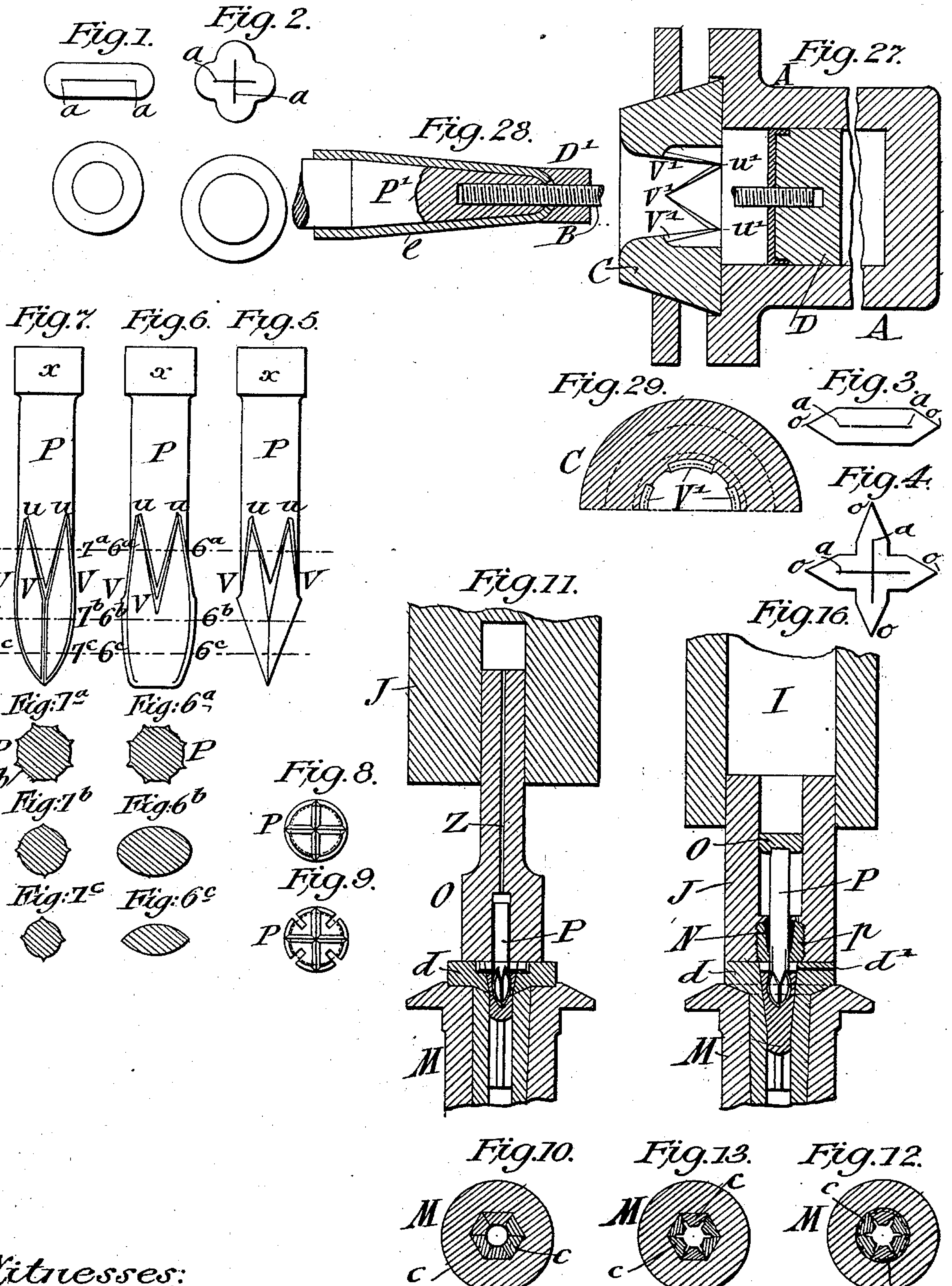
No. 671,752. Patented Apr. 9, 1901.

E. F. BOULET.

MANUFACTURE OF TUBES OR TUBULAR OBJECTS.

(Application filed Dec. 31, 1897.)

(No Model.) 3 Sheets—Sheet 1.



