

[54] **MULTI-ELEMENT INDUCTION
DEVICE HAVING COMMON
ARMATURE AND POWER-FACTOR
ADJUSTERS**

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Related U.S. Application Data

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[52] U.S. Cl.324/137
[51] Int. Cl.G01r 11/22
[58] Field of Search.....324/137, 138

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3,493,862 2/1970 Ramsey et al.324/137

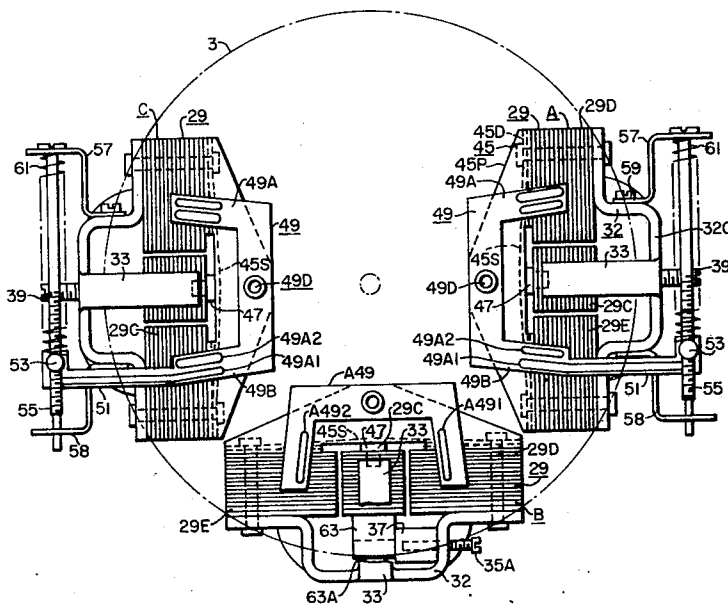
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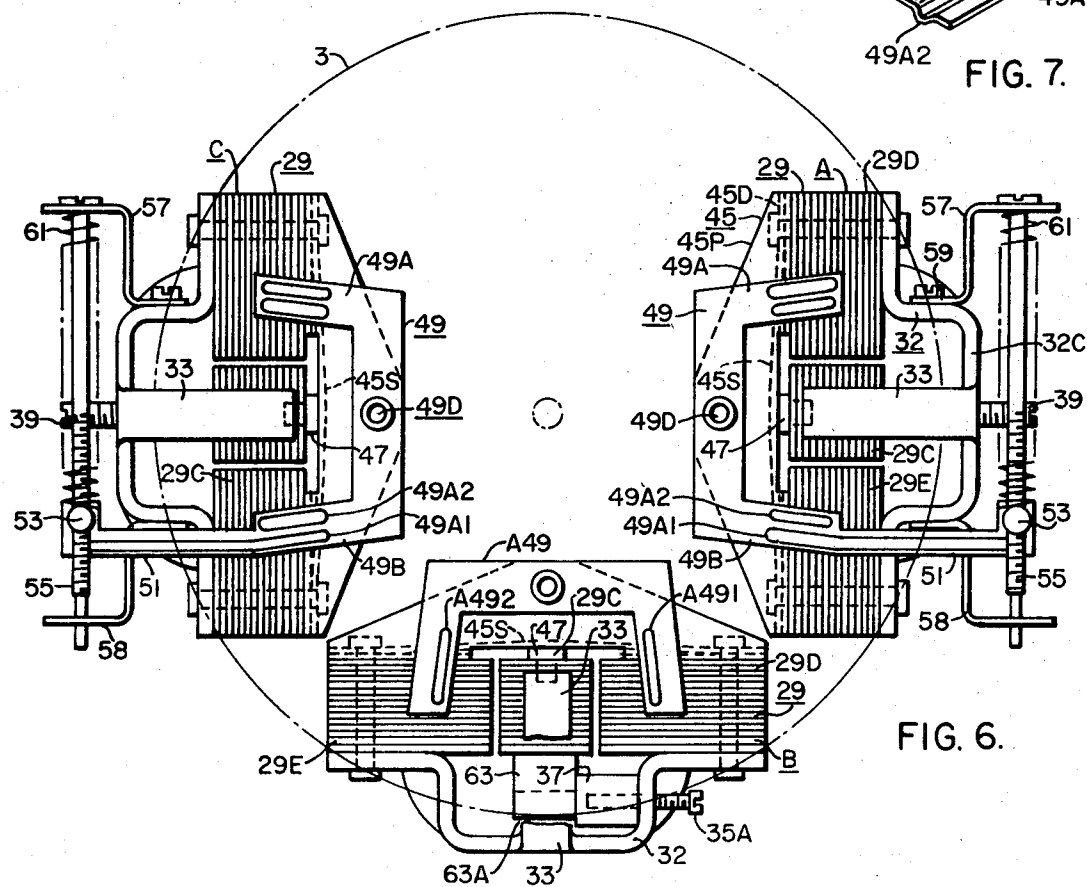
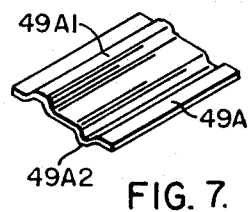
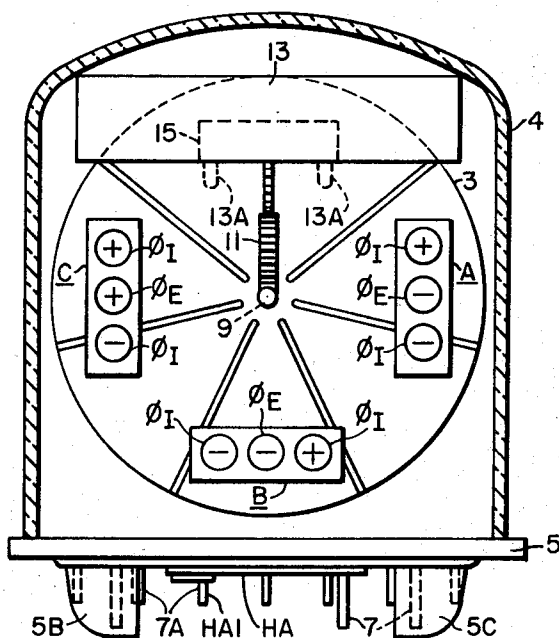
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[57] **ABSTRACT**

An induction watt-hour meter has multiple elements or electromagnets for applying torques to a common electroconductive armature. An element is provided with an E-shaped voltage electromagnet having a voltage pole and two auxiliary poles in a common plane. A power-factor compensator employs a magnetic path extending between the voltage pole and the auxiliary poles through a soft magnetic block attached to the voltage pole. This magnetic path is linked with an electro-conductive loading element. An adjustment is effected by rotation of a screw about an axis parallel to the common plane. The block also establishes another magnetic path which locates the element torque within a desired range.

