

March 5, 1946.

A. G. FOX

2,396,044

SWITCHING DEVICE

Filed Dec. 10, 1941

7 Sheets-Sheet 1

FIG. 1

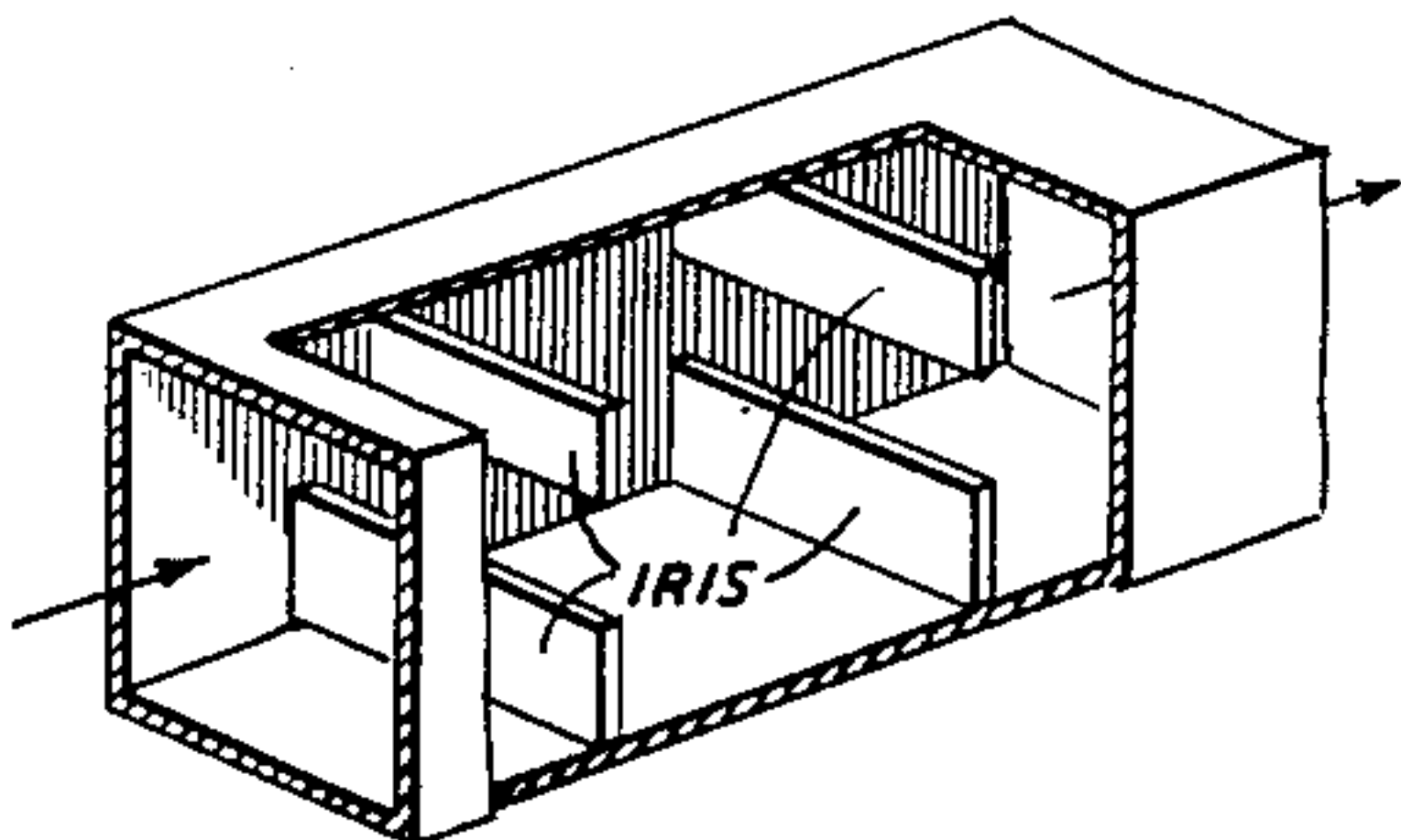


FIG. 1A

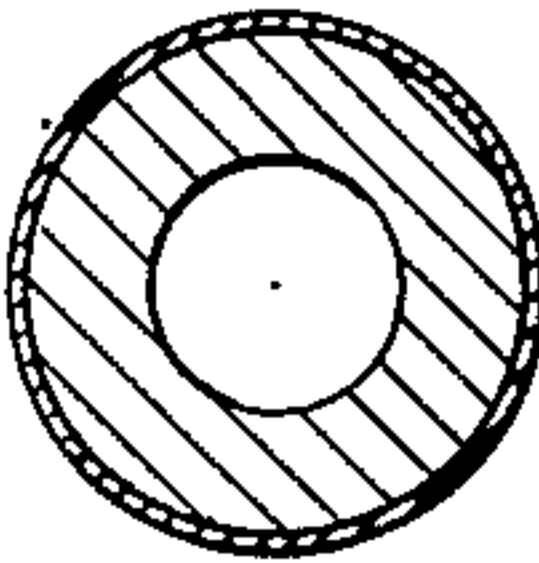
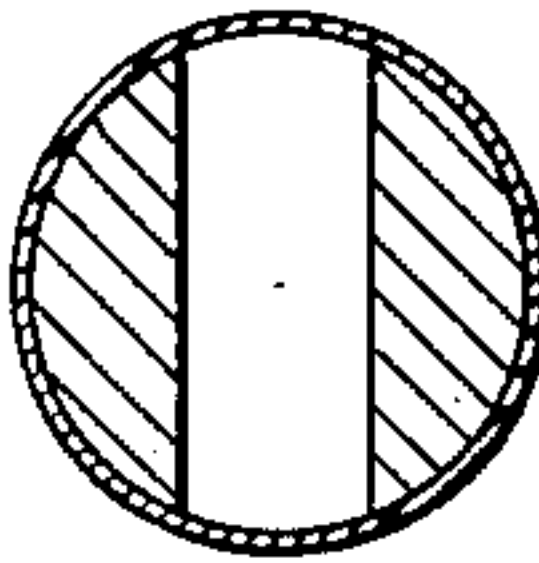
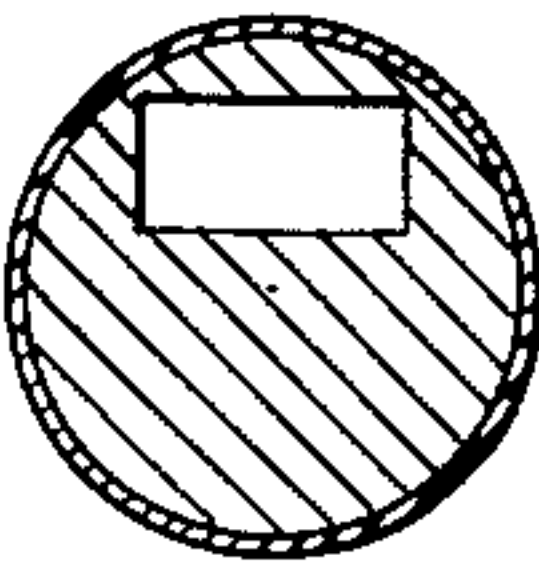


FIG. 2

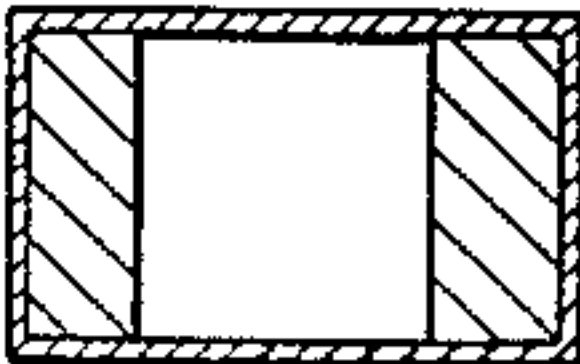
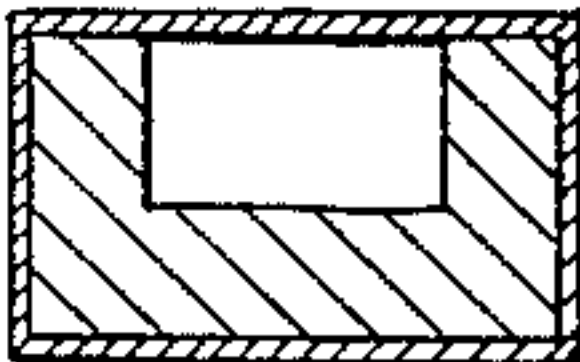
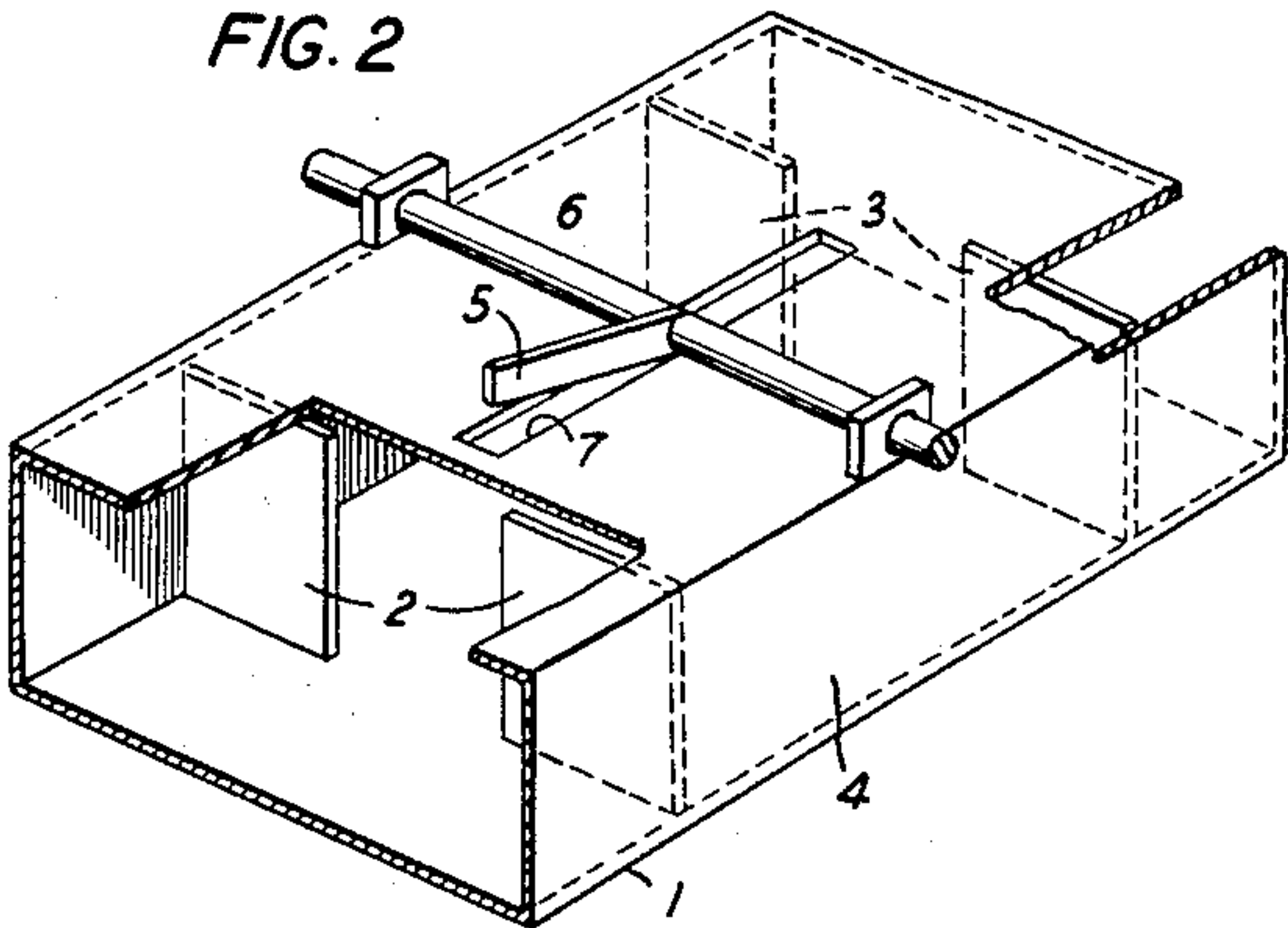
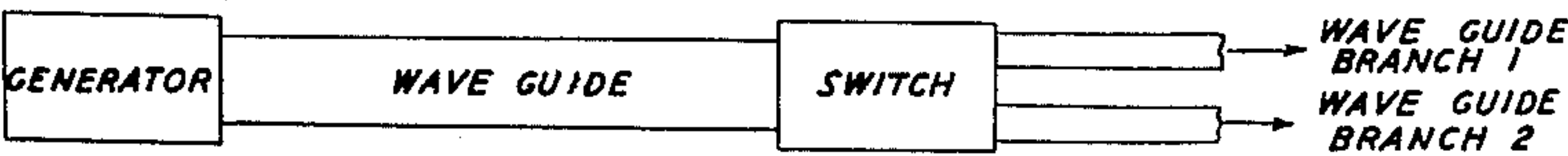


