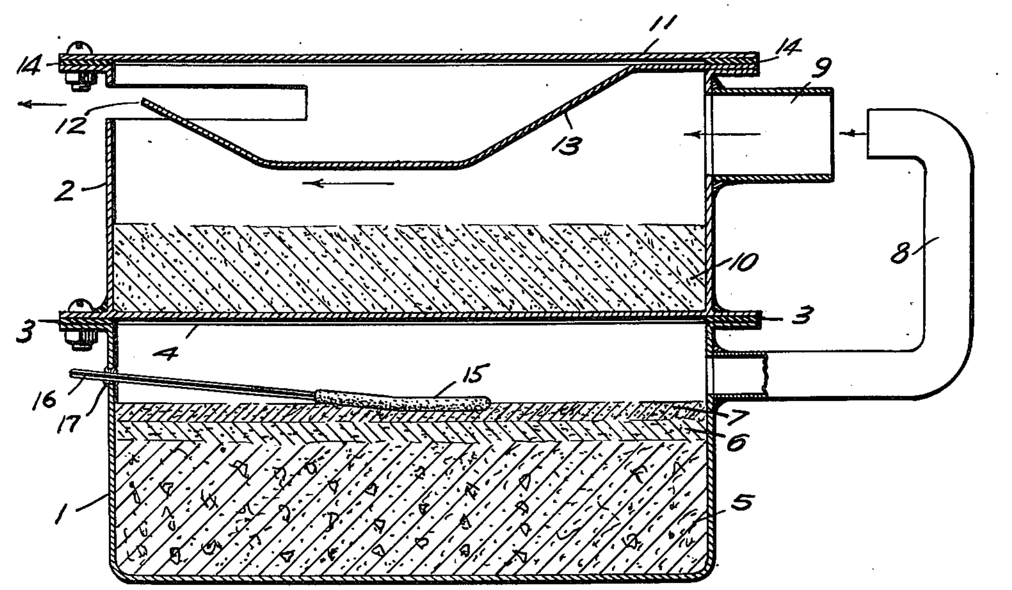
March 31, 1953 L. FINKELSTEIN ET AL 2,633,455

SMOKE GENERATOR

Filed March 31, 1944



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Patented Mar. 31, 1953

2,633,455

UNITED STATES PATENT OFFICE

2,633,455

SMOKE GENERATOR

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Application March 31, 1944, Serial No. 529,014

1 Claim. (Cl. 252—359)

(Granted under Title 35, U. S. Code (1952), sec. 266)

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The invention described herein may be manufactured and used by or for the Government, for governmental purposes, without the payment to us of any royalty thereon.

This invention relates to a type of device particularly useful for producing aerosol dispersions of smokes, such as screening smokes, irritant smokes, toxic smokes or simulated toxic mokes. The device in certain embodiments may be called a smoke candle or smoke pot and is particularly adapted for producing clouds of particulate irritant or blistering substances difficult to protect against. More generally, the invention is concerned with a method and means for dispersing a chemical agent by vaporization.

An object of this invention is to provide a smoke disseminating munition adapted for convenient manufacture and use.

Another object is to provide a means and method for generating smokes efficiently from agents that tend to undergo thermal decomposition at elevated temperatures.

Another object is to provide an efficient smoke-forming munition with an efficient autocombustible fuel composition, particularly a fuel that is suitably stable, effective in giving a satisfactory burning time, and which provides an adequate amount of heat at a moderated temperature with economy in strategic materials and with conveniently low weight and bulk requirements.

A further object is to provide a means and method for producing the smokes in a manner which conforms to ascertained principles for obtaining evolution of a dense smoke cloud within a reasonably short period with close to complete utilization of a smoke-forming agent.

A smoke-generating candle embodying principles of the present invention may have outside dimensions and a weight similar to those of the existing standardized portable 9-lb. toxic candle. In this embodiment, the candle is a cylindrical two-compartment container with about 750 g. of agent in the top compartment and 1260 g. of fuel composition in the bottom compartment.

