4 Sheets—Sheet 1.

S. H. ROUART.

Apparatus for Effecting Interchange of Temperatures of Fluids.

No. 224,611. **Patented Feb. 17, 1880.**

Fig. 1.

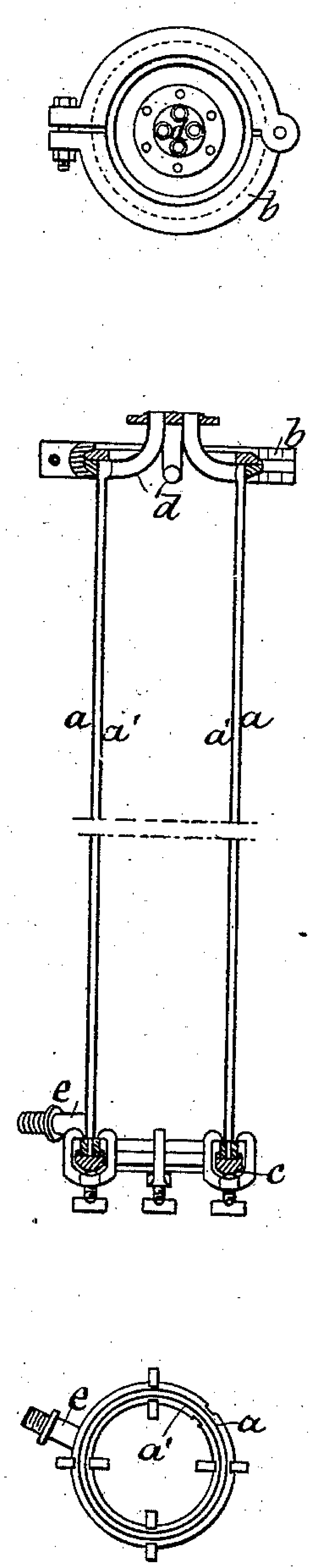


Fig. 2.

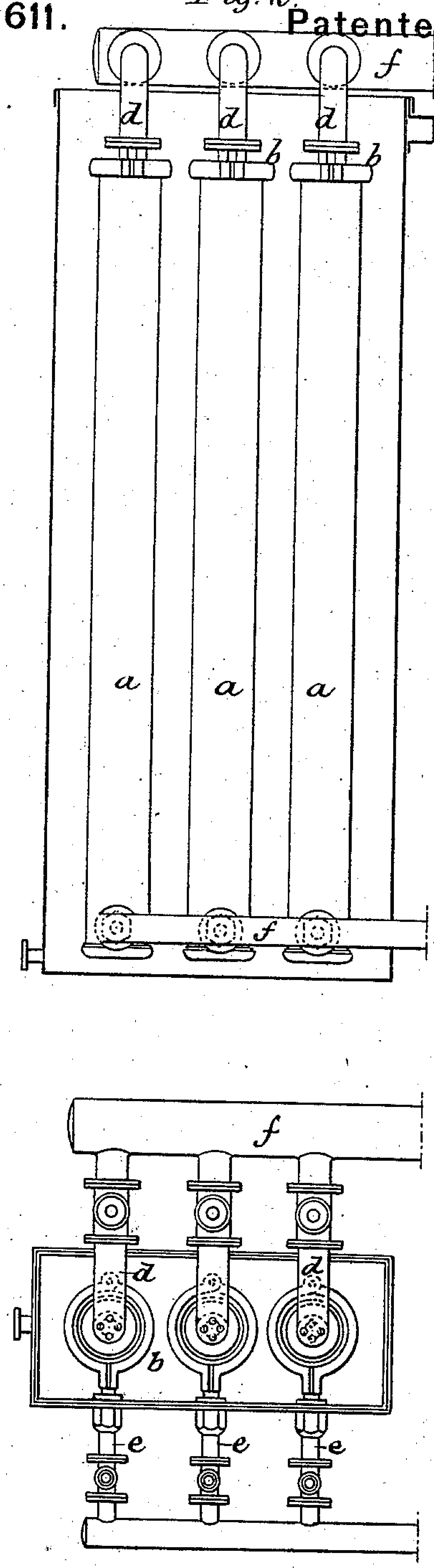
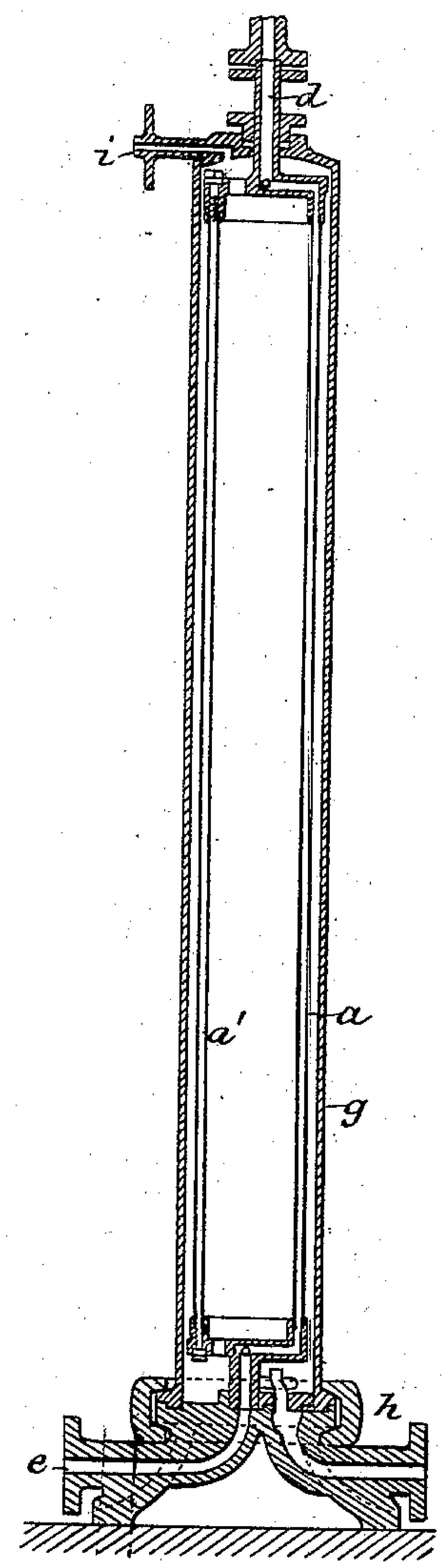


Fig. 3.



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S. H. ROUART.

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Fig. 4.

