

Feb. 17, 1953

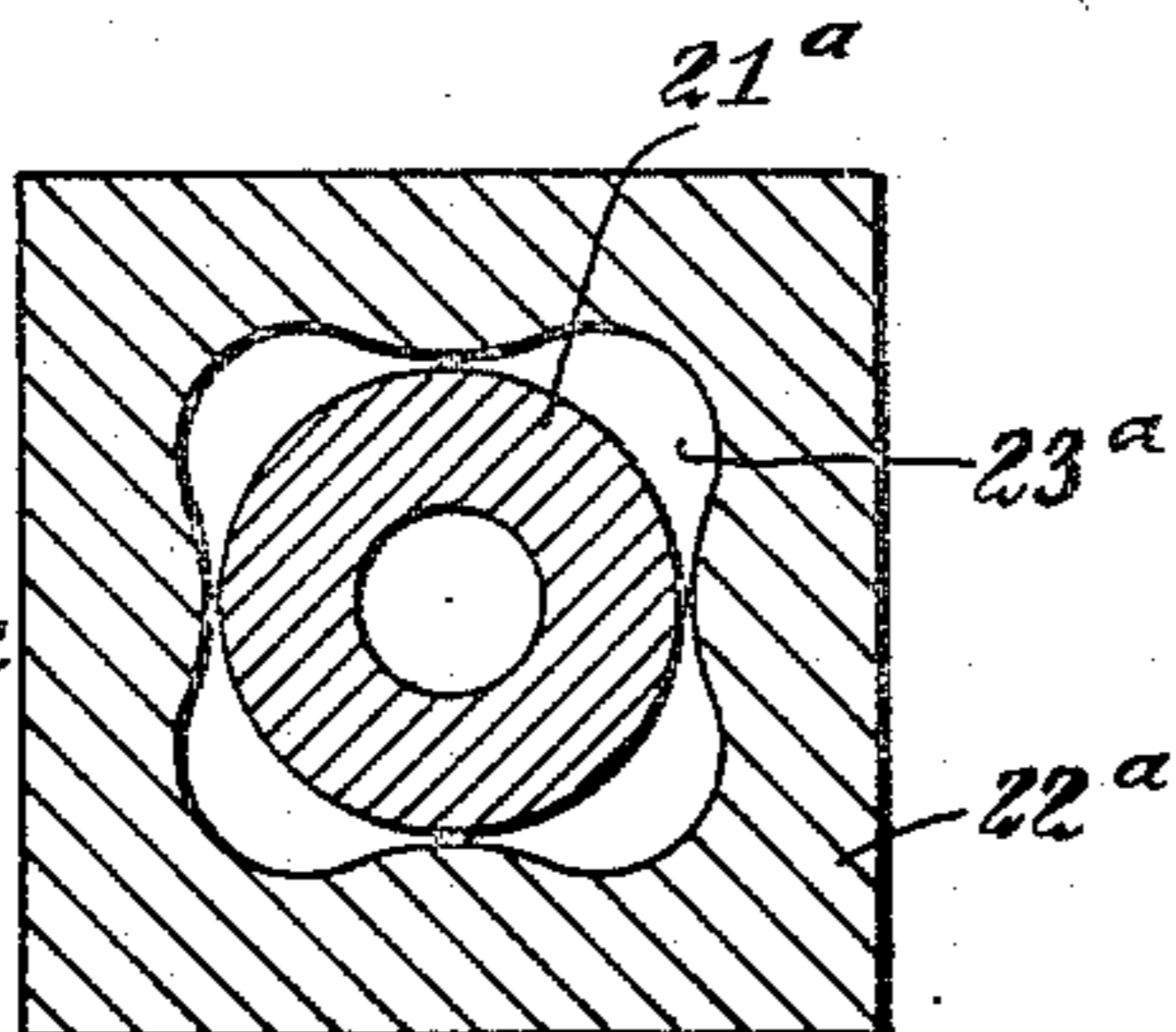
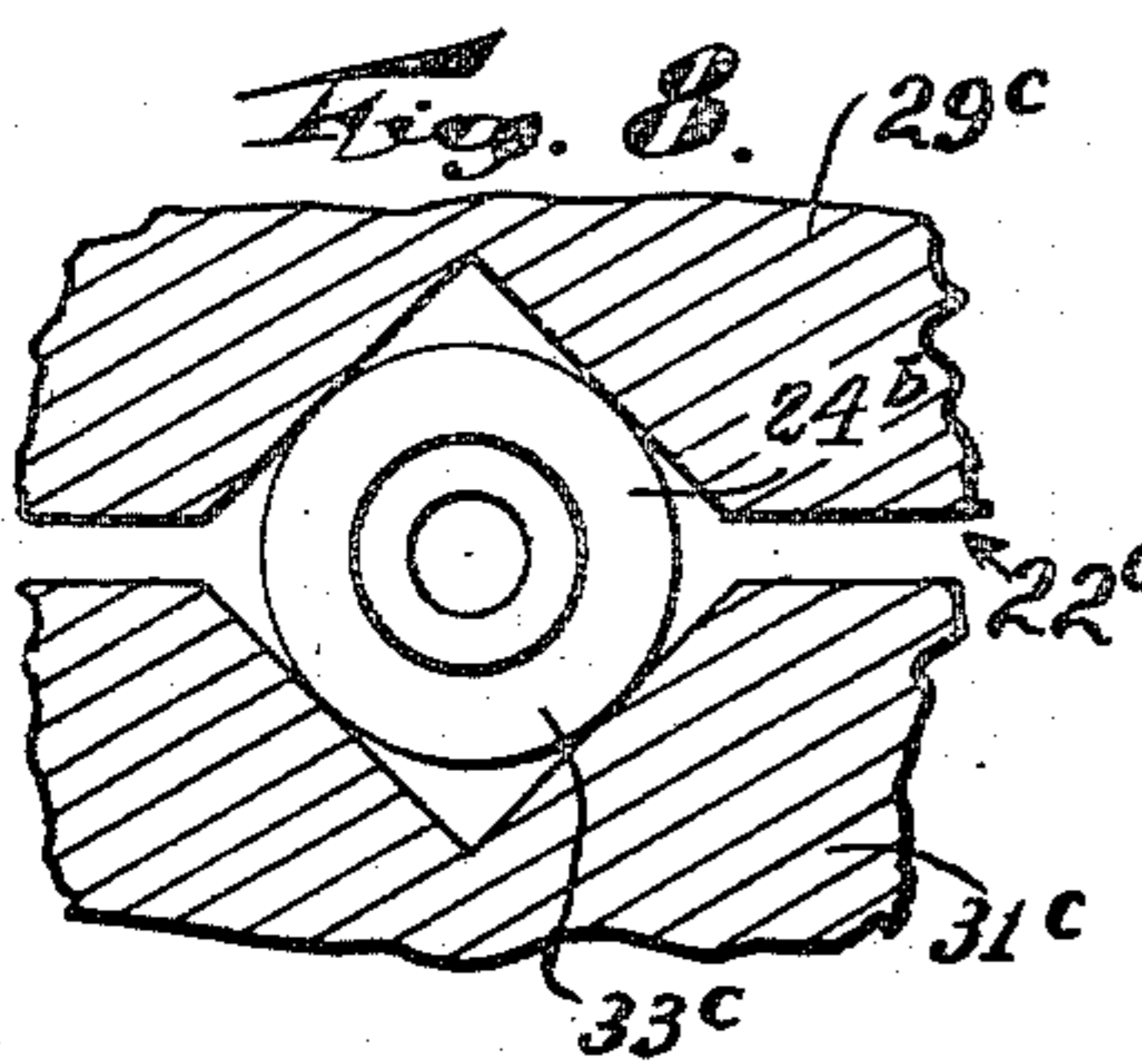
