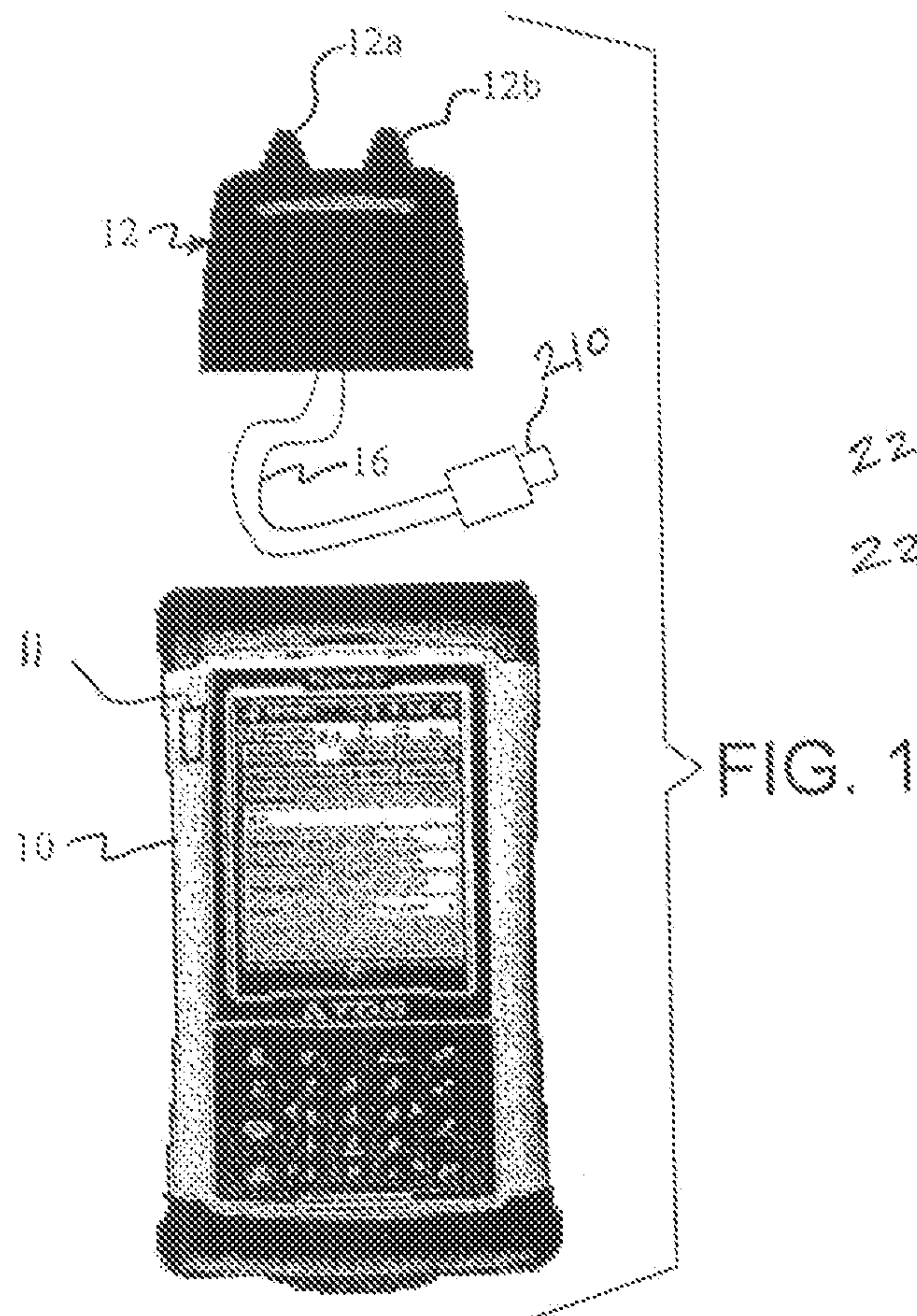
connecting the two electrical input terminals to the two detonator leg wires;

injecting a voltage reference into the two detonator leg wires and receiving an input signal from the two detonator leg wires in response to the injected voltage reference; and

displaying the mixed number-and-symbol system on the display of the handheld computer in response to the input signal;

wherein the mixed number-and-symbol system is a numerical value representative of, and in response to, the input signal being representative of a resistance at the two detonator leg wires falling within a pre-defined acceptable range; and

wherein the mixed number-and-symbol system is a string of characters in response to the input signal being representative of a resistance at the two detonator leg wires falling outside the pre-defined acceptable range.



