Aug. 1, 1939. S. S. GREEN 2,168,290

ELECTRIC METER

Filed May 2, 1936

Fig. 2.

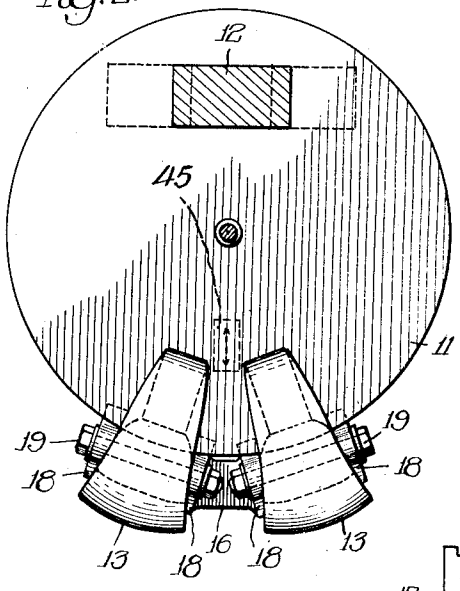


Fig. 3.

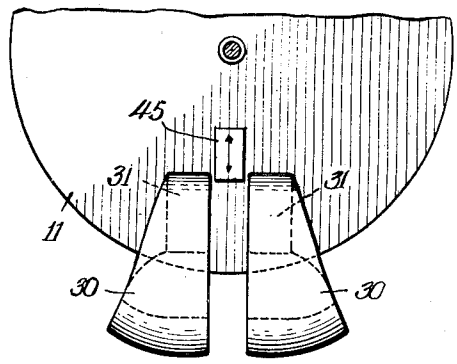


Fig. 1.

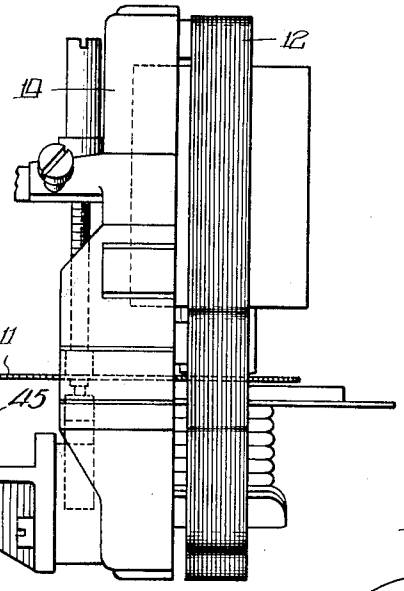


Fig. 4.

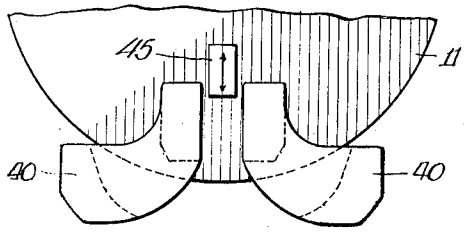
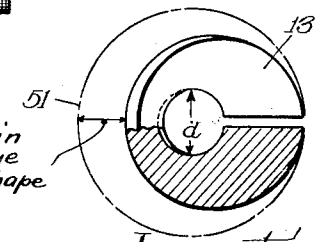


Fig. 5.



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2,168,290

ELECTRIC METER

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Application May 2, 1936, Serial No. 77,559

11 Claims. (Cl. 171—34)

This invention relates to watthour meters and more particularly to such meters which include a rotatable disc driven by one or more electromagnetic driving units and retarded by magnetic flux generated by one or more permanent magnets, called damping magnets.

In securing adequate damping torque, it is very important for the disc to pass through two adjacent fields of opposed polarity. In recent years these opposed fields have been obtained most commonly by two separate magnets, each straddling the disc to produce one field through the disc. One of the magnets would have its north pole above the disc and its south pole below the disc, and the other would have its south pole above the disc and its north pole below the disc. With the large magnets, which have been used heretofore, this arrangement has been obtained in a fairly simple and efficient manner by placing the two magnets in alinement with the outer side of each approximately tangent to the disc. Patent No. 1,686,727 issued to Bradshaw is an example of this arrangement of the damping magnets. This arrangement has resulted in making the long edges of the pole faces parallel to one another, so that they could be spaced apart substantially equally all along the lengths of the poles. Such positioning of the pole faces has been considered necessary to the greatest efficiency, since, if the magnets are too close together the leakage from one to the other above or below the disc is too great, while, if the magnets are too far apart, the change of flux passing through the disc is not sudden enough as the disc rotates from one field to the other field.

