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ELECTRIC PRESSURE TRANSDUCER

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2 Sheets-Sheet 1

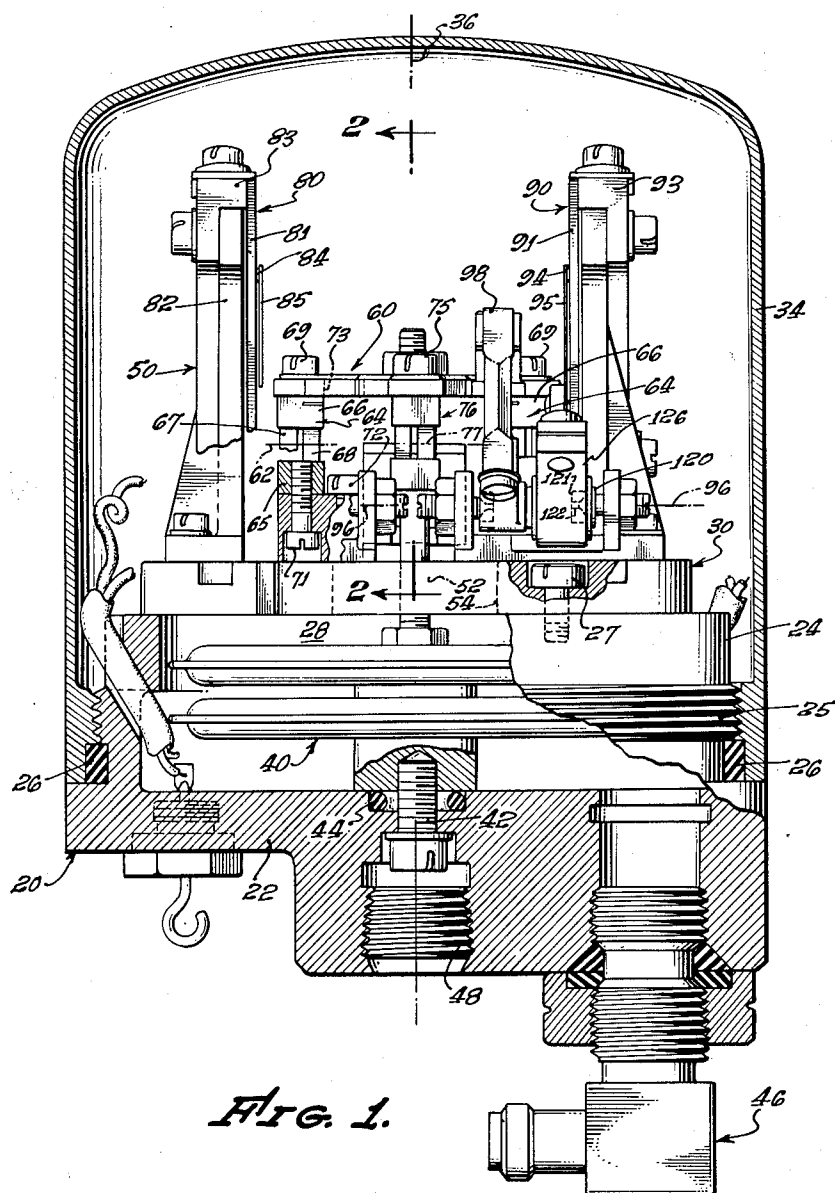


Fig. 1.

