

Nov. 15, 1938.

A. V. DE FOREST

2,136,375

METHOD OF AND MEANS FOR MAGNETIC INSPECTION

Filed Aug. 22, 1936

2 Sheets-Sheet 1

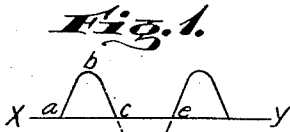


Fig. 2.

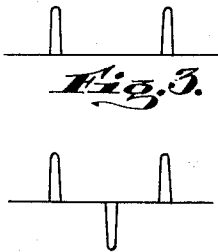


Fig. 3.

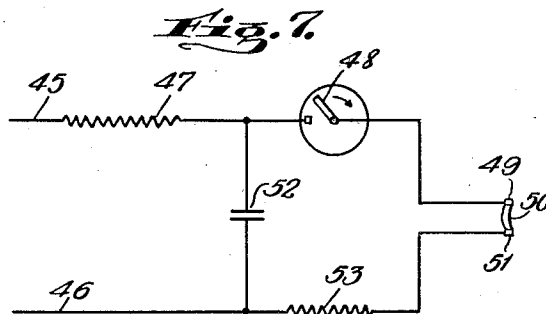
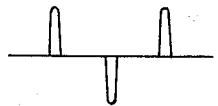


Fig. 8.

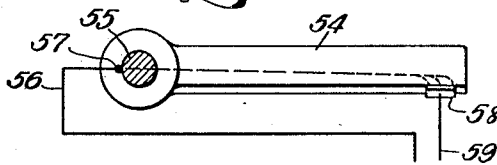


Fig. 6.

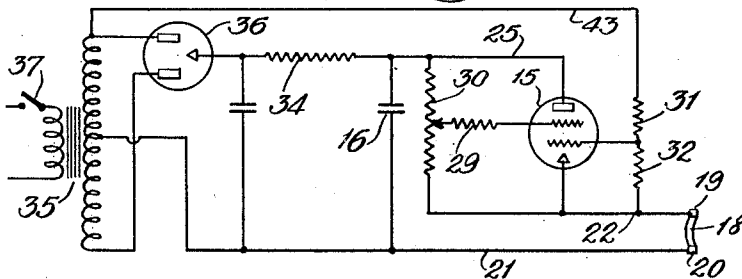


Fig. 10.

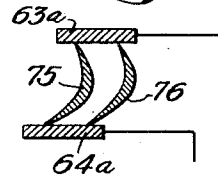


Fig. 9.

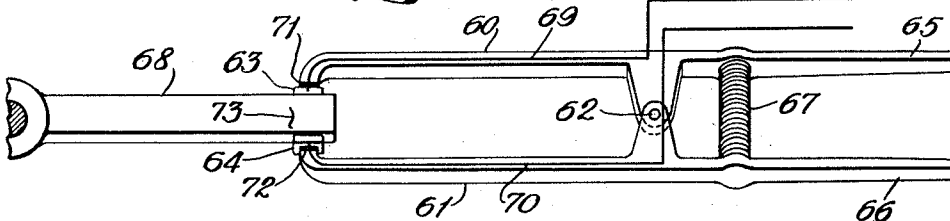
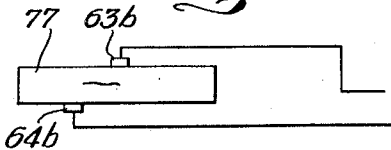


Fig. 11.



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2 Sheets-Sheet 2

Fig. 4.

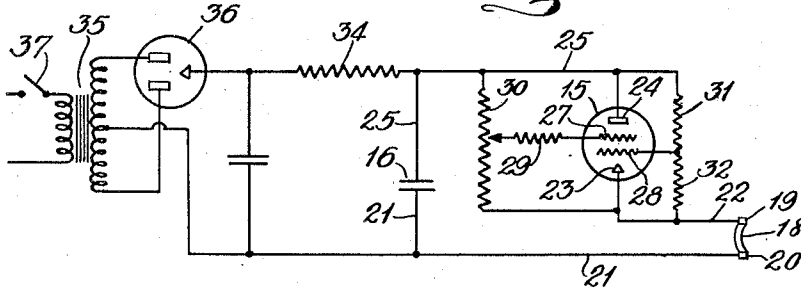


Fig. 5.