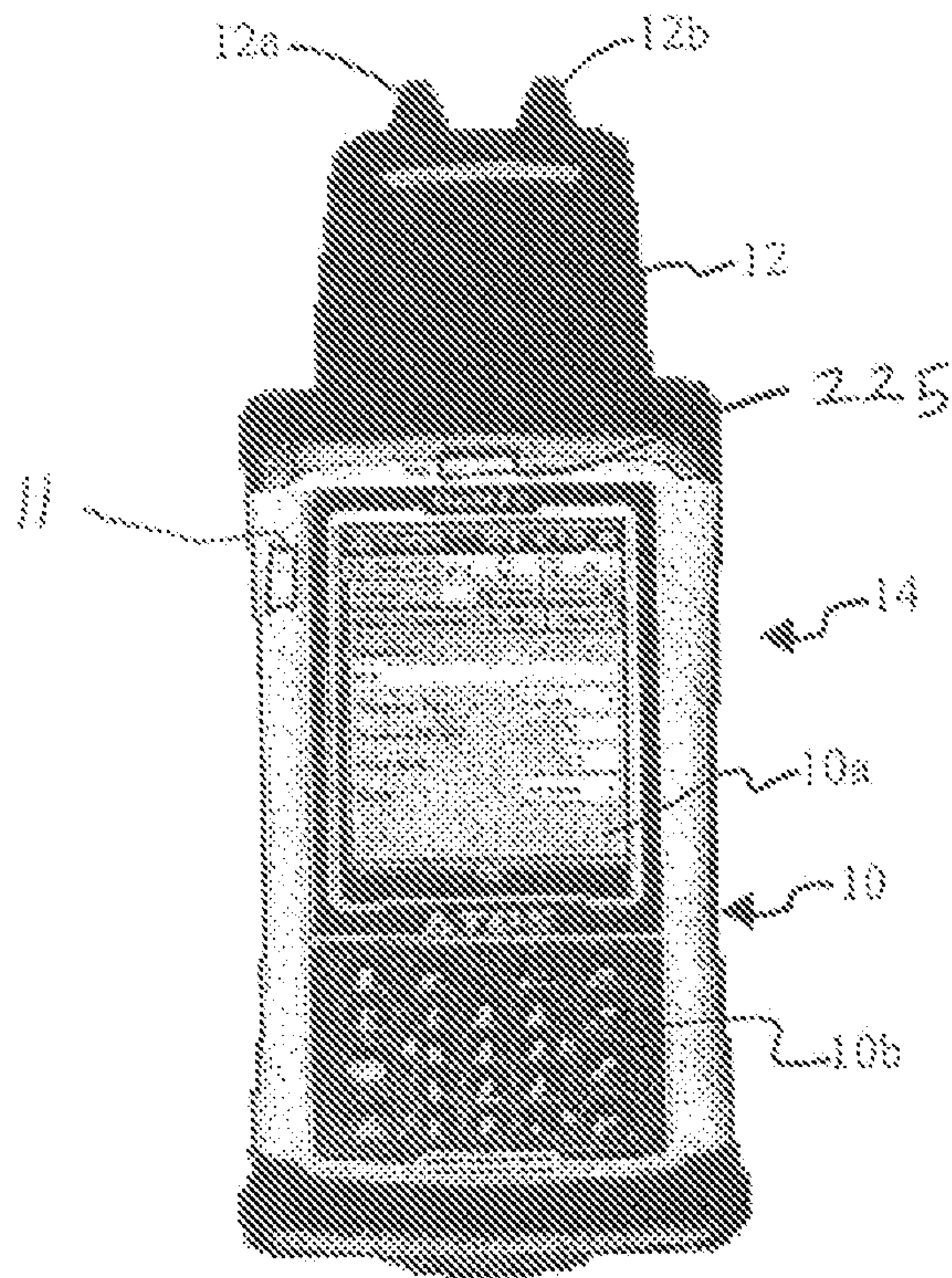


FIG. 2B

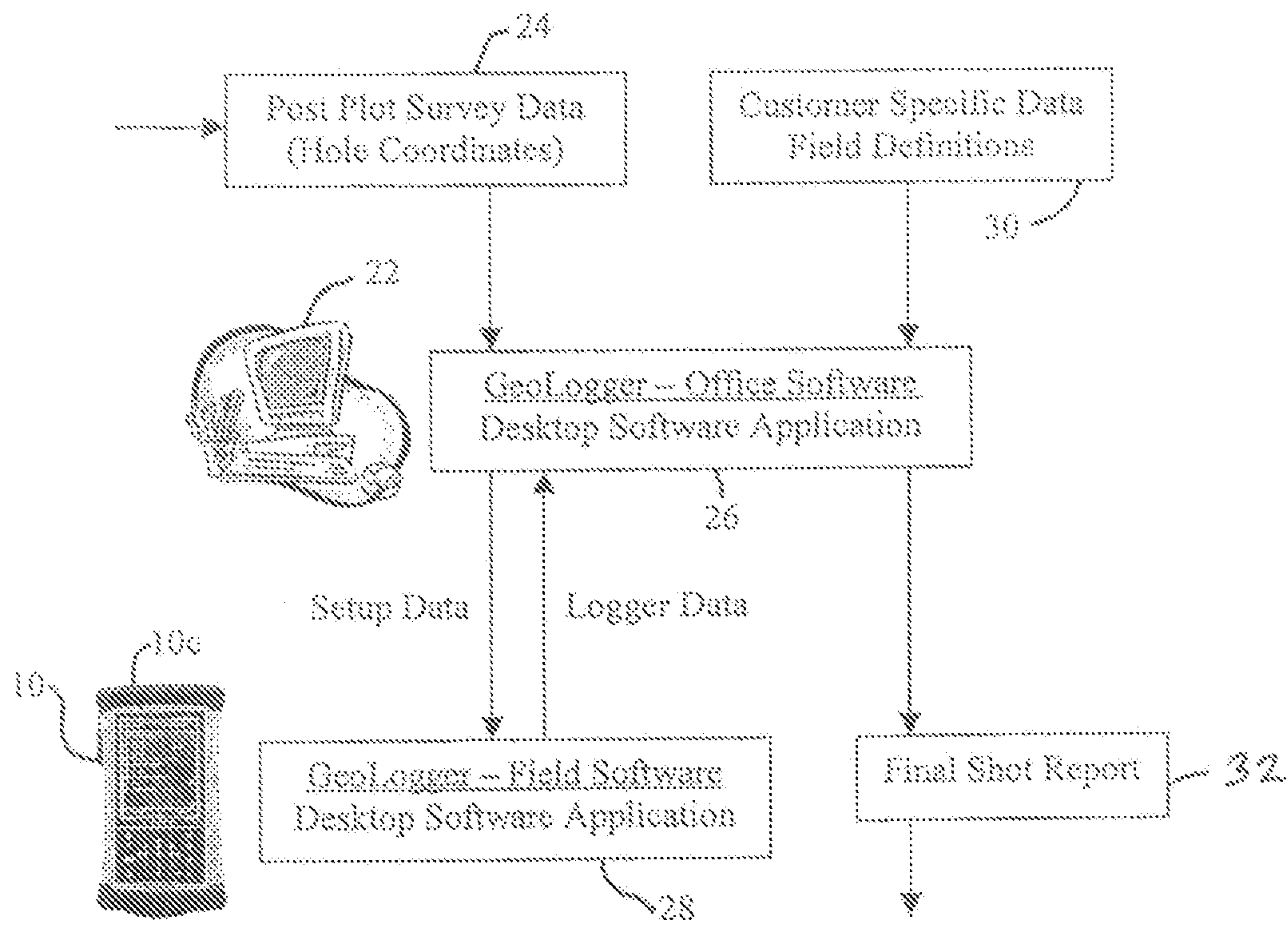


FIG. 4

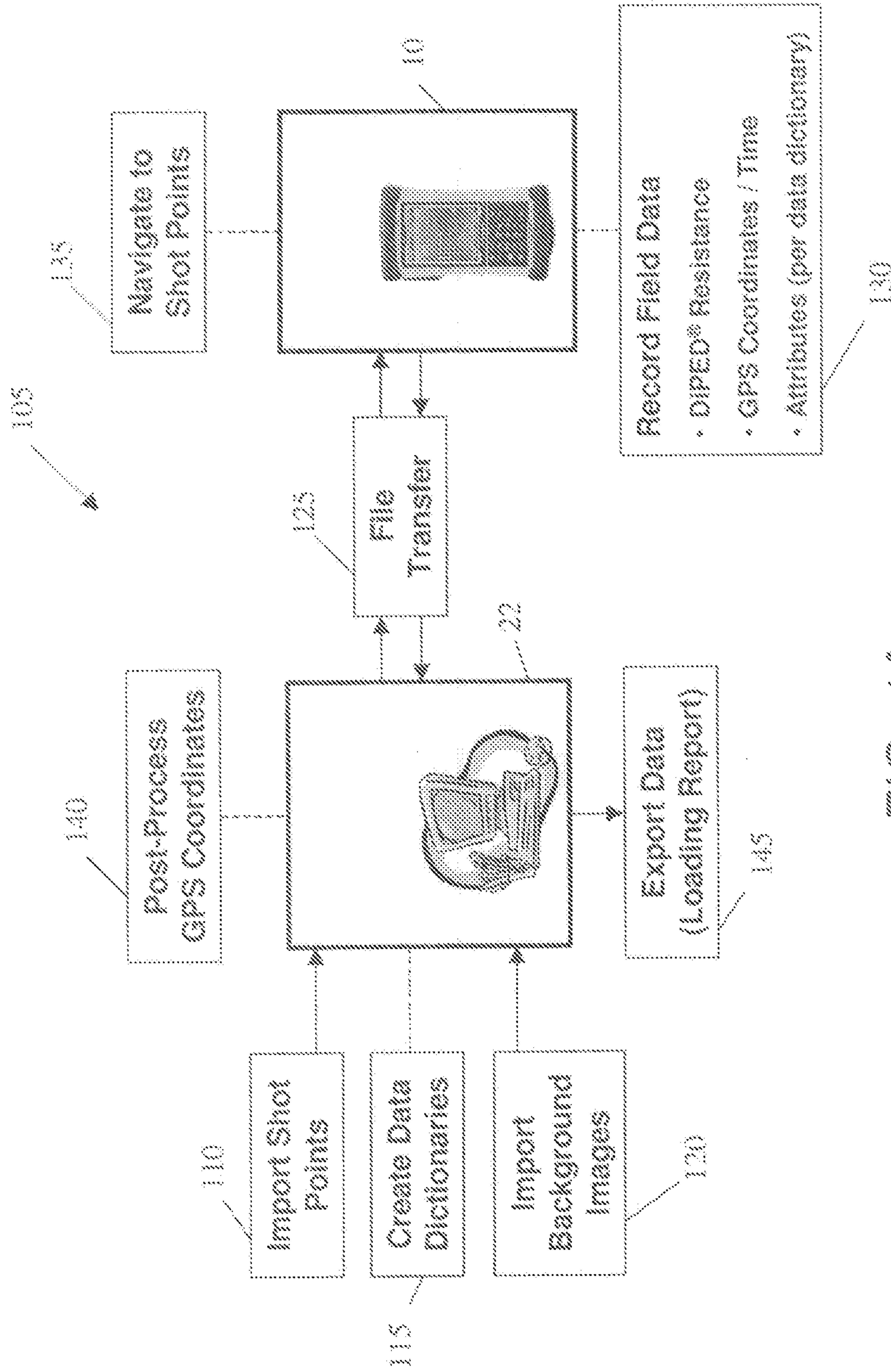


