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(71) Applicant(s)

Entek IRD International Corporation

(72) Inventor(s)

Richard L. Schiltz; Andrew J. Bates; Jeffery P. Watkins

(74) Agent/Attorney

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ENTEK IRD INTERNATIONAL CORPORATION.

(71) Applicant *(for all designated States except US)*: ~~ENTEK SCIENTIFIC CORPORATION~~ [US/US]; Suite 316, 4480 Lake Forest Drive, Cincinnati, OH 45242-3740 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: SCHILTZ, Richard, L. [US/US]; 7098 Walliswood Court, Hamilton, OH 45011 (US). BATES, Andrew, J. [GB/GB]; Westfields, Martin Street, Baltonsborough, Somerset BA6 8QY (GB). WATKINS, Jeffery, P. [US/US]; 2922 La Feuille Avenue, Cincinnati, OH 45211 (US).

(74) Agents: JONES, Larry, C. et al.; Bell, Seltzer, Park & Gibson, P.O. Drawer 34009, Charlotte, NC 28234 (US).

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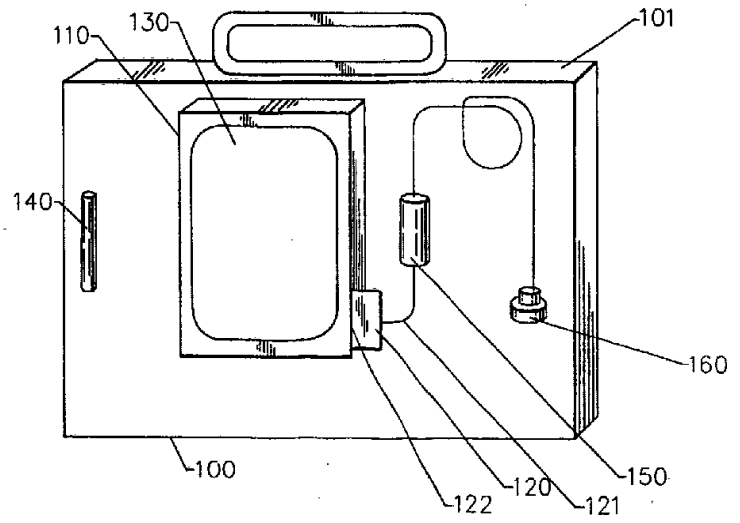
(54) Title: PORTABLE, SELF-CONTAINED DATA COLLECTION SYSTEMS AND METHODS

(57) Abstract

A portable self-contained data collection system (100) for measuring and collecting vibration data from machines includes an accelerometer (160) which is coupled to the analog input of a data acquisition card (120). The data acquisition card (120) samples and digitizes the analog signal to produce a time domain digital signal. The data acquisition card output (122) is coupled to a battery-powered portable computer (110). The battery-powered portable computer (110) includes a database (220) having machine identifications and associated measurement parameters. The portable computer (110) processes the time domain digital signal according to the measurement parameters associated with a selected machine identification, and produces a frequency domain digital signal by performing a Fast Fourier Transform and other digital signal processing operations. The frequency domain signal is also analyzed in the portable computer (110) to produce predictive maintenance information. A power supply (150) for supplying power to the accelerometer (160) is also included. The accelerometer power supply (150) electrically and mechanically couples the accelerometer (160) to the data acquisition card (120). It supplies power to the accelerometer (160) when the data acquisition card is activated. The portable self-contained data collection system (100) can be used to measure and collect vibration data from machines and to analyze this data to produce predictive maintenance information.



PORTABLE, SELF-CONTAINED DATA COLLECTION SYSTEMS AND METHODS

Field of the Invention

This invention relates to predictive maintenance systems and methods, and more particularly to computer-based data collection systems and methods for measuring and collecting vibration data from machines.

Background of the Invention

Data collection systems and methods are now widely used for measuring and collecting vibration data from machines, for predictive maintenance purposes. Data collection systems typically include two major components: a portable data collector and a host computer. The portable data collector is typically a dedicated instrument to which accelerometers can be coupled, and which stores accelerometer-based vibration data for a machine. An example of a state-of-the-art data collector is the EMONITOR® dataline™ data collector marketed by Entek Scientific Corporation, assignee of the present application. The EMONITOR® dataline™ data collector is described in a manual entitled *"EMONITOR® for Windows EMONITOR® dataline™ (U.S.) Data Collector User's Guide, First Edition 1995"*, Manual No. EEW2501A, published by Entek Scientific Corporation, the disclosure of which is incorporated herein by reference.

The host computer is typically a standard PC-based computer which runs predictive maintenance data management and analysis software thereon. The host software allows a user to set up a database to model

the machinery for which vibration data is to be obtained. The software allows lists of machines to be set up for data collection. Each list includes a set of measurement parameters that control where and how to take and store a measurement. The host software allows one or more lists to be loaded into the data collector for collection. The user then takes the data collector to a machine to be measured, accesses the measurement parameters for that machine, and collects and stores vibration and other information. After collection, the data is unloaded from the data collector to the host. The host software then allows the data to be analyzed. Reports can be generated, including reports of measurements that exceed alarms. Graphical displays of the data can be produced, including trend, spectrum, frequency trend, time waveform and spectrum map plots.

An example of a system for collecting and processing data is described in U.S. Patent No. 4,885,707 to Nichol et al. ("Nichol"). The system according to Nichol provides a battery operated vibration data collector and processor unit which is equipped with an electro-optical wand for reading a bar code affixed to each data collection station on the machinery that is to be tested. The vibration of the machinery is sensed by electro-mechanical transducers temporarily attached by an operator to permanent indexing mounts at each test station. The bar code identifies the station and automatically initiates a predetermined sequence of vibration data collection, data processing and data storage operations. The predetermined data collection and data processing parameters are defined in a host computer, and downloaded from the host computer to the portable unit. The portable unit includes four modules interconnected by a serial data bus and input/out interface including a central control module which initiates data collection in response to the bar code reader and

determines the operating sequence of the other modules, an analog-to-digital conversion module which conditions analog signals received from the transducers and converts the received analog signals to digital time domain data, a fast Fourier transform module which receives the digital time domain vibration data and converts it to frequency domain vibration data, and a mass memory module which receives and stores the frequency domain data. Once the data has been collected, the stored frequency domain data is transferred (uploaded) from the portable unit via a charger/interface into a host computer where the data is further processed (i.e., analyzed) to support predictive maintenance scheduling.

An example of data management and analysis host software is EMONITOR® for Windows, which is marketed by Entek Scientific Corporation, the assignee of the present invention. The EMONITOR® for Windows software is described in a manual entitled "*EMONITOR® for Windows User's Guide, Second Edition 1994*", Manual No. E2W0002B, published by Entek Scientific Corporation, the disclosure of which is incorporated herein by reference.