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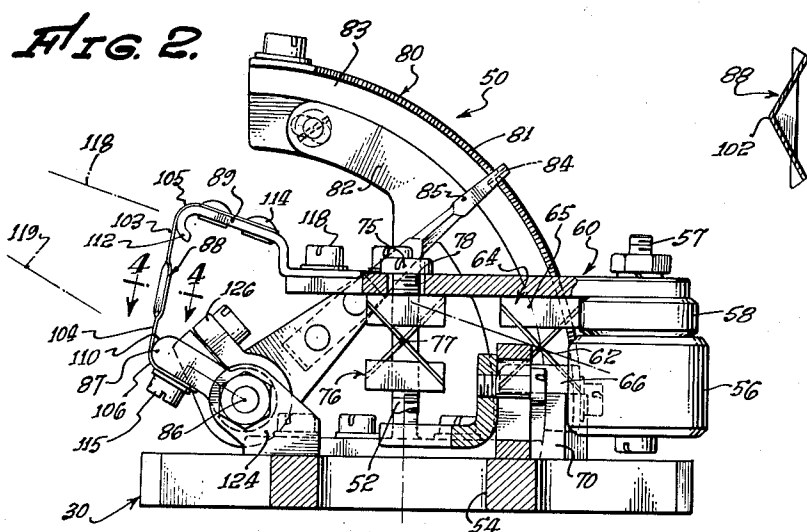
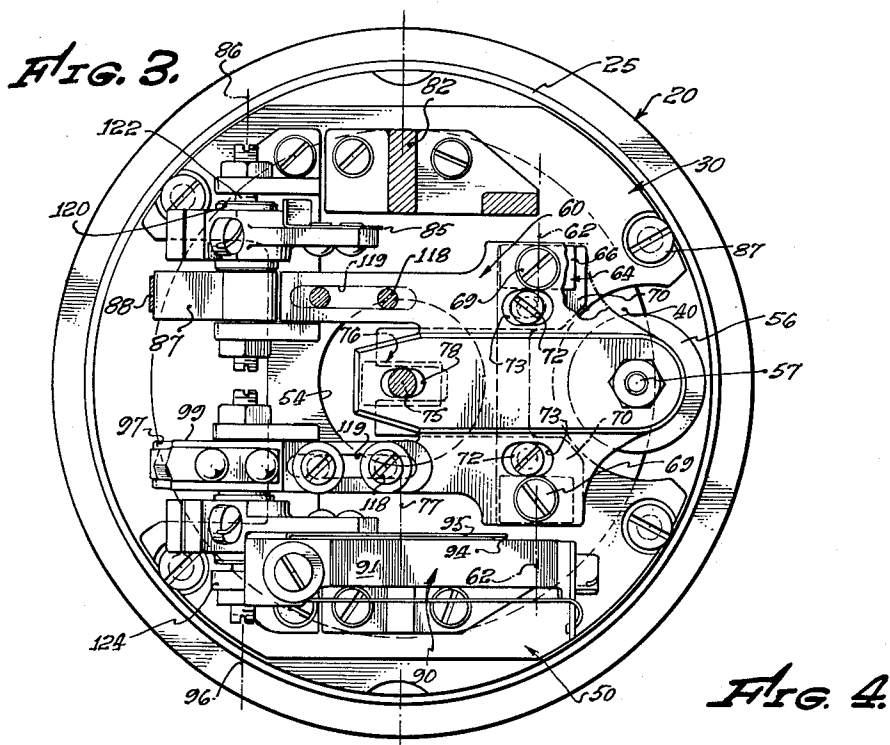
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ELECTRIC PRESSURE TRANSDUCER

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11 Claims. (Cl. 201—48)

This invention has to do with pressure transducers for producing electrical signals in response to variations of a fluid pressure or difference between fluid pressures.

The invention is concerned more particularly with providing a compact and reliable instrument that is capable of developing one or more electrical signals, such, for example, as direct current voltages, that vary accurately in accordance with the axial extension of a pressure responsive device.

A primary object of the invention is to provide such an instrument that is capable of responding to relatively small increments of pressure with a positive and reproducible change of output signal. That is accomplished by the invention by producing relatively great mechanical amplification of the initial movement of the pressure responsive element without appreciable friction, backlash or play of any type in the mechanical linkages that are employed, and without introducing excessive resilient restoring force into the overall system. It has been discovered that the described characteristics can be provided effectively by a two-stage amplifying device in which the first stage employs a lever mounted on flexure pivots which contribute substantially zero friction and play to the system, and a second stage which employs a lever mounted on pivot bearings which contribute substantially zero restoring force to the system.