FIG. 4A

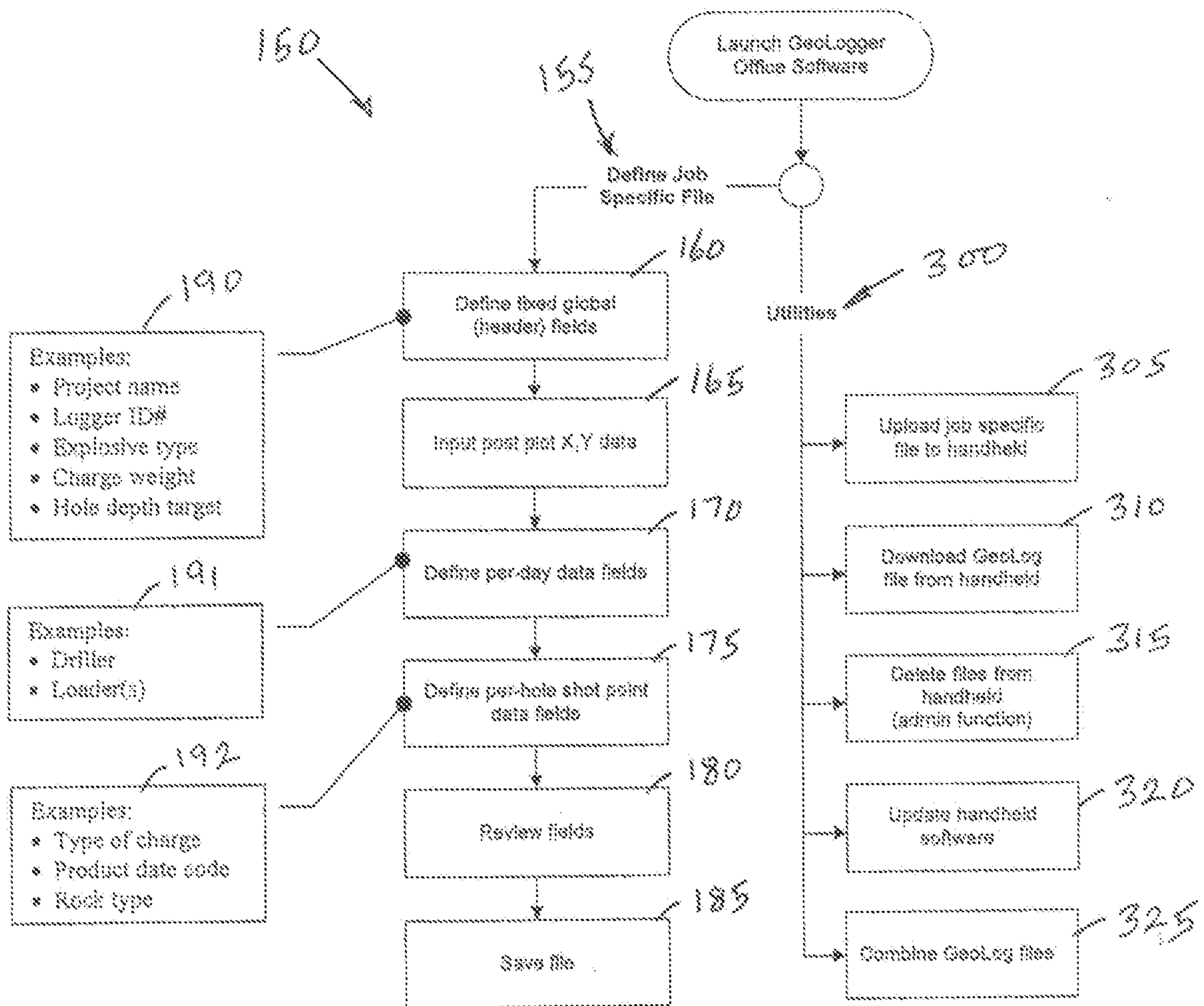


FIG. 5

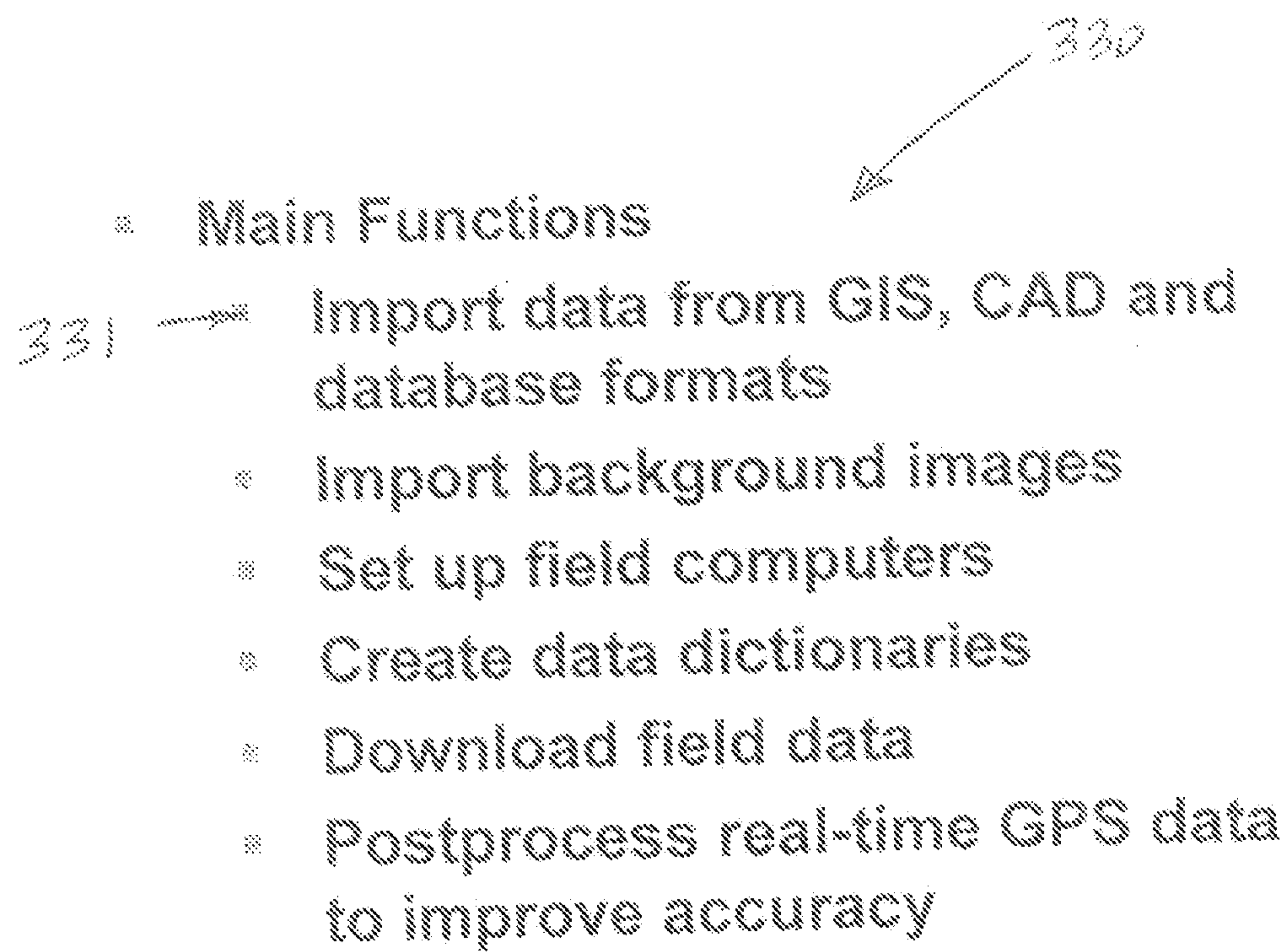