FIG. 5



INVENTOR
A. G. FOX
BY
Earl C. Laughlin
ATTORNEY

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A. G. FOX

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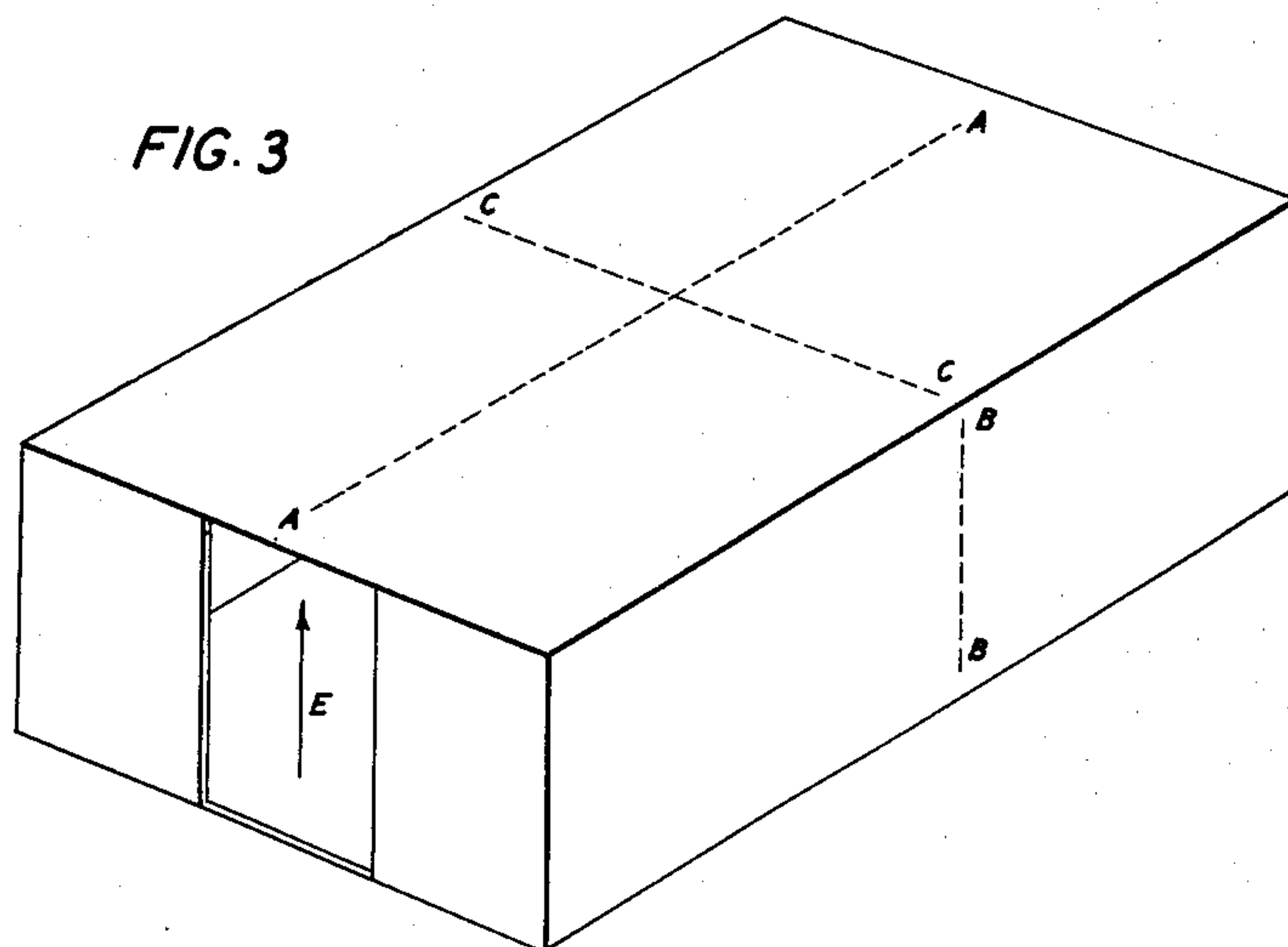
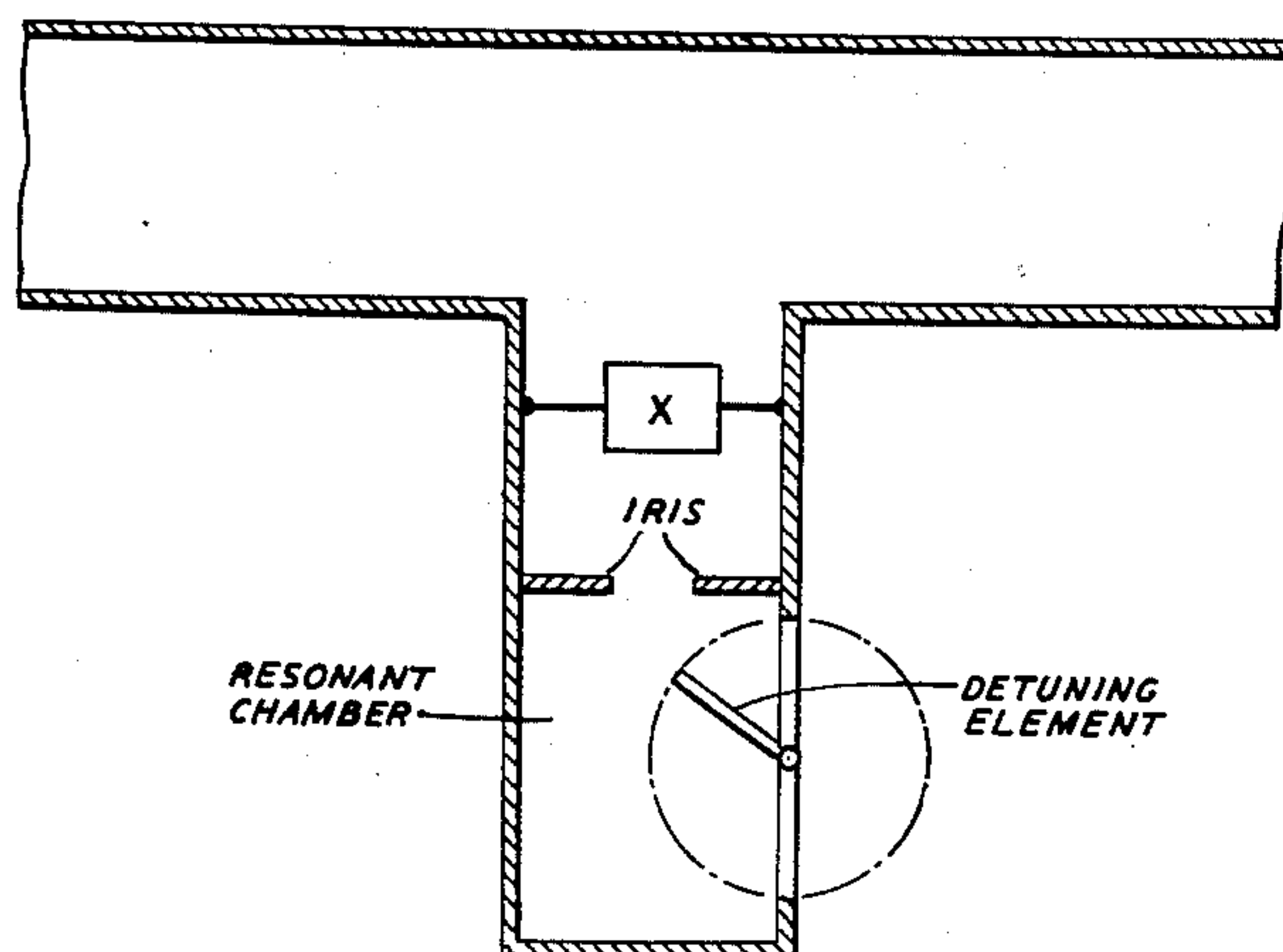


FIG. 4



INVENTOR
BY A.G. FOX
Earl C. Laughlin
ATTORNEY

March 5, 1946.