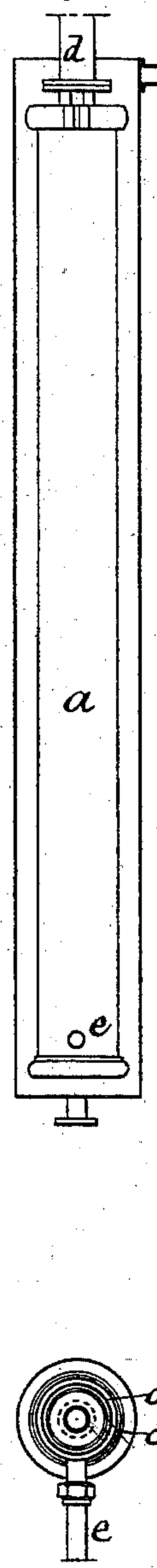

Fig. 5.

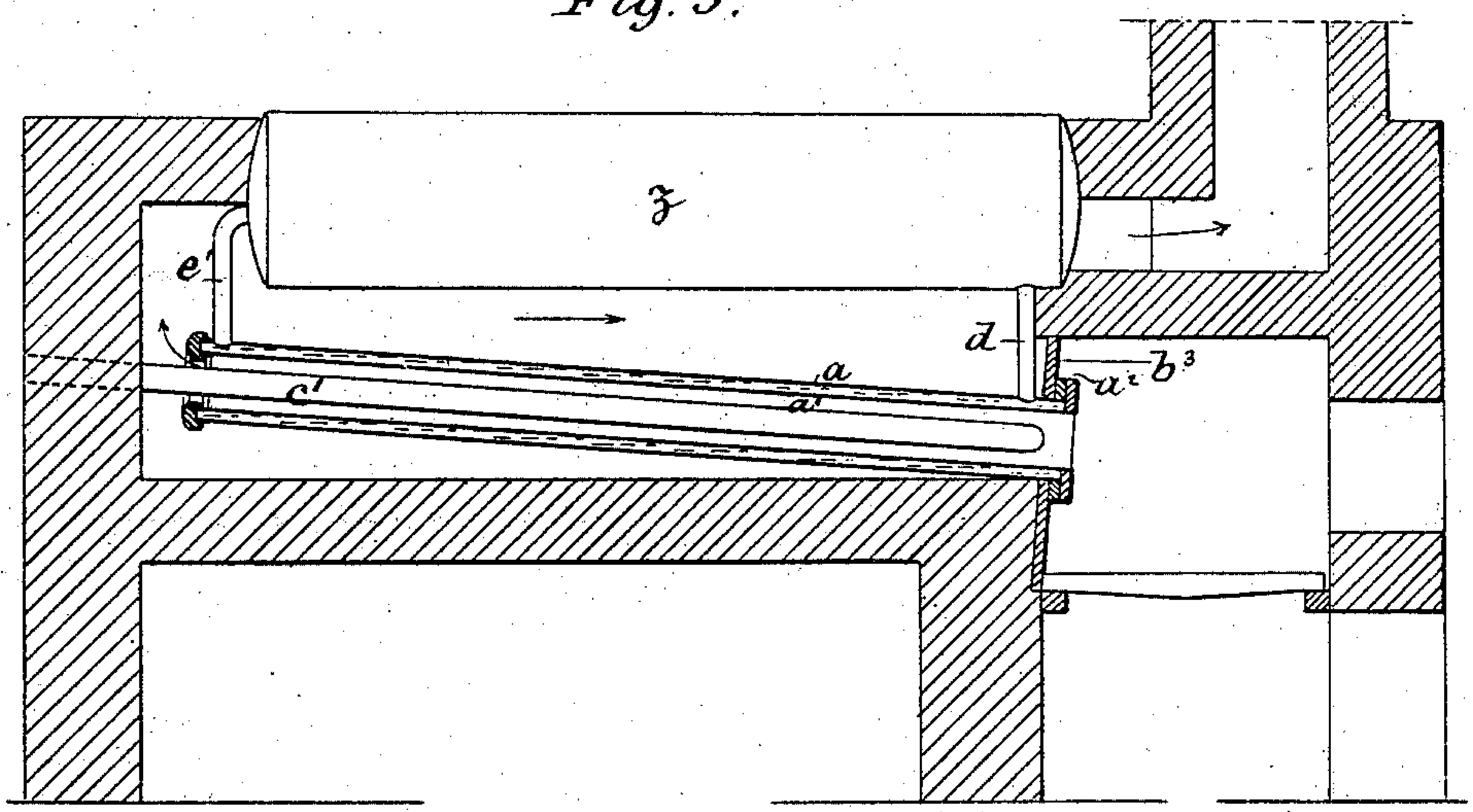

Fig. 6.

