May 17, 1949.

L. HARTRIDGE

2,470,351

TESTING PHASE ANGLE AND INJECTION PERIODS OF FUEL INJECTION PUMPS

Filed Feb. 22, 1944

3 Sheets-Sheet 1

FIG. 1

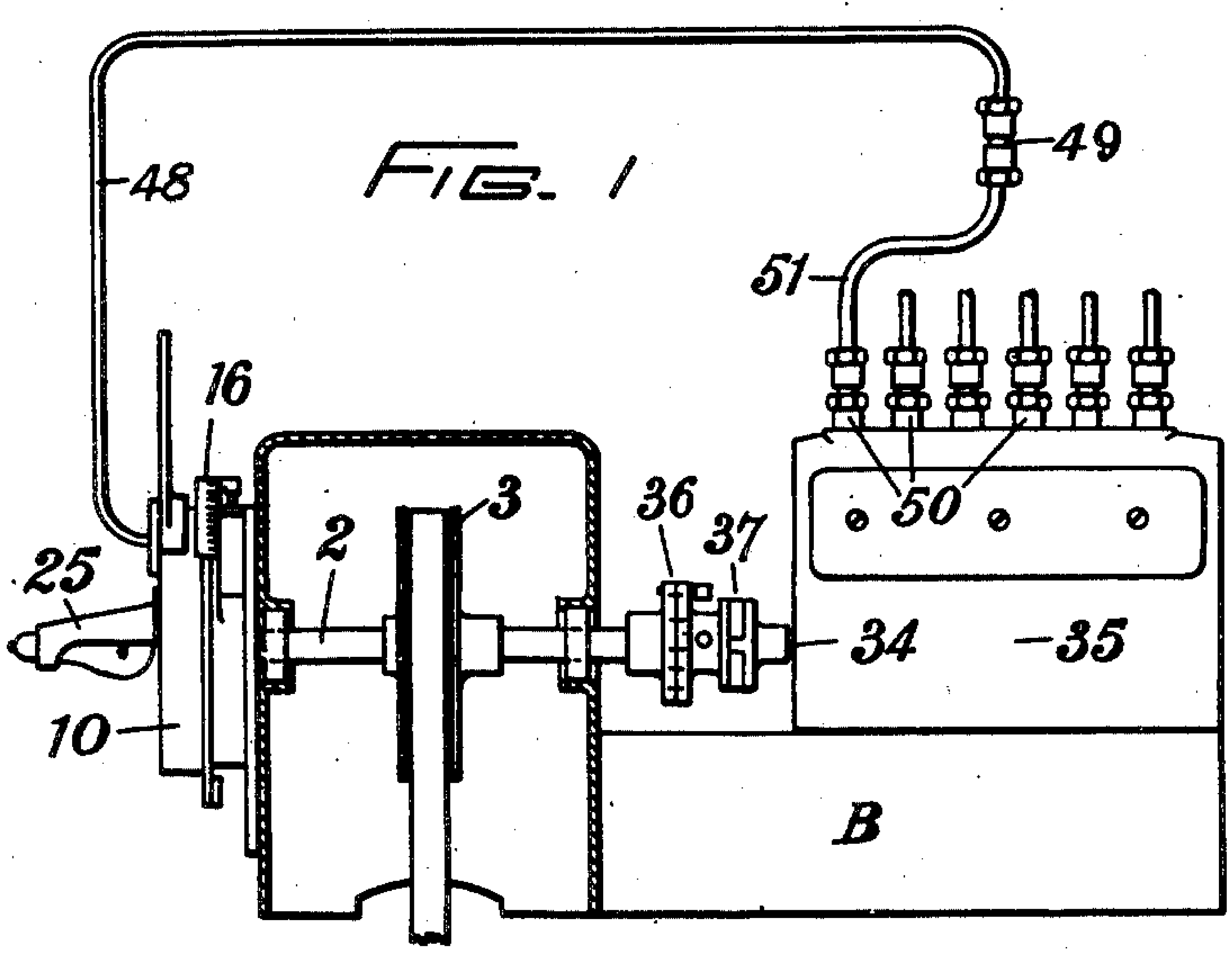


FIG. 8

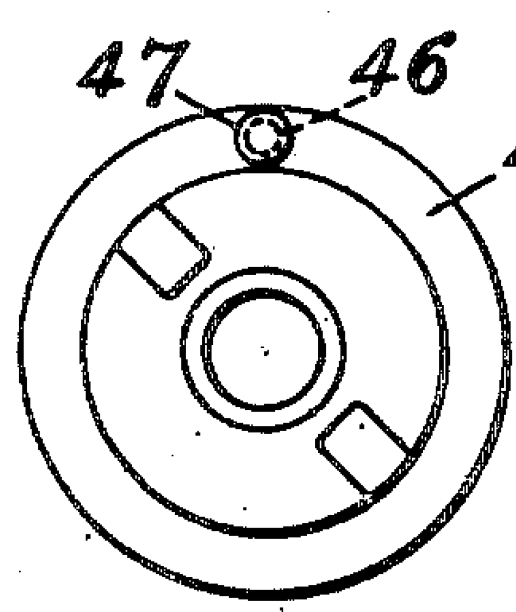


FIG. 7

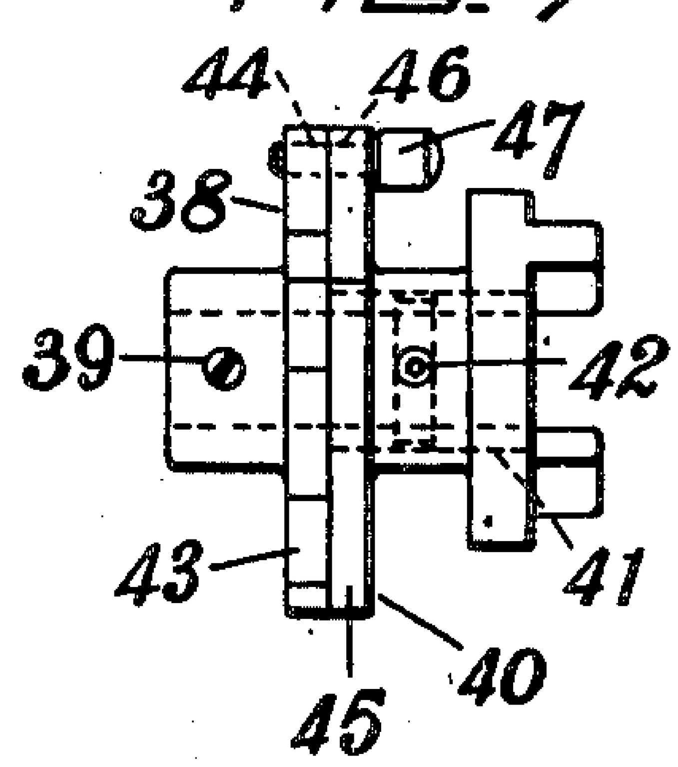


FIG. 9

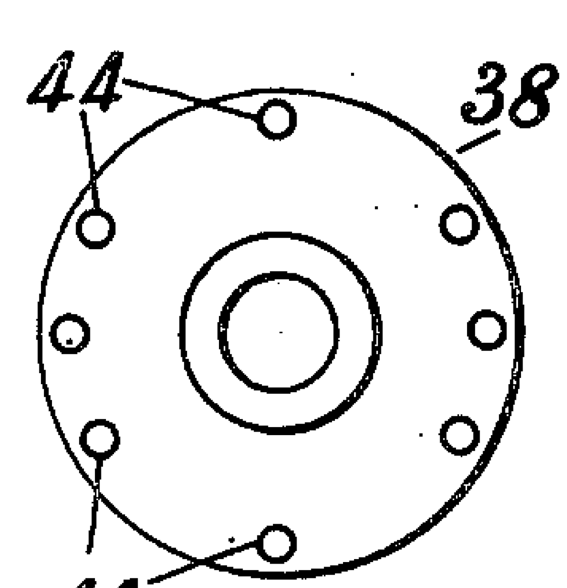


FIG. 10