A. G. FOX

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FIG. 6

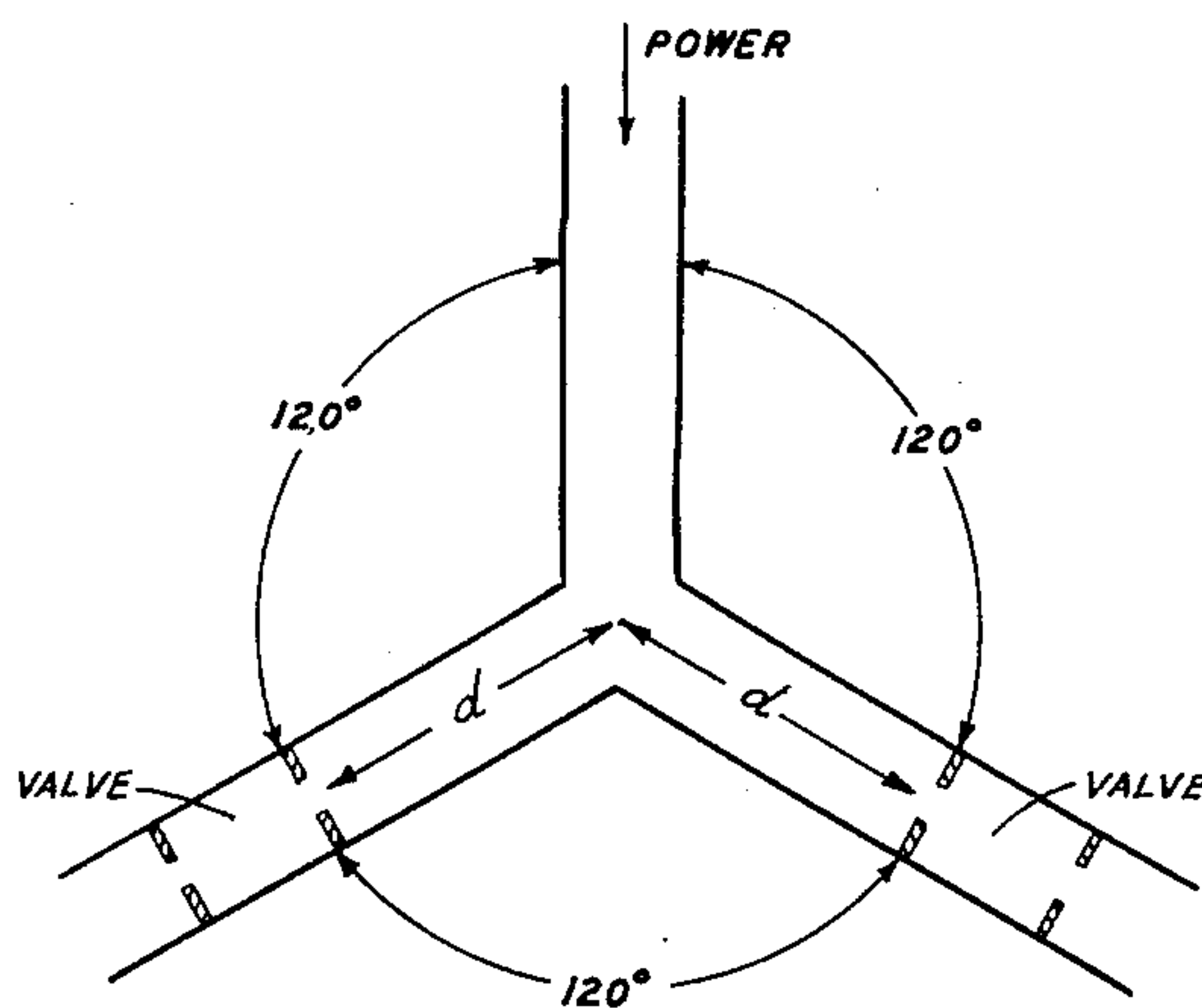
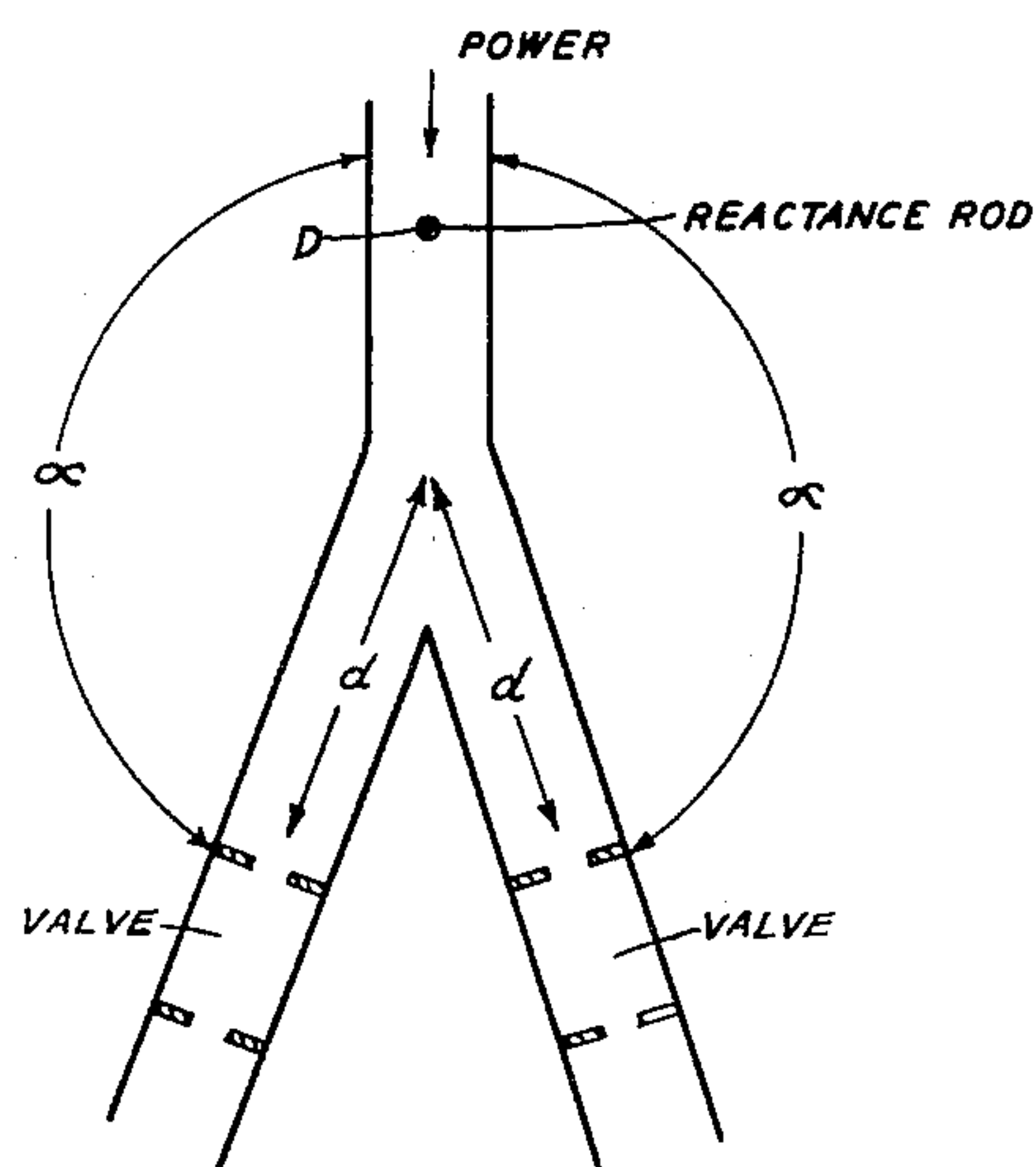


FIG. 7



INVENTOR
BY A. G. FOX

Earl C. Laughlin
ATTORNEY

March 5, 1946.

