(No Model.) 2 Sheets—Sheet 1.

G. ENGEL.

PROCESS OF AND APPARATUS FOR FORMING AND TREATING METALS

No. 528,661. Patented Nov. 6, 1894.

Fig. 1.

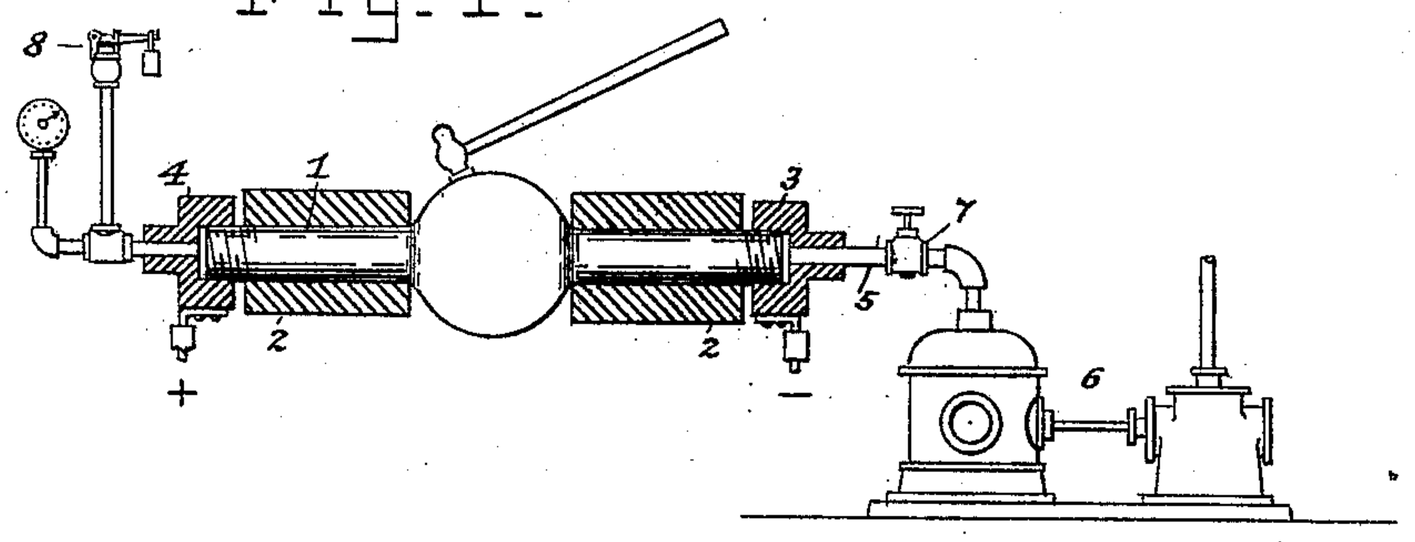


Fig. 2.