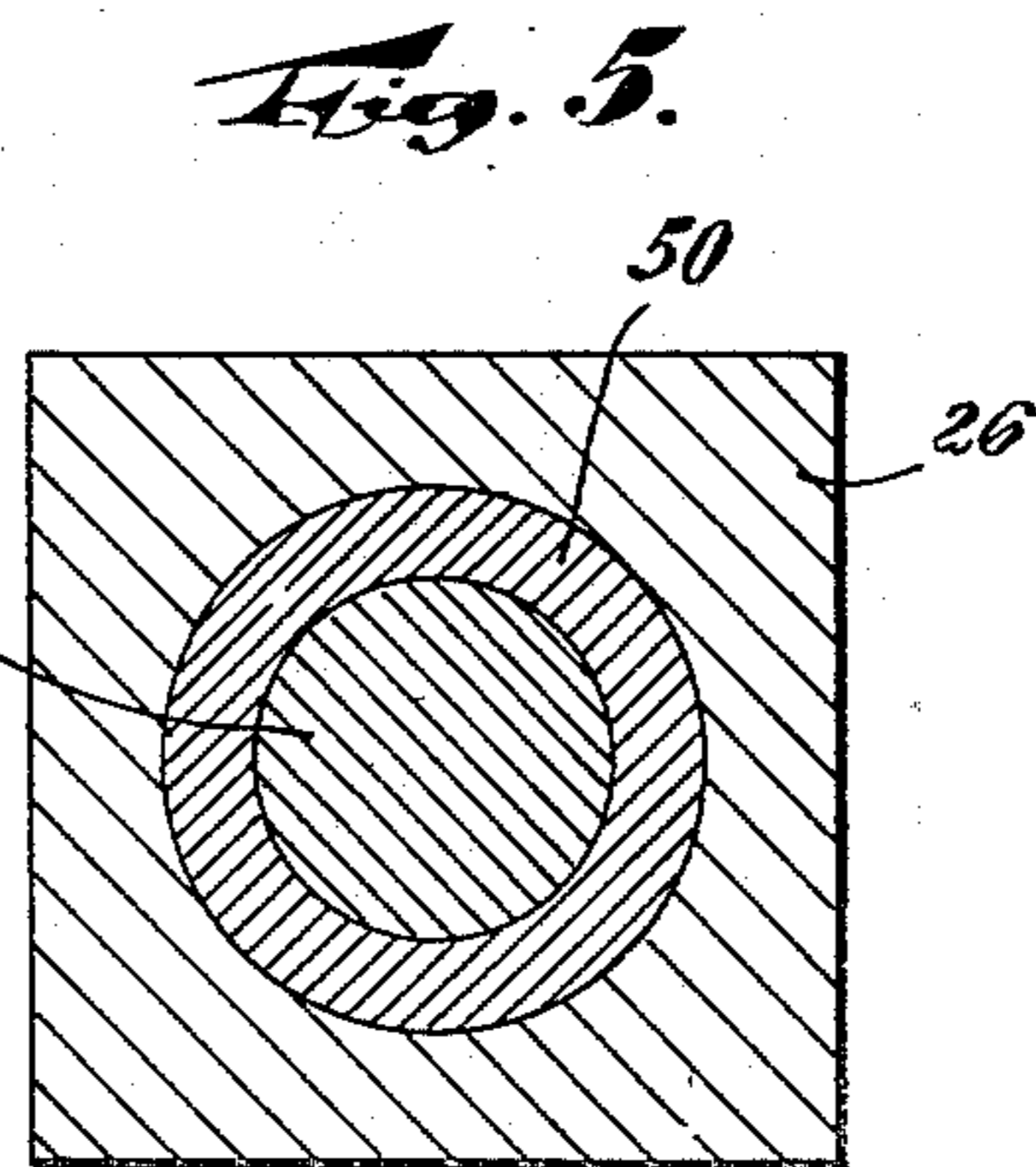
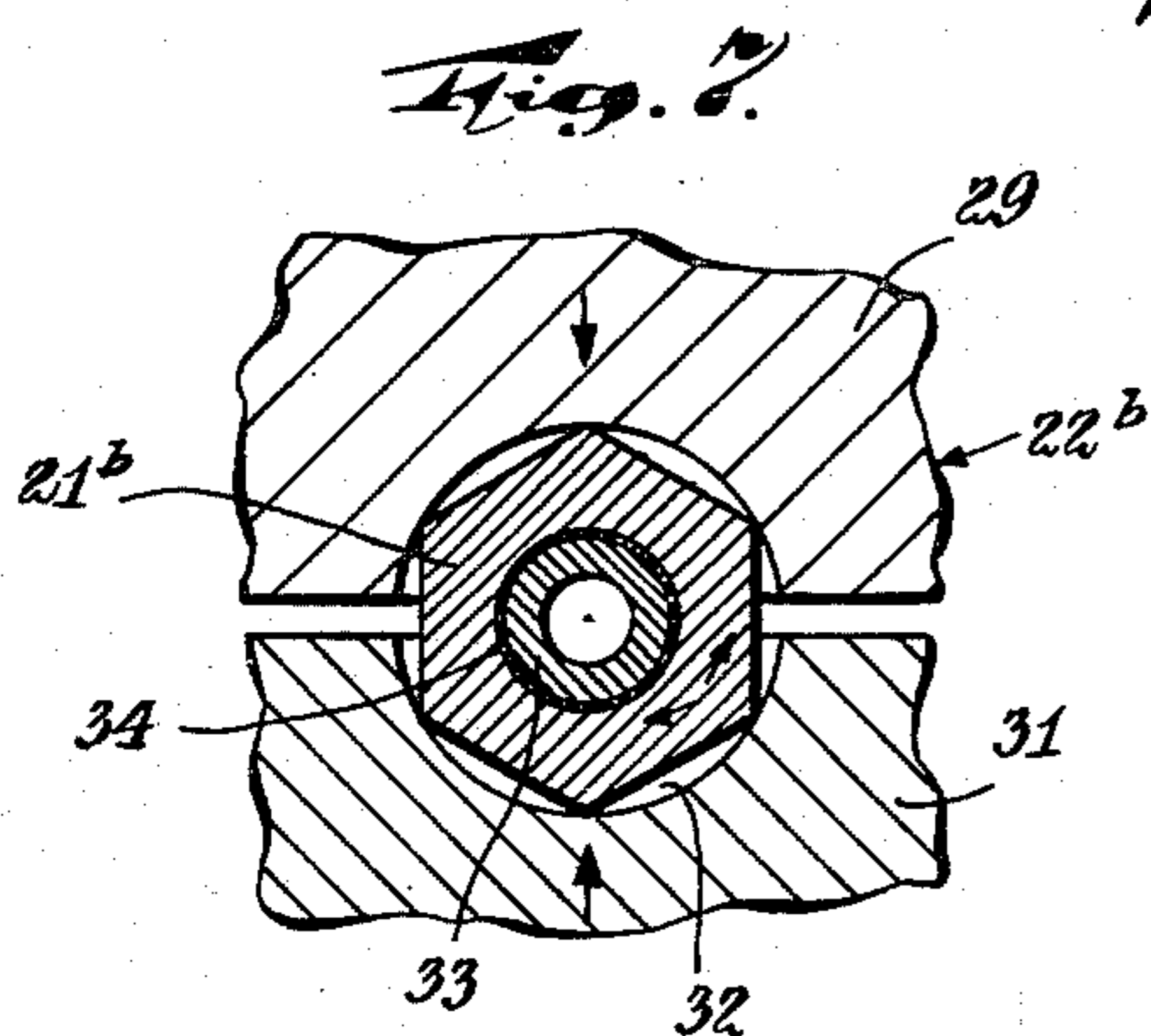
