

Jan. 7, 1958

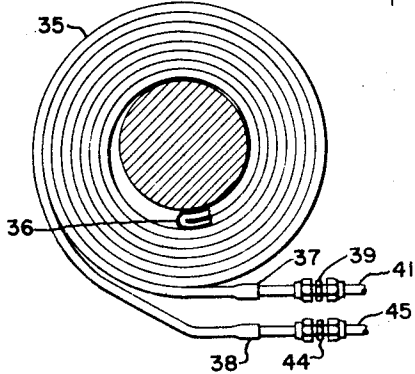
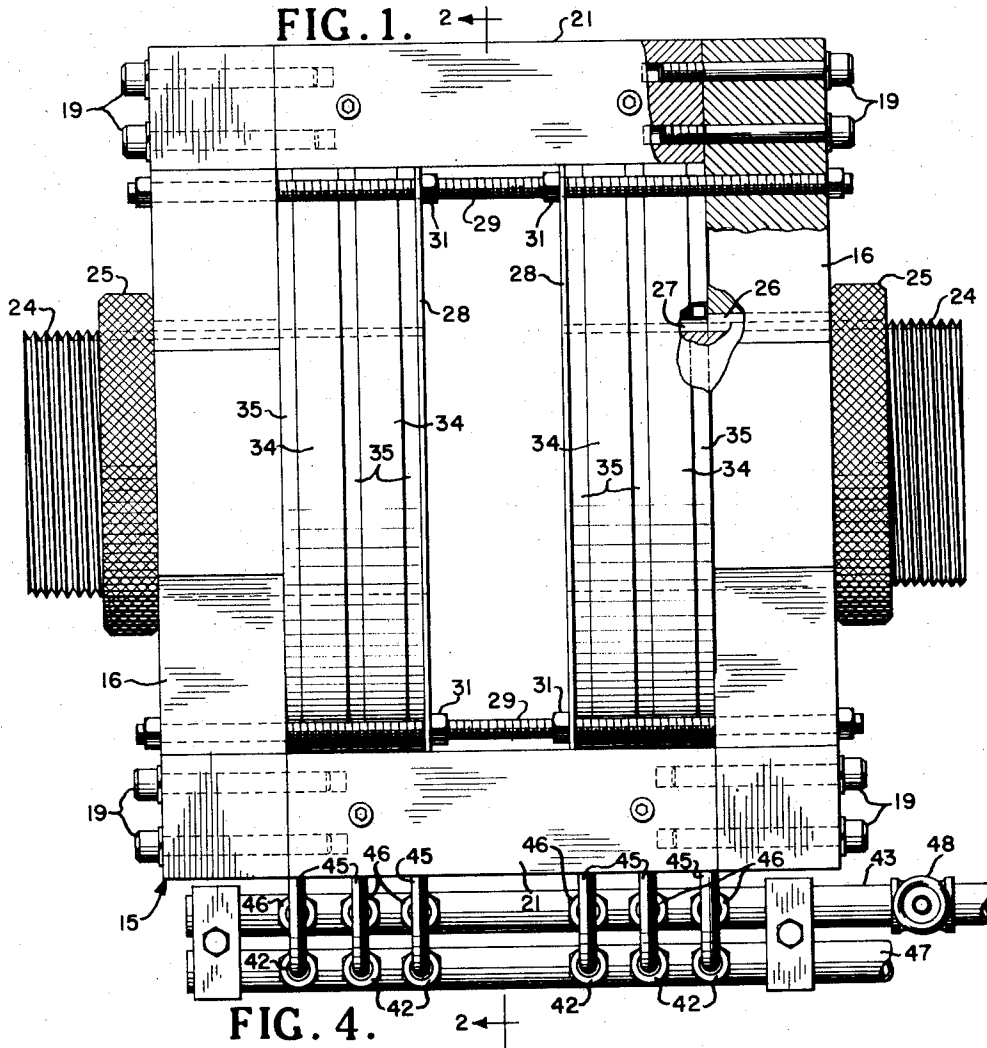
L. R. MAXWELL