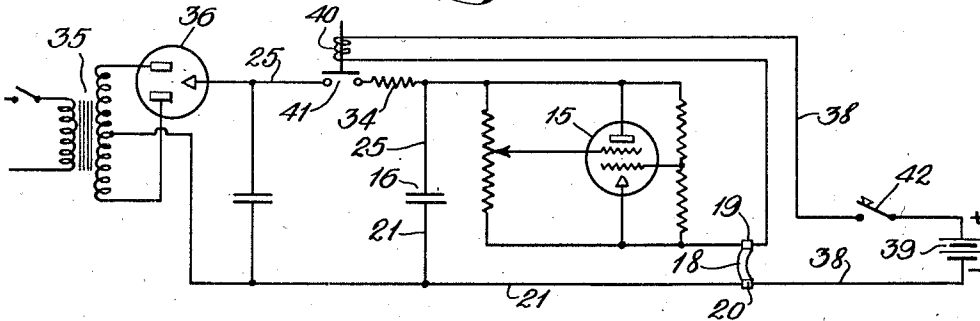


Fig. 12.

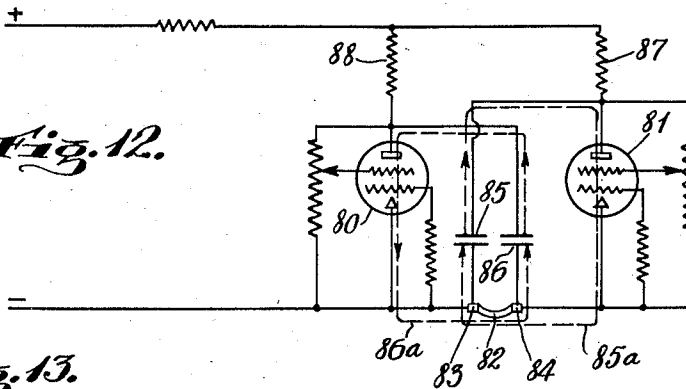


Fig. 13.

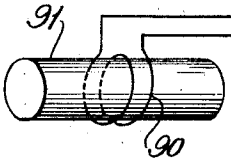


Fig. 14.



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2,136,375

METHOD OF AND MEANS FOR MAGNETIC INSPECTION

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Application August 22, 1936, Serial No. 97,415

32 Claims. (Cl. 175—183)

The present invention relates to improvements in methods of and means for inspecting magnetizable materials in which finely divided ferro-magnetic particles are employed to reveal the presence of minute cracks or other defects. These methods involve the creation of a magnetic field at the edges of the crack or other defect which may be accomplished by placing the specimen under test on the poles of a magnetic yoke or electro-magnet, the latter being energized by direct current. This method is disclosed in Patent No. 1,426,384, issued to William E. Hoke, August 22, 1922.

It is also possible to create the desired magnetic field by passing a heavy current through the specimen which induces a magnetic field at right angles to the direction of current flow. The current may be either direct or alternating as described in my Patent No. 1,960,898, issued May 29, 1934.

In carrying out the method disclosed in Patent No. 1,960,898, it is necessary to establish good electrical contact with the specimen which will carry several thousand amperes per square inch. This is customarily done by clamping the specimen in a machine built for the purpose with specially shaped copper contact blocks or with flexible copper braid between the specimen and the conductor. Even with all these precautions there is the danger of burning a test specimen at the contact point or marring a finished surface, such, for instance, as that of a bearing ball.

It is an object of the present invention to overcome this difficulty by supplying the magnetizing current for such a short duration of time that sufficient heat will not be developed to burn the surface. At the same time the voltage is greatly increased so that contact resistance is no longer a limitation on the current flow. It has been the usual practice when inspecting such parts as crank shafts to employ about 2000 amperes D. C. or 1000 amperes, 60 cycle A. C., per square inch of the sectional area under test, at a potential of between 4 and 16 volts, depending upon the equipment. In contrast to this method, the present method consists in carrying a current through the part of roughly the same value as before, that is, about 1000 to 2000 amperes, but for only a minute part of a second, say, one ten thousandth or one one-hundred thousandth part of a second, or even less. At the same time the potential may be increased to between 200 and 2000 volts or more, without difficulty. It is obvious that

the heating effect is directly proportional to the amount and duration of electrical current applied, while the magnetization is directly proportional to the amperage. Thus, by reducing the time factor to a minimum the heating effect is correspondingly reduced without reducing the magnetizing effect, except through the factor known as "skin effect" which limits only the depth to which magnetization penetrates.

Another object of my invention is to provide a method which can be carried out by much lighter equipment than has heretofore been possible. I have found that by the use of electrical impulses of very short duration, the flow of current and the magnetization, as well, are restricted to the extreme surface of the specimen so that the required current to magnetize the specimen is a function of its area rather than its volume. The small amount of energy necessary to provide magnetizing current for such a short time can readily be taken from a condenser. Obviously, this permits of the use of lighter equipment.

A further object of my invention is to provide means for producing a high frequency oscillation and suppressing all but single waves at predetermined time intervals so that only isolated impulses are utilized.

