(No Model.) 3 Sheets—Sheet 1.

C. H. RUDD.

THERMO-EXPLOSIVE CARTRIDGE.

No. 556,901. Patented Mar. 24, 1896.

Fig. 1

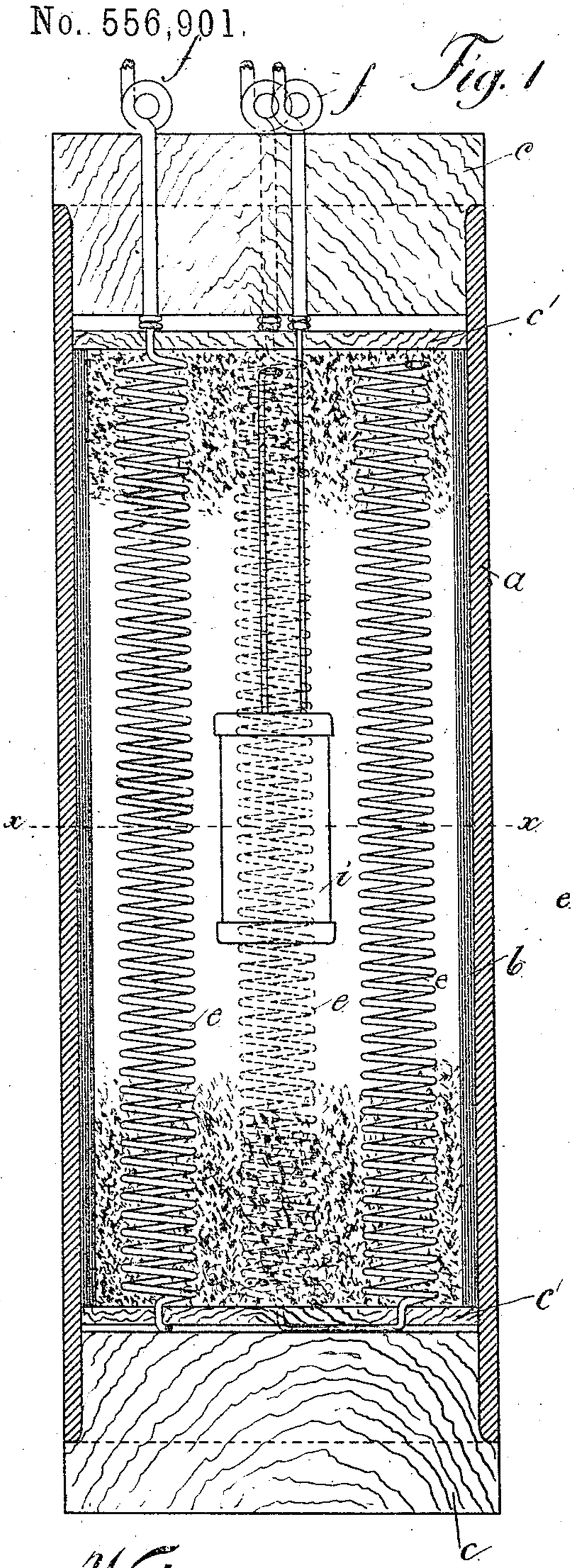


Fig. 2

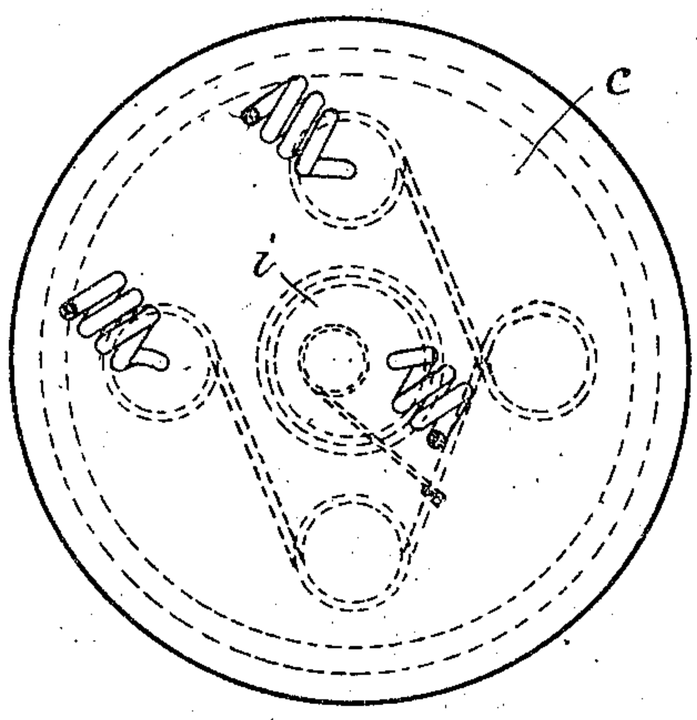


Fig 3

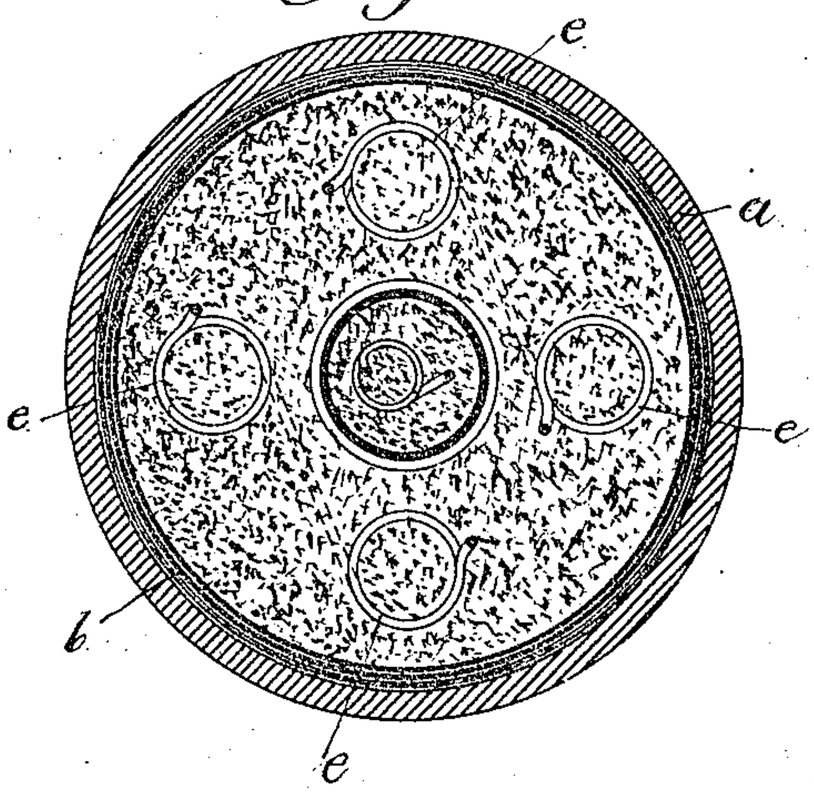
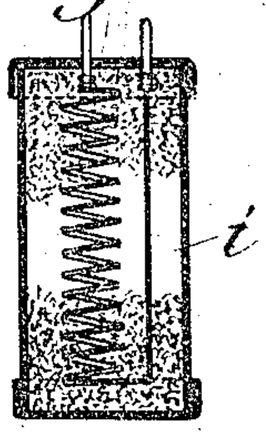


Fig 4



Witnesses:
W. Clyde Jones
George S. Buell

Inventor:
Charles H. Rudd.
by: Dawson & Brown Atty's.

(No Model.) 3 Sheets—Sheet 2

C. H. RUDD.

THERMO-EXPLOSIVE CARTRIDGE.

No. 556,901. Patented Mar. 24, 1896.