2,819,431

ELECTROMAGNET

Filed Dec. 5, 1952

3 Sheets-Sheet 1



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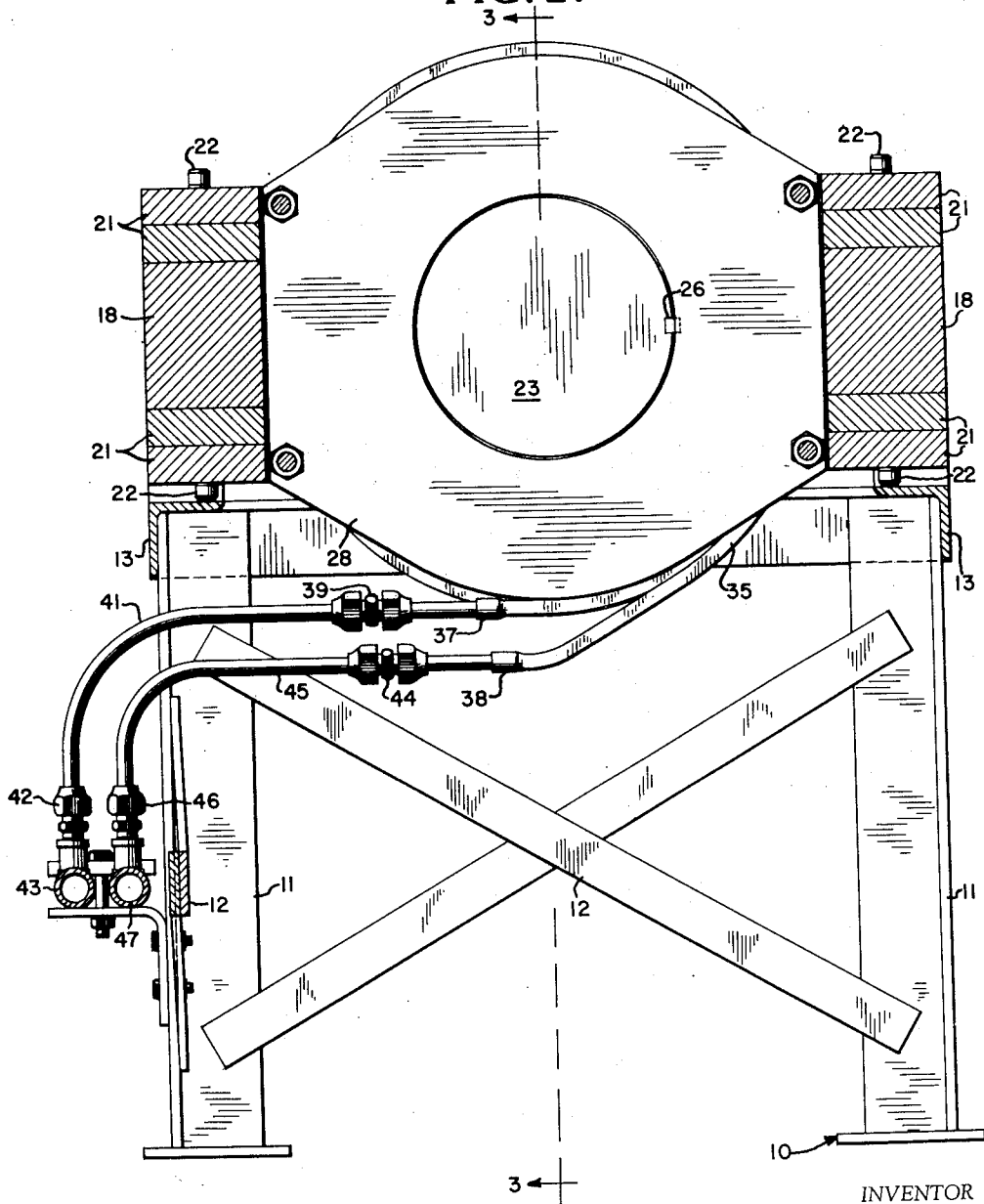
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FIG. 2.