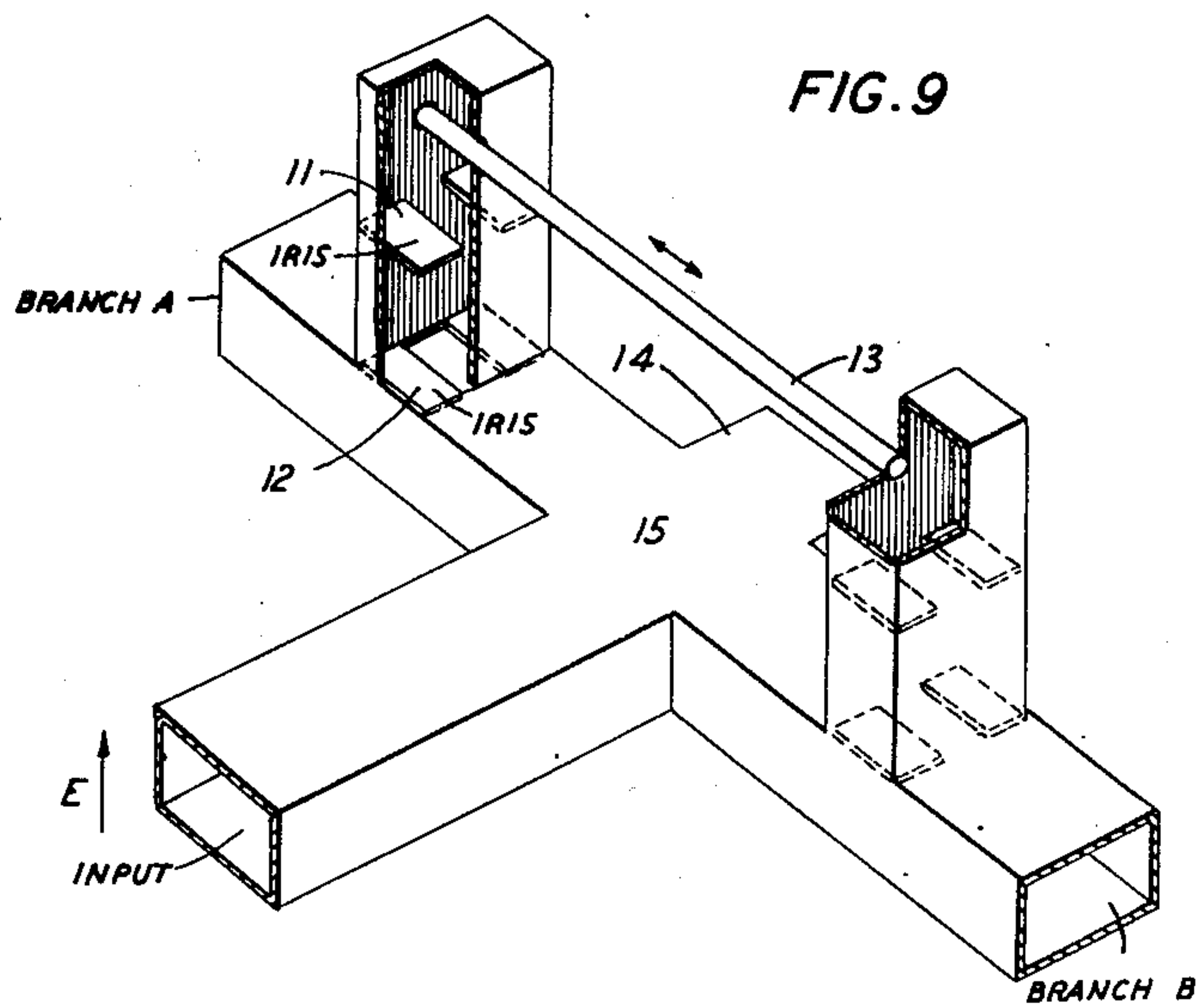
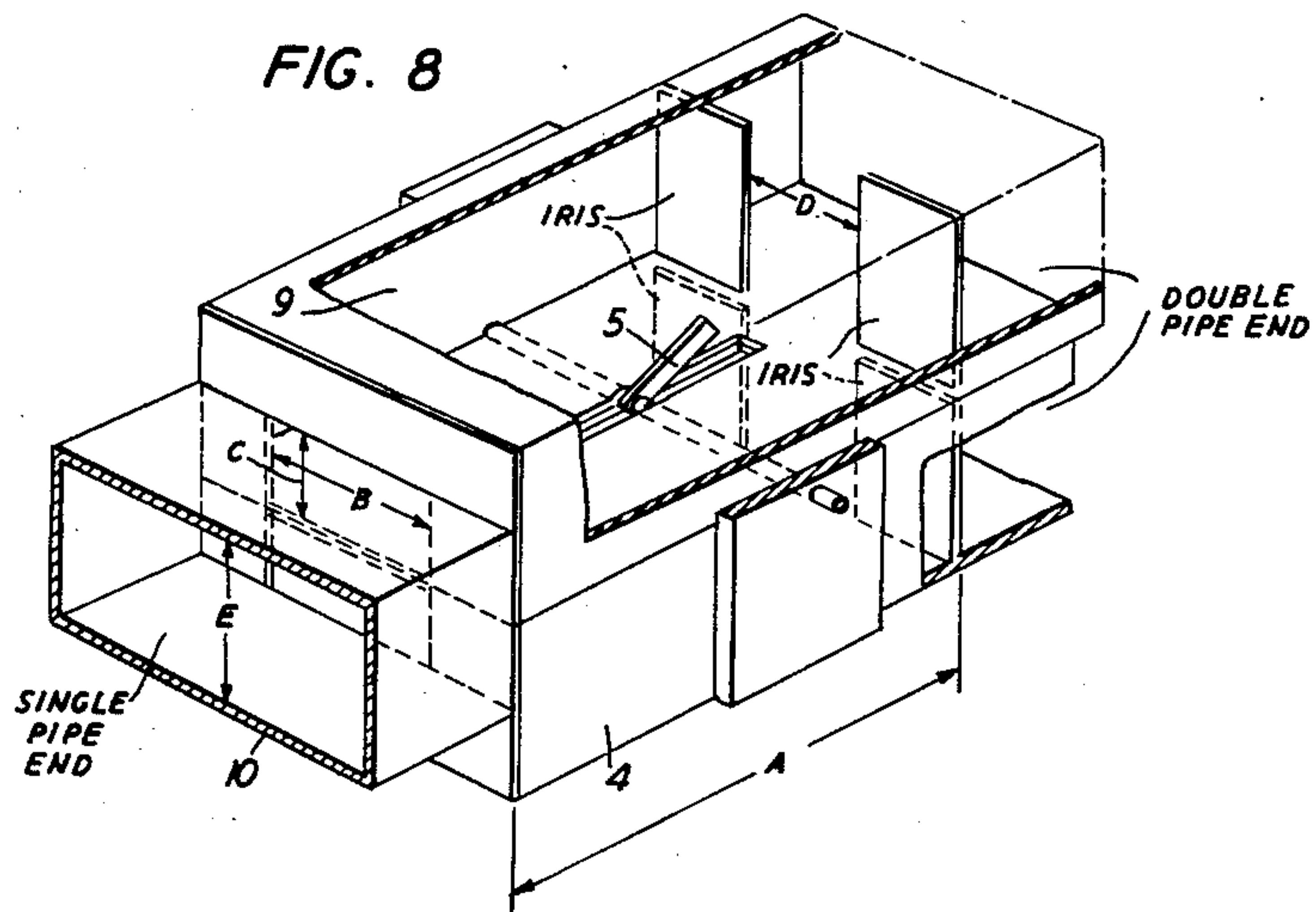
A. G. FOX

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INVENTOR
BY A.G. FOX

Earl C. Laughlin
ATTORNEY

March 5, 1946.

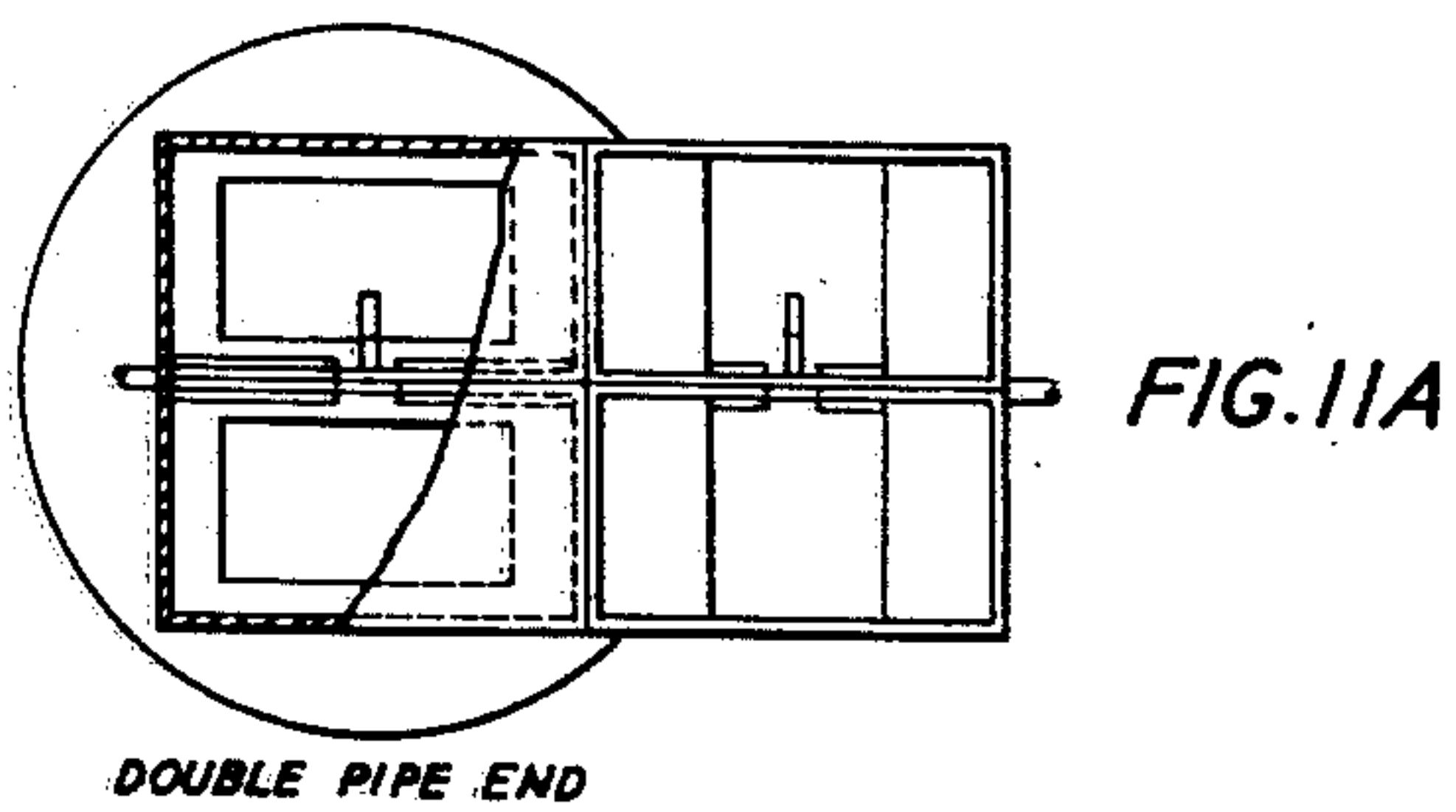
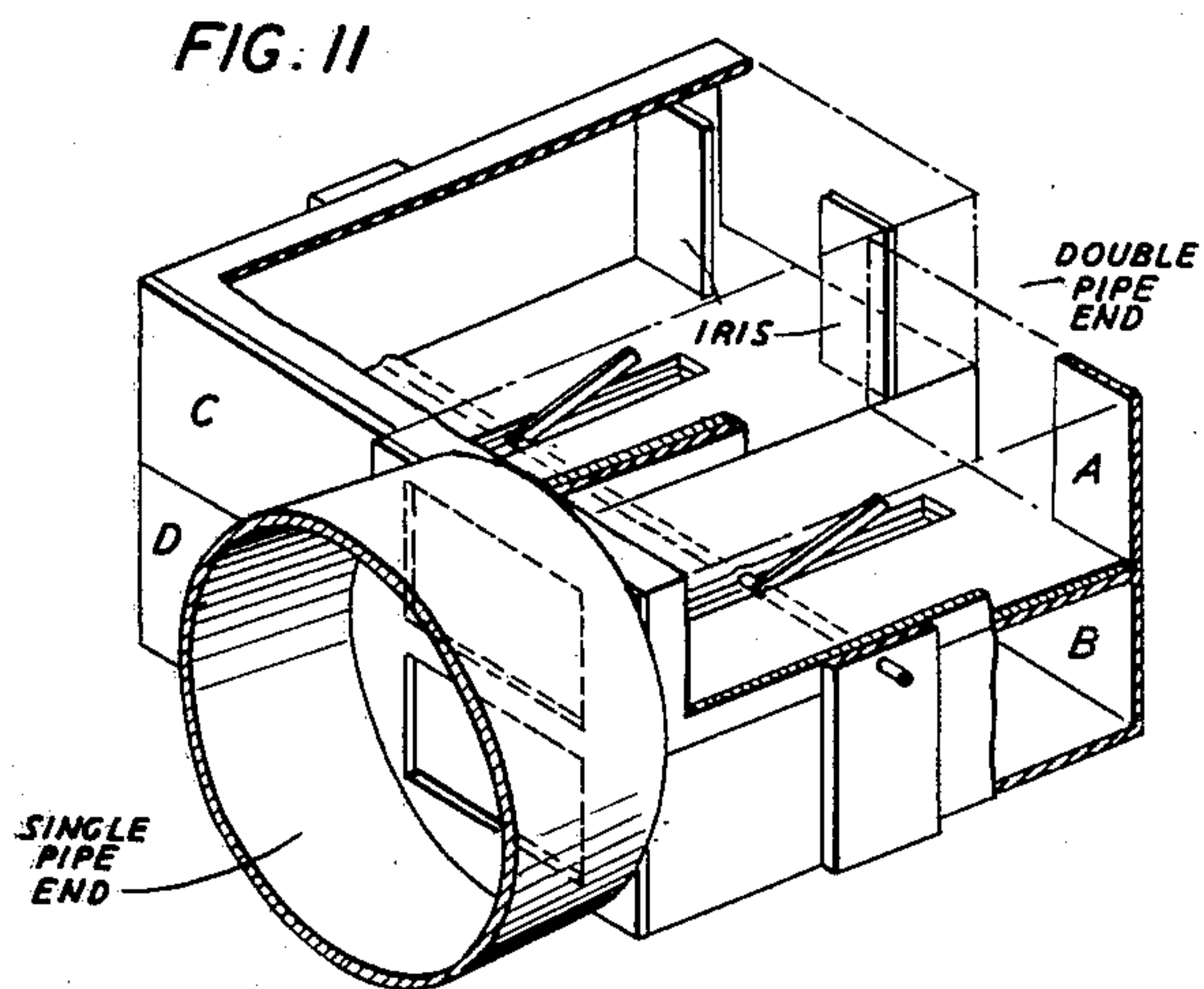
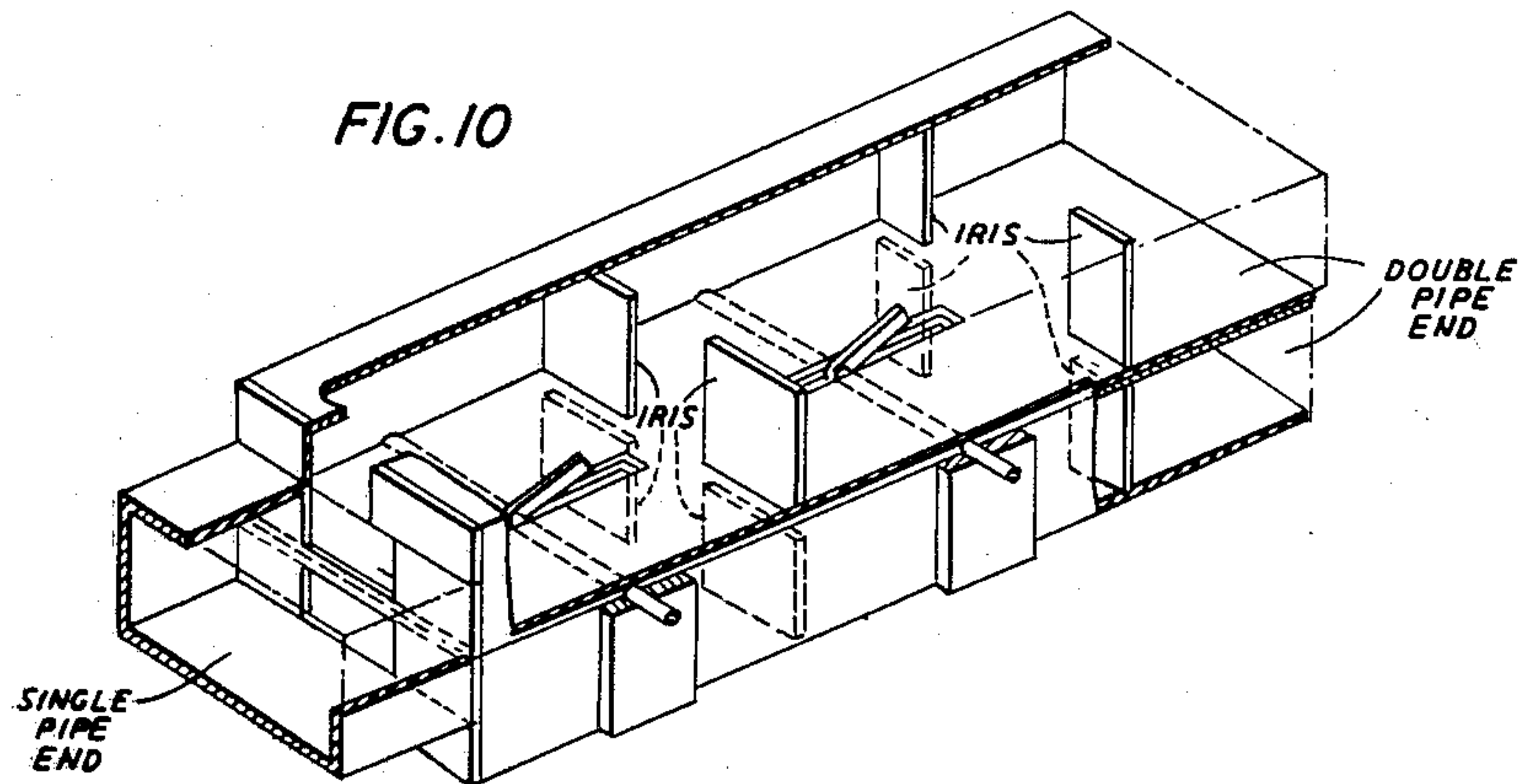
A. G. FOX