Fig. 5

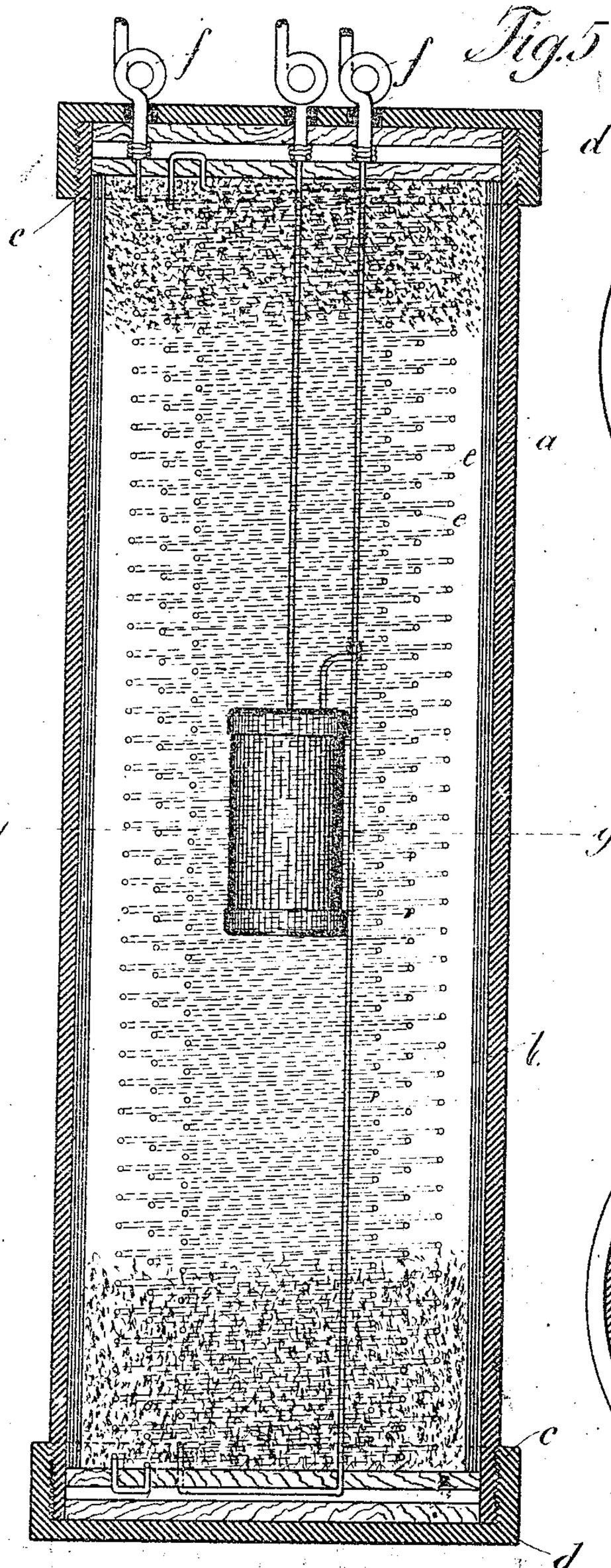


Fig. 6

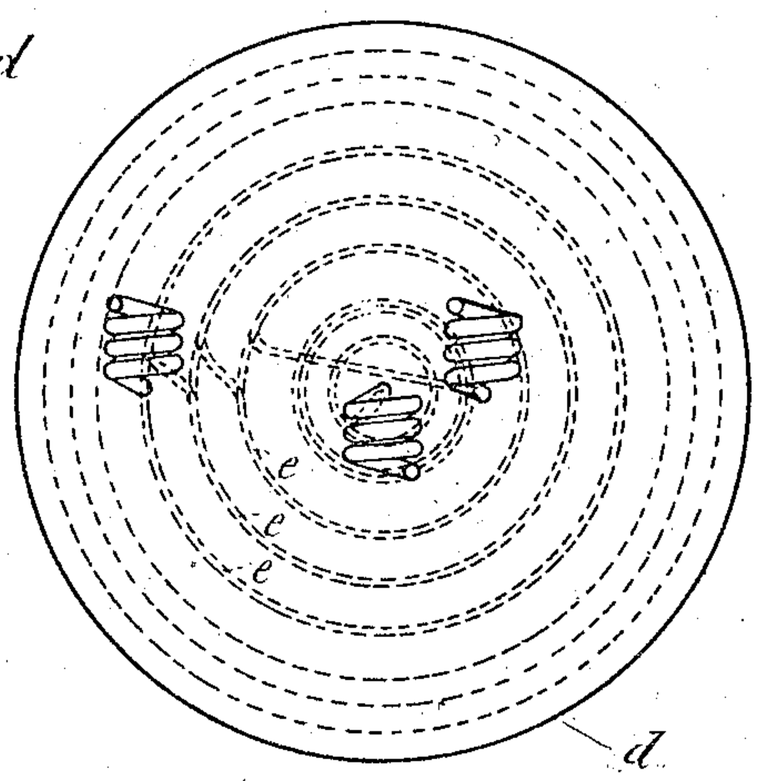


Fig. 8.