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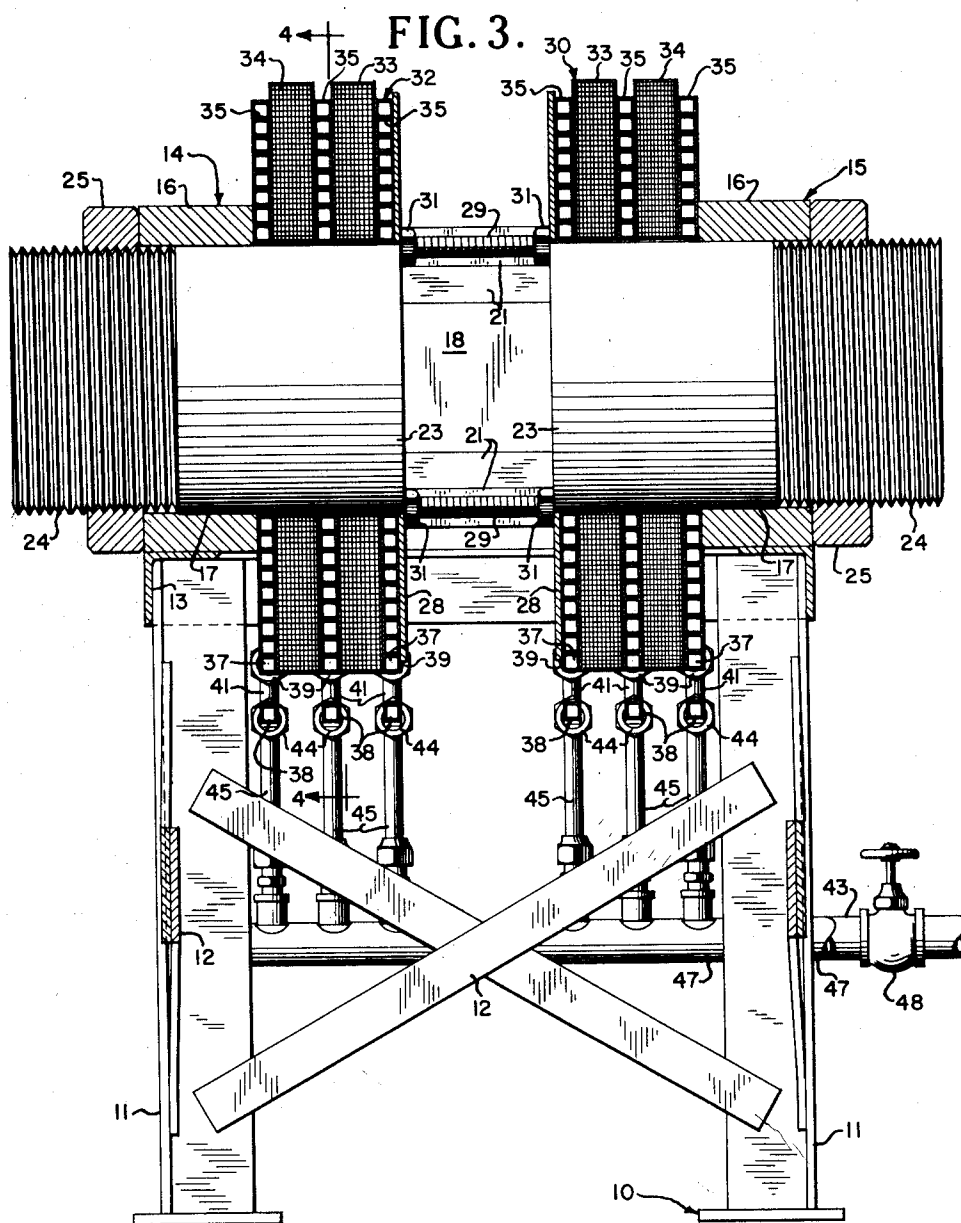
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3 Sheets-Sheet 3



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6 Claims. (Cl. 317—158)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to an electromagnet for use in measuring the susceptibility of specimens of magnetic material under test and is useful for experimentation on magnetic resonance of materials using microwaves. More particularly the invention relates to a closed type electromagnet having a double yoke preferably composed of soft iron to provide a magnetic return path from a pair of pole pieces, the pole pieces being translatably adjustable to provide a desired air gap when testing specimens of different sizes and under different conditions of magnetic field intensities and gradients.