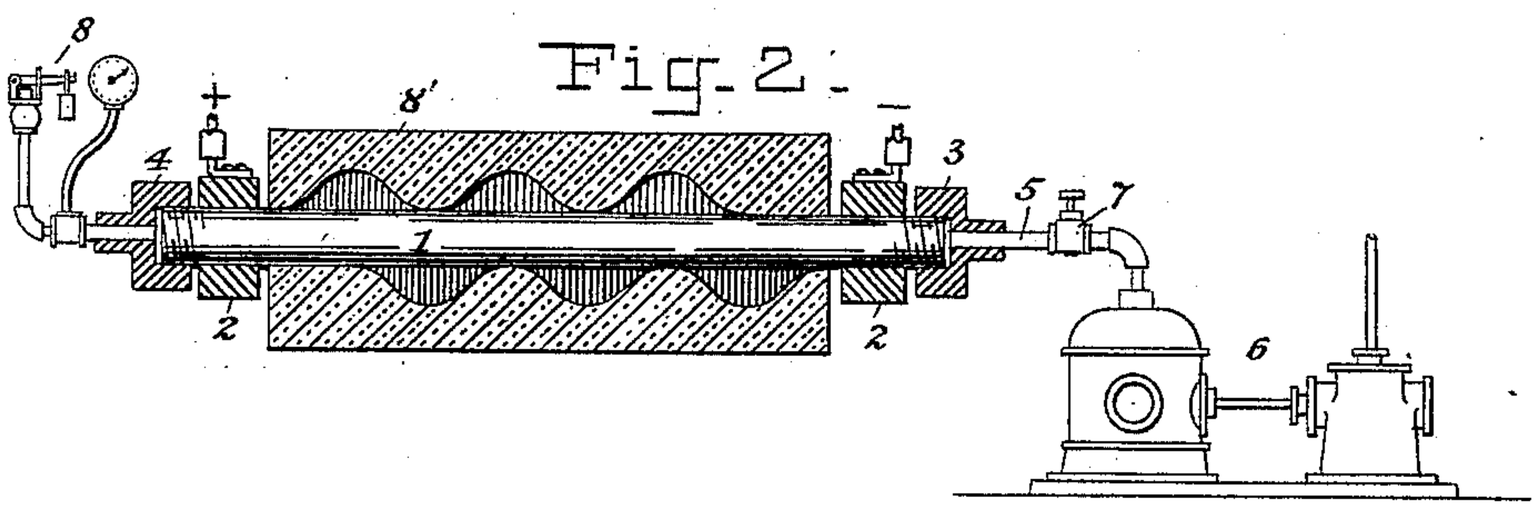


Fig. 3.

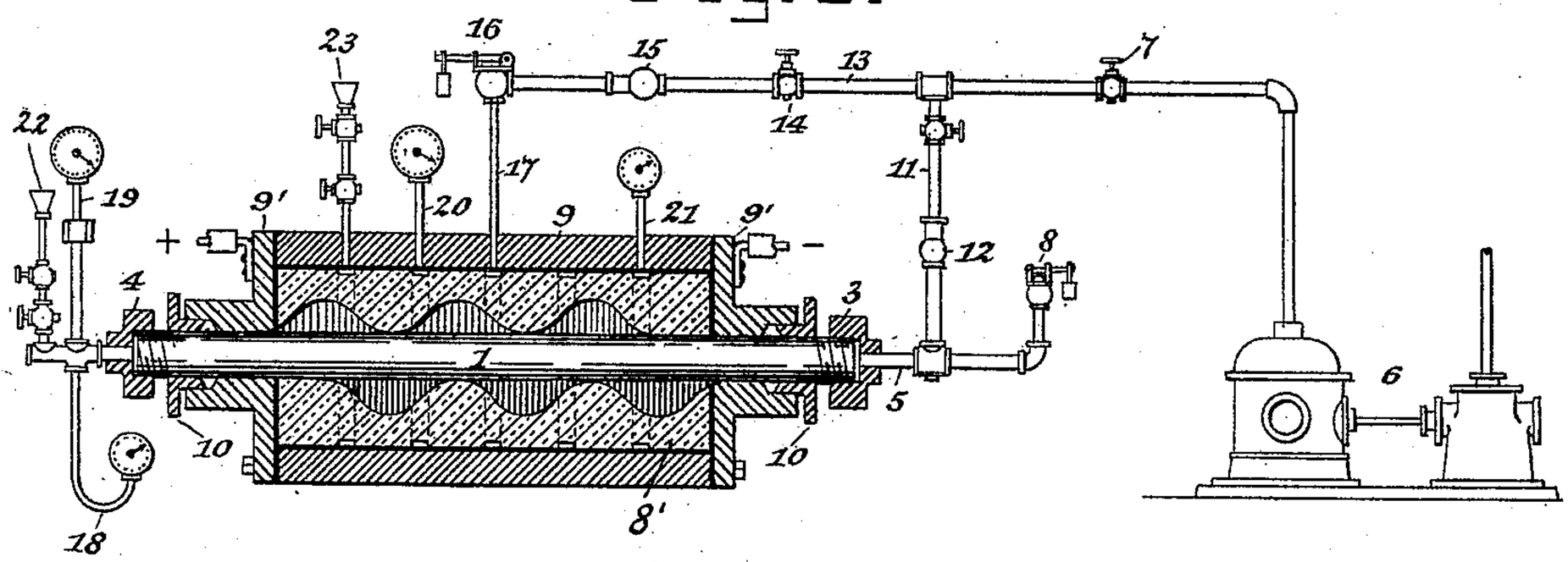
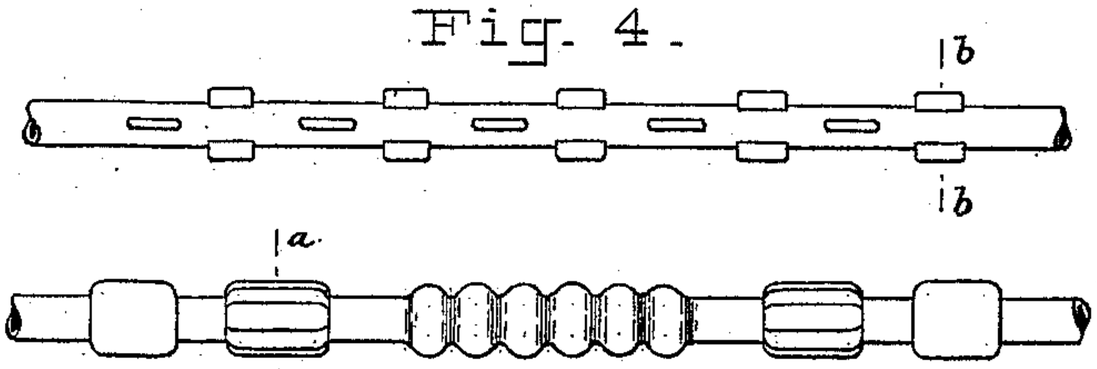


Fig. 4.