9 Claims, 5 Drawing Figures





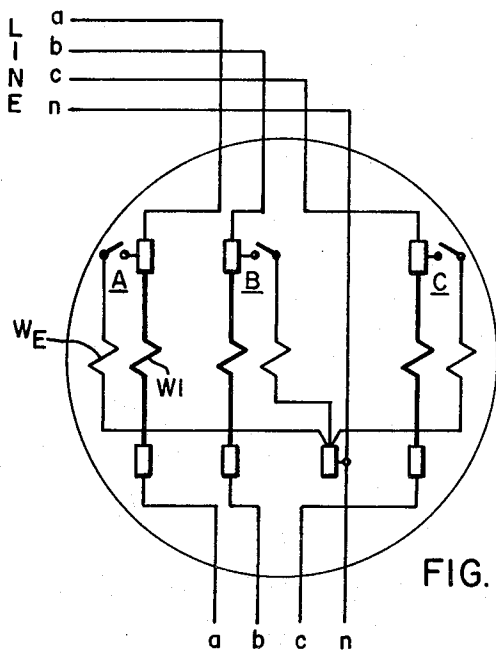


FIG. 2.

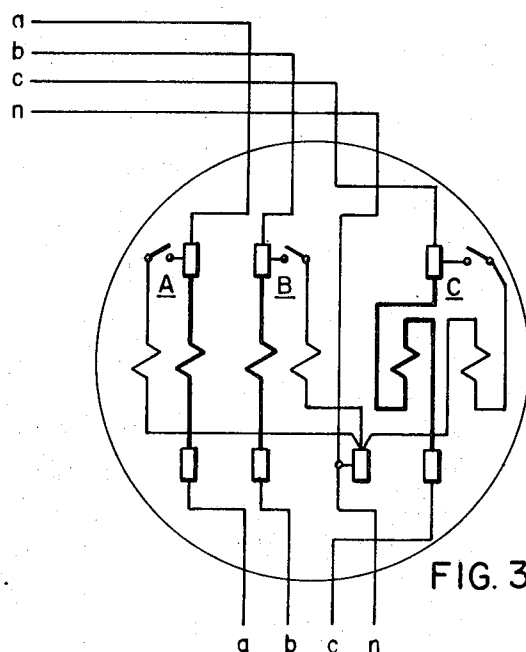


FIG. 3.

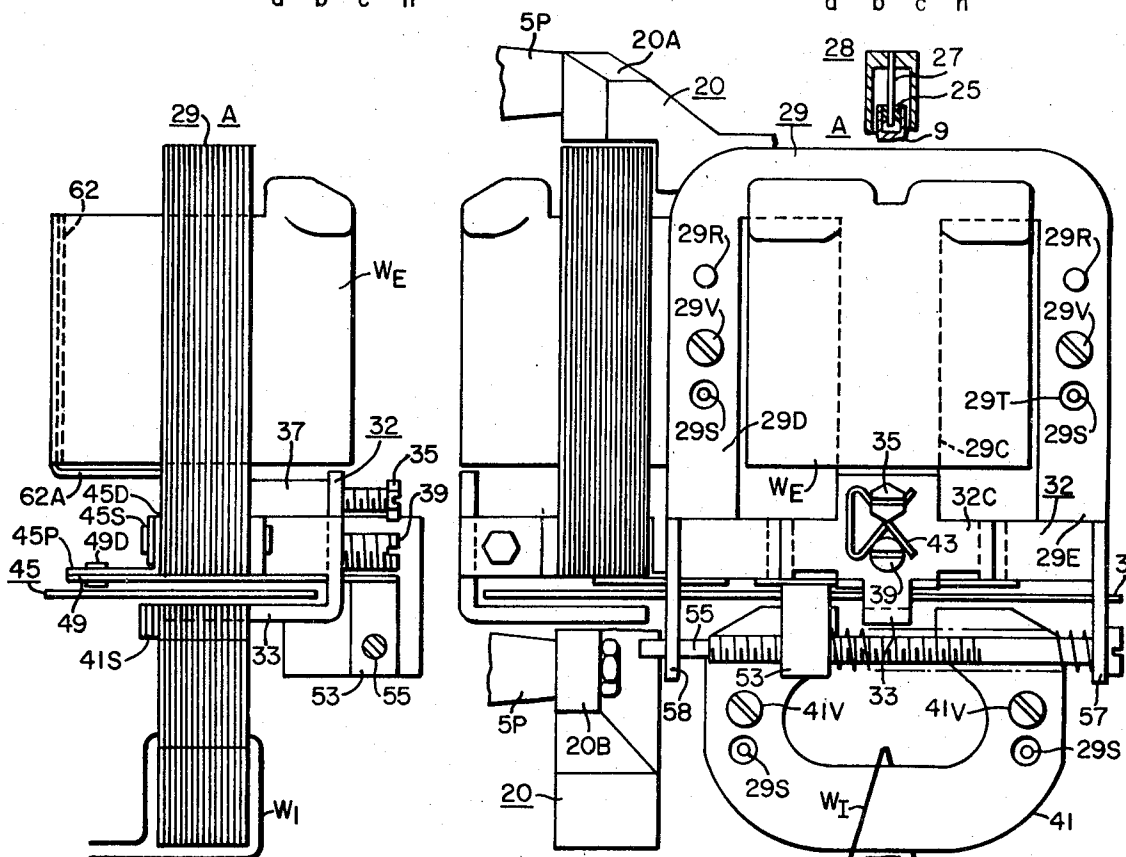
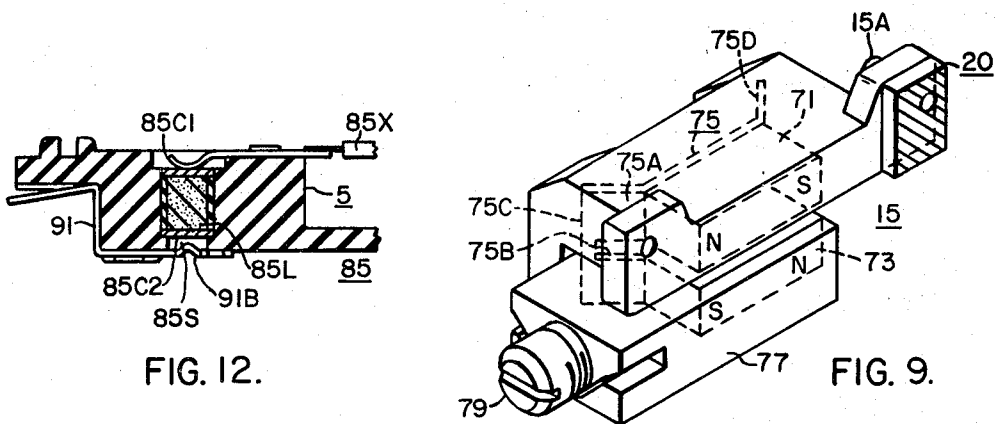
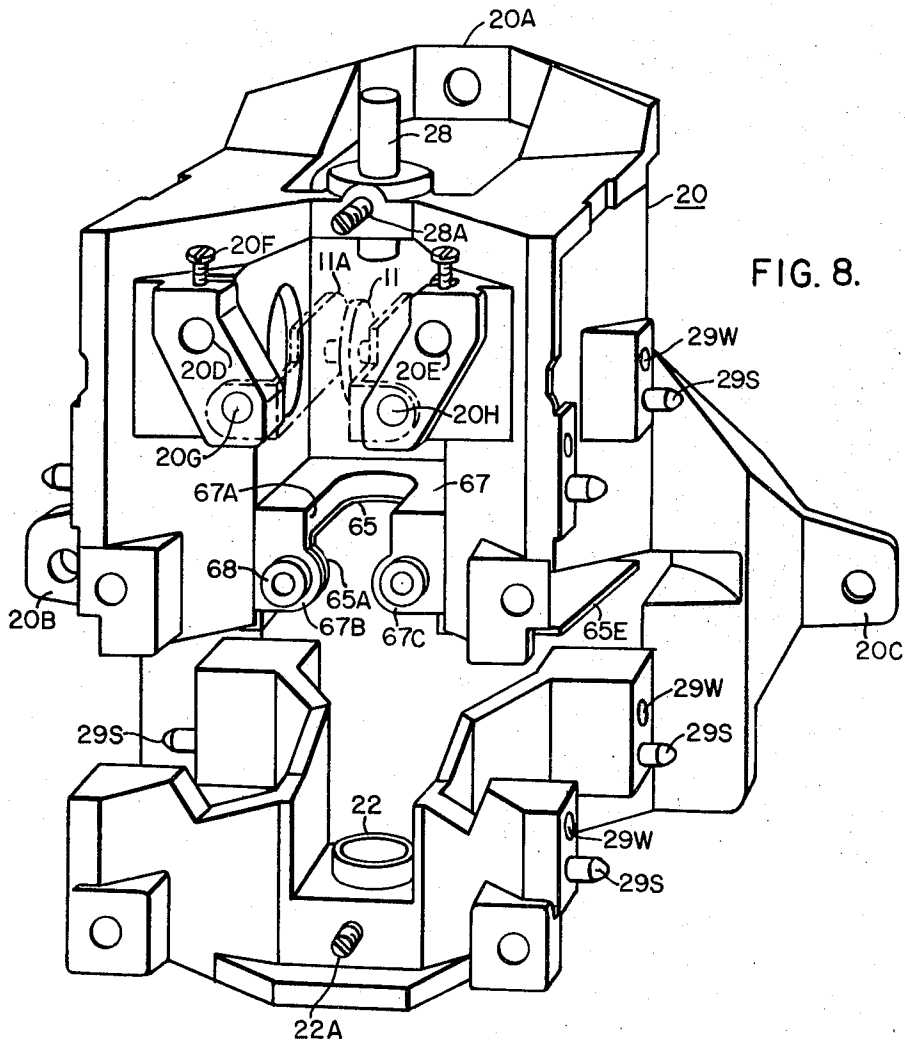