A further object of the invention is to provide means whereby a magnetic field may be swept over a surface in such direction as to cause progressive magnetization thereof, each impulse of current producing magnetization in a different zone of the surface.

Other objects and advantages of my invention will appear in the following description of a preferred method and certain modifications thereof and also of certain means for carrying out such methods.

In the accompanying drawings;

Figure 1 is a diagrammatic showing of the ordinary wave form of energizing current in which the negative impulses are eliminated;

Fig. 2 is a diagrammatic showing of my improved form of energizing current comprising widely spaced unidirectional impulses;

Fig. 3 shows diagrammatically a set of widely spaced impulses of alternately opposite polarity;

Fig. 4 is a diagram of electrical connections illustrating an apparatus for producing spaced unidirectional impulses of the type shown in Fig. 2;

Fig. 5 is a diagram of electrical connections in an apparatus similar to that shown in Fig. 4,

but with a relay control of the impulse producing apparatus;

Fig. 6 is a modification of the apparatus shown in Fig. 4 in which the impulses are synchronized with the alternating current supplied to the apparatus;

Fig. 7 is an electrical diagram of a mechanically interrupted direct current energized system which may also be employed for producing the intermittent energizing impulses;

Fig. 8 is a view, partly diagrammatic, illustrating the application of my method to a blade-like specimen, using one moving contact;

Fig. 9 is a view in perspective of a testing device for applying electric contacts to and moving both of them along a blade-like specimen;

Fig. 10 is a view in cross-section showing how a pair of turbine blades may be simultaneously tested and inspected;

Fig. 11 is a diagrammatic view showing how cracks that run longitudinally, as well as crosswise, of an elongated specimen may be simultaneously detected;

Fig. 12 is a diagram of a circuit for producing widely spaced impulses of alternately opposite polarity such as illustrated in Fig. 3;

Fig. 13 shows my method applied to a magnetizing winding surrounding a specimen; and

Fig. 14 shows in perspective a means for applying my testing method to an annular specimen, such, for instance, as a ball race ring, where the desired magnetization is circular.

My method of inspection involves first the creation of a magnetic field in the specimen with the lines of force disposed transversely to the supposed direction of the cracks or other defects. If the specimen is composed of material that will retain magnetism it may be magnetized by passing alternating current therethrough, and in order to leave a residual magnetic field in the specimen it is necessary to interrupt the current after it has reached maximum value and before it has passed the zero point and has started in the opposite direction to cause demagnetization; after the specimen has been magnetized fine particles of ferro-magnetic material may be applied thereto, such, for instance, as described in my Patent No. 1,960,899, and the particles will cluster about the cracks, prominently revealing them. If the specimen under test is of a material which will not retain magnetism, such, for instance, as wrought iron or low carbon steel, the magnetic testing powder may be applied to the specimen and then be slightly tapped or vibrated while the current is being passed through the specimen so that the particles will be assisted in moving to the points where the magnetic field is disturbed by cracks or other defects.

One of the great advantages of my method is the fact that contact resistance may be discounted by the employment of high voltage. This permits of the use of moving contacts whereby a broad area may be inspected by progressive magnetization. For instance, in testing a turbine blade which is apt to develop slight defects or cracks running crosswise of the blade my method permits of applying contact brushes of an energizing circuit to opposite edges of the blade and moving these brushes along the entire length of the blade. The current pursues a direct course from one brush to the other across the blade but since the brushes are moved lengthwise of the blade the entire area will eventually have been subjected to the energizing current.

This, according to the well known laws of physics, develops a magnetic field running at right angles to the direction of the current and this magnetic field intercepts the cracks that are apt to develop in a turbine blade.

In order to produce progressive magnetization of the blade it is necessary to employ only unidirectional impulses. For instance, in Figure 1, a sine wave, *a, b, c, d, e*, is shown in which the negative portion *c, d, e*, shown in broken lines, has been eliminated, leaving only the positive portion *a, b, c*. By thus rectifying the current, a series of unidirectional impulses will be passed through the specimen, progressively magnetizing the specimen.

The wave form shown in Fig. 1 represents that of commercial alternating current of say 50 cycles per second which has been merely rectified by eliminating such portions of each wave as pass below the zero line *x-y*. The heating effect of such waves, however, is high because of the time during which current is applied ($\frac{1}{120}$ sec. for each impulse). In order to reduce this heating effect, I provide means for converting a low cycle current into high frequency oscillations and suppress not merely such portions of each oscillation as pass below the zero line and also suppress all but single half wave oscillations which take place at fixed intervals. Thus, I am able to produce a wave form corresponding to that shown in Fig. 2. This wave form will have the same amplitude as that shown in Fig. 1 and the intervals between impulses may be the same, but the length of time the current is applied and therefore the heating effect of each impulse will be a very small fraction of that developed by the wave form shown in Fig. 1. For instance, I may convert 60 cycle frequency into 100,000 cycle frequency but utilize only one unidirectional impulse at each one-sixtieth of a second, suppressing all the intervening wave impulses. Although the heat energy developed by such relatively widely spaced impulses is slight, yet the surface magnetizing effect will be fully as great as that of the wave form shown in Fig. 1. With such relatively occasional impulses it is possible to use a high voltage with no substantial loss at the contacts.