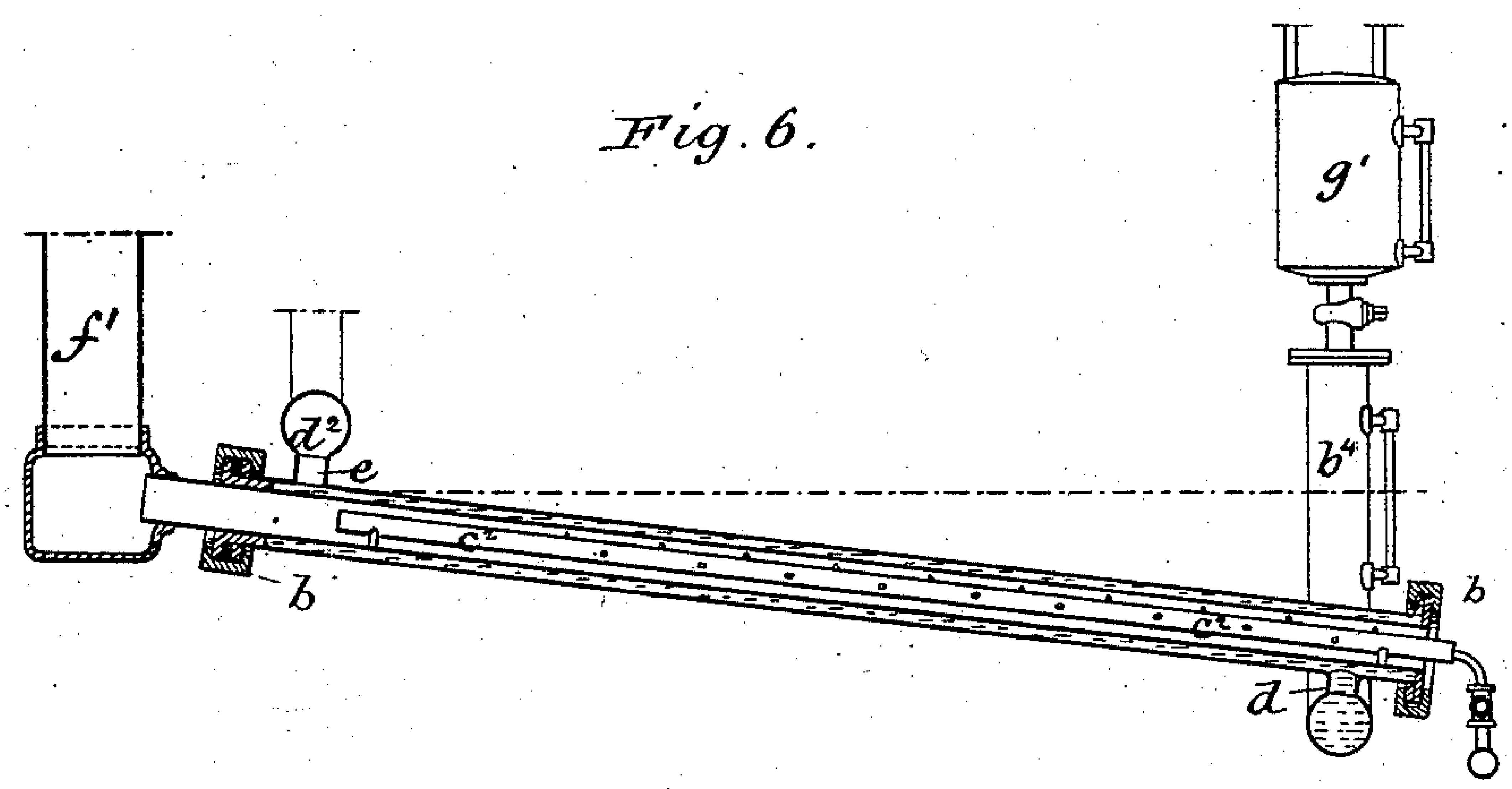

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Fig. 7.

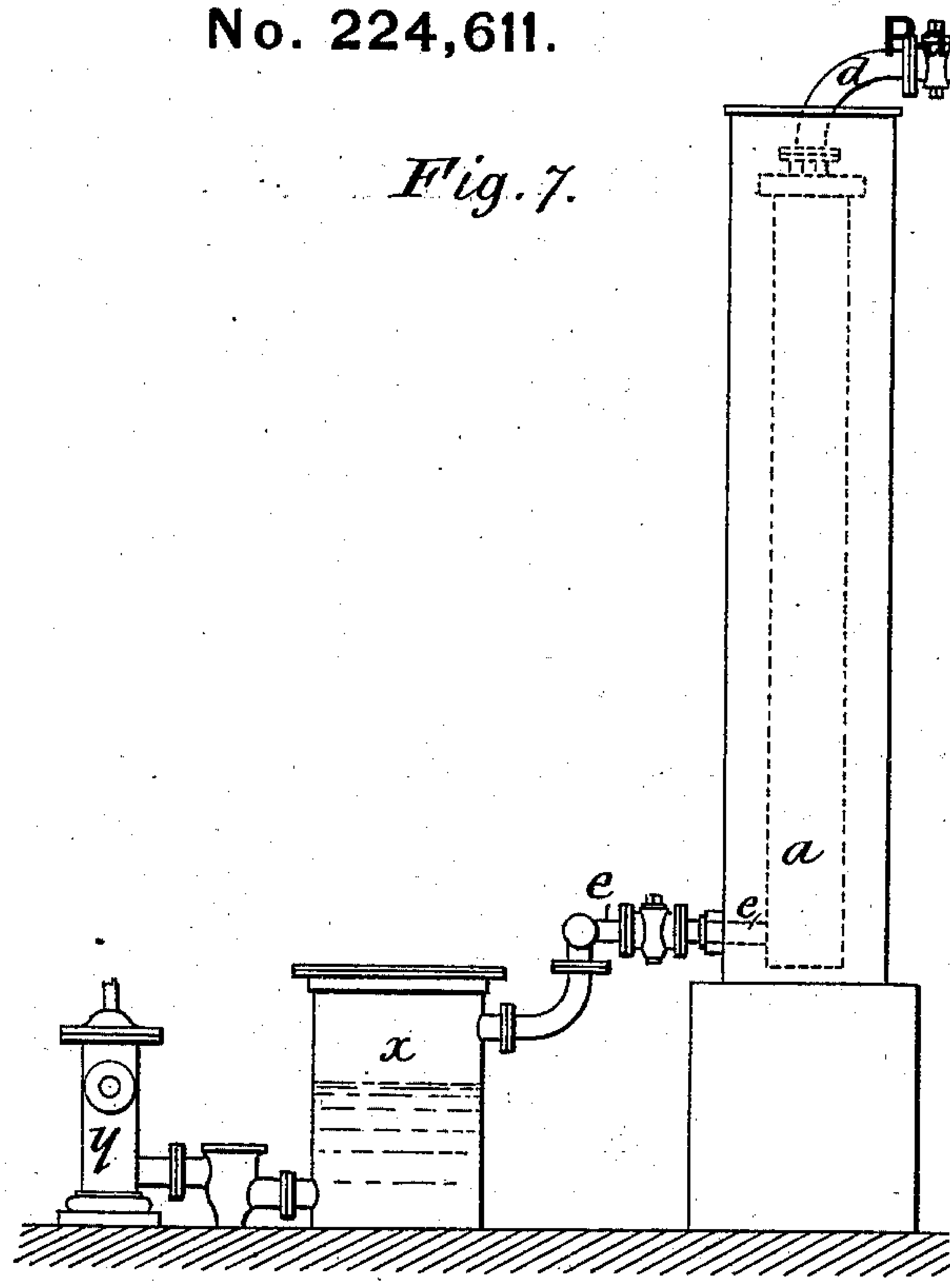


Fig. 8.