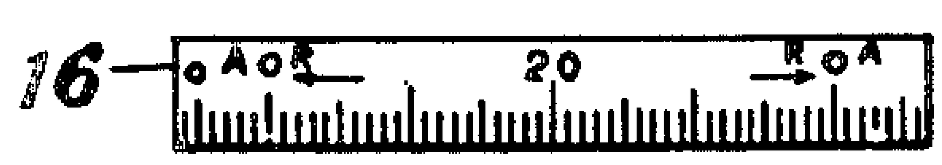
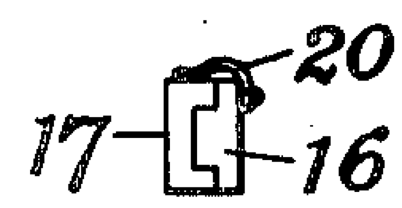


FIG. 11



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TESTING PHASE ANGLE AND INJECTION PERIODS OF FUEL INJECTION PUMPS

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FIG. 2

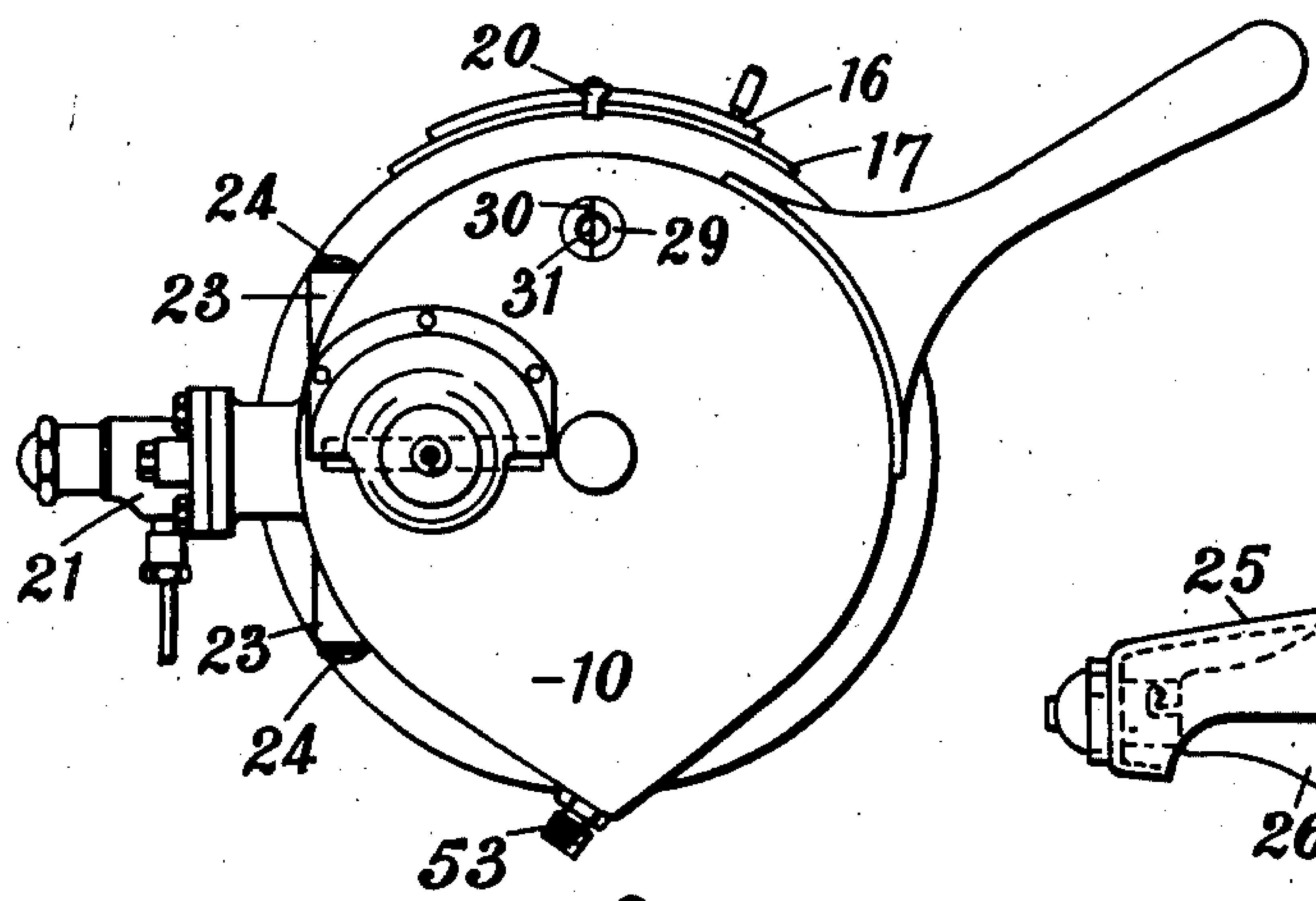
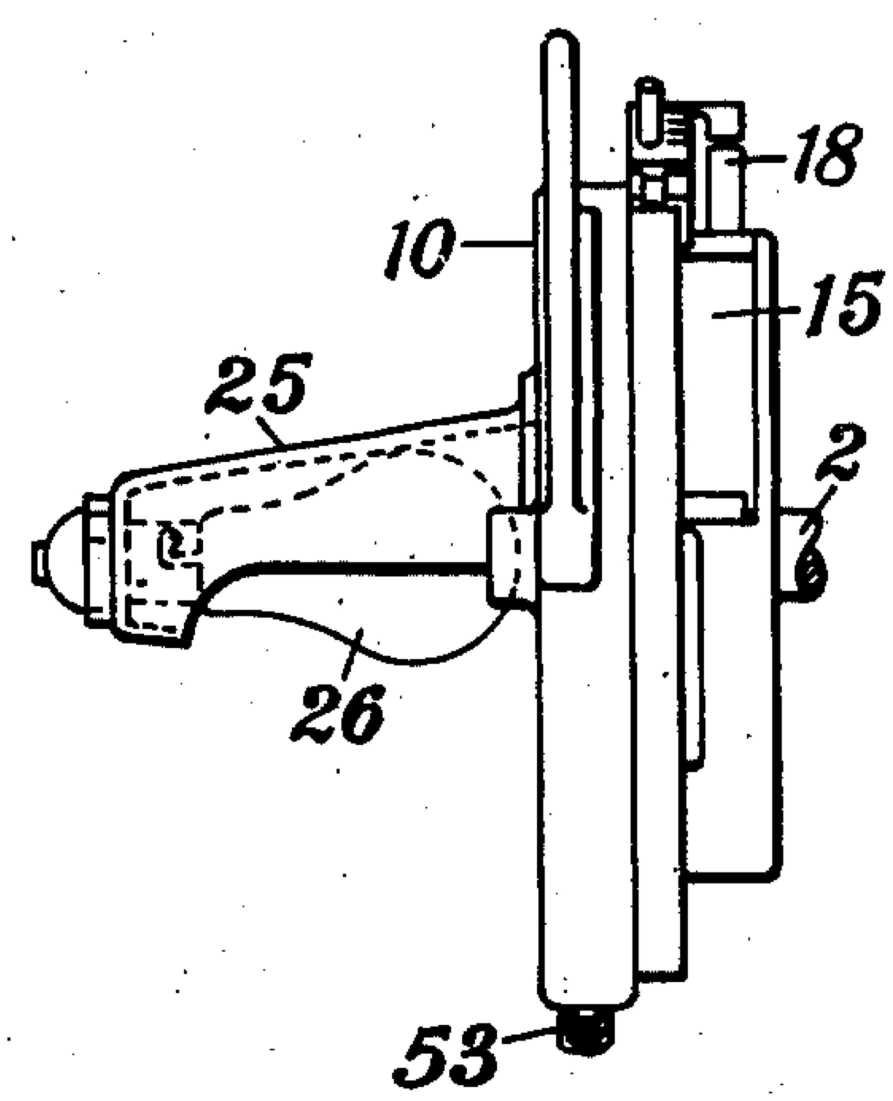