New magnetic materials have become known in recent years which are capable of forcing adequate damping flux through the disc (and through the gap in the magnet) with only a very small length of magnet. These metals are known as high coercive steels. It has been recognized for some time that a given amount of magnetic flux could be obtained more cheaply with certain of these high coercive steels than with the chrome steels commonly used heretofore. However, no one other than the present applicant has applied this knowledge to watthour meters, apparently because of the difficulty of making sufficiently full use of the magnetic properties of the metal if a high coercive steel is used. For example, the chrome magnets referred to could not be simply replaced by high coercive steel magnets, because in order to avoid having their sides scrape the edge of the disc it would be necessary for the high coercive steel magnets to be almost as large as the chrome magnets. This would be wasteful and would make the use of high coercive steel economically unsound, since there would be a great deal more magnetomotive force available than is actually needed in sending the maximum flux available from the magnet across the relatively small single gap of this form of generally C-shaped magnet. In order for the high coercive steel to be cheaper than the chrome steel, it must be reduced to about ⅙ of the weight of the chrome steel or approximately ⅙ of the volume.

In applicant's copending application, Serial No. 70,951, applicant has disclosed one commercially sound manner of using the high coercive steel. In that instance, he obtained his two opposed fields from a single magnet located entirely above the disc with a soft iron armature below the disc so that the flux would pass from the magnet down through the disc to the armature, through the armature and back up through the disc to the magnet. According to the present invention, various additional arrangements are provided, each of which may make the use of high coercive steel commercially practical. In general, all of these arrangements involve departing from the prior practice of placing the two magnets in simple alinement and require further change in the proportions of the magnet. In fact to make the best use of the metal a radical change of shape is necessary.

One of the problems which makes the efficient use of the metal difficult is the fact that, as a C-shaped or horse-shoe magnet with a relatively large cross section becomes smaller, its length along its outer edge may become two or three times as great as its length along the inner edge, with the result that, if its inner length is sufficient, its outer length is twice as great as sufficient. If the sides of the magnets are turned out of alinement so that they are positioned somewhat radially on the disc, for example, this difficulty is aggravated by the fact that for the purpose of efficiency it is desirable that the pole faces of the magnet be long in the radial direction as seen in Fig. 5. This means that if the magnet is in the customary form of a simple bar bent to the desired shape, its outer edge would be as shown in the dotted line in Fig. 5. If the length of the inner edge is the minimum required, the length of the outer edge would in this instance be three times as large as required. According to one feature of this invention, this special difficulty has been partially overcome by

making the magnet of a peculiar shape so that although its pole faces are relatively thin and long, the magnet at its center portion is just the opposite—i. e. relatively wide from side to side and relatively small in the transverse direction, while its cross sectional area is less at the poles than at the center.

The objects of the invention will be sufficiently clear from the foregoing statement but in summary they are to provide economical arrangements for making use of high coercive steel in the damping magnets of watthour meters. Other objects will be apparent from the following description and from the drawing, in which:

Fig. 1 is a side elevation of one form of meter mechanism embodying this invention.

Fig. 2 is a partially diagrammatic plan view of the meter illustrated in Fig. 1.

Fig. 3 is a fragmentary view corresponding to Fig. 2, but showing a different shape and arrangement of the magnets.

Fig. 4 is a view corresponding to Fig. 3, but showing a third possible arrangement of the damping magnets.

Fig. 5 is a side elevation of one of the magnets showing the lower half of the magnet in section and showing in dotted lines the size that would be necessary but for the special shapes.

Although this invention may take numerous forms, only three have been chosen for illustration. In each of these, the meter includes a rotatably mounted disc 11 which is driven by one or more driving elements 12 and retarded by a pair of damping magnets 13. One form of general assembly is seen best in Fig. 1. Except for the damping magnet assembly, this form may be the same as that illustrated in my Patent No. 2,110,417 resulting from a copending application, and therefore need not be described in detail. It is sufficient to state that driving element 12 may be secured to the base (not shown) in any manner, and that a meter frame 14 is secured to the said driving element and provided with suitable bearings for supporting the disc in such manner that it may rotate with as little friction as possible. The magnets 13 may be supported by the frame in any suitable way, as by means of a bracket 16 somewhat similar to the bracket shown in said Patent No. 2,110,417.

