(No Model.) 3 Sheets—Sheet 1.

F. A. KRUPP.

PRODUCTION OF SOUND INGOTS AND APPARATUS THEREFOR.

No. 271,717. Patented Feb. 6, 1883.

FIG. 1

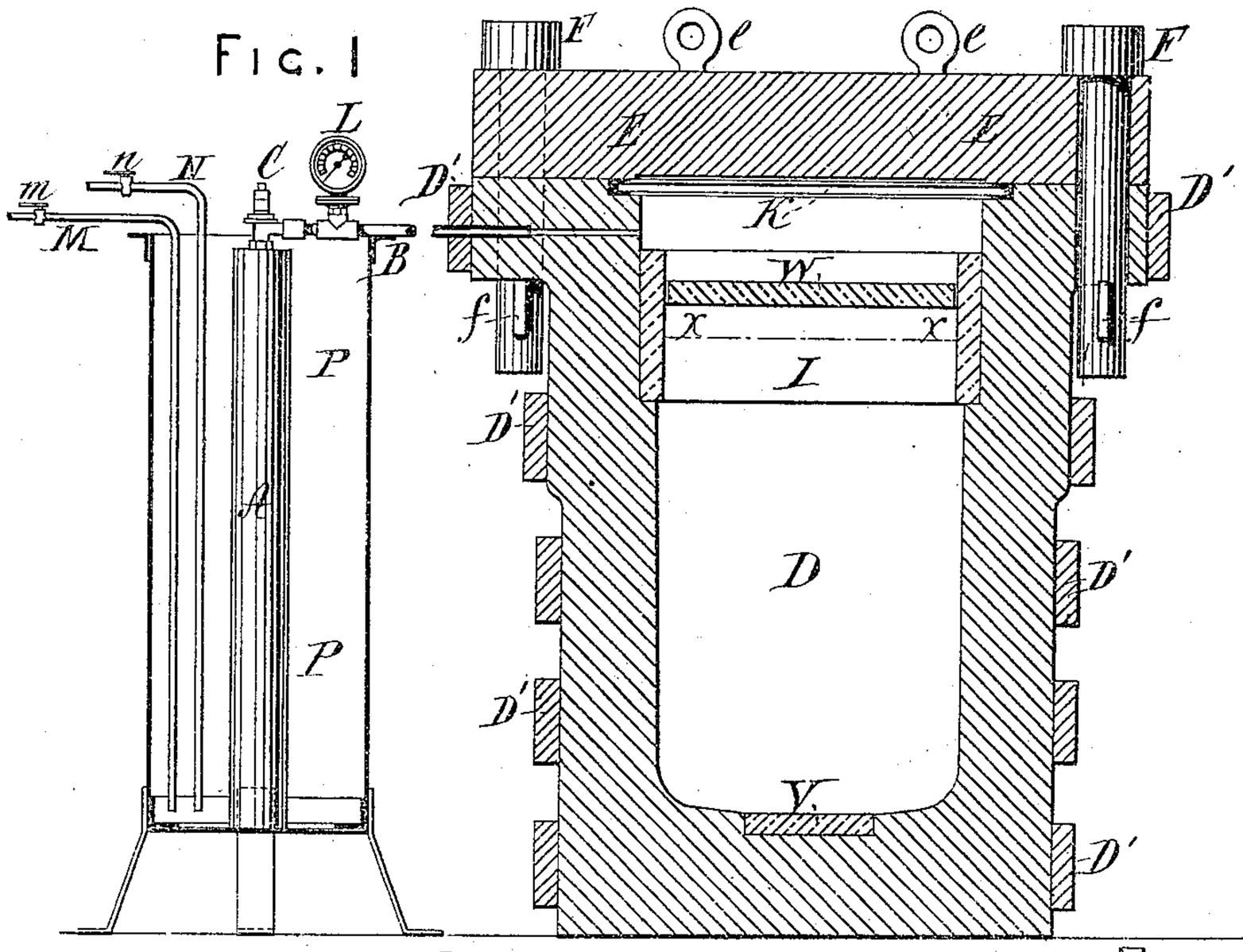
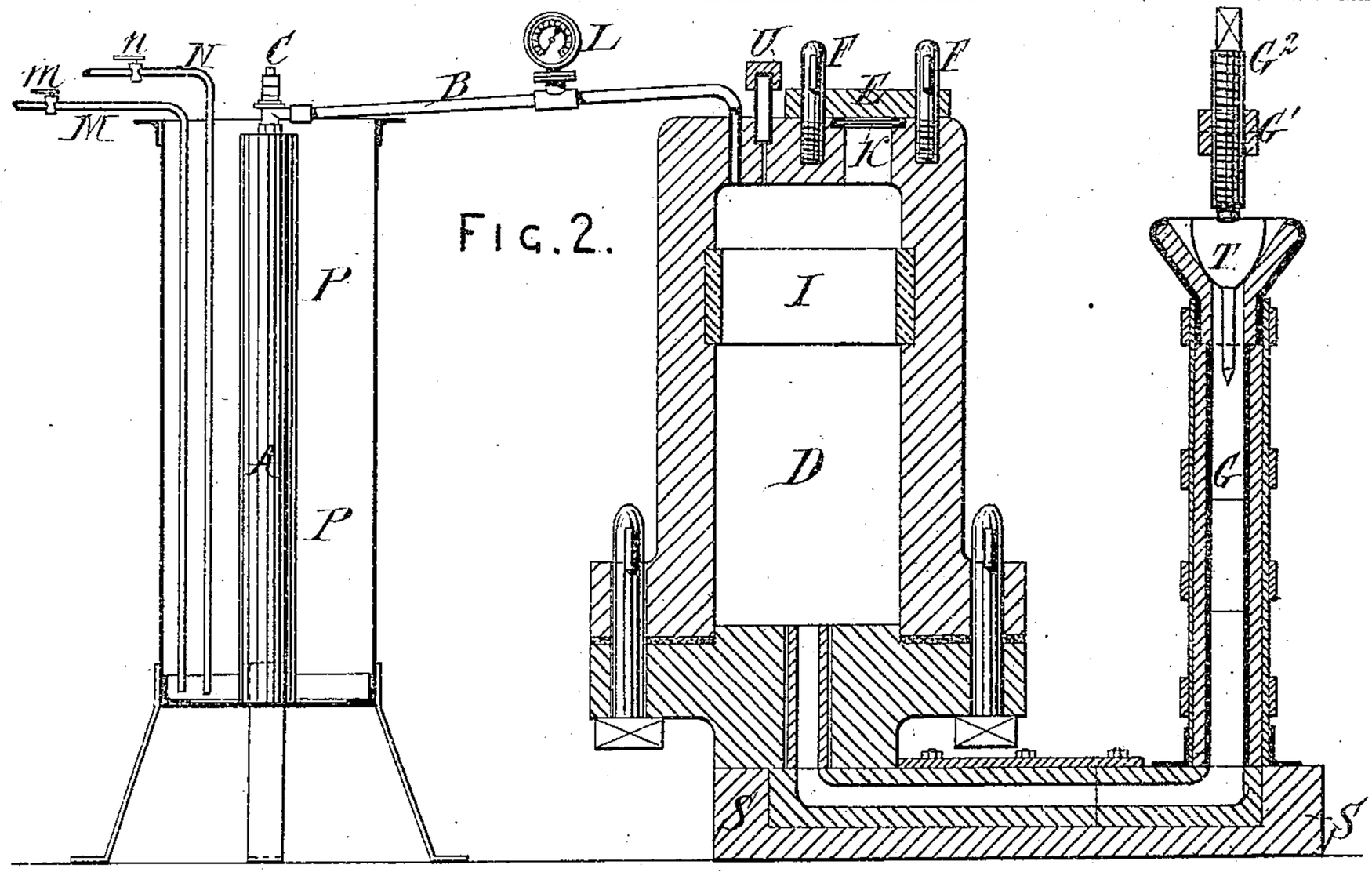