I show diagrammatically in Fig. 4 a preferred apparatus for producing widely spaced high frequency unidirectional impulses. In this apparatus an electronic tube 15 is employed to control the periodic discharge of a condenser 16. The specimen under inspection is indicated at 18 and is engaged by a pair of brushes 19 and 20. The brush 20 is connected by line 21 to one side of the condenser 16, while the other brush 19 is connected by line 22 to the cathode 23 of the gas filled tube 15. The anode 24 of said tube is connected by a line 25 to the other side of the condenser 16. Within the tube 15 are the grids 27 and 28. The grid 27 is connected through a resistance 29 to a variable point on a resistance 30 bridging the lines 25 and 22. The grid 28 is connected through a resistance 31 to the line 25 and through a resistance 32 to the line 22.

The condenser 16 is arranged to be charged through a current limiting resistor 34 from a conventional direct current power supply of say 400 volts. If desired, commercial direct current may be employed, or, alternating current may be used provided the current is rectified. In Fig. 4, I show a conventional means for rectifying alternating current, such means comprising a transformer 35 and a rectifying tube 36. The sup-

ply of current is controlled by a switch 37 which is preferably closed only after the brushes 19 and 20 have made proper contact with the specimen 18.

In operation, when the voltage across the condenser 16 reaches a predetermined value, say 350 volts, the tube 15 becomes conducting and permits the condenser to discharge through it and through the specimen. Since the impedance of the discharge path is low the current can rise to very high values—500 to 2,000 amperes. When the condenser 16 is completely discharged the tube 15 becomes non-conducting and allows the condenser to recharge through the resistance 34. The critical voltage at which the tube becomes conducting depends upon the bias voltages on its grids which voltages are determined by the bias resistors 30, 31 and 32. The circuit is of the well-known relaxation oscillator type and will give current impulses at a rate determined by the supply voltage, the condenser capacity, and the break-down voltage of the tube 15. It will be understood that in order to handle large currents the tube 15 must be of a special type, as most gas filled tubes, particularly those with hot cathodes will not stand such large currents as I employ in my inspection system. The current impulses are unidirectional because the tube 15 prevents the current in the discharge circuit from reversing due to the oscillatory nature of the circuit.

In practice it is desirable to prevent the brushes 19 and 20 from passing current until after a good contact is made with the work. To this end, a low voltage relay circuit may be used such as illustrated in Fig. 5. The relay circuit 38, which bridges the brushes 19 and 20, is energized by a battery 39. In this circuit there is a relay 40 which when energized closes a gap 41 in the line 25. However, the relay will not be energized sufficiently to close the gap until the brushes have made good contact with the work. If desired a push button or other control switch 42 may be provided in the relay circuit but in any case the operation of the impulse generating apparatus will depend upon the establishment of proper electrical contact between the brushes and the work. This will prevent the operator from receiving an accidental shock.

It is possible to make the circuit operate in synchronism with the alternating current line voltage by applying voltage directly from the transformer to one of the grids of the tube through resistance 31, as shown in Fig. 6. In this figure parts which correspond to those in Fig. 4 are given the same reference numeral. It will be observed, however, that the resistor 31 in Fig. 6 is not connected with the line 25, but is connected by a line 43 to the secondary coil of the transformer 35. Thus, if the line current alternates at 60 cycles per second, the impulses passing through the specimen 18 will also occur at the rate of 60 per second, but the impulses will still be isolated and relatively widely spaced from each other.

In Fig. 7, I show a mechanical means for producing electrical impulses of short duration with direct current. In this case, a source of direct current is supplied across the lines 45 and 46. In the line 45 there is a resistance 47 and a mechanical switch 48 which connects it periodically to the brush or contact 49 bearing on one side of the specimen 50. The other line 46 extends to the opposite brush 51. A condenser 52 is bridged across lines 45 and 46 and between this condenser

and the brush 51 there is a resistance 53. The switch 48 is mechanically rotated at suitable speed and each time the switch makes contact there will be a discharge of current stored in the condenser 52 which will produce a momentary impulse running through the specimen 50. Ordinarily, such a discharge would result in a series of rapidly damped oscillations. However, by introducing the resistance 53 the damping may be increased to such an extent as to produce substantially a single unidirectional impulse at each closure of the switch. It will be understood that there are other ways in which widely spaced impulses, such as indicated in Fig. 2, may be obtained.