A further object of the invention is to produce an instrument of the type described that is substantially stable against large accelerations in any direction, whether of sustained or periodic nature.

The invention is further concerned with providing an instrument of the type described that is lighter and more compact than the most nearly comparable instruments previously available. At the same time, an instrument in accordance with the invention is typically capable of providing two electrically independent output signals, which may represent different functions of the input pressure difference. As an illustration of the degree of compactness that has been attained without sacrifice of the other properties mentioned, the largest overall dimension of an instrument in accordance with the invention may be less than twice the diameter of the pressure responsive device and only about twice the effective coil length of the potentiometers by which the output signals are developed. For example, in an instrument that occupies no more than 15 cubic inches the pressure responsive device may be a capsule having a diameter of substantially 2 inches, and the output signals may be developed by potentiometer coils having a working surface nearly 1½ inches long and containing 1500 turns or more of wire.

A further aspect of the invention provides particularly convenient adjustment of the degree of amplification, which may be expressed, for example, as the effective potentiometer coil length per unit linear travel of the pressure responsive element. Moreover, the output signal may be made to represent a substantially linear function of the input pressure difference; or, alternatively,

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may be made non-linear, as may be required for various specific applications. In particular, a preferred type of mechanical linkage between the pressure responsive element and the potentiometer brush provides the advantage of compensating a typical form of nonlinearity of response of such elements, so that even in the presence of such non-linearity the overall output may be made to conform very closely, for example within about 1%, to a linear function of the input pressure.

In preferred form of the invention a primary lever is directly driven by the pressure responsive element, and a plurality of independently mounted secondary levers are independently linked to that primary lever. Independent output means are connected to the respective secondary levers. That preferred arrangement has marked advantages of economy, compactness and accuracy of performance. The mounting of the primary lever is in many respects the most critical aspect of the entire instrument, since any inaccuracy or play in that mounting is magnified by the remainder of the linkage system. Hence the use of a single primary lever makes for economy of construction and greatly simplifies the entire structure. And the provision of separate secondary levers for driving each potentiometer permits improved flexibility of operation. For example, relatively fine individual adjustments of those levers can be provided for compensating detailed differences among potentiometer coils. And radically different functional output responses can be provided by modifying the proportions and arrangement of one or more of the several secondary levers, all without complicating or disturbing the mounting of the single primary lever.

A further aspect of the invention concerns a particularly economical and effective manner of constructing a link for operatively connecting two levers of a mechanical movement.

A full understanding of the invention and of its further objects and advantages will be had from the following description of a specific preferred embodiment, of which description the accompanying drawings form a part. However, many changes may be made in that embodiment, which is intended only as illustration and not as a limitation upon the scope of the invention, that scope being defined in the appended claims.

In the drawings:

Fig. 1 is a vertical section of an illustrative pressure transducer in accordance with the invention;

Fig. 2 is a fragmentary section on line 2—2 of Fig. 1;

Fig. 3 is a plan, showing the instrument with cover removed; and

Fig. 4 is a fragmentary section on line 4—4 of Fig. 2.

As illustratively shown in the drawings, the instrument housing comprises a base 20, a mounting plate 30 and a cover 34. Base 20 comprises a circular plate portion 22, which forms one end wall of the instrument housing, and a shell portion 24 projecting from the inner face of plate 22. For convenience of description, base plate 22 will be assumed to be horizontal, as shown, with shell portion 24 extending upward, but it is emphasized that a particular advantage of the present instrument is that it may be mounted in any convenient orientation, the position shown being merely illustrative. Shell portion 24 is externally threaded at 25 to receive cover 34, which is of cylindrical form with closed upper end. A suitable pressure seal, indicated at 26, is provided between the cover and the base. Mounting plate 30 is rigidly but releasably mounted on the upper end of shell portion 24, as by the screws 27, partially enclosing a lower chamber 28 within the housing. The entire housing defines a main vertical axis 36, about which it has general cylindrical symmetry.

