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HIGH FREQUENCY VALVE

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Fig. 2

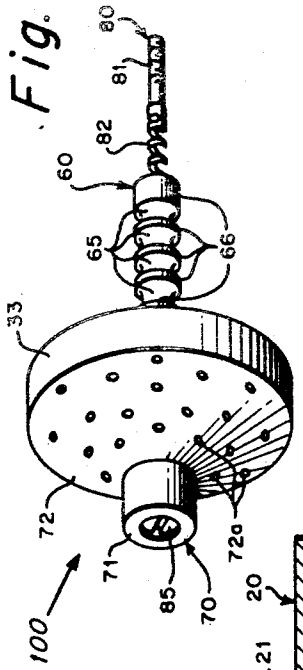
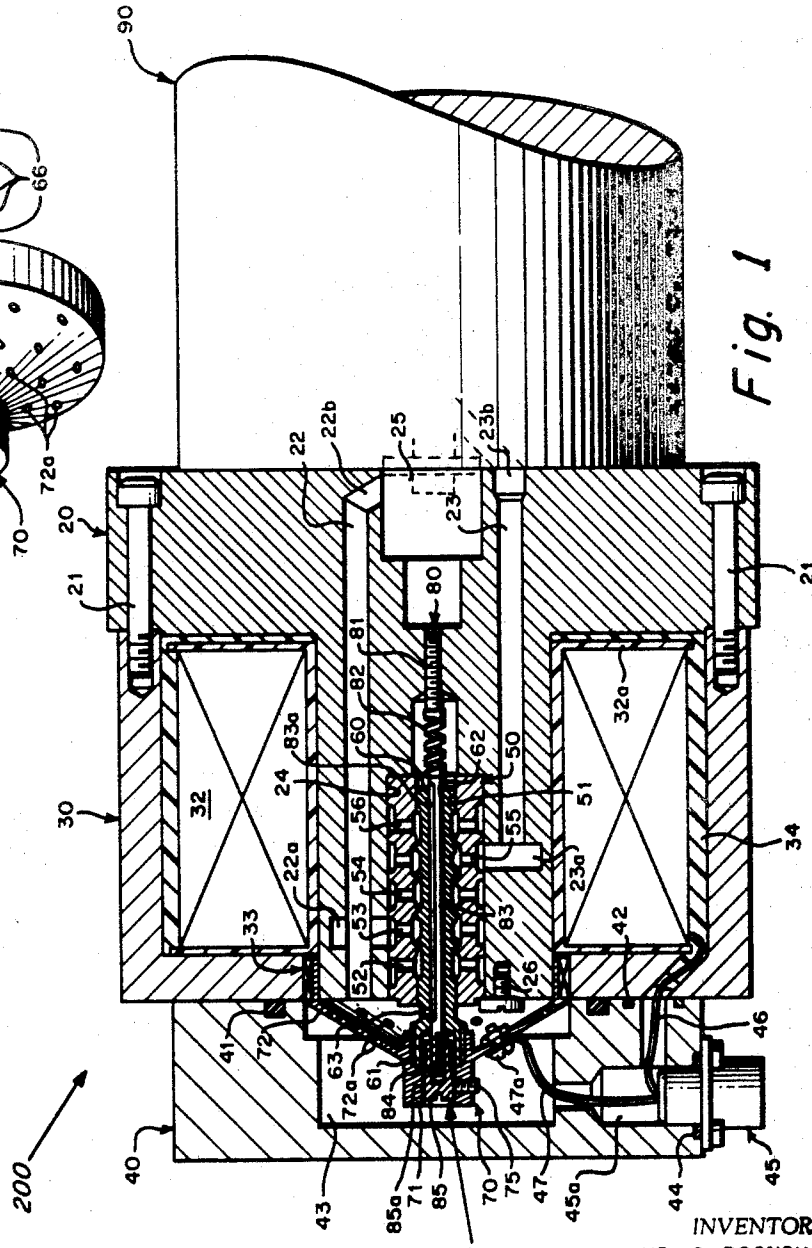


Fig. 1



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HIGH FREQUENCY VALVE

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ABSTRACT OF THE DISCLOSURE

A high frequency spool valve comprising a fixed flux electromagnet in the form of an annulus. A stem having a screw, spring and body portion joined together is disposed within the annulus with a yoke adjustably fixed to one end of the stem and to the other end of the stem affixed to the electromagnet. A valve spool and a plurality of channels and lines are disposed within the annulus. The spring is unstressed when the spool is in a neutral position; exerts tension force when the spool is in a position on one side of neutral and an equal compressive force when the spool is on the other side of neutral.