In Fig. 8, I illustrate an application of my method to the testing of a blade-like specimen 54 which is composed of a metal that will retain magnetism. The specimen is attached at one end to a shaft 55 which is connected to a conductor 56 by means of a fixed brush or electrical contact 57. A brush 58 is connected to a conductor 59 which forms the opposite pole of the impulse producing apparatus. This brush may be conveniently made of copper gauze or other suitable material which will give a broad and flexible contacting surface. In operation, the circuit, represented fragmentally by the conductors 56 and 59, is energized with periodic unidirectional impulses and the brush 58, at the same time, is moved along the edge of the blade 54 toward the shaft 55. The current impulses will flow from brush 58 to shaft 55 and thence to line 56, and in doing so will enter the edge of the specimen following in general the dotted lines shown in Fig. 8. In other words, the current will enter the blade at right angles to the edge and then will curve toward the shaft 55. The brush 58 will be moved gradually along the edge of the blade toward the shaft and each impulse of electric current will produce a corresponding magnetic field which will be retained in the blade 54, and the direction of this field will be substantially parallel to the edge of the blade along which the brush is moved.

This system of testing is particularly applicable to inspection of turbine blades which are apt to develop transverse cracks at the leading edge of the blade. Such cracks would be disposed at right angles to the direction of the magnetic field created by the electric flow. The penetration of this field will be confined rather closely to the edge of the blade and the test is applied to the leading edge of the blade. If it be desired to test the opposite edge, as well, the contact brush 58 may also be moved along the opposite edge of the blade.

Instead of having one fixed contact and one moving brush two opposed brushes may be employed, as shown particularly in Fig. 9. In this figure, I show a pair of contact arms 60 and 61 which are hinged together intermediate their ends, as indicated at 62. The arms are provided with contact brushes 63 and 64 respectively, and extensions of these arms at the opposite side of the pivot 62 form handles 65 and 66, respectively. These handles are normally pressed apart by a spring 67 which causes the brushes 63 and 64 to engage opposite sides of a specimen 68 to be tested. Testing current is supplied to the brushes 63 and 64 through leads 69 and 70. The brushes are suitably insulated from the arms 60 and 61 by blocks of insulation material indicated at 71 and 72, respectively.

In operation, the brushes are applied to oppo-

site edges of the specimen 68 which is to be tested, the handles 65 and 66 being squeezed to spread apart the brushes, and then on releasing the handles the spring 67 exerts sufficient pressure to maintain the desired contact of the brushes with the edges of the specimen 68. The current is applied and at the same time the device is drawn lengthwise of the specimen so that successive electrical impulses pass through parallel paths transversely with respect to the longitudinal axis of the specimen. This results in the production of successive magnetic fields extending lengthwise of the specimen so that any cracks or inhomogeneities, such as indicated at 73, will interrupt the magnetic lines of force. Magnetic testing powder is then applied to the specimen and the powder will collect at points where the magnetic lines are interrupted, indicating the defects.

If desired, the test may be applied to several specimens at a time. For instance, in Fig. 10, I show a pair of turbine blades 75 and 76 being simultaneously magnetized by means of a device similar to that shown in Fig. 9, but differing therefrom in having contact blocks 63a and 64a which are broad enough to bridge the pair of turbine blades.

While Figs. 8 to 10 show moving contact methods applied to blade-like forms the same systems may be used to magnetize portions of large pieces of material of any form. For instance, in searching for forging cracks or "flakes" in sections of billets, two brushes set at a distance apart of three to six inches may be so moved as to magnetize successively all portions of the surface. On large shafts of machines where cracks are suspected at fillets and keyways, these locations can be explored by drawing the brush contacts over the part with the current between contacts roughly parallel to the probable direction of the crack.

Fig. 11 shows another application of my improved method in which it is desired to detect cracks that extend longitudinally, as well as transversely, of a specimen 77. In this case, contact blocks 63b and 64b are provided which are not disposed directly opposite each other but are off-set lengthwise of the specimen, so that the flow of current from one contact block to the other will be oblique with respect to the longitudinal axis of the specimen. Such current will set up a magnetic field at right angles to the paths pursued by the electrical impulses and such magnetic fields when the magnetic testing powder is applied thereto, will betray the presence of all cracks, except those which are disposed parallel to the field.

In all cases where movable contacts are employed it is desirable to make good contact with the brushes before the current is turned on in the circuit, and to turn off this current before the contact is broken. This may be done by employing the system shown in Fig. 5 and the push button 42 may be conveniently located, as, for instance, on the handle 65 of the tool shown in Fig. 9.