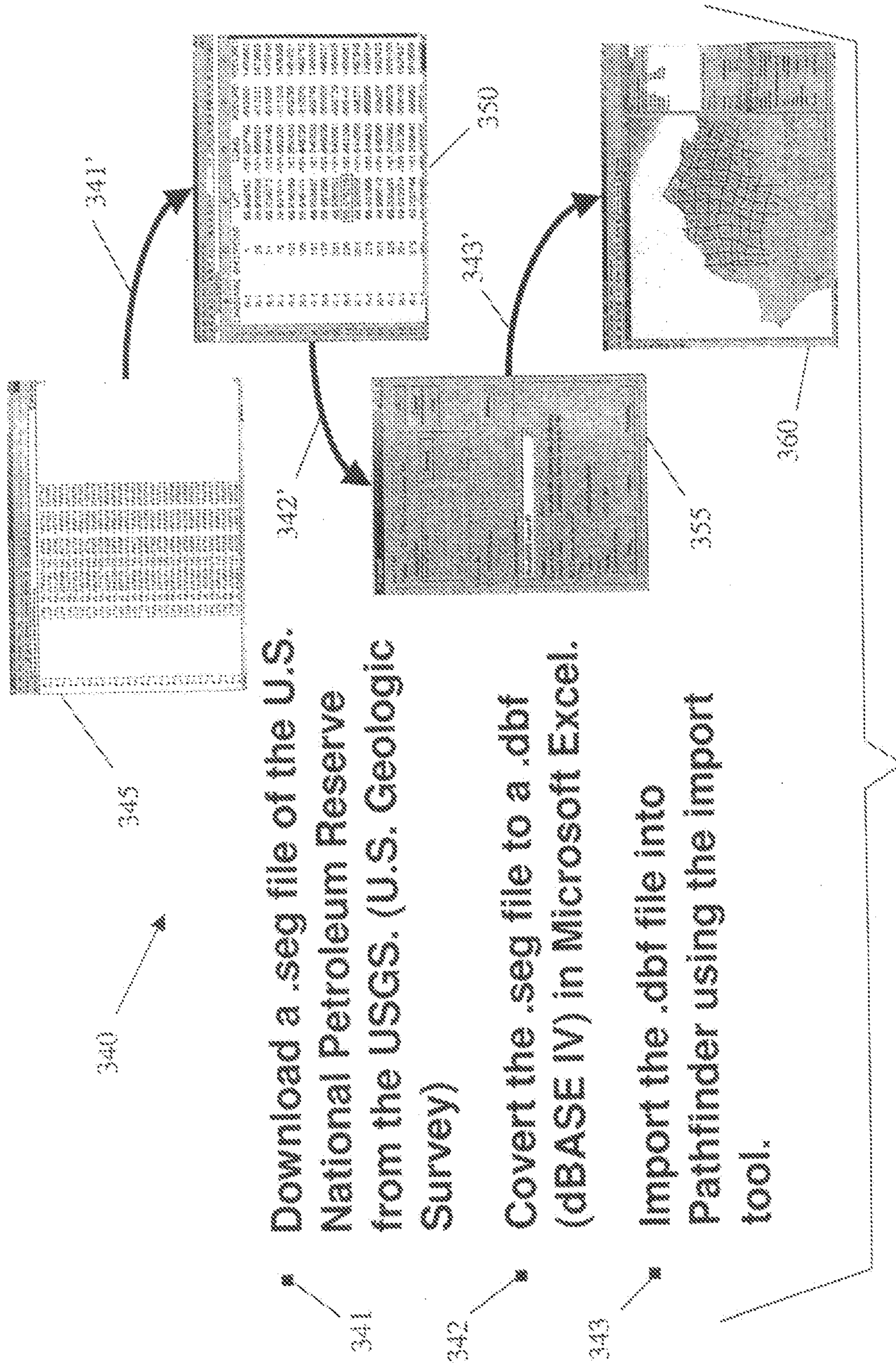


FIG. 6A

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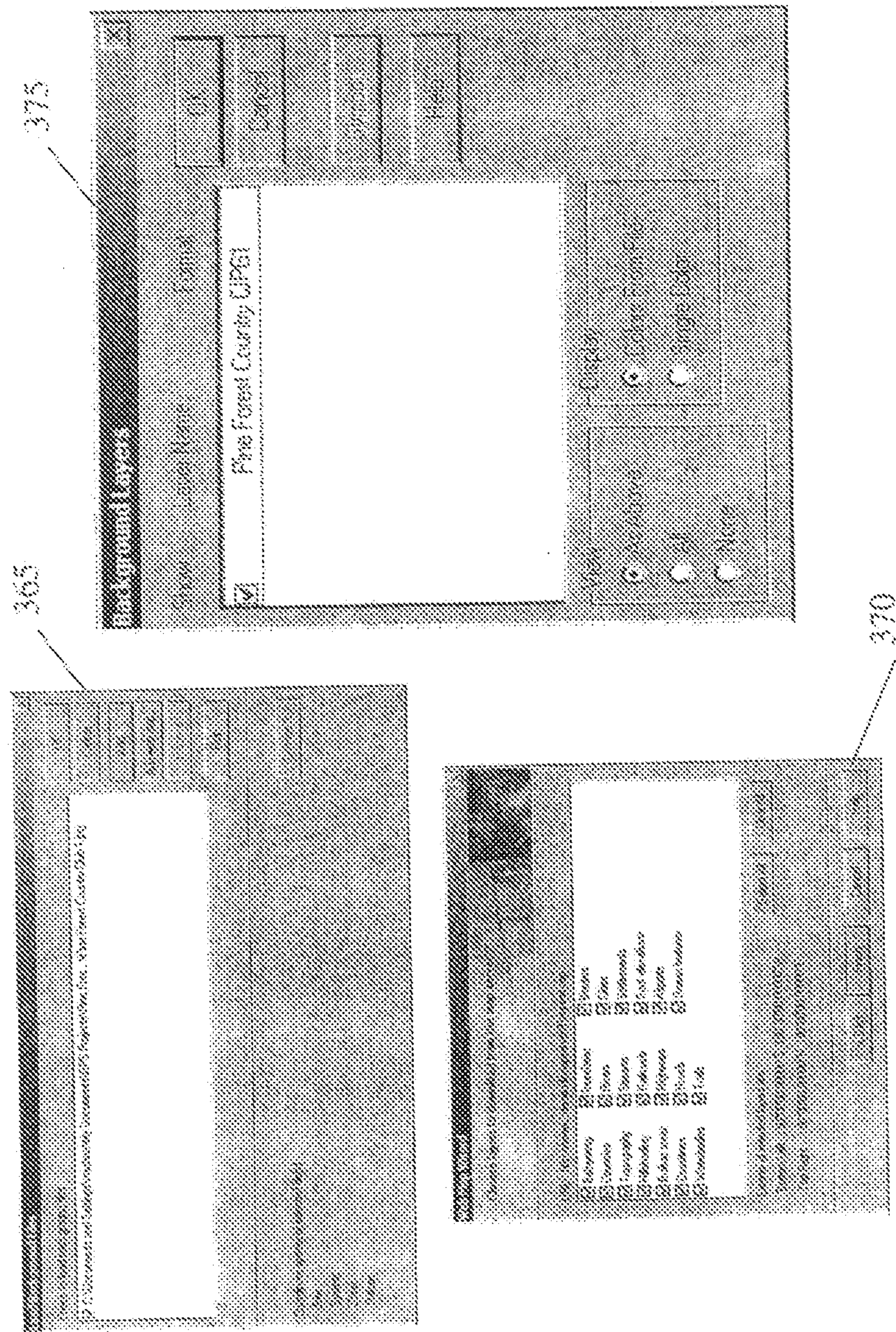