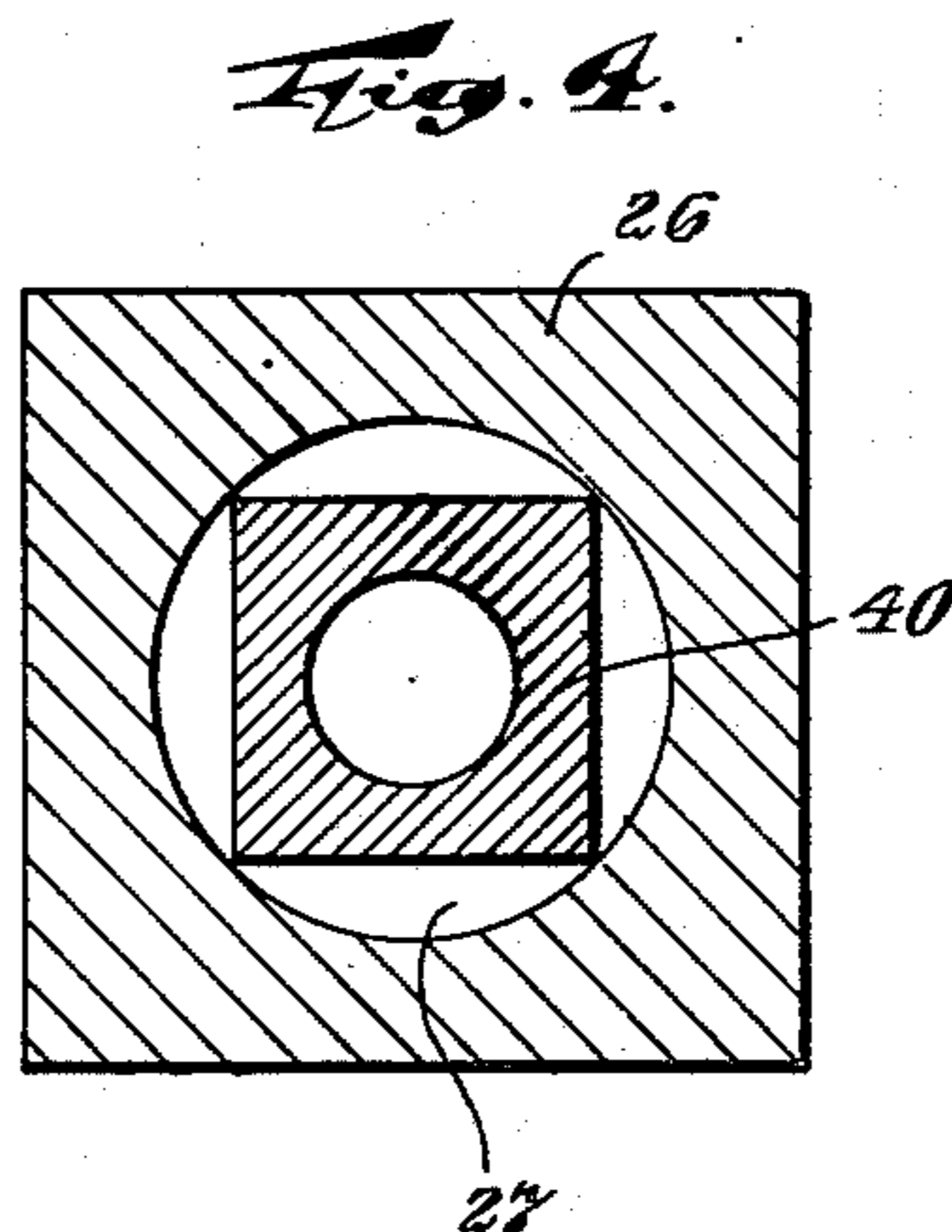
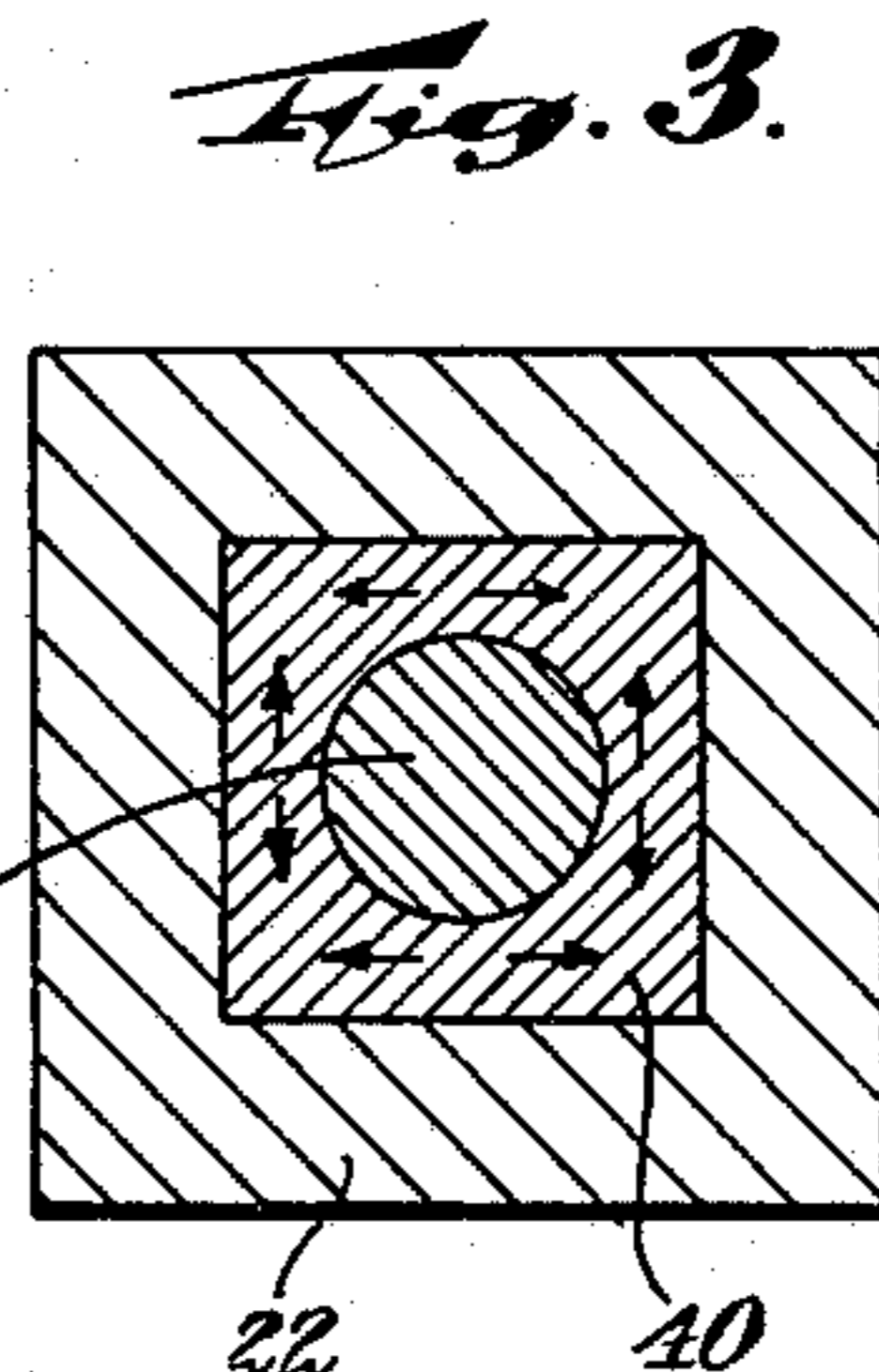