A disadvantage of prior art devices is that such devices require the use of shims or pieces of magnetic material, such shims or pieces being added to or subtracted from the pole pieces when it is desired to change the effective air gap thereof.

The device of the present invention has provided for the energizing coils thereof a plurality of fluid circulating coils mounted in close adjacency thereto for the purpose of cooling the energizing coils. Provision is also made for reducing the surge voltages as the D. C. voltage applied to the coils is varied.

An object of the present invention is to provide a new and improved electromagnetic device for testing the susceptibility of magnetic materials in an economical manner.

Another object of the invention is to provide a new and improved electromagnetic device wherein the pole pieces are arranged to be accommodated to a variety of sizes of test specimens and under a variety of conditions of field intensity and gradient.

Still another object is to provide a new and improved electromagnetic test device in which the energizing coils thereof are maintained at a substantially constant temperature.

A further object is to provide a new and improved electromagnetic device having selectably detachable means to vary the reluctance therein.

A still further object is to provide a new and improved electromagnetic device wherein the magnetic field intensity may be varied either by selectively adjusting the pole pieces or by selective detachable means.

Another further object is to provide a new and improved magnetic circuit wherein a first means is provided to finely vary the reluctance in a continuous manner and to coarsely vary the reluctance in increments independently of said first means.

Still another further object is to provide a new and improved electromagnetic structure having adjustable pole pieces to finely vary the reluctance and a plurality of detachable means in said structure to coarsely vary the reluctance.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following de-

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tailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a top plan view of the device of the present invention;

Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1;

Fig. 3 is a sectional view taken along the line 3—3 of Fig. 2; and

Fig. 4 is a sectional view taken along the line 4—4 of Fig. 3.

Referring more particularly to the drawings, wherein like numerals indicate like parts throughout the several views, 10 indicates generally a base having legs 11 cross-braced at 12 and having an upper rectangular angle iron frame 13 which may be secured to the legs in any well-known manner such, for example, as by welding.

Mounted on base 10 and resting on frame 13 is the electromagnetic device of the present invention indicated generally at 14 and comprising the soft iron yoke member 15 made up of end pieces 16 having bores 17 therethrough for receiving pole pieces to be hereinafter more fully described, and side pieces 18 bolted to the end pieces 16 as at 19. As a consequence of moving the cores, the reluctance of the magnetic field varies according to the variation in coupling between the pole pieces. Since the core movement may be effected in a continuous manner, the reluctance will vary continuously and is thus adaptable to be finely adjusted. A plurality of detachable sections 21 are bolted as at 22 above and below the side pieces 18, thus to provide for varying the magnetic reluctance of the return path of a magnetic circuit in incremental steps according to the size of the sections.

Slidably and respectively mounted in bores 17 and in mutually opposed relation are a pair of pole pieces or cores 23, each of the cores 23 being threaded at 24 on one end thereof to receive a nut 25. Nuts 25 bear against the outside of each of the end pieces 16 in order to hold the cores 23 in adjusted position with respect to each other and to a specimen to be mounted therebetween. Keys 26 are mounted in bores 17 and the cores 23 are provided with keyways 27 which ride on keys 26 thus preventing rotation of cores 23.

A pair of clamping plates 28 are mounted on a plurality of bolts 29 which, in turn, are mounted on the end pieces 16. Each of the bolts 29 is provided with clamping nuts 31. Mounted between the clamping plates 28 and the end pieces 16 and securely clamped therebetween are opposed coil assemblies indicated generally at 30 and 32, respectively. Coil assemblies 30 and 32 comprise, in each case, a pair of electrically energized coils 33 and 34 and having spirally wound tubular fluid circulating cooling coils 35 mounted therebetween and at the outer sides thereof, the cooling coils being of non-magnetic material. Coils 33 and 34 and cooling coils 35 are provided with sufficient axial clearance to permit cores 23 to move freely therethrough.

