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[54] **METHOD AND APPARATUS FOR DETONATING COMBUSTIBLE SUBSTANCES AT ATMOSPHERIC PRESSURE**

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[52] **U.S. Cl.** ..... **431/8;** 60/39.82 E; 60/39.47; 431/1; 431/2; 431/159

[51] **Int. Cl.**[2] **F23K 5/00**

[58] **Field of Search** ..... 431/1, 28, 159, 356; 60/39.82 E, 39.47

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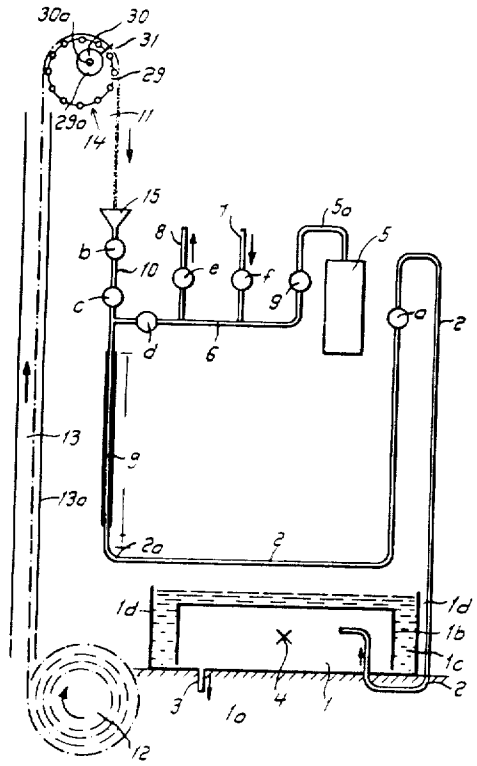
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[57] **ABSTRACT**

In a method of exploding a gaseous combustible substance of atmospheric pressure, said substance is charged together with air to a combustion chamber provided with controllable ignition means. Finely divided particles of an explosive substance are also charged to the combustion chamber, the size of the particles being such as to enable them to be suspended in the combustible substance-air mixture. The resulting mixture of explosive particles, combustible substance and air is then ignited. The amount of explosive particles charged to the combustion chamber can be regulated so as to control the rate of combustion of the gaseous mixture.