FIG. 3



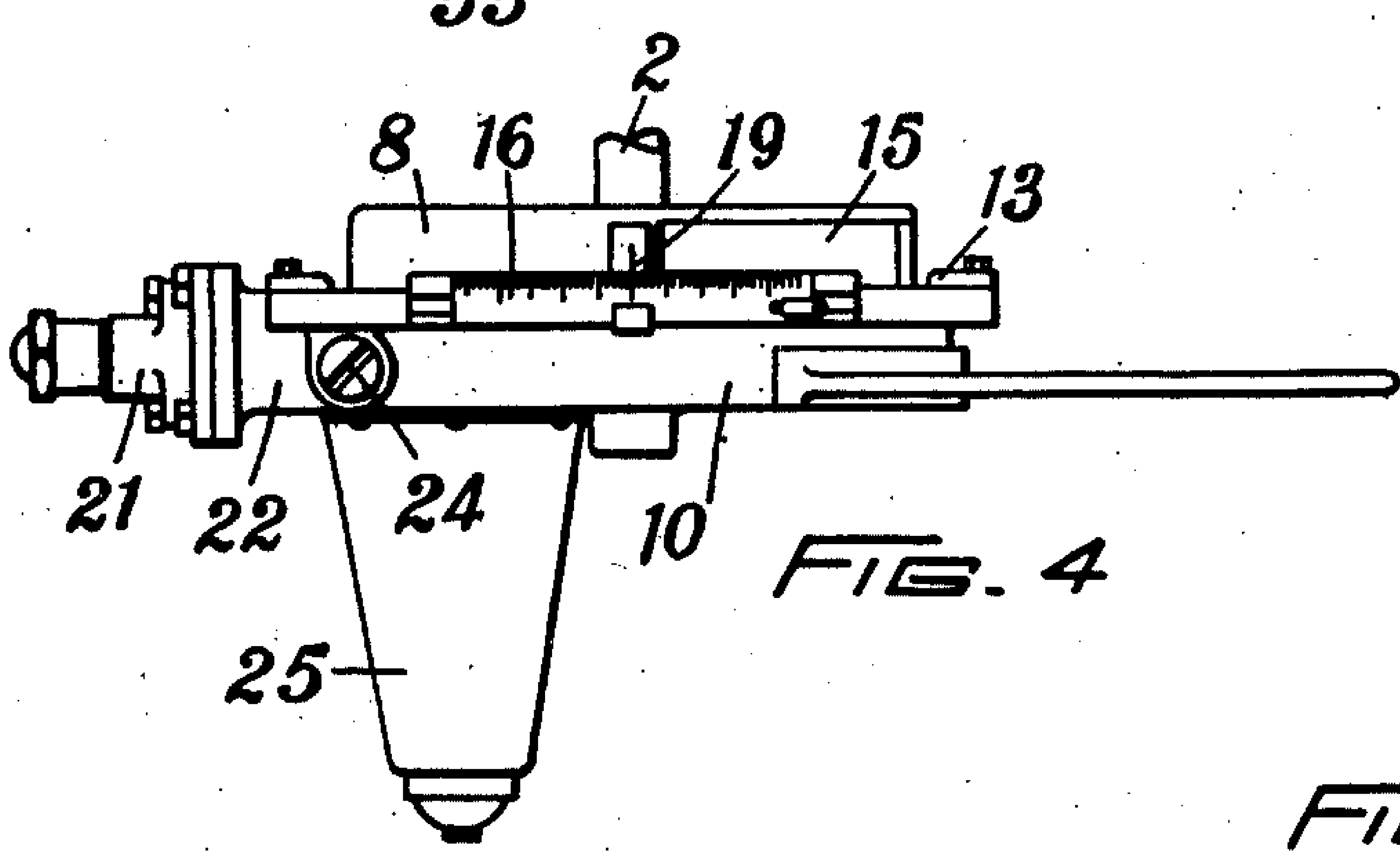


FIG. 4

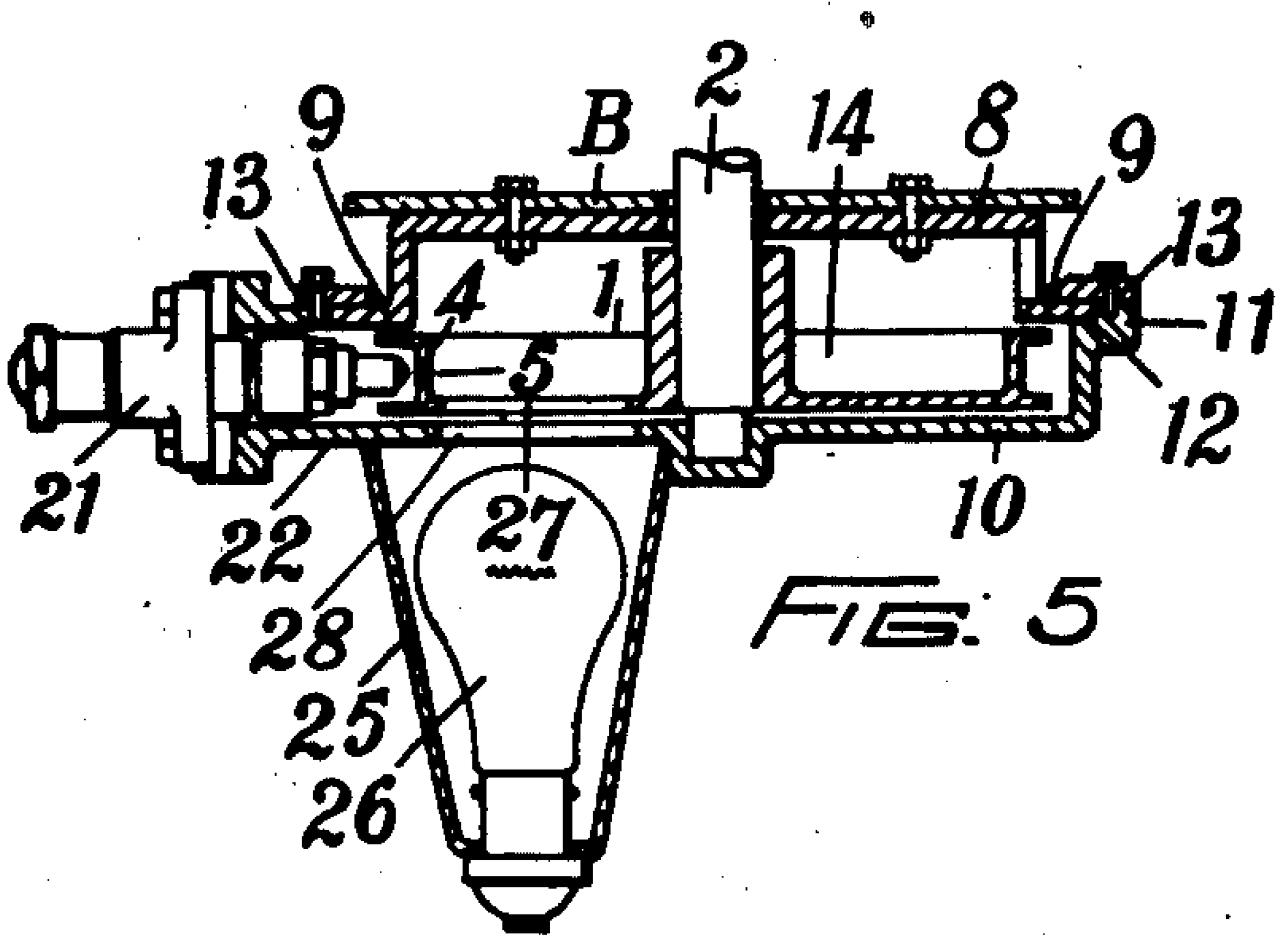
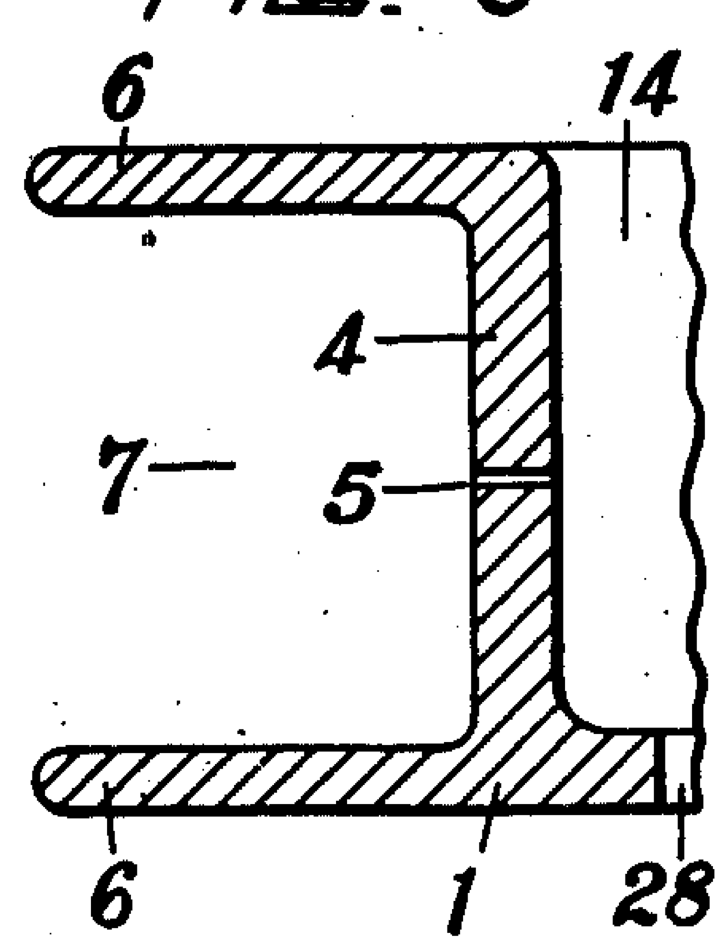


FIG. 5

FIG. 6



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