

- [54] **MULTI-ELEMENT INDUCTION
DEVICE HAVING COMMON
ARMATURE AND MAGNETIC LIGHT-
LOAD ADJUSTERS**
- [72] Inventor: **James E. Ramsey, Jr.,** Raleigh, N.C.
- [73] Assignee: **Westinghouse Electric Corporation,**
Pittsburgh, Pa.
- [22] Filed: **Sept. 23, 1970**
- [52] U.S. Cl.....**324/137, 324/107**
- [51] Int. Cl.....**G01r 11/02, G01r 11/32**
- [58] Field of Search.....**324/137, 138, 107**

- [56] **References Cited**
- UNITED STATES PATENTS**
- | | | | |
|-----------|---------|--------------------|---------|
| 2,136,251 | 11/1938 | Pratt..... | 324/137 |
| 3,493,862 | 2/1970 | Ramsey et al. | 324/137 |

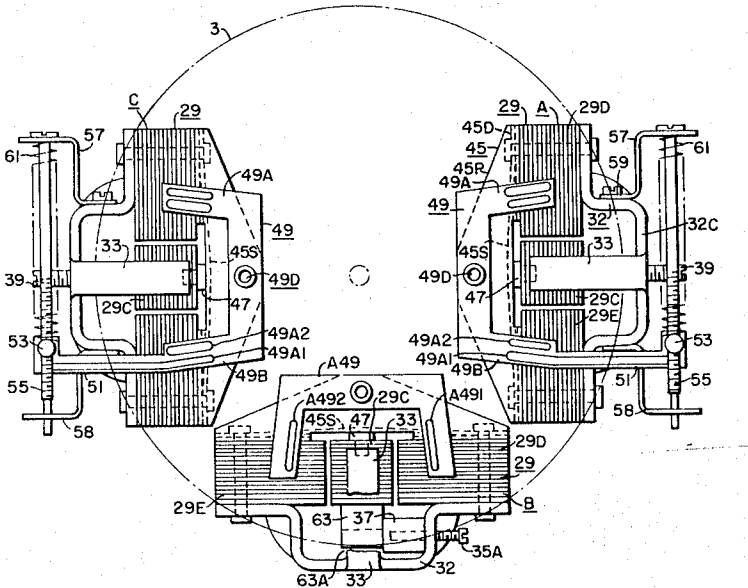
2,705,774	4/1955	Hewlett et al.	324/137
3,290,594	12/1966	Drew	324/137 X
2,129,010	9/1938	Kurz	324/137 X

Primary Examiner—Alfred E. Smith
Attorney—A. T. Stratton and C. L. Freedman

[57] **ABSTRACT**

An induction watt-hour meter has multiple elements or electromagnets operating on a common laminated electro-conductive armature. The laminations of the armature are slotted and the slots of adjacent laminations are staggered. The connections to one of the elements are reversed relative to the connections to the remaining elements. Magnetic shielding is provided for the voltage section on each of the elements. A magnetic light-load adjuster is provided for each of the elements.

17 Claims, 12 Drawing Figures



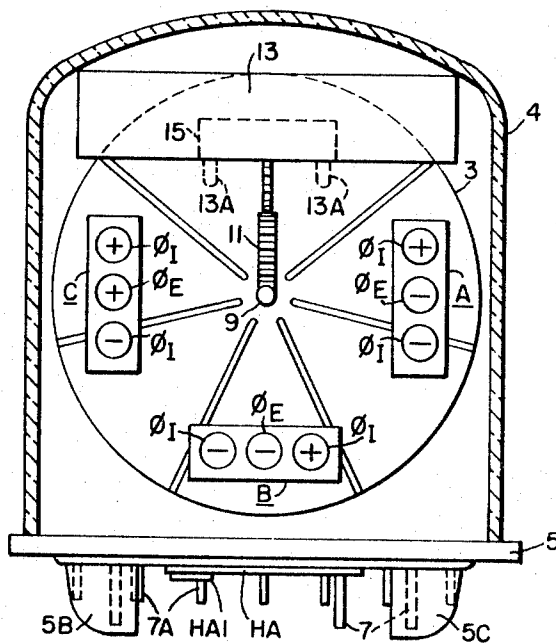


FIG. 1.