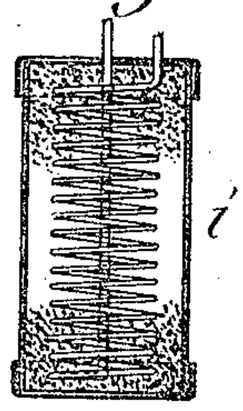
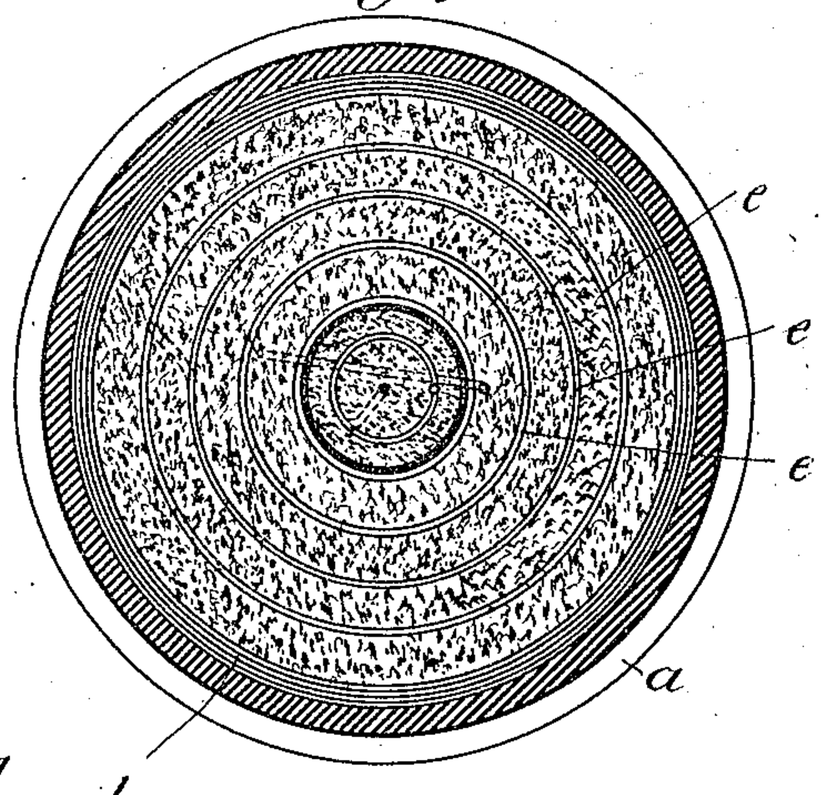


Fig. 7



Witnesses:
W. Clyde Jones.
George B. Buell.

Inventor:
Charles H. Rudd
by: Barton & Brown Atty's.