WITNESSES:

E. B. Bolton

H. W. Marble.

INVENTOR:

Godfrey Engel

By E. W. Marble

his Attorney

(No Model.) 2 Sheets—Sheet 2.

G. ENGEL.

PROCESS OF AND APPARATUS FOR FORMING AND TREATING METALS.

No. 528,661. Patented Nov. 6, 1894.

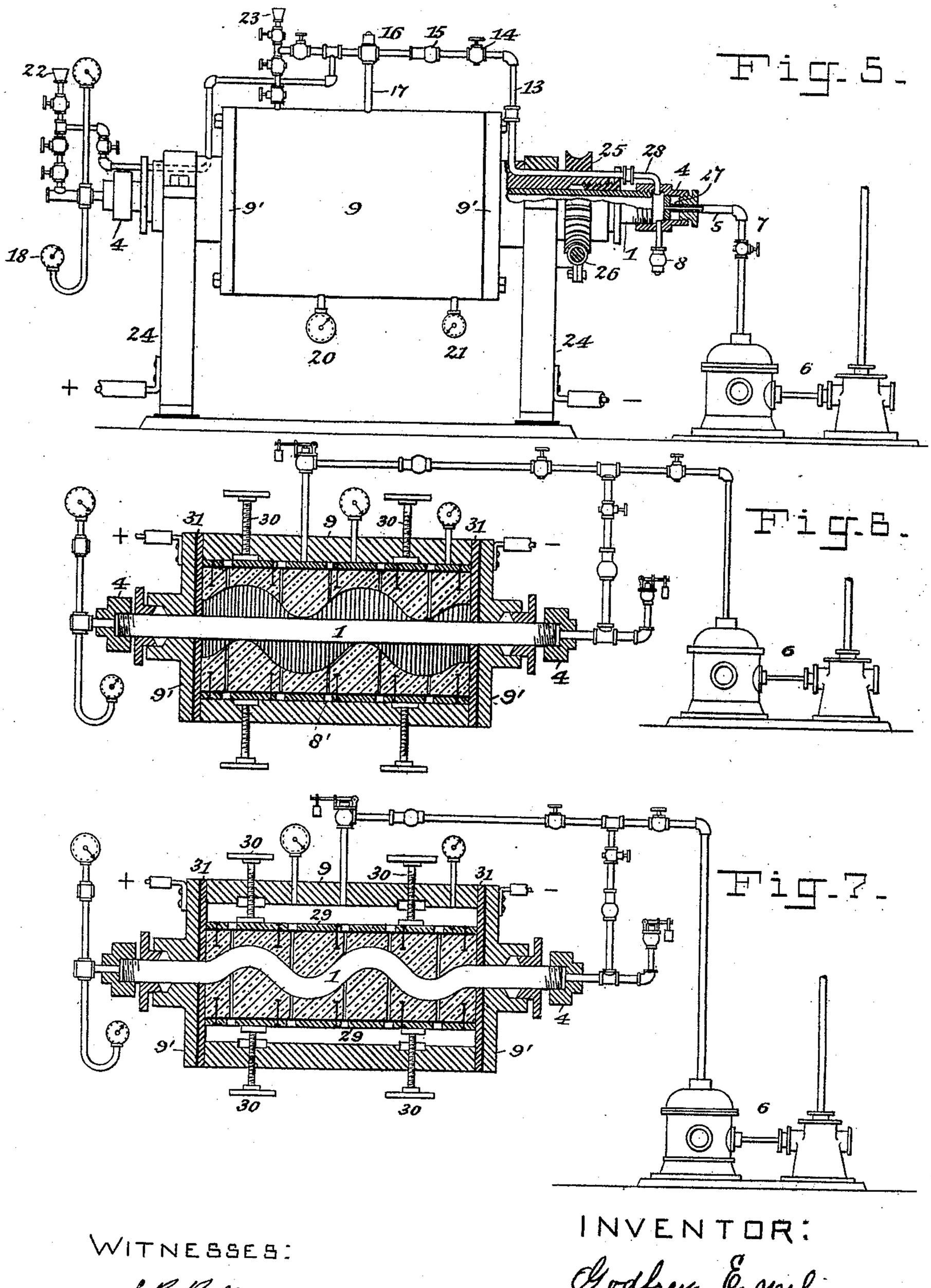


Fig. 5.

