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[54] **WORM-DRIVEN ADJUSTABLE POTENTIOMETERS**
8 Claims, 2 Drawing Figs.

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[51] **Int. Cl.** **H01c 5/02,** H01c 9/02
[50] **Field of Search** 338/143, 146, 148, 149, 162, 174, 175, 322, 325; 74/458

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ABSTRACT: A low-cost, worm-driven potentiometer is described which may be constructed using only a few components and yet retains good performance characteristics. Components which are conventionally used in this type of potentiometer, but which may at least be omitted in accordance with the instant invention without deleteriously affecting performance characteristics, especially the specific tolerance of resolution, include axial constraints for preventing the driving worm from moving axially in the potentiometer housing. This is made possible by utilizing a worm-drive comprising a driving worm having a threaded section of hourglass profile and a driven spur gear. The meshing engagement between the worm and gear is preferably effected with at least an interference tooth contact and the hourglass worm-drive provides self-nullification of axially directed forces which would tend to cause resultant axial displacements of the worm upon worm rotation. Further simplification is made possible by utilizing a collector pin as the axial support for the driven gear and as a means for preventing the overdriving of a contact element rotatable with the driven gear. Moreover, the contact element cooperates with the collector pin to provide a resilient axial support for the driven gear.

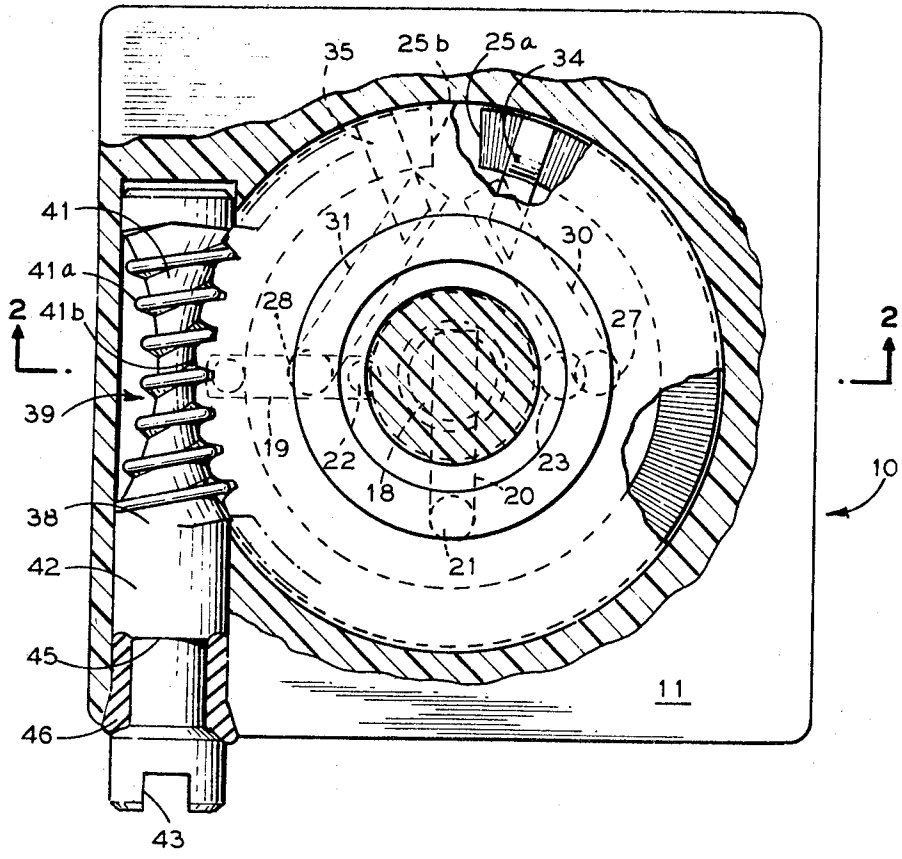


FIG. 1

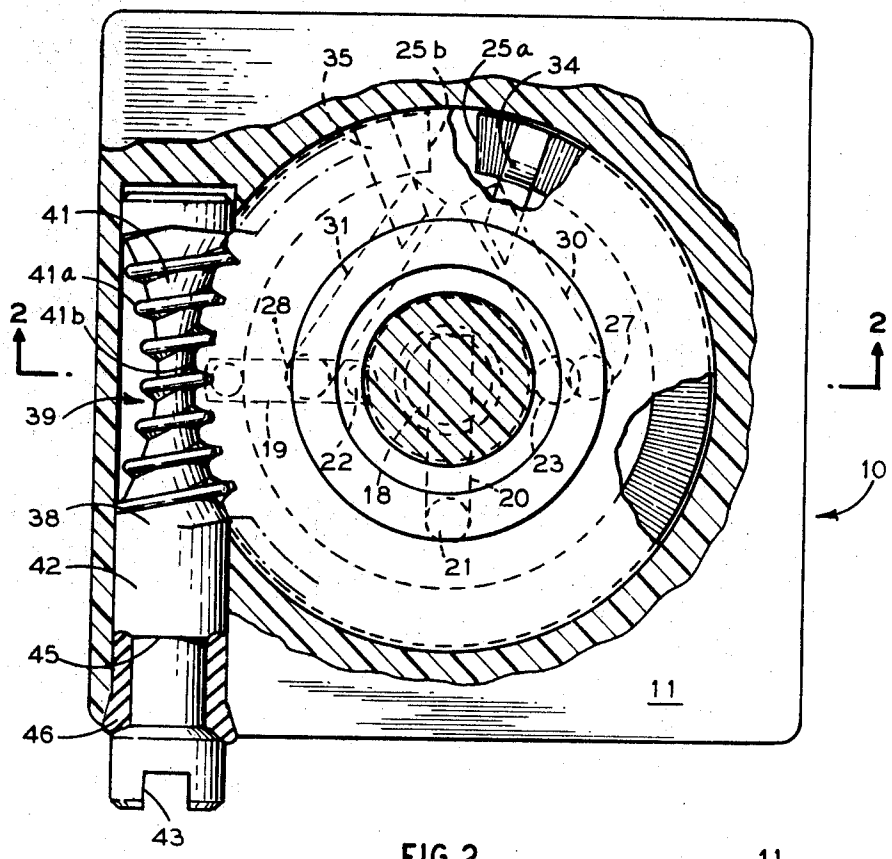
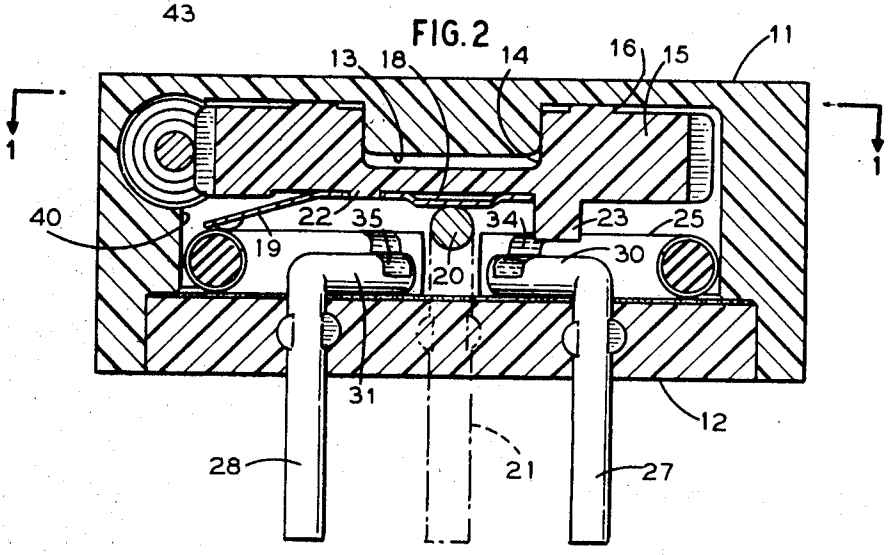


FIG. 2



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WORM-DRIVEN ADJUSTABLE POTENTIOMETERS

This invention relates to variable resistors and more particularly, to worm-driven potentiometers.

