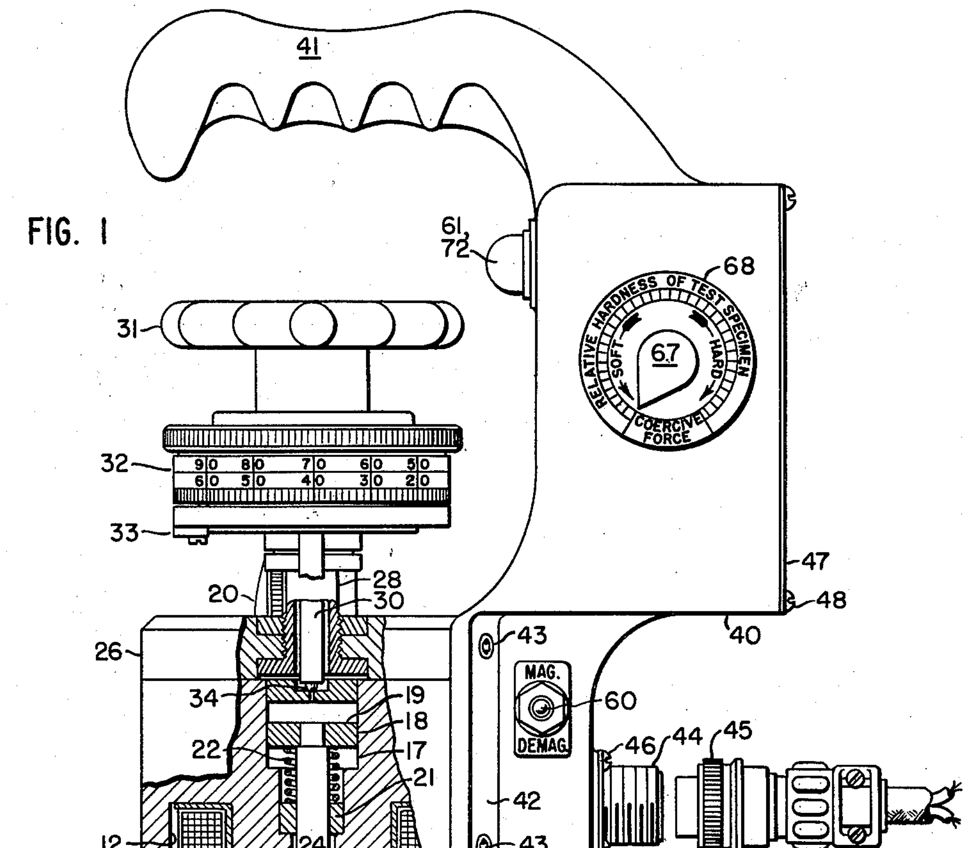
HARDNESS TESTERS

Filed Sept. 19, 1960

FIG. 1



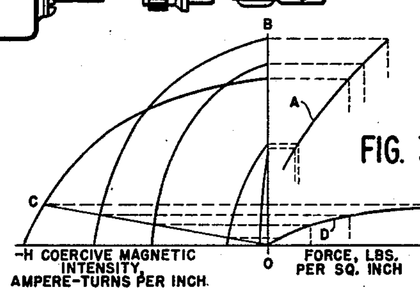


FIG. 3

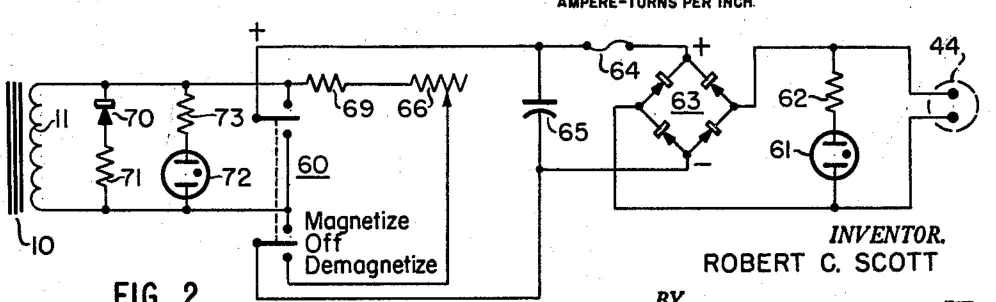


FIG. 2

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HARDNESS TESTERS

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This invention relates to an improvement in hardness testers of the kind shown and described in U.S. Patent No. 2,693,698, entitled "Hardness Tester," issued November 9, 1954 to Robert C. Scott. This patent describes a hardness tester which is adapted for testing ferromagnetic work pieces having variously formed surfaces, that can be affixed and firmly withheld to the work during the making of hardness tests by electromagnetic means, and that demagnetizes the work after completion of the tests to facilitate removal of the tester from engagement with the work. The electromagnetic means comprises an electromagnet having an annular recess to form inner and outer concentric pole cores which contact the work, a coil placed within the recess, and an armature comprising the work piece itself. This arrangement affords a high magnetic force to retain the tester securely in place on the work piece against the mechanical forces exerted during the testing operation.