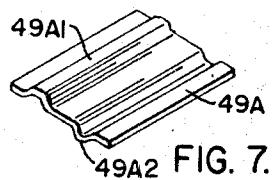


FIG. 7.

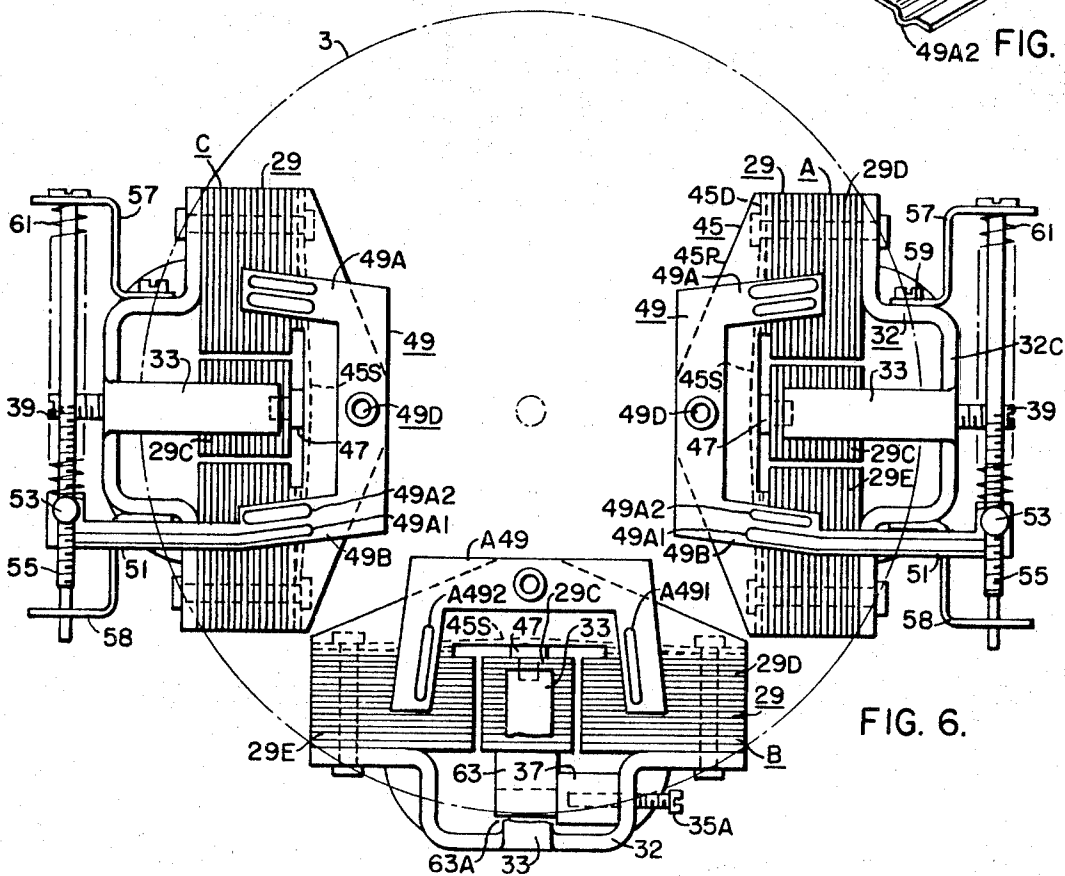