Fig. 6.

Fig. 7.

WITNESSES:

C. B. Bolton

H. M. Marble

By

INVENTOR:

Godfrey Engel

E. M. Marble

his Attorney.

UNITED STATES PATENT OFFICE.

GODFREY ENGEL, OF SOUTH BALTIMORE, MARYLAND.

PROCESS OF AND APPARATUS FOR FORMING AND TREATING METALS.

SPECIFICATION forming part of Letters Patent No. 528,661, dated November 6, 1894.

Application filed November 13, 1893. Serial No. 490,802. (No model.)

To all whom it may concern:

Be it known that I, GODFREY ENGEL, a citizen of the United States, and a resident of South Baltimore, in the county of Anne Arundel and State of Maryland, have invented certain new and useful Improvements in Processes of and Apparatus for Forming and Treating Metals, of which the following is a specification.

My invention relates to processes of and apparatus for forming metal objects by the use of pressure, and for coating or otherwise treating the same, and it consists in the novel steps of the process employed, and in the novel combination, construction, and arrangement of the apparatus for carrying out this process.

The objects of my invention are, first, to provide a process for forming metal objects the shapes of which are such that they are not readily constructed by forging or by the use of dies, and which because of their forms, or because of the material of which they are composed, or because of the uses for which they are intended, may not be formed of cast metal; by which the quality of the metal may not be injured while forming it into the desired shape; by which it may be possible to alter the qualities of the metal; and by which it may be possible to coat or glaze the surface of the metal to adapt it for its future uses; second, to provide apparatus capable of carrying out this process; and third, to make the carrying out of the process easy and cheap, and to so construct the apparatus employed as to make it durable, easy of manipulation, and not liable to derangement. These objects are attained in the process and apparatus herein described and illustrated in the drawings which accompany and form a part of this application, in which the same reference numerals indicate the same or corresponding parts, and in which—

Figure 1 illustrates the simplest form of apparatus for carrying out the process for forming metal, being intended for objects of simple form or design which may be readily shaped by the simultaneous use of my apparatus and of a blacksmith's hammer. Fig. 2 illustrates my apparatus as arranged for forming or shaping objects in molds, the shape to be produced being shown in this case as the zig-zag header of a sectional boiler. Fig. 3 illustrates a further development of this apparatus, being intended not only to shape the metal, but to cause it to assume the irregular form of the mold without stretching unduly any portion of the metal and without injury to its quality, and at the same time to compress or condense the metal, and to permit of coating or otherwise treating the metal to alter its qualities as may be necessary to prepare it for future uses. Fig. 4 illustrates some of the various forms of metal objects which may be constructed readily from malleable and ductile metal, by my process, and which it is difficult or impossible to form otherwise, except by casting. Fig. 5 illustrates a form of the apparatus in which the mold is revolubly mounted, and is arranged to be rotated while other steps of the process are being carried out. Figs. 6 and 7 illustrate a form of the apparatus used where the form of the object to be produced is such that it is impossible to introduce the blank into the mold without first separating the parts of the mold. Fig. 6 represents the mold as open to receive the blank, while Fig. 7 shows the mold closed with the completed article therein.

In many arts and for many uses it is frequently desirable to form from a malleable and ductile material, such as wrought iron, mild steel, or copper, objects the shape of which is such as to make difficult or impossible their construction by forging, pressing, by the use of dies, or by any method other than casting, and this may be true although the qualities of all available cast metals may be and frequently are such as to render the resulting article largely or entirely unfitted for the use for which it is intended. This fact is well illustrated by the zig-zag headers commonly used in sectional boilers. These headers it is customary to make of cast iron, although it is well known that cast iron is not well suited for the purpose, being often defective and weak because of the presence of blow-holes, because of the existence of shrinkage stresses, or because cast iron is not elastic and ductile, and when subjected to sudden stress is liable to be fractured. Yet the shape of these headers required in order that the boiler may be compact and efficient is such as to make it difficult or impossible

to construct them by forging or pressing, or by any method other than casting. Methods indeed have been devised for constructing headers by means of dies, but such methods have not proved commercially successful, as the expense attending their construction is almost prohibitive.

Other examples of work to which my process and apparatus are applicable are found in the construction of the coils of steam heaters or radiators, and in some forms of architectural iron work.

My invention is designed to afford a method and apparatus for constructing such objects of malleable and ductile material under the influences of heat and pressure, with or without the use of molds, and without injury to the quality of the metal treated; and at the same time to provide for the coating or otherwise treating the metal so as to change its qualities and make it better adapted for the purposes for which it is intended.