TESTING PHASE ANGLE AND INJECTION PERIODS OF FUEL INJECTION PUMPS

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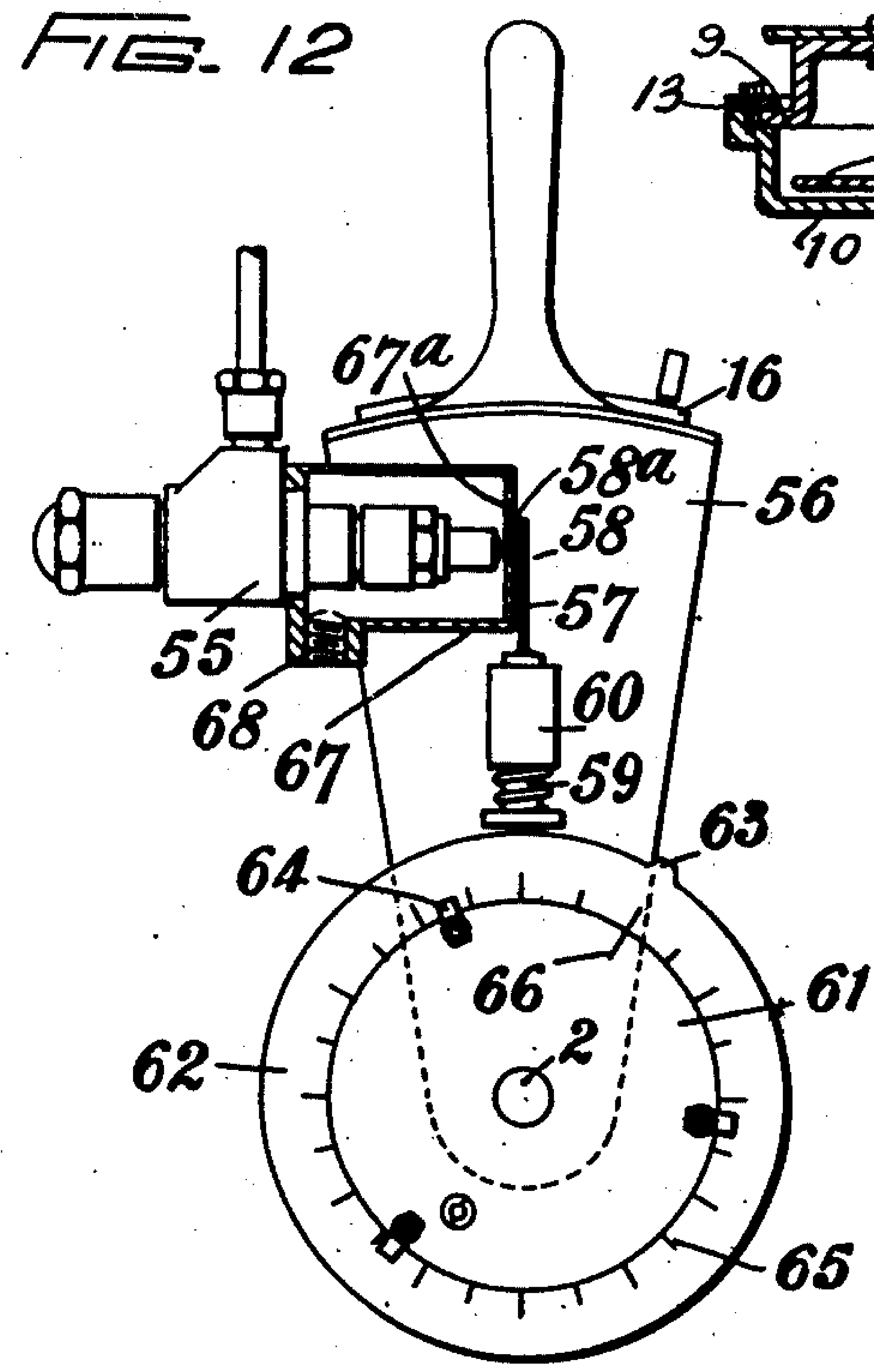
FIG. 12