One class of worm-driven potentiometers includes an arcuate resistance element having two spaced-apart ends and a contact or wiper member which is mounted on a rotatable, driven gear to rotate therewith and variously contact the resistance element. Additionally, this class of potentiometers typically utilizes some type of a stop means to prevent the rotated contact from being driven off either end of the resistance element.

In this class of potentiometers, the driven gear is rotated by turning a rotary worm having a shaft section accessible for rotation from the outside of the potentiometer housing. The threaded section of the worm is typically formed of a plurality of axially spaced-apart thread portions having respective root and outside thread radii which are constant throughout the length of the threaded section and thus the threaded section has a barrellike or cylindrical profile. Although this type of worm has been used almost exclusively in this class of prior art potentiometers it has several disadvantages that increase significantly the complexity and cost of the potentiometer.

One principal disadvantage is that this type of worm must be provided with some type of axial restraining means in order to prevent it from moving in axial directions relative to the potentiometer housing, especially if the worm-driven gear has been arrested and the worm is rotated in the same immediately previous direction. Under such conditions, and lacking suitable axial restraints, the continued rotation of the worm with respect to the arrested gear causes the worm to move axially relative to the potentiometer housing and, in some instances, may result in the worm revolving completely out of engagement with the gear.

The term "specific tolerance of resolution" is often used to describe the performance characteristics of potentiometers of the specified type and may be defined as the number of degrees that the worm must rotate in one direction before gear rotation is reinitiated.

Thus, the resolution of such potentiometers is determined principally by the amount of backlash or slippage which takes place between the worm threads and the meshing teeth of the driven gear. Backlash or slippage may be minimized by having the threads of the worm mesh as closely as possible with the teeth of the gear, which normally entails that the worm threads be cut to very accurate tolerances. As will be appreciated by those working in the potentiometer art, the manufacture of worms having cylindrical thread profiles to fine tolerances is a relatively expensive proposition.

Drive worms having a cylindrical thread profile usually have at the most two or three adjacent thread portions in engagement with teeth of the driven gear at any instant of time. To obtain a relatively low specific tolerance of resolution, it is necessary that the frictional forces (or torques) generated between the worm thread portions and the meshing gear teeth be of relatively high orders of magnitude. High magnitude frictional forces are often developed by providing appreciable frictional restraints against the rotation of the driven gear and results in severe wear on the two or three worm thread convolutions and the gear teeth in mesh therewith and, in some extreme instances, results in breakage of the worm thread and/or the gear teeth.

Principally, for these various reasons, conventional potentiometer worm drives are generally troublesome components which add appreciably to the complexity and cost of manufacturing the potentiometer.

It is an object of this invention to provide a potentiometer which may be manufactured at low cost, requires only a few parts to operate and yet retains good performance characteristics.

Another object of this invention is to provide a reliable worm drive for use in a potentiometer which does not require constraints to inhibit axial movement of the worm.

The present invention provides a low-cost, worm-driven potentiometer which has a tolerance of resolution at least as low as conventional potentiometers of similar type, but obviates the need for axially constraining the driving worm. To accomplish these and other advantageous results, the threaded section of the worm is formed with a substantially hourglass profile and meshes with at least an interference fit with teeth of a spur gear or spur gear wheel. In the absence of axial constraints this particular worm profile prevents the worm from moving axially in the potentiometer housing, even if the driven spur gear is arrested.

To reduce as much as possible the number of potentiometer parts, the worm-driven gear mounts a resilient contact, which in addition to providing brushing contact with a resistance element, has a resilient portion which rotates upon one end of a collector terminal pin and thereby provides a resilient mounting support for one end of the driven gear. The collector terminal, in addition to providing a fixed support base for the contact extends to intercept the path of rotation of a stop member formed on the gear and thus, additionally serves as an abutment for the stop member to prevent overdriving rotation of the contact.

