United States Patent

Walter

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[45] **Aug. 22, 1972**

[54] **APPARATUS UTILIZING AN AIR CORE TRANSFORMER FOR DETERMINING MAGNETIC MATERIAL CONTENT OF A SUBSTANCE**

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[52] **U.S. Cl.**.....**324/13,** 324/34

[51] **Int. Cl.**.....**G01n 27/00,** G01r 33/00

[58] **Field of Search**.....324/13, 14, 34, 55, 41, 43

[56] **References Cited**

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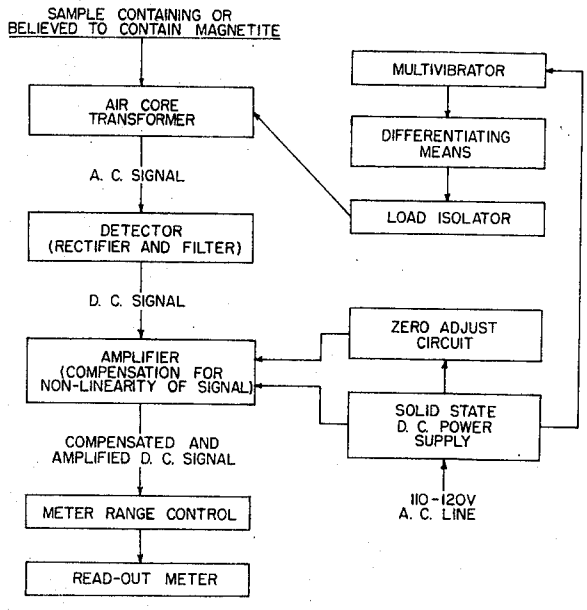
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[57] **ABSTRACT**

An air-core transformer is adapted to receive a sample of the substance to be tested for content of magnetic material, e.g., the mineral magnetite. It is supplied, usually through load-isolating means, with constant voltage, high frequency, A.C. power from a square wave generator or the like, preferably a multi-vibrator receiving voltage-regulated D.C. power from a suitable power supply. The resulting high frequency A.C. signal is detected by passage through rectifying and filtering means to yield a corresponding D.C. signal, which is fed to amplifying means that includes means for compensating for non-linearity of the signal. The compensated and amplified D.C. signal is zero controlled and fed to read-out means, such as a meter, through suitable range control means.

5 Claims, 5 Drawing Figures



Patented Aug. 22, 1972 **3,686,563**

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FIG. 1.

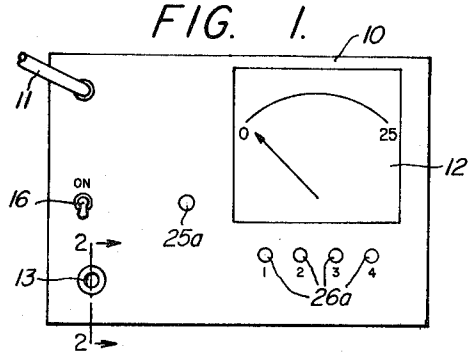


FIG. 2.