2,396,044

SWITCHING DEVICE

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7 Sheets-Sheet 5



INVENTOR
A. G. FOX
BY
Earl C. Laughlin
ATTORNEY

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A. G. FOX

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FIG. 13

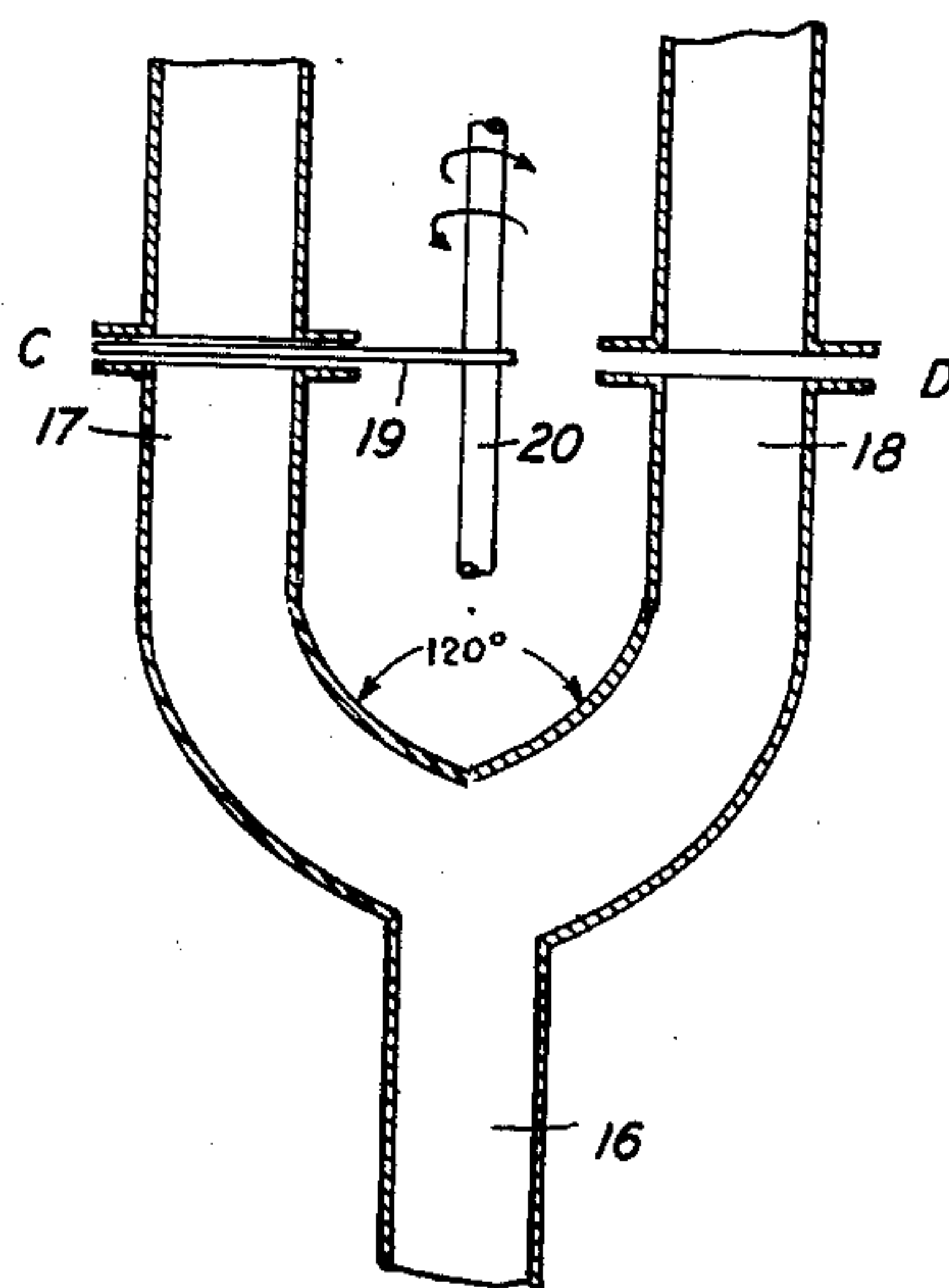
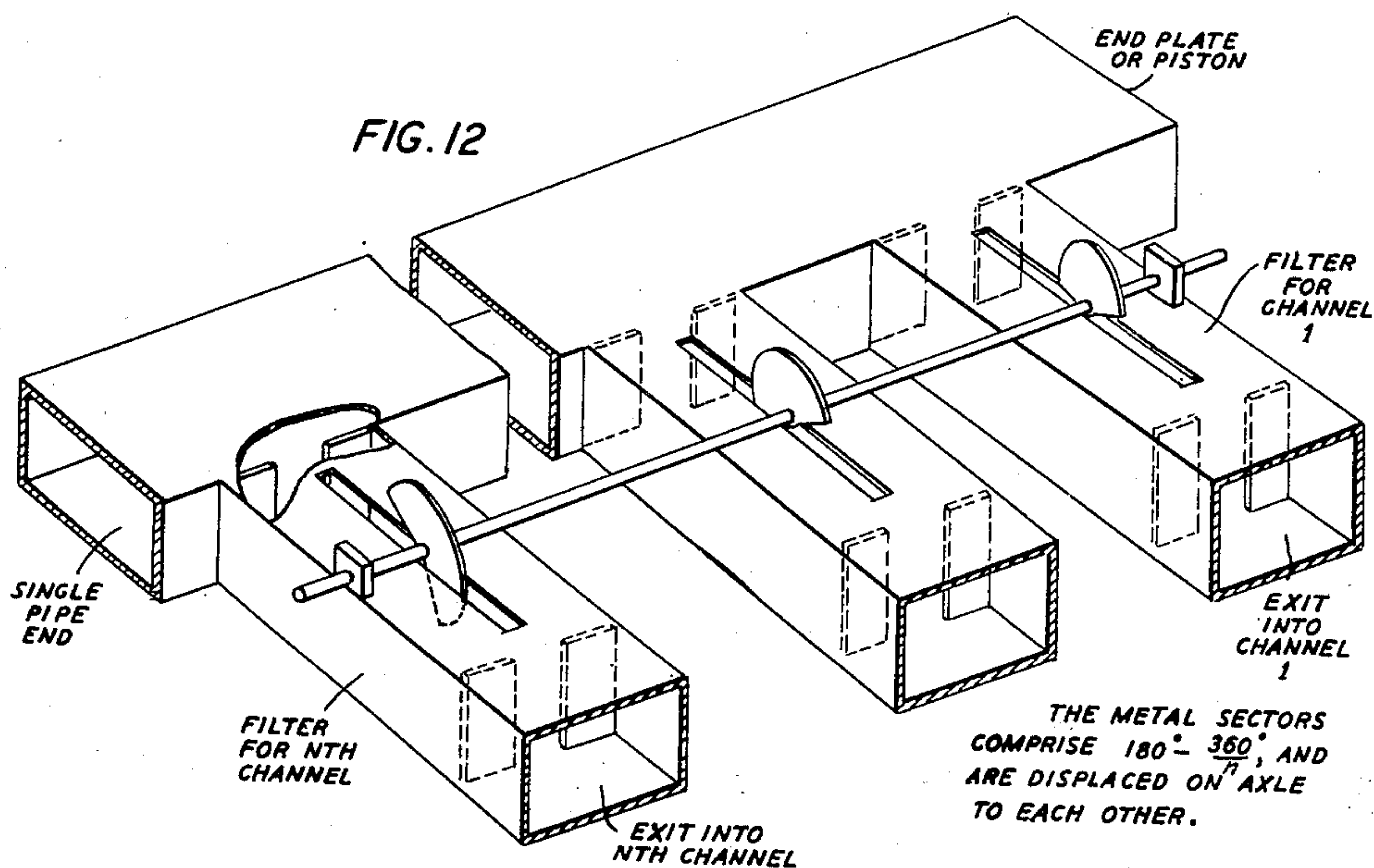


FIG. 12



INVENTOR
A. G. FOX

BY

Earl C. Laughlin

ATTORNEY

March 5, 1946.