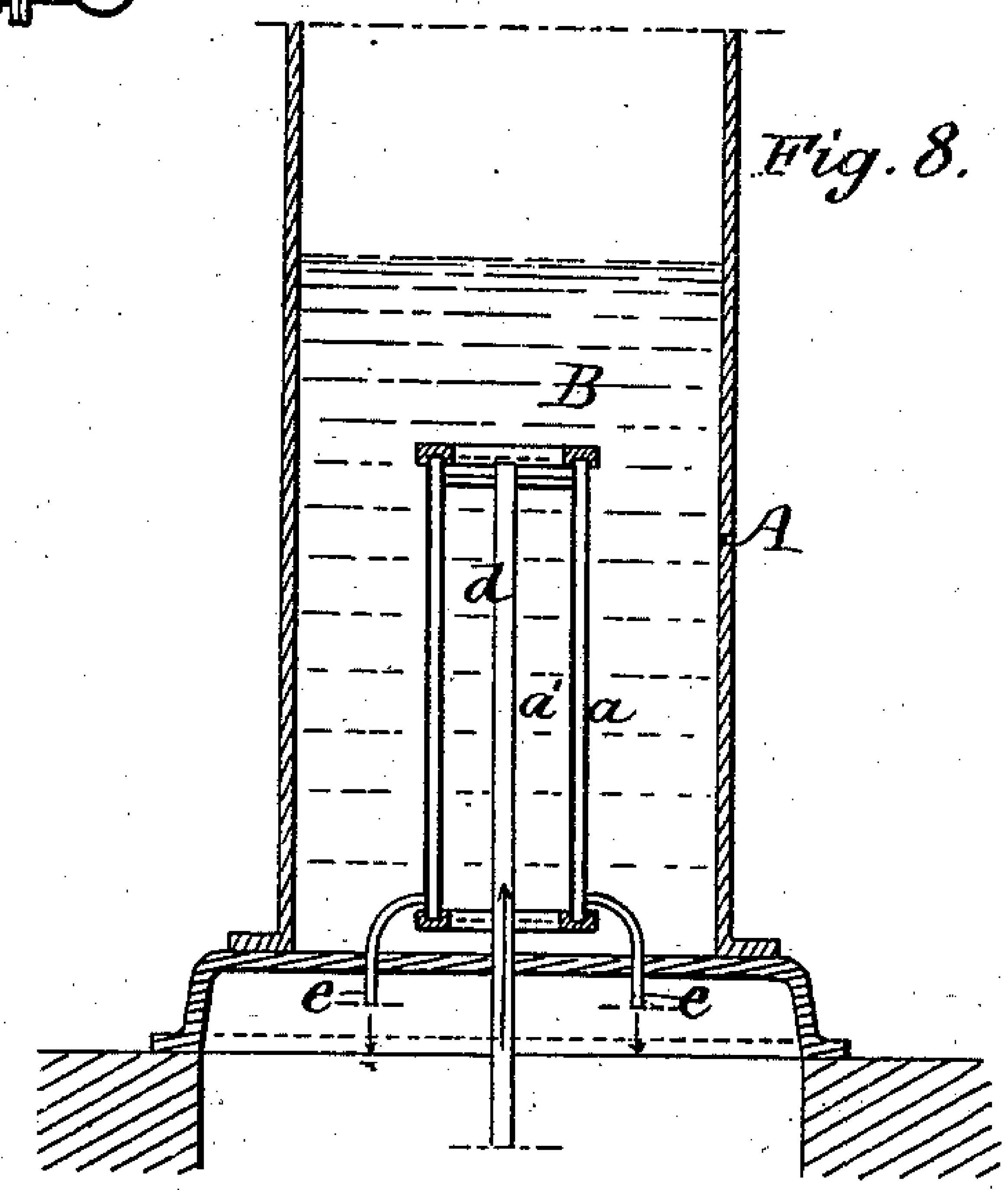


Fig. 9.