In state-of-the-art manufacturing environments, the capital investment in machinery can be staggering. Accordingly, there is a great need for predictive maintenance to prevent machine breakdowns and increase reliability. Moreover, with "just in time" manufacturing requirements, predictive maintenance becomes even more critical to eliminate machine down time. Accordingly, there is a great need for data collection systems and methods.

Unfortunately, the high cost of data collection systems is often a barrier to their widespread use. The high cost is in part related to

the use of special purpose hardware and software in the data collector. In addition to high cost, the use of special purpose hardware and software limits the flexibility of the data collector and makes it difficult to update and improve the data collector. Although portable computers, laptop computers, pen-based computers, palmtop computers and Personal Digital Assistants (PDA) have become widely available, they have not yet made a significant impact on data collectors. See for example, the publication in Automatic ID News, April 1995, entitled *"Be Ready for Technology Leap at the End of the Century: Three Non-ADC Developments to Springboard Automatic Data Capture Growth"*. See also the publication in Maintenance, January/February 1995, by Billson et al. entitled *"Portable Pen Computers - An Essential Tool for the Mobile Maintenance Engineer"*.

Summary of the Invention

The present invention is a portable, self-contained data collection system for measuring and collecting vibration data from machines. The system includes an accelerometer including a motion sensitive transducer and an accelerometer output. The accelerometer is coupled to a machine to produce an analog signal at the accelerometer output. The system also includes a data acquisition card having an analog input and a digital output. The accelerometer output is electrically coupled to the analog input. As used herein, electrical coupling includes wireless, optical or conventional wire coupling. The data acquisition card samples and digitizes the analog signal to produce a time domain digital signal, i.e. a sampled and digitized series of voltage versus time points, at the digital output. The system also includes a battery-powered portable computer such as a pen-based computer, which includes an expansion slot. The data acquisition

card digital output is electrically and mechanically connected to the expansion slot.

The battery-powered portable computer also includes a database having machine identifications and associated measurement parameters. User input means such as a pen allows user selection of a machine identification for measurement. The portable computer also includes signal processing means for processing the time domain digital signal according to the measurement parameters associated with the selected machine identification. Preferably, the signal processing means processes the time domain digital signal to produce a frequency domain digital signal by performing a Fast Fourier Transform (FFT), wavelet or other digital signal processing operations. Finally, the battery-powered portable computer also preferably includes signal analyzing means for analyzing the frequency domain digital signal to produce predictive maintenance information such as spectral distribution. The time domain digital signal can also be analyzed to produce crest factor and other predictive maintenance information.

A data collection system according to the present invention uses a standard portable computer such as a pen-based computer and a standard data acquisition card such as a PCMCIA sound card, to provide portable self-contained hardware for data collection and analysis. The machine database, signal processing means and signal analyzing means are preferably implemented using software modules which execute on the portable computer. The machine database and the signal analyzing software may be provided using EMONITOR® for Windows or other predictive maintenance software on the portable computer. Signal processing software may be provided by conventional digital signal processing software which provides digital filtering, integration from acceleration to velocity or

displacement units, Fast Fourier Transform or other mathematical functions, and averaging. Accordingly, a low cost self-contained data collection system is provided.

It will be understood that since the portable data collection system includes a database, signal processing software and signal analyzing software therein, a host computer connection is not required for operation. Rather, all predictive maintenance operations may be performed using only the portable self-contained data collection system. However, it will also be understood by those having skill in the art that the portable self-contained data collection system can be used as part of a networked data collection system wherein the portable computer includes transmitting means for transmitting at least one of the machine identifications, the measurement parameters, the time domain digital signal, the frequency domain digital signal or the predictive maintenance information to a second computer. The second computer may store this data for distribution to other users and the second computer or other users may also perform one or more of the processing functions of the portable data collector. The transmitting means is preferably wireless, such as a radio frequency (RF) transmitter. However, transmission may also be accomplished by uploading information to another computer using conventional wire communications.

According to a preferred form of the present invention, the portable self-contained data collection system also includes a power supply for supplying power to the accelerometer. In particular, conventional portable computers do not provide sufficient power for an accelerometer, which typically requires 24V at 2mA.

According to the preferred form of the invention, an accelerometer power supply electrically and mechanically couples the accelerometer output to the data acquisition card

analog input. The accelerometer power supply is preferably responsive to the data acquisition card for supplying power to the accelerometer when the data acquisition card is activated, and for deactivating when the data acquisition card is deactivated.

In particular, the accelerometer power supply includes a power supply housing and an accelerometer battery power supply in the power supply housing which provides sufficient power for an accelerometer. Output means including an output connector electrically and mechanically connects the accelerometer battery power supply to an accelerometer and receives accelerometer signals from the accelerometer. Input means including an input connector electrically and mechanically connects the accelerometer battery power supply to an external device, preferably the analog input of a data acquisition card. The input means receives a control signal from the external device, and also passes the accelerometer signals to the external device. The accelerometer battery power supply is responsive to the control signal, to activate the accelerometer battery power supply to supply battery power for an accelerometer to the output connector. In the absence of the control signal, the accelerometer battery power supply is deactivated. Preferably, the accelerometer battery power supply will pass signals from the output means to the external device in the absence of the control signal, so that non-powered transducers can be used.

When the accelerometer power supply is included, the portable self-contained data collection system includes three hardware components: a portable computer, a data acquisition card and an accelerometer power supply. The portable computer includes a portable computer housing, a portable computer battery power supply within the portable computer housing to supply power to the portable computer, and an expansion

slot in the portable computer housing. The data acquisition card is mechanically and electrically coupled to the expansion slot. The accelerometer power supply includes a power supply housing, and an accelerometer battery power supply within the power supply housing which provides sufficient power for an accelerometer. The accelerometer power supply is electrically and mechanically coupled to the data acquisition card and the accelerometer is electrically and mechanically coupled to the accelerometer power supply. The portable computer, data acquisition card and accelerometer power supply may be packaged in a ruggedized carrying case. The portable computer executes software including a database including machine identifications and measurement parameters, signal processing software for processing accelerometer signals and signal analyzing software for analyzing the processed signal to produce predictive maintenance information.

Data collection methods according to the present invention are used for measuring and collecting vibration data from machines, wherein the following steps are all performed in a portable battery-powered computer: A machine identification for measurement is selected. A time domain accelerometer signal is processed according to measurement parameters associated with the selected machine identification to produce a digital signal. The digital signal is analyzed to produce predictive maintenance information. If necessary, the processing step is preceded by the step of sampling and digitizing an analog accelerometer signal to produce the time domain accelerometer signal. The machine identifications, measurements, time domain signal, digital signal and/or predictive maintenance information can be displayed on the portable battery-powered computer. Portable self-contained data collection systems and methods are thereby provided.