Pressure responsive means of any suitable type are

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mounted within chamber 28. As illustratively shown, such means comprise the capsule 40 which is axially extensible in response to variations of the difference in pressure between its interior and exterior. Capsule 40 is coaxially positioned in chamber 28, with its lower end rigidly secured to base plate 22 as by the screw 42 and sealing ring 44. In the embodiment shown, the interior of capsule 40 is evacuated, providing constant internal pressure; and the pressure to which the instrument is responsive is admitted to the space surrounding the capsule and within the instrument housing, a pressure fitting for the purpose being indicated at 46. Alternatively, capsule 40 may be so constructed and mounted as to provide a fluid passage between its interior and the central threaded well 43 in base 20, which may then receive a second pressure fitting for supplying a fluid pressure to the interior of the capsule.

In accordance with one aspect of the invention, the entire mechanism 50 for developing one or more electrical signals representing the pressure supplied to capsule 40 is mounted on the upper face of the removable mounting plate 30. A single connection, shown as the threaded rod 52, extends in spaced relation through a central aperture 54 in plate 30 and operatively connects capsule 40 to that mechanism. Mechanism 50 can thus be entirely assembled on mounting plate 30 as a sub-assembly; and is fully accessible for adjustment merely by removal of cover 34.

As illustratively shown, a single primary lever 60 is supported by two flexure pivots 64 for limited swinging movement about a horizontal primary pivot axis 62, spaced from main axis 36. Lever 60 is generally parallel to plate 30 and spaced above it. Each of the flexure pivots comprises a fixed block 65 and a movable block 66 connected by crossed leaf springs 67 and 68, both of which pass through the pivot axis. Movable blocks 66 are rigidly mounted directly on the under face of lever 60, as by the screws 69; and fixed blocks 65 are rigidly mounted on the upper face of plate 30 by the screws 71 and the bracket 70. Bracket 70 may be secured to the mounting plate by the screws 72, which are accessible through clearance apertures 73 in lever 60, and which work in slotted holes in the bracket, permitting convenient adjustment of the spacing between primary pivot axis 62 and main axis 36.

Lever 60 is driven by capsule 40 via a connection, already mentioned, between the upper end of the capsule and the intermediate point of the lever at which it is intersected by main axis 36. That connection typically includes the threaded rod 52, rigidly mounted in coaxial position on the free end of capsule 40, and preferably embodies a flexure pivot 76, which may be of the same type as pivots 64. As shown, the upper block of flexure pivot 76 is rigidly mounted directly on the lower face of lever 30 by the screw 75. The lower block of pivot 76 is mounted on the upper end of threaded rod 52. With that construction, the effective point of application of the force applied by capsule 40 to lever 60 is at the axis 77 of flexure pivot 76. That axis normally intersects main axis 36 of the instrument, so that the effective lever arm for driving lever 60 is approximately equal to the separation of primary pivot axis 62 and main axis 36. The slotted hole 78 by which flexure pivot 76 is secured to lever 60 permits the pivot to be adjusted longitudinally of lever 60. When bracket 70 is shifted in the manner already described, that adjustment permits the axis of flexure pivot 76 to be maintained at main axis 36. The effect is then to change the effective driving lever arm for primary lever 60. Such adjustment of the lever arm is useful, for example, for compensating slight differences of rate among different capsules 40.

A counterbalancing weight is indicated at 56, mounted as by the screw 57 on a relatively short arm of lever 60 that projects outwardly with respect to main axis 36.

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The center of gravity of weight 56 is spaced below the plane of lever 60, that spacing being adjustable as by selection of the thickness of spacer 58. The longitudinal position of the weight on lever 60 is also adjustable, as by elongation of the hole in the lever that receives screw 57. By means of those adjustments, the effective center of gravity of the entire lever mechanism, including any unbalanced reaction upon lever 60 from the secondary levers to be described, is caused to lie substantially in primary pivot axis 62. The mechanism may thus be made to operate substantially independently of impressed accelerations, whether of relatively steady nature, as may be caused by curved flight of an aircraft, or of periodic nature, as may result from vibration impressed upon the entire instrument as a unit.