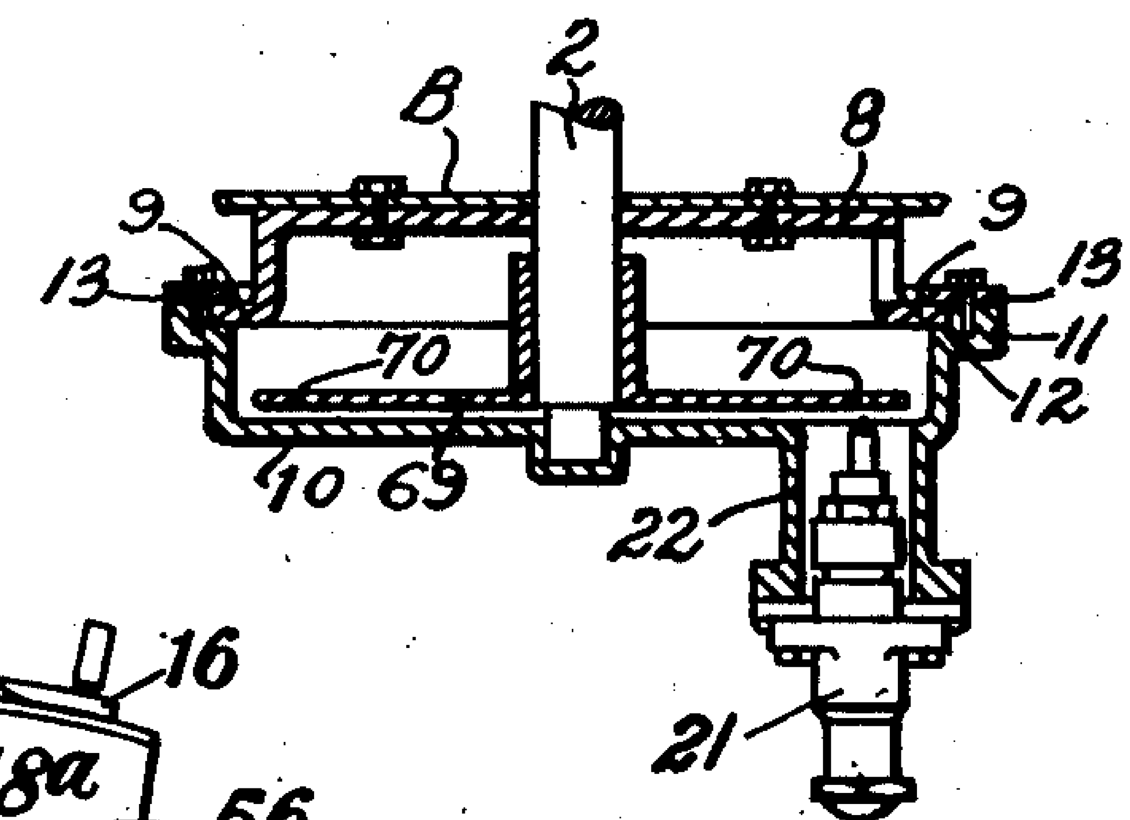


FIG. 14

FIG. 13

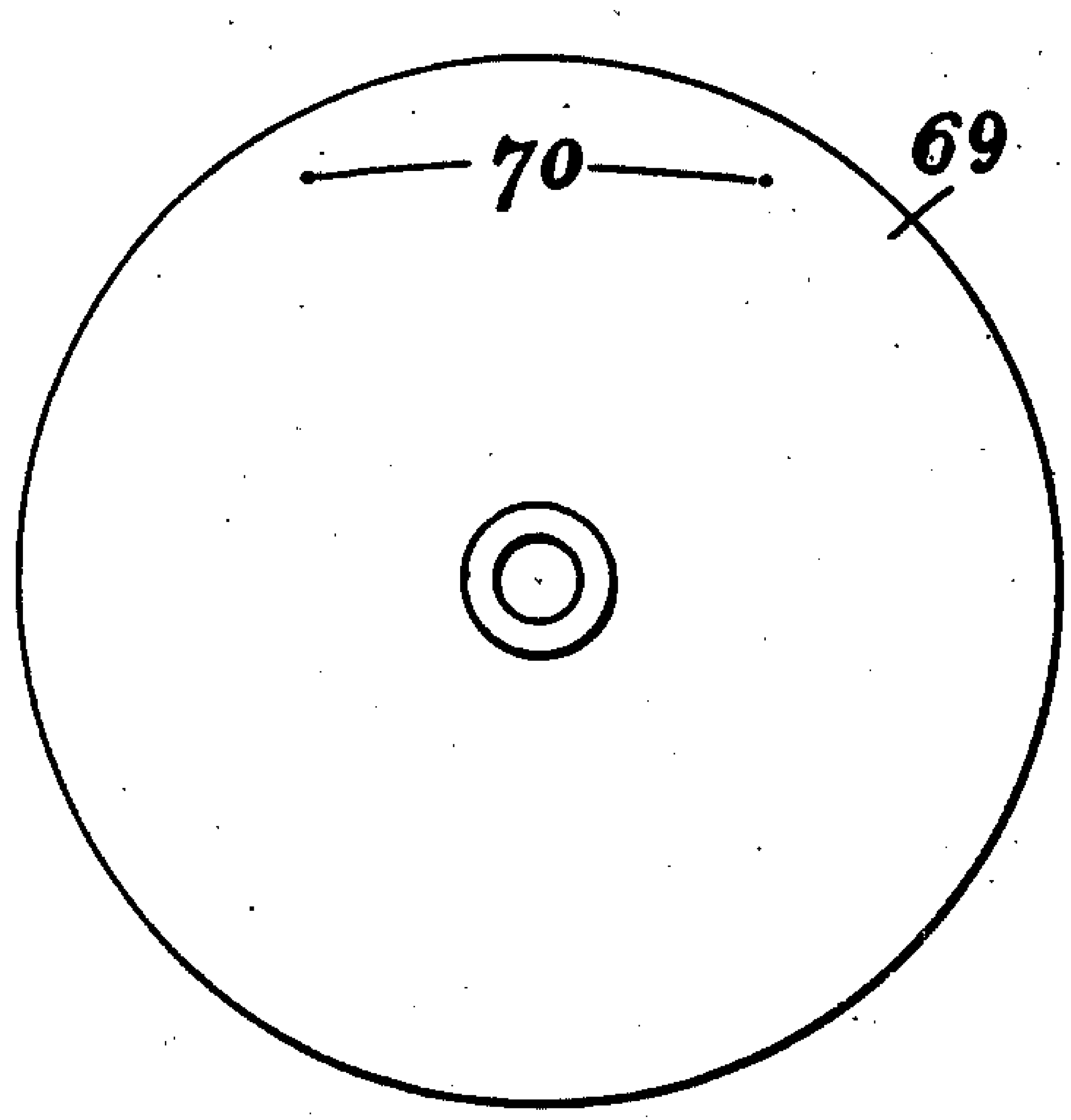
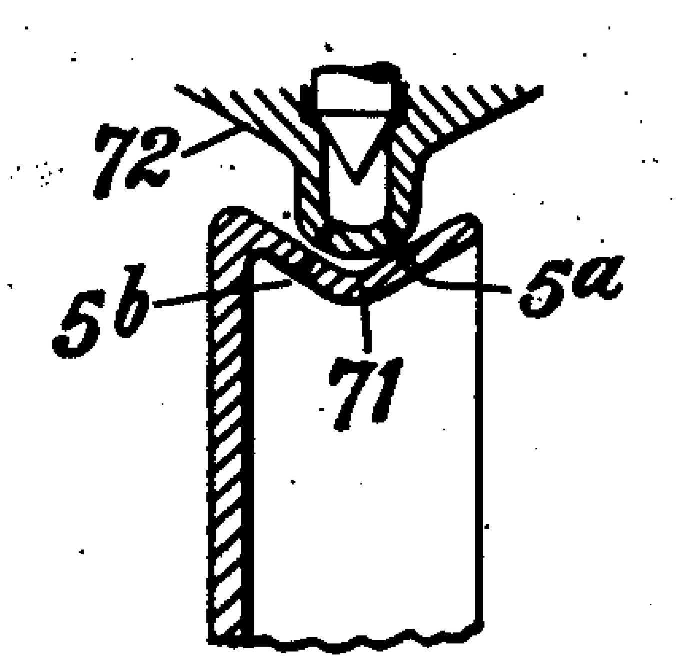