In addition, this information can be transferred to another computer.

One aspect of the present invention provides a data collection system for measuring and collecting vibration data from machines, said data collection system including:

an accelerometer including a motion sensitive transducer, an accelerometer output, and means for coupling said motion sensitive transducer to a machine to produce an analog signal at said accelerometer output,

a data acquisition card having an analog input and a digital output, said accelerometer output being electrically coupled to said analog input, said data acquisition card sampling and digitizing said analog signal to produce a time domain digital signal at said digital output,

a portable computer including an expansion slot, said data acquisition card digital output being electrically and mechanically connected to said expansion slot, said portable computer further including:

a database including a plurality of machine identifications and associated measurement parameters;

user input means for user selection of a machine identification for measurement;

signal processing means for processing said time domain digital signal to produce a frequency domain digital signal according to the measurement parameters associated with the selected machine identification; and

signal analyzing means for analyzing said frequency domain signal to produce predictive maintenance information.

Another aspect of the present invention provides A data collection method for measuring and collecting vibration data from machines, said data collection method including the following steps which are all performed in a portable battery powered computer:

allowing user selection of a machine identification for measurement;

processing a time domain accelerometer signal according to measurement parameters associated with the selected machine identification to produce a digital signal; and

analyzing said digital signal to produce predictive maintenance information.

The terms "comprise", "comprises", "comprised" and "comprising" when used in this specification are taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

Brief Description of the Drawings

Figure 1 illustrates a data collection system for collecting vibration data from machines according to the present invention.

Figure 2 is a block diagram illustrating a data acquisition card interfaced to an operating system, database, signal processing means and signal analyzing means implemented in a battery operated portable computer according to the present invention.

Figure 3 is a block diagram illustrating signal processing means, including filtering, integration, fast Fourier transform, and averaging, for processing a time domain digital signal according to the present invention.

Figure 4 is a block diagram illustrating a power supply for an accelerometer according to the present invention.

Figures 5a-5b illustrate data collection operations according to the present invention.

Figures 6a-6c are computer screen images illustrating a machine identification selection according to the present invention.

Figure 7 is a computer screen image illustrating signal analyzing according to the present invention.

Figure 8 is a diagram illustrating a data collection system implemented in a battery operated portable computer linked to other computers in a computer network according to the present invention.

Detailed Description of Preferred Embodiments

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments

of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

Referring now to Figure 1, data collection system **100** is illustrated, housed in a case **101**. As shown, data collection system **100** includes a battery-powered portable computer **110** mating to data acquisition card **120**, display means **130**, user input means **140**, power supply **150**, and accelerometer **160**.

The construction of battery powered portable computer **110** is well-known to those skilled in the art. Battery operated portable computers typically include a microprocessor, associated random access memory (RAM), nonvolatile data storage such as a hard disk drive, a battery power source and expansion slots designed to accommodate circuit boards electrically coupling the computer components to external devices such as keyboards, pens, mouses, transducers and displays. These expansion slots typically accommodate standard form factor circuit cards, such as the industry-standard PCMCIA form factor cards used in notebook and laptop computers. For field uses, such as monitoring of machinery for predictive maintenance purposes, battery operated portable computer **110** may be mounted in a lightweight, rugged hand-held case **101**, and user input means **140** may include a magnetic pen designed to operate with a magnetically sensitive screen matrix. An example of a typical battery operated portable computer designed especially for field use is the Fujitsu Stylistic 500, as described in Fujitsu brochure 58-0349-00B, the disclosure of which is incorporated herein by reference. This computer is referred to for

purposes of explanation only, and it will be understood by those skilled in the art that the present invention may be used with other portable computers.

Data acquisition card **120** is an analog to digital (A/D) converter card that mechanically and electrically couples data acquisition card **120** to an expansion slot in battery powered portable computer **110**, electrically connecting digital output **122** to battery operated portable computer **110**. Data acquisition card **120** is electrically coupled to accelerometer **160** at analog input **121**. Typically, data acquisition card **120** is a low-cost standard form factor sound card designed to receive audio frequency analog signals at analog input **121**. An example of such a sound card is the Magic Ram PCMCIA 16-bit audio adapter, which is described in a manufacturer's data sheet entitled "PCMCIA 16-bit Audio Adapter," the disclosure of which is incorporated herein by reference. This device is a standard PCMCIA form factor card that mates with a PCMCIA expansion slot. It will be understood by those skilled in the art that a data acquisition card according to the present invention includes any A/D converter card capable of receiving analog inputs and transmitting corresponding digital signals to a battery operated portable computer through a digital communications port, such as an expansion slot. It will also be understood by those skilled in the art that the present invention may be used with a battery operated portable computer **110** which includes an analog input and associated internal A/D.

Accelerometer **160** produces an analog signal corresponding to the accelerations experienced by a motion sensitive transducer included therein, and is electrically coupled to data acquisition card **120** by analog input **121**. The motion-sensitive transducer is typically piezoelectric and produces a voltage

proportional to the acceleration of the transducer. The accelerometer includes means for coupling the motion sensitive transducer to a machine from which the user desires vibration data, such as a probe extension, screw or magnet attached to the accelerometer structure. Examples of piezoelectric accelerometers may be found in Catalog QSG-200, published by Industrial Monitoring Instrumentation Division of PCB Piezotronics, Inc., the disclosure of which is incorporated herein by reference. It will be understood by those skilled in the art that the present invention may be used with other measurement devices producing analog output signals corresponding to accelerations, such as piezotransistor or variable resistance accelerometers.

Power supply **150** supplies electrical power to accelerometer **160**, receives output signals from accelerometer **160**, receives control signals from data acquisition card **120**, and conveys output signals from accelerometer **160** to data acquisition card **120**. Power supply **150** is mechanically and electrically coupled to both accelerometer **160** and data acquisition card **120**.

Referring now to Figure 2, a block diagram illustrates accelerometer **160**, data acquisition card **120** and user input means **140** interfaced to an operating system **200**, data collection interface **210**, database **220**, signal processing means **230** and signal analyzing means **240**. Operating system **210** is typically executive software that controls data collection interface **210**, database **220**, signal processing means **230**, signal analyzing means **240**, and data acquisition card **120**, responsive to commands received through user input means **140**. Such commands may be to acquire or store data, or to perform filtering, time domain analysis, or frequency domain analysis. An example of operating system **200** is Entek Scientific Corporation's EMONITOR® for Windows data management software, as described in

"EMONITOR® for Windows User's Guide, Second Edition 1994," Manual No. EEW0002B, the disclosure of which is incorporated herein by reference. This software is a Windows-based program that enables a user to perform database manipulation, data analysis or other operations via manipulation of screen icons. It will be understood by those skilled in the art that the present invention may be used, for example, with other operating systems running in a Windows, DOS, or UNIX environment.