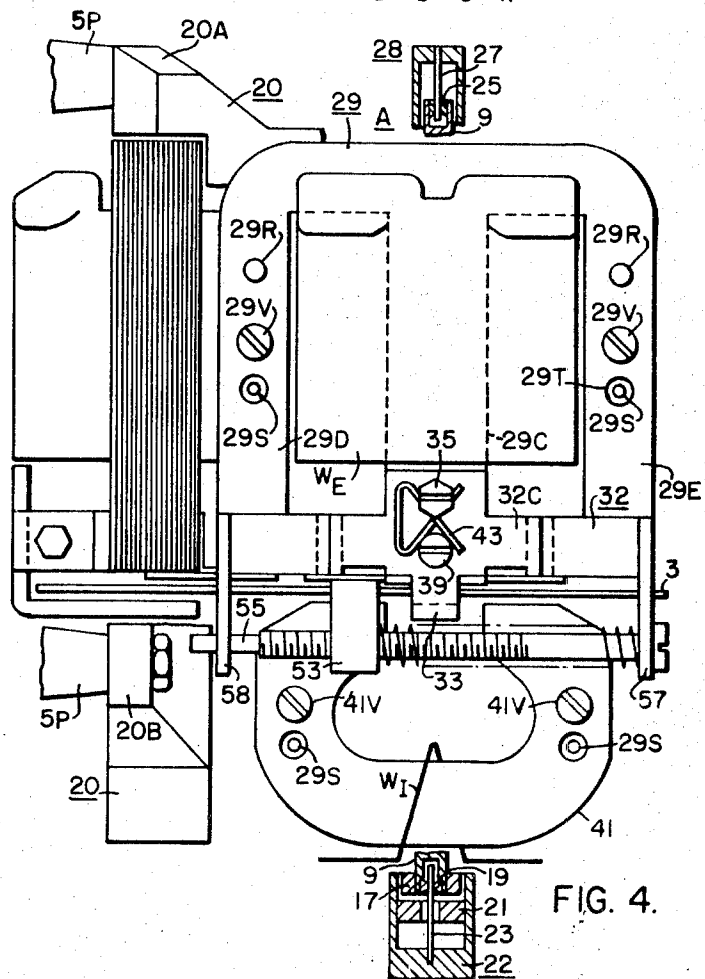
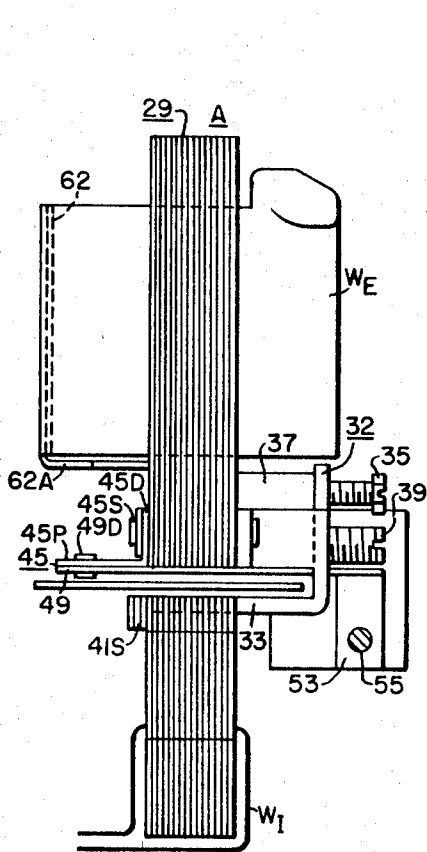