It has been found that to provide adequate stability against impressed accelerations of the entire instrument flexure pivots 64 should be relatively widely spaced from each other longitudinally of axis 62. That spacing is at least equal to, and preferably about 50% greater than, the effective driving lever arm of lever 60, which is the separation of axes 62 and 77, as already described.

The use of pivots of flexure type, utilizing crossed springs, both for mounting lever 60 and for providing the necessary flexibility of the driving connection to that lever provides substantially frictionless operation and practically eliminates any measurable play or backlash, which if present would be amplified by the remainder of the mechanism, to be described. The resilience of those flexure pivots introduces an appreciable restoring force into the system, which tends to resist deflection of lever 60 from its equilibrium position. However, an important advantage of the present mechanism is the fact that such restoring force applied to primary lever 60 has a relatively slight effect upon the final output of the mechanism, whereas backlash in operation of that lever would have a relatively amplified effect upon the output.

The present illustrative embodiment of the invention includes means for developing two electrically independent output signals. Those means typically comprise the two potentiometers 80 and 90, including the circularly curved potentiometer windings 81 and 91 and the contact brushes 84 and 94, respectively. Windings 81 and 91 are typically formed on relatively flexible cards that are then mounted on the convex faces of arcuate insulating members 83 and 93, supported on brackets 82 and 92, respectively. Those brackets are preferably mounted directly on the upper face of mounting plate 30, and are spaced on opposite sides of primary lever 60. Windings 81 and 91 may be of various detailed construction, providing either linear or tapered resistance as may be required, and may, for example, be connected alternatively as potentiometers, as in voltage dividing networks, or as variable resistances, as in bridge networks of various known types.

Brushes 84 and 94 are preferably arranged as shown to engage the curved inner edges of the respective potentiometer coils. They are resiliently mounted at the free ends of the brush arms 85 and 95. Those arms are mounted for swinging movement about respective secondary pivot axes 86 and 96, which preferably coincide with the axes of curvature of windings 81 and 91. As shown, those windings, and hence also the potentiometer arms 85 and 95, are coaxial, but the two secondary axes 86 and 96 may be mutually offset. Moreover, the two windings may have different radii of curvature and may differ in their electrical characteristics, including those already mentioned.

The potentiometer arms 85 and 95 are preferably driven independently from primary lever 60, as by the preferred linkage means illustrated. As shown, the arms 85 and 95 are rigidly, but preferably adjustably, related to respective secondary levers 87 and 97, which are driven from lever 60 by the respective links 88 and 89. Those links are effectively rigid, and are pivotally connected at one end

to the respective secondary levers and at the other end to the respective arms 89 and 99 which are rigidly mounted in axially spaced relation on primary lever 60. Those linkages may differ from each other in many particulars of structure and adjustment, but are shown substantially identical for clarity of representation. A full description of only one of those illustrative linkages will be given.

The link 88 embodies in typical form one aspect of the invention. The entire link and the flexure pivots by which its ends are connected to levers 60 and 87 are formed as a unitary structure from a single strip of resilient material such as a beryllium copper alloy, for example. That strip, which may typically be about 0.004 inch thick, is longitudinally folded, for example as shown clearly at 102 in Fig. 4, throughout an intermediate portion of its length. That fold renders that portion of the thin strip effectively rigid and capable of transmitting longitudinal forces in compression as well as in tension. The ends of the strip are rigidly connected to the respective levers, relatively short portions of the strip being left free between those connections and the ends of fold 102. Those unfolded portions, indicated at 103 and 104 retain their normal flexibility and permit swinging movement of the link about its connections to the respective levers. In preferred form of the link, at least part of the unfolded portion at each end of the link is longitudinally curved in a substantially circular curve of relatively short radius of curvature. Each of those curves preferably extends through an angle at least as great as the total range of variation of the angle formed by the link and the lever to which it is connected. As shown illustratively at 105 and 106, both curves of link 88 extend through approximately a right angle in central position of the linkage. The extreme end portions of the link then lie generally parallel to the lengths of the respective levers, making their rigid connection to those levers particularly convenient. Thus, the upper end of link 88 is rigidly connected to arm 89 by the rivets 114, and its lower end is adjustably connected to secondary lever 87 by the screw 115.