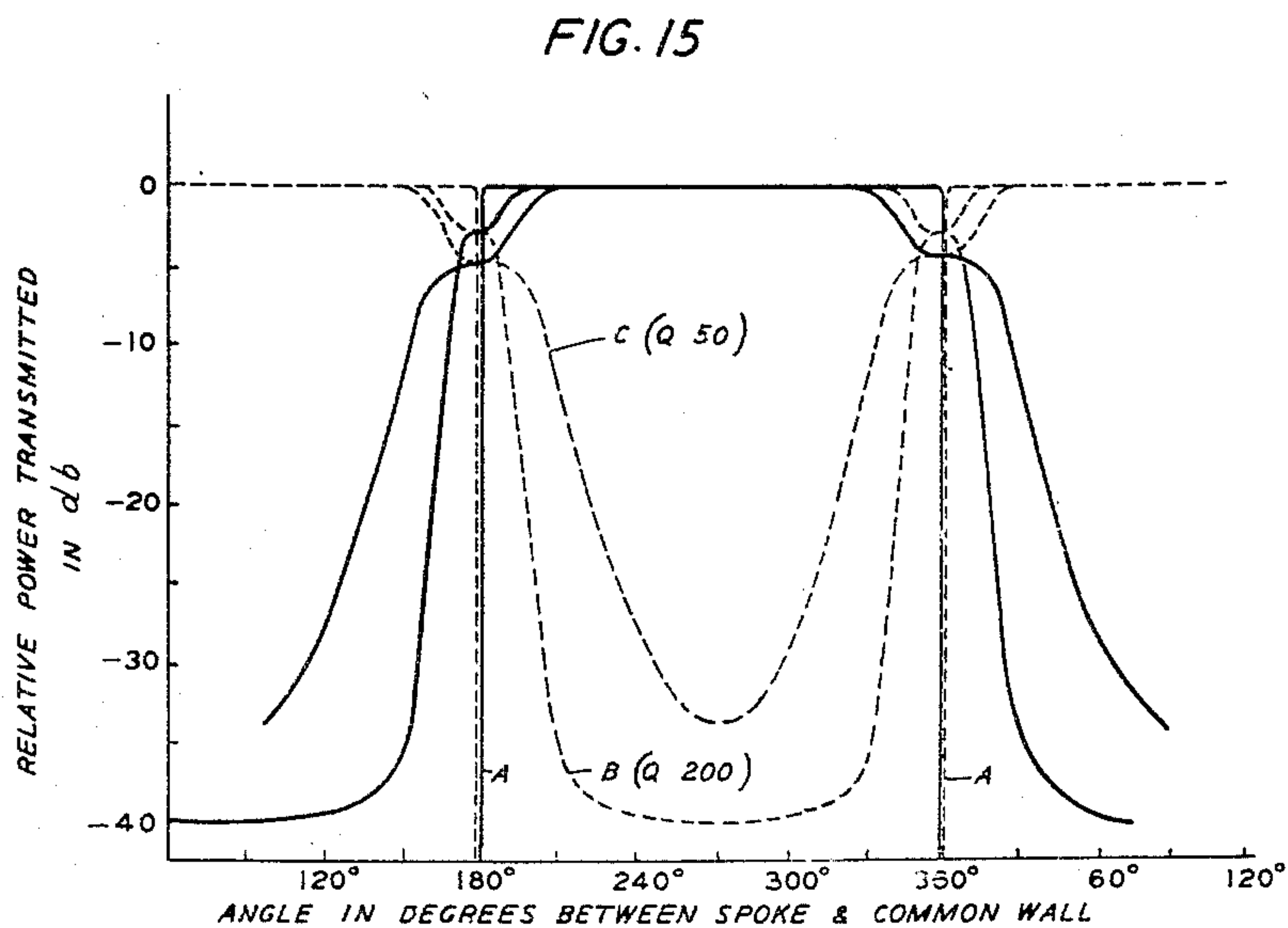
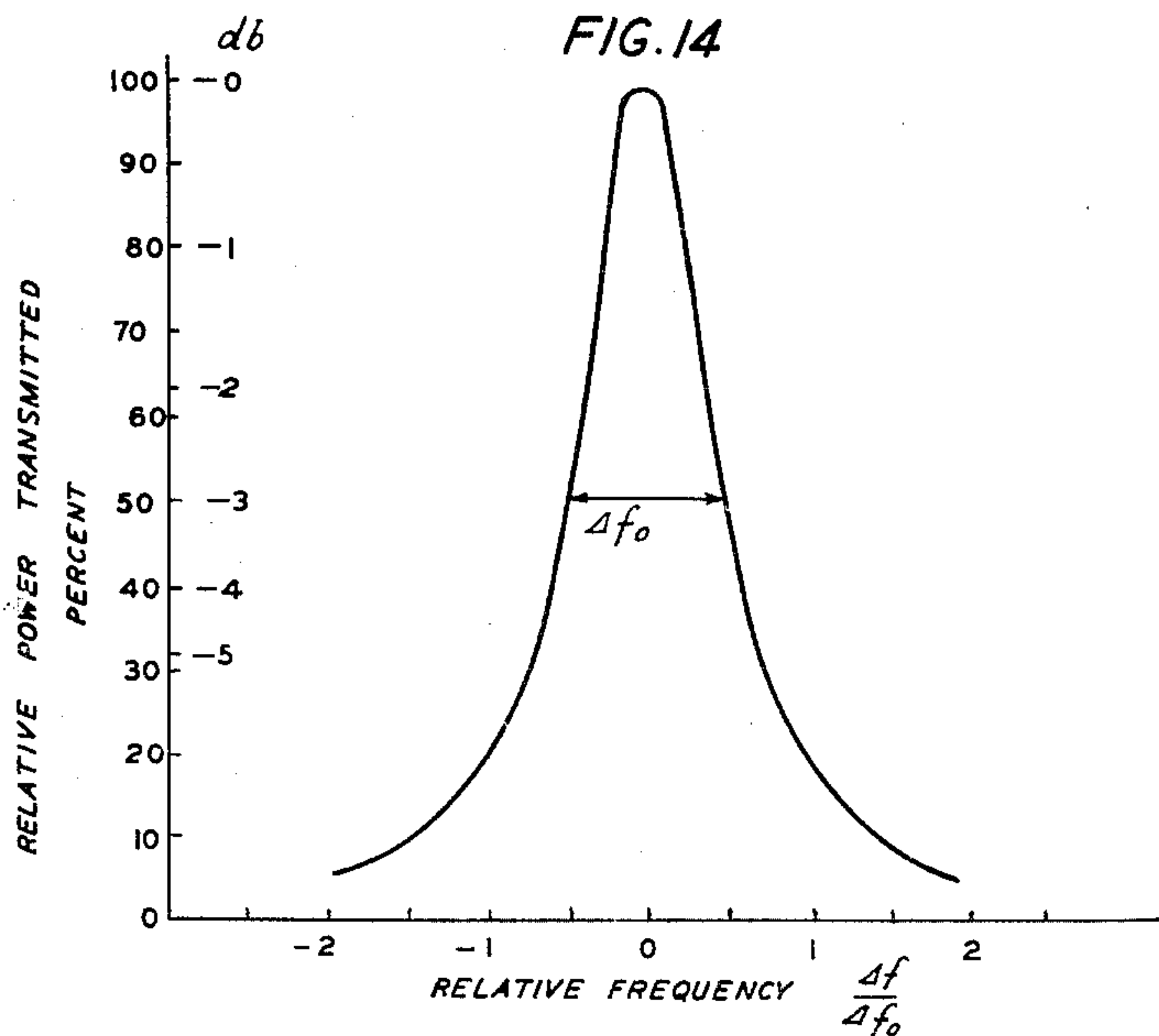
A. G. FOX

2,396,044

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INVENTOR
BY A.G. FOX

Earl C. Laughlin
ATTORNEY

UNITED STATES PATENT OFFICE

2,396,044

SWITCHING DEVICE

Arthur Gardner Fox, Fair Haven, N. J., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application December 10, 1941, Serial No. 422,408

9 Claims. (Cl. 178—44)

The invention relates to switching devices and particularly to switching devices for use in dielectric wave guide systems.

Objects of the invention are to control the flow of electromagnetic wave power in a dielectric wave guide system, and to switch the flow from one wave guide to any one of two or more other wave guides, in an efficient manner employing relatively simple and economical apparatus.

In accordance with the invention these objects are attained in part by the use of wave guide "valves" which operate either to allow wave power to pass over a guide without appreciable attenuation or to reflect substantially as much of the incident power as may be desired, one of these valves being placed in each branch wave guide of a dielectric wave guide system to control the flow of power through that branch. Also, the several wave guide branches with their valves are joined to the source of power through a suitable junction which will allow all of the incident power to flow into those branches in which the valves are open.

In one modification of the invention for accomplishing the above objects, a transverse cut is made in each wave guide branch and a metal plate is rotated first through the cut in one branch and then through the cut in the other branch. When the plate is inserted in the cut in one branch so as to completely separate one side of the wave guide branch from the other side, it operates as a piston to produce reflection of the incident wave power in that branch thus allowing transmission of the wave power through the other branch only.