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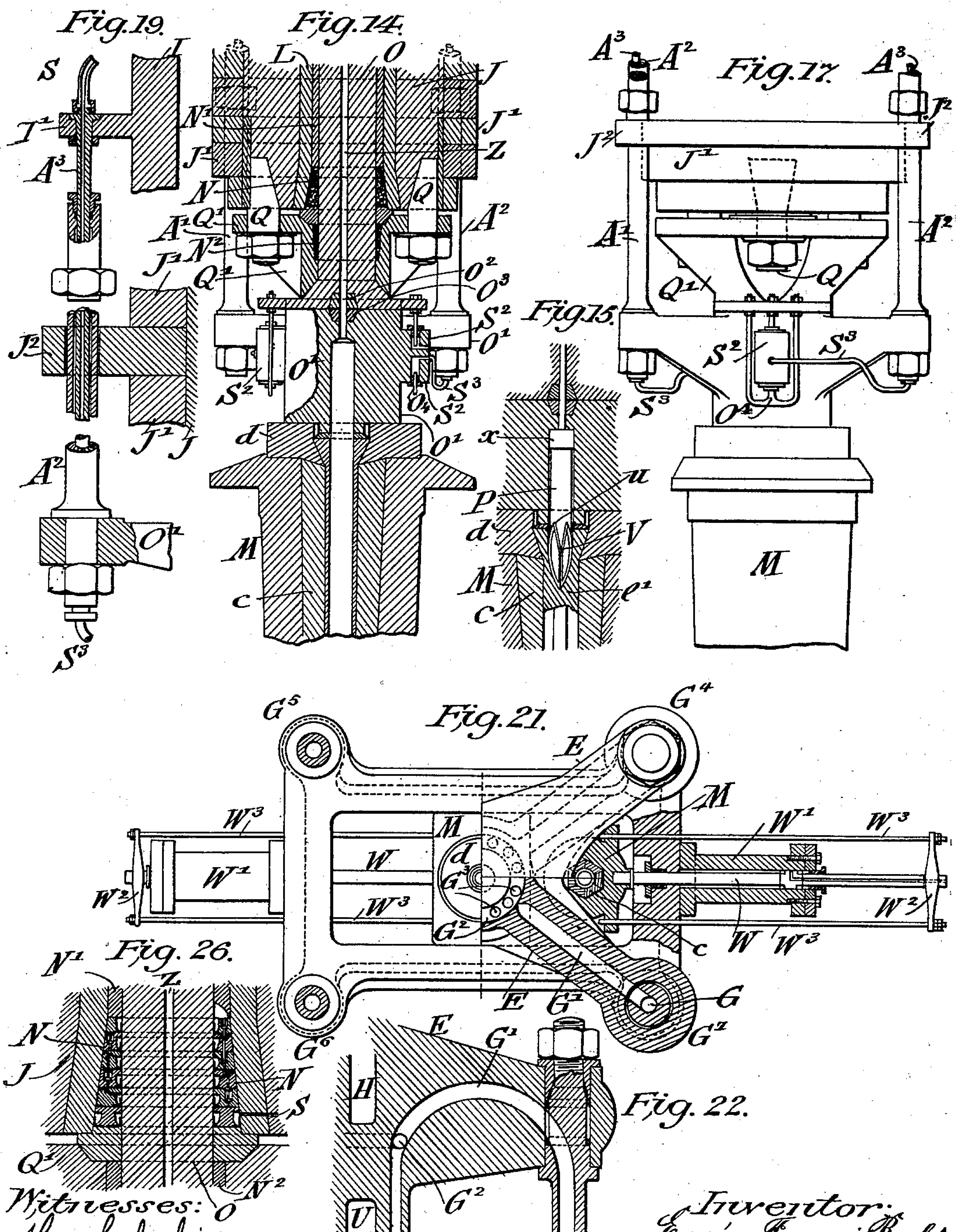

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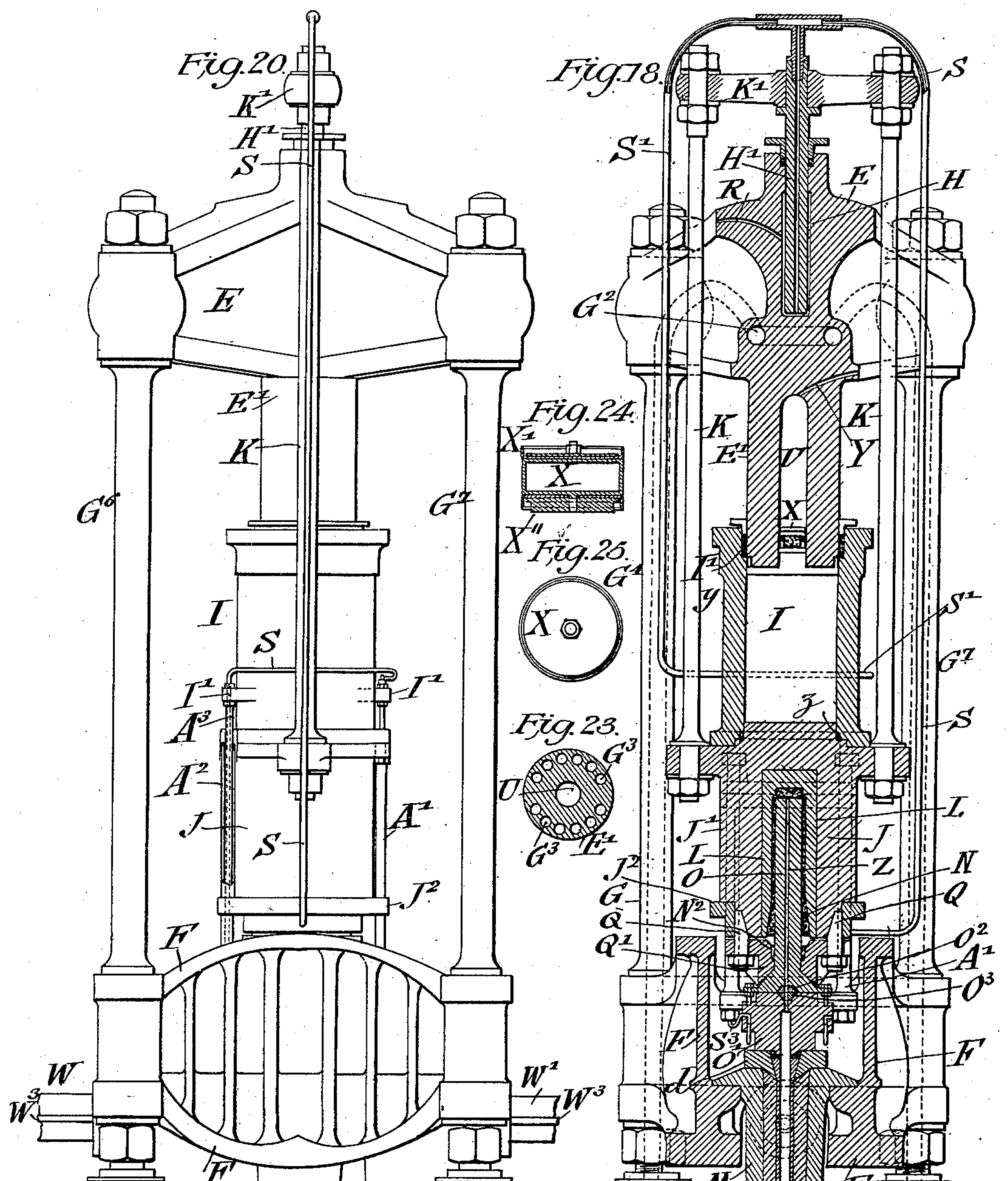

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UNITED STATES PATENT OFFICE.