The described curved portions of the link are preferably supported on their concave faces by correspondingly curved surfaces provided for that purpose on the ends of the respective levers. Such a supporting curved surface on secondary lever 87 is shown illustratively at 110; and on primary lever arm 89 at 112. It will be seen that as the linkage moves, the resilient strip tends in general to engage a longer portion of one of those curves and a shorter portion of the other, winding up on one lever and unwinding from the other. Those curved portions of the link are preferably resiliently pre-stressed, as by so forming the strip that the angle between its straight end portions, when in relaxed position, lies just outside the range of variation of that angle during actual operation of the instrument. The relatively light resilient restoring force exerted by the link is then always in the same direction, tending to minimize play in the secondary pivot bearings to be described.

Arm 89 of primary lever 60, to which the upper end of link 88 is connected, might be formed integrally with the lever. However, it is preferred to provide a bracket-like arm, as shown, which is adjustably mounted on the lever, as by the screws 118 which work in the longitudinal slot 119. By adjustment of arm 89 longitudinally of lever 60, the effective lever arm at which link 88 is driven may be conveniently modified, thereby changing the amplification of the overall linkage. Also, by substituting arms 89 of different form, the functional behavior of the overall linkage may be modified conveniently.

A particularly convenient and economical structure is shown for transmitting movement of link 88 to potentiometer arm 85. Secondary lever 87 is formed integrally with a hub 120, the ends of which are coaxially recessed to receive journal type jewel bearings 121. Pivot

screws 122 are mounted in aligned threaded holes in the two posts of bracket 124 and engage bearings 121. Potentiometer arm 85 is provided with clamp means 126, which engages an insulating sleeve placed over hub 120, and by which its rotary position with respect to lever 87 is readily adjustable. With clamp 126 tightened the arm and lever form a rigidly related unit. Use of jewel bearings for mounting that unit permits free rotation through an angle of substantially 90° without introducing any resilient restoring force into the system. The slight play permitted by such bearings, while it would be objectionable in the mounting of primary lever 60, is acceptable in the mounting of potentiometer arm 85, since any play of that arm is not further amplified before reaching the brush itself.

Normally it might be expected that optimum linearity of the overall system would result if the two lever arms connected by link 88 were so arranged as to be parallel when brush 84 is at the mid-point of its operating range. However, the described mechanism has been found to provide a further advantage when that is not the case. Pressure responsive capsules are sometimes very nearly linear in their movement, but have a general tendency to produce a smaller increment of movement per unit pressure change as they expand. It has been found that this commonly encountered type of non-linearity can be compensated remarkably effectively by arranging the mechanism so that radii drawn from the respective pivot axes 62 and 86 to the effective ends of link 88, as indicated schematically at 128 and 129, respectively, converge at a slight angle when brush 84 is at mid-position. With that arrangement, as capsule 40 expands, swinging primary lever 60 upward, the overall amplification of the mechanism tends to increase more rapidly than if the described radii were parallel. That increased amplification may be made to compensate the characteristic decrease in rate of the capsule.

We claim:

1. A pressure transducer, comprising a capsule axially extensible in response to pressure variations, a centrally apertured mounting plate supported coaxially of the capsule adjacent one end thereof, structure mounted on the face of the plate opposite to the capsule and defining first and second pivot axes parallel to each other and to the plate and spaced on opposite sides of the capsule axis by substantially equal distances, first and second levers pivotally mounted for swinging movement about the respective pivot axes, a link connecting the free ends of the levers, said link extending substantially perpendicularly to the plate at a point spaced outwardly of the second pivot axis, a potentiometer arm carrying a brush at its free end and mounted in fixed relation to the second lever and movable therewith, an arcuate potentiometer winding fixedly mounted on the mounting plate in position to be engaged by the brush, said potentiometer arm and winding being offset longitudinally of the said pivot axes with respect to the two levers, and a driving connection between the capsule and an intermediate point of the first lever, said driving connection extending in spaced relation through the aperture of the mounting plate.