For a better understanding of the present invention, together with other and further objects thereof, reference may be had to the following description taken in connection with the accompanying drawings, the scope of the invention being pointed out in the appended claims.

Referring to the drawings:

FIG. 1 is an enlarged plan view of a potentiometer, constructed in accordance with this invention, with part of the housing cut away to illustrate internal details; and

FIG. 2 is a transverse sectional view taken along section 2–2 of FIG. 1.

Referring now to FIGS. 1 and 2, the potentiometer **10** comprises a two-piece housing formed by a cap member **11** and a flat base or platform member **12** which, when assembled, interfit as depicted by FIG. 2. The cap and base members are secured to one another by any suitable means, such as an adhesive applied to mutually contacting cap and base surfaces prior to the interfitting assembly of the two members. The housing is preferably formed of an insulating material, for example, a thermosetting resin, and inside the interior chamber formed by the members **11** and **12** are housed the various potentiometer components.

Extending inwardly, or downwardly as viewed in FIG. 2, from the center of the cap **11** is a cylindrical center post **13** having a smooth peripheral surface. The post **13** serves to center and provide a bearing surface for a concentric, central hub of a spur gear **15**. The gear **15** is formed of an electrical insulating material, such as a suitable thermosetting or thermoplastic resin and rotates about an axis coaligned with the axis of hub symmetry. A concentric ring **16** formed on the upper face, as viewed in FIG. 2, of the gear **15** bears against an adjacent inner flat surface portion of the cap **11**. The ring **16** maintains contiguous portions of the upper gear face in spaced relationship from the cap **11** and serves to prevent the gear **15** from binding should there be slight irregularities between these opposing surfaces.

The gear **15** is biased resiliently upward against the cap through engagement between a resilient downwardly projecting section **18**, formed on a resilient, thin metal contact or wiper **19**, and the upper end **20** of a collector pin **21**. The end **20** is bent parallel to the lower surface of the section **18** and at right angles with respect to an adjoining portion of the collector pin **21**. The pin **21** is molded or otherwise affixed to the base **12** such that the longitudinal axis of the end **20** intersects perpendicularly the axis of rotation of the gear **15** and is in a plane which passes perpendicularly between spaced-apart ends **25***a*, **25***b*, of an arcuate resistance element **25**.

The contact section **18** should have a large enough surface area to remain in wiping electrical contact with the upper surface of the end **20** while the downwardly inclined free end of the contact is rotated to brush against various resistance coils of the element **25**. Hence, downwardly protruding section **18** is shaped as an enlarged, interior contact of substantially cir-

cular peripheral outline that centrally overlies the pin **20** and may be formed by dimpling a previously flat circular portion of the wiper **19** with a punch of appropriate size. To provide an unyielding stationary electrical contact surface for the section **18**, the pin end **20** is comprised of a relatively stiff metal conductor devoid of electrical insulation.

The contact **19** is centered on, and driven by, the gear **15** through a cylindrical eccentric gear pin **22** which projects downwardly from a lower surface of the gear **15** and receives with a press fit a complementary aperture formed in the contact **19** and located between the section **18** and the free contact end. With the contact **19** pressed tightly upon the pin **22**, the resilient section **18** snaps into the space defined between the inner edge of the pin **22** and an opposing inner edge of a stop pin **23**. The pin **23** is diametrically opposite the pin **22**, projects downwardly from a lower surface of the gear **15**, is eccentric to the axis of gear rotation, and rotates with the gear in a circular path which intercepts one side or the other of the end **20** depending upon the direction of contact rotation. The diameter of the end **20** and the width of the pin **22** are dimensioned such that opposite respective surfaces of the pin **22** abut opposite respective surfaces of the end **20** when the contact **19** is a predetermined distance from each respective resistance element end **25***a*, **25***b*.

Thus, the collector pin end **20** in addition to serving as a collector terminal for the contact **19** also serves as a fixed, lower support for the gear **15**, and in cooperation with the stop pin **23** serves as a stop means for arresting rotation of the contact **19** before the free end of the contact is driven off either resistance element end **25***a* or **25***b*.