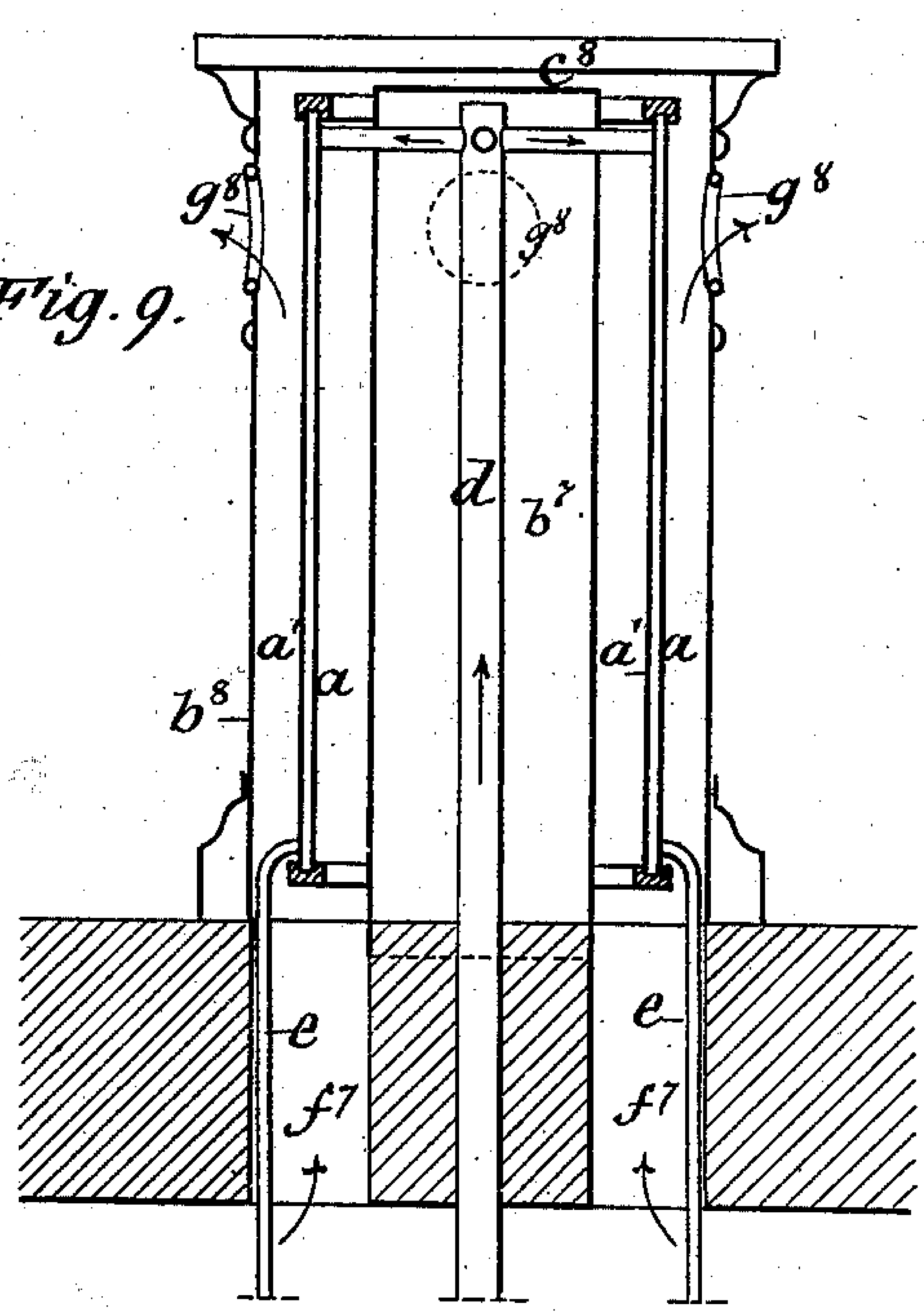
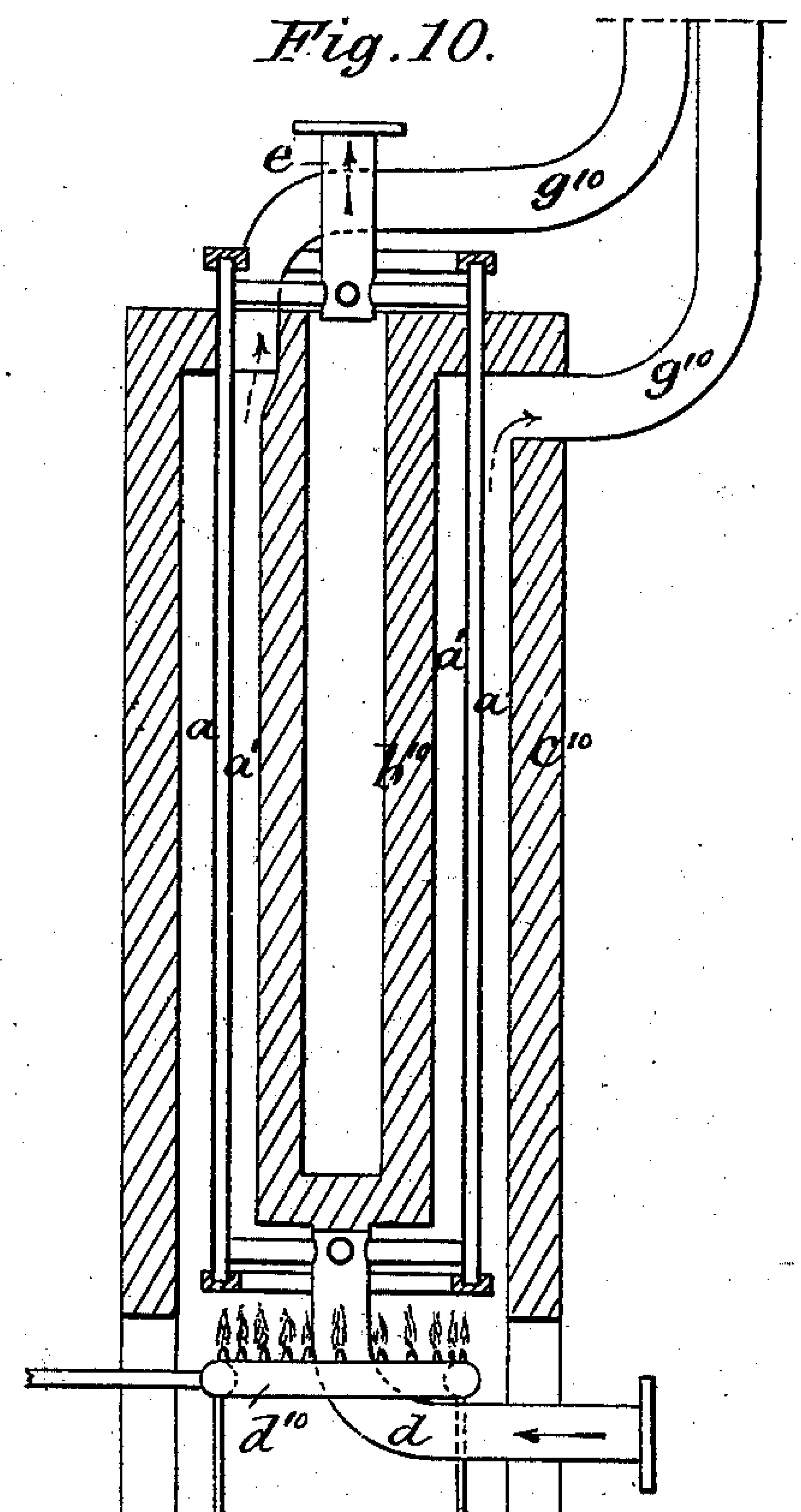


Fig. 10.