Each of the cooling coils 35 is formed with a loop 36 at the axial or inner end thereof and with inlet and outlet ends 37 and 38, respectively, at the periphery thereof, thus the cooling fluid such, for example, as water passes into the coil at inlet 37 spirally inwardly to loop 36 whereupon the fluid spirals outwardly through the convolutions of the coil to outlet end 38. Coils 35 are preferably formed of tubing which is square in cross section in order that a greater surface area be in contact with the sides of the coils 33 and 34 thus to facilitate the transfer of heat from the coils to the fluid contained in the cooling coils 35.

Inlet end 37 of each coil 35 is connected through coupling 39, tubing 41, and coupling 42 to inlet manifold 43, while outlet end 38 of each coil is connected through coupling 44, tubing 45, and coupling 46 to outlet manifold

47. It is, of course, understood that the cooling fluid is forced through coils 35 in any desired manner such, for example, as by connecting manifold 43 to a source of cool water under pressure, the water exhausting through outlet manifold 47 to be cooled and recirculated through the coils 35 or to be disposed of in any desired manner. In order to regulate the cooling capacity of coils 35 a valve 48 may be employed in manifold 43 to vary the flow of water through the coils in accordance with the amount of heat dissipation required for efficient operation of electrically energized coils 33 and 34 of coil assemblies 30 and 32.

In operation a specimen of magnetic material is mounted on suitable brackets (not shown) between cores or pole pieces 23, the cores being moved translatably to provide a desired air gap therebetween to properly receive the specimen. Current is supplied to the coils 33 and 34 of coil assemblies 30 and 32 at a predetermined value to give a required magnetic field intensity in the air gap, thus to affect the specimen. It is to be noted that as the pole pieces are adjusted to accommodate varying sizes of specimens, the current supplied to coils 33 and 34 must be readjusted to compensate for the changes in reluctance due to the movement of the cores. The cooling system is adjusted to provide a desired amount of dissipation of heat which is generated in the windings of the electrical coils. The apparatus is now ready for tests to be performed on the specimen to determine magnetic susceptibility or magnetic resonance measurements.

It is clear from an inspection of Fig. 1 that there has been provided a magnetic return circuit of the double yoke type in member 15 and that the magnetic reluctance of the return may be varied by adding or removing magnetic sections 21.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. Apparatus in which a magnetic field is produced comprising, in combination, a pair of spaced axially aligned coil assemblies each having an axially aligned clearance therethrough, a rectangular member of magnetic material forming a return path of predetermined reluctance for the magnetic field produced in the apparatus and arranged to fixedly support thereon said coil assemblies in said spaced aligned relationship, a pair of bores each formed in said member in axial alignment with the clearance through a respective one of said coil assemblies, a pair of core members each slidably supported for translatable motion in a respective one of said bores and extending through the axial clearance of individually respective ones of said coil assemblies to selectively define predetermined air gaps between confronting faces of said core members, said coil assemblies comprising alternately arranged electrical coils and fluid cooling coils in mutually abutting relation, said coils being energized to produce in conjunction with said rectangular member and said core members the magnetic fields, a plurality of extractable magnetic members detachably included in the return path of said rectangular member each of which magnetic members presents incremental reluctance cumulatively contributing to the formation of said predetermined reluctance, and decoupling means detachably securing said magnetic members in said return path and decouplingly adaptable to effectuate discrete extractions of said magnetic members from said return path whereby said predetermined reluctance is decrementally varied

2. Apparatus for testing the magnetic qualities of materials comprising, in combination, a supporting structure, a rectangular magnetic structure mounted on said supporting structure and comprising a pair of end members and a pair of side members, said end members having aligned

central bores therethrough, a plurality of detachable sections of magnetic material secured to each of said side members to define therewith and with said end members a closed path of predetermined reluctance, decoupling means detachably securing said sections in said closed path and decouplingly adaptable to effectuate discrete extractions of said sections from said path whereby said predetermined reluctance is decrementally varied, a core member individual to each of said end members and slidably mounted in the respective bore thereof to selectively define predetermined air gaps between confronting faces of said core members in accordance with selective air gap dimensions, a pair of pluralities of alternately arranged electrically energized coils and cooling coils, means for tightly clamping each plurality of coils against the opposing sides of said end members, said coils having axial clearance for receiving the core members therein, and stop means threadedly engaging said core members for selectively retaining said core members in selected adjusted positions.