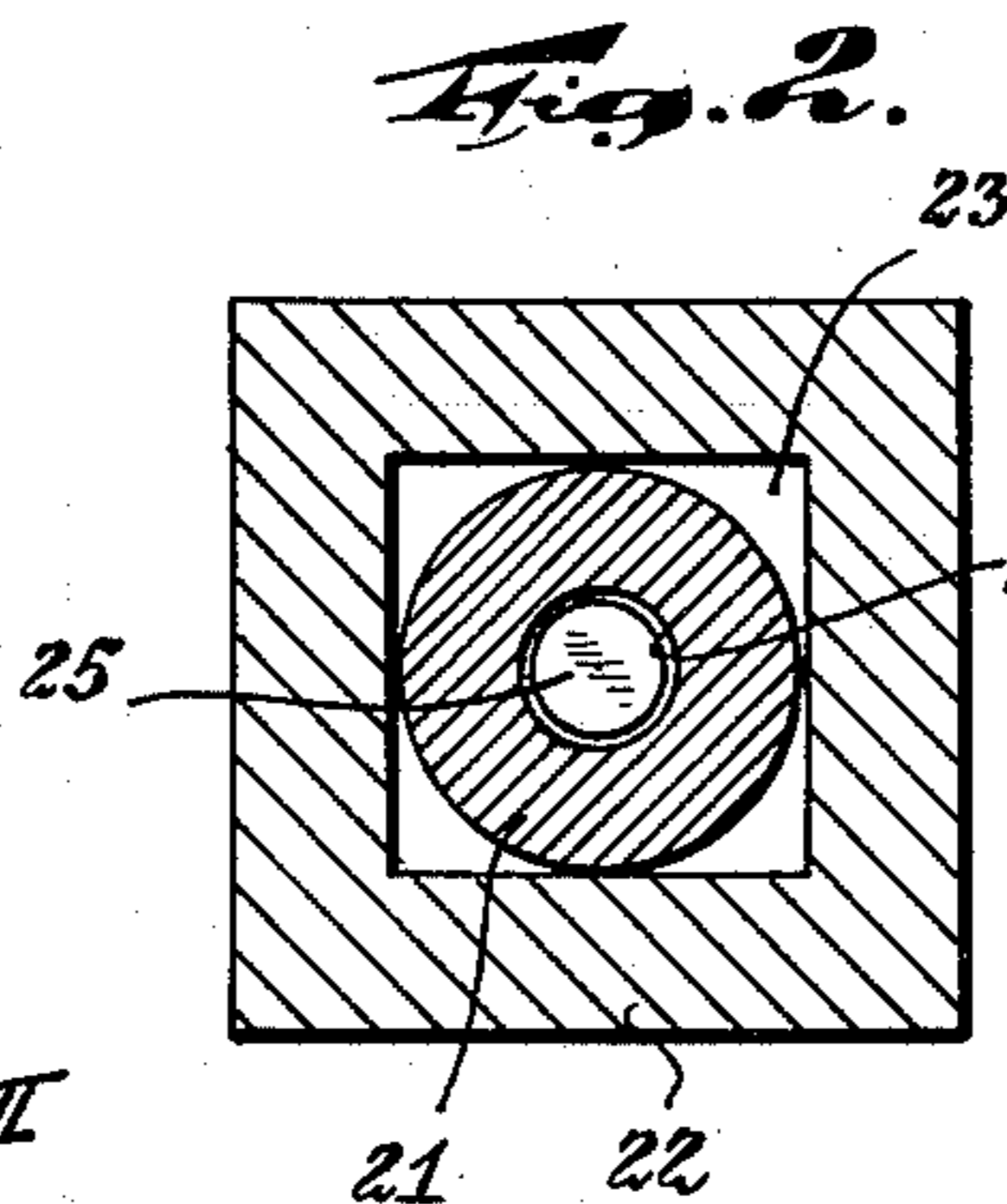
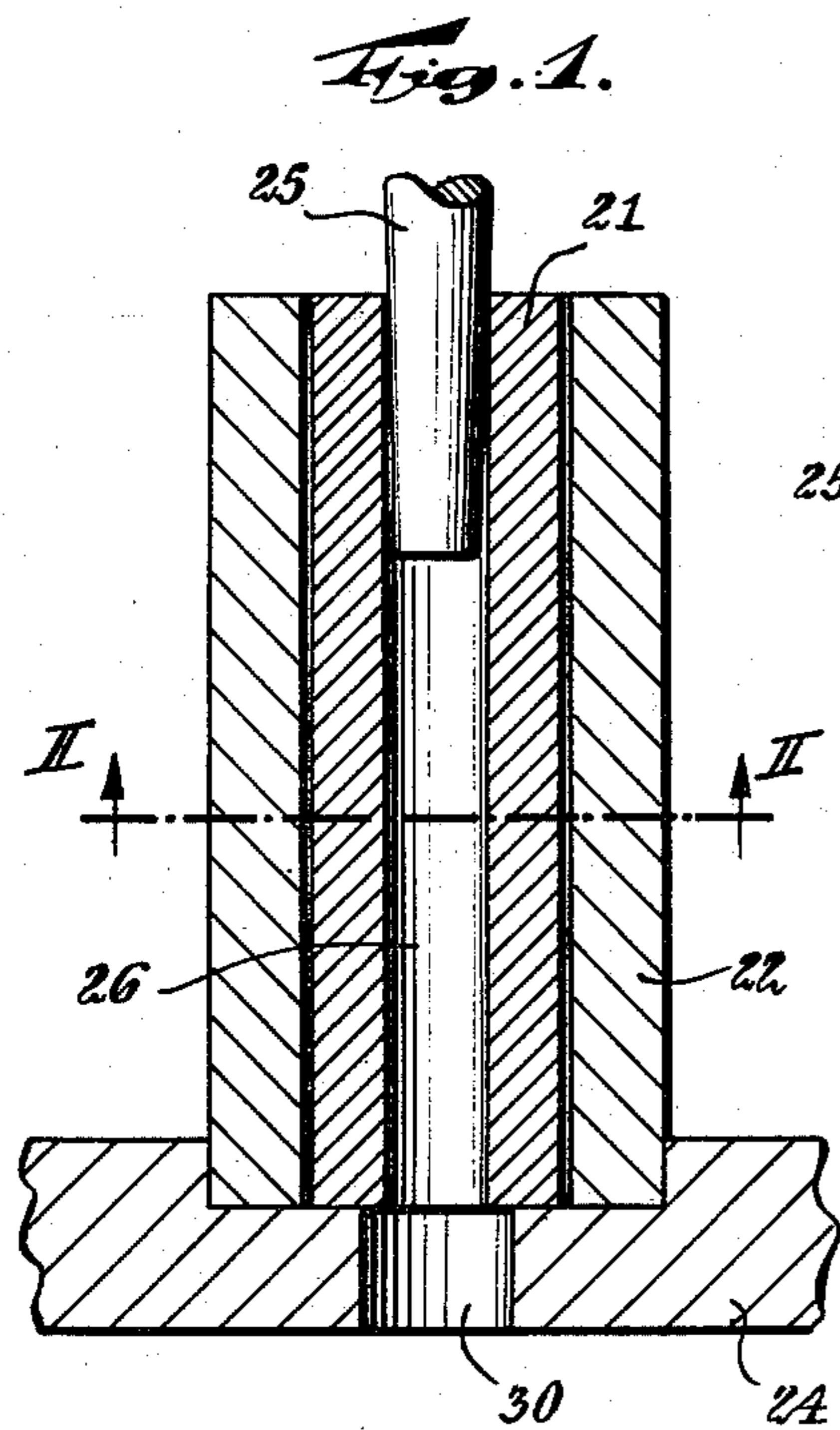
P. H. BRACE

