Jan. 24, 1950 D. E. BOVEY 2,495,627

METHOD FOR SORTING METALLIC ARTICLES

Filed July 16, 1947

Fig. 1.

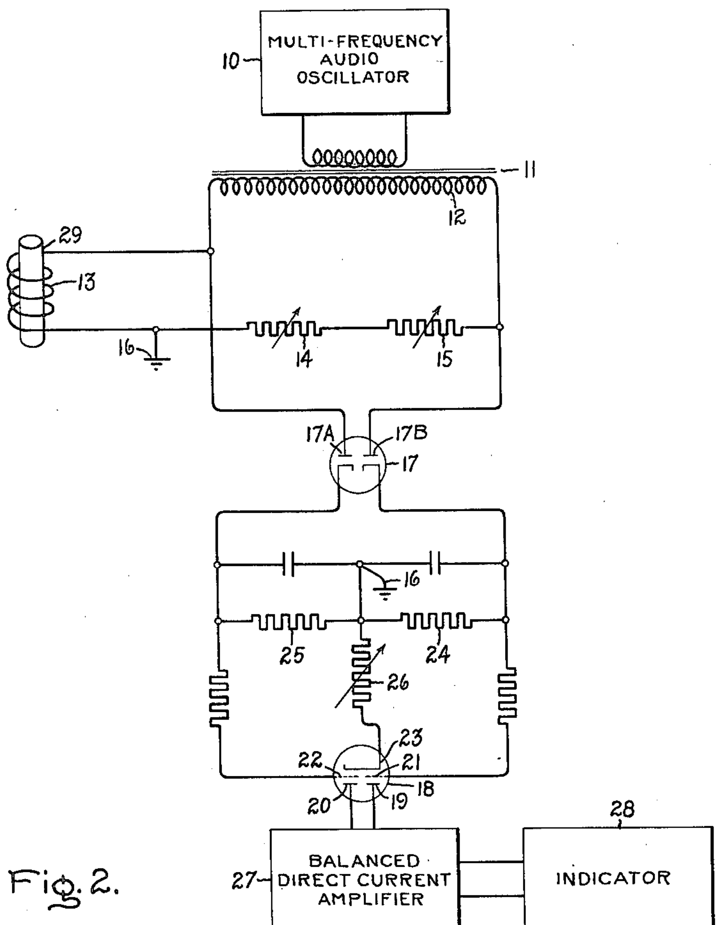
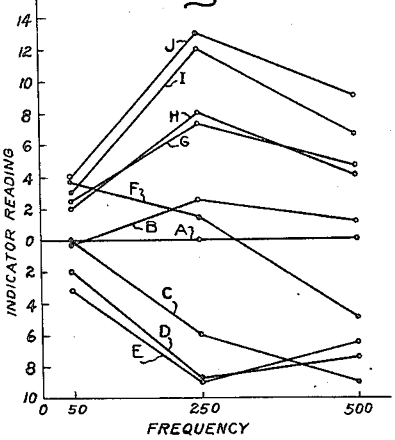


Fig. 2.



Inventor:
Donald E. Bovey,
by Prowell S. Mack
His Attorney.

Patented Jan. 24, 1950 2,495,627

UNITED STATES PATENT OFFICE

2,495,627

METHOD FOR SORTING METALLIC ARTICLES

Donald E. Bovey, West Albany, N. Y., assignor to General Electric Company, a corporation of New York

Application July 16, 1947, Serial No. 761,321

1 Claim. (Cl. 175—183)

1

My invention relates to an improved method for use in non-destructive inspection and comparison of metallic materials, and has as an object the provision of improved means for comparing and sorting metallic articles. Other objects and advantages will become apparent as the description proceeds.

In the practice of my invention, I provide apparatus which furnishes convenient and non-destructive means for determining whether or not a particular metallic article is identical with a standard specimen or article in composition and characteristics. The apparatus, in general, consists of a source of alternating voltage having means for selecting a plurality of frequencies. The voltage, at a selected frequency, is applied to a balancing circuit consisting of an inductor, which may be a solenoid, forming one leg of the balancing circuit, and a variable impedance, which may be a variable resistor, forming the other leg. The standard article is inserted in the magnetic flux path of the inductor; for example, inside the solenoid. Balance is first obtained with the standard article positioned inside the solenoid by adjusting the variable impedance. Following this, another metallic article is inserted in place of the standard one. In general, if such other article is not identical in electrical and magnetic characteristics with the standard article, the impedance of the solenoid is changed by the substitution and the circuit is unbalanced, a condition which can be read on an indicating instrument, such as a microammeter. The preferred apparatus includes means for separately rectifying the output from each side of the balancing circuit and differentially amplifying the rectified voltages, which then operate the indicating instrument. This arrangement provides much greater accuracy and sensitivity than has heretofore been obtainable with simple, commercially practicable apparatus.