The resistance element **25** may be of conventional type constructed of a cylindrical mandrel coated with an adhesive insulation, such as varnish, and wrapped helically with numerous turns of small-diameter resistance wire. The element **25** seats firmly in the internal, circular corner formed by adjoining surfaces of the cap **11** and the base **12**, by virtue of a slight expansion which takes place in the element when the ends **25***a* and **25***b* are allowed to separate.

Also secured perpendicularly to the base **12** are two similar, electrically conductive terminal pins **27** and **28** which have ends **30** and **31**, respectively, bent at right angles to terminate adjacent the ends **25***a* and **25***b*, respectively. The ends **30** and **31** are respectively electrically connected to various of the resistance coils of element ends **25***a* and **25***b* by similar conductive ribbons **34** and **35**, respectively. The outer ends of the ribbons **34** and **35** follow closely part of the inner circular contour of the ends **25***a* and **25***b*, respectively, and are suitably connected thereto by, for example, soldering or brazing. By partially following the inner peripheral contour of the ends **25***a* and **25***b* the corresponding ends of the ribbons fold under the path circumscribed during rotation of the free end of the contact **19**. The opposite or inward ribbon ends are electrically connected to the extremities of different ones of the terminal pins ends **30** and **31** by, for example, soldering or welding.

With the rotation of the gear **15** arrested as a result of one surface of the pin **23** abutting a surface of the pin **20**, further driving of the gear **15** by a gear-driving worm **38** is prevented.

The worm **38** is disposed rotation in a smooth bore **39** of generally cylindrical shape which extends at least partially through one end of the cap **11** parallel to, and inwardly of, an adjoining cap sidewall **40** and provides bearing surfaces for the cylindrical ends of the worm so that the worm is supported for rotation about the axis of the bore. The worm **38** includes a threaded section **41**, comprising a plurality of nonhelical thread portions or convolutions **41***a* equally spaced by alternate root surface portions **41***b*, and a cylindrical shaft section **42** having a projecting end **43** transversely slotted to receive, for example, the blade tip of a worm-adjusting screwdriver. The shaft section **42** may include a section of reduced diameter extending from a shoulder **45** to the end **43** to seat an annular sealing element **46** of conventional type. The cap sidewall **40** is set back from the root surface **41***b* of smallest diameter, FIG. **2**, to permit unimpeded meshing between the gear teeth and all threads of the worm.

As related hereinabove, worms which have been hitherto employed in potentiometers of the worm-driven type typically have both constant root and outer thread radii at least throughout that portion of the threaded worm section which meshes with the driven gear. In the potentiometer art, such drives suffer various important drawbacks, described hereinabove, principal among which being that various types of restraints are necessary to prevent the worm from moving axially in the potentiometer housing, that the worm threads and gear teeth need be cut, or otherwise formed, very accurately to reduce backlash and slippage problems, and that the gear often need be suitably countertorqued to insure a relatively high frictional contact with the two or three meshing worm thread portions or convolutions. Manifestly, these various drawbacks increase in severity as the potentiometer size decreases.

In accordance with an aspect of this invention which will hereinafter be described in detail, these and other disadvantages of cylindrical worm-drives are obviated with no increase, and in many, if not most, instances, with an attendant decrease in the specific tolerance of resolution of the potentiometer. The instant potentiometer may be manufactured easily, with but a few components, and at appreciably lower cost than conventional potentiometers of the same general type. Moreover, the instant potentiometer is highly adaptable to miniaturization and to the mass production of the various potentiometer components, especially the potentiometer adjusting means.

In contrast to conventional potentiometer worm-drives, the worm **38** has a threaded section **41** of substantially hourglass profile and therefore may be described as an "hourglass worm" or, when the driven spur gear or spur gear wheel is included, as an "hourglass worm-drive". Basic considerations involved in the design of hourglass worm-drives are described, for example, by Buckingham, *Analytical Mechanics of Gears*, N.Y., McGraw Hill, 1949, pp. 276—300, inclusive, and hence do not require further discussion herein.