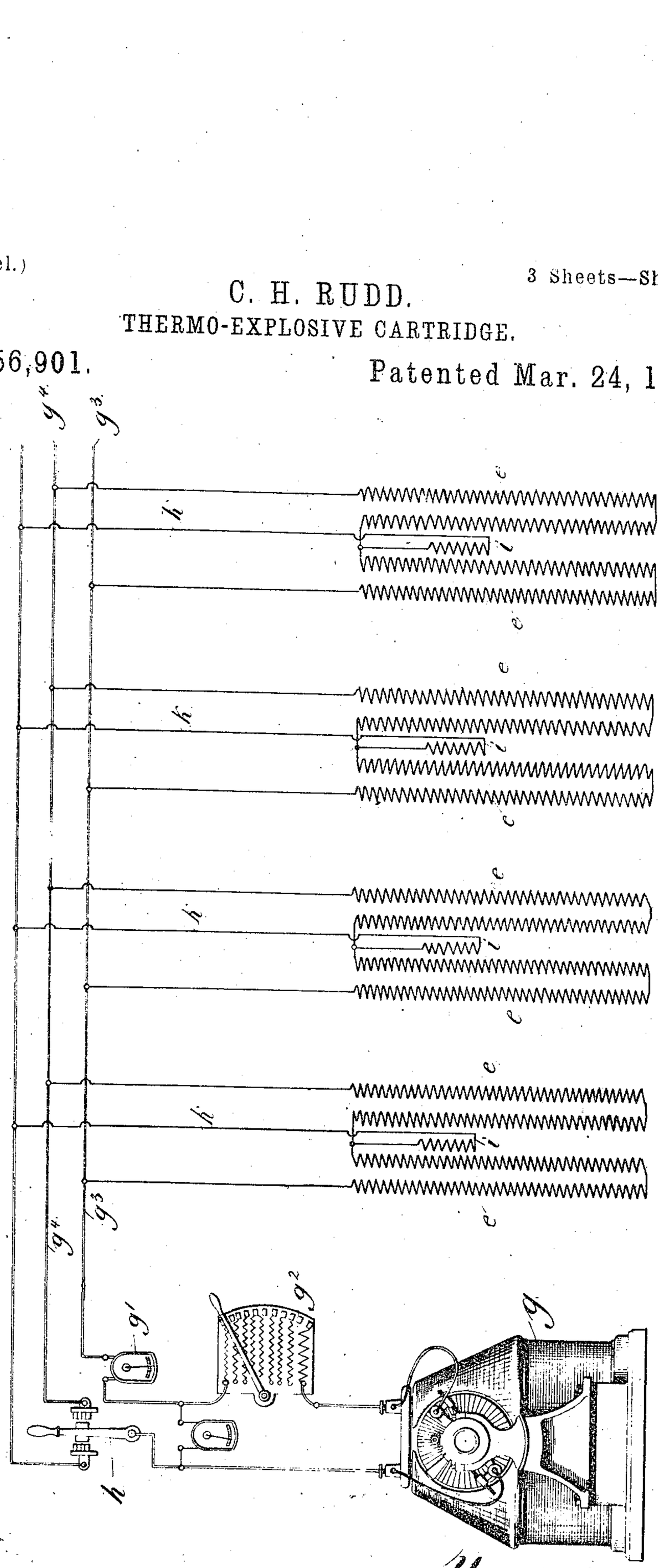
(No Model.) 3 Sheets—Sheet 3.

C. H. RUDD.

THERMO-EXPLOSIVE CARTRIDGE.

No. 556,901. Patented Mar. 24, 1896.

Fig. 3.



Witnesses:
W. Clyde Jones.
George B. Buell.

Inventor:
Charles H. Rudd
by Burton & Parker Attys

UNITED STATES PATENT OFFICE.

CHARLES H. RUDD, OF CHICAGO, ILLINOIS, ASSIGNOR TO THE WESTERN ELECTRIC COMPANY, OF SAME PLACE.

THERMO-EXPLOSIVE CARTRIDGE.

SPECIFICATION forming part of Letters Patent No. 556,901, dated March 24, 1896.

Application filed December 26, 1893. Serial No. 494,725. (No specimens.)

To all whom it may concern.

Be it known that I, CHARLES H. RUDD, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented a certain new and useful Improvement in Thermo-Explosive Cartridges, (Case No. 32,) of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, forming a part of this specification.

My invention relates to an improved means for and method of preparing for and producing explosions.

Through the method of my invention I am enabled to make use of materials which are not classed as explosives, and which under ordinary conditions and at ordinary temperatures are perfectly safe to handle. My invention is applicable likewise to the well-known explosives, and its advantages when used either with "explosive" or "non-explosive" materials, so called, will be made apparent through the description which follows.

Broadly considered and briefly stated, my invention consists in augmenting the violence of the chemical combination of explosive materials by means of heat applied to and stored up in the materials after they are in the place where it is desirable that the explosion shall take place. I shall describe the method in connection with the application of heat by means of the electric current, which is the manner of heating which I prefer to employ; but my invention is not limited to the particular method in which the electric current is employed for the heating.