FIG. 5.

FIG. 4.



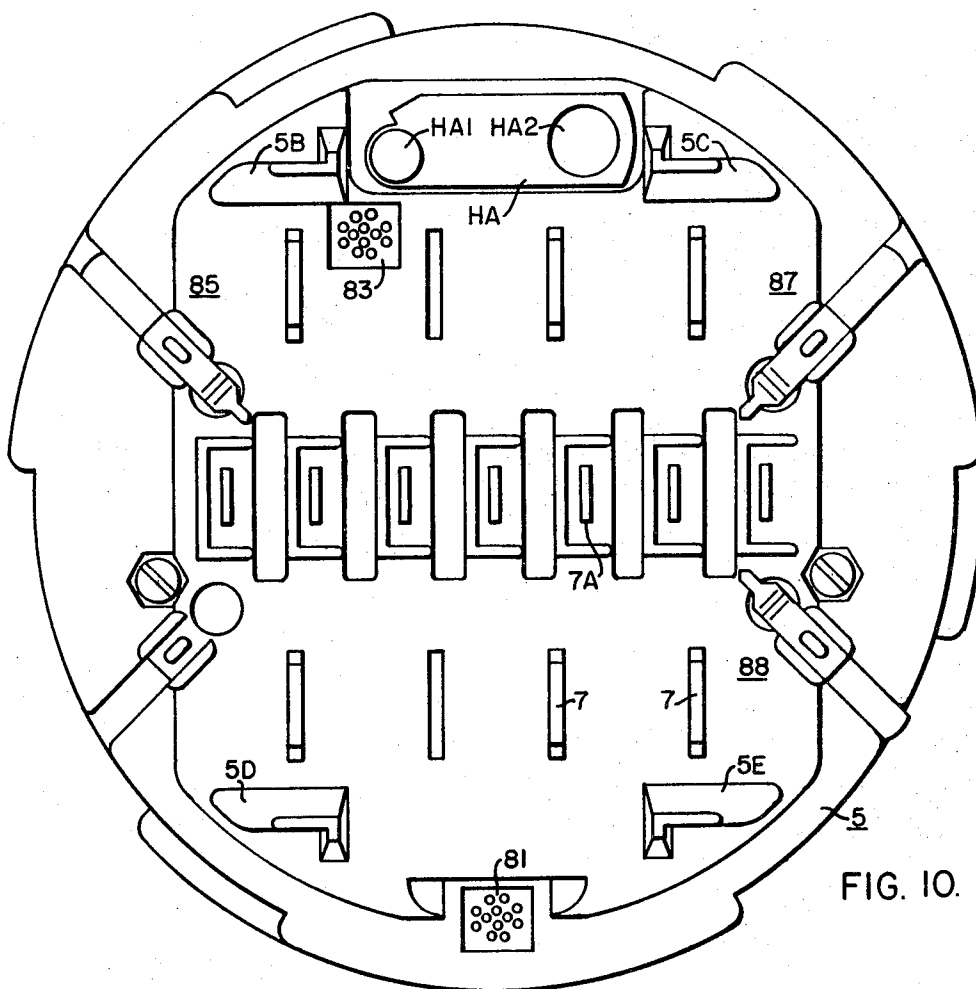


FIG. 10.