3. Electromagnetic apparatus for testing the susceptibility of magnetic materials comprising, in combination, a pair of opposed axially aligned cores of magnetic material mounted for translatable movement toward or away from each other to selectively define predetermined air gaps therebetween, a pair of spaced electrically energized coils surrounding each of said cores, a plurality of cooling coils abutting the sides of said electrically energized coils, means for clamping said electrically energized coils and said cooling coils in mutually close adjacency, a rectangular magnetic yoke supporting each of said cores in a respective bore formed in predetermined opposed sides of said yoke with said yoke and forming a return magnetic path of predetermined reluctance for said cores, said energizing coils and said cooling coils being fixedly mounted on said rectangular yoke, reluctance varying means for varying the reluctance of said return path, including a plurality of extractable magnetic sections detachably secured on said yoke in said return path, each of said incremental reluctance cumulatively contributing to the formation of said predetermined reluctance, said reluctance varying means further including decoupling means for detachably securing said sections in said return path and being adaptable to effectuate discrete extractions of said sections from said return path whereby said predetermined reluctance is decrementally varied, and stop means for retaining said cores at selected distances with respect to each other in defining predetermined air gaps.

4. Electromagnetic apparatus for testing the susceptibility of magnetic materials of various sizes comprising, in combination, a closed loop magnetic structure of predetermined reluctance, electrical energizing means mounted thereon to form therewith an electromagnetic assembly, said energizing means developing in said assembly a magnetic field the return path of which is formed by said structure, cooling means for said energizing means, adjustable magnetic means in said magnetic field movably mounted on said magnetic structure and defining a variable air gap adaptable to conformingly receive various sizes of said magnetic materials to be tested for the susceptibility thereof, and a plurality of extractable magnetic sections detachably secured to said structure in said return path for selectively varying said predetermined reluctance.

5. Apparatus in which magnetic fields are produced comprising, in combination, a rectangular magnetic double yoke member forming a magnetic return path of predetermined reluctance for the magnetic fields produced in said apparatus, a pair of axially-aligned opposed bores in said member, a pair of core members slidably mounted in said bores to selectively define predetermined air gaps therebetween in accordance with selected air gap dimensions, stop means for retaining said core members in selected adjusted positions, electrical energizing means

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mounted on said yoke member and operating in conjunction with said yoke member and said core members to produce said magnetic fields, cooling means for said energizing means, a plurality of extractable magnetic members detachably included in the return path of said yoke member each of which magnetic members presents incremental reluctance cumulatively contributing to the formation of said predetermined reluctance, and decoupling means detachably securing said magnetic members in said return path and decouplingly adaptable to effectuate discrete extractions of said magnetic members from said return path whereby said predetermined reluctance is decrementally varied.

6. In an electromagnet having electrical potential energizing means for developing a magnetic field of predetermined intensity therein and adapted to test the susceptibility of magnetic specimens of various sizes, operating condition varying means for accommodating the electromagnet to conformingly receive various sizes of specimens and for subjecting the individual specimens to varying degrees of magnetic field intensity comprising, in combination, a magnetic structure supporting the energizing means and having a predetermined reluctance for determining, with the potential of said energizing means, said predetermined magnetic field of intensity; said magnetic structure including a mechanically unitary yoke

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with opposed axially aligned bores, and a plurality of extractable magnetic sections detachably secured to said unitary yoke by decoupling means, said decoupling means being effective to effectuate progressive discrete extractions of said sections from said magnetic structure to thereby incrementally vary said predetermined reluctance and correlatively therewith said predetermined magnetic field intensity; and a pair of magnetic pole pieces translatablely disposed in respective ones of said bores to selectively define air gaps therebetween for conformingly receiving specimens of various sizes.

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