FIG. 15



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UNITED STATES PATENT OFFICE

2,470,351

TESTING PHASE ANGLE AND INJECTION PERIODS OF FUEL INJECTION PUMPS

Leslie Hartridge, Buckingham, England

Application February 22, 1944, Serial No. 523,448
In Great Britain February 22, 1943

14 Claims. (Cl. 73—118)

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This invention has reference to the testing of fuel injection pumps. The tests which can be carried out according to the invention with a multi-stage pump comprise testing the phase angle or timing between the stages thereof and also the following tests which can be carried out with single injector pumps as well as with multi-stage pumps: ascertaining that point in the rotation of the pump shaft at which liquid injection commences or ends, ascertaining the duration of the injection period of a single injector fuel pump or of any stage of a multi-stage fuel injection pump in terms of degrees of pump shaft rotation and for testing or ascertaining the behaviour of fuel injection pumps and injectors during fuel injection periods.

As the invention is applicable to the testing of pumps of various types the term "stage" used herein is a general term chosen to cover the term "pump element," "distributor point" or the like. Thus, if a pump comprising a single cylinder and a distributor adapted to control the flow of fuel from the pump to six separate injectors be considered the pump will have six stages, each stage comprising a distributor point.

The principle of the invention, which principle is thought to be novel, resides in directing liquid spray from an injector through an aperture which is momentarily exposed to the spray so that part of the latter passes through the aperture and, as a result, becomes visible at that side of the aperture furthest from the injector.

A phase angle or timing test is carried out according to the invention by intermittently supplying liquid to an injector from one stage of the pump under test, directing the resulting spray or parts thereof produced during successive injection periods from the said stage through an aperture at the moment of commencement of each of said periods whereby that portion of the spray (or a part thereof) produced at this moment becomes visible at the side of the aperture furthest from the injector and repeating this procedure with a second stage of the pump, the angular displacement of the shaft from the shaft position at which the preceding visible sprays occurred to the shaft position at which the succeeding visible sprays occur being noted and this angle being the phase angle (or the phase angle plus or minus any error that may be present) between the said stages of the pump.

A duration of injection test is carried out according to the invention by intermittently supplying liquid to an injector from the single injector type pump or pump stage under consideration, directing the resulting sprays or a part of each spray produced during successive injection periods of the pump or pump stage through an aperture at the moment of commencement of each of said periods whereby that portion of the spray (or a part thereof) produced at this moment becomes visible at the side of the aperture furthest from the injector and carrying out this procedure at the moment of cessation of the said successive injection periods, the angular difference between the position of the pump shaft at the moment of commencement of the injection periods and the moment of cessation thereof being noted and this angle being the said duration of injection.

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A method of ascertaining the behaviour of a fuel pump and injector during injection periods comprises intermittently supplying liquid to the injector from a single injector type fuel pump or from the required stage of a multi-stage injection pump and momentarily exposing an aperture to the successive sprays at relatively different points in successive injection periods whereby that portion of each spray (or a part thereof) produced at each point becomes visible at the side of the aperture furthest from the injector.

The aperture may be in a body oscillated or reciprocated in time with the pump shaft so as to register with the injection spray at the critical moments; or other suitable arrangements may be employed.

Apparatus according to the invention preferably comprises a rotor in which the aperture is formed and a rotatable mounting for the injector, said rotor being arranged to be driven in timed relation to the pump shaft so as to cause the aperture intermittently to cut across the spray path and the axis of rotation of the mounting coinciding with the axis of rotation of the rotor. Thus, by adjusting the injector angularly in relation to the rotor the aperture may be made to cut the sprays at the required moments (ascertaining phase angle error and testing duration of injection) and at the required points (testing or analysing behaviour of pump and injector or pump stage and injector); and the angle through which the injector is adjusted is the phase angle error or the angle of duration of each injection, as the case may be. The said angle of adjustment is measured by means of a protractor scale and index suitably provided.

The rotor preferably comprises a flanged disc, the aperture or, as will be described herein, a number of equi-angularly spaced apertures, being in the flange and radial with respect to the disc axis. Alternatively the rotor may comprise a disc in which the aperture or the apertures are formed.

In all cases, however, the injector is preferably on a rotatable mounting.

The actual injectors allocated to the pump or to the pump stages when in use may be used in any of the arrangements described. If necessary suitably shaped rotors may be used for special types of injectors, such as multi-hole injectors.

In order to render the visible spray or sprays more conspicuous (i. e., the spray or sprays which emerge from the side of the disc or the like) illuminating means are preferably provided which may act continuously or intermittently may comprise a beam of white or coloured light, a gas discharge lamp such as a neon lamp or a violet or ultra violet lamp. A highly satisfactory arrangement in conjunction with the flanged disc consists in providing a radial slot in the disc adjacent to the flange, the radial axis of the slot being in the radial plane containing the centre of the aperture, by providing a further slot in the casing, and in providing a lamp at the unflanged side of the disc so that a spray passing through the aperture towards the shaft axis is momentarily illuminated by the light passing through the slot in the casing and the slot in the flange.

The invention will now be described with reference to the accompanying drawings wherein:

Fig. 1 is a front elevation of a test bench B comprising the present apparatus and a pump;

Fig. 2 is an end elevation of the apparatus;

Fig. 3 is a side elevation thereof;

Fig. 4 is a plan view of the said apparatus and

Fig. 5 is a sectional plan view of the apparatus attached to the bench, part only of the latter being shown;

Fig. 6 is a detail showing part of the rotor on a larger scale than in Fig. 5;

Fig. 7 is a side elevation of a dividing coupling for use between the pump and the apparatus shown in Figs. 2 to 5;

Figs. 8 and 9 are views of the said coupling from the pump end thereof and the apparatus end thereof, respectively;

Figs. 10 and 11 are plan and end views, respectively, of a movable protractor scale for use in ascertaining the angle through which the injector is displaced, Fig. 11 including a guide for the scale;

Fig. 12 is an end elevation of a modified form of apparatus;

Fig. 13 is a face view of a rotor of disc form having a number of equi-angularly spaced holes;

Fig. 14 is a sectional plan view of apparatus similar to that shown in Fig. 5, but incorporating the rotor shown in Fig. 13, said apparatus being shown attached to a bench of which part only is shown.

Fig. 15 is a fragmentary view of a rotor designed for use with a multi-hole injector nozzle as shown, the parts being in section.

The apparatus according to Figs. 1 to 6 comprises a rotor 1 fixed to a driving shaft 2, said shaft being supported by the test bench and being provided with a driving pulley 3. The rotor is flanged at 4 and in the flange at about the middle thereof is a small diameter radial hole 5. This is the aperture referred to previously; its diameter may be about .01". The rotor also has outwardly directed extensions 6 which in

conjunction with the flange provide an annular channel 7.