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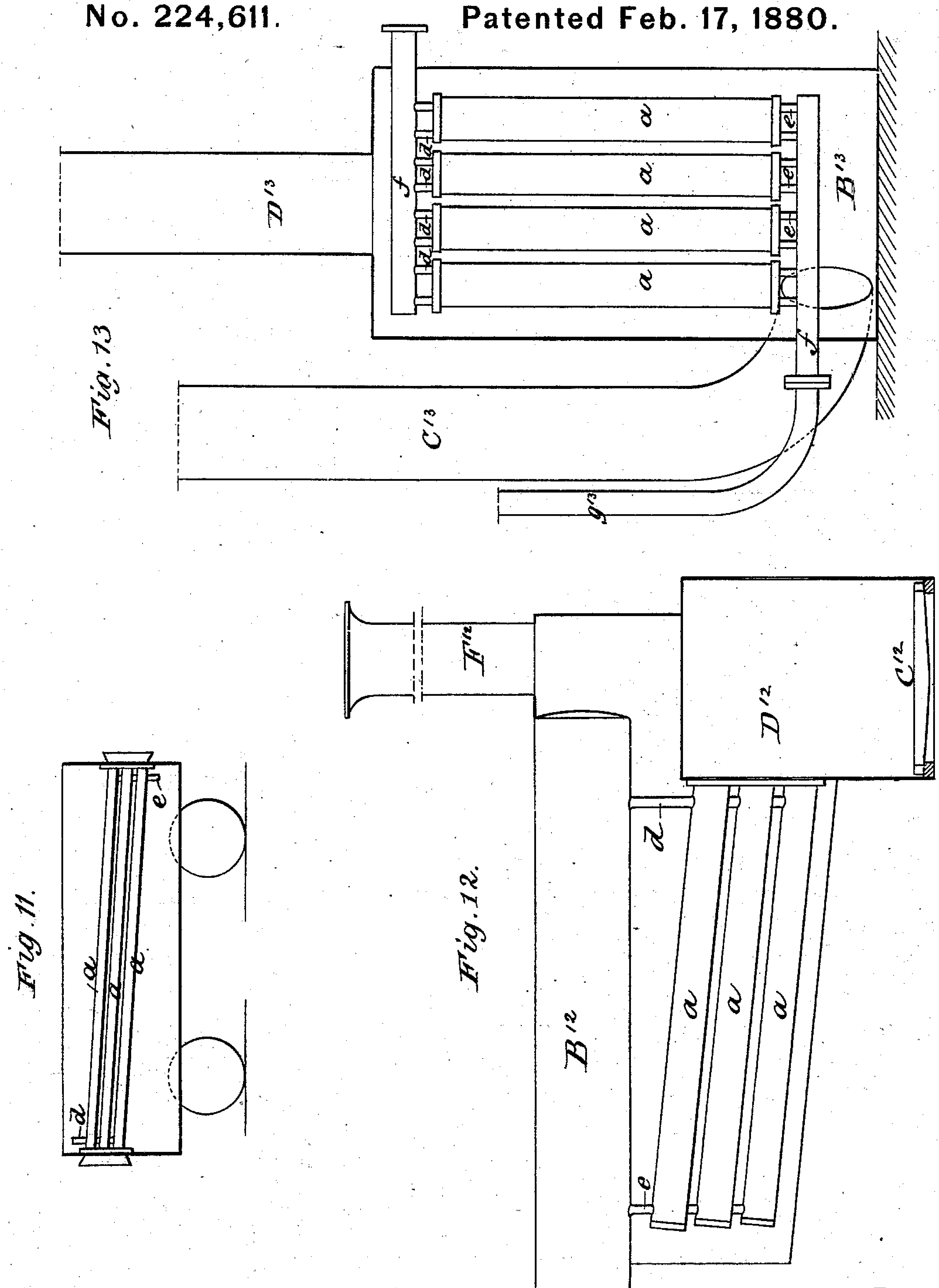

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UNITED STATES PATENT OFFICE.

STANISLAS H. ROUART, OF PARIS, FRANCE.

APPARATUS FOR EFFECTING INTERCHANGE OF TEMPERATURES OF FLUIDS.

SPECIFICATION forming part of Letters Patent No. 224,611, dated February 17, 1880.

Application filed December 17, 1879.

To all whom it may concern:

Be it known that I, STANISLAS HENRI ROUART, of the firm of Mignon & Rouart, engineers, of Paris, in the Republic of France, have invented Improvements in Apparatus for Effecting Interchange of Temperatures in Fluids, of which the following is a specification.

The general object of this invention is to impart the heat of one fluid to another in a better or more expeditious manner than it has been heretofore effected.

In the industrial arts, in the large majority of cases, the transfer of heat is caused to take place between fluids either between two liquids, or a liquid and a gas or vapor, or between two gases or vapors. All these fluids are, however, bad conductors, and generally in constructing apparatus for this purpose sufficient account is not taken of this lack of conductivity. It is well known that the temperature of fluids is most easily altered when in very thin films; but heretofore great practical obstacles have been encountered in the employment of thin layers, because the apparatus devised for the purpose in which such condition has been obtained are found to become readily obstructed, and it is almost impossible to take them apart and inspect or clean them.

In this invention the fluid is obtained in thin films, which might be termed "capillary," with apparatus which can be easily taken apart and put together again, and which consequently may be of small dimensions and yet possess great efficiency and rapidity of action in transferring the heat from one fluid to another. This efficiency is due in large part to the rapid renewal of the points of contact by a very rapid circulation of the fluids through the contracted places.

The apparatus is employed to raise or lower the temperature of a liquid or gas by means of another liquid or gas of higher or lower temperature, as required, or for converting a liquid into a gas or condensing a gas into a liquid. It is applicable to various arts and industrial purposes, among which may be mentioned furnaces for heating air, steam-heaters for houses, steam-generators, condensers operating by water or air for stationary, locomotive, and marine engines, heaters for water and other liquids, coolers for beer and other liquids, condensers and liquefactors of ice-machines, stills and condensers therefor, besides many others that will suggest themselves to skilled artisans, operatives, and mechanics.

The invention will be most readily understood in connection with the accompanying drawings, which form a part of this specification, and in which—

Figure 1 represents, in plan and in longitudinal and cross sections, a single element as a type; and Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13 illustrate the arrangement and combination with other devices of one or more such elements in apparatus for various useful purposes.

The same letters indicate like parts where they occur on all the figures.

Two tubes, *a a'*, of metal, of slightly different diameters and of a suitable size and thickness, are placed concentrically one inside the other, so as to leave a small space between the interior surface of one and the exterior of the other. This annular space is as small as is practically possible. The two tubes are connected and held in their relative positions by a grooved or U-shaped collar or head at each end. The joints are formed by plane surfaces. The several parts may thus be readily taken apart for cleaning or other purposes, and screw-threaded or swaged joints, stuffing-boxes, or similar devices heretofore used are dispensed with. In Fig. 1 such means are clearly shown. A grooved sectional collar, *b*, fits over conical flanges at the upper part, and at the lower part a U-shaped or grooved collar or head, *c*, is held by screw-clamps against the ends of the tubes.

One of the fluids suited to the special application passes through the annular space which is left between the two tubes, and the other circulates over the exterior and interior of the concentric tubes, so that all the surface is utilized for the interchange of temperatures. Whatever may be the fluid which is circulated in the annular space, it should, in general, be delivered at a number of points on the periphery of the interior tube, although in some cases delivery at a single point will answer. This delivery device is indicated by *d*. In Fig. 1 it is shown in a very simple form, being composed of four tubes, which pass through four holes in a plate which is attached over the mouth of a larger tube, as shown in Fig. 2. The device is, however, varied for different purposes. At the opposite end of the concentric tubes is placed the outlet *e*, connecting with the annular space between them.

In order to obtain a very large heating or cooling surface, as the case may be, a number of elements such as first described may be combined by connecting their several inlets and outlets by collectors *f*, Fig. 2, or by connecting them in series end for end, so that the fluid traverses them all successively, in the one case the quantity of the fluid whose temperature is modified being increased, and in the second the degree or amount of change in the temperature.

The general principle of the new apparatus having been explained, the application of the same to various machines will be readily understood. A number of these applications, showing a variety of types, are illustrated in the accompanying drawings, and will now be described.