2,628,516

TUBE MAKING PROCESS

Filed July 9, 1949

2 SHEETS—SHEET 1



INVENTOR
P. H. BRACE
BY *J. H. M. B. W. E.*
ATTORNEY

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2 SHEETS—SHEET 2

Fig. 9.

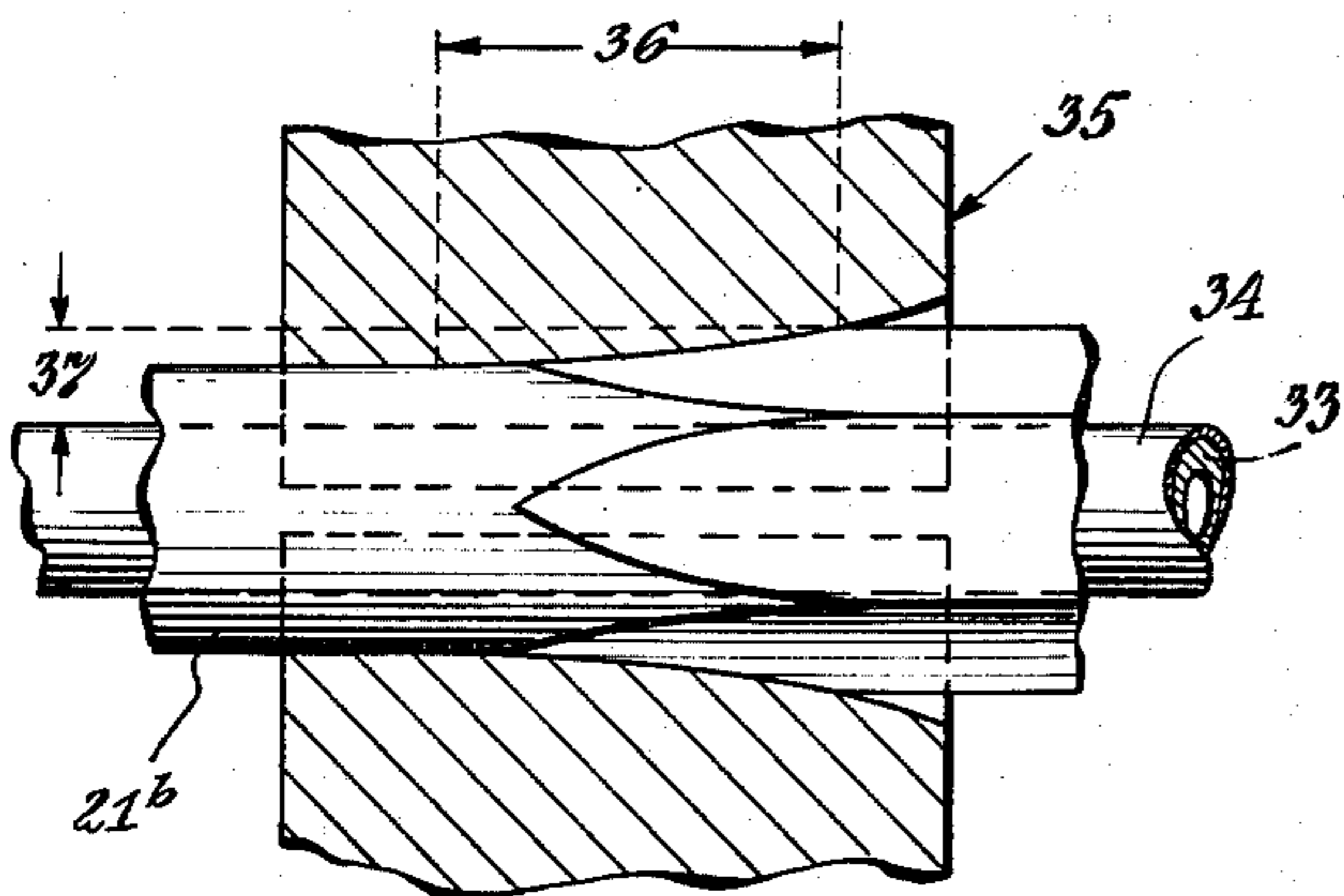


Fig. 10.

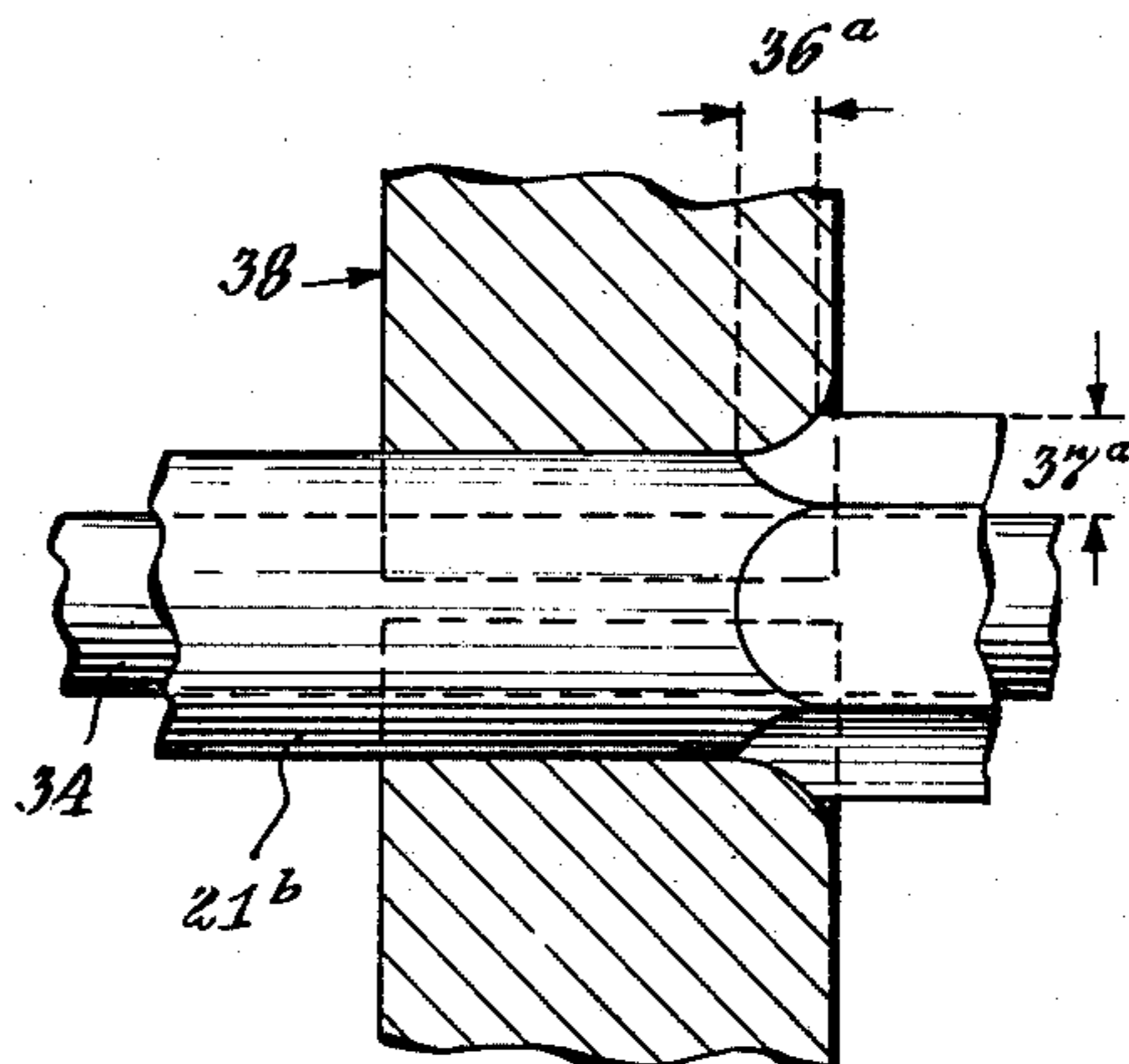


Fig. 11.

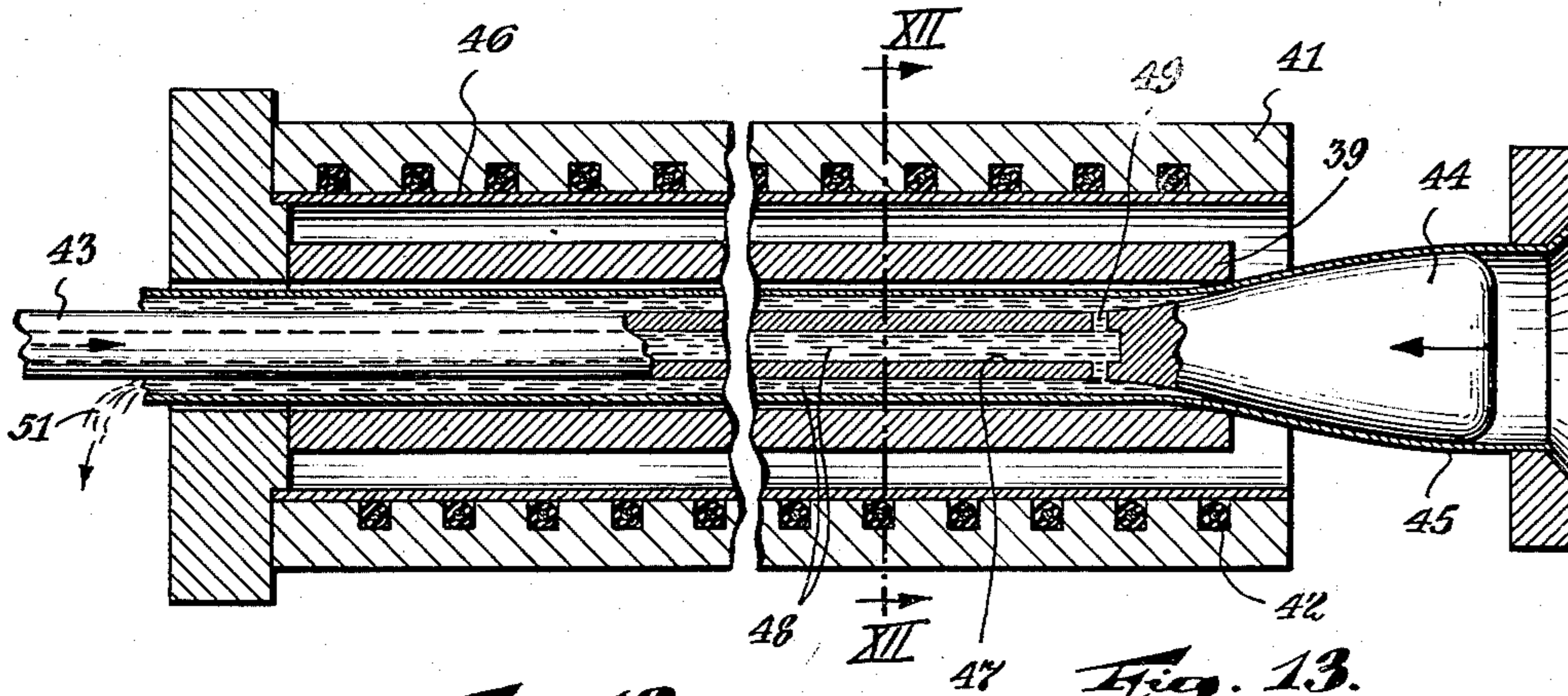


Fig. 12.