FIG. 6C

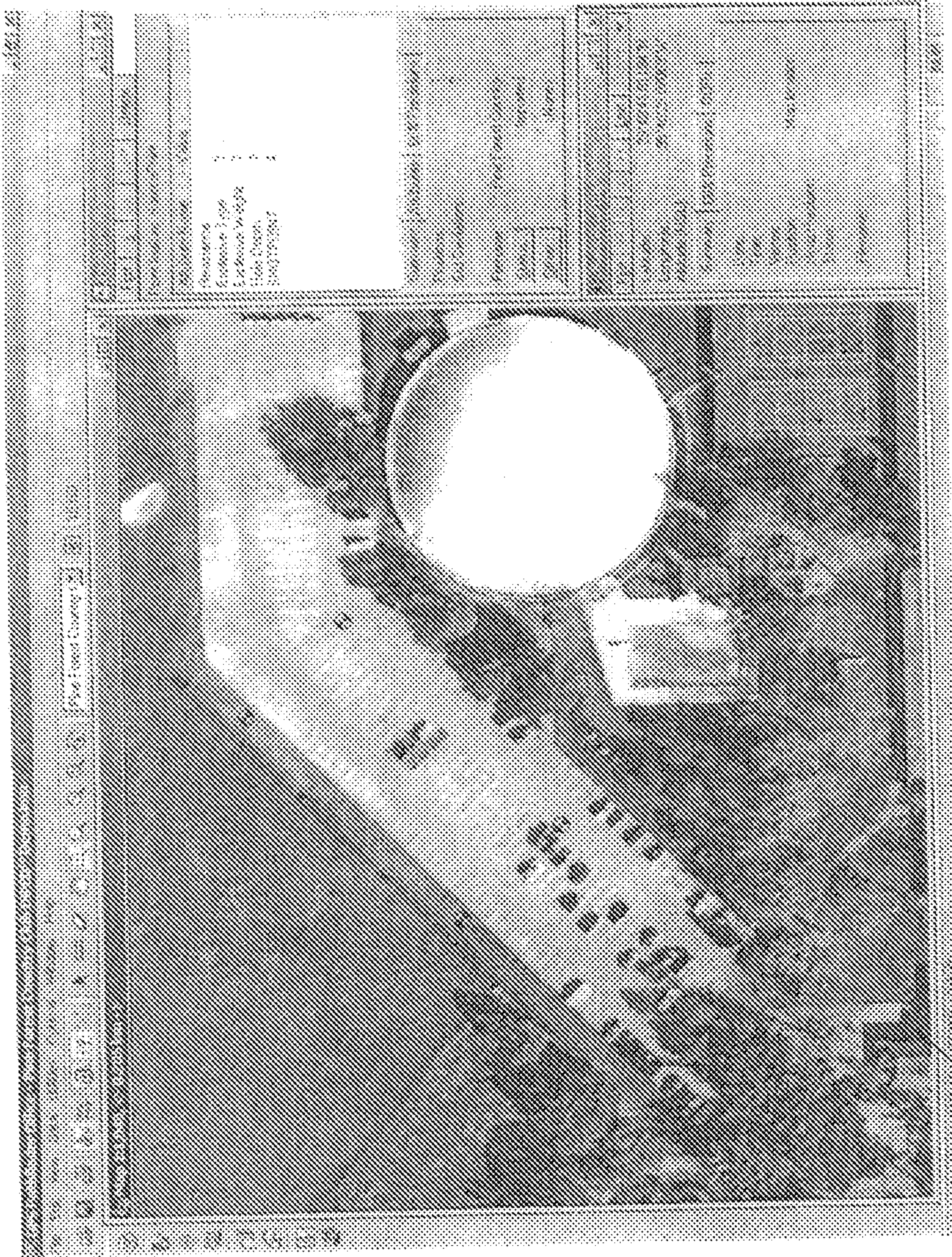
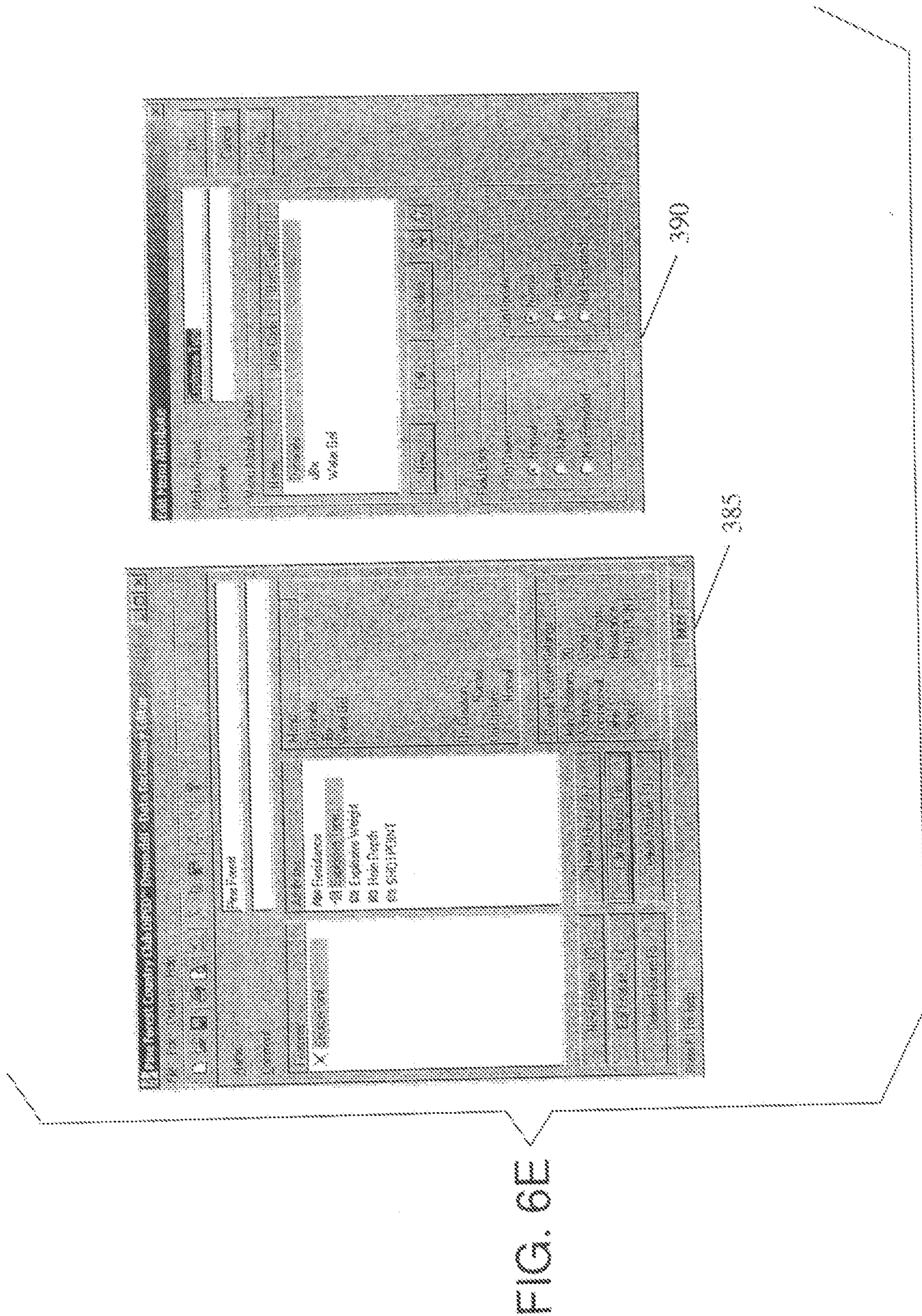