EUGÉNE FRANÇOIS BOULET, OF MONTLUCON, FRANCE.

MANUFACTURE OF TUBES OR TUBULAR OBJECTS.

SPECIFICATION forming part of Letters Patent No. 671,752, dated April 9, 1901.

Application filed December 31, 1897. Serial No. 664,836. (No model.)

To all whom it may concern:

Be it known that I, EUGÉNE FRANÇOIS BOULET, a citizen of the Republic of France, residing at Montlucon, in the Republic of France, have invented certain new and useful Improvements in the Manufacture of Tubes or Tubular Objects, (for which I have obtained Letters Patent in France, dated December 12, 1892, No. 226,330; in Belgium, dated June 12, 1893, No. 105,057; in England, dated July 12, 1893, No. 13,572; in Germany, dated June 16, 1893, No. 79,602; in Austria, dated April 16, 1894, No. 44 and No. 6,058, and in Italy, dated April 24, 1894, XXVIII, No. 36,229, and LXXI, No. 97,) of which the following is a specification.

A well-known means for forming a solid, ductile, and malleable metallic body into closed annular or tubular form without any break or interruption in its continuity consists in opening up this body by incisions, so that a nearly equal thickness of metal remains on each side and at the ends of such incisions, whereby a centrally-slitted blank is produced according to the form of the blank which is to be transformed, and afterward to throw or force the lips made by said incisions outwardly, so as to arrive at the desired annular form. This simple and effective means requires less mechanical force, subjects the metal to less strain in radial direction, and utilizes its elasticity to better advantage than the method which consists in using a punch for boring a hole and gradually opening a blank or piece of metal until the required tube is produced. Up to the present time the first method has not been applied to the opening up of blanks of a certain length—as, for instance, tubes or other hollow bodies open at both ends, these bodies having previously been opened by means of punches with round, oval, polygonal, or other cross-section, which punches are forcibly introduced into the blank which is to be transformed.

The present process for the manufacture of tubes or other hollow or tubular bodies consists mainly in penetrating a suitable blank of the form required for the article to be manufactured, and which in some cases may be a simple bar, by means of a punch, and at the same time, while the blank is in the course of transformation by the punch, subjecting the walls of the transformed part to the pressure of a suitable fluid, so that the tubular walls are pressed forcibly either against the matrix or against the punch, according as to whether the fluid-pressure acts on the interior of the transformed blank or on the exterior thereof. The purpose of using a fluid for pressing the walls of the tube against the matrix or punch, as the case may be, is to augment the resistance offered by the tube in the drawing operation to the force of traction during the period of transformation, so that the transformed tubular portion is caused to adhere either to the matrix or to the punch, as the case may be, by the pressure which the fluid exerts on this tubular portion by one or the other tool employed in the manufacture.

In order that my invention may be clearly understood, I will now proceed to describe the same with reference to the accompanying drawings, in which—

Figure 1 represents the end of a centrally-slitted blank and a tube which is produced therefrom. Fig. 2 represents a blank the section of which is cruciform and a tube which is produced therefrom. Fig. 3 represents a centrally-slitted blank prepared after Mercier's method patented in France in 1846 under No. 3,253 and improved by Muntz for less massive tubes and patented in France in 1852. Fig. 4 represents a cruciform and less massive blank. Fig. 5 represents a side elevation of a punch provided with a pointed end for producing the central incision of the massive blanks shown in Figs. 1 and 2. Fig. 6 represents a side elevation of a punch; and Figs. 6^a, 6^b, and 6^c are respectively various diagrams on corresponding section-lines, Fig. 6, of the cross-sections of the same for producing tubes from bars slitted by the method of Mercier and improved by Muntz, as shown in Figs. 3 and 4. Fig. 7 is a side elevation; and Figs. 7^a, 7^b, and 7^c are respectively various diagrams on corresponding section-lines, Fig. 7, of cross-sections of another form of punch for the same purpose. Fig. 8 is an end view of the punch shown in Fig. 7. Fig. 9 is a modification of the same punch, in which grooves are formed between the cutting edges. Figs. 10, 12, and 13 are cross-sections of dies or matrices which are provided with removable lining-sections. Fig. 11 is a vertical section through a punch, punch-holder, and matrix. Fig. 14 is an enlarged detail vertical section of the punch and a part of the matrix of the latter form of the invention, showing the blank in position in the matrix. Fig. 15 is a view, on a reduced scale, the same being in vertical section, of the effective working parts of the preferred form of the invention. Fig. 16 is a vertical central section of a modification of the means for guiding and forcing the punch. Fig. 17 is a side elevation of Fig. 14. Fig. 18 is a vertical central section, parts in elevation, of the entire apparatus. Fig. 19 is a sectional and partly-broken detail view of the same, showing the means for conducting the fluid to the holder for the punch. Fig. 20 is a side elevation of the apparatus. Fig. 21 is a plan view of the apparatus, partly in section. Fig. 22 is a detail cross-section through the upper cross-head, showing one of the channels in the same. Fig. 23 is an enlarged cross-section through the fixed guide-cylinder. Fig. 24 is a vertical central section of the piston guided in said fixed cylinder. Fig. 25 is a plan view of said piston. Fig. 26 is a vertical central section of a detail, showing the plunger-rod and the packing around the same; and Figs. 27, 28, and 29 are vertical central sections, respectively, of a modified form of plunger-matrix, and a plan of the draw-plate of the latter.

Similar letters of reference indicate corresponding parts.

The main form of my invention is principally illustrated in Figs. 14, 15, 17, 18, 20, and 21.

The apparatus for drawing tubes according to my method may be briefly described as follows:

E is an upper cross-bar or cross-head, and F a lower cross-bar, said cross bars being connected by means of suitable hollow columns G^4 G^5 G^6 G^7 for spacing the cross-bars or heads at proper distances apart. One of the columns serves for the transmission of water or other suitable fluid under high tension to the high-pressure cylinder J, which is supported, by means of hangers or connecting-rods K, from a movable cross-head K', mounted as hereinafter described. The second of said hollow columns serves for conducting water from the compression-pump, the third for conducting water or fluid under low tension, and the fourth serves to conduct the fluid or water from the larger cylinder I. The cylinder I is mounted upon the high-pressure cylinder J and is guided upon the fixed main piston E', which projects downwardly from the cross-head E.