The section **41** has several thread portions or convolutions, typically five or more, which mesh with a corresponding number of spur gear teeth of the gear **15**. The ratio between the outer thread and outer gear teeth diameters is typically on the order of 5:1. To minimize backlash or slippage in the hourglass worm drive the meshing engagement between the gear teeth and the worm thread is effected with at least an interference fit, and in some instances may be effected with a few mils lack of tooth and thread clearance, depending primarily upon the extent to which the gear teeth may be deformed without incurring permanent damage. To ensure at least an interference fit between the gear teeth and closely mating surfaces formed by adjacent worm thread surfaces the hourglass-worm drive is constructed as follows.

The gear teeth are preferably equally spaced-apart spur teeth of identical shape formed of a deformable, resilient material such as a synthetic thermosetting or thermoplastic plastic, suitably examples of each respective type of plastic being Diall and nylon. Usually the entire spur gear is formed of such a plastic by, for example, molding, and in such case, the crests of the gear teeth may have a substantially hemispherical profile and mate closely with thread roots **41***b* formed with similar profiles. The axis of rotation of the worm is in the plane of gear rotation and the axis of gear rotation is spaced perpendicularly from the axis of worm rotation a distance such that the worm threads and gear teeth mesh with at least a nominal interference line-to-line contact therebetween. Under these conditions, line-to-line interference contact may be ensured by forming the gear teeth so that at least the tooth surfaces which are to contact a worm thread are perpendicular to the plane of gear rotation.

The worm **38** is composed of a nonmagnetic and noncorrosive metal, such as brass, and may be easily and inexpensively formed by passing a precision hob transversely across a rotat-

ing brass cylinder. The worm manufacturing process is easy to control and a single hob may be used to precisely mass produce literally hundreds of hourglass worms of miniature size with very high orders of accuracy and practically identical, low thread tolerances. The cost of manufacturing hourglass worms suitable for use in potentiometers is usually appreciably less than the cost required to cut an equal number of comparably accurate, cylindrical worms.

To ensure that the worm remains self-constrained against the bore **39**, the worm thread convolutions of different radii are made symmetrical with respect to a plane of symmetry taken perpendicularly to the axis of worm rotation and through the midpoint of the threaded section **41** to provide, in effect, two symmetrical camming surfaces for the contacting gear teeth which slope downwardly toward one another and meet at this plane of symmetry. For example, in the illustrated potentiometer **10**, this plane of symmetry would pass through the midpoint of the fourth thread convolution **41***a* (of smallest thread radius) perpendicular to the longitudinal axis of the worm section **41**; there being three pairs of thread convolutions of respectively identical increasing thread and root radii spaced respectively equal axial distances from this plane of symmetry. The pairs of thread convolutions cooperate to constrain the worm against axial movement in the bore **39** by self-nullifying through the opposing camming surfaces any net axial force produced during rotation of the worm.

In view of the foregoing, it should be apparent that the instant invention provides a reliable, worm-driven adjustable potentiometer which may be inexpensively constructed and assembled and yet possesses good performance characteristics, especially a relatively low specific tolerance of resolution.

What I claim is:

1. In an adjustable resistor, the combination of:
housing means;
resistance means;
movable contact means;
a driven member for operating said movable contact means,
said driven member having an arcuate peripheral portion with a plurality of teeth;
a driving worm;
said housing means defining a worm-accommodating bore and a cavity,
said bore opening at one end to the exterior of said housing means,
a first portion of said housing means defining said bore presenting a right cylindrical bearing surface, a second portion of said housing means defining said bore defining an inner bore portion, said bearing surface being located between said one end of the bore and said inner bore portion, said second portion of said housing means being so constructed as to provide lateral communication between said inner bore portion and said cavity;
said resistance means, said movable contact means and said driven member being disposed in said cavity,
said contact means operatively engaging said resistance means,
said driven member being arranged to effect relative movement between said contact means and said resistance means;
said driving worm comprising:
a head end exposed at said one end of said bore,
a right cylindrical journal portion embraced by and engaged in bearing relationship with said bearing surface, and
a threaded portion of substantially hourglass profile, and
stop means operatively arranged to restrain movement of said driven member;
said threaded portion of said worm being meshed with a plurality of teeth of said driven member;
the maximum diameter of said threaded portion of said worm not exceeding the diameter of said journal portion of said worm, and said worm being substantially free for axial movement relative to said housing means in a direction outwardly of said bore save for said meshed engagement of said threaded portion with said driven member.