Database **220** comprises a plurality of machine identifications and associated measurement parameters. Database **220** may have a hierarchical, relational or other structure and is typically organized according to logical relationships between particular machines. An example of a hierarchical database structure is incorporated in Entek Scientific Corporation's EMONITOR® for Windows, as described in Chapters 4 and 5 of "EMONITOR® for Windows User's Guide, Second Edition 1994," Manual No. EEW0002B. This database is a SQL database that organizes machine identifications, and associates parameters such as machine location, signal processing parameters and previously measured data values with these machine identifications. This database is referred to for purposes of explanation, and it will be understood by those skilled in the art that the present invention may be used with other hierarchical or non-hierarchical database structures, and may include various combinations of machine parameters.

Data collection interface **210** is preferably a software module that controls the operation of data acquisition card **120** and signal processing means **230** through operating system **200**, although hardware or software/hardware combinations may be employed. Upon commands from data collection interface **210**, data acquisition card **120** samples and digitizes an analog

signal **115** received from a accelerometer **160** and provides a corresponding time domain digital signal **125**, which is conveyed to signal processing means **230**. In the embodiment of the present invention shown in Figure 2, data collection interface **210** is a software module operating in conjunction with, for example, an operating system such as EMONITOR® for Windows running in a Windows environment, and is conveniently accessed and controlled by user selection of appropriate icons in a display window.

Although the combination of elements described in Figure 2 envisions data collection, database management and data analysis integrated in a multitasking environment such as Windows, it will be understood by those skilled in the art that the present invention may be practiced using other means of interfacing data acquisition card **120**, signal processing means **230**, signal analyzing means **240** and database **220**. For example, data collection interface **210** may be a standalone software program capable of transferring data from data acquisition card **120** to database **220** for subsequent data management, signal processing and signal analysis. In another arrangement, data acquisition card **120** may include all or a portion of signal processing means **230**, allowing sampling, digitizing and processing of analog signal **115** to be performed on data acquisition card **120**. An example of such an integrated PCMCIA card is the $Bullet_{dsp}$ card marketed by Communication Automation and Control, Inc. The $Bullet_{dsp}$ card is described in a data sheet entitled "*PCMCIA TI TMS320C32*," published by Communication Automation and Control, Inc., the disclosure of which is incorporated herein by reference.

Signal processing means **230** performs digital signal processing of time domain digital signal **125** received from data acquisition card **120**. Typically,

signal processing means **230** is implemented in conventional modular software blocks, which may be selected and combined to perform various processing functions, as further illustrated in Figure 3. This software may implement functions such as filtering, fast Fourier transform, integration or averaging, which may be selected and arranged as desired.

Signal analyzing means **240** typically is software that examines processed digital signals received from signal processing means **230** and produces predictive maintenance information. Upon commands received through operating system **200**, signal analyzing means **240** conducts analyses such as trend analysis, alarm detection, spectral analysis, data plotting or report generation. An example of signal analyzing means **240** is the analysis software incorporated in Entek Scientific Corporation's EMONITOR® for Windows, as described in Chapters 7, 9, 10 and 11 of "EMONITOR® for Windows User's Guide, Second Edition 1994," Manual No. EEW0002B.

Referring now to Figure 3, a software block diagram illustrates signal processing software for implementing signal processing means **230** which includes modular processing elements **310a-310d** which may be selected and combined as required. It will be understood by those skilled in the art that other arrangements of signal processing elements may be used with the present invention. In addition, it will be understood by those skilled in the art that other non-modular signal processing software techniques may be used with the present invention.

Referring now to Figure 4, an electrical block diagram illustrates power supply **150** for accelerometer **160**. Power supply housing **410** encloses accelerometer battery power supply **420**. Accelerometer battery power supply **420** provides sufficient power to excite an external accelerometer. Output means **430**

electrically and mechanically couples accelerometer battery power supply **420** to an external accelerometer. Typically, output means **430** will include an MS-3106 connector commonly used in accelerometer applications, but it will be understood by those skilled in the art that other structures may be used with the present invention, including coaxial and other types of standard connectors.

Input means **440** electrically and mechanically couples accelerometer battery power supply **420** to an external device, such as an A/D converter, and receives control signal **450** from the external device. Accelerometer battery power supply **420** may be responsive to control signal **450**, deactivating power output to the external accelerometer in the absence of control signal **450**, thus offering the capability to minimize power consumption during non-measurement periods and extending battery life or time between recharges.

Figure 4 shows accelerometer battery power supply **420** further including battery **422**, charging means **424**, and regulating means **426**. Charging means **424** provides the capability to charge battery **422**. Regulating means **426** takes the power output from battery **422** and provides the voltage and current conditioning required to excite the external accelerometer. It will be understood by those skilled in the art that not all of these elements are required for all embodiments of the present invention. Different power supply configurations may, for example, utilize disposable or removable batteries and eliminate the need for internal charging means **424**.

Figure 5a illustrates operations for measuring and collecting vibration data from machines, implemented in a battery-operated powered computer. First, in Block **510** a user selects a machine identification for measurement. In Block **520** a time

domain accelerometer signal **515** is processed to produce a digital signal **525**. In Block **530** the digital signal is analyzed to produce predictive maintenance information, such as detection of alarm conditions due to vibration magnitudes exceeding predetermined limits or reports concerning machine vibration parameters. Referring to Figure 5b, in an alternate embodiment, the operations of Block **520** may be preceded by a step of sampling and digitizing an analog time domain accelerometer signal to produce a time domain digital accelerometer signal **516**, as shown in Block **511**. In addition, predictive maintenance information **526** may then be displayed, as shown in Block **540**.

Figures 6a-6b illustrate the selection step of Block **510** of Figure 5a-5b in greater detail. In Figure 6a the user enters a data collection window **600** in which he may select a machine identification for measurement, as shown at **601**. The display informs the user of the identification selected, which typically is a location on a particular machine, as shown at **602**. The user typically commands data acquisition by selection of an icon, as shown at **603**.