I' indicates a suitable packing between the movable cylinder I and the fixed cylinder E', and *y* indicates what is known as a "Bramah" packing, also between the said parts. The high-pressure cylinder J is cast in one piece and is fixed to the cylinder I, the joint between the same being packed by a Bramah packing *z*. Around the depending high-pressure cylinder J are arranged resistance bands or hoops J' for arresting the tendency to bursting of said cylinder.

L indicates an internal lining of the cylinder J, which is of suitable material for securing impermeability, and this lining is removable and a number of the same of varying internal diameters are furnished with the apparatus for use as required; but I do not limit myself to this means for producing a varying tension in cylinder J, as other means may suggest themselves to those skilled in the art without departing from the spirit and scope of the invention.

N (especially shown in Fig. 26) indicates a necessary packing, which is for the purpose of resisting the fluid-pressure to the high-pressure cylinder. One of these packings is requisite for each lining L and the plunger-rod O, which is guided therein. Fitted inside of the lining L, above the special packing N, is a guide-ring N', and another guide-ring N^2 guides the plunger-rod beneath the packing N, said guide-ring N^2 being supported by a crown-piece Q', which in turn is fixed against the lower end of the high-pressure cylinder J by means of suitable bolts Q, fitting in suitable sockets in said cylinder and retained therein by means of the aforesaid bands or hoops J'. The means of attachment of the bolts Q need not be confined to that shown.

M indicates a matrix, of which there are two, which may be guided under the apparatus by means of suitable guideways in the cross-piece F, as indicated in Figs. 18 and 21. These matrices are moved to and from their position by means of a suitable hydraulic apparatus W' W^2 W^3, Fig. 21, which apparatus imparts motion to the matrices and places them in the position required under the punch or out of position for the introduction of a blank or the extraction of a tube formed in the apparatus. A channel R passes through the upper cross-head E and places a chamber H, formed also in the cross-head, in constant communication with the source of compressed fluid. H' indicates a piston guided into said chamber H, provided with an axial passage and supporting the movable cross-head K' before referred to, the movement of the piston imparting an up-and-down movement to the cylinders I and J.

S is a tube which communicates with the lower part of the packing N, as shown in Figs. 18, 20, and 26, so as to place the same in communication with the chamber H through the medium of the passage in the piston H'.

S' is a tube which also communicates with the upper end of the piston H' and leads to the hydraulic-pressure device S^2, (shown in Figs. 14 and 17,) whereby the packings between the plunger-rod O, guided in cylinder J, and a suitable tool-holder O' are made tight by reason of the pressure exerted therein by said device, as will be described hereinafter.

The fixed piston guide-cylinder E' is provided with a central chamber U, adapted to contain a compressible fluid, which is separated from that in the movable cylinder I, guided over E', by means of a detached piston or float X, guided in said chamber, and by an oil-bath or other suitable liquid, so as to prevent its expansion and solution in the water in the cylinder I. Leading from the chamber U is a channel Y, through which the compressible fluid is introduced.

Before describing the especial and main features of my invention I will describe the simple modified form shown in Figs. 27, 28, and 29.

C indicates a draw-plate which is suitably fitted upon the cylinder A.

P' indicates a mandrel, upon which a metallic tubular blank *e* is fitted, such blank being in the form of a thimble and opened by any suitable means, and this blank *e* is fixed upon the mandrel P' by means of a screw-nut D', screwed upon the screw-rod B, screwed into the mandrel, said screw-rod B passing through the draw-plate C and carrying at its lower end a piston D, which is guided in the cylinder A. The draw-plate C possesses the peculiarity that instead of having a plain drawing-orifice the zone of the drawing action is over zigzag or sinuous draw edges *u'* V' *u'* V'. From Fig. 29, which is a section of the draw-plate C, it will be seen that the zigzag or sinuous draw edges project in a plane perpendicular to the axis of the draw-plate; but they conform to the outer profile of the tube after its formation.

Let us assume that the tubular thimble-shaped blank *e* has been inserted into the draw-plate C, so that the zigzag draw edges *u'* V' *u'* V' bear against the entire outer circumference of the tube. In this position a part of the tube has been regularly formed and has passed beyond the sinuous or zigzag draw edges and is forced into contact with the draw-plate over these sinuous or zigzag draw edges *u'* V' *u'* V' owing to the construction of the latter, as shown. Into the cylinder A is now introduced a fluid under a pressure strong enough to energetically force the formed tubular part against the mandrel P', so that the tube is caused to adhere to the mandrel by pressure. The fluid also drives the piston D into the cylinder, so that the screw-spindle B causes all of the parts D' B P' and the metal mass *e* being conformed to enter into the cylinder A, which regularly forms the outer profile of the tube, according to the projection of the zigzag or sinuous draw edges *u'* V' *u'* V' in a plane perpendicular to the axis of the tube—that is to say, the tube has been wire-drawn upon the mandrel by these sinuous draw edges. This wire-drawing action may be much more forcible than the usual wire-drawing, and indeed the extreme limit of the strain which may be exerted upon the blank during the drawing operation is that of the resistance to the compression in the direction of the axis of the same body or blank before the drawing action, according to the well-known means of drawing also embraced in the present system. The forcible pressure of the fluid against the tubular body fixes against the mandrel P' all parts of the tubes forced into the cylinder A up to the sinuous or zigzag edges V' *u'* V' *u'*. It would only be possible to break the tube along the line of the zigzag or sinuous cutting edges, for the reason that the pressure of the fluid fixes the tubular body against the mandrel.