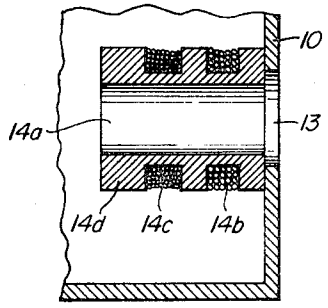
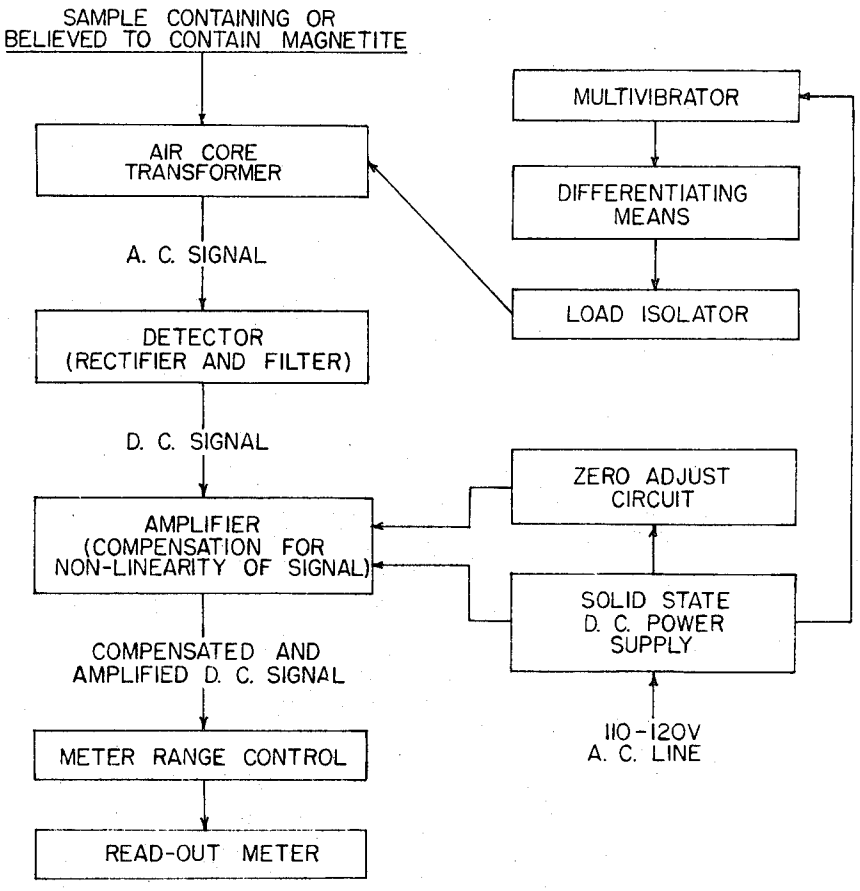


FIG. 3.



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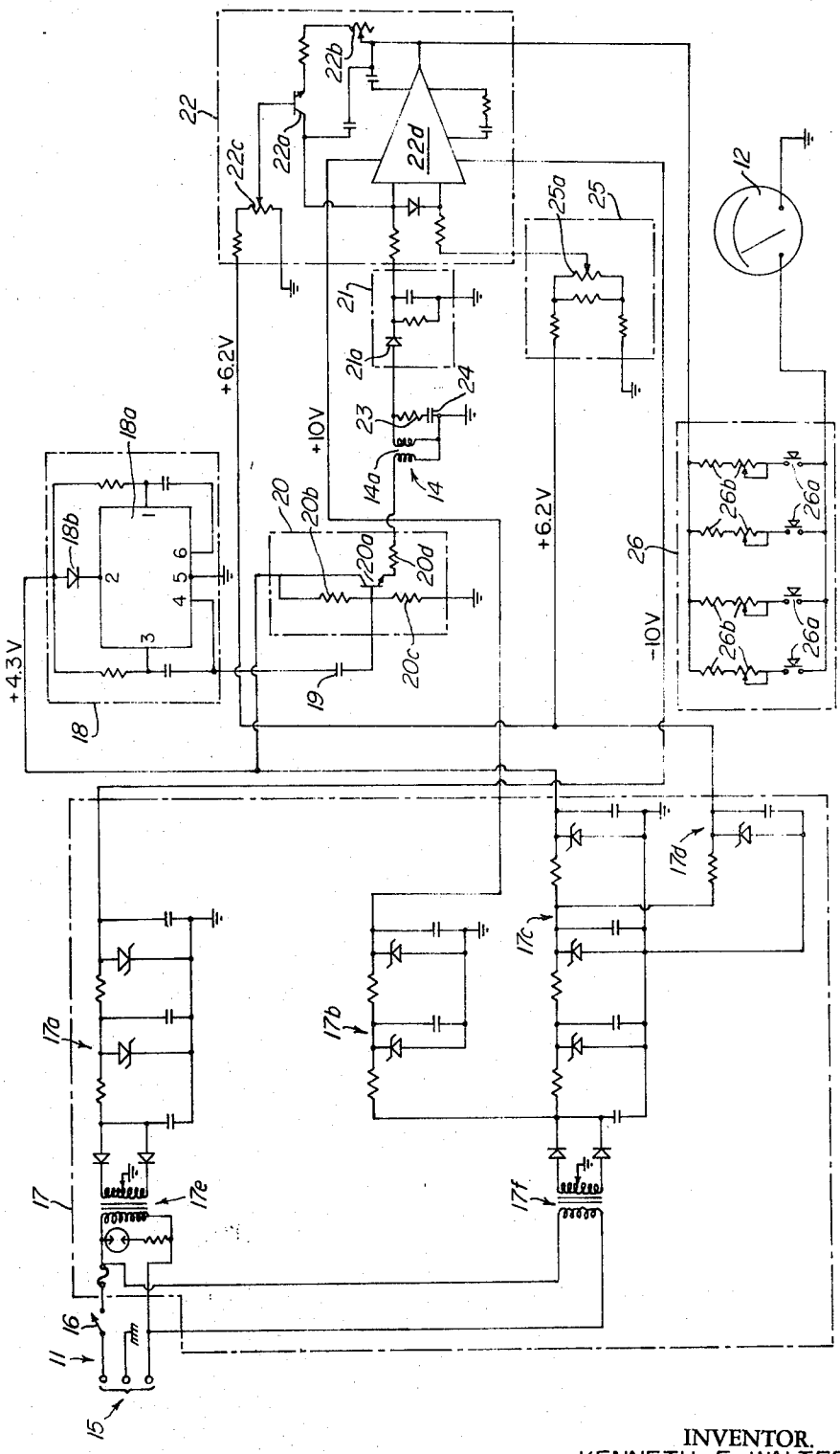