The parameters associated with a particular machine identification typically have been previously entered into a database. This may be done manually, as shown in Figure 6b. Within a data entry window **610**, the user selects a desired machine identification, as illustrated at **611**, and enters the associated parameters, as shown at **612**. Alternatively, parameters may be entered with the aid of predetermined machine templates, as shown in Figure 6c. These parameters may include signal processing parameters for use in the processing step of Block **520** of Figure 5, but it will be understood by those skilled in art that other arrangements may be used with the present invention, such as allowing the user to select particular signal

processing parameters while in data collection window **600**.

Figure 7 illustrates the signal analyzing operation of Block **530** of Figure 5, specifically the displayed results of a spectrum analysis. It will be understood by those skilled in the art that other analyses may be performed on digital signals, such as magnitude or crest factor calculations or detection of alarm conditions.

Figure 8 illustrates the data collection system of the present invention further including transmission of machine identifications, measurement parameters, time domain accelerometer signals, frequency domain digital signals and predictive maintenance information to other computers **820a-820n** linked to the battery operated portable computer **110** by means of a network **810**. It will be understood by those skilled in the art that network **810** may be hardwired or may employ radio frequency (RF) or other communications links. Under this aspect of the invention, machine-related data may be uploaded from the battery powered portable computer **110** to computers **820a-820n** for subsequent data management, processing, analysis or display.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A data collection system for measuring and collecting vibration data from machines, said data collection system including:

an accelerometer including a motion sensitive transducer, an accelerometer output, and means for coupling said motion sensitive transducer to a machine to produce an analog signal at said accelerometer output,

a data acquisition card having an analog input and a digital output, said accelerometer output being electrically coupled to said analog input, said data acquisition card sampling and digitizing said analog signal to produce a time domain digital signal at said digital output,

a portable computer including an expansion slot, said data acquisition card digital output being electrically and mechanically connected to said expansion slot, said portable computer further including:

a database including a plurality of machine identifications and associated measurement parameters;

user input means for user selection of a machine identification for measurement;

signal processing means for processing said time domain digital signal to produce a frequency domain digital signal according to the measurement parameters associated with the selected machine identification; and

signal analyzing means for analyzing said frequency domain signal to produce predictive maintenance information.

2. A data collection system according to Claim 1 further including means for transmitting at least one of said machine identifications, said measurement parameters, said time domain digital signal and the processed time domain digital signal to a second computer.

3. A data collection system according to Claim 1 further including means for transmitting said predictive maintenance information to a second computer.

4. A data collection system according to Claim 1 further including means for displaying at least one of said machine identifications, said measurement parameters, said time domain digital signal and the processed time digital domain signal.

5. A data collection system according to Claim 1 further including means for displaying said predictive maintenance information.

6. A data collection system according to Claim 1 further including power supplying means for supplying power to said accelerometer.

7. A data collection system according to Claim 6 wherein said power supplying means electrically and mechanically couples said accelerometer output to said data acquisition card analog input.

8. A data collection system according to Claim 7 wherein said power supplying means is responsive to said data acquisition card, for supplying power to said accelerometer when said data acquisition card is activated.

9. A data collection system according to Claim 1 wherein said signal processing means includes software modules which execute on said portable computer.

10. A data collection system according to Claim 1 wherein said data acquisition card is a PCMCIA data acquisition card.

11. A data collection system according to Claim 1 wherein said data acquisition card is a sound card.

12. A data collection system according to Claim 6 wherein said accelerometer power supplying means includes:

a power supply housing;

an accelerometer battery power supply in said power supply housing, which provides sufficient power for an accelerometer;

output means, for electrically and mechanically connecting said accelerometer battery power supply to an accelerometer, and for receiving accelerometer signals from said accelerometer;

input means, for electrically and mechanically coupling said accelerometer battery power supply to an external device, for receiving a control signal from the external device and for providing said accelerometer signals to the external device;

said accelerometer battery power supply being responsive to said control signal to activate said accelerometer battery power supply to supply power for an accelerometer to said output means.

13. A data collection system according to Claim 12 wherein said accelerometer power supplying means is responsive to absence of said control signal to deactivate said accelerometer battery power supply.

14. A data collection system according to Claim 13 wherein said input means provides said accelerometer signals to the external device notwithstanding absence of said control signal.

15. A data collection system according to Claim 12 further including battery charging means for charging said accelerometer battery power supply.

16. A data collection system according to Claim 12 wherein said input means includes means for electrically and mechanically coupling said accelerometer battery power supply to a PCMCIA sound card.

17. A power supply according to Claim 12 wherein said output means includes an MS3106 accelerometer connector.

18. A data collection system according to Claim 1 wherein said portable computer further includes:

a portable computer housing;

a portable computer battery power supply within said portable computer housing to supply power to said portable computer; and

wherein said data collection system further includes an accelerometer power supply including:

a power supply housing;

an accelerometer battery power supply within said power supply housing which provides sufficient power for an accelerometer;

means for electrically and mechanically coupling said accelerometer power supply to said data acquisition card; and

means for electrically and mechanically coupling an accelerometer to said accelerometer power supply.

19. A data collection method for measuring and collecting vibration data from machines, said data collection method including the following steps which are all performed in a portable battery powered computer:

allowing user selection of a machine identification for measurement;

processing a time domain accelerometer signal according to measurement parameters associated with the selected machine identification to produce a digital signal; and

analyzing said digital signal to produce predictive maintenance information.

20. A data collection method according to Claim 19 wherein said processing step is preceded by the step of:

sampling and digitizing an analog accelerometer signal to produce the time domain accelerometer signal.

21. A data collection method according to Claim 19 further including the step of transmitting at least one of said machine identifications, said measurement parameters, said time domain accelerometer signal, said frequency domain digital signal and said predictive maintenance information to a second computer.

22. A data collection method according to Claim 19 further including the step of displaying at least one of said machine identifications, said measurement parameters, said time domain accelerometer signal, said frequency domain digital signal and said predictive maintenance information.