FIG. 2.



Witnesses
Harold Serrell
Chas. H. Smith

Inventor
Frederic A. Krupp
per. Lemuel W. Serrell
Atty.

(No Model.) 3 Sheets—Sheet 2.

F. A. KRUPP.

PRODUCTION OF SOUND INGOTS AND APPARATUS THEREFOR.

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Fig. 3

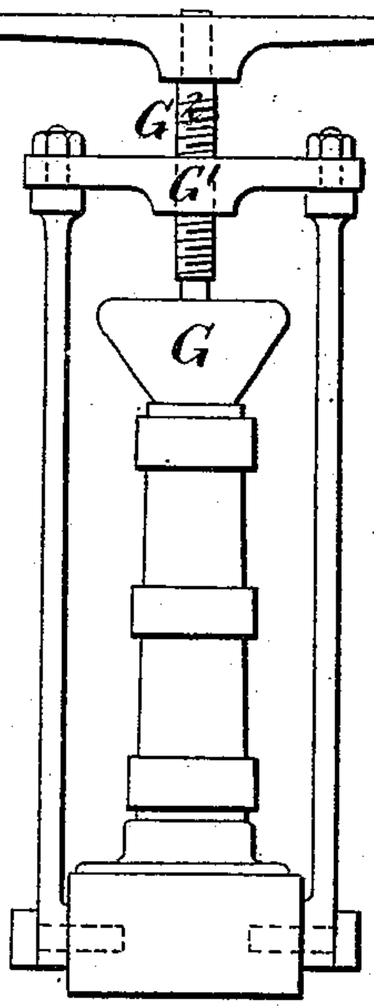


Fig. 4

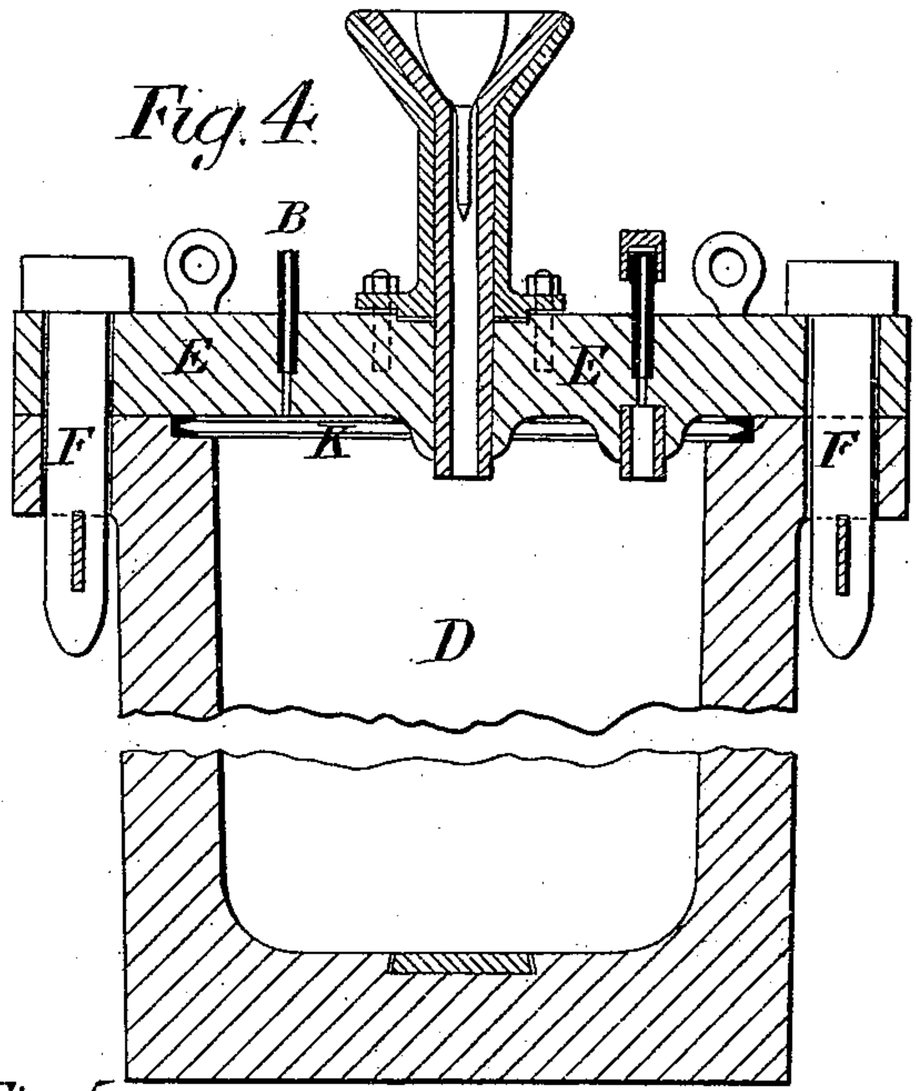


Fig. 5.

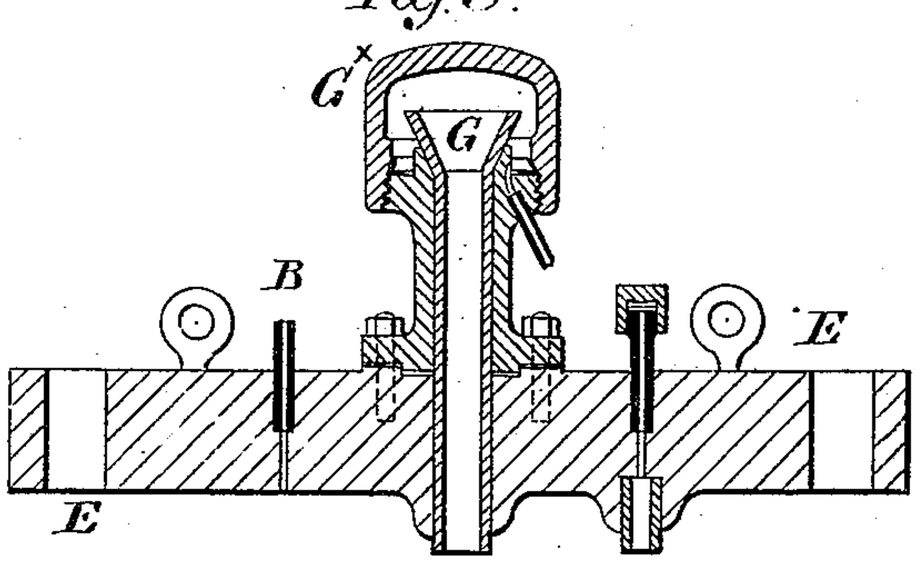
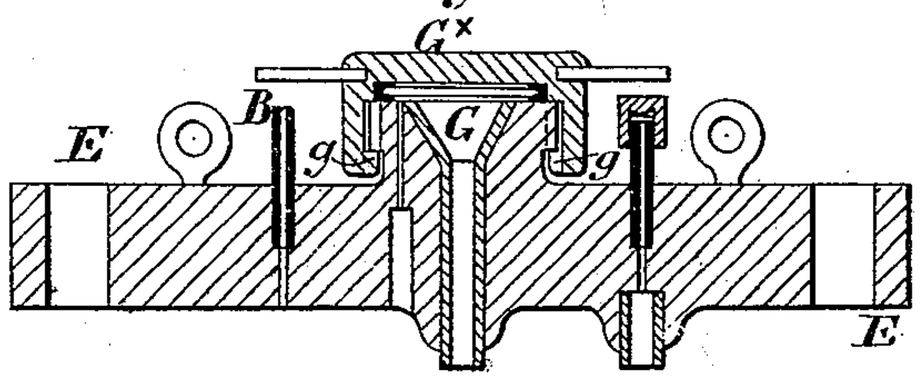