The effect of the zigzag or sinuous draw edges described may be conveyed over the mandrel itself. Referring to Fig. 7, P indicates a mandrel or punch which is provided with zigzag or sinuous edges *u* V *u* V, while the head *x* of the mandrel has a circumference or surface which lies in the plane in which the outlines of the former lie—that is to say, a plane which would be developed by their extreme edges. Between the head *x* of the mandrel or punch and the sinuous or zigzag line *u* V *u* V is a reduced or contracted portion for the purpose of clearing the latter. Now let it be assumed that the mandrel is entered into a blank the drawing of which is to be effectuated and this blank fitted into the matrix M, the bore of which, open from one end to the other, defines or produces the outside of the tube which is being formed. This blank is firmly held against the end of the matrix, with which it makes a joint and through the end of which blank the mandrel has entered. The tube, however, cannot slip into the matrix in advance of the zigzag or sinuous line only during the period of its being drawn. In this condition—that is, the mandrel having just entered the end of the blank—a fluid under pressure is forced against the mandrel on the open end of the tube, and this fluid surrounds the reduced or contracted portion of the mandrel up to the zigzag or sinuous line, so that the fluid will force the completed portion of the tube against the matrix with such energy as to prevent any slipping of the tube. This fluid also acts upon the mandrel and forces the same through the blank for forming the tube, and this fluid-pressure may be assisted, if desired, in any preferred manner which would suggest itself to those skilled in the art.

The fluid-pressure in the angles V *u* V of the zigzag or sinuous draw edges fixes the formed part of the tube against the matrix in practically the same way as in the construction shown in Figs. 27, 28, and 29, where it fixed it against the mandrel, and the fluid-pressure in connection with the zigzag edges likewise prevents any slipping of the tube upon the mandrel.

By the same method of drawing through a matrix it is permissible to regularly and evenly open up the tubes produced from blanks, the sections of which are as shown in Figs. 3 and 4. The method of preparing the blanks, as shown in said figures, is known as the "Mercier-Muntz" method. The lines *a a* indicate the incisions in the ends of the blanks; but under the Muntz method great difficulty is encountered in opening up the folds of the blanks without causing an inner rupture or creases or irregularities on the surfaces of the tube produced. According to my method the distances from the profiles *o* to the points *a* are greater than the thickness of the walls of the blank at the sides of the slits. In opening blanks of this character the mandrel or punch, as shown in Fig. 6, may be used. The mandrel shown in Fig. 6 is designed for opening up a blank the cross-section of which is as shown in Fig. 3, while the mandrel shown in Fig. 7 is designed for opening up a blank the cross-section of which is as shown in Fig. 4, and these mandrels are all provided with the described zigzag or sinuous draw edges. The split blanks, Figs. 3 and 4, are introduced into their matrices and the forward end of the mandrel engaged into the slit or slits of the blank, so that the whole makes a joint at the sinuous edges. When the fluid forces the madrel P through the blank, the forward separating or cutting edges *t* of the mandrel enter the slits of the bar or blank; but inasmuch as the cutting edges *t* widen out as they approach the zigzag portion *u* V *u* V they are forced close to the bottom of each slit, which is then opened up by the corresponding angular portions of the zigzag or sinuous edges, while diminishing the distance between *o* and *a*; but during this progressive decrease of the distance between *o* and *a* the cutting edges *t* gradually round up or widen till they arrive at the angles of the sinuous edges. The blank *e* is then opened by a progressive and rational forging of the same, while the drawing of the tubular body is carried out, as previously stated, so that the transformation of the tube is obtained under the most satisfactory conditions. When the tubular body to be drawn is cylindrical, the mandrel does not require the cutting edges *t*, (shown in Fig. 7,) as it is only necessary that the forward end of the mandrel have sufficient conicality.

Fig. 8 represents an end view of the mandrel shown in Fig. 7, while Fig. 9 is a similar end view of such a mandrel provided with recesses between the cutting edges *t* for the purpose of forming pinion-shaped tubes. It is obvious that by this method of drawing tubes the inner shape of the tube may be varied considerably, provided that the section of the blank be constant; but the outer form of the tube may have different forms, as rectangular, pinion shape, and so on. For this purpose it suffices that the die-sections *c*, Figs. 10 to 15, be removable from the matrix M, so that they can permit the forcing away of said sections from the finished product after they have been raised from the matrix. I am thus enabled by this means to make tubes with exterior teeth of helical formation, channeled, star-shaped section, wing-shaped, &c.; and to make the interior bore of the tube different from the exterior of the tube or product. This method of drawing may be done when the blank is hot or cold, and different fluids may be used in order to produce the effect of the sinuous or zigzag lines or draw edges. Moreover, when drawing the tubes out hot, as those of iron or steel, the drawing process may be carried out much beyond the limit permitted by the size of the blank in the processes heretofore used if the elasticity of the metal is altered by the sinuous or zigzag edges or lines because the metal, although transformed by this excessive drawing action, is immediately regenerated by the fluid-pressure, which by energetically pressing the formed part of the tube against the matrix forges the metal of the tubular transformed portion by this pressure and so produces a molecular grouping favorable to the quality of metal which is being treated.