As seen best in Fig. 2, the two magnets 13 are not positioned with sides in alinement as in the prior art, but are turned toward a radial position, as is discussed more fully below. Each magnet may be secured to the bracket 16 in any suitable manner, as by arms 18 formed integrally on the bracket 16 and pressed onto the magnet 13 while it is held in the desired position. While they are still held thus bolts 19 may if desired be inserted through the ends of arms 18 as illustrated, so as to secure these arms against loosening. It should be noted that the bracket 16 and, of course, the arms 18 and bolts 19 are made of a non-magnetic metal and preferably one which is soft enough to flow under the pressure applied to the arms 18, so that they will fit the magnets intimately and even lap slightly around the inner edges of the magnets.

The magnets are preferably made of one of the high coercive magnetic materials discussed more fully in applicant's Patent No. 2,110,418 resulting from a copending application. Such materials are also discussed in an article by C. S. Williams in the January 1936 issue of "Electrical engineering" and are disclosed in Patents Nos. 1,633,805, 1,947,274, 1,989,551, 1,968,569, 2,027,994, 2,027,995, 2,027,996, 2,027,997, 2,027,998, 2,027,999, and 2,028,000. It is probable that any of these steels which have sufficiently high coercive and flux values, and which are capable of being made really permanent could be used in accordance with this invention. One satisfactory material now available on the market is that known commercially as "Alnico." Although such materials are at present more expensive by weight or volume than the chrome steel now used in watthour meters, their high coercive force enables a much smaller magnet to force a given amount of flux through the meter disc so that if the high coercive strength can be sufficiently utilized, the materials in question, or some of them, can be used economically and with certain other advantages.

For reference, and to illustrate the difference in steels, the following table of typical coercive values of different known materials is included:

	Coercive force in oersteds	Approx. maximum residual flux in kilogauss
Low-coercive steel, customary 3.5% chrome steel	60 to 64	8.5
High-coercive steels, 36% cobalt steel	240 to 260	10.2
Alnico	420 to 440	7.0

It will be observed that the chrome steel cannot be considered as in a class with the latter two materials, since these are characterized by having a coercive force value of at least three times that of the chrome variety, that of Alnico being over six times. There are, of course, steels between those mentioned above, such as 17% cobalt steel, but this table shows the difference between low and high coercive steels.

It will be noted from the second column that the residual flux values of the Alnico are somewhat lower than for the other materials but this is more than made up for by the high coercive value for the material when used in accordance with this invention because the structure, gap and shaping of the magnet in this case is such as to capitalize on or take advantage of this factor rather than to throw it away. The last two metals can be used in much shorter magnets than the chrome steel and still force the same amount of flux through a given gap.

The purpose of these new arrangements is to make the use of a high coercive magnetic material commercially practical. To be economical, such C-shaped magnets must be no longer than necessary. Thus, as seen in Fig. 5, the inside diameter "*d*" of the C-magnets shown in Figs. 1 and 2 may be only about one-half of an inch. If, in accordance with present practice, the pole faces were positioned with their long sides parallel as seen at 31 in Fig. 3, and the magnets extended from these poles to the right and left, it is obvious that to clear the disc each magnet would have to be very much larger in diameter than that shown in Fig. 5. In fact, the inside diameter of the magnets would have to be at least an inch so that the magnets would be at least twice as large as they should be. To make the magnets twice as large as they should be, would require twice as much metal and would make the magnets more expensive than the present chrome magnets, since the high coercive metal is much more expensive per pound and the extra length in the high coercive steel is useless. The magnet length required for a given situation depends mainly on the gap length, and

in general the ratio of magnet length to gap length should be less than 25 to 1 to take advantage of the high coercive force of the metals under consideration. A ratio of 15 to 1 or less makes even better use of the high coercive force.

In order to shorten the magnets to a point where the high coercive metal can be used economically, the magnets are turned out of alinement toward a radial position. In turning them in this direction, however, a new difficulty is introduced for it is still desirable that the pole faces adjacent the disc be relatively long in a generally radial direction and relatively short in the transverse or circumferential direction, i. e., that they have their long edges approximately parallel. The reason for this is that the portion of the magnet field which is considerably removed from the center line between the magnet poles is of relatively less value. In other words, in order to have as much of the magnet fields as possible close to the center line between the magnets, the shape of the poles is changed so as to be elongated in the plane of the magnet, i. e., in the radial direction, and narrower in the direction from side to side of the magnet.