A dished back plate 8 which rotatably carries the injector mounting is bolted to the end of the test bench, cavity outwards. The sides of the plate surround the shaft and have an outwardly directed radial lip 9, which is coaxial with the said shaft. The injector mounting 10 is also of dished form; its cavity lies opposite that of the back plate and its sides surround the rotor in spaced relation. The said sides terminate in an outwardly directed radial lip 11 which is recessed at its inner margin at 12 for the reception of the outer margin of the lip 9. Securing fingers 13 on the lip 11 overlap the lip 9 to hold the elements 8 and 10 together. The fit of the lip 9 in the recess 11 and action of the fingers 13 are such as to permit the mounting 10 to turn on the lip 9 without play. A segment of the side of the dished plate 8 is removed to expose the cavity 14 of the rotor through the resulting opening 15.

A segmental scale 16 graduated in degrees is slidably carried by a guide 17 at the top of the mounting 10. The centre of curvature of the scale and that of the guide is in the axis of the shaft 2, which is also the axis of rotation of the mounting 10; and a small column 18 rigid with the plate 8 carries a fixed index mark 19 at the side of the scale. A friction spring 20 carried by the scale and rubbing against the side of the guide holds the scale in adjusted position on the guide.

The injector 21 is fixed to a hollow, radial boss 22 on the mounting 10 so that the nozzle end of the injector lies in the channel 7 in close proximity to the flange while the nozzle registers with the hole 5 once in every revolution of the rotor. Sight holes in hollow bosses 23 on the said mounting permit the position of the nozzle in relation to the flange to be ascertained. Normally the holes are closed by removable screw plugs 24.

The body of the mounting 10 carries a housing 25 for a lamp 26 and such mounting is radially slotted at 28 while the rotor is radially slotted at 27, the slots being so positioned relatively that slot 27 registers with 28 once in every revolution of the rotor and light from the lamp is able to enter the rotor cavity 14. The centre line of the slot 28 lies in the plane containing the axes of the shaft 2 and the injector 21 and the centre line of the slot 27 lies in the plane containing the said shaft axis and the axis of the hole 5. In order to indicate to the operator when the said planes are coincident, i. e., when the injector nozzle is in register with the hole 5 and the slots 27 and 28 are in register, the body of the mounting 10 has a countersunk hole 29 in it the inclined surfaces of which are provided with a radial mark 30 and the rotor has a radial mark 31 so located that it registers with the mark 30 when the said planes are coincident.

The shaft 2 is connected to the shaft 34 of the pump 35 by a dividing coupling 36 and a dog coupling 37.

The construction of the coupling 36 will now be described with reference, more particularly, to Figs. 1, 7, 8 and 9.

The coupling 36 comprises a flanged element 38 which can be releasably locked to the shaft 2 by means of a screw 39, and a second flanged element 40. A boss 41 on the element 38 projects into the bore of the element 40 and a locking screw 42 carried by the element 40 can be turned to lock the elements together relatively. One element of the coupling 37 is rigid with the element 40 and the other element of the coupling 37 is fixed to the shaft 34.

The object of the dividing coupling is to enable the shaft 2 and the rotor 1 to be displaced relatively to the pump by an angle equal to one or more phase angles in order that the hole 5 in the rotor shall occupy the position for co-operation with the injector according to the number of the pump element under consideration.

To enable the correct angular displacement to be made the flange 43 of the element 38 is provided with a number of holes 44 six of which are sixty degrees apart and four of which are 90° apart, two diametrically opposite holes in the series having 60° spacing being included in the series 90° apart; while the flange 45 of the element 40 has a single hole 46 with which any hole 44 can be made to register by turning the pump shaft through the angle separating the selected hole 44 from the hole 46. When these latter holes are in register the elements 38 and 40 are located relatively by a pin 47 which is also an accurate fit in the said holes so as to keep them in register. Owing to the spacing of the holes in the element 38 the coupling can be used with pumps having 1, 2, 3, 4 or 6 cylinders. If desired other holes may be provided to enable the coupling to be employed with other pump cylinder arrangements.

The supply pipe 48 of the injector passes to a union 49 which can be connected to any one of the elements 50 of the pump 35 by a wander pipe 51.

When a test is to be made the coupling elements 38 and 40 are locked together and to the shaft 2, the pump is connected to a supply tank containing suitable liquid, a pump element is connected to the injector by means of the pipes 51 and 48, the mounting 10 is moved through an angle of about 30° one side or the other of its central position in a direction opposite to the direction in which the pump shaft is to rotate and the shaft 2 is set in rotation so as to drive the pump and the rotor 1. The mounting is then gradually moved in the return direction until a light spray of liquid becomes visible in the rotor cavity 14, this light spray becoming so visible because the hole 5 has registered with the injector nozzle orifice at the moment of commencement of an injection period.

If a phase angle test is to be carried out the scale 16 is slid on its guide until the zero mark nearest the arrow on it agreeing with the direction of rotation of the pump shaft coincides with the fixed mark 19. The pipe 51 is connected to any pump element, preferably No. 1 element, and after the light spray has been produced in the rotor cavity and the scale 16 set, as above described, the shaft is stopped, pipe 51 is connected to the next pump element to operate and after the screw 42 has been released and the pin 47 withdrawn from a hole 44, the said shaft and element are turned through an angle corresponding to the correct phase angle of the pump. Thereafter the pin is introduced into the hole 44 which has been moved into register with the hole 46 and the screw is tightened. The shaft 2 is then restarted.

If the said next pump element is in phase with the previously operating element the sprays visible in the rotor cavity will be similar in appearance to the preceding series of sprays visible therein and slight movement of the mounting 10 opposite to the direction of rotation of the shaft 2 will cut the sprays off from the cavity.

If the said next pump element is out of phase the sprays visible in the cavity will be heavier than those of the preceding series or will not occur. By adjusting the mounting until the sprays of the succeeding series are similar to those of the preceding series, the adjustment being carried to a point where slight movement of the mounting cuts the visible spray off from the cavity, and observing the extent of the adjustment, plus or minus, by reference to the scale 16 and the index 19, the phase error can be ascertained. The reading is in effect the extent of the difference between the correct phase angle and the angular displacement of the shaft 34 from the position at which the preceding visible sprays occurred to the position at which the succeeding visible sprays occur.

The above procedure is then repeated for succeeding elements, the phase angle being corrected when necessary in the usual way until the scale 16 attains the zero position as each pump element is tested.

Duration of injection periods are ascertained by setting the scale 16 to zero after a light spray is visible in the rotor cavity 14 as above described and then moving the mounting 10 in the direction of rotation of the pump shaft until cut off of the visible spray occurs. The angle indicated by the scale and the index is the duration of the injection period in terms of degrees of pump shaft rotation and is in effect the angular difference between the position of the pump shaft at the moment of commencement of the injection periods and the moment of cessation thereof.

Injection behaviour during injection periods is tested or ascertained in much the same way as duration of injection periods except the scale 16 need not be brought into use. The mounting is gradually moved from the position at which injection commences to the position of injection cessation so that the hole 5 momentarily registers with the injection orifice at relatively different stages in successive injection periods and a spray is visible in the rotor cavity at each stage. Proper behaviour of the injector or secondary injection and other faults can be readily detected by the condition of the visible spray throughout the test.

The marks 30 and 31 on the mounting 10 and the rotor, respectively, are provided for the apparatus to be used in testing or ascertaining the angle at which commencement of injection occurs before the top dead centre position of the pump cams are reached.

To make this test the usual timing marks on the pump case and the coupling 37 are brought into register and the marks 30 and 31 are brought into register at the same time, the coupling 36 being suitably set to enable this to be done. The scale 16 is zeroised previously as described in connection with the commencement of injection of No. 1 element. The angular movement of the scale from the commencement of injection setting to the postion where marks 30 and 31 register (as shown by the scale) is the angle at which injection commences before top dead centre of the cam of No. 1 element.