2. The combination according to claim **1**, wherein said driving worm is of a material having a hardness substantially greater than the material of said driven member.

3. The combination according to claim **2**, wherein said driving worm is of metal and said driven member is of a resiliently deformable synthetic resin.

4. The combination according to claim **1**, wherein said driven member is a gear having equally spaced teeth the contact surfaces of which are perpendicular to the plane of rotation of the gear.

5. In an adjustable resistor, the combination of:
housing means defining a bore and a cavity;
said bore opening at one end to the exterior of said housing means and having an inner portion in communication with said cavity;
an arcuate resistance element mounted in said cavity;
rotary contact means;
a driven gear mounted in said cavity for rotary movement about a fixed axis,
said contact means slidably engaging said resistance element and said gear being connected to said contact means to move the same relative to said resistance element when said gear is turned;
a driving worm disposed in said bore and comprising:
a head end exposed at said one end of said bore, and
a threaded portion of substantially hourglass profile disposed in meshed engagement with a plurality of teeth of said gear; and
means operatively arranged to resist turning of said gear when said contact means has been moved to a predetermined rotational position relative to said resistance element, the wall of said bore slidably embracing said driving worm to support the same for rotation about the longitudinal axis of said bore while restraining the same against lateral movement,
said driving worm being positively constrained against axial movement in said bore, when said means to resist turning of said gear acts to resist movement of said gear at a time when a turning force is still applied to the worm, by the meshed engagement of said threaded portion with said gear.

6. The combination according to claim **5**, wherein:
said contact means includes a contact element comprising a fixed portion disposed generally at the center of one face of said gear;
the combination further comprises a collector terminal including a first portion extending within said cavity generally parallel to the axis of rotation of said gear and a second portion projecting laterally from said first portion and slidably engaging said fixed portion of said contact element;
said means to resist turning of said gear comprising a projection carried by said gear and disposed to be brought into engagement with said second portion of said collector terminal as a result of rotation of said gear.

7. The combination according to claim **5**, wherein:
said driving worm is of metal;
said gear is of resiliently deformable synthetic resin; and
the teeth of said gear and said threaded portion of said worm are disposed in meshed engagement with an interference fit.

8. In an adjustable resistor, the combination of:
housing means defining a cavity and a bore;
said bore opening at one end to the exterior of said housing means,
an inner portion of said bore communicating with said cavity,
the wall of said bore between said inner portion and said one end being right cylindrical;

an arcuate resistance element mounted in said cavity;
a gear mounted in said cavity for rotation about a fixed axis, said gear being of resiliently deformable synthetic resin;
a rotary contact member disposed in said cavity, said gear driving said contact member and said contact member slidably engaging said resistance element;
a driving worm disposed in said bore and comprising:
a head end exposed at said one end of said bore,
a right cylindrical portion journaled in said right cylindrical wall of said bore, and
a threaded portion of substantially hourglass profile disposed axially inwardly of said right cylindrical wall of said bore, said threaded portion having a maximum diameter not exceeding the diameter of said right cylindrical wall of said bore,
said threaded portion of said worm being meshed with a substantial number of teeth of said gear; and
stop means arranged to restrain said gear against rotation when said contact member has been moved to a last-mentioned relative to said resistance element,
said worm being constrained against axial movement outwardly, toward said one end, when said gear is restrained by said last-mentioned means, by reason of the meshed engagement between said threaded portion and said gear.