My aforementioned patent further describes a circuit for energizing the electromagnetic means with direct current, and for demagnetizing the work following a hardness test by energizing the electromagnetic means with direct current of diminished value and in the opposite sense by reversing the polarity of the energizing current, and then continuously diminishing the magnitude of the current and reversing its polarity in a cyclic manner by automatic means to produce a hysteresis loop that becomes smaller and smaller until it finally vanishes, leaving the work demagnetized. However, the circuit elements required for carrying out this automatic demagnetization cycle are relatively complex and bulky, requiring the use of a container external to the hardness tester.

It is the primary object of this invention to provide an improved hardness tester with manually controlled circuit means for energizing electromagnetic means thereof, and for demagnetizing a work piece following a hardness test, which is of increased simplicity and compactness.

It is a feature of this invention that the improved circuit means may be compactly mounted in a carrying handle of the hardness tester, thus eliminating the need for external equipment containers, and facilitating the portability of the tester.

Another feature of this invention is the provision of means for limiting to a safe value the counter-voltage which is induced in the magnetizing and demagnetizing coil by the rapid collapse of the magnetic flux when the magnetizing circuit is opened upon completion of a hardness test.

Other objects and advantages of my invention will become apparent as the following description proceeds, referring to the accompanying drawings, in which:

FIG. 1 is a view in side elevation of one embodiment of my improved hardness tester, partially in section, applied to a work piece, and showing the flux lines through the work piece;

FIG. 2 is a schematic diagram of the improved circuit means forming a portion of the invention; and

FIG. 3 shows curves which illustrate important magnetic properties of a group of typical ferromagnetic materials, and is included to aid in describing the improved circuit means provided for demagnetizing the work after making a hardness test.

Referring to FIG. 1, a preferred embodiment of my improved hardness tester is shown, which comprises electromagnetic means generally designated **10**, which are similar in construction and mode of operation to those described in my aforementioned U.S. Patent No. 2,693,698. These means magnetically affix and firmly retain the hardness tester on the surface of a work piece as shown, the hardness of which is to be measured. The electromagnetic means generally comprises a magnetizing and demagnetizing coil **11**, positioned within a recess **12** formed in an electromagnet **13** of the flat-faced armature type. The magnetizing and demagnetizing coil **11** is wound on a metal or moulded plastic bobbin **14**, and is retained in recess **12** by any suitable means (not shown).

The electromagnetic means is thus characterized by concentric magnetic poles of opposite polarity, and provides a balanced magnetic circuit of relatively short length and large sectional area, with two working air gaps. The air gaps, magnetically in series, are mechanically in parallel, and provide a holding surface of large effective area with optimum lifting or tractive force. The entire magnetic circuit comprises the pole core (inner), pole core (outer), yoke and armature. The ferromagnetic work being tested acts as the magnet armature, and thus forms part of the magnetic circuit when the magnetizing and demagnetizing coil is energized from a source of electrical supply. The flux lines in this magnetic circuit are shown at the bottom of FIG. 1, and if seen in a bottom plan view, would be radial.

The magnet structure (yoke and pole cores) is preferably made of soft iron or of low content carbon steel, suitably annealed after machining to provide high magnetic saturation and consequently high magnetic force, and to have low magnetic retentiveness and coercive force for facilitating demagnetization and removal of the hardness testing machine from the surface of the work after making hardness tests.

A recess **17** is milled in the top of the electromagnet yoke to provide clearance space for a load spring **18**, which I prefer to make of beryllium copper, suitably heat treated after fabricating and machining in order to provide and maintain elastic deflection with negligible hysteresis error and drift under maximum loading, and which is longitudinally slotted at **19** to form a compression type of hairpin spring. A load indicator **20** (only partially shown) is drivingly connected with the upper section of the load spring, and more fully described in my aforementioned Patent No. 2,693,698.

A hole **27** through the center of the inner pole core is counterbored at its upper end to accommodate a press-fitted bronze bushing **21** and a non-magnetic spiral spring **22**. Toward the face of the electromagnet a second bronze bushing **23** is press-fitted within the center hole. A penetrator extension rod **24**, which I prefer also to make of non-magnetic steel, is press-fitted into the lower section of load spring **18**. The penetrator extension rod and load spring assembly is centered and guided by bushings **21** and **23** which are precision aligned and reamed to provide a sliding fit for the penetrator extension rod. The lower end of the penetrator extension rod is threaded to take penetrator **25** which indents the work during the making of a hardness test, and which may be readily removed and replaced from the face of the electromagnet.