23. A data collection method according to Claim 19 wherein said digital signal is a frequency domain digital signal.

24. A data collection system substantially as herein described with reference to the accompanying drawings.

25. A data collection method substantially as herein described with reference to the accompanying drawings.

DATED this 18th day of August 1999

ENTEK IRD INTERNATIONAL CORPORATION

WATERMARK PATENT & TRADEMARK ATTORNEYS
290 BURWOOD ROAD
HAWTHORN VICTORIA 3122
AUSTRALIA

PNF:RLT:SLB
DOC28 AU7372396.WPC

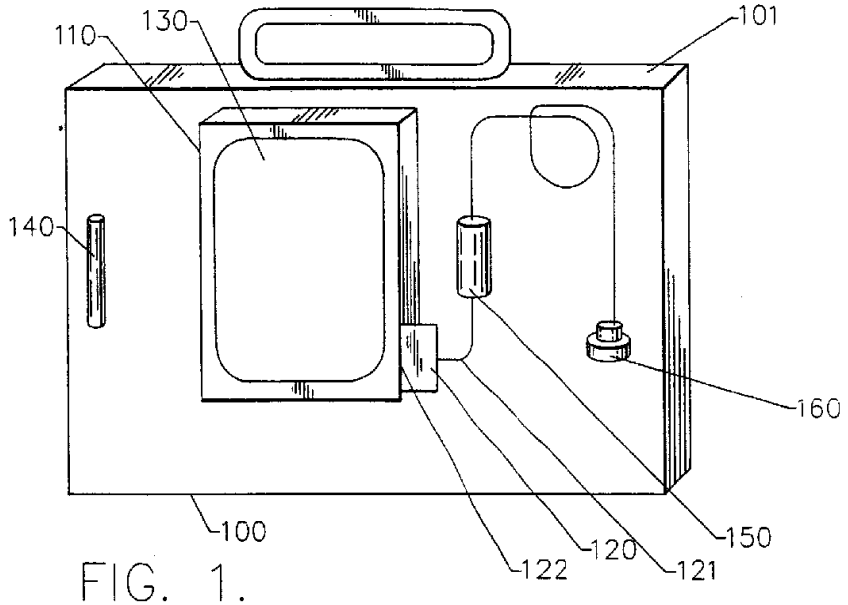

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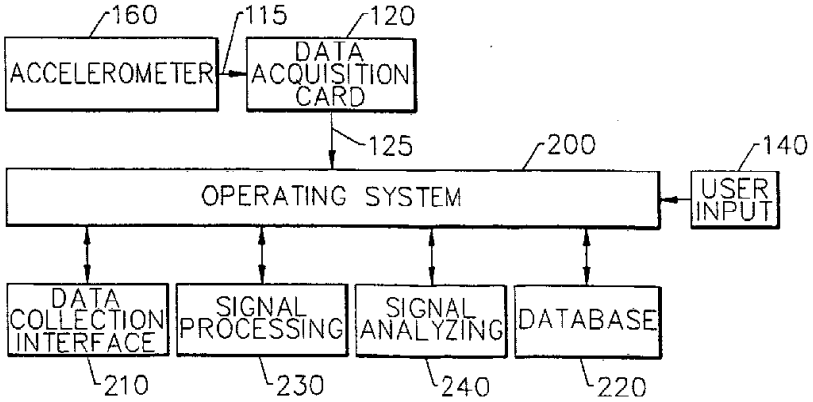
FIG. 1.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DATA ACQUISITION CARD
125
200
140
OPERATING SYSTEM
USER INPUT
DATA COLLECTION INTERFACE
SIGNAL PROCESSING
SIGNAL ANALYZING
DATABASE
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230
240
220

FIG. 2.

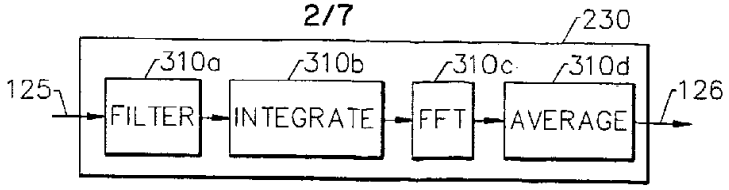


FIG. 3.

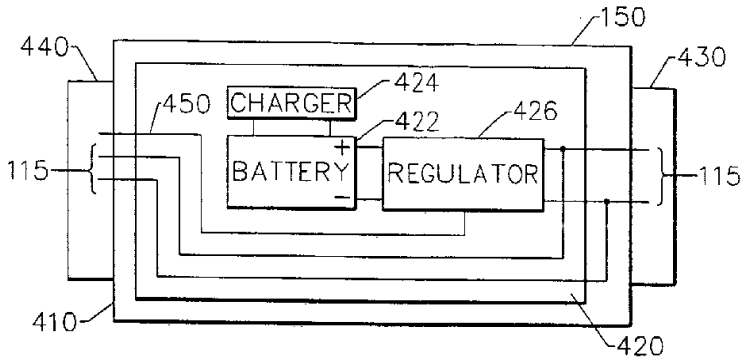


FIG. 4.

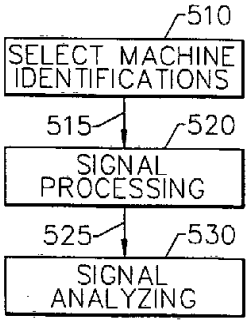


FIG. 5a.

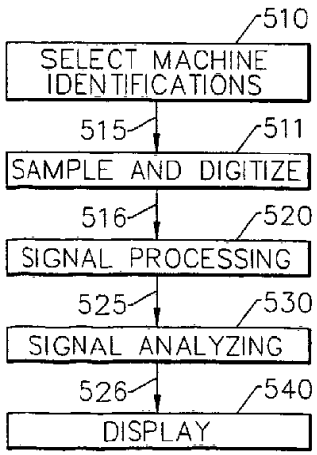
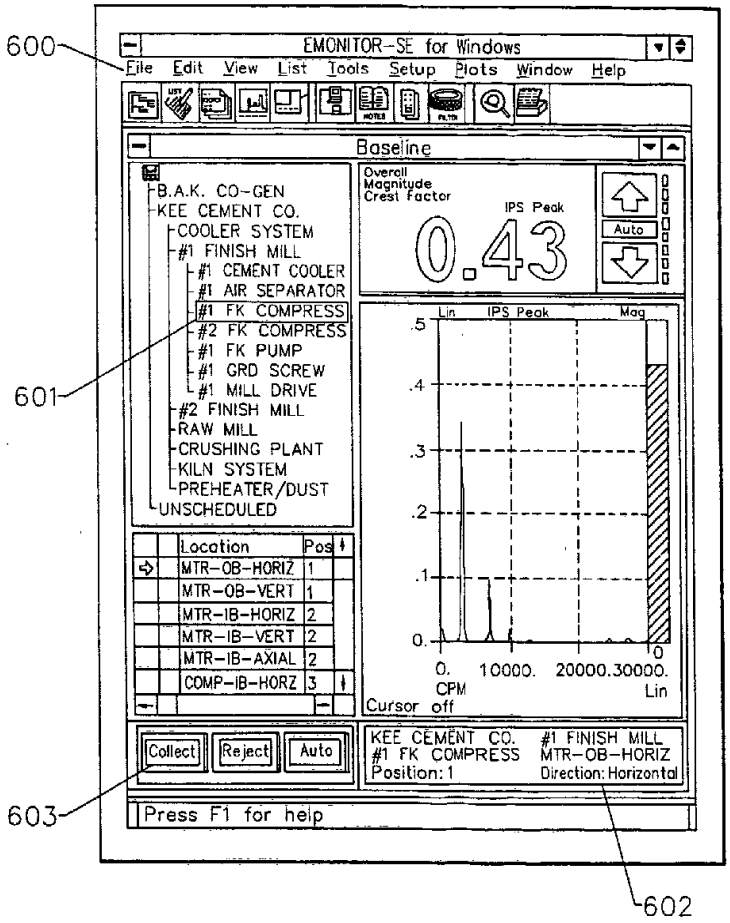