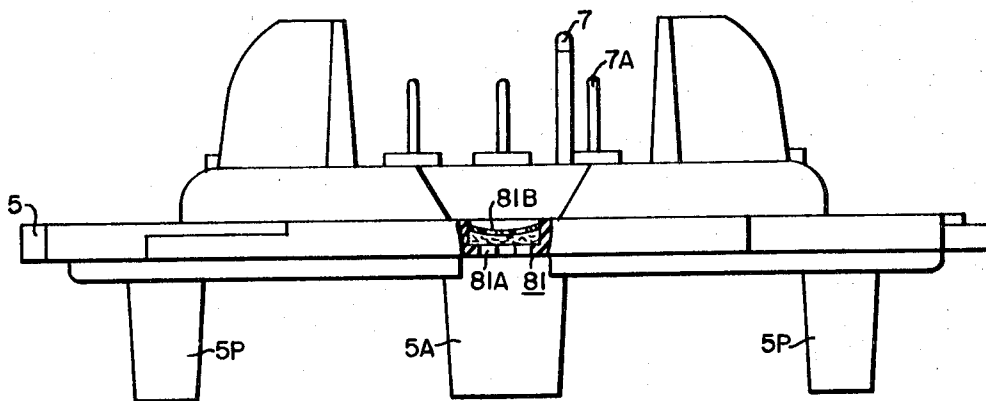


FIG. 11.

MULTI-ELEMENT INDUCTION DEVICE HAVING COMMON ARMATURE AND POWER-FACTOR ADJUSTERS

CROSS-REFERENCE TO RELATED APPLICATION

This is a division of my patent application Ser. No. 74,565, filed Sept. 23, 1970.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a multi-element induction device and it has particular relation to a polyphase induction watt-hour meter having several elements or electromagnets operating on a common electro-conductive armature.

2. Description of the Prior Art

In a multi-element induction device such as a three-element polyphase watt-hour meter three elements, electromagnets or stators may be associated with a common electro-conductive armature. Such a meter may have an error due to interference between stators as discussed briefly on page 118 of Electrical Metermen's Handbook, published in 1965 by the Edison Electric Institute of New York City.

As pointed out in the Electrical Metermen's Handbook, page 120, each stator of a multi-element meter is provided with power-factor compensation. Power-factor compensation or adjustment for a stator is discussed on pages 99-101 of the Handbook. It is desirable that the power-factor compensation be readily adjustable on each element of a multi-element meter regardless of the location of the element.

As pointed out in the aforesaid Handbook on page 120, in a multi-element meter the same torque must be produced by each stator when equal wattage is applied to each stator. To this end each stator is provided with a torque balance adjustment.

SUMMARY OF THE INVENTION

In accordance with the invention each stator of a multi-element meter is provided with a power-factor compensator device of the type shown in my U.S. Pat. No. 3,212,005, granted Oct. 12, 1965. Such a device is particularly desirable for multi-element meters because of its relative freedom from adverse effects on other characteristics, such as interference error.

For improved accessibility a soft magnetic block is located in the magnetic circuit of the adjustment device for one of the stators and the adjusting screw is positioned on an axis at right angles to that shown in my aforesaid patent to cooperate with the block. Preferably the block is part of a magnetic circuit which affects the torque balance. The dimension of the block is selected to provide an air gap in the magnetic circuit which locates the torque of the associated element in a desired range. Torque-balance adjusters on the remaining elements are adjusted to complete the balancing of the elements.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be had to the preferred embodiment exemplary of the invention shown on the accompanying drawings in which:

FIG. 1 is a view in top plan of a polyphase watt-hour meter embodying the invention with parts shown schematically;

FIGS. 2 and 3 are schematic views showing circuit connections which may be employed for the meter of FIG. 1;

FIG. 4 is a view in side elevation with parts broken away and with the casing removed of a meter which may be employed in FIG. 1;

FIG. 5 is a view in side elevation of one of the electromagnets employed in the meter of FIG. 4;

FIG. 6 is a view in bottom plan of the voltage electromagnetic sections employed in the meter of FIG. 4 with the frame omitted, and with parts broken away;

FIG. 7 is a detailed view in perspective of a portion of a magnetic light-load adjuster employed in the meter of FIG. 1;

FIG. 8 is a view in perspective showing a frame suitable for the meter of FIG. 1;

FIG. 9 is a view in perspective of a damping magnet assembly suitable for the meter of FIG. 1;

FIG. 10 is a view in rear elevation of a base suitable for the meter of FIG. 1;

FIG. 11 is a view in bottom plan of the base of FIG. 10; and

FIG. 12 is a detail view showing a surge arrester employed on the base of FIG. 11.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 a three-element polyphase watt-hour meter is illustrated having elements A, B and C which operate on a common electro-conductive disk armature 3. Components of the meter movement are located within a cup-shaped glass cover 4 having its open end closed by a releasable base 5 which may be constructed of insulating material such as a phenolic resin. Contact blades 7 and 7A project through the base 5 in a conventional manner for establishing connections between the meter and an external circuit. Guards 5B, 5C, 5D and 5E (FIGS. 1 and 10) project from the rear of the base.

The armature 3 is mounted on a shaft 9 for rotation about the axis of the shaft relative to the elements. In a conventional manner, the shaft 9 has a worm formed thereon which is in meshing engagement with a worm wheel 11 to drive a register 13 such as that shown in the aforesaid Lenehan patent.

The armature 3 is arranged to rotate through the field of a permanent magnet assembly 15 which provides damping for the meter in a manner well understood in the art.

The armature 3 preferably is of a laminated type as discussed in the Drew U.S. Pat. No. 3,290,594. Although one or more of the laminations may be of solid construction as described in the Drew patent, it will be assumed that the armature is constructed of seven similar slotted laminations which are cemented together and which are insulated from each other. It will be understood that the slots 3A in adjacent laminations are staggered for the purpose of minimizing starting watts. The laminations are constructed of an electro-conductive material such as copper or aluminum.

Each of the elements, A, B and C, is arranged to direct a central voltage magnetic flux ϕ_E through the armature and two outer current magnetic fluxes ϕ_I ,

through the armature. Instantaneous directions of flux flow are indicated by plus and minus markings. For present purposes, it may be assumed that a plus marking indicates movement of the flux in a direction away from the observer whereas a minus marking indicates movement of the magnetic flux towards the observer.

It has been observed that interference may be reduced materially by locating the elements A and C 180° from each other about the axis of the shaft 9 and by reversing the connections of one of these elements. By inspection of FIG. 1, it will be apparent from flux directions that similar connections are employed for the elements A and B whereas the connections of the element C are reversed relative to the remaining two elements.

The connections of the elements may be understood from a consideration of FIGS. 2 and 3. FIG. 2 is a reproduction of the three-phase four-wire wye circuits appearing on page 348 of the aforesaid Electrical Mettermen's Handbook. Each of the elements A, B and C is shown with a wide-line winding W_I for current energization and a thin-line winding W_E for voltage energization. It will be observed that each of the elements is connected to its associated external circuit in a similar manner.