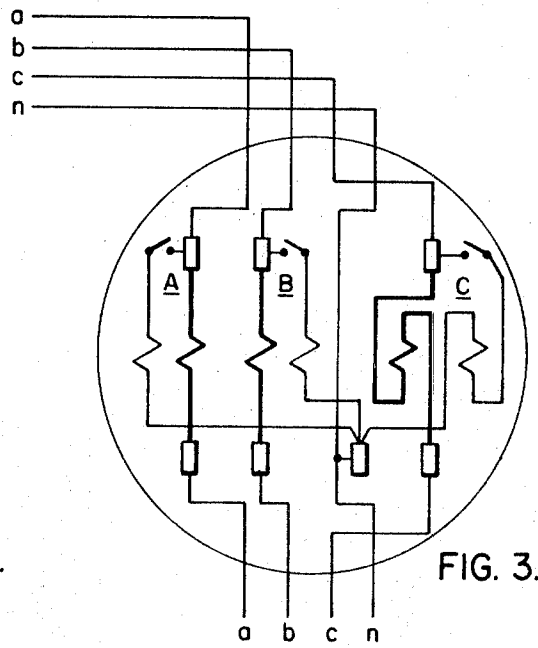
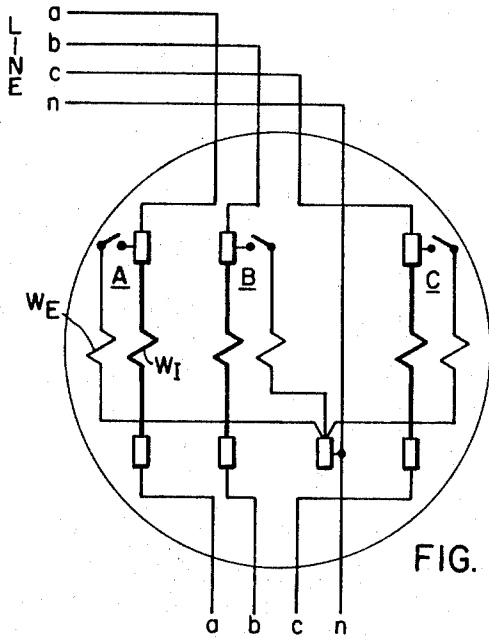
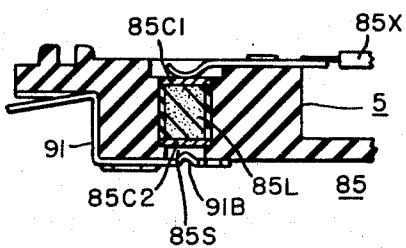