2. In a pressure responsive mechanism of the type that includes an axially extensible pressure responsive device; first lever means connected to the pressure responsive device for amplifying the movement thereof, said first lever means comprising a first lever, first pivot means supporting said lever for swinging movement about a first pivot axis, and a driving connection between the pressure responsive device and the lever, and second lever means for amplifying the movement of the first lever, said second lever means comprising a second lever, second pivot means supporting the second lever for swinging movement about a second pivot axis parallel to the first, a substantially rigid link, and flexure pivots connecting opposite ends of the link to the respective levers, and signal means

responsive to the movement of the second lever, said first pivot means comprising two sets of crossed spring hinges spaced longitudinally of the first pivot axis and contributing substantially zero friction and backlash to the system, and said second pivot means comprising a pair of pivot bearings that permit movement of the second lever through substantially a right angle and contribute substantially zero restoring force to the system.

3. In a pressure responsive mechanism of the type that includes an axially extensible pressure responsive device; first lever means connected to the pressure responsive device for amplifying the movement thereof, said first lever means comprising a first lever, first pivot means supporting said lever for swinging movement about a first pivot axis, and a driving connection between the pressure responsive device and the lever, and second lever means for amplifying the movement of the first lever, said second lever means comprising a second lever, second pivot means supporting the second lever for swinging movement about a second pivot axis parallel to the first, a substantially rigid link, and flexure pivots connecting opposite ends of the link to the respective levers, and signal means responsive to the movement of the second lever, said link and flexure pivots comprising a unitary structure consisting of a single strip of thin resilient material having a longitudinal fold throughout an intermediate portion of its length, opposite end portions of the strip being connected rigidly to the respective levers, and said end portions of the strip being spaced longitudinally from the respective ends of the said intermediate portion.

4. In a pressure responsive mechanism of the type that includes an axially extensible pressure responsive device; first lever means connected to the pressure responsive device for amplifying the movement thereof, said first lever means comprising a first lever, first pivot means supporting said lever for swinging movement about a first pivot axis, and a driving connection between the pressure responsive device and the lever, and second lever means for amplifying the movement of the first lever, said second lever means comprising a second lever, second pivot means supporting the second lever for swinging movement about a second pivot axis parallel to the first, a substantially rigid link, and flexure pivots connecting opposite ends of the link to the respective levers, and signal means responsive to the movement of the second lever, said link and flexure pivots comprising a unitary structure consisting of a single strip of thin resilient material having a longitudinal fold throughout an intermediate portion of its length, portions of the strip adjacent both ends of said fold being substantially circularly curved, end portions of the strip outwardly of said curved portion being rigidly connected to the respective levers, and the respective curved portions of the strip extending through angles that are greater than the respective ranges of variation of the angles formed by the intermediate portion of the strip and the respective levers.

5. In a pressure responsive mechanism of the type that includes an axially extensible pressure responsive device; first lever means connected to the pressure responsive device for amplifying the movement thereof, said first lever means comprising a first lever, first pivot means supporting said lever for swinging movement about a first pivot axis, and a driving connection between the pressure responsive device and the lever, and second lever means for amplifying the movement of the first lever, said second lever means comprising a second lever, second pivot means supporting the second lever for swinging movement about a second pivot axis parallel to the first, a substantially rigid link, and flexure pivots connecting opposite ends of the link to the respective levers, and signal means responsive to the movement of the second lever, said link and flexure pivots comprising a unitary structure consisting of a single strip of thin resilient material having a longitudinal fold throughout an intermediate portion of its length, portions of the strip adjacent both ends of said

fold being curved through respective angles that are greater than the ranges of variation of the angles formed by the intermediate portion of the strip and the respective levers, end portions of the strip outwardly of said curved portions being rigidly connected to the respective levers, and the levers having curved surfaces that correspond in curvature to the respective curved portions of the strip and that normally support the concave faces of said curved portions.