If this change were made in the natural way by giving the whole magnet a corresponding cross section, the shape of the outside of the magnet would be that of a large circle indicated diagrammatically by the dotted line **51** in Fig. 5. This would result in a considerable waste of metal, as seen by comparing circle **51** with the magnet **13**, since the outside diameter of the hypothetical magnet would be over three times the inside diameter of the magnet, which inside diameter is all that is necessary. In other words, the minimum inside diameter *d* will be chosen to give the necessary magnetic strength, and any length in excess of this will be wasted. To avoid this waste of metal the present invention contemplates radical change in shape for the magnet, so that its side elevation will appear as seen in Fig. 5, whereas, when seen from above it will appear as in Fig. 2. It will be observed that in referring to the radial dimension of the magnet the thickness of the magnet metal decreases from the poles to the mid-point, while in a direction from side to side of the magnet the thickness increases from the poles to the center. It is desirable that, regardless of shape, the cross sectional area increase slightly from the poles toward the center or in other words, that the magnets be tapered toward the poles. One reason for this is to allow for leakage flux which passes through the center portion of the magnet but not through its poles. The drawing is not intended to be exactly to scale, but illustrates the general nature of what is intended.

This peculiar shape of the magnets has an especial advantage in connection with the mounting of the magnets. It is evident that if the arms **18** engage sides of the magnet tightly, the magnet cannot slip closer to the disc, because this would wedge the arms **18** apart. On the other hand, if the top of the arms **18** lap over the inner edge of the magnet, the magnet cannot slip outwardly and tend to stretch the arm **18**. Hence the magnet cannot move in either direction.

In Fig. 3 the shape of the magnets **30** is very similar to that shown in Figs. 1, 2, and 5, except that they are widened primarily in one direction with the result that the pole faces **31** are parallel. Of course, the magnets of Figs. 1 and 2 may be positioned with the pole faces parallel or more nearly so than shown, if desired.

On the assumption that a certain minimum length is desirable, the inside of the central portion of the magnet has not been made arcuate in cross section as has the outside. The difference is clearly seen in Fig. 2, in which it is seen that the inside of the center portion of the magnet is flat opposite the pole pieces and arcuate to the sides of the flat portion, the curvature of the arc being such as to retain the minimum length in all possible paths.

In Fig. 4 has been shown a modified form of the invention, in which the magnets **40** are shaped to extend away from one another as far as possible. Although this is a somewhat more complicated shape for the magnet, it, nevertheless, has the advantage of reducing the leakage flux between the magnets.

All of the special shapes illustrated can be produced commercially because Alnico and other of the high coercive materials can be cast or otherwise molded to shape. Heretofore meter magnets have been formed by bending bar stock.

Although this invention has been illustrated with respect to a single phase meter having a single driving element, it should be understood that it can also be used with a polyphase meter having a plurality of driving elements, in which case the driving elements might be spaced say 120 degrees apart, or even more, on the disc. It might be mentioned that in connection with a polyphase meter of this type when the driving elements are unusually close to the damping magnets, the value of the high coercive magnetic material in the damping magnets is especially great, since it aids in enabling these magnets to overcome the demagnetizing effect of abnormal surges of current occasionally produced in the driving magnets due to accidental causes. As a matter of fact, the magnets illustrated might carry sufficient flux to adequately dampen the disc even if two driving elements were used. It follows that if only one driving element is used the damping magnets could be considerably reduced in cross section, this preferably being accomplished mainly by reducing the thickness from side to side.

Any suitable adjustable shunt may be provided for adjusting the meter by diverting more or less flux from the meter disc in accordance with common practice, as illustrated diagrammatically at **45**.

From the foregoing description, it is evident that this invention makes the use of high coercive magnetic material in the disc-straddling magnets of general C-shape commercially feasible. This is accomplished by changing the positions of the magnets to permit the use of a shorter magnet and by changing the shapes of the magnets to obtain a satisfactory positioning of the magnet poles in spite of this change of position of the magnets and to obtain the optimum use of this relatively expensive high coercive material.

Although but a few embodiments of my invention have been herein shown and described, it is to be understood that the invention is not limited thereby, but is to be limited only by the prior art. The following claims are intended to point out some of the features now recognized as new, rather than to limit the invention to these features.

I claim:

1. A watthour meter, including a continually rotatable disc, a driving unit for rotating said disc, and a damping unit for retarding the rota-

tion of said disc including a pair of permanent magnets formed of a magnetic material having a coercive force of at least 180 oersteds, said magnets straddling the disc and being positioned with their sides out of alinement, and extending approximately radially outwardly from the pole faces and with the poles of one magnet close to the opposed poles of the other magnet.