FIG. 5b.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COOLER SYSTEM
#1 FINISH MILL
#1 CEMENT COOLER
#1 AIR SEPARATOR
#1 FK COMPRESS
#2 FK COMPRESS
#1 FK PUMP
#1 GRD SCREW
#1 MILL DRIVE
#2 FINISH MILL
RAW MILL
CRUSHING PLANT
KILN SYSTEM
PREHEATER/DUST
UNSCHEDULED
Overall
Magnitude
Crest Factor
IPS Peak
0.43
Auto
Lin IPS Peak Mag
.5
.4
.3
.2
.1
0.
0. 10000. 20000. 30000.
CPM Lin
Cursor off
Location Pos
MTR-OB-HORIZ 1
MTR-OB-VERT 1
MTR-IB-HORIZ 2
MTR-IB-VERT 2
MTR-IB-AXIAL 2
COMP-IB-HORZ 3
Collect
Reject
Auto
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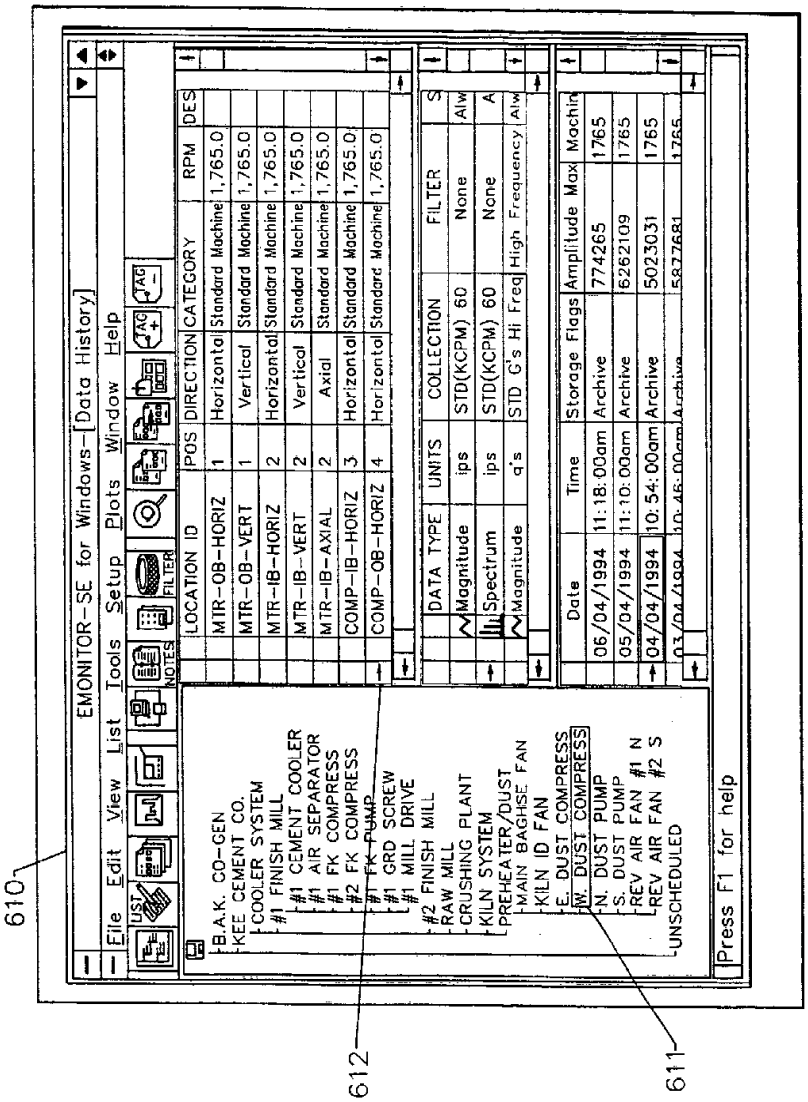
FIG. 6a.