To proceed further with a description of some of the remaining parts of my invention, the matrix M is provided with a through-and-through opening, which is in the form of a truncated cone or pyramid, which is partly blocked up or filled by means of the sectional lining-pieces *c*, arranged to form a cylindrical central opening in the matrix through which the tube is drawn. Fitted upon the matrix M and the lining-pieces *c*, in a recess formed therein, is a crown *d*. This crown *d* extends a little farther into the lining-pieces *c* than into the matrix M. In Fig. 16 the crown *d* and lining-piece *c* are shown as made integral and are removed together from the matrix. A blank *e'*, (see Fig. 15,) the section of which is as indicated in Fig. 2 and which is introduced into the matrix provided with parts *c d*, has a rounded or otherwise suitably-shaped head which will fill the hole in the crown *d*. This blank by its shape offers a sufficient resistance during the period of the piercing with the punch or mandrel P, such as shown in Fig. 7. In order to permit the penetration of the punch or mandrel P through the blank, the upper end or head *x* of the punch is fitted into the cavity in the lower part of the plunger or piston O in the simple modification, Fig. 13, or in the tool-holder O' carried by the plunger, Figs. 14 and 18, such plunger or piston moving within the high-pressure cylinder J in the direction of its axis. If into the cylinder a very highly-compressed fluid is caused to enter, the parts I, J, and O will descend with considerable pressure toward the matrix M, Fig. 15, and as both groups J O and M *c d* will be set or placed in the same axial line the punch or mandrel P will penetrate into the blank until the plunger or piston O, Fig. 11, or the tool-holder O', Figs. 14 and 18, strikes the crown *d*. At this time the fluid contained in the cylinder I is, through the medium of the channel or passage Z, placed in communication with its source, so that by its pressure it will flow around the punch or mandrel P up to the zigzag or sinuous edges u V u V and will force the punch or mandrel against the blank e. If the fluid-pressure be of sufficient strength, the punch or mandrel will pass completely through the blank and form a tube. Let it be assumed that at the moment that it has completed its mechanical penetration due to the thrust of the cylinder I, Fig. 15, the forward end of the punch has penetrated into the blank, which is tightly pressed between the punch and the parts c d of the matrix M. Then during the transformation of the blank into a hollow body or the complete drawing or formation of the hollow body or tube by the punch against the matrix a friction of the material which is being transformed will be caused against the matrix on the one hand and on the other hand, as the case may be, against the punch or mandrel. For similar sections of punch and matrix the pressure of the blank against each of said parts is uniform per unit of surface, so that the friction against the matrix which takes place on a greater surface is much stronger than the friction against the punch. Furthermore, the friction against the matrix may be made stronger by a rugosity of the matrix. This difference between the two frictions relieves the action of the tendency of the blank to break or split upon the zigzag or sinuous draw edges u V u V, which is the point of rupture to be feared.

According to the characteristic of the metal which is to be transformed into a tube and its ductility its resistance to the operation is represented by the relative condition of the surface of straight sections of the body before and after transformation, and the fluid-pressure must vary in these cases in order to produce the adherence of the tubular body either against the matrix or against the mandrel or punch. As long as the fluid tension is not higher than is sufficient to produce through pressure the slipping in the transformed portion which usually takes place in most methods of drawing the precautions which have to be taken are those usually employed in the well-known drawing methods in addition to those necessary to the proper effect of the zigzag or sinuous line and proper joints; but when the fluid-pressure necessary to produce the advancement of the mandrel or punch becomes so great as that the formed tube is moved by this pressure by the rolling of the transformed mass the latter forces the metal of the blank against the sinuous line and tends to cause it to pass the same.

The adhesion of the tubular body e' against the matrix is increased by the rugosity of the sectional pieces c in contact with the tubular body or by any other suitable method for increasing this adhesion and is also increased by the dilation or enlargement of the tubular body if the mandrel is provided with the sinuous or zigzag line or by the contraction of the tubular body upon the mandrel if the draw-plate is provided with the sinuous or zigzag line.

The utilization of the difference in friction of the transformed body against the sectional pieces c and against the punch or mandrel P, which varies to a great extent, is assisted by the rugosity of the inner faces of the sectional pieces c in contact with the metal, by the length of the punch or mandrel in advance of the zigzag or sinuous line, by the smoothness of the punch or mandrel, and by solid lubricants at the forward end of the punch, such lubricants being, for instance, kaolin, graphite, asbestos, &c. In each case it is necessary that this difference in friction be such as that when the blank to be transformed is passing under the influence of the zigzag or sinuous line or edge it is pressed forcibly or strongly enough so as not to undergo any deformation after its transformation, at least little if any deformation which will increase its body after having passed the zigzag or sinuous line, so that the fluid-pressure upon the metal of the blank which is being transformed does not force the metal under the sinuous or zigzag edges or lines. These actions vary with the nature of the material to be transformed, their degree of heat, and the rapidity of transformation. It is not possible to specify all these conditions, as they vary; but in some cases I use the hereinafter-described mechanism now particularly referred to.