For a better understanding of my invention, reference is made in the following description to the accompanying drawing in which Fig. 1 is a circuit diagram of apparatus constructed in accordance with my invention, and Fig. 2 is a graphic illustration of indications of relative reactance versus frequency obtained from apparatus shown in Fig. 1.

Referring now to Fig. 1, the numeral 10 designates a source of alternating voltage of selectively variable frequency, such as an audio oscillator capable of being adjusted to produce various frequencies selectively. For example, frequencies of 50, 250, 500, 1000, 2500, 4000, and 10,000 cycles per second may be provided.

2

The output of the oscillator is connected to the primary of an impedance matching transformer 11, the secondary 12 of which is connected across a balancing circuit consisting of a solenoid 13 connected in series with variable resistors 14 and 15. Preferably the junction of resistor 14 and solenoid 13 is connected to ground 16; but obviously the ground connections shown may be connected together by other means to complete the circuits. Resistors 14 and 15 together constitute a variable impedance. Resistor 15 may have a relatively large resistance value and provide coarse adjustment of the combined impedance of the two. Resistor 14 may have a smaller resistance value and provide a fine or "vernier" adjustment of the combined impedance.

Although a preference for utilizing variable resistances 14 and 15 is indicated, other impedance elements such as variable inductors or capacitors are equally feasible as balancing means, since the matter of phase relation has no bearing on the operation of the apparatus.

Voltage rectifying means comprising rectifiers 17A and 17B and resistors 24 and 25 connected as shown provide two D. C. voltages across the respective resistors. Rectifiers 17A and 17B may be comprised in a single envelope 17 as shown. Capacitors connected in parallel with resistors 24 and 25 bypass A. C. components of current. The rectified voltages have the same polarity since the polarity of the rectifiers is the same, and are equal when the combined impedance of resistors 14 and 15 equals the impedance of inductor 13. Any impedance unbalance results in a corresponding inequality of the two rectified voltages.

A D. C. voltage amplifier stage, including a duo-triode vacuum tube 18 having two triode sections respectively comprising anodes 19 and 20, control grids 21 and 22, and a common cathcde 23, differentially amplifies the rectified voltages across resistors 24 and 25.

An adjustable cathode resistor 26 provides an adjustable bias voltage for tube 18.

It is evident that when equal voltages are applied to control grids 21 and 22, which occurs when the two legs of the balancing circuit have equal impedances as hereinbefore explained, anodes 19 and 20 will have equal potentials and there will be no net voltage between these two anodes. But when the voltages applied to grids

21 and 22 are unequal, they are differentially amplified and a voltage proportional to their difference is produced between anodes 19 and 20.

An additional D. C. amplifier 27, which may be of a type known in the art, has its input connected between anodes 19 and 20, and thus is adapted to amplify the voltage between these two anodes. An indicating instrument 28 is connected to the output of amplifier 27. Preferably instrument 28 has a centered zero scale and is adapted to indicate both positive and negative values. Energizing voltages are applied to the D. C. amplifier stages by conventional means, not shown.

The apparatus may be operated in the following manner:

Assume that the multi-frequency oscillator 10 is suitably energized and adjusted to a selected frequency and that its output is applied to the balancing network consisting of solenoid 13 and variable resistors 14 and 15. A standard metallic article 29 is positioned inside solenoid 13, and resistors 14 and 15 are adjusted to balance the circuit. When the resistance of balancing resistors 14 and 15 is adjusted to the same value as the impedance of solenoid 13 at the particular frequency selected, the magnitude of the alternating potential across the balancing resistor group is equal to the magnitude of the potential across the solenoid (although these potentials are not in phase with each other), and equal voltages are applied to grids 21 and 22. Instrument 28 then indicates "zero."

After balance has been secured with the standard article in the solenoid and with all controls unaltered, the standard article is replaced by another article the electrical or magnetic properties of which are to be compared with the standard. The impedance of the solenoid 13 will be changed if the two articles have dissimilar properties; and as a result the balance of the circuit will be upset and instrument 28 will indicate some value other than "zero." This value or "indicator reading" may be in arbitrarily selected units. Because of the known correlation between the physical and chemical properties of materials and their electrical and magnetic properties, the relative magnitudes of values so obtained are an effective measure for comparing and sorting metallic articles.

In general, the impedance of the solenoid 13 is increased by an increase of either the permeability or the resistivity of the article inserted therein. It is possible to find two articles, dissimilar in their electrical and magnetic properties, which will produce balance at some particular frequency and will thus test alike at that frequency.