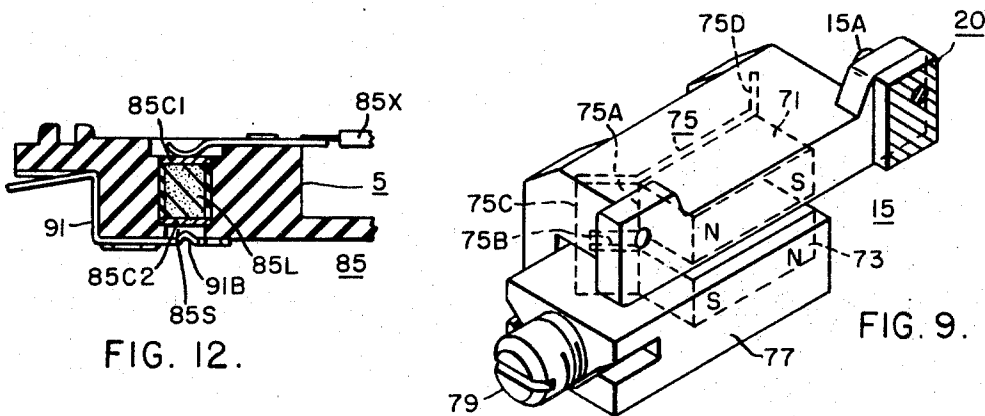
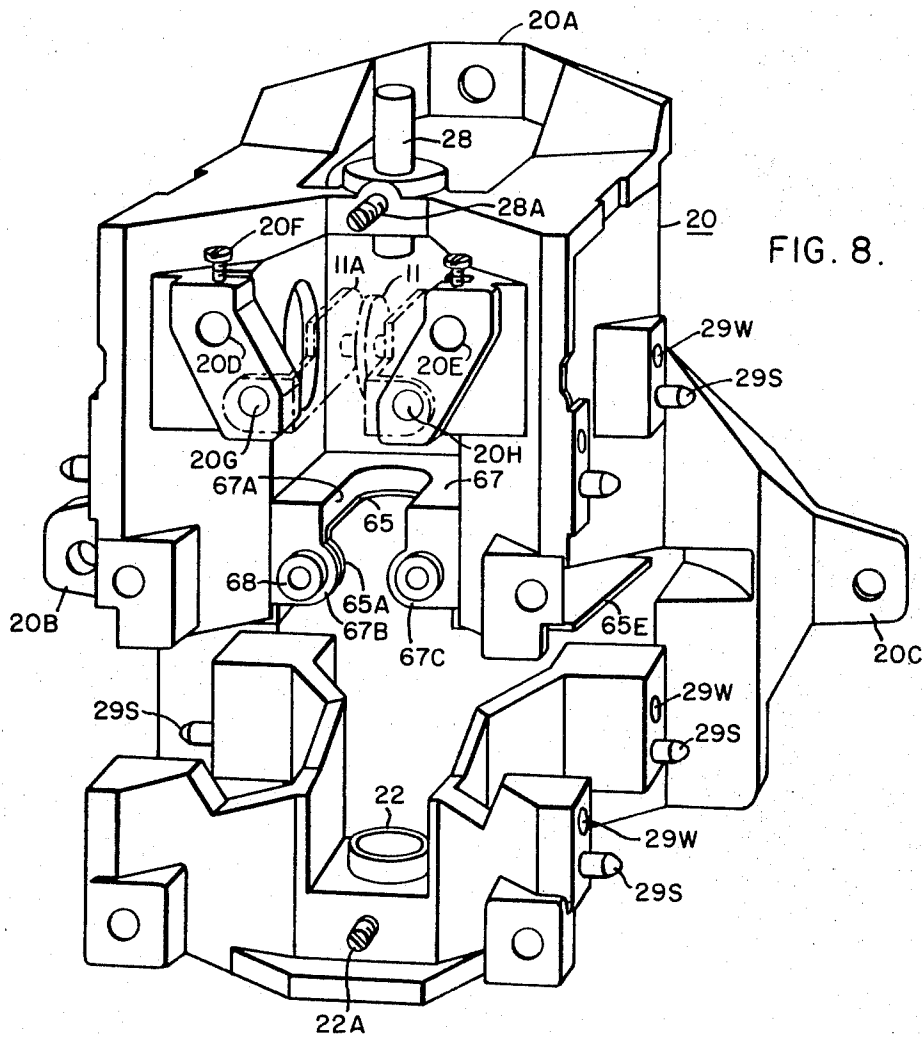