The penetrator or indentor may alternatively be a spheroconically shaped diamond, a hardened steel ball, or some other type of indenting tool. A cylindrical cap **26**, which I prefer to make of soft iron or mild steel, is secured to the top of the magnet yoke. In the center of the cap, and on the center line of the penetrator extension rod, an inner supporting tube **28** is threaded and firmly secured by means of its flanged end.

The supporting tube **28** receives a load spindle **30**, which is drivingly connected by suitable means (not shown) with a load handwheel **31** and a barrel dial hardness indicator **32**, as more fully described and shown by the aforementioned patent. The lower end of the load spindle **30** is work-hardened and seated to conform to the contour of hardened steel ball 34. The upper section of load spring 18 is counterbored and also work-hardened and seated to conform to the contour of hardened steel ball 34, so that the load spring 18 is interposed between the load spindle 30 and the penetrator extension rod 24, which are on a common center line.

By turning the load handwheel in a clockwise direction, the load member assembly (which comprises the load spring 18, dial indicator 20, penetrator extension rod 24 and penetrator 25), will be moved downward in the vertical direction, and at first resisted only by the load member return spring 22. Then when motion of the penetrator is resisted, as when the hardness tester is magnetically affixed to work that is being hardness tested, the load spring 18 will be compressed an amount which will be indicated by the pointer on the dial indicator, and the motion of the pointer will be proportional to the applied load. The barrel dial rotates in the same direction and in proportion to the movement of the handwheel, and cooperates with a fixed pointer 33 to indicate the hardness of the work piece as shown by the appropriate scale on the barrel dial.

By turning the load handwheel in a counterclockwise direction the load member return spring will move the load member assembly upward, after the testing load has been removed as shown on the dial indicator.

By correlating the load with the type of penetrator used, an accurate indication of the hardness of the work piece may be readily derived. The manner of operation of the means thus far referred to are more fully described in my aforementioned patent, and therefore no further detailed description of them is believed necessary.

According to a feature of the present invention, I provide improved circuit means for energizing coil 11 to magnetize and demagnetize electromagnetic means 10 and the work piece. These circuit means are relatively compact, and are mounted within a housing portion 40 of a light-weight carrying handle 41, which is preferably formed of high-strength aluminum alloy. The handle is provided with mounting flanges, one of which is shown at 42, and is secured to the electromagnet 10 and the cap 26 by means of capscrews 43. In order to supply alternating electric current for operation of the hardness tester, a conventional removable connector comprising a female socket 44 and male plug 45 are provided. The socket 44 is mounted on the housing portion 40 by means of screws 46. A cover plate 47 is provided to afford access to the circuit elements contained in the housing portion 40, and is removably secured thereon by screws 48.

Referring now to FIGS. 1 and 2, circuit means for magnetizing and demagnetizing the work piece are shown. These means include manually operated double-pole double-throw switch means 60, which is shown in an open circuit position, and is operable to first and second positions for magnetizing and demagnetizing the electromagnetic means 10. Switch 60 selectively connects the coil 11 in a first circuit for magnetizing energization, and in a second circuit for demagnetizing energization. Both circuits are energized by direct current rectified from an alternating current supply, by means of a full-wave bridge-connected rectifier 63 comprising four solid state silicon diodes. The alternating current input is connected to the rectifier by means of a connector 44. A neon pilot light 61 and an associated resistor 62 are connected across the incoming alternating current leads to indicate whether the alternating current supply is on. The direct current output of the rectifier is connected to a manually operated double-pole double-throw switch means 60 with polarity shown, which controls magnetizing energization of the first circuit and demagnetizing energization of the second circuit respectively, depending upon the closed position of the switch. The rectifier and circuitry are protected against overloads as well as defective or improper operation by a fuse 64. A capacitor 65, which is preferably

of the dry electrolytic type, is connected across the output of the rectifier to reduce the "ripple" of the rectified direct current, thereby providing a magnetic field with relatively constant intensity when the magnetizing and demagnetizing coil 11 is energized.

The first or magnetizing circuit includes a neon pilot light 72 with an associated resistor 73 connected across the leads of the magnetizing and demagnetizing coil 11, to indicate magnetizing energization of the coil when the double-pole double-throw switch means 60 is closed in the first or "magnetize" position.

The second or demagnetizing circuit includes a fixed resistor 69 of suitable value, in series with a variable resistor or rheostat 66, which are connected mutually in series with the magnetizing and demagnetizing coil 11 when the double-pole double-throw switch 60 is closed in the second or "demagnetize" position. By varying the value of resistance of the rheostat 66 by means of a knob 67 (FIG. 1), which is indicated by its associated scale 68, and demagnetizing current may be varied over a suitable range of values.