For example, if one article has higher permeability but lower resistivity than another, the differences could be such that both would provide a substantially similar reading on indicator 28 at an oscillator frequency of 250 cycles per second. However, since the permeability and loss effects of materials generally vary at different rates with respect to frequency, they would not produce the same results at some other frequency, such as 500 cycles per second. To take advantage of this phenomenon, in the preferred apparatus I provide means for supplying voltage at frequencies of 50, 250, 500, 1000, 2500, 4000 and 10,000 cycles per second. Other and higher frequencies can be utilized. Where sample specimens of the different materials to be identified are available, it is a simple matter to try different frequencies to determine which one gives the best identification.

Fig. 2 represents graphically a method of selecting a suitable frequency in order to provide the best identification or comparison. A number of articles are tested in the manner hereinbefore described, and the indicator readings at each frequency are plotted. Curves A through J are drawn respectively connecting all points plotted from data obtained from testing articles A through J. "A" represents the standard article and all other values plotted are relative to A.

It can be observed from the curves how the identification and sorting of articles is facilitated by selection of an appropriate frequency. Although the standard article A and the articles B and C provide indications which at 50 cycles per second are practically impossible to distinguish at 250 cycles per second they are easily distinguishable, and at 500 cycles per second the separation between the A and C indications is even greater. It is thus apparent that articles A and C can be most easily identified for sorting by using a frequency of 500 cycles per second, but that 250 cycles per second is preferable if B must also be identified and sorted.

Curves D through J represent other articles which may be present in the sample tested. In any case, the optimum frequency to be selected depends upon the articles present and the groups into which they are to be sorted, as is evident from Fig. 2. Thus the group of articles ABCDE could be separated from group FGHIJ most easily by using a frequency of 250 cycles per second, group ABF could be separated from CDE and from GHIJ at 250 cycles per second, and AB could be separated from CDEF and from GHIJ at 500 cycles per second.

By properly selecting in the manner described a frequency which gives a good separation into the groups desired, the operation of identifying, comparing, or sorting metallic articles becomes very simple.

In the case of non-magnetic material having a permeability of approximately unity, the use of low frequencies in the neighborhood of 50 cycles per second generally is not satisfactory. Consequently, higher test frequencies, for example, 1000, 2500, 4000 and 10,000 cycles per second or higher, are provided for the testing of non-magnetic materials. Conversely, the lower frequencies are generally preferred for comparing ferro-magnetic materials.

The magnetic fluxes produced at low frequencies penetrate the entire specimen and identification is based on the composition of the surface and cores of said specimens. On the other hand, at high frequencies, the flux produced permeates and predominates in the surface of the material under test and, therefore, provides the means for testing plated or case-hardened surfaces to determine their uniformity, etc. This is another consideration which influences the selection of a high or low frequency.

In conclusion, it may be said that my invention provides rapid, economic and simple means for identifying, comparing and sorting of magnetic and non-magnetic materials and is adapted to stockroom and production checking of such material by unskilled operators. In addition to the above, visual fatigue is substantially eliminated since my invention is readily adapted to use galvanometer-type indicators in preference to the oscilloscope type, although where it is desirable to use this last-named form of visual indication my invention is also adapted to utilize same.

The embodiment of my invention which has been illustrated and described has been selected for the purpose of setting forth the principles involved. It will be obvious, that the invention may be modified to meet various conditions for different specific uses, and it is, therefore, intended to cover by the appended claim all such modifications which fall within the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

The method of sorting metallic articles comprising the steps of selecting a sample of the articles to be sorted, providing an alternating voltage across an inductor, successively varying the frequency of the alternating voltage to a plurality of values, at each frequency successively placing each article of the sample in the magnetic flux path of the inductor, obtaining indications of the relative reactance of the inductor with each article of the sample so positioned at each frequency, plotting such indications as a function of frequency for each article of the sample to determine the frequency which provides the greatest differences in values of relative inductance between groups into which the articles are to be sorted, adjusting the alternating voltage to the frequency so determined, successively placing each of the articles to be sorted in the magnetic flux path of the inductor, obtaining indications of the relative reactance of the inductor with each article, and sorting the articles into groups according to the indications so obtained.

DONALD E. BOVEY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,727,388	Affel	Sept. 10, 1929
1,917,417	Zuschlag	July 11, 1933
2,057,835	Karajan et al.	Oct. 20, 1936
2,226,275	Abbott et al.	Dec. 24, 1940
2,269,584	Eldredge	Jan. 13, 1942
2,320,761	Tait et al.	June 1, 1943
2,337,231	Cloud	Dec. 21, 1943
2,434,547	Browne	Jan. 13, 1948