In another modification of the invention, the control and switching operations are performed by valves comprising resonant chambers operating as filters in the several wave guide branches. These filters may be arbitrarily tuned or detuned so as to change the transmission efficiency of the respective branches and thereby redirect the flow of power. The tuning or detuning of the resonant chamber is effected by the insertion within the chamber at a suitable point of a conducting metal rod or vane. To obtain cyclic switching conveniently such a rod or vane may be rotated about an eccentric axis so as to be inserted through a slot in the wall of the chamber and withdrawn therefrom at a periodic rate. The slot required to produce entrance of the vane may be cut in the wall in certain places where the resultant leakage of energy through the slot will be negligible. The resonant chamber may also be arranged so as to allow the branch power to flow

directly through the filter during transmission, or may be placed so as to control the flow of power through the wave guide past the entrance of the chamber.

In one specific embodiment of the latter modification, the switching device is applied to a dielectric wave guide structure comprising two wave guide branches of hollow metal pipe fed with electromagnetic waves from the same source, such as another hollow metal pipe wave guide transmitting such waves. The switching device consists of adjacent resonant chambers in the two pipe branches, and a metal rod, vane or disc mounted on an axle, like a spoke on a wheel, so as to be rotatable through slots in the walls of the two chambers either in one chamber or in the other. The metal vane while passing through the resonant chamber in one wave guide branch detunes the chamber to an extent sufficient to substantially prevent transmission of the applied waves through that wave guide branch and when it passes outside the chamber allows the waves to pass with little attenuation through that wave guide branch.

The various objects and features of the invention will be better understood from the following detailed description when read in conjunction with the accompanying drawings in which:

Figs. 1 and 1A show respectively a perspective view of a known type of wave guide filter and sections of various types of irises which may be used in such a filter;

Fig. 2 shows a detuning arrangement in accordance with the invention applied to such a filter to form a wave guide switch;

Fig. 3 shows diagrammatically various places for locating the slot for inserting the detuning element in such a wave guide filter;

Fig. 4 shows a sectional view of an alternative type of wave guide switch in accordance with the invention;

Fig. 5 shows diagrammatically how the switching device of the invention would be applied for switching power in a wave guide system;

Figs. 6 and 7 illustrate different types of junctions for wave guide branches;

Figs. 8 to 13 show perspective, end or cross-sectional views of various wave guide switching arrangements in accordance with the invention;

Fig. 14 is a curve showing the transmission characteristics of a typical filter of the type shown in Fig. 2; and

Fig. 15 shows curves illustrating the switch-

ing characteristics of some of the arrangements shown in Figs. 8 to 13.

In the following description of the system of the invention, the discussion will be limited to the dominant transmitted waves in hollow metal wave guides, but it is to be understood that the general principles set forth may be applied as well to other wave types and other types of wave guides.

Inasmuch as the action of certain of the switching devices of the invention depends upon the detuning of wave guide filters, it is necessary to discuss briefly the construction and behavior of such wave guide filters. The simplest form of wave guide filter may be constructed by placing two appropriately spaced discontinuities in a wave guide. These discontinuities may take the form of irises, i. e., metal plates with holes of appropriate shape and size, placed across the cross section of the guide. Fig. 1 shows a perspective view of a simple filter of this type with a portion of the walls broken away to show the irises. The transmission characteristic of such a filter with respect to frequency is shown in Fig. 14. Fig. 1A shows sectional views of various types of irises which may be employed in this type of filter. The distance between the two irises in the filter of Fig. 1 determines the wave-length at which the filter resonates, i. e., allows the wave guide power to be transmitted with no loss due to reflection from the filter. This inter-iris distance is approximately one, two, or more, half wave-lengths (wave-length measured in the guide). The width of the transmission peak characteristics, Fig. 14, depends upon the size of the irises; the smaller the irises, the sharper the transmission characteristic.

It is also convenient to provide some means for changing the resonant frequency of such a wave guide filter. This may be done by using tuning screws, i. e., screws through the walls of the guide, so that a variable amount of the screw projects within the filter. For a filter of one half wave-length the most effective location for the tuning screws is halfway between the irises, through the wall in such a way as to be parallel with the lines of electric force.

Just as the tuning screws may be used to line up such a filter for optimum transmission at a given frequency, so also may they be used to detune a filter. If the detuning is sufficiently great, the transmission will be for most practical purposes, negligible. In such a case, the filter reflects almost all of the incident wave guide power. It constitutes, therefore, a stop to that flow of power, almost as effective as if a metal plate were placed completely across the cross section of the guide. The wave guide switches in accordance with the invention to be described depend upon the detuning of such filters. In practice, however, it is usually not convenient to effect the detuning by methods employing tuning screws as described above. They are of utility mainly for slight frequency trimming.

Fig. 2 shows in conjunction with a rectangular wave guide 1 employing spaced apertured irises 2 and 3 to provide a resonant chamber 4 forming a single unit filter which may have its tuning frequency initially adjusted to a desired value by means of tuning screws (not shown) as described above, an arrangement which has been found useful for rapid and frictionless detuning of the filter. This arrangement as indicated comprises a metal rod 5 attached as a spoke to the axle 6 extending through the resonant chamber 4 of the

wave guide, at some intermediate point, so that when rotated by rotation of the axle the spoke 5 may be made to enter the resonant chamber through the longitudinal clearance slot 7, to cause detuning of the filter to take place. For small angular penetrations, the principal effect of the spoke 5 is to shift the resonance peak with respect to frequency; for large penetrations, there is an additional effect, consisting of the introduction of a resistance loss so that the transmission is poor even at the resonant frequency.

There are three preferred places where a slot may be cut in the wall of such a resonant chamber with minimum resultant leakage, and these are shown diagrammatically in Fig. 3. Slots cut along the center lines at AA or BB should theoretically allow no leakage of power through the wall. A slot CC along a center line will result in some leakage, but for a high Q chamber this would be very small. Experiments have shown that for the case where the chamber was completely divided by a cut along CC and BB the transmission was still quite efficient. These experiments established that a metal plate inserted through the cut without touching the walls would completely detune the chamber. It is important that electrical contact is not required as this permits the use of rapidly rotating detuning elements involving a minimum of friction.

The detuning element specifically referred to above is a metal rod or vane which is rotated about some axis, and hence requires a slot in the wall of the chamber for admission. It is also possible to detune a chamber by inserting a metal rod longitudinally through a small hole in the wall of the chamber, and employing a simple reciprocating action to effect switching. The hole required would allow negligible leakage to take place no matter where it is cut in the chamber. This allows somewhat greater freedom of design, although in the interest of efficiency it is still desirable to place the rod at a voltage maximum.

Still another type of resonant chamber valve may be mentioned. In this case the power does not flow directly through the chamber but rather flows past the end of it, as shown in Fig. 4. In general it will be necessary to use such a chamber in conjunction with a shunt reactance X (which may be either an iris, tuned diametral wire, etc.), and the spacing between this and the junction aperture must be properly adjusted. The arrangement may be adjusted so that when the chamber is resonant, energy is allowed to pass down the main wave guide freely or, on the other hand, it may be adjusted to reflect energy. Then when the chamber is detuned the situation is reversed. In the latter case, energy will be transmitted only when the chamber is detuned.

Fig. 5 shows diagrammatically how any such resonant chamber switches or valves would be utilized for switching electromagnetic energy transmitted from a suitable source over one main wave guide between two or more wave guide branches.

If several wave guide branches are connected together at some point, it is necessary for each branch to present a certain impedance at the junction in order that the flow of power takes place down any particular branch. For example, in the case of parallel wire transmission lines connected in parallel at the junction, each non-conducting branch must look like an open circuit at the junction. If any of these does not present an infinite impedance, then reflection of

energy may take place from the junction even though one branch is perfectly transmitting.

In the case of wave guides the requirements are somewhat more general. It is obvious that each non-conducting branch must look like a pure reactance in order that no power is absorbed. This requirements is easily met provided the valve in that branch can be made totally reflecting. However, it is further necessary that the reactance presented have a specific value, and this will depend upon and partly determine the physical configuration of the junction.

In the case of a three-branch junction the simplest arrangement is the one shown in Fig. 6. For the 120° Y a total reflector in either branch can cause all the power to flow down the other branch providing the latter is freely transmitting and providing the distance d is properly adjusted so that the required reactance is presented at the junction. For other symmetrical Y's as shown in Fig. 7 it would be necessary to place a shunt reactance at an appropriate place in the common arm (at D). Other types of junctions are shown in Figs. 8, 9 and 12.

The switching system of Fig. 5 may comprise the arrangement of Fig. 2 combined with an additional similar filter 9 to form a wave guide switch, as illustrated in Fig. 8. For such a valve guide switch, it is convenient to place the two filters 4 and 9 in contact with a single slot in the contacting walls through which the spoke 5 may rotate. It is moreover, advisable to choose the spoke width equal to the double-walled thickness of the contacting walls of the two filters 4 and 9 so that as one edge of the spoke leaves one filter, the other edge enters the other filter. Electromagnetic waves of voltage E indicated by the vector so labeled are fed over the single rectangular wave guide or hollow pipe 10 to the hollow metal pipes including the filters 4 and 9.

The switch shown in Fig. 8 operates as follows: The two filters 4 and 9 are made identical and are designed (and trimmed with tuning screws, if desired) so that their transmission peak coincides with the frequency of the incident waves. The spoke will project into each filter during 180 degrees of axle rotation. For any given spoke position, therefore, except for the two positions in the common wall, one filter will retain its initial tuning so that it will pass the applied wave guide power, whereas the other filter, detuned by the spoke, will provide sufficient attenuation to substantially block the transmission of the applied wave guide power. In the single pipe 10 which connects to the filters 4 and 9, only one of the two irises will be "electrically open" at any given time. The other iris, beyond which is a detuned chamber, is "electrically closed" not in the sense that a metal plate has been effectively inserted across its cross section, but rather in the sense that the "closed" iris appears as a low shunt reactance across the end of the single wave guide. That is to say, an iris suitable for a filter is like a shunt reactance placed across a transmission line, with the shunt impedance low compared with the characteristic impedance of the line. This shunt reactance will constitute an effective short circuit unless it happens to be a part of a filter resonant at the fixed frequency of the incident waves.

It is to be noted that the general scheme of switching by means of detuning filters does not constitute any serious limitation upon the wave guide power level which may be transmitted. It is true that there is a voltage step-up within each filter and that, as the spoke is rotated into one of

the filters, for sufficient high power levels (e. g., 25 kilowatts) there will tend to be some formation of corona on the end of the spoke. Such corona will, of course, disappear as the spoke penetrates further into the filter. The fact, however, that the corona is taking place only in that filter which is desired to be detuned, i. e., inactive, means that the transmission through the other active filter is unimpaired. The only limitation is, therefore, imposed by the filters themselves. It is known, however, that the filters are usable at power levels of at least 25 kilowatts (peak) power.

If the detuning effect of the spoke were great even for extremely small angles of penetration, the switching characteristics would take the form shown as curve A in Fig. 15 where the transmitted power in decibels is plotted as a function of the angle between the spoke and the common wall through which it passes. Actually, however, the spoke is not very effective for a small entrance angle and, moreover, the lower the Q of the filter, the less effective is the spoke. Thus, the switching characteristics are actually of the form exhibited by the curves B and C of Fig. 15. The latter two curves represent the results of experiments with switches having filters of different Q 's.