Upon opening of the switch 60 from the magnetizing position, the rapid collapse of flux in the coil 11 tends to induce a momentary counter-voltage in the coil which may reach excessive values such as to damage the insulation of the coil and its associated circuiting. A feature of my invention is the provision of current-limiting means which limits this counter-voltage to a safe value, but does not adversely affect normal energization of the coil in either of the closed positions of the switch. These current-limiting means include a rectifier 70, preferably comprising a solid state silicon diode as shown, and a resistor 71, which are connected mutually in series, and in parallel with the coil. The rectifier is arranged so that an open circuit is presented to the rectified direct current supplied to the coil during its magnetization, while during demagnetization, when the polarity of the direct current is reversed, the diode acts as a unidirectional switch and thus connects the resistor 71 in parallel with the coil, having no adverse affect on the demagnetization means. However, the counter-voltage induced in the coil upon opening of the switch from the magnetizing position is reduced to a safe fraction of the value which would otherwise result.

Curves which illustrate important magnetic properties of a group of different ferromagnetic materials are shown in FIG. 3, wherein the axis O, —H represents the coercive magnetic intensity, or demagnetizing ampere turns per inch, and the axis O, B represents the magnetization of the materials in residual flux density. To the right of the ordinate, curves A and D show the affect of the coercive intensity in producing residual tractive force, which is represented on the abscissa to the right of the ordinate axis. Curve A shows the residual tractive force when there is no air gap in the magnetic circuit. The force values in pounds per square inch are obtained by projecting horizontally from the residual flux densities of the different materials on the axis O, B to curve A, as shown by the broken lines. Since, however, there is always an air gap in the magnetic circuit, the air-gap permeance line OC is drawn to represent an air gap in terms of its proportional relationship to the length of the magnetic circuit, and the intersection of line OC with the demagnetization curves gives the air-gap flux densities. Projecting these intersections on the force curve D, which is plotted to a scale that bears only a fractional relationship to the scale of curve A, the residual tractive forces are obtained. In like manner, air gaps of greater proportional lengths will result in smaller values of residual tractive force, and conversely, air gaps of smaller proportional lengths will result in larger values of residual tractive force.

The curves illustrate in a striking manner the wide difference in magnetic properties of ferromagnetic materials, and also the need for demagnetizing the work after making a hardness test. They also show the wide variation of coercive magnetic intensity, or ampere-turns per inch required for demagnetization of the materials.

In making a hardness test, the face of the electromagnet is placed upon the work piece, if necessary with an attached shoe adapter of the type shown and described in my aforementioned patent. The switch 60 is moved to the first or magnetizing position, completing the magnetizing circuit to energize the coil 11 with rectified direct current, thus magnetically affixing and firmly holding the hardness tester to the work piece. A hardness test is then carried out in the manner shown and described in my aforementioned patent. Before attempting to remove the hardness tester after making a hardness test, the work is demagnetized by first turning the knob 67 of the rheostat 66 to a position indicated on the scale 68 that corresponds to the relative hardness of the work, since the coercive magnetic intensity and consequently the magnitude of the demagnetizing current is approximately proportional to the relative hardness of most ferromagnetic materials. Furthermore, the length of air gap normally encountered in the making of hardness tests will not appreciably influence the magnitude of the demagnetizing current, as shown in FIG. 3. Therefore, by moving switch 60 through the open position to the second or demagnetizing position, the polarity of the rectified direct current through coil 11 will be reversed. If the magnitude of the demagnetizing current is optimum, the return of the switch 60 to its open position will demagnetize the work, and the hardness tester may be readily removed therefrom.

Although I have shown and described a preferred embodiment of my invention for illustrative purposes, it is to be understood that the invention is not limited to the specific mechanical and electrical details described, for numerous modifications within its spirit will readily occur to one skilled in the art to which it pertains. Therefore, it is my intention that the limits of the invention be defined only by the appended claim.

What I claim as new and desire to secure by Letters Patent is:

In a hardness tester for magnetizable metals, the combination comprising electromagnetic means for holding a work piece to be tested, means including a penetrator for testing the hardness of a work piece held by said electromagnetic means, said electromagnetic means including a coil, double-throw switch means electrically connected with said coil, first circuit means connected to supply direct current to said switch means in a first position thereof for energizing said coil to magnetize and magnetically affix the tester to the work piece, and second circuit means including a manually-variable resistor connected to supply direct current of adjustable preselected magnitude and opposite polarity to said switch means in a second position thereof to energize said coil in the opposite sense to demagnetize the tester and the work piece and scale means cooperating with said manually-variable resistor to indicate the setting thereof, said scale means having indicia indicating relative hardnesses of test specimens in inverse scalar relationship to corresponding resistance settings, whereby upon setting of said resistor according to the hardness of a test specimen, the value of the demagnetizing current supplied by said second circuit means is in direct relationship to the relative hardness of the specimen.

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