A vertical side view of the candle in section is diagrammatically shown in the drawing.

Referring to the drawing, the candle-type device comprises a lower compartment 1 bolted or otherwise fastened to the upper compartment 2, with a suitable heat-resistant gasket material 3, for example, compressed asbestos, between the compartments to make an air-tight connection. A ring gasket 3 may be fitted between the bottom flange of the upper compartment 2 and the top flange of lower compartment 1; or, if more heat

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insulation for the upper compartment is desired, the gasket 3 may be a disk which covers the entire bottom 4 of the upper compartment.

At the bottom of the lower compartment 1 is placed a suitable fuel, preferably in stratified layers comprising mainly a fuel mixture of charcoal or equivalent combustible carbonaceous material, ammonium nitrate or equivalent oxidizing agent and a cooling agent, such as ammonium chloride, in the bottom layer 5, a concentrated fuel starter mixture, i. e., less diluted or undiluted by a cooling agent in intermediate layer 6, and an igniting layer of readily ignitible substances in top layer 7.

An important feature of the candle is the Venturi-type injector means for admixing a suitable proportion of air with hot gaseous products of combustion from the fuel. The injector may comprise simply a bent delivery tube 8 attached at its inlet opening to the side and near the top of the fuel compartment 1 and having its discharge end concentrically aligned with a relatively larger orifice tube 9 which is connected to the upper compartment 2. Air is admitted at the gap between the tube 8 and orifice tube 9.

A block 10 of the smoke-producing agent is disposed in the bottom of the upper compartment 2 with its top surface below orifice 9.

The upper compartment 2 has a top closing cover 11 bolted or otherwise fastened to its upper flange, an exit vent 12 for emission of smoke, and incloses a deflector 13.

The deflector 13, as shown, is a thin circular disk extending to the walls of compartment 2 except where it leaves a space near the exit slit 12 and where it protrudes in a segment over the orifice 9 to be clamped between the cover 11 and the upper flange of compartment 2 for holding the disk in place. A tight seal is made between the cover 11 and the upper flange or compartment 1 by a pressed asbestos gasket 14. The deflector disk 13 is bent so that the injected gases from orifice 9 are deflected downwardly toward the surface of the agent 10 where the gas stream gains speed, then expands and flows upwardly and out through the exit slit 12. The deflector brings the incoming gases into close contact with the agent at a desirable accelerated flow rate without excessively increasing resistance to the flow. With the deflector, almost twice as much agent is volatilized for a given flow rate from the injector as would be volatilized without the deflector, and there is no hindrance to the functioning of the injector.

An electric squib 15, acting as an igniting means, has attached wires 16 introduced and sealed by a suitable plastic at hole 17 in compartment 1.

For the purpose of demonstrating the invention, with respect to the candle-type or portable smoke pot munition, the following detailed description of the construction and operation of a model candle is given:

The bottom fuel and top agent compartments of the model were made from No. 20 gage cold rolled steel. Each of these compartments were made with existing equipment used in the manufacture of containers for the standard 9-lb. smoke candle. Each compartment had a diameter of about 7 inches and a depth of above 2⅞ inches. The injector tube was made of ¼-inch standard steel pipe. The gas inlet orifice tube for attachment to the agent compartment was made of 1⅛ inch O. D. steel tubing 1½ inches long. The exit slit 12 in the upper part of compartment 2 was ⅜-inch wide. The deflector disk 13 was dished downwardly a distance of 1⅛ inches at the center.

In the model candle a satisfactory 3-layer fuel block was 2 inches thick. It included a bottom 1160 g. layer of an intimate mixture of 197 g. ammonium chloride, 135 g. charcoal, and 828 g. ammonium nitrate; an intermediate layer of 86 g. ammonium nitrate mixed with 14 g. charcoal; and a top 100 g. layer of igniting mixture consisting in 8% Mg, 25% Sb and 67% CuO.

In the agent compartment 2 was placed a 1-inch cake of 750 g. of a simulated agent, diphenylamine, which has physical characteristics very much like those of the irritant smoke agent, mustard sulfone.