6. In a mechanical movement, two levers pivoted on respective mutually spaced parallel pivot axes, and a driving connection between the levers comprising a single strip of thin resilient material having a longitudinal fold throughout an intermediate portion of its length, and means rigidly connecting opposite end portions of the strip to the respective levers, said end portions being spaced longitudinally from the respective ends of the said intermediate portion.

7. In a mechanical movement, two levers pivoted on respective mutually spaced parallel pivot axes, and a driving connection between the levers comprising a single strip of thin resilient material having a longitudinal fold throughout an intermediate portion of its length, end portions of the strip spaced from said intermediate portion being rigidly connected to the respective levers, the strip being longitudinally curved between the intermediate portion and the said end portions.

8. In a pressure responsive mechanism of the type that includes an axially extensible pressure responsive device and a plurality of electrically independent output means responsive to said device; primary lever means connected to the pressure responsive device for amplifying the movement thereof, said primary lever means comprising a primary lever, primary pivot means supporting said lever for swinging movement about a primary pivot axis normal to the axis of the pressure responsive device, and a driving connection between the pressure responsive device and the lever, a plurality of secondary lever means for amplifying the movement of the primary lever, said secondary lever means comprising respective secondary levers, pivot means supporting the secondary levers independently for swinging movement about respective secondary pivot axes, and respective driving connections between the several secondary levers and the primary lever, and independent driving connections between the several secondary levers and the respective output means.

9. In a pressure responsive mechanism of the type that includes an axially extensible pressure responsive device and a plurality of electrically independent output means responsive to said device; primary lever means connected to the pressure responsive device for amplifying the movement thereof, said primary lever means comprising a primary lever, primary pivot means supporting said lever for swinging movement about a primary pivot axis normal to the axis of the pressure responsive device, and a driving connection between the pressure responsive device and the lever, a plurality of secondary lever means for amplifying the movement of the primary lever, said secondary lever means comprising respective secondary levers, pivot means supporting the secondary levers independently for swinging movement about respective secondary pivot axes, and respective driving connections between the several secondary levers and the primary lever, each of the last said driving connections including independently adjustable means for varying the relationship between the movement of the associated secondary lever and the movement of the primary lever, and independent driving connections between the several secondary levers and the respective output means.

10. In a pressure responsive mechanism of the type that includes an axially extensible pressure responsive device and a plurality of electrically independent output means responsive to said device; primary lever means connected to the pressure responsive device for amplifying the movement thereof, said primary lever means comprising a pri-

mary lever, primary pivot means supporting said lever for swinging movement about a primary pivot axis normal to the axis of the pressure responsive device, and a driving connection between the pressure responsive device and the lever, a plurality of secondary lever means for amplifying the movement of the primary lever, said secondary lever means comprising respective secondary levers, pivot means supporting the secondary levers independently for swinging movement about respective secondary pivot axes, substantially rigid links pivotally connecting the free ends of the respective secondary levers and the primary lever, means on the primary lever for independently varying the radial distances from the primary pivot axis to the points of connection of the respective links, and independent driving connections between the several secondary levers and the respective output means.

11. In a pressure responsive mechanism of the type that includes a capsule axially extensible in response to pressure variations, the rate of the capsule decreasing with increasing extension thereof, primary lever means con-

5 nected to the capsule for amplifying the movement thereof, said primary lever means comprising a primary lever, primary pivot means supporting said lever for swinging movement about a primary pivot axis normal to the capsule axis, and a driving connection between the capsule and the lever, secondary lever means for amplifying the movement of the primary lever, said secondary lever means comprising a secondary lever, pivot means supporting the secondary lever for swinging movement about a secondary pivot axis parallel to the first, a substantially rigid link, means pivotally connecting the opposite ends of the link to the respective levers, and output means responsive to movement of the secondary lever within a predetermined range of movement thereof, the radii drawn from the primary and secondary pivot axes to the respective ends of the link converging at an oblique angle when the secondary lever is at the mid-point of its said range of movement.

No references cited.