As previously pointed out, one of the elements A or C has its connections reversed. This is shown in FIG. 3 wherein the connections of the element C are reversed. Inasmuch as both the current winding and the voltage winding of the element C have the connections reversed, the torque applied by the element C to the armature is unchanged in direction. This reversal of connections materially reduces interference error, particularly at high currents and with either phase sequence.

Preferably the weight of the rotor assembly is supported by a magnetic mounting. Shown more particularly in FIG. 4, a ring permanent magnet 17 is secured to the lower end of the shaft 9. A ring bearing 19 is concentrically mounted within the magnet 17. The stator includes a frame 20 mounting a lower fixed bearing assembly 22 with a ring permanent magnet 21 which is positioned directly below the magnet 17 and a resilient pin 23 which is received in the ring bearing 19 to restrain the rotor assembly against transverse movement. The magnets 17 and 21 are magnetized to act in repulsion for the purpose of supporting the weight of the rotor assembly. The upper end of the shaft 9 has a ring bearing 25 for receiving rotatably a resilient pin 27 forming part of an upper fixed bearing assembly 28 which is secured to the stator assembly. This restrains the upper end of the shaft against transverse movement while permitting relative rotation between the pin and the ring bearing.

The mounting is essentially similar to that shown in the U.S. Pat. No. 3,143,704 to D. F. Wright which issued Aug. 4, 1964. However, the ring bearings 19 and 25 preferably are constructed of an aromatic polyimide resin containing 4 to 80 percent by weight of a lubricant such as a fluorocarbon polymer which may be polytrifluoromonoethylethylene as set forth in the Redecker et al. patent application Ser. No. 746,641 filed July 22, 1968. The provision of the aromatic-polyimide-resin-containing material instead of the graphite ring bearings of the Wright patent materially reduces tilt error. This is of appreciable importance for multi-element meters.

The permanent magnets 17 and 21 may be similar to those disclosed by Wright. If more support is desired with no increase in size one or both magnets may be constructed of other material such as Alnico VIII.

Attention now will be directed to the construction of the element A. As shown in FIGS. 4 and 5, the element A includes a voltage magnetic section 29 of E configuration having a center leg 29C and two outer legs 29D and 29E connected at their upper ends. The lower ends of the legs 29D and 29E as shown more clearly in FIG. 6 extend towards the center leg 29C to provide extended pole faces bordering the air gap in which the armature 3 is located and spaced by a small distance from the center leg. The voltage magnetic section 29 is constructed of a plurality of laminations of soft magnetic material each having the E-configuration shown in FIG. 4 and riveted together by solid rivets 29R. The center leg 29C of the voltage magnetic section is surrounded by a voltage winding W_E which is constructed of a large number of turns of small diameter insulated copper wire in the manner shown in the U.S. Pat. No. 3,496,504 to Daley issued Feb. 17, 1970. When the voltage winding W_E is energized by an alternating voltage, magnetic flux is directed into the air gap containing the armature 3 between the center leg 29C and the other legs 29D and 29E of the voltage magnetic section 29.

The magnetic section 29 is located on a face of the base 20 by means of dowels 29S secured to the base and snugly but releasably received in holes 29T press fitted into openings in the magnetic section 29. Machine screws 29V releasably secure the magnetic section to the base.

For greater efficiency in flux generation, a U-shaped soft magnetic bracket 32, which may be of cold rolled steel, has its ends riveted by solid rivets respectively to the lower ends of the outer legs 29D and 29E. The bracket has a center portion 32C which extends across but is spaced from the center leg 29C.

The bracket 32 has a projection or tongue 33 extending from the center portion 32C of the bracket to underlie the pole face of the center leg 29C. Consequently, when the voltage winding W_E is energized, a strong voltage magnetic field is established between the tongue 33 and the pole face of the center leg 29C. A portion of the armature 3 passes through this field.

In order to adjust the phase relationship between the voltage and current magnetic fluxes, which is referred to as power-factor adjustment, a soft magnetic screw 35 is in threaded engagement with the center portion 32C of the bracket 32, and extends towards the center leg 29C of the voltage magnetic section 29. This screw passes through an electro-conductive tube or sleeve 37 which may be constructed of copper. By adjusting the screw 35, the voltage and current magnetic fluxes may be brought into the proper phase relationship.

To provide Class II temperature compensation for the element A the sleeve 37 may be constructed of two concentric tubes or sleeve sections, one of which is of an electro-conductive material such as copper and the other of which is of a material having a substantial negative temperature coefficient of permeability such as an austenitic-iron-nickel alloy having approximately 30 percent nickel. A structure of this type is disclosed in my U.S. Pat. No. 3,212,005 which issued Oct. 12, 1965. This power-factor correction or adjustment is

particularly suitable for multi-element meters for the reason that it does not adversely affect materially the interference error of the meter.

In multi-element meters it is the practice to provide torque-balance adjustments for the purpose of balancing the torques developed by the different elements of the meter. In the present embodiment such an adjustment is provided by a soft magnetic screw 39 which is in threaded engagement with the center portion 32C of the bracket 32 and which projects towards the center leg 29C of the voltage magnetic section 29. By adjusting the screw 39 relative to the center leg 29C, the torque developed by the element A may be adjusted. This construction is desirable for the reason that it does not have any material adverse effect on the interference error of the meter.

A C-shaped current magnetic section 41 is provided and is constructed of soft-magnetic laminations in a manner similar to that employed for the voltage magnetic section. The current winding W_i is wound around the web connecting the two legs of the current magnetic section. The current winding may comprise one turn or a relatively small number of turns of relatively large-diameter insulated electro-conductive wire such as copper wire. It is to be noted that the pole faces of the two legs of the current magnetic section are spaced from the pole faces of the voltage magnetic section to define an air gap within which a portion of the armature 3 is located. One or more saturable soft-magnetic overload shunts 41S extend in a conventional manner across the current poles (FIG. 5) with spacers of non-magnetic material between the shunts and the poles.

In order to guard against movement of the screws 35 and 39 under the influence of vibration, a cruciform spring 43 has its ends biased respectively against the screws 35 and 39.

Attention now will be directed to the problem of light-load adjustment of the meter. Experience has shown that the well-known electro-conductive light-load adjuster has a bad effect on interference error. For this reason it has been proposed that light-load adjusters be omitted from multi-element meters.

The current magnetic section is located on one face of the frame 20 by two of the dowels 29S which are press fitted into holes in the frame and which are received snugly in openings provided in the section. Machine screws 41V are threaded into threaded holes 29W (FIG. 8) provided in the frame to secure the section to the frame.

I have found that a magnetic light-load adjuster may be employed which actually decreases the interference error of a multi-element meter. The preferred light-load adjuster is of the general type shown in the U.S. Pat. No. 3,493,862 to Ramsey Jr. et al. which issued Feb. 3, 1970.