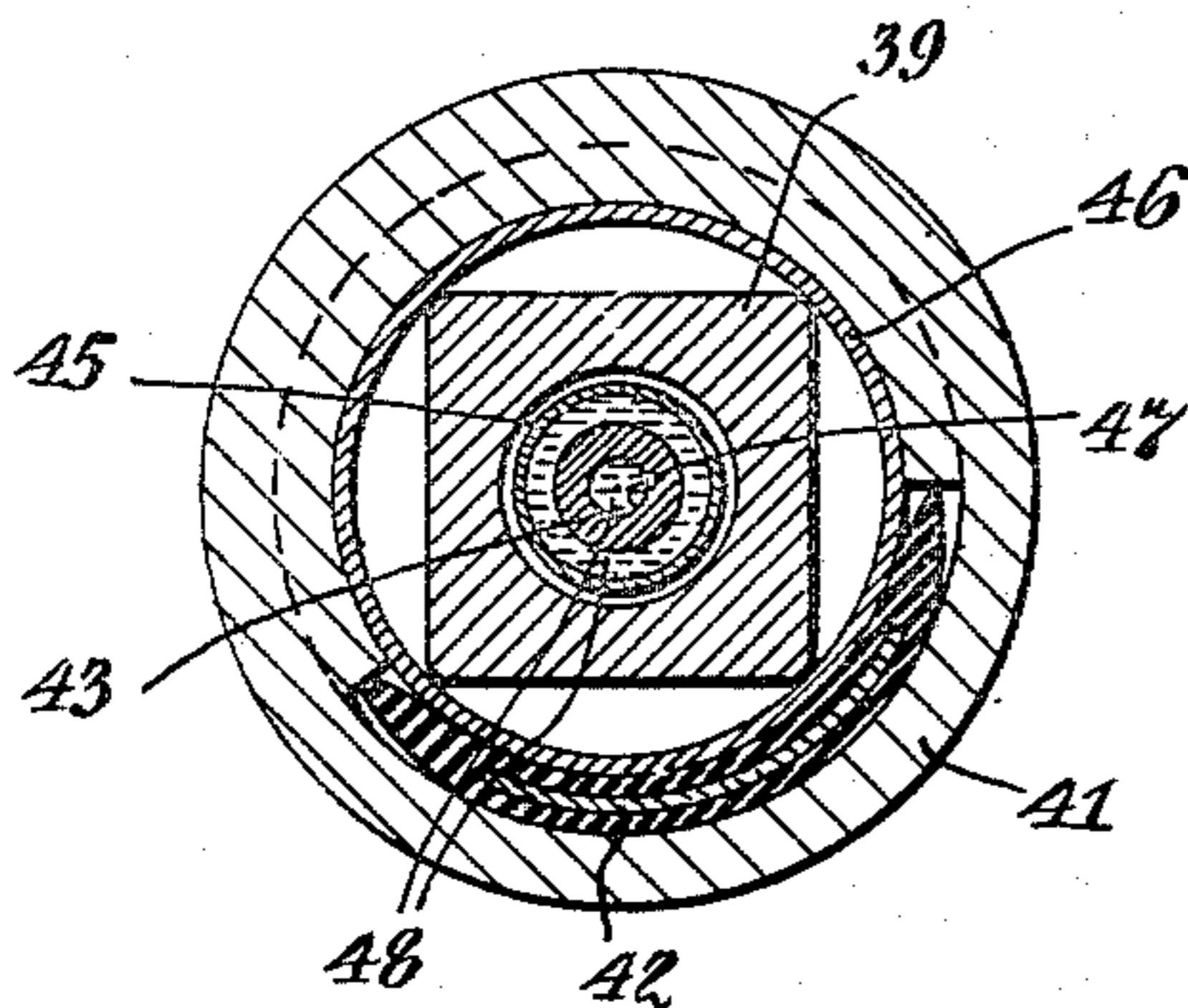
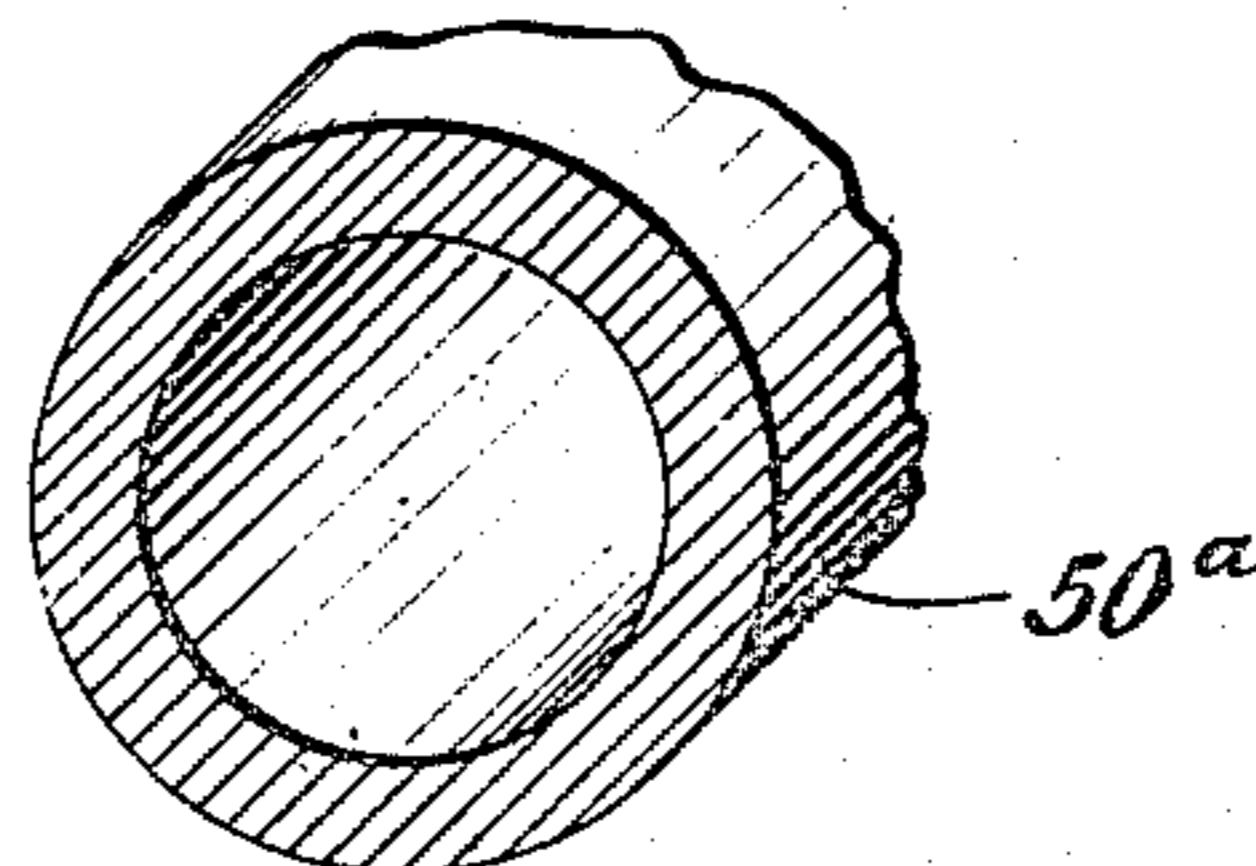


Fig. 13.



INVENTOR
P. H. BRACE
BY *J. H. Newcomb*
ATTORNEY

UNITED STATES PATENT OFFICE

2,628,516

TUBE MAKING PROCESS

Porter H. Brace, Forest Hills Boro, Pa., assignor
to Westinghouse Electric Corporation, East
Pittsburgh, Pa., a corporation of Pennsylvania

Application July 9, 1949, Serial No. 103,846

3 Claims. (Cl. 78—81)

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This application is a continuation-in-part of my application, Serial No. 555,971, filed September 27, 1944, and now abandoned.