FIG. 6D

380

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11/15

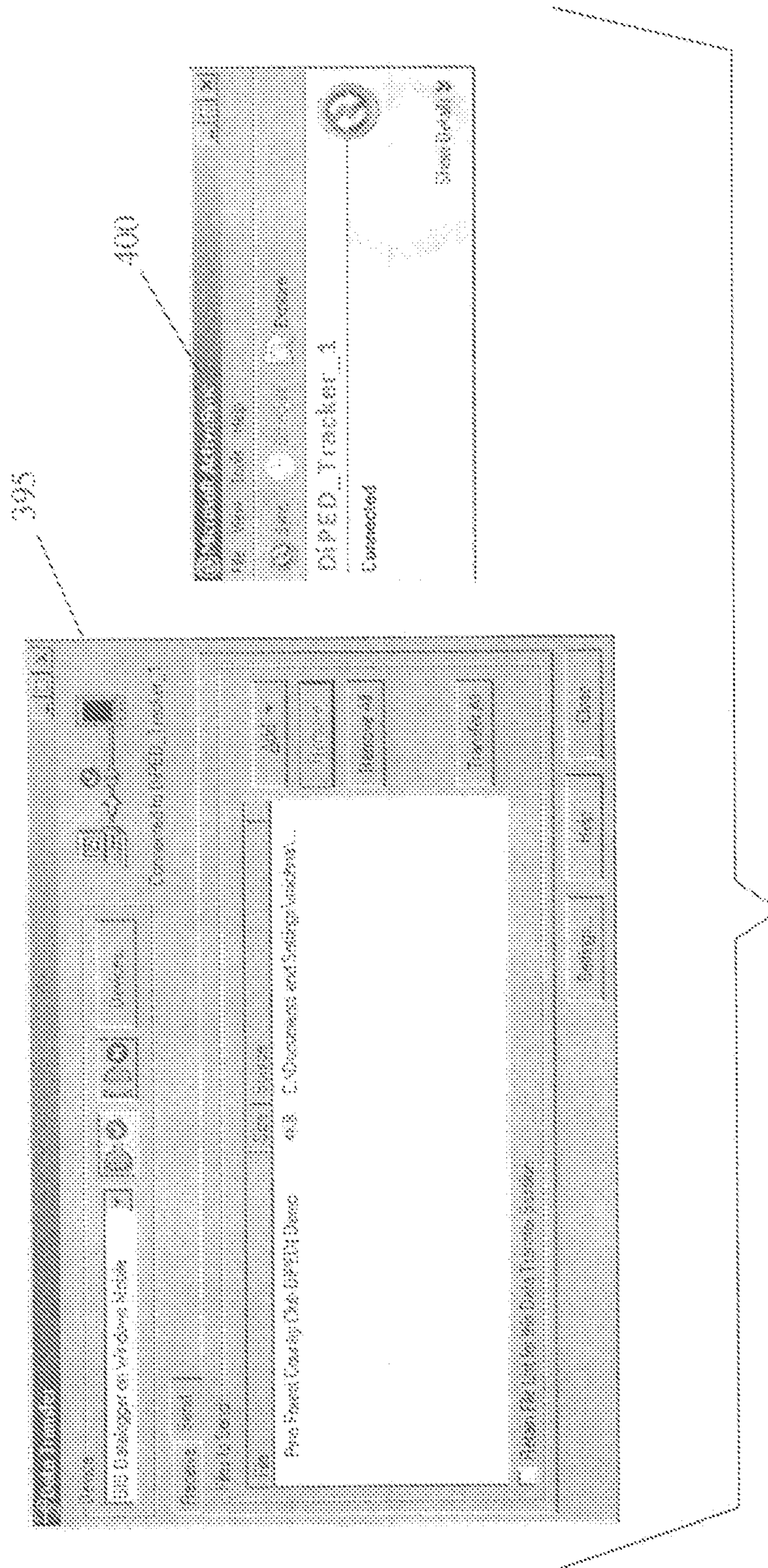


FIG. 6F