While it is necessary to use unidirectional impulses in the case of sliding contacts it will be evident that where the contacts are fixed, alternating current impulses may be employed, such as shown in Fig. 3. A circuit for producing such impulses of alternately opposite polarity is shown in Fig. 12. In this circuit there are two stroboscopic tubes 80 and 81 connected in parallel and fed with direct or rectified current of suitable potential, say 400 volts. The specimen 82 under

test is located between the tubes and is engaged on opposite sides thereof by brushes 83 and 84, respectively. A pair of condensers 85 and 86 are charged through resistors 87 and 88 respectively. Conductor 85 is connected at one side to the brush 83 and the other side thereof is connected through tube 81 to brush 84, while one side of condenser 86 is connected to the brush 84 and the other through tube 80 to brush 83. Thus, the path of discharge through the specimen will be in one direction for condenser 85 and in the opposite direction for condenser 86, as shown by the broken lines 85a and 86a. The tube which reaches a critical potential first will fire, discharging its condenser. Since the tubes are never exactly alike they will never fire at the same time. The bias on the tubes is adjusted so that they tend to run at the same frequency. When a condenser is discharged the voltage across it is low. This will increase the voltage drop in its resistor and will slightly reduce the voltage on the other condenser which will tend to prevent the other tube from firing until the first condenser has had a chance to partly recharge. This effect will cause the tubes to fire alternately and thus produce current pulses through the specimen, such as shown in Fig. 3.

While the method as so far described has called for the passage of the current through the specimen, it will be obvious that the same effect could be obtained by placing the specimen within a coil through which the impulses pass and thereby inducing electrical impulses in the specimen. Fig. 13, for instance, shows a winding 90 of solenoid form suitable for longitudinal magnetization of bar stock 91 or similar shapes by impulses of high current for short lengths of time. The winding must be properly proportioned for the rapid discharge of current.

In Fig. 14, a ball race ring 95 is shown within a winding 96 through which impulses of electrical current are passed. If the impulses are of high amplitude but of relatively wide spacing and small area, such as shown in Fig. 3, the heat developed is comparatively small and yet a high magnetization is obtained. After the ball race has been magnetized, it is subjected to test with the magnetic testing powder to reveal such flaws as will show up as the powder clusters about the cracks or other defects in the specimen.

While I have shown a number of systems for producing isolated electric impulses of high intensity and potential but individually of very minute duration, I do not wish to be limited to the particular systems described. It will be understood therefore that I reserve the right to employ other means for producing such impulses and for applying such impulses to specimens under test without departing from the spirit and scope of my invention as set forth in the claims.

I claim:

1. The method of magnetizing a ferro-magnetic object for the purpose of locating a supposed defect therein, which consists in passing an impulse of electric current through the object in such direction as to induce a magnetic field disposed transversely to the supposed direction of said defect, said impulse being of high voltage and amperage but of minute duration not exceeding one one-thousandth of a second.

2. The method of magnetizing a ferro-magnetic object for the purpose of locating a supposed defect therein, which consists in passing a unidirectional impulse of electric current through the object in such direction as to induce a magnetic

field disposed transversely to the supposed direction of said defect, said impulse being of high voltage and amperage but of minute duration not exceeding one one-thousandth of a second.

3. The method of magnetizing a ferro-magnetic object for the purpose of locating supposed defects therein, which consists in subjecting the object to periodic pulsations of electricity of high voltage and amperage but individually of small duration and separated by inert intervals, and so directing said pulsations as to induce a magnetic field in the object disposed transversely to the supposed direction of said defects.

4. The method of magnetizing a ferro-magnetic object for the purpose of locating supposed defects therein, which consists in producing high frequency oscillations of electric current of high voltage and amperage, suppressing all but isolated oscillations at comparatively widely spaced intervals, passing said isolated impulses through the object in such direction as to induce a magnetic field in the object of a direction transverse to the supposed direction of said defects.

5. The method of magnetizing a ferro-magnetic object for the purpose of locating supposed defects therein, which consists in subjecting the object to periodic unidirectional electric pulsations of high voltage and amperage but individually of small duration and separated by inert intervals, so directing the pulsations as to induce a magnetic field in the object of a direction transverse to the supposed direction of said defect, and causing displacement of the object with respect to the pulsations in a direction transverse to the direction of the pulsations.

6. The method of magnetizing a ferro-magnetic object for the purpose of locating supposed defects therein, which consists in generating isolated unidirectional electric impulses of high voltage and amperage but individually of minute duration and separated from each other by inert periods, each inert period being many times greater than the duration of each impulse, passing said impulses through the object in such direction as to induce a magnetic field of a direction transverse to the supposed direction of said defects and causing a lateral displacement of successive impulses whereby the energizing effect of the impulses will be spread over a broad area of the object.