A tabulation of pertinent data from representative test results on the model candle is given in the table below.

Although it was commonly necessary to use smokeless powder as a fuel in the standardized toxic candle hitherto, the candle of the present invention permits an efficient use of a fuel containing less strategic materials, such as ammonium nitrate mixed with charcoal. The reaction of ammonium nitrate and charcoal can take place in a number of different ways depending upon the ratio of the ammonium nitrate to charcoal. The optimum weight proportions of these ingredients are in the ranges of 80 to 90% for ammonium nitrate and 10 to 20% for charcoal. Temperatures obtained by burning a fuel mixture of 86% ammonium nitrate and 14% charcoal were compared with temperatures obtained with smokeless powder as a fuel in the candle. In both cases the burning times were about the same, but an average temperature obtained with the ammonium nitrate-charcoal fuel was 620° C., whereas that obtained with the smokeless powder fuel was 740° C.

The ratio of ammonium nitrate should not be much below the stated optimum proportions or the oxidation of carbon becomes less complete, with the result that more carbon monoxide is produced and the temperature becomes unduly lowered; also, if the ammonium nitrate proportion is too low, unburned residue forms.

With optimum proportions of ammonium nitrate and charcoal, cooling agents may be added to obtain a satisfactory burning time and a moderated temperature. A suitable proportion of cooling agent is in the range of 10 to 20% by weight of the total fuel mixture. Such a mixture supplies hot gases which do not overheat the agent compartment.

Various cooling agents were incorporated in the fuel to reduce the temperature of the fuel gases. The fuel ingredients were diluted with

Average Temperature in Agent Compartment	Maximum Temperature in Agent Compartment	Average Temperature of Gases in Agent Compartment	Average Temperature of Gases in Fuel Compartment	Grams of Agent Volatilized	Burning Time
166° C.	180° C.	198° C.	701° C.	720 g. Diphenylamine	4 min., 45 sec.

From the foregoing results it was determined that the model was satisfactorily designed for accomplishing objects of the invention.

Based on performance of the designed smoke-generating apparatus which was demonstrated to give satisfactory results, the following principles were found to govern the selection and proportioning of the fuel ingredients and added air for a given agent to be volatilized:

(1) The agent should not be heated substantially above the temperature at which decomposition sets in, this temperature being about 183° C. to 200° C. for mustard sulfone and 180° C. for diphenylamine, for example.

(2) The burning time of the fuel, the heat value of the fuel, and the volume of vaporizing gas contacting the agent should be such as to evolve a satisfactory concentration of the agent with as close to complete volatilization of the agent as possible, e. g., 5 minutes for about 750 g. of agent in a candle.

(3) The size and weight of the candle, including the fuel and agent, should be limited for the sake of economy and convenience of handling, e. g., the candle should approximate the standardized 9-lb. toxic candle in size and weight.

various percentages of ammonium chloride, ammonium carbonate, ammonium sulfate and ammonium oxalate. The more cooling agent added, the lower was the temperature and the longer the burning time in each case.

It was found that the use of a cooling agent was especially desirable in the candles provided with air injectors, because without the cooling agent the fuel gases tended to burn at the injector when hot carbon monoxide became mixed with air. With sufficient cooling agent in the fuel, the temperature was lowered below the ignition temperature (about 650° C.) of the carbon monoxide and air mixtures.

Ammonium chloride is recommended as a cooling agent on account of its cheapness, stability and availability. In general, the cooling agents are substances which are decomposed endothermically in evolving gas.

It is desirable to compress the mixture of fuel ingredients and cooling agent so that the mixture occupies a smaller space and burns more uniformly for a longer time, but the compressed fuel is more difficult to ignite. It was found that a satisfactory ignition of the pressed fuel block could be obtained by spreading over the fuel block a starting mixture comprising the fuel ingredients mixed with little or no cooling agent. This contiguous layer of starting mixtures may be pressed also. When ignited, it burns readily and gives a quick uniform start to the lower fuel block containing the cooling agent. A layer of the amount of 100 g. of the starter is sufficient on a fuel block of 1260 g. and 7 inches in diameter and about 1½ inches thick. The starter makes the whole contiguous surface of the fuel block ignite at about the same time.