FIG. 4.

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Patented Aug. 22, 1972 3,686,563

3 Sheets-Sheet 3

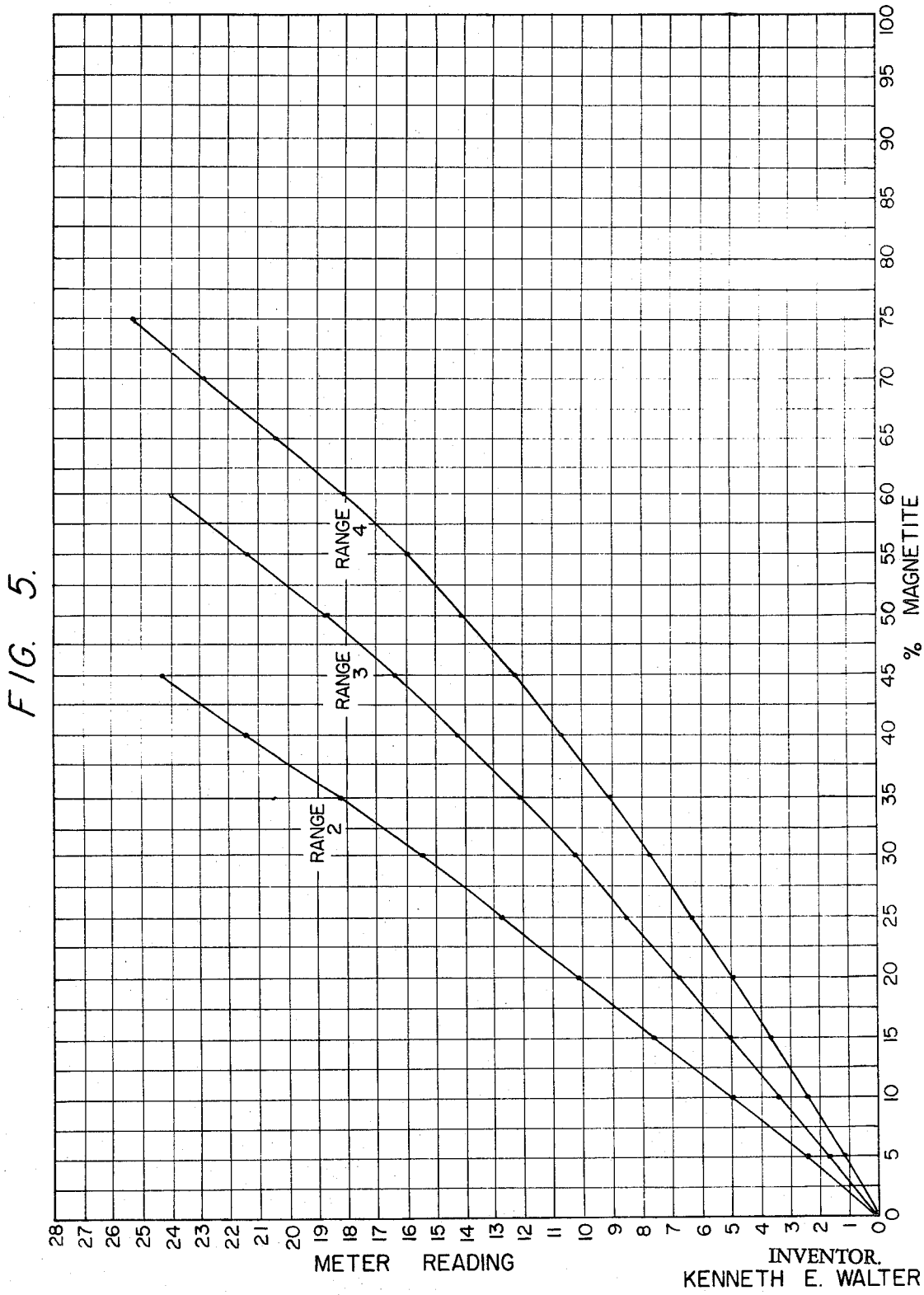


FIG. 5.

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APPARATUS UTILIZING AN AIR CORE TRANSFORMER FOR DETERMINING MAGNETIC MATERIAL CONTENT OF A SUBSTANCE

BACKGROUND OF THE INVENTION

1. Field

The invention is in the field of electrical apparatus for measuring the magnetic material content of various materials, particularly mineral materials, such as ores and slags, containing or believed to contain magnetite.

State of the Art

A variety of types of electrical apparatus for determining the magnetite material content of ores and ore materials have been developed heretofore. Although some of these have been designed to be portable, those using iron-core transformers have been heavier than desirable and all have left something to be desired in terms of stability and sensitivity.

SUMMARY OF THE INVENTION

In accordance with the present invention an air-core transformer, having primary and secondary coils wound about a magnetically inert carrier recessed centrally to receive a sample of the material to be tested, is connected in electrical circuit with a constant voltage D.C. power supply through a square wave generator and, if required, a load isolator. Thus, the transformer receives high frequency A.C. power that is not subject to line voltage fluctuations.

An A.C. signal from the transformer, constituting, in effect, a measurement directly proportional to the amount of magnetic material in the sample, is passed through detector means for rectification and filtering to produce a corresponding D.C. signal, which is then passed through an amplifier provided with means in its feedback circuitry for compensating for nonlinearity of the signal. The detector means advantageously comprises a diode arranged in circuit with resistance and capacitance. The means in the amplifier feedback circuit compensating for signal nonlinearity advantageously comprises transistor circuitry.