The fluid tension must be greater than is necessary for obtaining the effect of the zigzag or sinuous line when the punch or mandrel P is fed forward; but this excess of fluid tension does not become injurious, since it also forces the material of the blank against the sinuous or zigzag line, which necessitates that the material of the blank be pressed or forced strongly between the forward end of the punch and the segmental pieces c. The forward end of the punch cannot be of indefinite length, and, hence it is preferable to enable a mechanical counter-pressure upon the lower part of the blank in a direction reverse to the action of the punch. So long as this counter-pressure is no greater than is necessary to force the metal between the punch and the lower part of the blank there is no advantage in altering the described construction; but inasmuch as the compression of the metal which is caused by the mechanical counter-pressure forces the metal and causes it to rub upon the walls of the matrix there is occasion for changing this action, especially if the counter-pressure is very great and the metal hot. The structure shown in Fig. 16 shows an apparatus for fulfilling these conditions. The punch P is guided by a screw-nut p, applied to the lower end of the cylinder J, such nut pressing a suitable packing N against the bottom of the cylinder. Within the cylinder J slides a piston O, which is adapted to produce a compression force upon the punch P, and the cylinder J itself acts as a piston for the cylinder I. The parts of the matrix and those fitted therein are the same as described with relation to Figs. 10 and 13. The parts I J O P are so arranged that the piston O cannot plunge farther into the cylinder J than as shown. An incompressible fluid is located under the piston O, so that when a sufficiently-compressed fluid acts within the cylinder I the parts J O P descend, causing the punch or mandrel P to penetrate into the blank *e* until the cylinder J meets the crown *d*. At this moment a fluid under sufficiently high tension is introduced through the channel *d'* in the crown *d* into the space between the blank *e* and the nut *p* for producing the effect of the sinuous or zigzag edges or lines *u* V *u* V, and at the same time the fluid situated under the piston O is led out to the open air in a suitable manner, and the high-pressure fluid contained within the cylinder I drives down the piston O together with the punch or mandrel P, causing the latter to penetrate the blank and form a tube. This means permits the piercing of the blank more effectively than the means previously described; but the length of the tube to be formed is limited to that of the length of the punch or mandrel P, and consequently the compression is only possible up to the limit of the resistance of the mandrel or punch. When this means is applied to the drawing or forming of hollow bodies or blanks, the advancement of the punch may also be assisted by a mechanical operation thereon, which is effected by a rod connected with the mandrel or punch and passing through the bore of the tubular article to be drawn, all in an evident manner. It may suffice to combine this latter means with a fluid tension for producing the effect of the line *u* V *u* V. As soon as the counter-pressure becomes higher the exterior surface of the blank-section must approach more and more to that of the bore of the matrix, and it must be equal to that of the bore when the counter-pressure crowds the metal of the blank *e* against the active end of the punch; but in this case, although the sharp edges of the punch do not have to force out the tubular body formed by their own incisions, it is desirable to provide the punch with them in order to permit it to penetrate through the mass of the blank more readily and to cause it to exert a lateral or wedge-like pressure against the matrix, which pressure is transmitted to the matrix and causes the aforesaid difference of friction. For the same reasons the punches or mandrels should have the swells *b*, Fig. 7, between the cutting edges *t* dispensed with in order to enter the metal between the punch and the matrix more satisfactorily. The result of this is that one of the characteristic features of my invention is the possibility of penetrating a bar or drawing a tubular blank through a much greater length than with other methods, because in my method of manufacturing metallic tubes the bending of such tool cannot occur when the tool is forced forward by a fluid tension, since the tool is quite short, and this bending of the punch or mandrel limits the length of the tubes in other methods. Furthermore, where there is a high compression the sinuous edges or lines can even be dispensed with, and the transformation of the blank into a tube will be effected under satisfactory conditions upon the regulation of the counter-pressure in such a way as that in connection with the difference between the friction of the blank against both the matrices and the punch or mandrel a compression of the blank takes place over the zone of the sinuous or zigzag lines whatever its development may be. Notwithstanding the fewer advantages which the greater or less reduction of the development of the zigzag or sinuous lines or edges in my method possesses over the former methods, nevertheless there is maintained the adaptability of piercing or drawing to a greater length, and it reduces the friction of the blank up to the sinuous line or edge to a minimum, both as to the degree of friction and the duration of time during which the friction takes place, or the contrary occurs when a plunger drives the metal of the blank against a stationary punch or mandrel.

The apparatus, Figs. 18 and 20 to 26, inclusive, for forming a metallic tube according to my method has been previously described, and it is now pertinent to describe the operation of the same.

In order to simplify the elucidation of the operation of the apparatus, it will be assumed that the fluid introduced through column G^4 into the cylinder I is water under pressure, that the fluid introduced into the high-pressure cylinder J through column G^5 and tube S is also water, likewise that within the chamber H in the cross-head E, and that the fluid introduced through column G^6 into the chamber U of the fixed cylinder E' is compressed air. Three of the columns place the cylinder I in communication with a source of fluid under pressure, and the fourth, G^7, with the open air or a reservoir. The continuous channels G G' G^2 G^3 are each provided with a stop-cock, (not shown,) so as to establish or interrupt the supply of the fluid. When all the stop-cocks are closed, the apparatus remains stationary. In order to commence the operation, the stop-cock of the column G^7, communicating with the open air, is opened, so that the piston H', the cylinder H of which is always under the action of a source of fluid under pressure, will lift the group of cylinders J and I, as well as the plunger O and the tool-holder O', &c., expelling the water in the cylinder I through the channels G^3 G^2 G' G, leading to a reservoir or into the open air. When the cylinders J I, together with their accessories, have been sufficiently lifted, the discharge-cock of the cylinder I is shut off and the parts again become stationary. A stop-cock controlling the pipe S' is then opened and the plunger O and tool-holder