11 Claims, 7 Drawing Figures



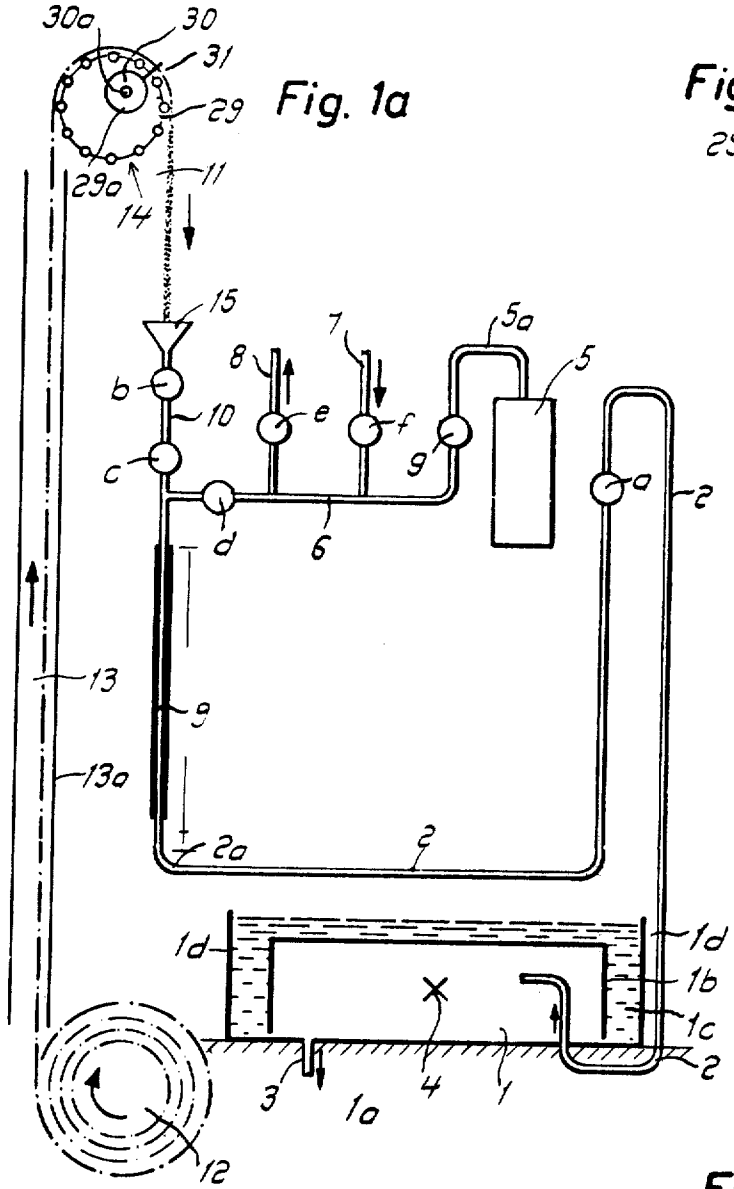


Fig. 1a

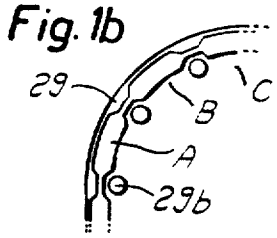


Fig. 1b

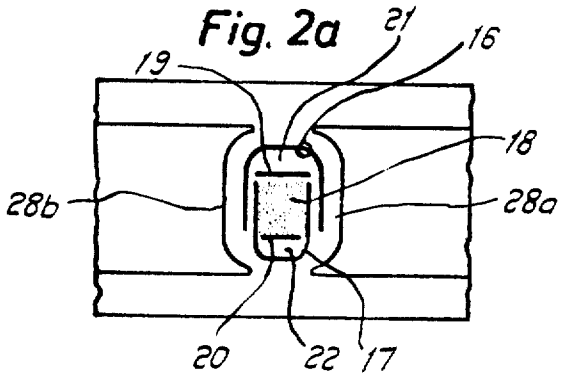


Fig. 2a

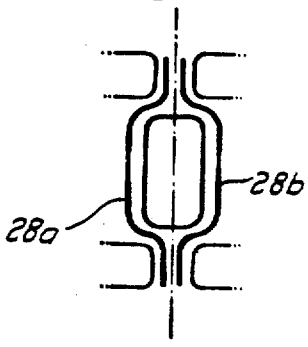


Fig. 2b

Fig. 3

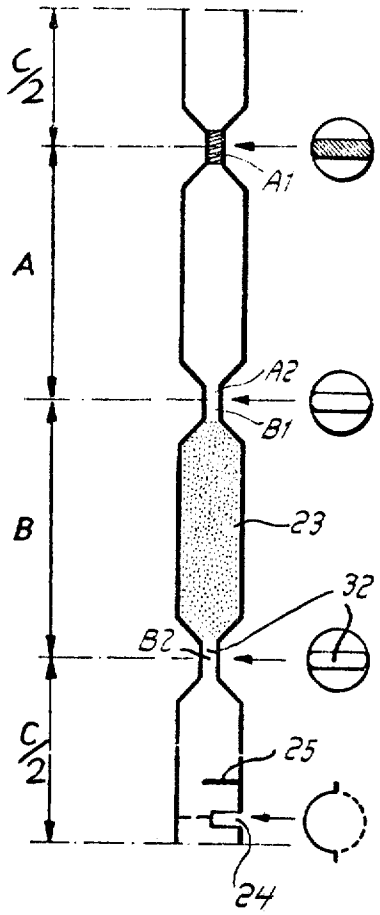


Fig. 4a

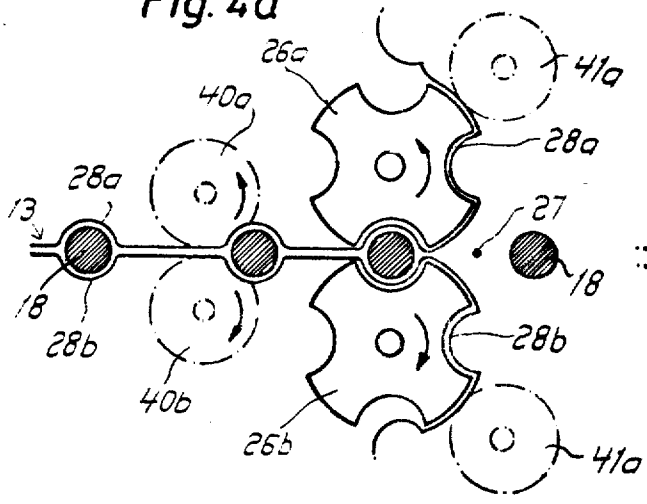
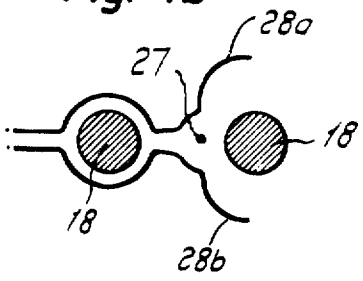


Fig. 4b



METHOD AND APPARATUS FOR DETONATING COMBUSTIBLE SUBSTANCES AT ATMOSPHERIC PRESSURE

FIELD OF THE INVENTION

The present invention relates to a method of exploding or detonating combustible substances at atmospheric pressure and an apparatus for putting the method into effect.