FIG. 6.





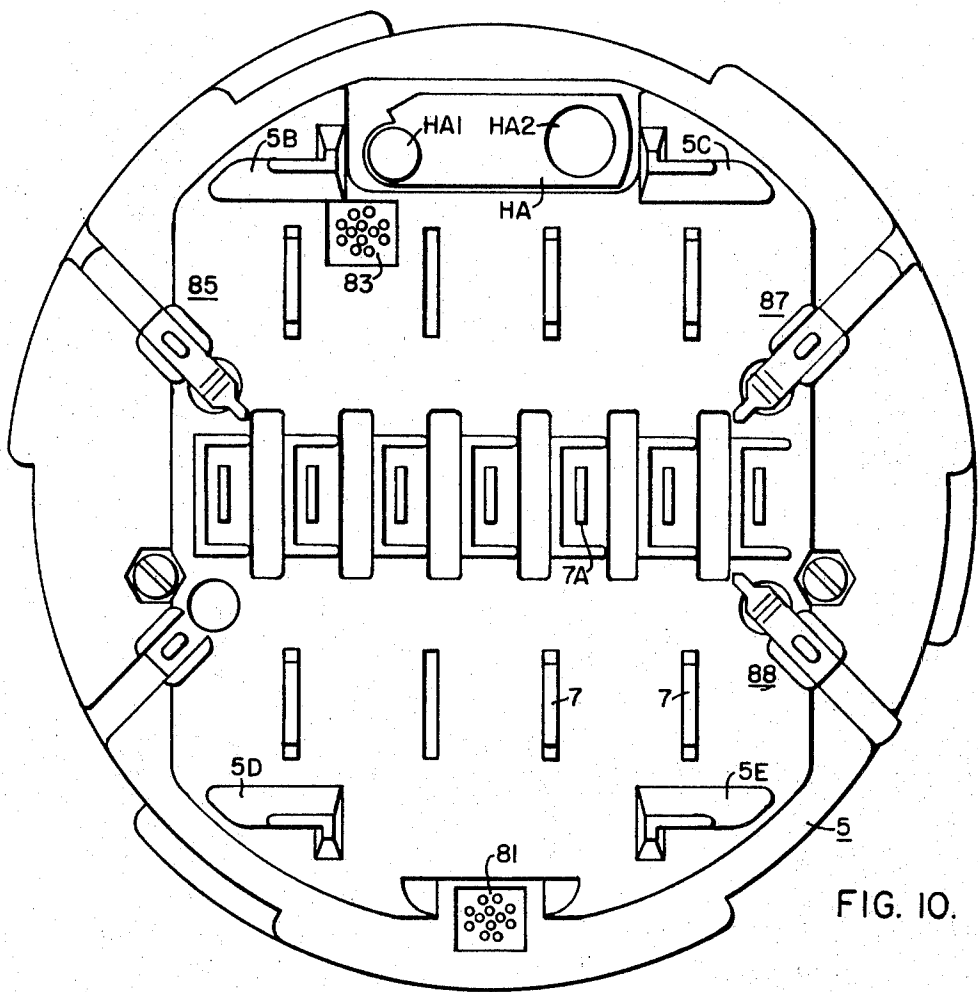


FIG. 10.

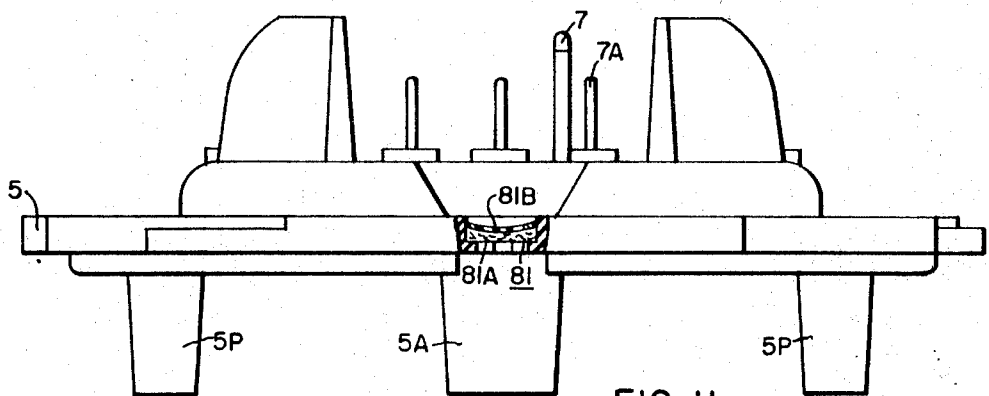


FIG. 11.

MULTI-ELEMENT INDUCTION DEVICE HAVING COMMON ARMATURE AND MAGNETIC LIGHT-LOAD ADJUSTERS

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. The importance of this error is shown by the inclusion of Test No. 18 on Independence of Stators in the AEIC-EEI-NEMA Standards for Watt-hour Meters which is identified as EEI Publication No. MSJ-10-1966, published by three groups, one of which is The Edison Electric Institute of New York City. The error may be dependent on the phase rotation and on the balance of loading of the elements. The importance of the error also is shown by the following excerpt from the aforesaid Electrical Metermen's Handbook: "Polyphase meters must have a high degree of independence between the stators. Lack of this independence is commonly known as 'interference' and can be responsible for large errors in the various measurements of polyphase power." (Page 118).

Some of the prior art attempts to minimize interference error may be reviewed briefly. Thus it has been proposed that a separate armature be provided for each element of a polyphase meter. Two elements of a three-element meter may be associated with one common armature and a third element may be associated with another armature.

In another approach, a common armature is employed for the elements but the armature is so constructed that the eddy currents induced in the armature for each of the elements are localized adjacent such element. In one example, the armature is constructed of concentric sections, the sections being insulated from each other. Each of the sections is associated with a separate element of the meter.