FIG. 6b.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#1 CEMENT COOLER
#1 AIR SEPARATOR
#1 FK COMPRESS
#2 FK COMPRESS
#1 FK PUMP
#1 GRD SCREW
#1 MILL DRIVE
#2 FINISH MILL
RAW MILL
CRUSHING PLANT
KILN SYSTEM
PREHEATER/DUST
MAIN BAGHSE FAN
KILN ID FAN
E. DUST COMPRESS
W. DUST COMPRESS
N. DUST PUMP
S. DUST PUMP
REV AIR FAN #1 N
REV AIR FAN #2 S
UNSCHEDULED
LOCATION ID
POS
DIRECTION
CATEGORY
RPM
MTR-OB-HORIZ 1 Horizontal Standard Machine 1,765.0
MTR-OB-VERT 1 Vertical Standard Machine 1,765.0
MTR-IB-HORIZ 2 Horizontal Standard Machine 1,765.0
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MTR-IB-AXIAL 2 Axial Standard Machine 1,765.0
COMP-IB-HORIZ 3 Horizontal Standard Machine 1,765.0
COMP-OB-HORIZ 4 Horizontal Standard Machine 1,765.0
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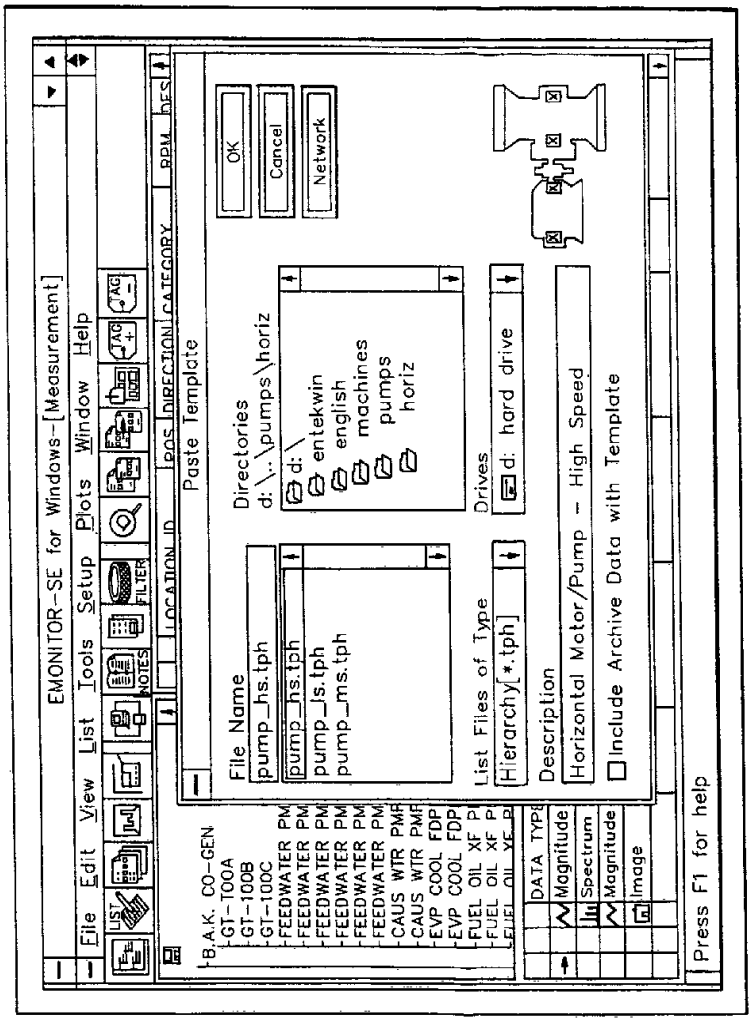
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GT-100B
GT-100C
FEEDWATER PM
FEEDWATER PM
FEEDWATER PM
FEEDWATER PM
FEEDWATER PM
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CAUS WTR PMP
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EVP COOL FDP
EVP COOL FDP
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pump_ls.tph
pump_ms.tph
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entekwin
english
machines
pumps
horiz
Drives
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Cancel
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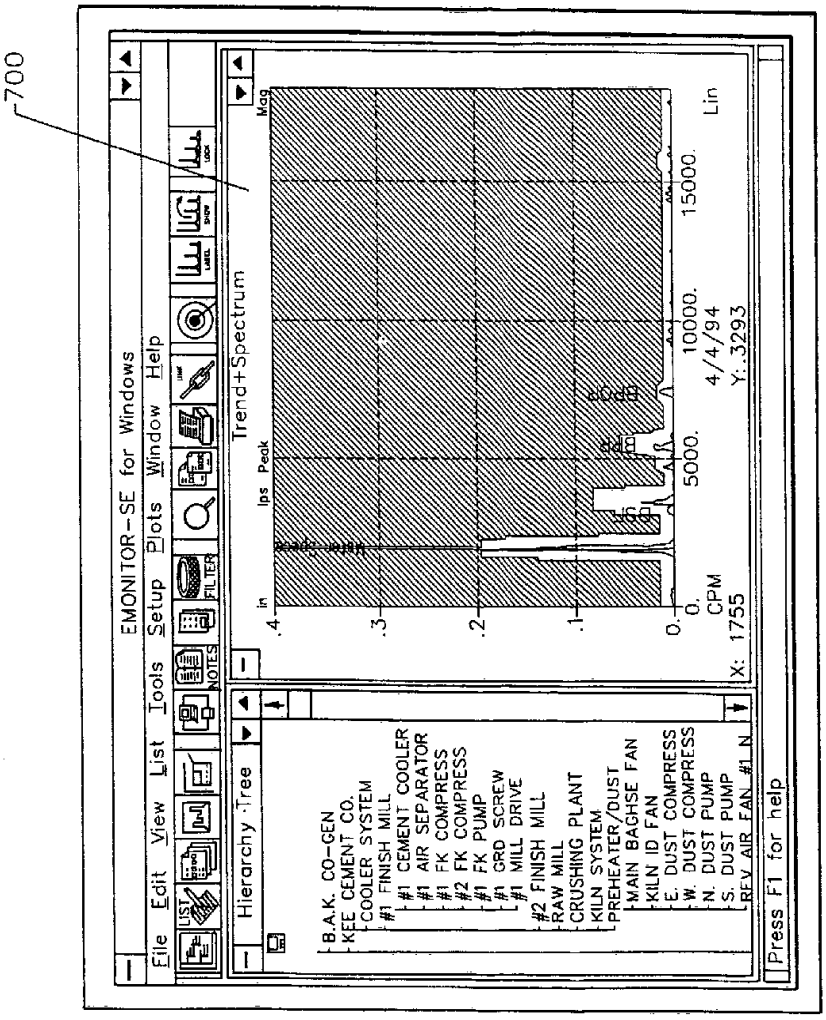
Spectrum
Magnitude
Image
Press F1 for help

FIG. 6C.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EMONITOR-SE for Windows
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KEE CEMENT CO.
COOLER SYSTEM
#1 FINISH MILL
#1 CEMENT COOLER
#1 AIR SEPARATOR
#1 FK COMPRESS
#2 FK COMPRESS
#1 FK PUMP
#1 GRD SCREW
#1 MILL DRIVE
#2 FINISH MILL
RAW MILL
CRUSHING PLANT
KILN SYSTEM
PREHEATER/DUST
MAIN BAGHSE FAN
KILN ID FAN
E. DUST COMPRESS
W. DUST COMPRESS
N. DUST PUMP
S. DUST PUMP
REV AIR FAN #1 N
Trend+Spectrum
in
Ips Peak
Mag
.4
.3
.2
.1
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FIG. 7.

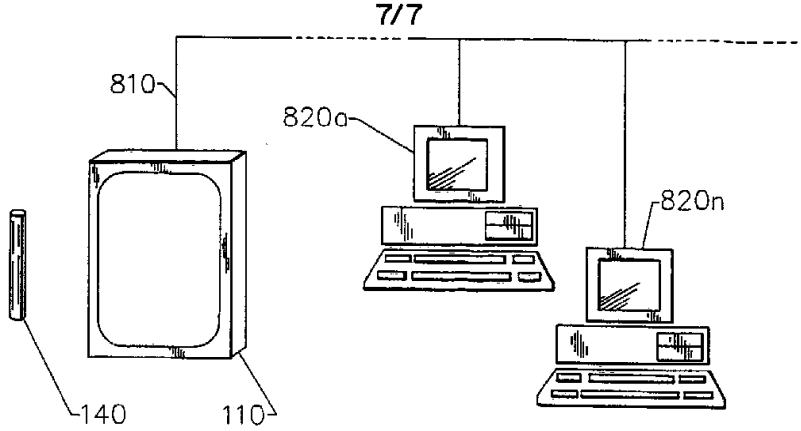

FIG. 8.