Since even without a sample in the core of the transformer there is some coupling between the primary and secondary, provision is made to adjust for the inevitable small D.C. leakage taking place, so the system will be zero calibrated. The means to accomplish this advantageously comprises a potentiometer circuit.

For readout of magnetic material content of samples tested, a meter, oscilloscope, recorder, etc., could be employed. It is preferred to utilize a meter having a range of 0 to 25 microamps, so the amplifier need provide only for moderate gain, and to employ a range control device utilizing a series of resistors that can be selectively brought into circuit, as by push buttons.

THE DRAWINGS

A specific embodiment of apparatus constituting the best mode presently contemplated of carrying out the invention is illustrated in the accompanying drawings in which:

FIG. 1 is a view in front elevation of the apparatus in preferred console arrangement for convenient handling as portable instrumentation for the intended purpose;

FIG. 2, a fragmentary view in vertical section taken on the line 2—2 of FIG. 1 and drawn to a larger scale;

FIG. 3, a block diagram descriptive of the system;

FIG. 4, a wiring diagram of the preferred circuitry; and

FIG. 5, specimen calibration curves for use with meter readings to determine percent magnetite in an ore sample.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

In the form illustrated, the apparatus is mounted in a console housing **10**, FIG. **1**, provided with an electrical cord plug-in connection **11** for a standard electrical receptacle supplying A.C. power of 110–120 volts from the usual line source. A readout meter **12** is mounted in a suitable aperture in the front panel of housing **10**, and various utility and operating facilities are grouped around its exposed face, as shown, including an opening **13** leading into the hollow core of an air-core transformer **14**, FIG. **2**, that is suitably mounted within housing **10**. In use, samples of material containing or thought to contain magnetic constituents, such as the mineral magnetite, are inserted into and removed from the transformer core **14***a* by way of opening **13**.