This invention ralates to a valve. More particularly, it relates to an hydraulic valve capable of very high frequency of operation in response to an electrical signal.

This invention has particular applicability as a pilot valve, serving as the first stage of a two-stage servo valve.

It has been known to provide two-stage servo valves in which the first stage is a pilot valve response to electrical signals and the second stage is an operating valve which is controlled by the output of the pilot valve. In such a two-stage servo valve, the operating valve has a greater flow capacity than the pilot valve. It is a desirable characteristics of such two-stage valves to have as high a frequency of operation as can be obtained.

The present invention contemplates what may be described as a single stage servo valve suitable for use as the first stage of a two stage valve. It is characteristic of the present invention to have a higher frequency than is available in other known valves of the same general class of service, and to be so arranged as to be able to cooperate with a second stage valve in a manner to maximize the overall frequency of the two stage valve.

It is an object of this invention to provide a high frequency valve.

It is another object of this invention to provide a high frequency hydraulic valve of simple construction and low current consumption.

It is another object of this invention to provide a high frequency hydraulic servo valve to respond to electrical signals, and to provide relatively low flow capacity at high pressures.

It is yet another object of this invention to provide a high frequency hydraulic servo pilot valve of simple construction, low current consumption, relatively low flow capacity, adapted to be coupled to an operating valve to obtain the maximum frequency of operation available in said operating valve.

It is yet another object of this invention to provide a high frequency servo hydraulic fluid switching deivce suitable as a pilot valve or to operate a shaker.

Other aims and objects of this invention are made apparent in the following specification and claims.

The invention is best understood in connection with the accompanying drawings in which like reference numerals refer to like parts, and in which:

FIGURE 1 is an elevational sectional view taken along the diameter of the valve; and

FIGURE 2 is a perspective view of the valve stem and parts attached thereto.

The high frequency valve is generally designated **200**. A main body or case **30** encloses the central portion of the valve **200**. A cap member **40** encloses one end of the valve, and a coupling member **20** comprises the major portion of the other end of the valve.

It is understood that FIGURE 1 is a longitudinal cross-section taken along the diameter of the valve **200**. The valve is preferably circular in transverse cross-section, as far as its operating elements go. FIGURE 2 illustrates the transverse shape of the valve elements. In practice, it is possible to make the outward appearance of the valve rectangular in transverse corss-section but this external shape involves only the external contours of the members **20**, **30** and **40**, and does not affect the operting structure or function of the valve.

A fixed flux magnet **32** is provided. This is an angular magnet and is contained within the main body **30**. A steady voltage is maintained at all times in magnet **32**. It is desirable to produce a steady high flux density from this magnet. The exact specifications of magnet **32** are not essential, but it may preferably draw a current substantially in excess of one ampere. In general, the stronger the fixed flux the better, and the density of the flux is limited by current drain, heat, physical size, and economics.

A variable flux magnet **33** is provided. This is also in the shape of an annulus. However, the variable flux magnet **33** is part of the moving structure, and it is highly desirable to minimize the weight of the variable flux magnet **33** to minimize the inertial effects. The flux density of variable flux magnet **33** is thus much less than that of the fixed magnet **32**. There is no exact critical specification for magnet **33**, but typically it may operate at 28 volts D.C. and draw substantially less than one ampere of current.

An electrical connector **45** is provided which introduces leads **46** which connects to fixed flux magnet **32** and leads **47** which connect to variable flux magnet **33**. The cap member **40** is provided with a chamber **45***a* to receive electrical connector **45**. An annular seal **44** is provided around connector **45** where it enters cap **40**. The connector **45** is held to the cap **40** by any convenient means, and seal **44** prevents the escape of oil or other hydraulic fluid from the interior of the valve. Leads **47** do not go directly to magnet **33**, but are brought to connector **47***a* which is mounted on yoke **70**, described below, and thence are conducted to the magnet **33**. Fixed flux magnet **32** is at least partially enclosed with a magnetically permeable cover **32***a*. The magnet **32** is conveniently held in place within case **30** by means of adhesive filler material **34**.