Even with the use of a starter layer, it was found that there was an erratic time length in starting the burning of the fuel; frequently there was an induction period of several minutes. A satisfactory avoidance of the delay in burning was found to be obtained by using a surface layer of an igniting mixture which can be ignited almost instantaneously and thereupon begin the burning of the starting mixture.

Igniting mixtures found to be suitable are characterized in general by ingredients of readily oxidized reducing substances, such as a finely divided metal or a metal sulfide having a high affinity for oxygen, and an oxidizing agent, such as an oxide, nitrate or chlorate. Some examples of igniting mixtures used are as follows:

		Per cent
(1)	Sb Metal powder	55
	Zinc dust	17
	$KClO_4$, technical grade	28
(2)	KNO_3, 40 mesh	42
	Sb_2S_3	26
	FeS	26
	Dextrin	6
(3)	Magnesium, Mg, metal powder, 150 mesh	8
	Antimony, Sb, metal powder	25
	Copper Oxide, CuO, C. P. grade	67
(4)	$KClO_3$	63
	Sb_2S_3	25
	Dextrin	12

The preferred ignited mixtures are those which are stable, not sensitive to shock or friction, and which do not evolve large amounts of gas suddenly. Accordingly, the No. 3 type mixture is the preferred type.

A satisfactory burning time with prompt starting burning was obtained by using 100 g. of the ammonium nitrate-charcoal over 1160 g. of the fuel containing cooling agent, and spreading 100 g. of the No. 3 igniting mixture over the fuel block as a top layer. The bottom part of the fuel block was put into the fuel compartment of the candle and pressed by means of a hydraulic press ram under 1500 lbs. per square inch. The intermediate starting mixture layer was also pressed under the same pressure. The combined height of the two layers was about 1¾ inches. 100 g. of the ignition mixture was moistened with 5 ml. of orange shellac to a sandy consistency and spread evenly over the fuel block, then pressed smooth with a wooden block. With the fuel block thus prepared, the fuel compartment receptacle was put in an oven and heated at about 50° C. until the top layer of the starter became hardened when the shellac had dried. The shellac coating serves to protect the fuel and starter from air and moisture.

Various types of initial igniting means may be used, but it is desirable that such means be capable of being inserted into the fuel compartment and operated without leakage of gas. The well known Bickford type fuse may be employed. Also, an electric squib may be used. By using electric squibs, a plurality of candles may be emplaced, then fired simultaneously with remote

control. The initial igniting means may be imbedded in the top layer and partly covered with fuel.

To prepare the agent compartment, the desired amount of agent, e. g., 750 g., is melted into the compartment and allowed to cool; then the deflector, gasket and cover are put in place. The asbestos gasket may be moistened with a solution of sodium silicate before being placed over the upper flange of the compartment, after which the cover is bolted into place. The top compartment thus prepared is bolted to the flange of the bottom compartment, the joint being sealed with an asbestos gasket moistened with sodium silicate or other suitable luting material. It is desirable to assure a tight seal between the top and bottom compartments, as leakage of gases tends to decrease the pressure and thereby reduce the efficiency of the injector.

With the model candle described, it was found impossible to lower the temperature in the agent compartment to a satisfactory level and arrive at a reasonable burning time without providing sufficient carrier gas in addition to the gas supplied by the fuel and cooling agent; therefore, it was found necessary to adopt a means for adding air to the gases generated in the fuel compartment.

A fluid steaming out of the injector delivery tube will impart some of its momentum to gas surrounding it and cause the surrounding gas to flow in the same direction. By having a stream of gas rapidly issue from the tube, and flow in contact with air a short distance before entering a relatively larger orifice tube, it is possible to have a stream of gas draw in air several times the volume of the injecting gas. The use of the injector not only provides sufficient air to cool the product of combustion to a desired temperature, but also supplies an adequate amount of heat carrier gas to vaporize an increased amount of agent within a given period. It should be noted that though the injector acts like a pump, it has no moving parts and, therefore, introduces no difficulty in the fabrication of the candle.