The circuitry within housing **10** includes the various components indicated in FIG. **3** interconnected as shown in FIG. **4**.

Air-core transformer **14** comprises primary and secondary coils **14***b* and **14***c*, respectively, wound in separate channels on a carrier **14***d* of magnetically inert material which defines sample-receiving air core **14***a*.

Power is supplied the system from the usual electrical supply lines by plugging cord **11** into outlet terminal connections **15**, FIG. **4**. It travels to sample transformer **14** by way of a manually controlled on-off switch **16**, a D.C. power supply **17**, a square wave generator in the form of a multivibrator circuit **18**, a differentiating capacitor **19**, and a load isolator circuit **20**.

It should be noted that load isolation is not required if the square wave generator has drive capability sufficient to maintain constant frequency under varying load conditions in the transformer due to varying quantities of magnetic material in the sample. Ordinarily, load isolation is advisable.

As illustrated, D.C. power supply **17** comprises dual-Zener regulated, negative and positive supplies **17***a* and **17***b*, respectively, of 10 volts each, and two triple-Zener regulated, positive supplies **17***c* and **17***d*, respectively, of 4.3 volts and 6.2 volts. Direct current for the Zener diodes employed in **17***a* is provided by a full wave rectifier circuit **17***e* and for the Zener diodes employed in **17***b*, **17***c*, and **17***d* by a full wave rectifier circuit **17***f*. Although this type of power supply is preferred, other types such as a series transistor regulated voltage power supply could be used to achieve essentially the same results.

Multivibrator circuit **18** of the present embodiment comprises a logic element **18***a* of standard usage, wired to perform as a multivibrator. The pin number designations are of a Fairchild Type 914 Dual 2-input gate. Diode **18***b* is for temperature compensation and the entire circuit provides a free running multivibrator of approximately 3 kilocycles. It should be noted that a frequency of at least 2 or 3 kc enables the use of an air-core transformer as against the usual iron core.

The square wave signal from multivibrator circuit **18** is differentiated into sharp spikes by capacitor **19** and passes to transformer **14** through solid state, load isola-

tion circuit **20**. As shown, circuit **20** comprises transistor **20***a* and resistors **20***b*, **20***c*, and **20***d* connected to function as an emitter follower isolating the load from the signal source. Load isolation is desirable in most instances to prevent pulling of the signal source frequency due to changing load conditions in the sample transformer. Such pulling would introduce undesirable nonlinearities into resulting calibration curves.

The secondary **14***c* of sample transformer **14** is connected to a detector circuit **21**, which rectifies and filters the transmitted A.C. signal and passes a resultant D.C. signal on to amplifier circuitry **22** provided with means **22***a* to compensate for signal nonlinearity. A resistor **23** and capacitor **24** in transformer circuit **14** are provided to dampen oscillations in the secondary. It should be noted that transformer **14** provides signal source coupling to detector **21** which is directly proportional to the magnetic material content of the sample being tested.

Amplifier circuitry **22** is of any standard type, e.g., as shown. The means **22***a* compensating for signal nonlinearity is, in this instance, a transistor serving as a nonlinear element in the amplifier feedback circuit which approximately counteracts the nonlinearity introduced by diode **21***a* of detector circuit **21**. Gain and slope controls **22***b* and **22***c*, respectively, are provided in the amplifier circuitry. Power for the amplifier comes directly from power supply **17** as indicated in the wiring diagram of FIG. **4**.

A zero-adjust circuit **25**, receiving its power from power supply **17**, feeds a compensating D.C. signal into amplifier **22***d*. This enables the operator to offset the small D.C. leakage current that passes from primary to secondary of transformer **14** even though no sample is present in core **14***a* thereof. Thus, an initial zero setting on meter **12** is obtainable. Circuit **25** is a potentiometer utilizing standard resistors in a conventional arrangement, as shown in FIG. **4**, and controlled at **25***a*.

To enable the use of a sensitive readout meter, e.g., one having a scale reading from 0 to 25 microamps, it is advantageous to provide for range control of the output signal. For this purpose, meter range control means **26** is provided, comprising a plurality of push-button switches **26***a*, respectively, arranged, along with respective sets **26***b* of resistors, in electrical parallel to enable selection of one or another range for the meter at any given time.