The coupling member **20** is held to the main body or case **30** by means of bolts **21**. The cap **40** may be similarly fastened to case **30** by means of bolts, which do not show in FIGURE 1, because they lie along another diameter. Annular seals **41** and **42** are provided between cap **40** and body member **30** to prevent the escape of oil from the interior of the valve.

Variable flux magnet **33** is carried on a yoke **70**. The general structure of yoke **70** is understood in connection with both FIGURES 1 and 2. It may be described as a generally funnel-shaped member. FIGURE 1 is a view taken along one diameter thereof while FIGURE 2 shows a perspective view of the yoke as it would be seen generally from the direction of cap **40**. As shown in both figures, magnet **33** is affixed to the rim of the yoke at its wide mouth. Yoke **70** includes the conical portion **72** and the hollow shaft portion **71**. The conical portion **72** is provided with a plurality of holes **72***a*. These holes exist to reduce the weight of the yoke and also to facili-

tate its movement through oil. Only representative holes **72***a* are shown in the figures; in practice, it is preferable to have more holes and have them closer together, and representative holes are shown for convenience in illustration. The exact nature, number, and size of these holes are not critical.

The yoke **70** is supported on stem **80**; the means of its support permits a very fine adjustment of the location of the yoke longitudinally with respect to the stem. The interior of hollow shaft **71** is threaded and the exterior of insert **85** is also threaded so that there are a set of engaging threads **85***a* between the insert **85** and the shaft **71**. The insert **85** is in turn carried on one end of the stem **80**.

The stem **80** comprises four portions; a first threaded portion **81**, a spring portion **82**, a body portion **83**, and a second threaded portion **84**. These portions of stem **80** are arranged in the order set forth above. The body portion **83** is provided with a longitudinally extended groove or slot **83***a* for keying purposes, as is described below.

The insert **85**, in addition to its external threads, is provided with a hollow interior also threaded, these interior threads engage the threaded portion **84** of the stem **80**. Insert **85** is provided with means to rotate it with respect to both stem **80** and shaft **71**. This means it is here shown as a slot on the end of the insert, suitable to receive a screwdriver blade. A set screw **75** is provided through shaft **71** so that the insert **85** may be selectively locked in place against rotation when the proper adjustment has been made.

The first threaded portion **81** of stem **80** is threaded into the coupling member **20** as shown. When stem **80** has been threaded into the coupling member **20** to a proper desired distance, it is secured in place against rotation or further movement by any convenient means. Preferably, this is accomplished by a set screw extending from the exterior of the coupling member to the stem. This set screw is not shown in the drawing since it lies on a different diameter than the one shown.

With stem **80** located with respect to coupling member **20** as described, the fine adjustment of the longitudinal position of the yoke may be made. The arrangement of the internal and external threads on insert **85** make a very fine adjustment possible. If insert **85** is rotated so that it advances on stem **80**, it is apparent that yoke **72** would similarly advance if it rotated with the insert. The pitch of the external threads **85***a* are so related to the interal threads that if insert **85** is rotated to advance on stem **80** and yoke **72** is held against rotation, the threads **85***a* cause the yoke to move away from the stem. In making the fine adjustment, the yoke is held against rotation, the stem is held against rotation as described above, and slotted insert **85** is rotated. There is a difference between the degree of pitch on the internal and external threads of the insert so that for a given rotation, the longitudinal distance that the yoke is carried toward the stem by one set of threads is different than the longitudinal distance that the yoke is carried away from the stem by the other set of threads. Thus, the differential pitch of the internal and external threads of insert **85** results in what may be termed a vernier adjustment attainable by rotation of the insert.