For "slow" switching, i. e., where it is desired to switch the incident wave power into one of the two guides and to keep the power flowing through this one guide for a considerable period of time, the construction in Fig. 8 may be employed in conjunction with a toggle action mechanism (not shown) of any suitable type which will snap the spoke from a position (say at 45 degrees to the common wall) in one filter to the mirror image position in the other filter. For such an application, it is of little consequence how ineffective the spoke may be as it moves into a filter, provided that the filter is well enough detuned at the end of the stroke, i. e., in the "rest" position. Very low Q filters should be satisfactory, therefore, for "slow" switching.

For "rapid" switching, i. e., where it is desired to switch the wave power back and forth cyclically, possibly at a rapid rate, the axle in Fig. 8 may be rotated or vibrated at the cyclic rate. In this latter application, the effectiveness of the switching depends directly upon how effectively the spoke detunes as it enters the filter and, therefore, upon the switching characteristics such as shown in Fig. 15. If the character of the switching is the only factor to be considered, it is clear from Fig. 15 that the Q of the filters should be high. There are, however, situations where it is desired to secure a switch with a broad frequency response; in such cases, the choice for the Q of the filters must be a compromise.

The side arm type of resonant chamber shown in Fig. 4 may be used as a switching element in connection with any of the branching schemes herein described. Fig. 9 illustrates one particular application involving the use of a T junction of an input wave guide with two colinear wave guide branches A and B, a side arm including a resonant chamber joined to each of the latter branches by a T junction and a reciprocating rod for detuning the resonant chambers. Iris 11 forms one boundary of the resonant chamber. Iris 12 is used as the reactance X shown in Fig. 4. The metal rod 13 slides back and forth into first one and then the other of the two chambers. Its length is such that as it just leaves one chamber, it just enters the other, so that only one is detuned at any instant. The junction here shown is a special case of the junction shown in Fig. 7

where the reactance there shown at D is replaced by the wave guide stub 14. The length of this stub and the distance of the side arms from the junction 15 must be adjusted so that when one branch is completely reflecting, all of the power will be directed down the other branch. The resonant chambers are shown connected through the top walls of branches A and B. It is, of course, also possible to connect them through the side walls.

If two of the single wave guide filters, tuned to the same frequency, are suitably coupled, a band-pass filter is obtained. A suitable coupling may consist of placing the filters together with adjacent irises in contact and then in replacing the two adjacent irises by an iris of considerably smaller size. Fig. 10 shows such a wave guide switch involving two such band-pass filters. In this arrangement, two axes, each with a spoke, are provided and are to be rotated or vibrated in unison so as to detune simultaneously both units of either filter. Compared with the switches of Figs. 8 and 9, the use of band-pass filters will give the advantage of a broad response without sacrificing the sharpness of the switching.

Figs. 11 and 11A (end view) show a modification of the wave guide switch of Fig. 10, the main change being that the two parts of each filter are coupled by an aperture in a common side wall. This arrangement allows the detuning to be effected by two parallel spokes mounted on a single axle as shown. It may be stated, in general, that arrangements such as shown in Figs. 10 and 11 may be readily designed to give essentially flat transmission over a band of 1 per cent of the frequency with a switching sharpness which could be attained with the arrangement of Figs. 8 and 9 only with a high Q filter.

Filters of even greater complexity, i. e., with three or more chambers may be used to construct wave guide switches with still broader frequency response and sharper switching than with switches with double-chamber filters. The form of such multichamber filter, double switches can be visualized as an extension of the arrangements of Figs. 8 to 11.

Wave guide switches which will switch a flow of wave guide power from one guide to any one of several guides may readily be constructed by a tandem combination of any of the arrangements already described for switching from one guide to either of two guides.

Multiple wave guide switching can also be accomplished by causing all of the branches to join the main wave guide at a common junction. For example, instead of the two irises shown in the end wall of the guide, three, four, or more irises may be placed in the end wall and open into their respective filters or branches. Another possibility is the one illustrated by Fig. 12 in which the front irises of the resonant chambers (used as valves) open directly into the main guide through the side walls. The operation of the switch of Fig. 12 is as follows: For any given position of the axle, all the filters are detuned except one. This one "open" filter, in conjunction with the plate (or piston) at the end of the feed pipe, constitutes a termination in characteristic impedance for the feed pipe. The filters are spaced one half wavelength apart along the feed line and approximately an odd number of quarter wave-lengths from the end plate. In this way each of them, when not detuned, presents the same impedance and, therefore, can terminate properly the feed pipe.

Fig. 13 shows diagrammatically a modified wave guide switching system in accordance with the invention employing valves which do not employ resonant chambers, for switching electromagnetic wave energy transmitted over the main hollow metal wave guide 16 into either one of the two hollow metal wave guide branches 17 and 18 symmetrically connected to the main wave guide 16. The wave guide branches 17 and 18 are cut transversely at the points C and D equidistant from the junction with the main wave guide. A metal plate 19, which may be a semicircular disc, is rotated about an axle 20 so as to be periodically inserted through the transverse cuts first into one branch guide 17 and then in the other 18. If the junction is properly designed (i. e., 120 degrees between branches) the plate can be assumed to act as a piston and for a given position across the cross section of the guide will completely separate the lower part of a wave guide branch from the other and thus produce complete reflection of power from the point C or D. When this takes place in one wave guide branch, substantially all of the wave energy from the main guide 16 will pass over the other wave guide branch from which the plate 19 is withdrawn. There will be some leakage of energy from the gaps in the wave guide branches where the plate is inserted and this will result both in attenuation of power during transmission and in incomplete reflection of energy during reflection. This leakage may be greatly reduced by placing metal flanges on the ends of the wave guide branches at either side of the gap, as shown.

The above discussion and the various figures of the drawings present only a few of the simplest variations of wave guide switches. It must be emphasized that the number of varieties of wave guide switches which could be constructed in accordance with the principles set forth is virtually unlimited. These varieties could be obtained by varying (1) the number of chambers for each filter, (2) the number of filters used, i. e., the number of channels among which the switching takes place, (3) the frequency response, i. e., both the resonant frequency and the band width, (4) the geometry according to which the various filters are arranged, and (5) the mechanical arrangements for detuning the filters. From the above discussion of principles and the simpler forms, it will be apparent to any one skilled in the art how to construct these more complicated forms.

This application discloses subject-matter relating to filter structures which is being claimed in my copending United States patent applications, Serial Nos. 614,936 and 614,937, filed September 7, 1945, which are continuations in part of this application and divisions of my copending United States patent application, Serial No. 452,851, filed July 30, 1942.

What is claimed is:

1. In combination, a dielectric wave guide structure comprising a hollow metal pipe fed from a source of wave energy and a plurality of symmetrical hollow metal pipe branches leading therefrom, a transverse cut through the walls of each of said pipe branches, and a metal plate rotatable on an eccentric axis first through the cut in one branch across the cross section thereof and then through the cut in another branch across the cross section of the latter branch, said plate when rotated to a given position within one branch and out of another branch substantially preventing transmission of said wave energy over

said one branch while allowing its transmission with little attenuation over said other branch.

2. In combination, a dielectric wave guide, means for impressing electromagnetic wave energy of a given frequency on said wave guide for transmission thereover and switching means for controlling the transmission of said wave energy over said wave guide comprising a resonant chamber in said wave guide tuned to said frequency, and a metallic member rotatable through said chamber, which in one position detunes said chamber sufficiently to substantially prevent transmission of said electromagnetic wave energy over the guide, and in another position maintains the tuning of said chamber to allow the transmission of said wave energy over said guide with little attenuation.

3. In combination, a dielectric wave guide structure comprising a main metallic pipe and a plurality of metallic pipe branches leading therefrom, means for transmitting electromagnetic wave energy of given frequency over said main pipe to said pipe branches, and means for switching the electromagnetic wave output of said main pipe into any of said branches and effectively excluding it from other branches comprising a resonant chamber in each branch, tuned to said given frequency and a metallic switch member movable through the chamber in each branch, which in one position detunes the chamber sufficiently to substantially prevent transmission of the applied energy through that branch, and in another position maintains the tuning of the chamber so as to allow transmission of the applied energy through the branch with little attenuation.

4. In combination, a source of electromagnetic waves of a given frequency, a hollow metal pipe wave guide supplied with said waves, irises in said wave guide spaced from each other at such a distance as to form in said guide a chamber resonant to said frequency, a slot in the wall of said chamber between the irises, a metal vane rotatable through said slot in and out of said chamber, said vane when it projects into said chamber a given degree operating to detune the latter sufficiently to prevent substantially any of the supplied wave energy from passing there-through over said guide, and when it is rotated outside said chamber restoring the tuning of the latter to allow transmission of the supplied wave energy over the guide.

5. The combination of claim 3 in which the metallic switch members for the resonant chambers in certain of said pipe branches are interconnected so that when the switch member in one or more of said resonant chambers is moved to the tuning position the switch member in one

or more of the other resonant chambers is moved to the detuning position.

6. The combination of claim 2 in which said dielectric wave guide includes at an intermediate point a branch portion at right angles to the main wave guide, including said resonant chamber and a reactance element of proper value in shunt with said branch portion, said chamber and said reactance element being properly spaced from each other and the junction of said branch portion with the main wave guide so as to respectively prevent and allow the transmission of said wave energy over said guide past the end of said branch portion for the detuned and tuned condition of said chamber, respectively.

7. The combination of claim 3 in which each of said pipe branches includes at an intermediate point symmetrically located with respect to the junction of the branches with the main pipe, a portion at right angles to the pipe branch, including the resonant chamber for that branch and a shunt reactance element of the proper value properly spaced with respect to each other and the junction of the right angle portion with the pipe branch, so that the tuning of the chamber to said frequency allows the transmission of the wave energy from the main pipe over that branch past the end of the right angle portion therein, and the detuning of that chamber substantially prevents the transmission of the wave energy over the branch past the end of the right angle portion, the switch members controlling the tuning and detuning of the several resonant chambers being so related that when one chamber is tuned the others are detuned thereby allowing transmission of the wave energy from the main pipe over only one pipe branch at a time.

8. The combination of claim 4 in which said hollow metal pipe wave guide includes at an intermediate point a branch portion at right angles to the main guide including said resonant chamber and another iris in shunt with said branch portion between said chamber and the junction between said branch portion and the main guide, said other iris and said chamber being spaced proper distances from each other and said junction so that when said chamber is in the detuned condition substantially all of said wave energy is transmitted over said wave guide past the end of said branch portion and when said chamber is in the tuned condition substantially none of the wave energy is transmitted over said guide past said end of said branch portion.

9. The combination of claim 1, in which the angle between said pipe branches at the junction with said hollow metal pipe is 120 degrees.

A. GARDNER FOX.