This invention relates to the manufacture of tubes and more particularly to such of the more refractory metals which develop "mechanical anisotropy," notably molybdenum and tungsten.

The principal object of my invention, generally considered, is to provide tubing with high bursting strength, especially of refractory metals which develop "mechanical anisotropy" and which are, therefore, wrought in such a manner as to provide circumferential or peripheral grain elongation, that is such at angles to radii of the tubing.

Another object of my invention is to provide a method of working metals by radially forcing hollow articles thereof into dies of varying cross-sectional shapes so as to elongate the grain structure circumferentially.

A further object of my invention is to manufacture tubing with circumferential grain elongation comprising expanding a hollow billet in a die cavity of a shape different from the outer contour of said billet (or as an alternative, compressing such a billet about a mandrel by die members having engaging surfaces shaped differently from that of the billet), then expanding the deformed billet in a die cavity of a different shape (or if the alternative is followed, again compressing such a billet about a mandrel by die members having engaging surfaces shaped differently from that of said billet), and so on until a tube of the desired size and shape is produced.

A still further object of my invention is to manufacture tubing by first placing a hollow cylindrical or prismatic billet, while heated to working temperature, in a die block cavity of different cross-sectional shape, that is, polygonal or circular in cross section, as the case may be, expanding it by a tapered mandrel to quickly drive the plastic metal outward to fill the die cavity, removing the prismatic or cylindrical billet so formed, again placing it in a die block cavity of different cross-sectional shape, that is, circular or polygonal in cross-section, as the case may be, again expanding it by a mandrel to fill said cavity, and alternating with the polygonal and circular die cavities until tubing of the desired size is produced.

Other objects and advantages of the invention, relating to the particular arrangement and construction of the various parts, will become apparent as the description proceeds.

Referring to the drawings:

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Figure 1 shows in axial section, a die block of polygonal cross section within which is a hollow cylindrical billet having an outside diameter slightly less than that of the circle inscribed in the polygon representing the die cavity, a tapered mandrel being shown in the process of entering the billet.

Figure 2 is a transverse sectional view of the line II—II of Figure 1, in the direction of the arrows.

Figure 2a is a view corresponding to Figure 2, but showing in section, a modification of the mandrel thereof to a larger scale.

Figure 3 is a view similar to Figure 2, but showing the parts after the mandrel has expanded the billet to the size of the die cavity.

Figure 4 is a view similar to Figure 2, but showing the billet, formed as in Figure 3, removed from the die thereof and placed in a die having a cylindrical cavity for subsequent working.

Figure 5 is a view corresponding to Figure 4, but showing the billet after the same has been expanded in the cylindrical die cavity, as by forcing a tapered mandrel thereinto.

Figure 6 is a view corresponding to Figure 2, but showing an alternative form of die into which a cylindrical billet is to be expanded.

Figure 7 is a view of an alternative apparatus in which a prismatic billet is to be squeezed to cylindrical form about a mandrel.

Figure 8 is a view corresponding to Figure 7, but showing the billet after having been squeezed to cylindrical form, the die portions removed therefrom, and the next set of differently-shaped die portions positioned for the next operation.

Figure 9 is a sectional view of a long-throated die in which a prismatic billet is being forced by a mandrel to thereby get both circumferential and axial metal flow.

Figure 10 is a view corresponding to Figure 9, but showing the employment of a short-throated die, whereby the proportion of axial flow, as compared with circumferential flow, is increased.

Figure 11 is an axial sectional view, with parts in side elevation, of apparatus for making long tubes using a draw bar and expansion head enclosed in a thin walled metal slip tube.

Figure 12 is a transverse sectional view, on the line XII—XII of Figure 11, in the direction of the arrows.

Figure 13 is a perspective view of a portion of a tube manufactured in accordance with my invention.

Certain of the more refractory metals, notably molybdenum and tungsten, are obtainable in

large masses only by powder metallurgy processes, that is, by compacting and sintering the metals in powdered form, such as may have been obtained by gaseous reduction of their oxides.

The billets as sintered may have considerable strength but at ordinary temperatures they are quite brittle and not well adapted to mechanical application.

By forging, swaging and rolling, commencing at temperatures generally in excess of 1000° C., or between 1000° C. and 1500° C., when molybdenum is being manufactured, and generally in excess of 1200° C., or between 1200° C. and 1750° C. for tungsten, the sintered billets may be compacted, inter-crystalline bonding completed, and grain growth and grain elongation brought about, with the result that ductility is developed to a useful degree and acceptable mechanical properties obtained.

Tubing, for example, of molybdenum or tungsten, can be made by drilling wrought bars and swaging or drawing these blanks over mandrels to elongate them and correspondingly reduce the wall thickness to the desired extent. However, because molybdenum and tungsten develop "mechanical anisotropy," this kind of working produces tubing with only its axial strength due to the effected grain elongation strongly developed. In consequence, the circumferential mechanical strength and ductility are both relatively low, so that such tubing is of little use for high pressure applications.

In order to provide such wrought tubing with circumferential grain elongation and improved resistance to bursting stresses, I propose the following sequence of operations, commencing with relatively-thick walled tubes prepared by drilling billets or wrought bars, or by hot piercing or inverse extrusion of wrought billets. Although my process is particularly adaptable for manufacture of tubes of molybdenum, I do not wish to be limited to this metal as other "anisotropic" metals such as tungsten, may be similarly treated. Therefore, in this specification and in the claims, the words, "the group consisting of molybdenum and tungsten" and like expressions, do not exclude alloys in which the proportion of the metal or metals incorporated with the molybdenum, tungsten, or alloy of such metals, is not large enough to substantially affect the "anisotropic" characteristics or impair the working properties.

I desirably start with a hollow cylindrical billet 21, although one of prismatic or non cylindrical shape may be substituted, if desired. The billet may be of molybdenum produced in any desired manner, as by powder metallurgy, but preferably in accordance with the teachings of the Hall et al. Patent No. 2,431,690, dated December 2, 1947. The billet 21 is introduced into a die 22 having a cavity different in cross-section from the outer cross-section of the billet. For example, if the billet 21 is cylindrical, the die 22 has a cavity 23 different in cross-section, in this instance being shown as a polygon, specifically a square. Of course, if a billet prismatic in shape is started with, as in Figures 11 and 12, then the die cavity may be cylindrical, as in Figure 4, that is, circular in cross-section, or other shape different from the particular prismatic shape of the billet.

The die or mold 22 is shown resting on a supporting table or block 24, desirably apertured as indicated at 30, and the billet 21 is assumed to be at a working temperature, say, between ap-

proximately 1000° and 1400° C. if formed of molybdenum. A suitable mandrel 25 is quickly forced into the hollow interior 26 of the billet 21 and the aperture 30, causing the billet, which initially has a diameter only slightly less than that of the circle inscribed within the polygon representing the mold cavity, to expand in the mold 22, as illustrated in Figure 3, so that it flows laterally and more or less completely fills the cavity space 23, thus causing metal thereof to flow and be worked in the directions of the arrows, that is, toward the corners of the die, forming longitudinal thickenings at such locations. Such treatment involves a consequent circumferential grain elongation of the metal, and forms the billet 40 of a different shape.

The extent of working during a single cycle of operation will range from approximately 10% at the start while the billet is "tender" i. e. likely to fail by tensile fracture, to 30% during later stages after some degree of circumferential fibering has developed and, concomitantly, a higher degree of plasticity.

Although the mandrel shown by Figure 1 consists of a single, tapered bar circular in section, it may advantageously consist of a series of segments free to move radially under the impulse of a coaxial tapered wedging member as illustrated in Figure 2^a, where 25^a is the entire modified mandrel and 55 represents the tapered wedging member and 56 the corresponding segments that are forced radially outward when the wedging member is forced axially in the appropriate direction.

The next step in the process is to remove the billet 40, which is now square or other different shape in sectional outline, while still having a circular but enlarged bore. In order to facilitate removal of the billet from the die 22, the latter, as well as other dies for working such billets, may be slightly tapered axially.