DESCRIPTION OF THE PRIOR ART

It is generally known that although hydrocarbons such as propene, propylene, butane, acetylene and the like are relatively inexpensive in relation their energy content, their use in practice is restricted because of their low rate of combustion. It has been established that when combusting the aforementioned hydrocarbons at atmospheric pressure, there is obtained an adiabatic pressure increase of the order of magnitude of 7 atm. it has also been established that when hydrocarbons are ignited in a certain manner, in an especially designed combustion chamber, it is possible to obtain working pressures which are many times greater that that aforementioned. In this latter respect, it has been necessary to initiate the combustion process by means of an electric shock or a laser beam of significant energy content. With such combustion processes it must be ensured that the quantity of gas located nearest the spark and combusted in the first stage of said combustion process, creates a pressure of such magnitude as to change the combustion conditions for adjacent gas particles. It will be gathered from this that the immediately adjacent gas particles are combusted in a microenvironment which differs in respect of pressure and temperature from the total environment which existed in the combustion chamber prior to the ignition of said hydrocarbons. Previously, the problems associated with the task of obtaining a considerable increase in the combustion rate of hydrocarbons, and therewith in the exploding or detonating force, have been difficult by resolved.

OBJECTS OF THE PRESENT INVENTION

It is an object of this invention to provide ways and means whereby a combustible substance, such as gas or gaseous mixture can be detonated at atmospheric pressure so that the combustion rate of said substance and the energy produced therewith can be controlled. By charging a combustible substance together with oxygen, preferably atmospheric oxygen, into a combustion chamber and, at the same time, charging to said chamber particles of a material, which, in combination with said combustible substance, is capable of causing a detonation, it is possible to select the rate of the mixture in said chamber and the energy produced thereby can be controlled by appropriate selection of the components of said mixture. The ignition of the combustible substance together with the particles admixed therewith is effected via a low-energy ignition device. The size of the explosive particles mixed with the combustible substance to facilitate the combustion thereof is preferably such as to enable said particles to be suspended in said substance. The particles shall also have a high rate of combustion.

In accordance with one aspect of the invention the aforementioned particles may comprise particles of an explosive substance, and it will readily be perceived

that the quantity of particles charged to the combustible substance may be varied so that the combustion rate of said substance can be controlled and so that the forces resulting from the detonation can be controlled.

The invention also relates to apparatus for exploding or detonating a combustible substance, such as gas or a gaseous mixture, at atmospheric pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the invention will be more readily understood and further features thereof made apparent a preferred embodiment of the invention will now be described with reference to the accompanying drawing, in which

FIG. 1*a* illustrates diagramatically an apparatus for detonating a combustible gaseous substance at atmospheric pressure,

FIG. 1*b* shows in larger scale an element of the apparatus of FIG. 1*a*,

FIG. 2*a* shows diagramatically a first particle transporting means in the form of an ampule,

FIG. 2*b* is another view of the ampule shown in FIG. 2*a*,

FIG. 3 shows a second particle transport means in the form of a tube,

FIG. 4*a* shows part of a transport and separating device for the ampule type particle transport means shown in FIGS. 2*a* and 2*b*, and

FIG. 4*b* shows in large scale elements of the arrangement shown in FIG. 4*a*.

DESCRIPTION OF THE PREFERRED EMBODIMENT.

FIG. 1*a* shows diagramatically an embodiment of an apparatus with which a combustible gaseous substance can be exploded or detonated at atmospheric pressure, said apparatus comprising a combustion chamber 1 in which said substance is detonated or exploded. With the illustrated embodiment, the chamber 1 comprises an inverted double-walled box-like structure, the vertical inner walls 1*b* of said structure being spaced from the outer walls 1*b* thereof. This box like structure is intended to rest on a supporting surface 1*a* and contained within the respective walls of said structure 1 is a liquid, as shown at 1*c*. Connected to the chamber 1 is an inlet pipe 2 having a valve *a* incorporated therein. The valve *a* facilitates the supply of a combustible gaseous substance to the chamber 1, in which chamber the gaseous substance is admixed with particles of an explosive substance, as hereinafter described.