A light-load adjuster 49 for the element A is mounted on a bracket 45 having a base 45D which is secured to the voltage magnetic section by the same rivets employed to secure the bracket 32 to the section. The bracket and rivets may be formed of a non-magnetic material such as brass or aluminum. A voltage shunt 45S of soft magnetic material which saturates at higher values of flux may be secured to the voltage magnetic section by the same rivets. A spacer 47 spaces the center portion of the shunt from the center leg 29C

of the voltage magnetic section in the same manner shown in the aforesaid Ramsey et al. patent.

The bracket 45 also has a platform 45P which extends at right angles from the base 45B. On this platform, the U-shaped soft magnetic adjuster 49 is pivoted by means of a pivot pin 49D. The adjuster has two legs 49A and 49B which extend over engage and slide upon the pole faces respectively of the two legs 29D and 29E of the voltage magnetic section 29.

Each of the legs 49A and 49B has two ribs which project in opposite directions from the leg. Thus the leg 49A is bent as shown in FIG. 7 to provide a first rib 49A1 which projects upwardly and is biased to slide upon the pole face of the leg 29D. The leg 49A also has a rib 49A2 which projects away from the pole face and is employed to permit reversal in position of the adjuster for reasons which will be discussed below.

An operating arm 51 extends away from the leg 49A and may be manipulated for the purpose of pivoting and thus adjusting the light-load adjuster 49. The arm 51 may be constructed of a non-magnetic and non-electro-conductive material which may be secured in any suitable manner to the adjuster 49. Preferably, the arm 51 is constructed integrally with the adjuster of the same soft magnetic material. As shown in FIG. 6, the arm 51 preferably has a reduced width so that it has a relatively small effect on the light-load characteristics of the element. It will be noted that the rib 49A1 extends along the arm 51 for the purpose of making the arm more rigid.

In order to facilitate adjustment of the light-load adjuster 49, a post 53 projects downwardly from the arm 51 and has a threaded opening for threaded reception of an adjusting screw 55. The screw extends slidably through an opening in a support 57 which is secured to one leg of the bracket 32 by a screw 59. A coil spring 61 in compression biases the post 53 away from the support 57 to the extent permitted by the head of the screw which engages the support 57 and the rotational adjustment of the screw. This spring eliminates backlash and prevents changes in adjustment of the parts due to vibration. It will be noted that the adjusting screws 35, 39 and 55 are readily accessible from the side or front of the meter. A support 58 is attached by a screw to a second leg of the bracket 32, and has a hole for slidably securing the free end of the screw 55.

A soft magnetic shield 62 is positioned adjacent the meter axis side of the voltage magnetic section of each of the elements (FIG. 5). This intercepts leakage magnetic flux which might cause an interference error. The lower part of the shield is bent inwardly to form a flange 62A underlying part of the voltage winding W_E.

The element C is similar to the element A except that the magnetic light-load adjuster 49 for the element C is rotated 180° about a horizontal axis as viewed in FIG. 6 to position the arm 51 adjacent the lower end of the element C as viewed in FIG. 6. It will be noted that the support 57 is located at the upper end of the bracket 32 to position the head of the screw 55 towards the front of the meter. With this positioning of the parts, the rib 49A2 is located to engage the pole face of the leg 29E of the element C.

The element B is similar to the element A except for the following changes.

It has been found that the light-load adjuster for the element B may be adjusted at the factory and thereafter need not be adjusted. For this reason, an adjusting arm and an adjusting screw corresponding to the arm 51 of the screw 55 of the element A may be omitted from the light-load adjuster A49 provided for the element B. Furthermore, only one rib A491 or A492 is required for each leg of the light-load adjuster A49. The ribs are positioned to engage the pole faces of the legs 29D and 29E for the element B.

In order to improve the accessibility of the power-factor adjustment for the element B, a soft magnetic block 63 is secured to the end of the center leg 29C for the element B. The power-factor adjustment screw 35A (corresponding to the screw 35) for the element B is in threaded engagement with the bracket 32 but extends along an axis parallel to the plane of the associated voltage magnetic section. It will be noted that rotation of the screw 35A for the element B readily may be effected from the side of the meter and moves the screw towards or from the block 63. The screw 35A passes through a sleeve 37 for the element B which is similar to the sleeve employed for the element A.

The threaded opening in the bracket 32 which receives the screw 35A of the element B is similar to the threaded opening in the bracket 32 which receives the screw 59 securing the support 57 of the element A.

Referring again to FIG. 6 it will be noted that a number of soft magnetic parts intercept leakage magnetic flux and thus assist in minimizing interference error. These parts include the bracket 32 with its adjustment screws, the block 63, the light-load adjuster 49 and the shunt 45S. The direct engagement of the pole faces the outer legs 29D and 29E by some of these components assures efficient handling of the leakage flux.

It will be noted that the light-load adjusters for the three elements provide a substantial ring extending around the inner sides of the three elements. It has been found that this construction materially decreases the interference error of the meter. Test results have shown that interference errors of the order of 0.5 to 0.8 percent may be achieved with these magnetic light-load adjusters while errors of 1.2 to 1.5 percent were the best obtained with a construction similar except for the replacement of a magnetic light-load adjuster by electro-conductive light-load adjusters of conventional construction.

As shown in FIG. 6 the soft magnetic block 63 is spaced from the web of the bracket 32 to define an air gap 63A. This establishes an auxiliary magnetic path for voltage magnetic flux which extends from the center leg 29C through the block 63, the air gap 63A and substantially symmetrically in parallel through the two legs of the bracket 32 and the outer legs 29D and 29E back to the center leg 29C. The torque developed by the element B may be determined at the factory by the selection of the length of the block 63 which defines the air gap 63A. By proper selection of the length of the air gap the torque of the element B may be located in a desired range. The balance screws 39 of the remaining two elements A and C then may be adjusted to establish proper balance.

The damping magnet assembly 15 is secured to the frame 20 by machine screws 15A (FIG. 9). It includes

two bars 71, 73 of a high-coercive, high-energy-product permanent-magnet material such as an alnico material. The two bars are parallel to each other and are spaced to form an air gap within which a portion of the armature 3 is located. The bars are magnetized to form north poles N and south poles S as shown.

Class I temperature compensation for the meter is provided by a strip 75 of material having a negative temperature coefficient of permeability which is slotted to receive a portion of the armature 3. Such material is well known and may take the form of a nickel-iron alloy containing approximately 30 percent nickel. The slot divides the strip 75 into two ribbons 75A and 75B each engaging a side of a separate one of the magnets. The ends of the ribbons 75A and 75B are connected by connectors 75C and 75D of the same material which extend around the edge of the armature. The resultant assembly is die cast into a block 77 of aluminum-base die-casting material which is slotted to receive a portion of the armature 3. As is well known in the art the strip 75 acts as a shunt to provide Class I temperature compensation for the meter.