For the purpose of clearer presentation the apparatus are divided into three classes, an interchange of temperature or transfer of heat being effected in the first between two liquids, in the second between a liquid and a gas or vapor, and in the third between two gases or vapors.

I. In the first class there are two distinct types—to wit, (1,) in which both liquids are under pressure, and (2) in which one only is under pressure.

(1.) As an example of the former type may be taken the exchanger or condenser which is employed in ice-machines, operating by means of an ammoniacal solution. An apparatus of this kind is shown in Fig. 3. The tubes *a a'* should be capable of withstanding the pressure to which they are to be subjected. The annular space is closed at the top and bottom, as shown, and the cylinders are plunged into a vessel, *g*, containing a medium which is itself under pressure. The tube *d*, through which the hot liquid is introduced into the annular space, passes through a stuffing-box. At the lower end of the apparatus the outlet *e* is arranged. The other liquid enters the apparatus at *h*. It escapes by the outlet *i*, being heated in its passage through the apparatus. The sides of the vessel *g* are held to the base by a sectional collar. The liquid which enters by the tube *h* is divided and passes over the cylinders *a a'*, which constitute what is called the "capillary cluster." The efficiency of this apparatus has, from numerous experiments, been demonstrated. It is constructed for use with ammonia, of iron parts, without any soldering or brazing with other metals, so that it is thus rendered very solid.

(2.) As an example of the second type, an exchanger or cooler for breweries may be taken. The capillary cluster is constructed as shown in Fig. 1. The beer to be cooled passes through the annular space between the concentric tubes, and the water which is employed to carry off its heat passes over their surfaces. If it is desired to economize in the amount of water used, the size or diameter of the vessel in which it circulates should be diminished, as shown in Fig. 4. The exchange of temperatures is very perfect, and the water for cooling escapes very hot, so that consequently a less quantity is required.

II. As examples of the second class of exchangers, in which a transfer of heat is effected between a gas or vapor and a liquid, steam-boilers heated by a fire or by gas, surface-condensers, and steam-heaters for raising the temperature of liquids may be taken.

(1.) Steam-boilers using the capillary cluster should be fed with distilled water, which may be obtained from surface-condensers, as otherwise obstruction is liable to occur. It should be considered, however, that by a very rapid circulation the deposition of solid matter from the water when the latter is not overcharged with calcareous salts is avoided. The construction of a boiler of this class is shown in Fig. 5. The capillary cluster *a a'* is placed in an inclined position under the body of the boiler or reservoir *z* for the steam and water. It is connected at the lower end with the reservoir at the bottom, and at its highest part it is connected therewith at a point just below the level of the water. The joint a^2, which unites the parts of the capillary cluster, connects the cluster also with a plate, b^3, which forms the back of the fire. Inside the cluster is located an iron tube, *c'*, closed at the end, which tube, by reason of its central position, forces the gases to come in contact with the interior walls of the tube *a'* of the cluster. The products of combustion pass through the tube *a'*, and then return on the outside of the tube *a*, under the reservoir *z*, to the uptake, as shown by the arrows.

(2.) If it is desired to heat the boiler by illuminating or other combustible gas, the disposition shown in Fig. 6 is adopted. The gas is brought by a central tube, c^2, perforated at suitable intervals. The water is fed to the annular space in the cluster from a reservoir, b^4, to which it is supplied by the bottle or reservoir *g'*. The steam is collected in a reservoir, d^2, while the burned gas is carried off by the chimney *f'*. There is no loss of steam, and consequently none of the water in the boiler, so that the size of the cylindrical body may be reduced to a minimum. Such a disposition of the boiler as described has the advantages of being fired, so to speak, instantaneously, of being entirely safe, of permitting the heat to be increased or decreased by a simple turning of a stop-cock, which can be effected at any desired point in the house, and, finally, of allowing, by simple means, the regulation of the pressure within a certain maximum limit by controlling the flow of gas.

(3.) Steam-condensers operating by means of water for land or marine engines can be made in the simplest manner by the aid of the tubular or capillary cluster. By causing the steam to flow into the annular space, Fig. 1, it condenses very energetically. Under ordinary conditions one kilogram of steam has been condensed per square decimeter of surface per hour, which is equal to one hundred kilograms per square meter, or about five times greater than is commonly obtained. This power of condensation gives great advantages, particularly in marine engines, where space is necessarily limited, and, in connection with the facility of taking apart, cleaning, and putting together of the apparatus, it is obvious that this system will render large services to navigation. The annular spaces are, however, as in other surface-condensers, liable to have their efficiency impaired by oily matters deposited from the steam.

The remedy for this inconvenience is very simple, and is as follows: If the condensing-surface required is that of six similar elements, seven or eight are used, so that one or two may be isolated from the others by means of stop-cocks, as shown in Fig. 2, and consequently while the apparatus is in full operation any one of these elements can be isolated and cleaned. The condensation in the annular capillaries produces therein a vacuum which is apt, by reason of the narrowness of the space in which condensation takes place, to cause the water to remain in suspension and prevent further condensation. To overcome this difficulty a water-reservoir with constant level (see Fig. 7) is interposed between the feed-pump *y* and the condenser, and into this reservoir the condensed water is drawn. If necessary, a vacuum can be made therein by a small jet of steam.

As another example under this second class the heating of liquids by steam may be taken. The coils commonly used in steam-heaters are replaced by the capillary cluster, and the following disposition is or may be adopted: The capillary cluster *a a'*, Fig. 8, is placed in the center of a heater or boiler, A, at the lower part thereof, but at some distance from the bottom, so as to be immersed in the liquid B contained in the boiler A. Steam enters by the pipe *d* and escapes by the pipe *e*. A very efficient, compact, and easily-made apparatus is thus produced.

III. As examples of the third class, in which exchange of temperatures is effected between two gases or vapors, apparatus for heating air by steam or gas, steam-condensers operating by air, and hot-air furnaces used in metallurgy or other arts may be taken.

(1.) In order to heat air by steam, the coils or systems of pipes heretofore used are replaced by the capillary cluster, so that thereby economical stoves or heaters of great efficiency can be constructed. Fig. 9 represents, in vertical section, a stove or heater of this description. The steam is introduced by the pipe *d* into the annular space between the tubes *a a'*, and after condensation passes off by the pipe *e*. Exterior and interior cylinders, b^8 b^7, of earthenware, sheet-iron, or other suitable material, inclose the capillary cluster, and cause the air which enters through the openings f^7 to come into contact with the surfaces thereof. The heated air passes off by the openings g^8. The top of the stove or heater is indicated by c^8.