My process is particularly applicable to the construction of hollow or tubular articles, though not necessarily limited thereto.

In carrying out my process, the metal under treatment is heated to a high temperature by the passage of a strong electric current through it, so as to render it extremely malleable and ductile. An evenly distributed pressure, such as is afforded by a gas, as air, under pressure, is then applied to the inside or outside of the metal object, or to both sides, as is required, and then, under the influence of heat and pressure, together with the proper use of a hammer or of a mold of the desired shape, the metal is caused to assume the desired form. These and other features of the process will become apparent from the following description.

Considering first Fig. 1, which shows the simplest form of the apparatus, 1 is a metal tube or blank from which an object is to be formed. 2 2 are metal jaws or clamps, the object of which is to make electrical contact with the tube 1. In this simple form of the apparatus they may likewise form the means of support for the tube while it is being shaped; or other means of support, as an anvil, may be provided. The clamps or jaws may be constructed like the similar jaws or clamps of electrical welding machines. They are electrically connected to some source of electric current, which current should preferably have large ampèrage and low voltage. The electric current used may be either direct or alternating, but it will usually be found more convenient to use the alternating current, a transformer being used if necessary to reduce the potential of the current to the desired amount. Before commencing operations, the ends of the tube 1 are screw-threaded and are fitted with metal caps, 3 and 4. Into the end of cap 3 is screwed a pipe 5, leading to an air compressor 6, and between the cap and the air compressor is placed a throttle valve 7. Into the end of the cap 4 is screwed a pipe leading to a safety or relief valve 8. When the tube 1 has been secured in the clamps 2 2, and after the connections have been made at its ends, the electric current is passed through it, and the tube is thus heated. This heating may continue until the whole length between the clamps is heated to nearly a white heat. When the tube has reached the desired temperature, the valve 7 leading to the air compressor is opened, and compressed air fills the interior of the tube. Under the influence of this internal pressure, which may be regulated as desired by opening or closing the valve 7 or in any other suitable manner, that portion of the tube which is highly heated will expand and bulge out, in the manner shown, and as it expands the metal may be shaped with the hammer, the blows of the hammer at the same time serving to keep the metal dense and to prevent one portion from expanding more rapidly than another. The heat derived from the electric current is steady and may be continued as long as desired. Suitable means may be provided for regulating the strength of this current, so that the ductility and malleability of the metal may be varied to suit the needs. The metal may in this way be shaped as desired.

The apparatus just described illustrates the simplest form which may be used conveniently, and carries out only a portion of my complete process, in that it makes no provision for treating the metal in any way. The shapes that may be produced by this apparatus are necessarily limited to the simplest forms.

In Fig. 2 I have illustrated an apparatus for forming objects of more complex shape, the article to be constructed being in this case the header of a sectional steam boiler. In this apparatus there is employed a mold 8′, having the shape of the article to be constructed. This mold is composed of some refractory material as asbestos which is likewise a non-conductor of electricity. 1 is the metal tube from which the header is formed. It may conveniently be a tube made by the Mannesman process, and therefore seamless. It is placed between the parts of the mold, which are then firmly clamped together. The connection at the ends of the tube are substantially the same as in Fig. 1, and the method of operation is in general the same. After the tube has been heated sufficiently, the valve 7 connecting with the air compressor is opened, and pressure is applied to the interior of the tube. Under the influence of this pressure the walls of the tube expand outwardly against the walls of the mold, and so are pressed into the crevices of the mold, and take the shape desired. By this method, articles of complicated shape may be readily and easily constructed. There is some danger, however, that the metal may be stretched or drawn out unequally in certain parts, or that it may be rendered coarse in fiber and

porous, and perhaps, that it may even be torn or broken. To remedy these objections, I have devised the apparatus shown in Fig. 3, which is the complete form of my apparatus.

In passing iron through rolls, as in rolling mills, the metal block or billet is subjected to great pressure on its top and bottom. The effect of this pressure is to toughen and condense the metal, and at the same time to increase its length and breadth, though its thickness is reduced. The apparatus shown in Fig. 3 is designed to act upon a similar principle in expanding the metal to the shape of the mold, though the pressure is applied by other means than rolls. 8′ is a mold, as before, having the shape of the desired object or article to be constructed. It is inclosed within a strong metal box or "monitor" 9, which holds the mold against internal pressure. The monitor is provided with end pieces 9′ 9′, which are bolted securely against the ends of the monitor, insulating packing being however inserted between the monitor and the end pieces to prevent the passage of electric currents and to insure air tight joints. The end pieces are provided with stuffing boxes 10, 10, through which pass the ends of the tube from which the desired article is to be formed. These stuffing boxes may be packed with refractory packing material. The end pieces 9′ 9′ form the means by which current is transmitted to the tube 1, taking the place of the contact clamps 2 2 of the other figures. As before, the ends of the tube are fitted with caps 3 and 4. 6 is the air compressor. The air supply pipe is divided into two branches, one of which, 11, is provided with a check valve, 12, and communicates with the interior of the tube 1 through the cap 3, and with a safety or relief valve 8. The other branch 13, has a reducing valve 14, a check valve 15, and a safety or relief valve 16, and communicates through a pipe 17 with the interior of the mold. To the cap 4, on the end of the tube 1, is connected a pressure gage 18, and a pyrometer 19 for indicating the temperature of the metal in the mold. Similar pyrometers may of course be used in the forms of apparatus shown in Figs. 1 and 2. A pressure gage 20, is also provided, communicating with the interior of the mold, and a pyrometer 21 may likewise be provided for indicating the temperature of the interior of the mold.