After removal and reheating to the working temperature desired, the prismatic billet 40 is then placed in a die or mold 26 having a cavity of different shape, such as a cylindrical cavity 27, the diameter of the cavity being desirably only slightly greater than a maximum diameter of said prismatic billet. A mandrel 28 is then quickly forced into the prismatic billet 40, so that it is again expanded, this time to approach the hollow cylindrical form, as indicated at 50 in Figure 5. The process described in connection with Figures 2 and 3 may then be repeated, and alternated with that described in connection with Figures 4 and 5, until the pipe 50^a, illustrated in Figure 13, has the desired length and wall thickness. As the tube wall becomes thinner, the number of sides of the die cavity should be increased.

An alternative form is illustrated in Figure 6, in which the die 22^a instead of having a truly prismatic cavity, or one square in cross section, has a cavity 23^a, which is approximately square, but the walls thereof are curved rather than straight, as illustrated. The use of this kind of cavity for the reception of a billet 21^a results in a greater working per step, while at the same time avoiding the formation of billets with sharp edges or corners. This type of cavity enables deformation to be effected with lower radial forces than with flat-sided cavities.

Figure 7 illustrates apparatus for effecting working by alternative means, that is, the die 22^b is shown in two parts, designated respectively 29 and 31, forming when closed a generally

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cylindrical cavity 32, in which a billet 21^b prismatic in shape is shown. In this instance, the billet is shown having a hexagonal cross section and a hollow mandrel 33 is disposed therewithin and separated therefrom by a lubricated film or sheet 34. The mandrel 33 is hollow to allow for circulation of a cooling fluid such as water. In this instance, the working is effected by forcing the die portions 29 and 31 together about the heated billet 21^b, or by forcing the tapered mandrel 33 thereinto, or both operations may occur simultaneously or sequentially, resulting in the formation of a cylindrical billet or pipe 24^b, as shown in Figure 8.

The next step in the process, analogous to that in the preceding instance, is to place the billet 24^b, which as illustrated is now circular in sectional outline, also having a circular bore which may be somewhat reduced in section because of the preceding operation, after reheating to the working temperature desired, between the parts 29^c and 31^c of the die 22^c. These parts are like the parts 29 and 31 of the die 22^b in Figure 7, except that they have plane billet-engaging surfaces defining a prismatic cavity, which in this case is generally square in section. A mandrel 33^c of appropriate size, but otherwise as employed in the preceding operation may be used.

In this instance, the working is effected by forcing the die portions 29^c and 31^c together about the heated billet 24^b, or by forcing the mandrel 33^c, if tapered, thereinto, or both operations may occur simultaneously or sequentially, resulting in the formation of a prismatic billet corresponding with that designated 40 in Figures 3 and 4.

The process described in connection with Figure 7 may then be repeated, and alternated with that described in connection with Figure 8, until a pipe or tube such as illustrated in Figure 13 is produced, which has the desired length and wall thickness. In other words, the process described in connection with Figures 7 and 8 is just the opposite of that of Figures 1 to 6, inclusive, in that the working is effected by force exertion and compression from the outside in, with or without expansion from the inside out, rather than mere force exertion and expansion from the inside out.

The two procedures, have, however, the common feature, that is, the important feature of my invention, namely, that lateral, plastic flow of the billet material is produced and, in consequence, the circumferential strength and ductility of the wrought tube increased.

Alternatively or in conjunction with procedures described above, other kinds of swaging may be resorted to for inducing circumferential flow together with more or less axial elongation.

For example a prismatic billet may be swaged over a round mandrel which may be water-cooled to preserve its strength and thermally separated from the billet to conserve the temperature of the latter and to facilitate the removal of the mandrel after swaging. Or a prismatic billet is converted to a circular one by tangential flow from corner regions.

The proportion of circumferential to axial flow during the working process may be regulated by the design of the swaging die or mold. With a long-throated die 35, as shown in Figure 9, where the approach distance 36 is great, compared with the radial distance 37 between the surface of the mandrel and the corners of the billet, most of the flow will be tangential. However, where

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the approach distance 36^a is small compared with the radial distance 37^a, with a short-throated die 38, as shown in Figure 10, the axial extension will be relatively great. Thus we have the means for adjusting the relative extent of the axial and circumferential extensions.

Referring now to the Figures 11 and 12, there is shown apparatus for making long tubes. Here the billet 39 at working temperature is slipped into a long die tube 41 provided with a coil 42, suitably insulated therefrom, for maintaining the working temperature of the billet. This coil may either heat by radiation or by carrying high frequency power. A draw bar 43 with expansion head 44 is enclosed in a thin-walled metal slip tube 45, thrust through the bore of the billet, and attached to a draw head, that is, the movable head of the conventional draw bench. The attached head 44 is then pulled through the slip tube 45, expanding that and the billet 39, and causing circumferential flow of the metal in the billet, after which a corresponding change in the die and continued working may be effected, as described hereinbefore. It will be noted that as the billet is shown prismatic, that is, square in exterior section, while the die 41 is shown having a cylindrical cavity defined by an inner tube 46 surrounded by the heating coil 42, the form of the billet after working is cylindrical, so that subsequent working, if any, involves the use of a prismatic die, as in Figure 2.

The function of the slip tube 45 is to provide a relatively cool lubricated surface in which the expansion head 44 can slide as it advances along the bore of the billet 39. The slip tube may be of thin-walled seamless steel and will then add little to the resistance encountered by the expansion head, by greatly minimizing friction and wear, as compared to that which would occur if the expansion head were to slide for a considerable distance along the bore of the heated billet.

The draw bar 43 may be hollow, as indicated at 47, to allow for oil 48 or other lubricant and coolant which flows out of apertures 49 into the annular space between the slip tube 45 and the draw bar 43, from whence it discharges as indicated at 51.

While I have shown mandrels and dies for the most part with plane surfaces, I do not restrict my proposals to such. For example, I may use both dies and mandrels with surfaces having wavy curvatures, as shown in Figure 6, to minimize the area of contact between die and billet, thus reducing the radial forces required to induce circumferential flow, as well as increase the amount of working per die.

I also contemplate introducing fluid at high pressure into the bore of the billet, or more particularly into the annular space between draw bar and slip tube, to provide supplementary radial forces to minimize the duty on the expansion head.

There is also the problem of maintaining the temperature of the billet while in the die. In addition to the use of the heating coil 42, I contemplate placing an insulating refractory lubricious coating on the die say, mica, graphite, oil, or a thin pre-formed sleeve of mica with inorganic bond, and passing current longitudinally through the billet to heat or to supplement that otherwise supplied.

From the foregoing disclosure, it will be seen that I have provided a method for producing seamless tubing with tangential fibre, and consequent superior ductility and strength in tangen-

tial or circumferential directions. Although particularly directed to the production of tubing of molybdenum and tungsten, in which circumferential ductility has been developed to a useful degree in billets produced by the powder metallurgy process, I do not wish to be limited thereto, as other materials, such as where the billets are initially cast in shape, may be similarly worked.

I claim:

1. The steps in the method of making a tubular metallic member comprising enclosing a tube of compacted and sintered metal powder, while the same is heated to working temperature, for its full length in a die of generally polygonal cross-section, passing a tapered mandrel through said tube to expand it to fill the die, removing the expanded tube, enclosing said tube, while heated to working temperature, for its full length in another die of generally circular cross-section, and passing another tapered mandrel through said tube to expand it to fill the generally circular die.

2. The method of making a member of molybdenum comprising enclosing a tube of compacted and sintered molybdenum powder, while the same is heated to between 1000° C. and 1500° C., for its full length in a die of generally polygonal cross-section, passing a tapered mandrel through said tube to expand it to fill the die, removing the expanded tube, enclosing said tube, while heated to between 1000° C. and 1500° C., for its full length in a die of generally circular cross-section, and passing another tapered mandrel through said expanded tube to further expand it to fill the generally circular die.

3. The method of making a member of tungsten comprising enclosing a tube of compacted and

sintered tungsten powder, while the same is heated to between 1200° C. and 1750° C., for its full length in a die of generally polygonal cross-section, passing a tapered mandrel through said tube to expand it to fill the die, removing the expanded tube, enclosing said tube, while heated to between 1200° C. and 1750° C., for its full length in a die of generally circular cross-section, and passing another tapered mandrel through said expanded tube to further expand it to fill the generally circular die.

PORTER H. BRACE.

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