From experiments made with an apparatus as last described, ten kilograms of steam per hour have been condensed per square meter of the condensing-surface by the passing air. Theoretically, therefore, about eight hundred cubic meters of air can be heated from 5° centigrade to 20° centigrade per square meter of condenser per hour.

(2.) In order to heat air directly by the combustion of gases, the capillary cluster is combined in an apparatus, as shown in Fig. 10. The air to be heated passes through the annular space between the tubes *a a'*, and the gas is supplied to the burner d^{10}. The products of combustion pass over the surface of the capillary cluster, against which they are directed by the cylinders b^{10} and c^{10}, and escape by openings or pipes g^{10}, which carry them to a suitable chimney.

It is obvious that the separating-cylinders b^{10} c^{10} could be made hollow and serve as the conduits or receptacles for the gas. A number of holes or burners would in that case be placed on their surface, so as to take the place of the burner d^{10}.

It will be understood that the rapidity of the circulation of the air through the annular space of the capillary cluster is to be regulated in accordance with the heating effect of the burning gas, and if necessary recourse is had to a ventilator or other air forcing or circulating apparatus.

(3.) The application of the capillary cluster to steam-condensers operating by air is very important. It will therefore be spoken of more in detail. It has already been stated that in a general way, by means of the capillary cluster, about ten kilograms per hour and per square meter of surface could be condensed by a current of air at ordinary temperatures. The condensation by air will therefore be about ten times less active for the same surface as the condensation by water. The condensing-surface in this cluster being five times more active than the ordinary condensing-surfaces in use, it follows that, with surfaces double those now used for condensers operating by water, steam-condensers operating by air can be constructed. In a large number of cases, therefore, this class of apparatus can be advantageously employed—for example, in locomotive-engines, assuming that a locomotive consumes per hour two thousand kilograms of steam, to condense these two thousand kilograms there must be about two hundred square meters of surface. If a capillary cluster of about sixteen centimeters in mean diameter be taken, it will furnish a square meter of active surface per meter in length, so that two hundred meters will be necessary. Allowing five meters for each cluster, forty elements will be necessary, and these can readily be placed on the tender in the manner substantially as represented in Fig. 11. The capillary clusters are placed in position inclined to the horizon, or even vertically. The steam enters the annular spaces at the upper part, and the condensed water passes off at the bottom. It may be returned to the boiler by the means already indicated for condensers operating by water, and which therefore need not be again described.

It is obvious that the activity, so to say, of the condensing-surface will depend on the speed of the train, so that the air being drawn through the capillary clusters will produce therein a very rapid change of temperature. From these condensers the locomotive-boilers can be fed with chemically-pure water, and the small additional quantity necessary to supply the losses from the cylinder-cocks, whistle, safety-valve, and from the use of steam for creating the blast can be supplied by water distilled or of sufficient purity from reservoirs located at suitable points on the line. In consequence of this purity of the water, locomotive-boilers with capillary clusters analogous to those already described, and as represented in Fig. 12, may be employed.

B^{12} is the cylindrical body of the boiler, which serves as a reservoir for the water and steam; C^{12}, the grate, D^{12} the fire-box, and F^{12} the smoke-stack. Under the body B^{12} a series of clusters, *a a a*, are arranged in an inclined position, as shown, and connected with the body B^{12} by the pipes *d* and *e*.

The advantages of the foregoing system are the dispensing with the largest part of the feeding of water at stations, great improvement in the efficiency of the vaporizing-surfaces, ready inspection and cleaning of these surfaces, an almost indefinite increase in the travel of trains without stoppage, and considerable economy in coal by the transformation of high-pressure into low-pressure engines.

It is obvious that the condensers may be applied as well to stationary as to movable engines with advantages analogous to those described for locomotives.

(4.) The hot-air furnaces for metallurgic purposes heretofore used have been of considerable proportions, and consequently very costly. Their size is due to the difficulty of effecting interchange of heat between the fluids air and gas—both bad conductors. The size of apparatus of this description, and therefore the price also, is considerably reduced by the adoption of the capillary clusters, which are given the dimensions ascertained by practice. To this end a series of capillary clusters are placed in a chamber located at the bottom of a chimney. The hot gases from a blast-furnace are admitted into the lower part of this chamber, and escape by the chimney after passing over all the capillary clusters, in which the air to be heated is circulated by means of a blower or other forcing apparatus. The cold air enters the annular spaces in the clusters from a collector at the top, and it escapes in a heated condition by a collector at the bottom, to be delivered at the blast or other furnace. This disposition is represented in Fig. 13, *a a a a* being the capillary clusters; *d*, the inlet-pipes into the annular spaces, and *e* the outlet-pipes; *f*, the collectors; B^{13}, the exchanging or air-heating chamber; C^{13}, the conduit for admitting the hot gases; D^{13}, the chimney, and g^{13} the pipe for conveying the hot air to the blast-furnace, which pipe should be as short as possible.

If desired, centrally-arranged tubes or deflectors, as shown in Figs. 5, 6, 9, and 10, could be used in the clusters shown in this figure, or in others wherein it is not so represented.

In order to secure the grooved collars or heads to the concentric tubes in the apparatus shown in Figs. 5, 8, 9, 10, 11, 12, and 13, the clamps shown in Fig. 1 applied to the head *c* could obviously be employed; but other efficient means could be used instead.

Having thus fully described my said invention and the manner in which the same is or may be carried into effect, what I claim, and desire to secure by Letters Patent, is—

1. A capillary cluster consisting of two concentric tubes of slightly unequal diameter, combined with a U-shaped or grooved collar or head at each end, as set forth, for holding the tubes in their proper positions relatively to each other, and for closing the annular space between said tubes, while permitting passage through the interior of the inner tube, thereby rendering the parts of said cluster readily detachable for cleaning or other purposes, and dispensing with screws, stuffing-boxes, swaged joints, and similar devices heretofore employed, substantially as described.

2. One or more capillary clusters having the joints formed by plane surfaces and adapted to be readily taken apart and cleaned, each cluster being composed of two concentric tubes and a collar or head at either end, closing, as described, the annular space between said tubes, in combination with means, substantially as set forth, for circulating or permitting a circulation of one fluid through the annular space or spaces and another over the surfaces of the cluster or clusters, whereby the said clusters are specially adapted to the uses indicated.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

STANISLAS HENRI ROUART.

Witnesses:
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ROBT. M. HOOPER.