For full-load adjustment, a large-diameter soft magnetic screw 79 is in threaded engagement with the block 77. Rotation of the screw causes the screw to recede from or approach one of the permanent magnets to vary the effective damping applied to the armature.

The meter casing is sealed except for one or more filters in the manner discussed in the U.S. Pat. Nos. 3,337,802 and 3,413,552. In FIG. 10 two filters 81 and 83 are shown across vent openings in the base 5, and these may be ceramic filters similar to those shown in the patents for blocking entry of foreign particles or dust having a size or diameter in excess of 120 microns. One of the filters 81 is located substantially adjacent the lowest point of the casing to drain moisture from the casing. It includes a filter layer 81A of fiber-glass mat held in place by a perforated spring-metal retainer 81B. The second filter 83 is located at a higher point in the casing. For the filtering material the filters desirably may be constructed of fiber-glass mat having the desired filtering and drainage performance.

Sealing of the casing except for such filters is particularly desirable for multi-element meters because of various factors such as size, complexity and cost of such meters.

A difficult problem to solve in a meter involves lightning or surge protection. This is particularly true of multi-element meters which have more circuits to be protected and which often are more subject to surges.

In FIG. 10 three surge arresters 85, 87 and 89 are shown. Inasmuch as they are similar in construction a discussion of the arrester 85 suffices. The arrester 85 in effect connects one of the contact blades to ground through a current limiter 85L and a spark gap 85S in series.

In the event that a surge breaks over the spark gap, the current limiter limits the amount of power-follow current. The current limiter 85L may be a block of silicon carbide similar to that employed in lightning arresters. As representative of suitable construction the block may have a diameter of one-half inch, a length of four-tenths inch, ends coated with electro-conductive material 85C1 and 85C2 and a cylindrical surface

coated with waterproof material such as an epoxy resin. The block is located in an opening provided in the base 5 and is essentially within the casing. A lead 85X connects the inner coating 85C1 to one of the contact blades associated with a meter circuit requiring protection. An electro-conductive strip 91 is spaced from the coating 85C2 to form a spark gap therebetween. The strip 91 may be similar to the strip 61 of the U.S. Pat. No. 2,889,494 to Schmidt et al. which issued June 2, 1959, and similarly has a part positioned to engage a meter socket (not shown) for grounding.

The strip may have a contact secured thereto as in Schmidt et al. In the present embodiment the strip is deformed to provide a bump 91B for the same purpose. The width of the strip is less than the diameter of the opening leading to the block 85L by an amount sufficient to permit the spark discharge to the exterior of the casing.

A surge arrester of this type is shown in the U.S. patent application of Redecker et al., Ser. No. 708,854, filed Feb. 28, 1968.

A hanger HA is pivoted at one end on the rear of the base 5 by means of a pivot pin HA1. A hole HA2 in the other end is provided for reception of a pin on which the meter is hung when such end is pivoted away from the base.

The operating parts of the meter are mounted on the frame 20 which may be die cast of an aluminum-base diecasting alloy. This frame is designed to be stable under all operating conditions. To assist in maintaining stability, a brace 67 extends between the frame sides which support the elements A and C. This brace has a notch 67A for receiving the shaft 9. If the damping magnet assembly 15, register 13, transfer gearing 11, and upper and lower fixed bearing assemblies 22 and 28 are removed, the notch 67A permits removal of the rotor assembly through the front of the meter. The bearing assemblies are releasably held in holes provided in the frame by means of set screws 22A and 28A.

The frame 20 has three ears 20A, 20B and 20C with holes therethrough. Bolts are extended through these holes and spacing pillars 5P formed on the base 5 to secure the frame to the base (FIG. 4).

The brace 67 has two ears 67B and 67C with holes which are employed for releasably mounting the soft magnets assembly 65 of an interference control shunt if employed as noted below.

For a two-element meter, the element B is omitted. Although the laminated armature 3 may be retained, it is found that with the magnetic-light-load adjuster the elimination of the element B makes it possible to employ a solid armature.

Preferably for a two-element meter a soft magnetic bridge 65 is employed to reduce interference error as discussed in U.S. Pat. No. 2,243,130, issued May 27, 1941. Although a solid slotted armature may be employed as disclosed in the patent, the present design renders such slots unnecessary. The bridge conveniently may have its ends (e.g. 65E) engage the voltage shunts 45S of the elements A and C. The center part of the bridge may be bent upwardly as shown to abut the brace 67 and has two ears (e.g. 65A) with holes. Rivets 68 pass through the holes in the ears of the bridge 65 and brace 67 to unite these parts.

The bridge 65 has a notch 65C to receive the shaft 9 and to permit removal of the shaft through the front of the meter. The bridge is omitted for a three-element meter.

Preferably when the voltage sections of the elements A and C are secured to the frame they slightly compress the bridge, which is somewhat resilient, to establish firm contact.

As previously noted the elements are releasably secured to the frame 30. In FIG. 8 several of the dowels 29S are shown pressed into holes in the frame 20. Adjacent each of the dowels one of the threaded holes 29W is shown for receiving one of the machine screws 29V or 41V as shown in FIG. 4.

Various other components are secured to the frame 20. Thus two holes 20D and 20E are shown for receiving the usual mounting pins 13A of the register 13. The pins are releasably held in mounted position by set screws 20F.

In the illustrated embodiment the single worm wheel 11 is employed for coupling a worm (not shown) on the shaft 9 to the register 13. This worm wheel is mounted for rotation in a carriage 11A which is releasably secured to the frame 20 by machine screws (not shown) which are received in two threaded openings 20G and 20H provided in the frame.

As previously pointed out the magnetic light-load adjusters contribute materially in reducing interference error. I have found that the magnetic light-load adjusters permit a further control over interference error by recourse to a novel positioning. In such positioning two of the adjusters are preset in opposite direction.

Thus the magnetic light-load adjuster on the rear electromagnet B of the three-element meter may be preset in a direction causing the meter to run slow. The right-hand electromagnet C then may have its magnetic light-load adjuster preset in a direction causing the meter to run fast. The two effects on light-load operation are in opposite directions and may be proportioned to cancel each other or to have a resultant effect as desired. The final light-load adjustment then is made by operation of the magnetic light-load adjuster on the left-hand electromagnet.

These presettings of the light-load adjusters on the rear and right-hand electromagnets materially reduce interference error. As an example, I have found that an interference error of the order of 1.3 percent may be reduced to an error of the order of 0.7 percent by such presettings.

Setting of the light-load adjusters in opposite directions in this manner also is helpful in minimizing the interference error of other meters such as the two-element meter in which the element B is omitted. For the two-element meter one adjuster similarly is set in a direction causing the meter to run slow and the other adjuster is set in a direction causing the meter to run fast. The difference in these opposing effects is selected to provide light-load compensation.