Fig. 6.



Witnesses
Chas. H. Smith
J. Hall

Inventor
F. A. Krupp.
per Lemuel W. Serrell
Atty.

(No Model.) 3 Sheets—Sheet 3.

F. A. KRUPP.

PRODUCTION OF SOUND INGOTS AND APPARATUS THEREFOR.

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Fig. 7.

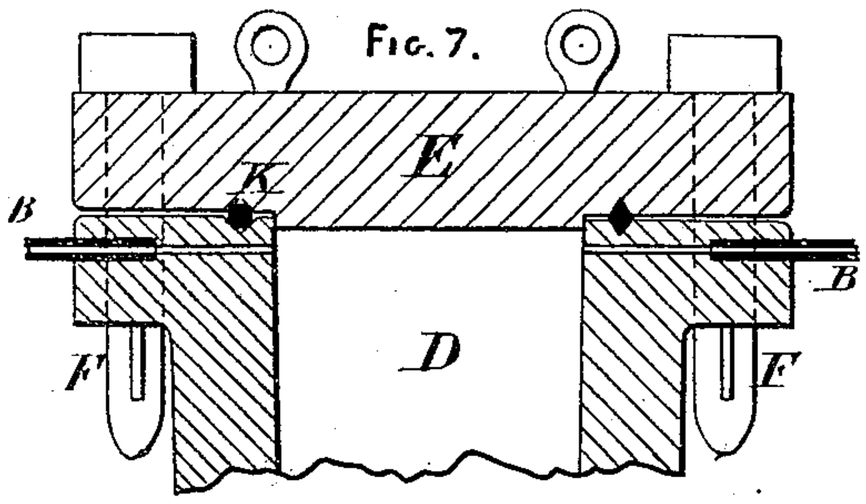


Fig. 8.

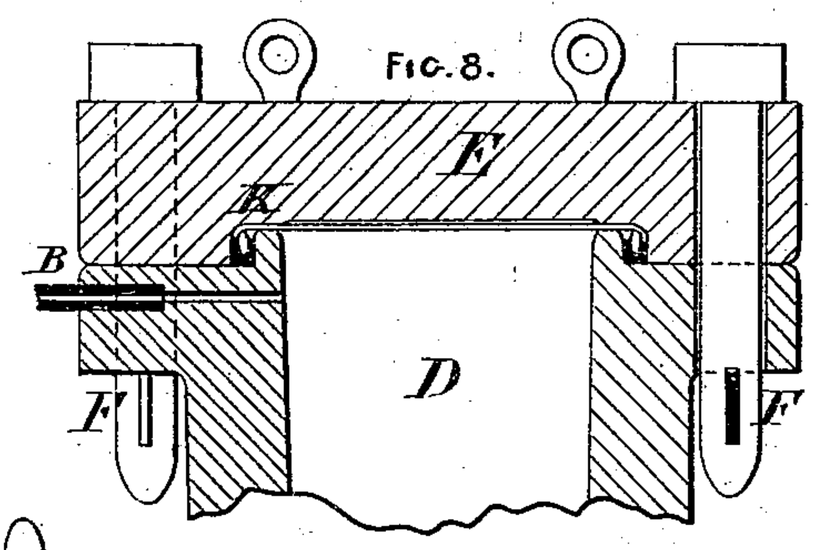


Fig. 11.