7. The method of exploring a ferro-magnetic object for supposed defects therein, which consists in inducing a magnetic field in the object in a direction transverse to the supposed direction of said defects by passing isolated pulsations of electric current through the object at right angles to the desired direction of said field, each pulsation being of high voltage and amperage but of minute duration and spaced from the next pulsation by an inert interval greater than the period of duration of the pulsation, and applying finely divided ferro-magnetic particles to the object, whereby the particles will cluster about any defects traversed by the magnetic field and will thereby reveal their presence.

8. The method of magnetizing an object of ferro-magnetic material for the purpose of locating supposed defects therein, which consists in generating isolated unidirectional impulses of high voltage and amperage but individually of minute duration and spaced apart by comparatively long inert periods, passing said impulses through the object between a fixed point on the object and an opposed point movable along the object at an angle to a direct line connecting said

points, thereby inducing a magnetic field in the object.

9. The method of magnetizing an elongated object of ferro-magnetic material for the purpose of locating supposed defects therein extending transversely to the major axis of the object and adjacent a longitudinal edge thereof, which consists in generating isolated unidirectional electric impulses of high voltage and amperage but individually of minute duration and relatively widely spaced apart, passing said impulses through the object between a fixed point at one end thereof and a contact point on said edge, and moving the contact point along said edge.

10. The method of magnetizing an elongated object of ferro-magnetic material for the purpose of locating supposed defects therein, said defects being supposedly directed transversely to the longitudinal axis of the object, which consists in generating isolated unidirectional electric impulses of high voltage and amperage but individually of minute duration and relatively widely spaced apart, passing said impulses through the object at right angles to the longitudinal axis thereof so as to induce a magnetic field in the object of a direction transverse to the supposed direction of said defects.

11. The method of magnetizing an elongated object of ferro-magnetic material for the purpose of locating supposed defects therein, suspected to extend either parallel or transversely to the longitudinal axis of the object, which consists in generating isolated unidirectional electric impulses of high voltage and amperage but individually of minute duration and relatively widely spaced apart, and passing the impulses through the object diagonally to the longitudinal axis thereof.

12. The method of magnetizing a ferro-magnetic object for the purpose of locating supposed defects therein, which consists in converting a low frequency alternating current into separated unidirectional impulses of the same frequency and amplitude as the waves of said current but each impulse enduring for a small fraction of the duration of the corresponding wave of said current, passing said impulses through the object in such direction as to induce a magnetic field therein of a direction disposed transversely to the supposed direction of said defects, and simultaneously laterally displacing the line of application of the impulses.

13. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of current adapted to energize said circuit, a discharge circuit for the condenser including means for subjecting the object to the influence of the condenser discharge so as to induce a magnetic field in the object, and control means adapted to limit discharge of the condenser to isolated impulses at predetermined intervals.

14. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including means for subjecting the object to the influence of the condenser discharge so as to induce a magnetic field in the object, means in said circuit permitting discharge of the condenser

only at predetermined periods, and means for damping oscillations of the condenser discharge.

15. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including contact terminals adapted to make electrical connection with the object to pass the condenser discharge therethrough and thereby induce a magnetic field in the object, and control means adapted to limit discharge of the condenser to isolated impulses at predetermined intervals.

16. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including a pair of terminals adapted to make electrical connection with the object to pass the condenser discharge through said object, and an electronic tube interposed in the discharge circuit and arranged to permit unidirectional discharge of the condenser only at predetermined intervals.

17. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including a pair of terminals adapted to make electrical connection with the object to pass the condenser discharge through said object, and control means in the discharge circuit arranged to permit unidirectional discharge of the condenser only at predetermined intervals, at least one of the terminals being movable along the object in such direction as to spread the pulsations of condenser discharge over a broad area.

18. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including a pair of terminals adapted to make electrical connection with the object to pass the condenser discharge through said object, control means arranged to limit discharge of the condenser to isolated impulses at predetermined intervals, a normally open switch in the charging circuit of the condenser, and means adapted to close said switch only when a connection of predetermined low resistance has been established between the terminals and said object.

19. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including a pair of terminals adapted to make electrical connection with the object to pass the condenser discharge through said object, control means arranged to limit discharge of the condenser to isolated impulses at predetermined intervals,

a normally open relay switch in said charging circuit, a relay circuit for operating said switch, said relay circuit bridging said terminals, and a supply of low voltage current adapted to energize the relay circuit, said relay circuit being so electrically proportioned that the relay switch will not close unless a contact of low resistance has been established between the terminals and the object.

20. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including a pair of terminals adapted to make electrical connection with the object to pass the condenser discharge through said object, control means arranged to limit discharge of the condenser to isolated impulses at predetermined intervals, a normally open relay switch in said charging circuit, a relay circuit for operating said switch, said relay circuit bridging said terminals, a supply of low voltage current adapted to energize the relay circuit, said relay circuit being so electrically proportioned that the relay switch will not close unless a contact of low resistance has been established between the terminals and the object, and a manually operable switch controlling the relay circuit.

21. An apparatus producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a supply of alternating current, means for rectifying said current and charging the condenser therewith, a discharge circuit for the condenser including a pair of terminals adapted to establish electrical connection with said object whereby the condenser will discharge through the object, an electronic tube interposed in the discharge circuit and arranged to permit unidirectional discharge of the condenser at predetermined intervals, said tube including a bias grid energized by said alternating current and controlling the discharge of the condenser whereby said discharge will have a frequency corresponding to that of said alternating current.

22. Apparatus for producing isolated electrical impulses of alternately opposite polarity and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a pair of condensers, a charging circuit therefor in which the condensers are connected in parallel, a source of direct current adapted to energize said circuit, each condenser having a discharge circuit including an electronic tube adapted to control the discharge thereof, and a pair of terminals adapted to establish electrical connection with the object, the discharge circuits of the condensers being oppositely connected to said terminals whereby the discharge of one condenser through the object will be in opposite direction to the discharge of the other condenser therethrough.

23. A tool for applying pulsating current to an elongated object to induce a magnetic field therein for the detection of suspected defects, said tool comprising a pair of levers pivoted together, a contact brush mounted at the forward extremity of each lever but electrically insulated therefrom, a spring acting on the levers to force the brushes into engagement with opposite sides of said object, and leads connecting said brushes to a

source of pulsating electric current, one of the brushes being advanced with respect to the other so that the current will pass through the object diagonally with respect to the longitudinal axis of the object.

24. A method of magnetizing a ferro-magnetic object which consists in electrically interlinking the object with an electric circuit, producing high frequency oscillations of electric current of high voltage and amperage, suppressing all but isolated oscillations at comparatively widely spaced intervals, and passing said isolated impulses through the circuit so as to induce a magnetic field in said object.

25. A method of magnetizing a ferro-magnetic object which consists in electrically interlinking the object with electric circuit, producing high frequency oscillations of electric current of high voltage and amperage, suppressing all but isolated oscillations at comparatively widely spaced intervals, passing said isolated impulses through the circuit so as to induce a magnetic field in said object, and displacing the object in such direction as to spread the magnetizing effect of the impulses over a broad area of the object.

26. An apparatus for magnetizing an object, said apparatus comprising a condenser, a charging circuit therefor, a source of current adapted to energize said circuit, a discharge circuit for the condenser including means for subjecting the object to the influence of the condenser discharge so as to induce a magnetic field in the object, and control means adapted to limit the discharge of the condenser to isolated impulses at predetermined intervals.

27. An apparatus for magnetizing an object, said object comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including means for subjecting the object to the influence of the condenser discharge so as to induce a magnetic field in the object, means in said circuit permitting discharge of the condenser only at predetermined periods, and means for damping oscillations of the condenser discharge.

28. An apparatus for magnetizing an object, said apparatus comprising a condenser, a charging circuit therefor, a source of current adapted to energize said circuit, a discharge circuit for

the condenser including a portion electrically interlinked with the object so as to induce a magnetic field in the object, and control means adapted to limit discharge of the condenser to isolated impulses at predetermined intervals.

29. An apparatus for magnetizing an object, said apparatus comprising a condenser, a charging circuit therefor, a source of current adapted to energize said circuit, a discharge circuit for the condenser including a coil surrounding said object so that the condenser discharge will induce a magnetic field in the object, means permitting discharge of the condenser only at predetermined intervals, and means for damping oscillations of the condenser discharge.

30. An apparatus for magnetizing an object, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including means for subjecting the object to the influence of the condenser discharge so as to induce a magnetic field in the object, and an electronic tube interposed in the discharge circuit and arranged to permit uni-directional discharge of the condenser only at predetermined intervals.

31. The method of locating defects in a ferro-magnetic object which comprises passing periodic pulsations of magnetic flux through the object across the supposed defect and in a direction at an angle to the supposed direction of said defect, each impulse being of minute duration and spaced from the next impulse by an inert interval.

32. An apparatus for producing isolated electrical impulses and passing the same through an object to induce a magnetic field therein for the detection of suspected defects, said apparatus comprising a condenser, a charging circuit therefor, a source of direct current adapted to energize said circuit, a discharge circuit for the condenser including a pair of terminals adapted to make electrical connection with the object to pass the condenser discharge through said object, control means arranged to limit discharge of the condenser to isolated impulses at predetermined intervals, and means adapted to close the charging circuit of the condenser only when an electrical connection is established between said terminals.

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