After the tube is in place in the mold with the connections with the air compressor and with the various attachments made, and after the end pieces 9′ 9′, have been screwed down and the stuffing boxes made tight, the tube is heated as before by passing an electric current through it. After the tube has reached the desired temperature, as shown by the pyrometers, the valves communicating with the air compressor are opened, and both the tube and the mold are filled with compressed air. The walls of the tube are thus subjected to pressure both inside and outside. The pressure on the two sides is maintained nearly equal, though the pressure on the inside should ordinarily be slightly greater, the pressure used being regulated according to the work to be done. The heating by the electric current is very uniform and is much less likely to cause injury to the quality of the metal by burning than is the ordinary furnace heat; moreover it is perfectly under control and the temperature of the metal may be regulated to the exact degree desired. The tube may, therefore, be heated uniformly throughout the length inclosed within the mold until it reaches a temperature at which it is exceedingly soft and ductile. Being in this condition, the pressure exerted upon it by the compressed air, causes it to expand in linear dimensions in a manner similar to the expansion of metal when rolled. The expansion of the metal will cause its surface to warp and bend, and since the greater pressure on the inside of the tube prevents any inward depression of the metal walls, the walls of the tube will be caused to expand slowly and uniformly throughout the length of the tube within the mold, against the walls of the mold, until the tube has attained the shape of the mold. The expansion to the shape of the mold is thus produced by uniform expansion, and not by local expansion at certain points, as is likely to be the case in the apparatus shown in Fig. 2. There is therefore no danger of the existence of local stresses in the metal. Moreover, the pressure exerted on both sides of the metal walls keeps the metal dense and free from flaws. After the tube has nearly expanded to the shape of the mold, the pressure on the interior of the tube may be increased somewhat, and the pressure on the exterior of the tube may be proportionally decreased so as to insure that the shape of the mold shall be taken at all points, and to prevent dropping down during the time of cooling. The object of the safety or relief valves in this and in the apparatus previously described, is to prevent the pressure in the tube and mold from rising above a safe point through irregular action of the compressor or for any other reason, and also to afford escape for gases in the tube and mold should explosions take place therein, as is sometimes the case. The reducing valves may be automatic with advantage.

For the construction of headers for boilers the metal will usually require no further treatment than that just described; but in the manufacture of articles for other purposes, it will frequently be desirable to glaze or otherwise treat the surface of the metal to protect it from oxidation or from the action of acids or other chemical substances, or to prevent the radiation of heat through it, or for various other purposes. This may be done during or after the forming operation above described, by introducing proper foreign substances into the interior of the tube