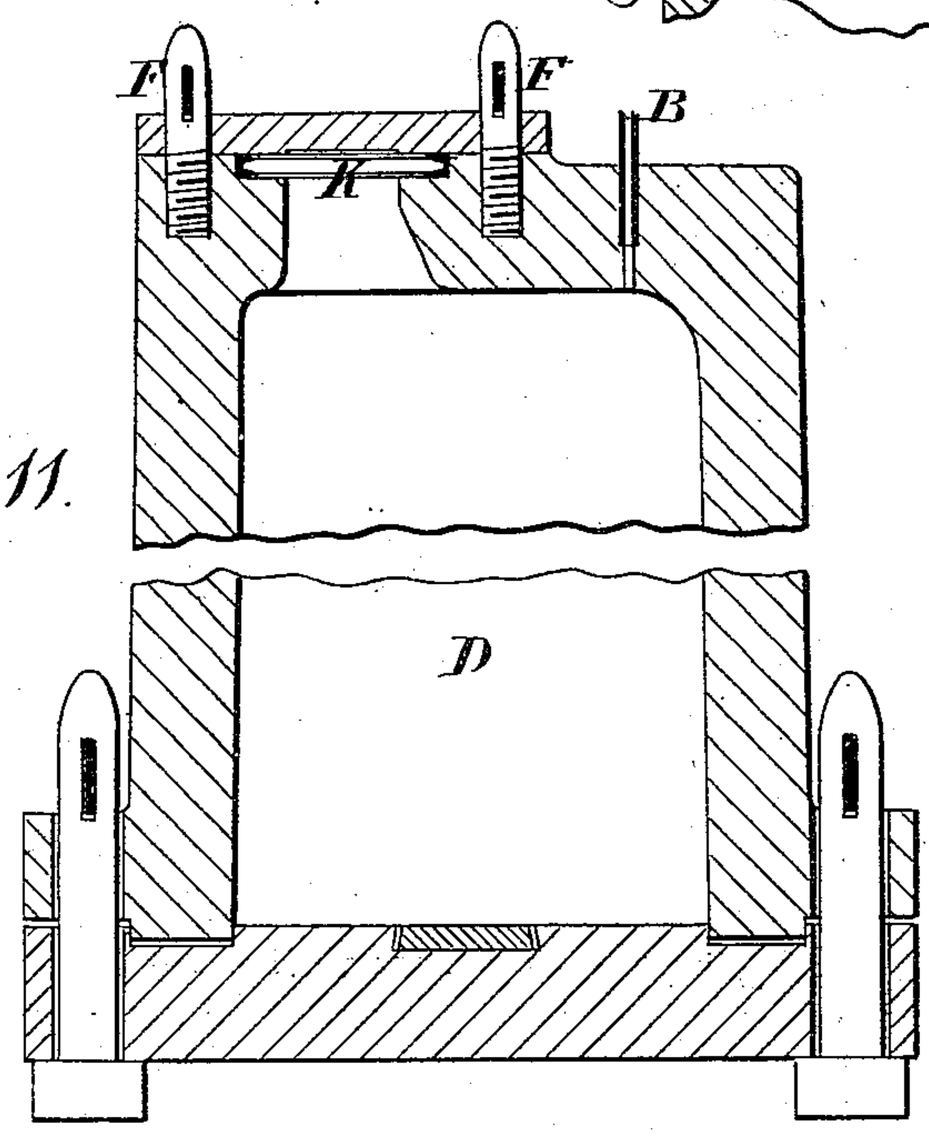


Fig. 9.