In operation, the material to be tested will usually be a sample of crushed and finely ground ore or slag in a free-flowing, dry state. As such, the sample will be placed in a vial made of some magnetically inert material, e.g., a plastic, dimensioned to fit closely into core **14***a*. Power switch **16** will be turned on and the system left for a period of at least 10 minutes for warm-up. Thereafter, meter range button No. **1** will be pressed and held down while zero-adjust knob **25***a* is turned until the pointer of meter **12** rests at 0 on the readout scale. The meter range button will then be released and the sample vial inserted in transformer core **14***a* by way of access opening **13**.

Following insertion of the sample, assuming it to be material containing or believed to contain magnetite, meter range button No. **4** should be pressed. If the meter reading is above **15**, No. **4** calibration curve, FIG. **5**, is to be consulted for percent magnetite. If the meter reading is below **15**, meter range button No. **3** should be pressed to obtain a reading above **15** for use with calibration curve No. **3**. If the meter reading is still below **15**, meter button No. **2** should be pressed to obtain a reading above **10** for use with calibration curve No. **2**. If the meter reading is below **10**, meter range button No. **1** should be pressed. Since meter range No. **1** is linear, percent magnetite can be read directly from the meter scale.

It should be noted that a corrective factor must be applied to meter readings depending upon system warm-up time. Thus, readings will be 1.3 percent too high after a 10 minute warm-up; 0.8 percent too high after 30 minute warm-up; and 0.4 percent too high after 60 minute warm-up.

Care should be taken in sample preparation. Thus, for best results, the material to be analyzed should be ground in a nonmetallic grinder, such as a ceramic pebble mill. If a common iron ball grinder is used, there will be from 2 to 4 percent iron contributed to the sample from the grinder. The fineness of grind should be −100 mesh. Packing of the ground sample is very important. A reading lower than the actual magnetite content will be obtained if the sample is not packed very tightly. A slightly higher than true reading will be obtained if the material is packed too tightly. This error is much smaller than that which will result if the sample is not packed firmly enough. A funnel and tamping tool of plastic or other magnetically inert material should be used for packing the ground sample material into the vial. The funnel should be placed in the vial, which should be set on a firm surface. The vial should be filled about one-fourth of its capacity and then tamped to about three-sixteenths of its capacity, this procedure being repeated until the vial is filled to just over the top. The material should be leveled off the top and the cap of the vial firmly and completely seated on the upper rim of the vial.

The calibration curves are prepared by inserting samples of known magnetite content, in terms of percent by weight, mixed with more or less of a magnetically inert material, such as a pure silica sand.

The system can be battery powered, in which event the power supply circuitry **17** will be replaced by a battery with voltage regulating circuitry of known type.

Whereas this invention is here illustrated and described with respect to certain preferred forms thereof, it is to be understood that many variations are possible without departing from the inventive concepts particularly pointed out in the claims.

I claim:

1. Apparatus for determining the magnetic material content of a substance, comprising:

an air-core transformer adapted to receive, in its core, a sample of the said substance;

a constant voltage D.C. power supply for the apparatus;

square wave generator means and means for differentiating the generated square wave interconnected between said power supply and said transformer for converting D.C. power to high frequency A.C. power for the transformer;

detector means for rectifying and filtering A.C. signals from the transformer to produce corresponding D.C. signal output;

means for amplifying said D.C. signal output, including means for compensating for nonlinearity of the signal;

zero control means for the amplified signal; and

readout means controlled by the amplified and zero-controlled signal.

2. Apparatus in accordance with claim 1, additionally including range control means for said readout means.

3. Apparatus in accordance with claim 2, wherein the readout means is a sensitive microammeter and the range control means comprises a plurality of sets of resistors and switches, said sets being interconnected in electrical parallel.

4. Apparatus in accordance with claim 1, additionally including means for isolating the transformer load from the oscillator, resulting in a constant voltage A.C. signal output independent of the magnetic content of the sample in all instances of use of the apparatus.

5. Apparatus in accordance with claim 4, wherein the load isolation means comprises solid state circuitry including a transistor and resistors connected to function as an emitter follower.

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