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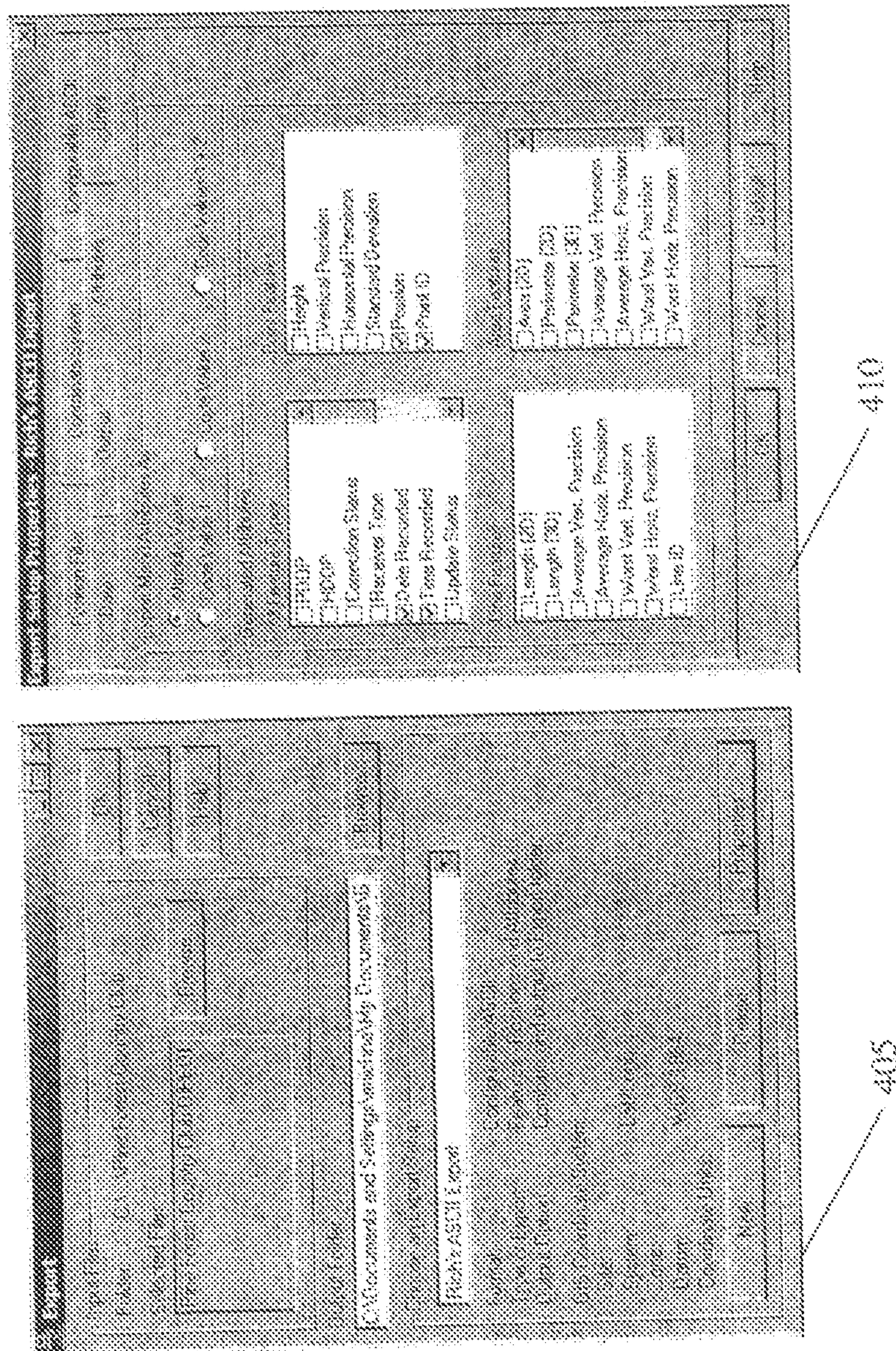
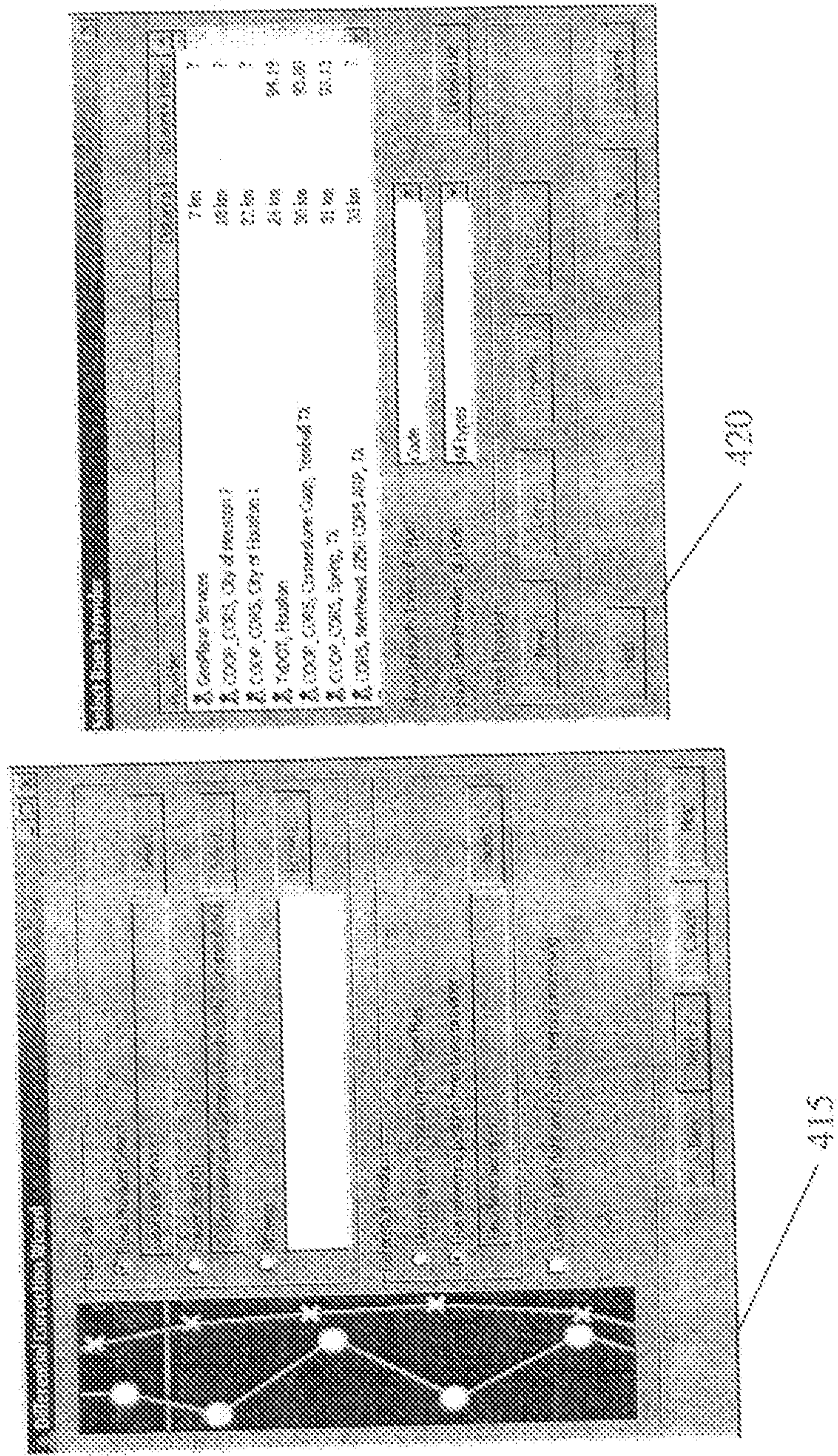