In order to localize the eddy currents, a common electro-conductive armature may be constructed of a plurality of slotted laminations. An armature of this type is discussed in the U.S. Pat. No. 3,290,594 to Drew which issued Dec. 6, 1966.

Other approaches involve the supply of compensating magnetic flux from one element to another element through the utilization of windings as described in the U.S. Pat. No. 2,909,728 to Lenehan which issued Oct. 20, 1959 or magnetic bridges as discussed in the U.S. Pat. No. 2,243,130 to Sherwood issued May 27, 1941.

Magnetic shields have been employed on the current or voltage sections of the electromagnets and are mentioned in the aforesaid Drew patent.

In some of the prior-art three-element common armature meters, adjacent elements have been spaced

120° from each other about the axis of rotation about the armature. In another approach, two of the elements are displaced 180° about the axis of the armature and the remaining element is located at a point 90° from each of the other two elements.

Also, it has been proposed that for a three-element common-armature meter one of the elements have its windings reversed relative to the connections of the other elements.

SUMMARY OF THE INVENTION

In accordance with the invention, magnetic light-load adjusters are provided for all or part of the elements. It has been found that such magnetic light-load adjusters materially reduce the interference error particularly when employed with other expedients such as a sectionalized common armature, reversed energization for one of the elements, provision of magnetic shielding for all or parts of the electromagnets and the location of two of the elements displaced from each other 180° about the axis of rotation of the armature with the remaining element located 90° from each of the first named two 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 aforesaid Drew patent. 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 Metermen'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.

Preferably the weight of the rotor assembly is supported by a magnetic mounting. Shown more particu-

larly 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. to D. F. Wright No. 3,143,704 which is 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 polytrifluoromonochloroethylene 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. to Daley No. 3,496,504 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_v 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 powerfactor 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 powerfactor 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 or 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 electroconductive 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 nonmagnetic and nonelectro-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 of 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 from 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 $\frac{1}{2}$ 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. to Schmidt et al. No. 2,889,494 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. Pat. 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 die-casting 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 pro-

vided 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 (eg. 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 20. 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.

Thus the magnetic light-load adjuster on the rear electromagnet may be preset in a direction causing the meter to run slow. The right-hand electromagnet 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.

I claim:

1. In a multi-stator induction meter, a rotor structure having an electro-conductive armature, a stator structure, and means mounting the rotor structure for rotation about a first axis relative to the stator structure, said stator structure comprising a plurality of drive stators spaced from each other angularly about said axis, each of the stators including a magnetic unit having pole pieces defining an air gap for reception of a portion of said armature, and voltage winding means and current winding means effective when energized in accordance with voltage and current respectively of an alternating current system for directing voltage and current magnetic fluxes respectively through said pole pieces to produce a shifting magnetic field in said air gap, said shifting magnetic field generating by induction action on said armature a torque acting between said structures to produce rotation of the rotor structure about said axis relative to the stator structure, and each of said stators further including flux control means comprising a magnetic member controlling the distribution of said voltage magnetic flux of the associated stator in said armature, each of said flux control means excepting one having a predetermined position effective to reduce interference errors due to interfering magnetic fields between said stators to a desired minimum level, and the remaining one of said flux control means having a predetermined position effective to control the magnitude of said torque at low levels thereof so as to establish a desired light load characteristic of said meter.

2. A meter as claimed in claim 1 wherein said magnetic member is located substantially between the magnetic unit and the axis.

3. A meter as claimed in claim 2 wherein each of said magnetic members is mounted symmetrically relative to the other of said magnetic members for pivotal adjustment about a second axis parallel to the first axis and located between the magnetic unit and the axis.

4. A meter as claimed in claim 3 wherein the magnetic member is U-shaped with legs extending from the connecting web into the air gap.

5. A meter as claimed in claim 4 wherein a projection extends from one of said legs through the air gap, and means engaging the projection after it passes through the air gap to adjust the magnetic member pivotally about the second axis.