As has been described, the stem **80** includes a spring portion **82**. This spring portion **82** is a machine screw which is machined directly out of the integral stock of stem **80**. The purpose of this type of construction is explained below. The body portion **83** of stem **80** is provided with a key or slot so that it may be keyed to a valve spool **60**. The valve spool is provided with a central longitudinal aperture **62** to receive the body portion of the stem. It is positioned thereon and may be held in place as by a set screw **63**. The valve spool **60** is provided with a series of transverse annular grooves **65** separated by a plurality of transverse annular ridges **66**. The assembly comprising the yoke, the threaded insert, the spool, and

the stem, as shown in FIGURE 2, together may be described as a moving or operating element of the valve, generally designated **100**. It is understood of course that the extreme right hand end of stem **80**, that is, the first threaded portion **81**, does not move, but is anchored to the coupling member **20** as has been described. Coupling member **20** may also be called the block since in addition to providing the coupling function at the right hand side as shown if FIGURE 1, it extends to form the interior of the entire valve in which the operating element is positioned.

The block **20** is provided with a central aperture **24** to receive the fixed channeled insert **50**. This channeled insert is held in aperture **24** by retaining screw **26**. The channeled insert **50** cooperates with the valve spool to channel the flow of fluid through the valve. In the embodiment shown in FIGURE 1, the valve spool is provided with a set of five annular grooves **65**, separated by ridges **66**. The channeled insert **50** is provided with a central aperture **51** to receive the spool **60**. The central aperture **51** of the insert **50** is provided with a set of five annular transverse grooves or channels **52, 53, 54, 55** and **56**. These grooves are separated by raised ridges or lands in the same manner as the grooves **65** are separated by the ridges or lands **66**, and the spacing of the grooves **52–56** corresponds with the spacing of the grooves **65**. The ridges or lands of the spool and the insert contact each other with a sliding fit.

Certain of the annular grooves **52–56** communicate with external fluid communication lines as is described below. Thus, the grooves in the interior surface of the fixed channeled insert **50** communicate with bores or apertures through the insert which lead to the outer surface thereof so that communication is made to external lines. Channel **52** communicates with a pressure inlet line, not shown because it lies on a different diameter than the view taken. Channel **53** communicates with the longitudinal first output line **22** by means of the transverse connecting channel **22***a*. Groove **54** communicates with an exhaust or return line, not shown since it lies on a different diameter than the view taken. Channel **55** communicates with the second output line **23** by means of connecting channel **23***a*. Channel **56** is connected to a pressure supply line, not shown. The spool **60** centers the yoke **72** with respect to the longitudinal axis of the spool by means of its expanded left hand provided with splines **61** which slidably coact with corresponding grooves in the interior of the shaft portion **71** of yoke **72**.

The valve **200** is shown in a central or neutral position in which no line communicates with any other line. If the spool moves to the right, which it may do because of the gap shown between magnets **32** and **33**, channel **52** will communicate with channel **53**, and channel **54** will communicate with channel **55**. Thus, the pressure will be admitted to the first output line **22** and second output line **23** will be connected to the return line from channel **54**. When the spool is moved an equal distance from neutral but to the left, that is, so that the magnets are twice as far apart as they are in the neutral position, channel **53** will be connected to channel **54**, and channel **55** will be connected to channel **56**. Thus, first output line **22** will be connected to the return line, and the second output line **23** will be connected to pressure. The cap member **40** is provided with a chamber **43** to enclose the operating element **100** and permitted to move therein without striking the wall of the cap member.

A second stage or operating valve generally designated **90** is shown in a close-coupled position directly against coulping member **20**. Coupling member **20** is provided with an aperture **25** to receive part of the second stage valve **90**. The first output line **22** is continued to segment **22***b*, which is shown to turn downwardly and open into aperture **25**. Second output line **23** continues to segment **23***b* which is shown as an expanded portion opening to the righthand face of coupling member **20**. It is apparent

that the first and second output lines of valve **200** terminate close together on opposite sides of the aperture **25**, and slightly displaced from each other with respect to the longitudinal direction along the valve **200**. For reasons to be described below, this structure is valuable in transferring the high frequency output of first stage or pilot valve **200** to control the second stage or operating valve **90** to take maximum advantage of the high frequency capabilities of the second stage of valve **90**. To achieve this aspect of the present valve's advantages, the second stage valve may have an actuating piston which actually extends partly into the body of coupling member **20** of valve **200**, and uses the interior of aperture **25** as part of its cylinder. A schematic representation of such an actuating piston is shown in phantom lines. It is seen that output line **22** ends in segment **22***b* on one side of the piston and output line **23** terminates in segment **23***b* which leads to the other side of the piston through a channel in the body of the second stage valve. Such a channel in the second stage valve is also shown schematically with dashed line. It is the structure of the described valve **200** which permits this type of possible coaction with a second stage valve.