or of the mold. Thus silicious substances may be introduced which under the influence of the heat and pressure will combine with the metal, forming a glaze which will remain permanent after the cooling of the metal. Or it may be desirable to introduce copper compounds, especially where the metal under treatment is iron, which will combine with the surface of the metal, forming an alloy which will protect the surface of the iron from oxidation. Or carbonaceous compounds may be introduced, which will change the surface of the iron into steel, by a process similar to case-hardening. Where working steel, it will likewise be desirable under many circumstances to introduce borax or other similar substances which will form a tough, glassy coating over the surface of the metal, thus protecting it from oxidation, or from admixture with impurities present in the mold. In order to accomplish these several ends, I have provided cups 22 and 23, with double-valved connections, leading respectively to the interior of the tube 1 and to the interior of the mold, through which the foreign substances may be introduced. In order to insure a thorough distribution of the substance thus introduced over the surface of the metal, the mold and its attachments may be revolubly mounted so that it may be rotated slowly during the operation of treating the metal. Such an apparatus is illustrated in Fig. 5, in which 9 is as before the monitor which incloses the mold and is provided with the end pieces 9′ 9′ insulated from said monitor. The bosses of these end pieces which form the stuffing boxes 10, 10, likewise form journals which rest in suitable bearings formed in supports 24, 24. These supports are insulated from the bed-plate of the machine, and are electrically connected with the source of electric current, which current is therefore transmitted through the supports 24 and through the end pieces 9′ 9′ to the tube 1. 25 is a worm wheel keyed to the boss of one of the end pieces 9′, and 26 is a worm meshing therewith. By rotating the worm the monitor 9 and the mold contained therein are caused to rotate. In order to permit of the rotation of the monitor and attachments, the pipe 5 passes through a stuffing box 27, in the end of one of the screw-caps 4. A pipe 28 communicates with the interior of the screw-cap, and passing through a groove in the journal of the end piece 9′ and so through the worm wheel 25 and support 24, communicates with the pipe 13, which communicates with the interior of the mold, and is provided with a reducing valve 14, a check valve 15, and a spring relief valve 16. In this figure there is likewise shown a modification in the devices for admitting foreign substances into the interior of the mold and tube 1. The cups 22 and 23 have treble valved instead of double valved connections, and branches from the compressed air pipe 17 communicate with the spaces between the first and second valves. By admitting compressed air into these spaces the pressure therein may be brought to the same pressure as exists in the interior of the mold, so that there may be no difficulty in causing the foreign substances to pass into the mold when the second and third valves are opened. This modification may likewise be applied to the apparatus of Fig. 3.

The mold shown in Fig. 3 is so shaped that the blank from which the object desired is to be formed may be introduced into the interior of the mold without difficulty. With all molds this is not possible, however, but it may be required to separate the parts of the mold considerably before the blank can be introduced therein. Figs. 6 and 7 show an apparatus arranged to permit of this separation, Fig. 6 showing the mold opened, the blank having just been introduced, while Fig. 7 shows the mold closed the blank having been formed to the shape of the mold. The parts of the mold 8′ are provided with metal backing plates, 29, 29, secured thereto, and screws 30, 30, are provided for moving these backing plates, 29, 29, and therefore the parts of the mold, in and out. Instead of using these screws, directly, the same movement may be obtained by suitable wedges operated by screws in the end pieces 9′ 9′. Plates 31, 31, cover the ends of the monitor and mold, thus giving a smooth surface over which the ends of the mold may pass. Suitable insulating packing material is inserted between the plates 31 and end pieces 9′, 9′. In using this form of apparatus the parts of the mold are first separated by turning the screws, 30, until the blank 1, may be placed in the mold. The plates 31, 31, and end pieces 9′, 9′, are then put in place and secured, the stuffing boxes are packed, and the screw caps 4, 4, are put upon the ends of the tube and the proper connections made. The tube is then heated by passing the electric current through it, and when it is heated sufficiently compressed air is admitted to both the inside and outside of the tube, as in the apparatus shown in Fig. 3. The walls of the tube are thus caused to expand and to take the shape of the mold, and as this expansion takes place the parts of the mold are gradually brought together, until the mold is completely closed. The air pressure is continued until the tube has completely assumed the shape of the mold.

I have described the forming operation as being carried on by compressed air. In so doing, I have used the term air as indicating a gas which is the most common and convenient of all gases, and the action of which is best understood. I do not limit myself to the use of air, however, for it is evident that so far as the application of pressure is concerned, other gases will perform the same function quite as well as does air. I believe that there are gases other than air which for chemical reasons will be found preferable to atmospheric air, particularly carbonic acid gas, or carbon

dioxide. Atmospheric air under great pressure would be likely to produce oxidation or burning of many metals, particularly steel and brass, while carbonic acid gas can produce no such oxidation. Moreover, it is probable that at high temperatures carbonic acid gas will give up a portion of its carbon to iron, especially when under pressure, so that the surface of the iron will be converted into steel, thus improving the resulting article for many uses. Other carbonaceous gases may be used in a similar manner, for accomplishing the same purpose, and for cases where an entirely inactive gas is required, nitrogen might be employed. For most purposes, however, carbonic acid gas would seem to be the most satisfactory. In using it, I may substitute for the air compressor shown in the drawings, (which of course might be used to compress carbonic acid gas or other gases if desired,) a chemical apparatus for generating the gas under pressure.

I do not limit myself to the use of gases for producing the necessary pressure, as fluids which are non-conducters of electricity, and the boiling points of which are sufficiently high at the pressure to be used, may be used with equal or greater facility, in the same manner that gas is used. Liquid sulphur is particularly likely to be adapted for such use, with many metals.

Although as I have described the steps of the process, the pressure is not applied to the blank until it has been highly heated, it is of course obvious that pressure might be applied to the blank before the heating begins, though this pressure would not usually be effective until the blank has been highly heated. It may, however, be desirable under some circumstances to apply the pressure to the blank before passing the current through said blank, in order that the gas or fluid by which pressure is applied to the blank may not while cold come in contact with heated surfaces of the blank.