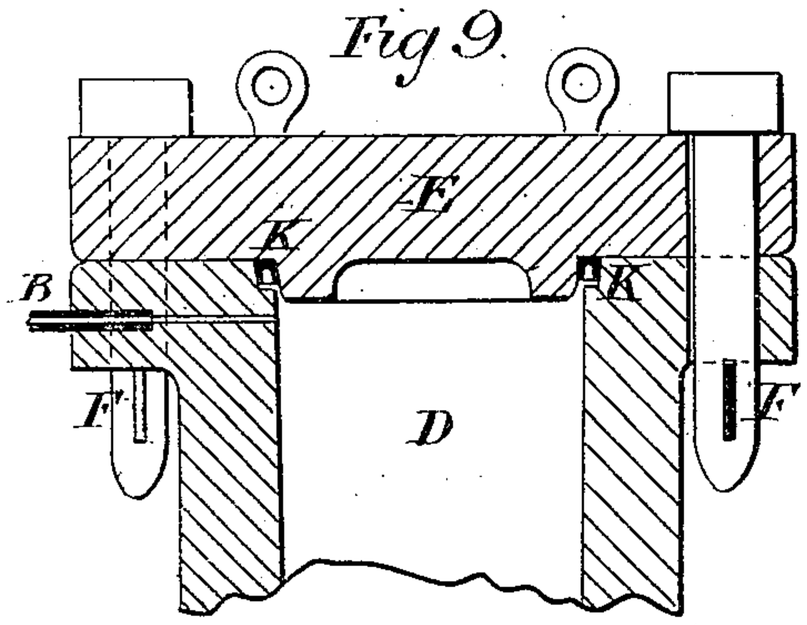
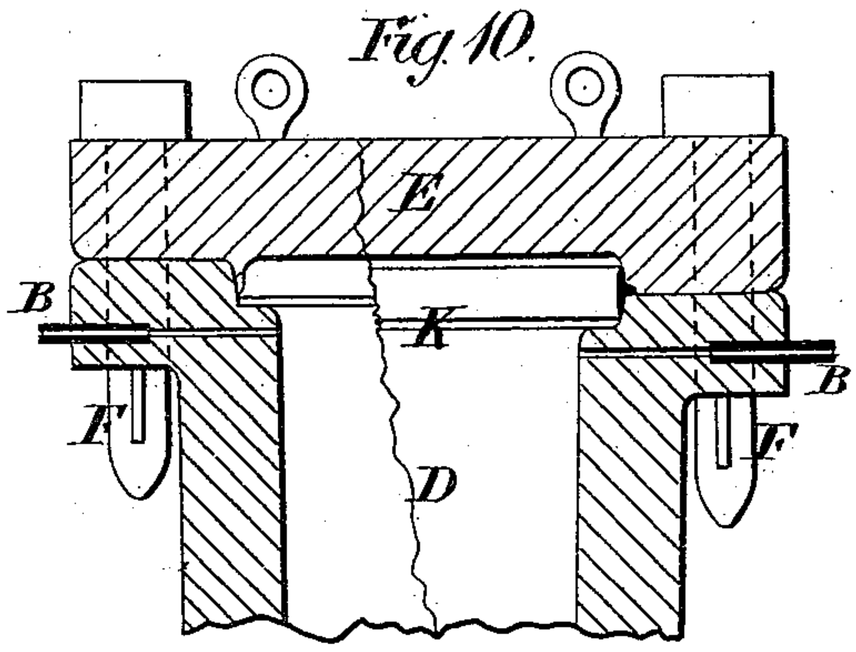


Fig. 10.



Witnesses
Chas. H. Smith
J. Stahl

Inventor
F. A. Krupp
per Lemuel W. Serrell
atty

UNITED STATES PATENT OFFICE.

FRIEDRICH A. KRUPP, OF ESSEN, GERMANY.

PRODUCTION OF SOUND INGOTS AND APPARATUS THEREFOR.

SPECIFICATION forming part of Letters Patent No. 271,717, dated February 6, 1883.

Application filed September 23, 1881. (No model.) Patented in England June 30, 1881, No. 2,860; in Germany June 30, 1881, No. 17,056; in France September 3, 1881, No. 144,704; in Belgium September 5, 1881, No. 55,660; in Luxemburg September 10, 1881, No. 159; in Italy September 30, 1881, XV, 13,374, and XXVI, 419; in Portugal October 10, 1881, No. 698; in Austria-Hungary November 12, 1881, No. 1,905 and No. 1,904; in Sweden December 2, 1881, and in Spain January 28, 1882, No. 2,180.

To all whom it may concern:

Be it known that I, FRIEDRICH ALFRED KRUPP, of Essen, in the Empire of Germany, have invented new and useful improvements in the production of sound ingots and casting of steel and other metals, and in apparatus connected therewith, of which the following is a specification.

Various modes and means have heretofore been proposed with the view of applying the pressure of steam or carbonic-acid or other gas onto the upper or on the entire surface of molten metal or alloy in ingot and other molds for the purpose of insuring a sound ingot or casting, without pores or blow-holes. Steam-pressure has thus been proposed to be applied to the surface of the molten metal, so that the steam, when admitted, acquired a considerably larger but uncontrolled pressure by the heat in mold itself. Gas-pressure has also been proposed to be used, the gas being generated from combustible or explosive matters in the mold or around the mold, the said mold being inclosed in a so-called "pressure-vessel," and so as to necessitate a previous preparation of the mold for that purpose, and involving complicated appliances. It has also vaguely been proposed to put such a pressure-vessel with interior mold in communication with a gas-reservoir heated externally or otherwise, without any indication as to how such an idea might be carried into effect practically and successfully.