O′, supported thereby, are forced away from the high-pressure cylinder J for a certain distance by means now to be described. For the purpose of introducing into the high-pressure cylinder J the fluid necessary to the movement of the punch and to derive the effects resulting therefrom, a hermetic closure or joint is introduced or formed in the passage Z, which places the high-pressure chamber in communication with the socket in the tool-holder O′. This closure or joint is formed by the insertion of a frangible membrane or diaphragm of sheet-iron or other suitable material possessing sufficient resistance between plugs or filling-pieces O^2 and O^3, arranged in suitable sockets of the plunger O and the tool-holder O′. The tight holding of this diaphragm is obtained by mechanism hereinafter described. The tool-holder O′ is provided with four radiating arms having sockets supporting bolts A′ and A^2, as shown in Figs. 14, 18, and 19. Each of these bolts is adapted to slide in one of the lugs J^2, which are cast with the hoops J′ surrounding the high-pressure cylinder J. The screw-nuts of these bolts A′ A^2 are adjusted as desired for limiting the stroke of the plunger O and introducing into the pressure-cylinder J only the quantity of fluid necessary for its operation. Two diametrically opposite bolts A^2 are hollow throughout for the purpose of serving as cylinders for the plungers A^3, which are themselves hollow and are rigidly fixed to lugs I′, which are cast integral with the cylinder I, so that the water supplied by tube S passes through said hollow bolt-cylinder A^2, so as to forcibly push back the tool-holder O′, thus separating the plunger O and the tool-holder O′ from each other, so that the frangible membrane or diaphragm of required resistance can be inserted between the fixed plugs or filling-pieces O^2 and O^3; but the separation of the parts O and O′ is restricted by means of piston-supporting straps O^4, which are fastened to the tool-holder O′, (see Figs. 14, 17, and 18,) inasmuch as the pistons of the straps O^4 slide within the cylinders S^2, fastened to the tool-holder O′. As such cylinders S^2 are in optional communication through the medium of the valve-controlled pipe S^3 with the compressed fluid contained within the bolt-cylinders A^2, then as soon as the cylinders A^2 and S^2 are placed in communication (the pistons O^4 being larger than the plungers A^3) the tool-holder O′ is moved toward the plunger O, so as to forcibly compress the frangible membrane or diaphragm between the plugs or filling-pieces, so that a hermetic closure or joint is formed in the passage Z between said plugs or filling-pieces. The stop-cock of the pipe or tube S, which cuts off the communication between the chamber H at the upper part of the apparatus and the lower part of the packing N N′, is then opened, as shown in Figs. 14, 18, and 26, so that the fluid under tension acts upon the valves with which each packing-ring is provided and flows through the packing N N′, expanding finally into the high-pressure cylinder J, whereby the plunger O and the parts carried thereby are moved downwardly until the screw-nuts on the upper ends of the bolts A′ strike the lugs J^2 on the hoop or band. The high-pressure cylinder is thus charged with the required quantity of fluid under pressure. The function of the packing N N′ (shown more clearly in Fig. 26) is to maintain the fluid under high pressure within the cylinder J, and its special construction forms no part of the present invention. These preliminaries having been attended to, the punch or mandrel P is introduced into the cavity of the tool-holder O′ and is held in position therein by friction or other suitable means. The matrix M and parts *c d*, containing the blank *e*, Figs. 18, 20, and 21, are then moved to the proper position under the punch through the medium of the mechanism W′ W^2 W^3 before referred to, and the stop-cock of column G^4, controlling the channels G G′ G^2 G^3, is opened, so as to conduct the water under low pressure through the passages shown in cross-section in Fig 23 into the cylinder I. The two cylinders I J are then caused to descend by reason of the pressure of the water in the cylinder I, the tension of which is sufficient to cause the punch or mandrel P to penetrate into the upper end of the blank *e*, as shown in Fig. 15. When the tool-holder is about to come in contact with the crown-piece *d* of the matrix, a high pressure is substituted for the low pressure in the cylinder I, and this is done by shutting the stop-cock controlling the low-pressure channels G G′ G^2 G^3 and opening the stop-cock controlling the column G^5 and the channels for the high-pressure fluid. The tool-holder O′ then meets with the crown-piece *d* due to the high pressure within the cylinder J, and a further descent of the cylinders I and J is thereby prevented, so that the water contained within the high-pressure cylinder J instantly acquires a tension represented by that which acts inside of cylinder I, augmented by the action or portion of the surface of the cylinder I on the cylinder J. This sudden increase of tension within the cylinder J causes the frangible membrane between the plugs O^2 and O^3 to burst, so that the fluid in the cylinder J immediately and forcibly comes in contact with the head x of the punch and surrounds the latter down to the zigzag or sinuous edges u V u V, whereupon the fluid forces the punch through the blank *e* in the manner described relatively to Figs. 7 and 11. The punch passes through the body of the blank while forming the tube; but when the latter is about to be opened it is necessary to cut off the supply of water to the cylinder I, so that the descent of the cylinders I and J under the pressure of the water coming from the accumulator is interrupted, but completed by the pressure due to the expansion of the compressed air contained in the chamber U. The compressed air in the chamber is separated from the water in the cylinder I by the pistons X′ X″, between which a cushioning-space is formed, as shown in particular in Figs. 24 and 25. When the supply of water under pressure to the cylinder I has been shut off, the forward end of the punch has already opened the tube. The blank offers from this moment a small resistance to the punch, so that the air contained in the chamber U expands and expels the water underneath the pistons X′ X X″, which causes the group of cylinders I and J to descend with a gradually-diminishing pressure, but still sufficient to permit completion of the tube under the action of the punch, but at a comparatively low pressure.

The motive agent, which may be water or any other desired fluid, requires consideration. In some cases water may be used, especially in operating on soft and cold metals. When the metal is harder and has flaws or is porous, the water tends to pass over the sinuous or zigzag edges or lines, and it then becomes necessary to soften the metal to be transformed by heat. Furthermore, in operating on hard metal it must be remembered that certain metals at once cause certain liquids to assume the spheroidal state, while with other liquids these same metals become sprinkled with the liquid, and these effects may vary for the same metal with the heat and pressure employed. It is necessary, therefore, to select suitable temperatures and pressures, and also, if there should be occasion, to employ mechanical means to cause the perforation by the punch combined with a suitable pressure obtained by the sinuous or zigzag edges.

The process described becomes more economical in proportion to the higher pressure used. If the metal is at a white heat, the punch cannot remain more than from six to eight seconds at the maximum in contact with the metal, as after that time the surface of the punch is softened and damaged. Moreover, in connection with metals which can be welded the immense pressure to which the metal is subjected during the motion of the tubes causes a new grouping of molecules, as by hammering, and if any flaws or other defects exist in the metal these defects will become welded up, as iron or steel does not require very high temperature for welding under a strong pressure, especially if the oxygen is prevented from affecting the surfaces to be welded.

Having thus described my invention, I claim as new and desire to secure by Letters Patent—

1. The herein-described method of manufacturing tubes or tubular objects, consisting in forcing a punch or mandrel through the blank and simultaneously subjecting the transformed tubular portion of the blank to fluid-pressure, substantially as set forth.

2. The herein-described method of manufacturing tubes or tubular objects, which consists in forcing a punch or mandrel through the blank, and simultaneously subjecting the transformed tubular portion of the blank to external fluid-pressure, substantially as set forth.

3. The herein-described method of manufacturing tubes or tubular objects, which consists in forcing a punch or mandrel into the blank, then submitting it to high pressure sufficient to overcome a frangible obstruction in the high-pressure channel, then forcing the punch or mandrel into the transformed portion of the blank, and then changing the high pressure of the fluid to a progressively-decreasing pressure for releasing or detaching the fore end of the punch or mandrel and permitting the expulsion of the punch or mandrel from the blank at low pressure, substantially as set forth.

In testimony that I claim the foregoing as my invention I have signed my name in presence of two subscribing witnesses.

EUGÈNE FRANÇOIS BOULET.

Witnesses:
GEORGES CHAPINS,
JACQUES CONDOMY.