6. A meter as claimed in claim 4 wherein each of said legs has a rib projecting in each direction parallel to the first axis, whereby one of the ribs can engage an adjacent pole piece associated with said voltage magnetic flux.

7. A meter as claimed in claim 4 wherein first and second ones of said stators are angularly displaced from each other 180° about the first axis at the sides of the meter, a third one of said stators equiangularly dis-

placed between the first and second stators, and means accessible from the front of said meter for adjusting each of the flux control means of the first and second stators.

8. A meter as claimed in claim 7 in combination with an alternating polyphase electric system, each of said stators being connected to a separate phase of the system; the connection of one of said stators being reversed relative to the connections of the remainder of the stators.

9. A meter as claimed in claim 2 wherein said magnetic member is adjacent to the armature, each of said stators comprises a second magnetic member adjacent the armature, said magnetic unit of the last-named stator being between the second magnetic member and the axis.

10. A meter as claimed in claim 9 wherein each of the magnetic units of said stators includes an E-shaped voltage soft magnetic section having a center leg and two outer legs each terminating in pole faces adjacent the armature and winding means for establishing a magnetomotive force between the pole face of the center leg and the pole faces of the outer legs in parallel, said pole face of the center leg being substantially surrounded by each of the associated magnetic members for reducing interfering leakage flux thereof, said second magnetic member having its ends magnetically coupled to said outer legs and being spaced from the center leg, and adjustable soft magnetic means for adjusting the magnetic coupling between the second magnetic member and the center leg.

11. A meter as claimed in claim 10 in combination with a separate magnetic shunt extending between the axis sides of the outer legs of each of the stators adjacent the armature, each of said shunts extending adjacent, but spaced from the associated center leg to shunt voltage magnetic flux between the associated center and outer legs and thereby further reduce said interfering leakage flux.

12. A meter as claimed in claim 10 wherein said adjustable magnetic means comprises first and second magnetic screws each adjustable for varying the magnetic coupling through the associated screw between the second magnetic member and the center leg, and an electro-conductive element substantially surrounding one of the screws.

13. A meter as claimed in claim 1 wherein said armature comprises a plurality of electro-conductive disks having said first axis as a common axis, the disks being laminated together and insulated from each other, each of said disks having a plurality of angularly spaced radial slots, the slots of each disk being angularly spaced about the first axis from the slots of the remainder of said disks, each of said magnetic units having an E-shaped voltage section defining an inner pole piece and two outer pole pieces, said voltage winding means when energized establishing a magnetomotive force between the inner pole piece and the two outer pole pieces in parallel, a soft magnetic bracket extending across said outer pole pieces adjacent the air gap, the pole pieces being between the bracket and the first axis, means establishing a path for magnetic flux between said bracket and the inner pole piece, and power-factor control means responsive to magnetic flux traversing said path.

13

14. A meter as claimed in claim 13 in combination with a soft magnetic shield for the voltage section of each of said stators.

15. The method of adjusting a multistator induction watt-hour meter wherein each stator has voltage and current windings for applying voltage and current magnetic fluxes to a common armature arranged for rotation about an axis, which method comprises the following steps: establishing an asymmetric magnetic path for the voltage magnetic flux of all except one of the stators to produce a resultant torque acting on the armature in a first predetermined direction about the axis so as to reduce undesired torque developed by interfering fluxes between the stators to a desired minimum level and establishing an asymmetric magnetic path for voltage magnetic flux of the remaining one of the sta-

14

tors to produce a desired light-load torque acting on the armature in a second predetermined direction about the axis.

16. A method as claimed in claim 15 wherein first and second ones of the stators are spaced substantially 180° from each other about the axis, and a third one of the stators is spaced substantially 90° from each of the first and second stators, and any one of said first, second and third stators is effective for producing said desired light-load torque.

17. A method as claimed in claim 16 in combination with the step of connecting the windings of the stators to energize the second stator in reverse directions relative to the energizations of the windings of the first and third stators.

* * * * *

20

25

30

35

40

45

50

55

60

65