As previously pointed out, the power-factor adjustment devices contribute to the minimizing of interference error. The soft magnetic brackets 32, screws 35 and 35A, and block 63 all assist the soft magnetic light-load adjusters 49 and shields 62 in providing shielding for leakage magnetic flux which otherwise could increase interference error. The direct voltage flux path

provided by the tongue 33 assists in the reduction of interference error.

I claim as my invention:

1. In an induction device responsive to a function of the volt-amperes in an alternating current circuit, an electromagnet device comprising an E-shaped planar soft magnetic voltage section having a central voltage pole and two outer legs disposed in a common plane, a soft magnetic current section having current poles spaced from the voltage pole to define an air gap therebetween, voltage winding means effective when energized in accordance with an alternating voltage for directing first alternating magnetic flux through the voltage pole into the air gap, current winding means effective when energized at least in part by alternating current for directing second alternating magnetic flux through the current poles into the air gap to establish with the first magnetic flux a shifting resultant magnetic field in the air gap, an electro-conductive armature device mounted for rotation relative to the electromagnet device about an axis, said armature having a portion positioned in the air gap to develop a torque from said resultant magnetic field which acts to rotate the armature device relative to electromagnet device about said axis, said electromagnet device establishing a first magnetic path for the first alternating magnetic flux which includes the voltage pole, the outer legs, the air gap and a portion of the armature device, a magnetic path unit establishing a second magnetic path for the first alternating magnetic flux including a soft magnetic member magnetically linked to the face of the voltage pole and extending parallel to the plane of the voltage section adjacent the air gap, and magnetic means completing with the magnetic member the second magnetic path so as to exclude the air gap and the armature device, and a closed circuit electro-conductive unit inductively linked substantially only with magnetic flux carried by the second magnetic path to effect loading of the voltage winding means, at least one of said units being adjustable along an axis substantially parallel to the plane of the voltage section to vary the loading of the voltage winding means by the electro-conductive unit and vary the phase relationship between the first and second alternating magnetic fluxes, said magnetic means including a soft magnetic device extending from a position adjacent the magnetic member to the free ends of the outer legs to define with the magnetic member said second magnetic path which is clear of the armature device, said magnetic means directing magnetic flux between the voltage pole and each of the outer legs through the magnetic member.

2. An induction device as claimed in claim 1 wherein said adjustable one of the units comprises a soft magnetic screw having a screw axis substantially parallel to the plane of the voltage section and being in threaded engagement with a part of said magnetic path unit.

3. An induction device as claimed in claim 2 wherein said voltage and current sections are included in a watt-hour meter, wherein said voltage section is constructed of a plurality of E-shaped laminations each parallel to the plane of the voltage section and stacked in a direction transverse to such plane, and wherein said magnetic means comprising a soft magnetic element abutting an outermost one of the laminations.

4. An induction device as claimed in claim 1 wherein said magnetic means comprises a soft magnetic element adjacent the voltage pole and said magnetic device comprises a soft magnetic bracket extending between the free legs of the outer legs and spaced from said soft magnetic member so as to establish a third magnetic path for shunting said first alternating magnetic flux from the air gap, one of said units comprising a screw having an axis parallel to the common plane of the voltage section and operable for varying the loading of the voltage winding means by movement relative to said electro-conductive unit.

5. An induction device as claimed in claim 4 wherein said soft magnet member includes block secured to the voltage pole and wherein said screw is constructed of soft magnetic material and is operable for movement along a path extending between said voltage pole and one of said outer legs for varying the magnetic reluctance in an air gap between the bracket and the soft magnetic member to adjust said loading of the voltage winding means, the spacing between the bracket and the soft magnet element constituting an air gap in said third magnetic path which directs magnetic flux away from the electro-conductive unit and the air gap including said armature device to control the torque response of the induction device to energization of the winding means.

6. In a multi-stator induction device responsive to a function of the volt-amperes in an alternating current circuit; a rotor structure having an electro-conductive armature device; a stator structure; and means mounting the rotor structure for rotation about an axis relative to the stator structure; said stator structure comprising a plurality of electromagnet devices each comprising an E-shaped planar soft magnetic voltage section including a center pole and two outer legs disposed in a common plane, a soft magnetic current section having current poles spaced from the center voltage pole to define an air gap therebetween, voltage winding means effective when energized in accordance with an alternating voltage for directing first alternating magnetic flux through the center voltage pole into the air gap, and current winding means effective when energized at least in part by alternating current for directing second alternating magnetic flux through the current poles into the air gap to establish with the first magnetic flux a shifting resultant magnetic field in the air gap, said armature device having a portion positioned in the air gap to develop a torque from said resultant magnetic field which acts to rotate the armature device relative to electromagnet unit about said axis; each of said electromagnet devices comprising a first magnet path for the first alternating magnetic flux which includes the center voltage pole, the outer legs and a portion of the armature device, a magnetic path unit including a soft magnetic member, and magnetic means completing with the magnetic member a second magnetic path which excludes the air gap for magnetic flux produced by the voltage winding means, and a closed circuit electro-conductive unit linked substantially only with magnetic flux carried by the second magnetic path to effect loading of voltage winding means, at least one of said units being movably adjustable to vary the loading of the voltage winding means by the electro-conductive unit and vary the phase relationship between

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the first and second alternating magnetic fluxes, said magnetic means including a soft magnetic device extending from a position adjacent the soft magnetic member to the free ends of the outer legs to define with the magnetic member said second magnetic path which is clear of the armature, said magnetic means directing magnetic flux between the center voltage pole and each of the outer legs through the magnetic member; the movably adjustable one of said units for each of two of said electromagnet devices comprising an adjustment screw having an axis extending substantially transverse to the plane of the associated voltage section; and the movably adjustable one of said units for a third one of said electromagnet devices comprising an adjustment screw having an axis extending substantially parallel to the plane of the associated voltage section.

7. An induction device as claimed in claim 6 in combination with a base on which the induction device is mounted extending generally parallel to the voltage section of the third one of said electromagnet devices and adjacent thereto, said adjustment screw for the third one of said electromagnet devices being intermediate the plane of such voltage section and the base.

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8. An induction device as claimed in claim 7 wherein for the third one of the electromagnet devices said magnetic member comprises a soft magnetic block substantially abutting the associated center voltage pole adjacent the free end thereof and a soft magnetic bracket extending between the free ends of the outer legs and spaced from said magnetic element, said adjustment screw for the third one of the electromagnets being of soft magnetic material and being responsive to rotation for movement along its axis to adjust the magnetic reluctance between the soft magnetic block and the bracket.

9. An induction device as claimed in claim 8 wherein for the third electromagnet device said soft magnetic element is spaced from the bracket by an air gap proportioned to pass voltage magnetic flux through a path independent of the adjustment screw adjustment and independent of the first named air gap for such third electromagnet device thereby establishing a third magnetic path for said first alternating magnetic flux effective to control the torque developed on said armature device by said resultant magnetic field.

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