The successful maximum high frequency response of valve **200** is obtained when it is set as follows. The spool is positioned in its neutral position, as illustrated, and the adjustments as described, are made so that magnet **33** is spaced from magnet **32** a distance so that when the magnets are brought into contact, the valve will be in one of the communicating positions. It will be appreciated that the gap between the magnets resulting from the neutral position is exactly one-half the total longitudinal travel distance of magnet **33**. That is, when the variable magnet has moved a further distance away from the fixed magnet equal to its neutral position distance, the valve will be in another communicating condition, reversed from the condition that exists when the magnets contact each other. With the spool in neutral position, the adjustments are made to provide the magnet gap as described, and the elements are then locked in place with the set screws as has been described. This adjustment is made with no magnetic forces being applied and it will therefore be appreciated that the spring portion **82** is in an unstressed condition. This is because the structure permits adjustment to be made of the yoke position without compressing or tensioning the spring **82**.

Now, it is apparent that during operation, when fixed flux magnet **32** is operated, and the field in variable flux magnet **33** is such that it is attracted toward magnet **32**, spring **82** is compressed a certain amount. When the flux in magnet **33** is such that it is repelled from magnet **32**, and the spool has shifted to the left position, the spring **82** is under tension by the same amount that it was previously under compression, since the travel to both sides of the unstressed position of the spring is the same. This provides a highly balanced return bias due to the spring, regardless of which communicating position the valve is in. Because a single spring is used, the spring has a high rate, and the movement is relatively very small compared to the overall dimensions of the spring.

The major potrions of the operating elements of the valve are contained within the annulus of the fixed flux magnet **32**. This structure has the advantage of permitting the use of the hydraulic fluid flowing through the valve in its normal operation to be used as a cooling medium for the relatively large coil **32**. The provision of such automatic cooling is valuable in that it keeps the current consumption lower, or alternatively, permits the use of a smaller magnet to obtain the required flux, since, it is well known, the magnet operates more efficiently if cooled.

The valve **200** can handle approximately five gallons per minute of oil, at an input pressure of 3,000 p.s.i. with a drop of 1,000 p.s.i. Its frequency of operation may be as high as 1,000 cycles per second. When used with a second stage or operating valve **90**, which can be conventional in its structure except that it is operated by reversing the applied pressure and exhausts to the two sides of a single piston at one end thereof, such an operating valve may handle a flow of 200 gallons per minute at a frequency of up to 500 cycles per second.

The spring portion **82** may have a rate of 1,000 pounds per minute of oil, at an input pressure of 3,000 p.s.i. with on the spring during the operation of the valve is approximately 10 pounds. It is thus seen that the total travel of the yoke from the neutral position to one of the communicating positions may be on the order of approximately 100th of an inch.

The high speed frequency advantages of the present valve are due to an additive combination of several factors. The use of a single spring, relying on slight displacements on either side of its unstressed condition, means that are a balanced return force of either position is much more easily obtainable than can be achieved by attempting to set two different springs. The making of the rate of the spring very high, that is making the spring relatively stiff and heavy, compared to the total force the spring is expected to exert in either tension compression, insures that the balance restoring forces are equal and reliable. In this embodiment, it is seen for example that the total force required from the spring is of the order of 100th of the unit rate.

A very small throw involved contributes to the high frequency response. The light weight of the moving structure contributes to the response, and to this end, the perforated structure of the yoke **72** is important, as has been described. The small throws and consequent small dimensions permit most of the structure to be within the annulus of the magnet **32** as has been described. This in turn makes it possible to achieve the automatic cooling function with its desirable attributes as has been described.

The use of two magnets in the control permits a quicker response. It also permits the step of setting the spacing at the neutral condition as has been described, since both magnets may of course be turned off. The entire structure of the valve as described permits very short output lines to be brought to the boundary of the valve, terminating close together. This in turn permits their most intimate relationship with the operating piston of a cooperating second stage valve, as has been shown and described. Thus, as has been shown, the operating piston of a second stage valve may actually be introduced into the body of valve **200** and the output lines may be conducted to the opposite sides of this second stage valve operating piston. This structure, considered together minimizes the length of hydraulic line from the pilot valve to the second stage valve. The minimization of the quantity of oil and length of line at this point increases the effective transmission of the high frequency of valving. This structure also prevents a great difference in the length of the output lines, and this near approach to equal line length also increases the efficiency of the high frequency valving.