To enable those skilled in the arts to which my invention relates to practice my invention, I will describe it as applied to producing explosions in blasting, it being readily understood that the same process may be used for other purposes where the explosive force of chemical combinations taking place in confined spaces is employed, and while I shall describe with particularity the specific details of the means I preferably employ in carrying out my invention I do not wish it understood that by so doing I limit myself to these specific means.

Referring to the accompanying drawings, Figure 1 is a partial sectional elevation of one form of the cartridge with part of the explosive material removed to clearly reveal the position of the coils. Fig. 2 is a plan view of the same. Fig. 3 is a sectional plan view on line *x x* of Fig. 1 with the coils shown in full plan. Fig. 4 is a detail sectional view of the igniter. Fig. 5 is a longitudinal sectional view of a similar cartridge having a different arrangement of the heating-coils. Fig. 6 is a plan of this form of cartridge; and Fig. 7 is a section on the line *y y*, Fig. 5. Fig. 8 is an igniter with the igniting-wires arranged in a manner similar to those in the cartridge of Fig. 5. Fig. 9 shows in diagrammatic form the circuits connecting the coils and the exploder within the shell of the cartridge with the source of electricity.

In all the views like parts are designated by similar letters of reference.

For a casing or shell of a cartridge *a*, I use in practice iron tubes, and for cheapness and convenience I have found old boiler-flues readily available. For purposes of insulation, both with respect to heat and electricity, I line the shell of the cartridge with thick paper *b*. The cartridge-case itself might be made of paper or wood, or of other suitable material. In using iron tube I have preferred to close the ends by driving in soft wooden plugs *c c*, as seen in Fig. 1, by screw-pressure. In an alternative plan I have closed the ends by screw-caps *d d*, as shown in Fig. 5. I fill the cartridge-shell with a charge containing in suitable proportions elements having the necessary chemical affinities, so that when heat is applied to these materials in accordance with my process the chemical affinities are developed or increased up to the point necessary for efficient action.

As a material for filling the cartridges, potassium chlorate mixed with paraffine-oil gives good results. I mix them in the proportion of about fifteen parts, by weight, of chlorate to one of oil.

For doing moderately heavy work I have used cartridges with shells two and three-fourths inches inside diameter and four feet long in the clear and holding about eleven pounds of the above-described mixture.

Throughout the mixture and insulated from the shell of the cartridge I employ German-silver wires *e e e e* of No. 18 gage, insulated with cotton boiled in paraffine. The wire required for such a cartridge as I describe is about one hundred and twenty-five feet in length, and the electrical resistance is adjusted with a considerable degree of accuracy to fifteen ohms. This wire will carry without being prematurely destroyed six ampères of current. In the form of cartridge shown in Fig. 1 I arrange the entire length of wire, for convenience, in four spirals, each coiled about three-quarters of an inch in diameter, and the four coils are joined in series. These coils are placed lengthwise in the shell and fastened at the lower end to a wooden disk *c'* that fits the shell, so as to permit the heat when applied to reach with approximate uniformity the entire mass of the charge. In the other form of shell the heating-coils of German-silver wire are shown arranged in large spirals, which are placed concentrically in the shell. This may, perhaps, produce a more uniform distribution of the heat throughout the mass of active material; but being more flexible it is more readily displaced in filling the cartridge. Other dispositions of wire to attain the result of approximate uniformity of heating will readily suggest themselves to electricians. After the spirals are placed the charge, which is a granular substance somewhat resembling "C" coffee-sugar, is poured into the shell. Some care is necessary in filling the shell to avoid disturbing the approximate ~~symmetrical~~ distribution of the coils. The top covering or plug has lead wires *f f* carried through and tightly fitted into it, and after the shell is filled the top plug is pressed into place and the shell is then deposited in its final position for doing work.