2. A watthour meter, including a continually rotatable disc, a driving unit for rotating said disc, and a damping unit for retarding the rotation of said disc, including a pair of generally C-shaped permanent magnets formed of a material having a coercive force of at least 180 oersteds, and straddling the disc with their pole faces close to one another, said magnets being wider from side to side at their centers than at their poles.

3. A watthour meter, including a continually rotatable disc, a driving unit for rotating said disc, and a damping unit for retarding the rotation of said disc, including a pair of generally C-shaped permanent magnets formed of a material having a coercive force of at least 180 oersteds, and straddling the disc with their pole faces close to one another, said magnets each being wider from side to side, and thinner in the transverse direction parallel to the disc, at their centers than at their poles.

4. A watthour meter, including a continually rotatable disc, a driving unit for rotating said disc, and a damping unit for retarding the rotation of said disc, including a pair of generally C-shaped permanent magnets straddling the disc with their pole faces close to one another, said magnets having their pole faces elongated approximately in a radial direction and being of at least as great cross section throughout the rest of the magnet as at the pole faces, but having the shape of the cross section gradually changed with the center of the magnet being elongated in the direction from side to side of the magnet, said magnets being formed of a magentic material having a coercive force of at least 180 oersteds.

5. A watthour meter comprising a continuously rotatable disc, a torque producing electromagnet for driving said disc, and a damping unit for said disc, said damping unit including two opposed permanent magnets of general C-shape located close together and each straddling the edge of the disc, and said magnets being made of a material having a coercive force of at least 180 oersteds and each being of such size and shape that the ratio of the length of the flux path in the magnet to the length of the air gap of the magnet is less than 25 to 1.

6. A watthour meter comprising a continuously rotatable disc, a torque producing electromagnet for driving the disc, and a damping unit for said disc, said damping unit including two opposed permanent magnets of general C-shape located close together and each straddling the edge of the disc, and said magnets being made of a material having a coercive force of at least 180 oersteds and being of such size and shape that the ratio of the length of the flux path in the magnet to the length of the air gap of the magnet is less than 15 to 1.

7. A watthour meter comprising a continuously rotatable disc, a torque producing electromagnet for driving said disc, and a damping unit for said disc, including two opposed permanent magnets of general C-shape located close together and each straddling the edge of the disk and extending in a generally radial direction from the pole faces outwardly, said magnets being made of a material having a coercive force of at least 180 oersteds and being of such size and shape that the ratio of the length of the flux path in the magnet to the length of the air gap of the magnet is less than 25 to 1.

8. A watthour meter comprising a continuously rotatable disc, a torque producing electromagnet for driving said disc, and a damping unit for said disc, including two opposed permanent magnets of general C-shape located close together and each straddling the edge of the disc and extending in a generally radial direction from the pole faces outwardly, said magnets being made of a material having a coercive force of at least 180 oersteds and being of such size and shape that the ratio of the length of the flux path in the magnet to the length of the air gap of the magnet is less than 15 to 1.

9. A watthour meter comprising a continuously rotatable disc, a torque producing electromagnet for driving said disc, and a damping unit for said disc, including two opposed permanent magnets of general C-shape located close together and each straddling the edge of the disc and extending in a generally radial direction from the pole faces outwardly, said magnets being made of a material having a coercive force of at least 180 oersteds and being of such size and shape that the ratio of the length of the flux path in the magnet to the length of the air gap of the magnet is less than 25 to 1, the pole faces of said magnets being elongated in a generally radial direction and the outer part of said magnets being elongated from side to side.

10. A watthour meter comprising a continuously rotatable disc, a torque producing electromagnet for driving said disc, and a damping unit for said disc, including two opposed permanent magnets of general C-shape located close together and each straddling the edge of the disc and extending in a generally radial direction from the pole faces outwardly, said magnets being made of a material having a coercive force of at least 180 oersteds and being of such size and shape that the ratio of the length of the flux path in the magnet to the length of the air gap of the magnet is less than 15 to 1, the pole faces of said magnets being elongated in a generally radial direction and the outer part of said magnets being elongated from side to side.

11. A watthour meter comprising a continuously rotatable disc, a torque producing electromagnet for driving said disc, and a damping unit for said disc, including two opposed permanent magnets of general C-shape located close together and each straddling the edge of the disc and extending in a generally radial direction from the pole faces outwardly, said magnets being made of a material having a coercive force of at least 180 oersteds and being of such size and shape that the ratio of the length of the flux path in the magnet to the length of the air gap of the magnet is less than 15 to 1, the inside length of each magnet being approximately the minimum length of an arc extending between its pole faces and straddling the edge of the disc with a safe clearance.

STANLEY S. GREEN.