The injector tube and the orifice tube may be detachably connected by a threaded or friction fit connection to the compartments so that they may be removed for shipment and attached when the candle is to be prepared for use. The openings may be taped until the candle is made ready for use.

In order to obtain a sufficient amount of gas flowing over the agent to vaporize the agent at a suitable temperature and within a reasonable time, it was determined that the ratio of the volume of injected air to the volume of gases from the fuel compartment should be at least three for a candle operating on the scale of the model candle described in disseminating an agent like mustard sulfone. In general, a major proportion of air has to be admixed.

The exact proportion of air to be added to the gaseous combustion products from the fuel depends upon the kind of fuel, the vaporization requirements of the specific agent, and the particular construction of the smoke-generating device. The proportion of air added to the hot gases from the fuel compartment can be regulated by adjusting the injector and related gas passages which determine the flow rates of the gases. To obtain an efficient injection, there should be a correct relationship between the area of the throat of the injector (entrance to orifice tube 9) and the area of the exit slit 12, for example, the cross-sectional area at the throat of the injector is less than ½, preferably about 43%, of the area of the exit slit in the agent compartment. To obtain the proper proportioning of added air in the described model candle, it was found that there should be a gap of ⅛ inch between the delivery tube **8** and the orifice tube **9**.

A straight orifice tube was used in the model candle on account of its simplicity and ease of construction, but an improvement may be made in the injection by having the lines of approach of the inlet to the orifice change gradually. It is to be noted, however, that it is desirable for the gases to flow through an elongated orifice tube before entering the agent compartment, since the orifice functions to eliminate eddy currents which would be set up otherwise when the gas issues from the delivery tube of the injector. The eddy currents would consume much of the energy of the gas and thus decrease injection efficiency.

The deflector in the agent vaporizing compartment functions to adjust the flow rate of the gases and the degree of their contact with the agent. It also causes the gases to make ripples in a liquefied agent so that a spray ensues. By this means a very rapid evaporation takes place, thus permitting volatilization of the agent in a shorter time.

Although the invention has been shown to have more particular applications to the dispersion of chemical agents, which are chemical substances used in war for their direct physiological or chemical effects, it also has industrial applications, as, for example, in volatilizing solid or liquid chemicals difficult to vaporize on account of their low vapor pressures when heated to temperatures at which they tend to decompose, or in drying substances which tend to decompose at elevated temperatures.

Although the invention has been described with reference to specific embodiments in the form of the model candle, it is to be understood that it is applicable to larger scale apparatus with variations in the type of agents and fuels used and that other modifications come within the spirit and scope of the invention.

We claim:

A candle type generator consisting of a cylindrical container provided with an air injector,

an upper compartment having a smoke outlet, a centrally depressed deflector and being adapted for holding a heat vaporizable smoke agent decomposable at an elevated temperature and a lower compartment for holding an autocombustible fuel composition adapted to generate fuel gases at said elevated temperature and having means for igniting said composition; each of said compartments having a side wall, an airtight base and being rigidly and detachably connected together in an airtight manner at the base of the upper compartment and the top of the lower compartment; said injector being of the Venturi type and having a lower, upwardly bent tubular portion projecting out of and operatively connected at its inlet opening to the upper part of the side wall of the lower compartment and being provided with an upper tubular orifice projecting outwardly from an upper part of the wall of the upper compartment and spaced apart from, in coaxial alignment with and larger in diameter than the discharge end of said lower tubular portion and being concentrically aligned with said orifice to the end that, when the composition in the lower compartment is burning, a gaseous pressure will be generated therein and the fuel gases will be forced out of the lower compartment into said lower tubular portion and inject a mixture of said gases and of atmospheric air into said upper tubular portion and said upper compartment at a temperature substantially below the temperature at which said gases are generated.

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