FIG. 6G



100

14/15

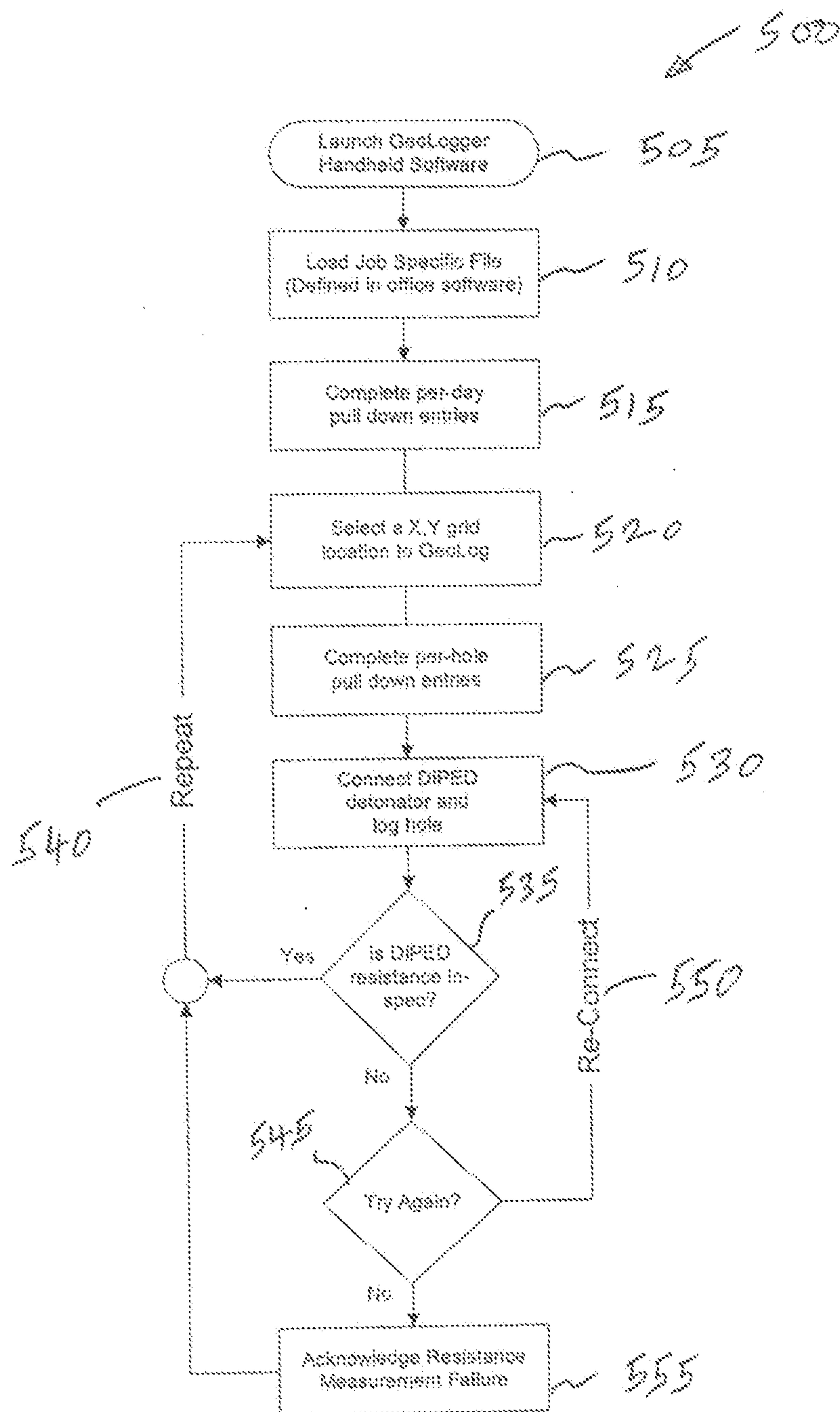


FIG. 6I

15/15

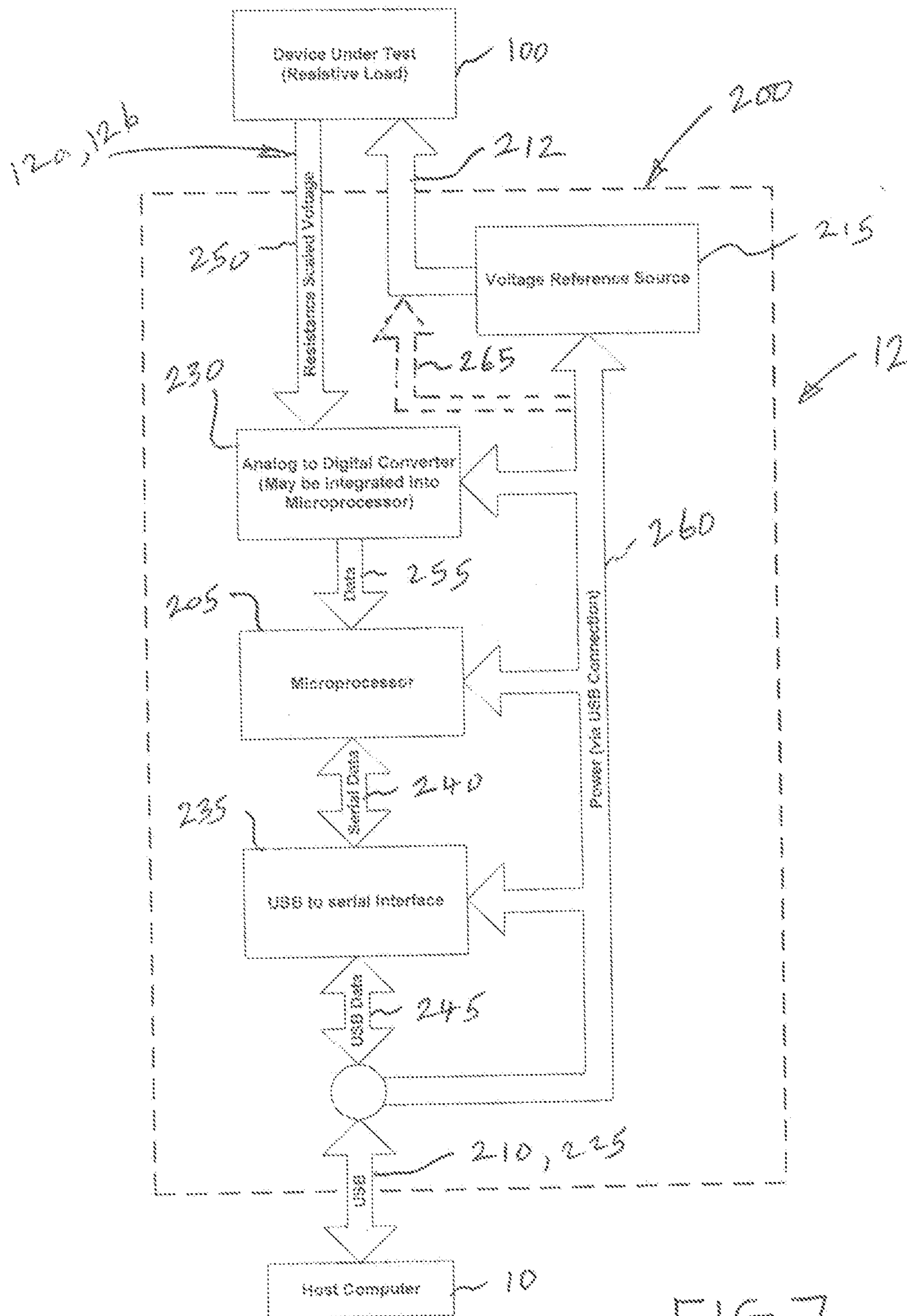


FIG. 7

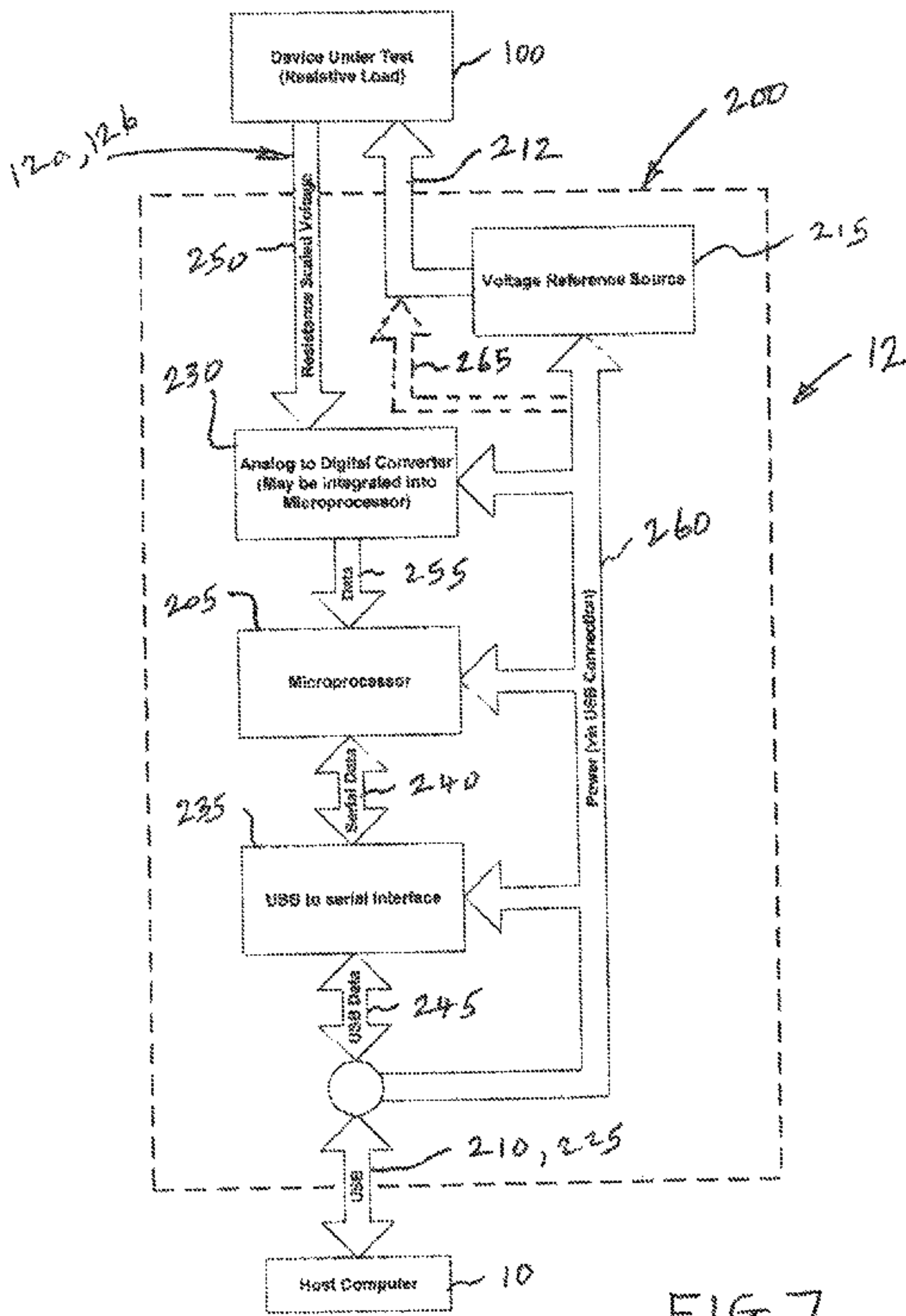


FIG. 7