The sprays produced in the rotor cavity 14 when the above tests are carried out are made more conspicuous by the stroboscopic action of the lamp 26 and the slots 27 and 28. Once in every revolution of the rotor the slots 27 and 28 register and when this happens the zone in which the sprays appear or should appear in the cavity 14 is momentarily illuminated with the result that the occurring sprays are similarly illuminated.

Liquid from the injector either strikes the flange 4 or enters the cavity 14 and falls onto the inner periphery of the flanges. In both cases the liquid is flung into the cavities of the parts 8 and 10 and gravitates to a draining nipple 53 on the mounting 10 whence it may be led back to the supply tank, not shown, for the pump by means of a flexible pipe connected to the nipple.

The hole may be in a body which is oscillated in time with the pump shaft to bring the hole into register with the injector orifice at the critical moments.

A construction wherein the hole is in a reciprocating body will now be described with reference to Fig. 12. The injector 55 is carried by a mounting 56 turnable about the axis of the shaft 2 and the said mounting is provided with a scale 16 for use in conjunction with a pointer as described with reference to preceding figures. The reciprocating body is indicated by 57 and the hole in it by 58. The body is in the form of a plate at the top of a spring plunger 59 mounted in a guide 60, which guide is secured to the mounting 56. A disc 61 fixed to the shaft 2 adjustably carries a ring 62 on which is a cam tooth 63 adapted once in every revolution of the shaft 2 to lift the plunger and the body to such an extent as momentarily to bring the hole 58 into register with the injector orifice. The ring 62 can be turned on the disc 61 to enable the cam to be set in conformity with the pump element under test (the use of a coupling as 36, Fig. 1, being dispensed with by this means) and is secured in the adjusted position by clamping fingers 64 on the disc. A scale 65 and index 66 are provided on the ring and the disc, respectively, to facilitate correct setting of the said ring. The injector is in a housing 67 which receives most of the liquid discharged by the injector and from which the liquid is drained by way of a nipple 68.

Instead of using a flanged disc as shown in Figs. 1 to 6 a plane disc 69, Fig. 13, may be used. in such a case, as shown in Fig. 14, the injector is at right angles to the plane of the disc at one side thereof and the hole which is exposed to the sprays passes through the disc from side to side. Actually six such holes, indicated by 70, are shown in Fig. 13. The holes are equidistant and lie on a circle struck from the centre of the disc. This disc is suitable for use with a 1, 2, 3 or 6 cylinder pump and because there is one hole appropriately positioned for each pump element a coupling as 36, Fig. 1, is not necessary. The injector is carried at right angles to the plane of the disc by the boss 22 on the mounting 10, Fig. 14. This figure is similar to Fig. 5 and corresponding parts have been given corresponding reference numerals. The lamp housing 25, lamp 26 and slot 28 are, however, omitted from Fig. 14.

When the invention is to be employed in conjunction with multi-hole injectors the rotor is shaped accordingly. For example, in Fig. 15 the rotor flange 71 is of V-section to accommodate the multi-hole nozzle 72 of an injector and apertures 5^a and 5^b are provided in the sides of the V.

The sprays may be momentarily directed through the aperture or apertures once in any chosen number of revolutions. That is to say, the rotor may be driven more slowly than the pump shaft in order to prolong the periods during which the aperture passes liquid.

The drive to the shaft 2 is preferably of variable speed type so that the tests can be carried out at different speeds.

What I claim is:

1. A method of ascertaining the phase angle or timing between the pump stages of a multi-stage fuel injection pump, consisting in intermittently supplying liquid to an injector from a pump stage, directing the resulting sprays produced during successive injection periods of the pump stage through an aperture open to the spray only at the moment of commencement of each of said periods whereby that portion of the spray produced at this moment becomes visible at the side of the aperture furthest from the injector and repeating this procedure with a second stage of the pump, the angular displacement of the shaft of the pump being tested from the shaft position at which the preceding visible sprays occurred to the shaft position at which the succeeding visible sprays occur being noted and this angle being the phase angle between the said stages of the pump.

2. A method of ascertaining the duration of the injection periods of an injector fuel pump in terms of degrees of pump shaft rotation, consisting in intermittently supplying liquid to an injector from the pump or pump stage under consideration, directing the resulting sprays produced during successive injection periods of the pump or pump stage through an aperture exposed to the spray only at the moment of commencement of each of said periods whereby that portion of the spray produced at this moment becomes visible at the side of the aperture furthest from the injector, repeating the described procedure at the moment of cessation of the said successive injection periods, the angular difference between the position of the pump shaft at the moment of commencement of the injection periods and at the moment of cessation thereof being the said duration of injection.

3. A method according to claim 2, which consists in effecting the change-over from spray commencement to spray cessation by angularly displacing the injector and ascertaining the angle of displacement, said angle representing the angular difference between the position of the pump shaft at the moment of commencement of the injection periods and at the moment of cessation thereof.

4. An apparatus for determining the phase angle of a pump stage in a fuel injector pump arranged to produce a series of liquid injections, comprising an injector for producing a spray, a rotor to be driven by the shaft of the pump under test, means for delivering a liquid from the pump to the injector to create a spray, an apertured member operatively driven by said rotor to move across the path of the spray from the injector, a mounting supporting said injector for movement about the axis of said rotor for angular adjustment in relation to the rotor for positioning the injector to project a spray through the aperture, and means for determining said angular adjustment.

5. An apparatus as defined in claim 4 wherein the rotor comprises a disc and the member comprises a flange around said disc, the aperture being located in the flange.

6. An apparatus as defined in claim 5 wherein said flange is of channel section and said injector projects into the channel.

7. An apparatus as defined in claim 4 wherein the mounting is rotatable upon a fixed support, a scale on said mounting, and an index on said

fixed support and adjacent said mounting to cooperate with said scale for indicating the angular displacement of the rotatable mounting.

8. An apparatus as defined in claim 4 wherein a divided coupling is interposed between the rotor and the pump shaft, said coupling comprising two elements which are relatively displaceable through an angle corresponding to the phase angle of the pump, and locking means for securing said elements in the selected relatively displaced position.

9. An apparatus as defined in claim 4 wherein a light source is carried by said mounting, and means for illuminating the aperture and spray zone on the side opposite the injector by said light source.

10. An apparatus as defined in claim 4 wherein said apertured member is carried by said rotor and said mounting encloses said rotor, an opening in said mounting through which said rotor is visible, index marks respectively at said opening and on that zone of the rotor that is visible therethrough, said marks being so relatively positioned that they register when the injector is aligned with the aperture carried by the rotor.

11. An apparatus as defined in claim 4 wherein the delivery means comprises a liquid supply pipe connected at one end to the injector, a union at the other end of said pipe, and a wander pipe connected to said union, the free end of said wander pipe being selectively connectable to elements of the pump under test.

12. An apparatus as defined in claim 4 wherein the rotor and the apertured member are jointly embodied by a disc and the aperture is located in the disc.

13. An apparatus as defined in claim 4 wherein the apertured member is mounted for reciprocal movement in front of said injector, and means operative by said rotor to reciprocate said member in timed relation to the pump shaft.

14. An apparatus as defined in claim 4 wherein the apertured member is mounted in juxtaposition with said rotor for reciprocal movement in front of said injector, and a cam carried by said rotor to reciprocate said member in timed relation to the pump shaft.

LESLIE HARTRIDGE.

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