According to my invention sound ingots and castings of steel and other metals—such as iron and copper—and alloys—such as bronze—are produced by pressure of gas on the molten metal in molds which are constructed so as when closed to be able to withstand a very considerable internal pressure, and all in the manner hereinafter described. After the steel or other metal has been poured into the mold the latter is tightly closed, and immediate communication is then made between the space above the molten metal in the interior of the mold and a vessel or reservoir which contains a substance in liquid or solid form—such as carbonic acid—which under ordinary pressure and temperature is in the gaseous state. According to the temperature to which the reservoir or the substance therein is exposed, and according to the properties of the substance employed, a gas-pressure of any required strength may be thus obtained. This pressure must be regulated within limits decided upon, as desired, and for this purpose I place the reservoir in a bath of water, oil, or other suitable fluid, which, by the admission of steam or water thereto, can be heated or cooled as required. By the ordinary temperature of the atmosphere—say at 60° Fahrenheit—the pressure obtained by the liquefied carbonic acid is about fifty-two atmospheres, at 86° about seventy-four atmospheres, and, according to my latest experiments, at 212° Fahrenheit the pressure rises to about four hundred atmospheres, and at 400° Fahrenheit even to eight hundred atmospheres. The amount of these pressures depends upon and is influenced by the quantity of filling or contents of the vessel containing the fluid gas when such gas has a temperature higher than 30° centigrade (86° Fahrenheit,) or, as it is termed, the "critical point." For the purpose of keeping the upper part of the molten metal hot as long as possible while the ingot is gradually and evenly cooling and contracting, I provide that part of the mold with an interior lining of refractory material. An equivalent or additional means for the same important object or end consists in pouring in a layer of molten slag onto the surface of the molten metal immediately after it has been poured into the mold, and before closing the mold and admitting the gas-pressure into same. Another additional but not so important means of keeping this part of the metal in a molten state as long as possible consists in making use of a thick cover of a refractory material which is a bad conductor of heat. This cover is dropped onto the top of the molten metal or slag. To insure success, the covering with slag or the use of the lining is necessary; but the use of both means together is preferred. The pressure is maintained on the metal in the mold until there is no further tendency to the formation of hollow spaces or pores in the ingot or casting.

Figure 1 of the accompanying drawings is an elevation in part section of a mold and a gas-reservoir constructed for the purpose of this inven-

tion, and arranged for the mold to be charged with the molten metal from above. Fig. 2 is an elevation in part section of a mold and a gas-reservoir where the mold is charged from below. Fig. 3 is an end elevation of part of Fig. 2—that is, of the conduit for conveying the molten metal into the mold. Fig. 4 is a vertical section through mold to be charged from above. Figs. 5 and 6 are sectional views illustrating two forms of mold-covers. Figs. 7 and 8 are sectional views showing two other forms of mold-covers and modes of forming joint with the mold. Figs. 9 and 10 are sectional views showing other forms of mold-covers and modes of forming joint with the mold. Fig. 11 is a sectional view of a modified form of mold.

Referring to Fig. 1, A is a very strong metallic reservoir or flask, made, say, of wrought-iron welded, and containing the carbonic acid or other substance which is to supply the required very high gas-pressure to the molten metal in the mold. The flask A is placed in a bath, P, of water, oil, or other suitable fluid.

M is a pipe for conveying steam into the fluid for the purpose of heating it, and N a pipe for conveying water into the fluid for the purpose of moderating the heat of the fluid. By means of the valves *m* and *n* on these pipes M and N, respectively, the regulation of the heat of the fluid in the bath P is effected as required, and thereby, again, the heat and pressure of the substance contained in the flask A.

C is a valve for closing or opening the flask A, as required. By means of valves and pipes the flask A may of course be put in communication with any desired number of molds.

D is the mold, here shown of a form suitable for casting ingots; but it may be made of any desired form to suit the casting required to be produced. A pipe, B, forms communication between the flask A and the upper part of the mold. The valve C serves to regulate the admission of the carbonic-acid gas or other substance from the flask A to the mold D. The latter may, as here shown, be formed with a refractory lining, I, which forms a bad conductor of heat for the purpose (as already stated in the preamble to this specification) of keeping the upper part of the metal in a molten state as long as possible, so as to allow it to cool and contract evenly and slowly. This lining is placed in the upper part of the mold D, as shown in Fig. 1, and only forms a partial lining to said mold.

The line *x x* indicates the level to which the metal should be charged into the mold.

W is a loose cover of refractory material, which is dropped onto the surface of the molten metal or slag for the purpose of keeping that part hot as long as possible while the ingot cools down.

D′ D′ are wrought-iron hoops shrunk on the outside of the mold to strengthen it.

E is a strong cover. F F are bolts whereby it is secured to the mold D, and *f f* are cotters passed through them.

K is a turned ring, of steel or copper, of the section shown, and serving to make a gas-tight joint for high pressure. It acts on the same principle as the so-called "cup-leathers" in hydraulic presses, inasmuch as the gas-pressure in the mold tends to force the two lips of the ring K apart, and therefore one lip against the bottom of the turned or faced part of the cover and the other lip in the other direction—that is, against the bottom of the recess in which the ring K is placed. The higher the pressure the tighter the ring will make joint. The jaw between the mold D and its cover E may be made with plumbago, or with asbestus, mill-board, or in other suitable well-known manner for high heat and high pressure, instead of with the ring K, as shown here.

L is a pressure-gage.

V is a disk of refractory material, placed in the bottom of the mold to protect this part against the direct melting or cracking influence of the stream of molten metal.