The only class of work to be performed by the various apparatus shown in the drawings, is the forming of objects which require the walls of the tubular blank to be expanded outwardly. For many varieties of work, however, the articles desired may with advantage be formed from tubular blanks, the walls of which are bent inwardly, an internal mold, core, or die being used to give the desired form to the object. To this class of work my apparatus is equally well adapted, a plaster core or a collapsible die being inserted in the tubular blank, which is then placed within a closed chamber similar to that formed by the monitor shown in Fig. 3. The blank is then heated as before by passing an electric current through it, and pressure is then applied to the heated blank, either from the outside alone, by filling the interior of the monitor with compressed air or other gas, or from both inside and outside, by filling the interior of the blank as well as the monitor with compressed air, the pressure on the outside of the blank being kept the greater. In this way the walls of the blank will be expanded and forced inward so that the blank will take the form of the mold; and after it has so taken its shape the mold or die may be removed, leaving the complete article.

Having thus completely described my invention, what I claim, and desire to secure by Letters Patent, is—

1. The herein described process for forming or shaping metal articles, which consists in inclosing the metallic blank from which the desired article is to be formed in a mold of suitable shape, and composed of material having a great electrical resistance, heating the said blank within the mold by passing an electric current through it, and in applying pressure thereto by means of a gas or fluid, of great electrical resistance, substantially as described.

2. The herein described process for forming or shaping metal articles, which consists in inclosing the metallic blank from which the desired article is to be formed in a mold of suitable shape, heating the said blank within the mold by passing an electric current through it until it becomes highly malleable and ductile, and in applying pressure thereto on both sides of the metal of the blank, by means of a gas or fluid of great electrical resistance and so expanding said blank to the shape of the mold, substantially as described.

3. In an apparatus for forming or shaping metal articles, the combination, with a mold composed of material having a great electrical resistance, having the shape of the article to be produced and adapted to receive a blank, of a source of electric energy and suitable connections for passing an electric current through the blank and heating the same, and means for applying pressure to the blank by a gas or fluid, of great electrical resistance whereby the blank may be expanded to the shape of the mold, substantially as described.

4. In an apparatus for forming or shaping metal articles, the combination, with a mold composed of material having a great electrical resistance, having the shape of the article to be produced and adapted to receive a blank, of a casing surrounding said mold and adapted to resist internal pressure, a source of electric energy and suitable connections for passing an electric current through the blank within the mold and heating the same, and means for applying pressure to the sides of the metal of said blank, while heated, by a gas or fluid of great electrical resistance, whereby the blank may be expanded to the shape of the mold, substantially as described.

5. In an apparatus for forming metal articles, the combination, with a mold, composed of material having a great electrical resistance, having the shape of the article to be produced and adapted to receive a blank, of

a source of electric energy and means for passing an electric current through the blank and heating the same, and means for applying pressure to the interior of the blank, while heated, by a gas or fluid, of great electrical resistance whereby the blank may be expanded to the shape of the mold, substantially as described.

6. In an apparatus for forming metal articles, the combination, with a mold, composed of material having a great electrical resistance and adapted to receive a blank, of a source of electrical energy and suitable connections for passing an electric current through the blank and heating the same, a casing or monitor surrounding said mold, and means for applying pressure to the blank, while heated, by a gas or fluid, of great electrical resistance whereby the blank may be caused to conform to the shape of the mold, substantially as described.

7. In an apparatus for forming metal articles, the combination, with a source of electric energy and suitable connections for passing an electric current through a blank from which the article is to be formed and heating the same, of means for applying pressure to the interior of said blank, while heated, by a gas or fluid, and means for introducing foreign substances into the interior of said blank for the purpose of treating its surface, substantially as described.

8. In an apparatus for forming hollow metal articles, the combination, with a mold adapted to receive a blank, of a source of electric energy and suitable connections for passing an electric current through said blank and heating the same, means for applying pressure to the blank, by a gas or fluid, thereby causing the blank to conform to the shape of the mold, and means for applying foreign substances to the blank while heated and within the mold, substantially as described.

9. In an apparatus for forming hollow metal articles, the combination, with a mold adapted to receive a blank and revolubly mounted, of a source of electric energy and suitable connections for passing an electric current through said blank and heating the same, means for applying pressure to the blank, by a gas or fluid, means for applying foreign substances to the blank while heated and within the mold, and means for rotating the mold, substantially as described.

In testimony whereof I hereto affix my signature in the presence of two witnesses.

GODFREY ENGEL.

Witnesses:
F. D. WALKER,
H. SCHOMAKER.