The length of the fixed channeled insert may be on the order of one and three quarter inches. The internal diameter of the fixed flux magnet **32** annulus may be on the order of one and three quarter inches. The total length of the stem **80** may be approximately three and one-quarter inches, its diameter approximately one-eighth inch, and the length of the spring portion **82** approximately one-half inch. These dimensions are not in themselves necessarily critical, but are given to provide a context to place this valve in its appropriate field of art.

We claim:

1. A high frequency valve comprising a fixed flux electromagnet in the shape of an annulus,

an operating element having a major portion thereof within said annulus, said operating element comprising a stem, said stem including a screw portion, a spring portion and a body portion joined together,

a valve spool disposed within said annulus affixed to said body portion, a yoke adjustably fixed to one end of said stem, the other end of said stem being affixed to said electromagnet, said yoke being positioned outside of said annulus, a variable flux annular electromagnet mounted on said yoke and opposing said fixed flux electromagnet,

a plurality of channels and lines in said valve inside said annulus, said channels being selectively intercommunicating depending on the position of said spool with respect thereto,

said spring portion being unstressed when said spool is in a neutral position blocking intercommunication of said channels, said spring exerting a tension force when said spool is in a position on one side of said neutral position to intercommunicate certain said channels, and said spring exerting an equal compressive force when said spool is in a position on the other side of said neutral position to interconnect others of said channels.

2. A high frequency valve as set forth in claim 1 in which said spring portion and body portion are formed from a one piece stem and the unit rate of said spring portion being high compared to the total compressive bore tension force to be exerted by said spring portion.

3. A high frequency valve set forth in claim 2 wherein said yoke comprises a generally circular member and said variable flux electromagnet is affixed to the outer rim thereof, and the center of said yoke comprises a shaft, and said shaft is affixed to said stem by vernier adjusting means.

4. A high frequency valve as set forth in claim 3 wherein said vernier adjusting means comprise a rotatable insert, threaded externally and internally, said external threads cooperating with matching threads on the interior of said shaft, and said internal threads cooperating with matching threads on the end of the said stem, said set of external threads and said set of internal threads differing in pitch so that when only insert is rotated, one set of threads moves said yoke in one direction and the other set of threads tends to move said yoke in the opposing direction at a different speed.

5. A high frequency valve as set forth in claim 4, wherein a first output line, a second output line, a pressure line and a return line are provided in said valve, said lines being selectively intercommunicating with certain

of said channels, said intercommunication depending on the position of said valve spool.

6. A high frequency valve as set forth in claim 5 wherein when said valve spool is in said neutral position, neither of said output lines communicates with any of said channels, when said valve spool is in a position so that said spring is under its maximum tension one of said output lines communicates with a pressure line and the other output line communicates with a return line, and when said spool is in a position so that said spring is in its maximum compression, the first mentioned said output line is connected to a return line and said second mentioned output line is connected to a pressure line.

7. A high-frequency valve as set forth in claim 6 wherein a coupling member is provided at one end of said valve, a recess is provided in a face of said coupling member and both of said output lines terminate close together on opposite sides of said recess.

8. A high frequency valve as set forth in claim 7 in combination with a second stage valve to be controlled by said high frequency valve, said second stage valve being coupled to said face of said coupling member, said second stage valve having a single actuating piston extending at least partly into said recess in said face, one of said output lines communicating to one face of said piston, and the other of said output lines communicating to the other face of said piston.

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91—429, 137—625.65; 267—1

Disclaimer and Dedication

3,466,003.—*Julius C. Boonshaft*, Huntingdon Valley, and *Kenneth W. Zeuner*, Newton, Pa. HIGH FREQUENCY VALVE. Patent dated Sept. 9, 1969. Disclaimer and dedication filed Feb. 4, 1970, by the assignee, *Weston Instruments, Inc.*

Hereby enters this disclaimer to the entire remaining term of said patent and dedicates the patent to the Public.

[*Official Gazette May 26, 1970.*]