The four-foot cartridge above described I place in the bottom of suitable holes bored for the required distance into clay or rock. Care needs to be taken to have the wires well insulated and uniformly distributed throughout the mass of the charge. The amount of resistance in the heating-wire is plainly a matter of adjustment on the part of the engineer, and would be varied according to circumstances affecting the special features of the work to be done. A large proportion of the blasting requires a simultaneous firing of a number of charges. For such simultaneous work a suitable number, say twenty, holes are bored, and the cartridges with lead wires attached are placed one or more in each hole, according to the depth of the ledge which is to be thrown out. For a source of electric current I use a dynamo-machine *g*, and a current of one hundred and twenty ampères at a pressure of one hundred and ten volts at the machine I have found sufficient for firing twenty four-foot charges simultaneously. I divide this current through the twenty charges in multiple, so as to give each charge a current of about six ampères. Diagram Fig. 9 shows the arrangement of the wires and circuits. An ammeter *g'* is connected in the circuit from the dynamo together with a rheostat g^2, by which the strength of the current in the heating-circuit g^3 g^4 may be adjusted to and maintained at the proper amount.

It will be understood that as the temperature of the heating-coils and the surrounding mass in the cartridges increases the resistance between the terminals of the heating-coils will change, which change will necessitate a continual adjustment of the current strength. When absolutely simultaneous firing is desired, the heating is continued nearly but not quite to the degree at which the charge will explode spontaneously. I have found that a temperature of about 400° in the cartridges such as I have described is sufficiently high to produce high efficiency, and that it is not high enough to bring about spontaneous discharges. As a rule, the closer the approximation to the point of spontaneous combination the greater will be the efficiency of the discharge. The degree of heat which I have employed in practice is reached in about thirty minutes' application of the current. When the charges are heated to the required temperature, I turn a switch *h*, which may be located either at the dynamo or at any convenient place at a safe distance from the place of explosion, and divert the current through igniters *i i*, placed one in each charge. The igniter consists of a tube of paper, say three-quarters of an inch in diameter and five inches long and capped with paper caps filled with a powder composed of one part, by weight, of soot, such as may be readily obtained from a boiler-flue, and five parts of potassium chlorate. This mixture is a slow-burning one when lighted in the open air, but when heated and confined within the heated cartridge it acts instantaneously and gives the necessary impetus to fire the entire charge in which it is embedded. Within the charge of the igniter is a piece of No. 33 iron wire adapted to receive a current of electricity for firing. The arrangement of the branch circuits *k k* containing the igniters I show in Fig. 9, together with the switch. I believe it is original with me to use an igniter such as I have described for firing a charge of explosive material.

When applied to dynamite my practice is to substitute dynamite for the potassium chlorate and oil, and I may substitute detonators made of fulminate of mercury, such as are ordinarily employed in firing dynamite, in place of igniters. My igniters, however, may be used with dynamite with greater safety than such detonators.

My method of applying the firing-current in multiple arc instead of in series (as is the practice with dynamite) enables me to secure greater certainty of firing, since the burning off of any one firing-wire by an infinitesimal period of time in advance of another does not deprive the other firing-wire of current.

I have used ammonium nitrate and potas-

sium nitrate and manganese dioxide in place of the potassium chlorate. Instead of paraffine-oil I have used powdered carbon. I have also employed mixtures composed of the above-named sources of oxygen mixed in various proportions. For applying heat I have used electricity on account of the convenience with which it can be applied to the charge when deposited in place for doing its work. It is evident, however, that other methods of heating might be employed. Some of these other methods would be more readily available in firing ordnance, especially in fortifications and on ships. For instance, the necessary heat energy could be derived from the sudden transformation of motion into heat, as when the shell penetrates an armor-plate, or by a sudden heavy compression analogous to that obtained by the operation of the fire-syringe. An advantage of the electric heating is that it is so fully under control. The charge, consisting at the start of inert material, may be prepared for firing in the course of a few seconds, or heat may be applied sufficiently slowly to blow the plugs by simple vapor-pressure. For ordnance work this enables me to secure by simple adjustment the entire range of action which is included between slow-burning and quick-burning (or detonating) explosives, meal-powder being at one end of the range and oxygen and hydrogen gas being perhaps at the other end of the range. I can by adjustment of the rapidity and degree of heating attain results at either extreme or at any desired intermediate point between the extremes.

The advantage which my invention affords in rendering possible the use of materials which at ordinary temperature are safe to handle has as a consequence the further advantage of safety in removing a charge or a part of a charge which has failed to explode, and any unexploded fragments of material which may be scattered by a charge are also harmless.