The mode of casting with this apparatus is as follows: When the cover E has been removed (for which purpose it is provided with eyebolts *e* to lift it by) or turned to one side, after all the bolts F except one, have been removed, the molten metal is poured in. When it has reached to about the level *x x*, a layer of molten slag is poured in on the top of it, for the reason stated. The lid W is then dropped onto the top of the slag, and the joint-ring K is then placed into its recess and the cover E quickly put on and fastened down securely and tightly. I then open the cock C, admitting gas-pressure onto the top of the slag and molten metal in the mold, and this gas-pressure is maintained until the ingot has cooled down to a dull-red heat, whereupon the valve C is closed and the cover E then removed, so that the ingot may be taken out. If the bottom of the mold were not protected by the disk V, the hot stream of metal impinging directly on it, would melt this part and form a recess therein or crack it. The gas-pressure is indicated by the gage L, and can, as stated, be conveniently regulated to any required extent by means of the steam-valve *m* and water-valve *n*.

In Figs. 2 and 3 I illustrate the mode of casting from below. The metal is run into the mold from the conduit G. G′ is a nut formed in a cross-head, which, by means of two rods, is so connected to the bed-plate S that it can be swung out of the way of the conduit inlet-funnel when the metal is to be poured in by the said inlet-funnel. G^2 is a screw working in the nut G′, and furnished with a crutch-handle, so that the screw can be forced down upon the cone-plug T to close the inlet-funnel securely against the high internal gas-pressure. Other suitable means may be used for this purpose, some of which will be described further on with reference to molds to be charged from the top. U is a valve or cap to allow the air to escape during casting, but

which is closed before admitting the carbonic-acid gas. The joint between the mold and the bottom may be secured by asbestus or other suitable material, or by an expanding metallic ring.

Fig. 4 shows a mold with a cover, E, which is fastened down before pouring the metal in, and it is therefore provided with an inlet-funnel through the cover similar to that shown at the conduit G, Figs. 2 and 3—that is, with a cone-plug, T, which can be similarly fastened down in its seat by means of screw and nut, as described. To charge this mold, take the cone-plug out, open the air-valve U, run the metal in, then the slag on the top of it, put in the plug, close the cap or valve U again, and let the gas-pressure in, as before. In Fig. 5 the cover inlet-funnel is closed by means of a screw-cap, $G^{\times}$.

Fig. 6 shows a cover inlet-funnel with a cap, $G^{\times}$, provided with projections *g*, which take under lugs on the neck in such manner that the cap $G^{\times}$, by a partial turn, is locked or unlocked, as required, in a similar manner to a bayonet-joint.

Figs. 7, 8, and 9 show two kinds of cover-joint rings K—viz., in Fig. 7 a copper or other ring, which, originally of a round section, is forced into a square-cornered groove formed in the cover and in the top of the mold, and in Figs. 8 and 9 a double-flanged steel or copper ring, such as shown at Fig. 1, but placed differently, the mode of action, however, being the same as described with reference to Fig. 1.

Fig. 10 shows on one side one form of cover-joint, in which an angle-shaped thin metallic ring is used for making a joint, and on the other side another form of cover, in which the joint is made by means of a T-shaped thin metallic ring, the internal pressure in both cases, as above described, tending to force the thin edges of the rings against the mold and its cover.

Fig. 11 shows a mold closed at the top, except in one place, where it has a hole suitable for pouring in the molten metal and then the molten slag. The hole is then closed by means of a small cover, E, and cottered bolts F, a metallic joint-ring, K, having first been placed in the recess formed for it.

The metallic joint-rings shown I have found suitable for the purpose, and they may also be applied to other purposes wherever a joint is needed to be made that shall withstand high gas or steam or other pressure, and especially where high heat is also present.

Having thus described and ascertained the nature of this invention and modes in which the same may be carried into effect, I declare that I claim—

1. The method herein specified of producing sound non-porous metallic ingots, consisting in pouring the molten metal into a mold, maintaining the temperature and preventing the upper part of the metal consolidating too rapidly by a refractory lining in the upper part only of the mold, pouring a layer of molten slag on the surface of the molten metal, closing the mold, and applying a high pressure during the cooling of the metal, substantially as and for the purposes set forth.

2. In an apparatus for producing sound ingots of cast-steel, the combination of the vessel P, the holder A for the gas-producing substances, the pipes M N and valves for the heating and cooling fluids, the mold for the ingot, and a pipe connecting the vessel A to the same, substantially as set forth.

3. In an apparatus for the production of sound ingots of cast-steel, the combination, with the mold, of a lining, I, in the upper part, and a cover, W, of refractory material, as and for the purposes set forth.

4. In an apparatus for the production of sound ingots of cast-steel, the combination, with the mold D, cover E, lining I, and cover W, of the holder A, bath or vessel P, pipes M N, valves *m n*, pipe B, and valve C, substantially as and for the purposes set forth.

F. A. KRUPP.

Witnesses:
FERDINAND VOGELER,
GOTTFRIED RADERMACHER.