I am aware that it is old in the art to use the electric current to ignite explosive material either by means of a wire heated to incandescence or by means of a spark. In either case the process has been one of simple combustion and the electric current has been simply the initial cause of the combustion. The process and result of my present invention differ from simple combustion and explosion of compound elements, first, in heating the charge uniformly throughout the mass, thereby weakening the stability of the combinations of or dissociating all the elements which are to enter into new combinations; second, in storing up heat in the material, thereby enabling the expanding gases to absorb or render latent the heat required for expansion, thereby greatly lessening the demands upon the heat developed by combustion. This is an important feature of my process, which by way of preparation for the explosive union of elements stores up a supply which is available at the critical moment of expansion of the gases. The result of this is that the explosive force is made much greater than it would be if a portion of the heat of combustion were required to furnish the latent heat of the expanding gases, as is the case in the process of producing explosions by combustion. A third distinction between the processes of producing explosions heretofore known and the process of my invention lies in the freedom and readiness with which the dissociated elements of the materials tend to combine under the influence of the continuous application of heat as contrasted with materials which are allowed to cool after their elements are dissociated or the stability of their combinations is weakened. In the case of the combustion or detonation of simple elements, as oxygen or hydrogen, my process provides a supply of heat to take the place of that rendered latent by expansion and facilitates the instantaneous combination of the elements by heating them throughout their mass.

There is, of course, a greater gain in efficiency by my process when the materials employed for the charge are capable of being raised to a high temperature, and so of receiving a larger store of heat than when materials of another character are used, such as cannot be heated to a great degree. The heat energy, amounting approximately to three hundred and fifty foot-tons, which in the course of half an hour is stored in each one of the cartridges which I have previously described (less what little may have been lost through the insulation) is expended in a small fraction of a second, thus enormously increasing in the ways I have mentioned the efficiency of the charge by being available at the instant of time when it is needed.

My process is especially applicable to such compound substances as require a high degree of heat for complete dissociation of their elements, and is therefore available in the use of compounds which at ordinary temperatures can be handled with absolutely safety, but which are not commonly used as explosives on account of their slow combustion.

I consider the broad feature of my invention to be the preparation of the explosive material in the place where it is to be used by the storage of heat energy applied throughout the mass of the material, and by "preparation" I mean bringing the material to the verge of explosive combination of its elements or some of them. As specific processes, subsidiary to this broad generic invention, are various methods of bringing about the actual explosive union of the elements of the material, one of such specific processes being that described herein, wherein an igniter or detonator is used for firing the charge.

In my application Serial No. 430,094 I have described and claimed a method limited in its application to substances which are con-

ductors of electricity, and which is subordinate to the broad invention of this case.

In my application Serial No. 430,096 I have described and claimed a method which is specific and subsidiary to the generic invention of the present case in that it is directed to the process of producing the actual explosive union of the elements of the materials by means of continued application of the heat until the explosive union of the elements is determined, a process which is practical and advantageous for single-shot firing, but which does not lend itself so readily to the production of simultaneous discharges of several cartridges, as does the method herein described, in which igniters or detonators are used.

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

1. The herein-described method of producing explosions which consists in confining substances which do not combine explosively at initial temperature, uniformly heating said substances to a temperature near that at which explosive union of the substances takes place when the same are ignited, and then causing the explosive union of said substances; substantially as described.

2. The herein-described method of producing explosions which consists in confining substances which do not combine explosively at initial temperature, subjecting said substances to the heating effect of an electric current to raise the same to a temperature near that at which explosive union takes place, and then by a sudden application of heat by the passage of an electric current causing the explosive union of said substances; substantially as described.

3. In an electrically-exploded cartridge, the combination with an inclosing shell, of substances contained therein which do not explosively combine at initial temperature, electrical conductors embedded in said substances to uniformly heat the same throughout, a fulminating-cap, and an electrical igniter therefor; substantially as described.

In witness whereof I hereunto subscribe my name this 18th day of December, A. D. 1893.

CHARLES H. RUDD.

Witnesses:

HARRIET G. TEMPLETON,

W. CLYDE JONES.