To eliminate the risk of unintentional exploding or detonation of the particles of explosive substance, said particles are preferably pre-packed to form a string 13 which is wound on a drum or the like 12. The chamber 1 also communicates with a pipe 3, through which waste gases can be evacuated from the chamber. The reference numeral 4 illustrates an ignition device adapted to create a spark in the chamber 1 for an initial ignition of the gaseous substance, said spark being of sufficient strength merely to ignite that portion of the gaseous substance located adjacent the spark gap of the sparking device, this portion of the gaseous substance in turn igniting immediately adjacent portions of said substance, which as a result on their rapid explodation or detonation-like process of combustion in combination with particles of explosive substances admixed therewith cause the wave to propagate to respective adjacent portions of said gaseous substance. The ignition device does not form part of the present invention and

any appropriate, conventional ignition device may be used with the apparatus of the invention. The ignition device used may be one with which the explodation or detonation process can be initiated automatically in the chamber **1** by means of a program-controlled mechanism. The device may also be a manually controlled device. The combustible gaseous substance, which as before-mentioned may comprise hydrocarbons, is located in a gas container **5**, from which said substance is fed through a pipe **6**, via a pipe **5***a* and a valve *g*. Oxygen, for example atmospheric oxygen, is supplied to the apparatus via a line **7**, to which is connected a valve *f*, the line **7** being connected to the pipe **6** upstream of the valve *g*. The apparatus may be placed under a pressure below atmospheric or under a pressure below the prevailing ambient pressure via a pipe **8**, which is also connected to the pipe **6** and which has a valve *e* associated therewith. As beforementioned the particles of explosive substance are preferably packed in transport packages to prevent unintentional detonation thereof. Before being charged to the chamber **1**, however, the particles are released from said packages, as hereinafter described. As will be seen from FIG. **1***a*, the conduit **2** has a portion which in the position of use of the apparatus, forms a preferably vertically extending space **9** in which the particles of explosive substance, subsequent to being released from said packages, are able to fall and be collected in a curved portion **2***a* of said conduit **2**. As seen in the drawing, there is located above the space **9** a feed chamber **10**, which is separated from the space **9** via a valve *c* and which is sealed from the ambient pressure by a valve *d* incorporated in the pipe **6**.

The particles of explosive substance are packed in unit packages, which are supplied to the apparatus in the form of a string of such packages. As before-mentioned, the packages may have the form shown in FIGS. **2***a*, **2***b* or **3**. Which ever form the package has, however, said packages shall be joined together to form said continuous string **13**. The drum **12** on which the string **13** is wound comprises a rotatable magazine, from which the string **13** may be conveyed through a passage **13***a* to a package unit transporting and separating device **14**.

The particle packages or ampules shown in FIG. **2***a* and **2***b* comprise two hollow halves **16, 17**, in the interior of which particles **18** of an explosive substance are stored. With the illustrated ampule, the particles are enclosed between two mutually parallel loosely arranged plates **19, 20**, each of which defines one side of two air spaces **21, 22**. In the string **13**, the ampules are loosely enclosed between two string halves **28***a* and *ϕb*, the string halv **28***b* being omitted in FIG. **2***a* for the sake of clarity. The string halves may have the form of double Cellophane layers provided with bulges in the form of halv ampules and are arranged to release the ampules at the device **14** so that, as shown in FIG. **1***a*, said ampules are able to fall from said device **14** through a safe-fall distance **11**, down into a funnel **15**, valve *b* which is located upstream of funnel **15** being open. The ampules are then fed through the feed chamber **10**, whereafter the valve *b* is closed. The valve *e* in pipe **8** and the valve *d* in pipe **6** are then opened, to lower the pressure in space **9**, whereafter said valves are reclosed. It is assumed that during this latter sequence the valve *a* is closed. Valve *c* is then opened, to permit an ampule to fall down into the space **9** and, as a result of the subpressure prevailing in said space, the air enclosed in spaces **21** and **22** of the ampule will expand, causing the two halves **16, 17** to separate from each other, whereupon the loose plates **19, 20** will act as plungers to release the enclosed particles **18**, so that said particles fall through the space **19** to be caught in the bend **2***a* of the conduit **2**. The gaseous combustible substance is then passed to the space **9** from the gas container **5**, via the pipe **6**, and oxygen which may be in the form of atmospheric oxygen, is fed from a source not shown to the pipe **7** located downstream of the container **5**, the gaseous mixture forcing the particles of explosive substance into the chamber **1**, via the conduit **2** and the valves *a*.

An alternative embodiment of the particle transporting package unit is shown in FIG. **3**. The particles, here identified by the reference **23**, are enclosed in a tubular package which is compressed at predetermined sections therealong to form mutually coherent portions A, B, C, each of said portions having the same form and the same volumetric capacity. The portion A is sealed at its upper and lower ends A1 and A2 resp. and contains as gas, such as air for example. The portion B contains a unit quantity of explosive particles **23** and, similarly to portion A, is sealed at its respective upper and lower ends B1 and B2. The portion C may be caused to serve as a pre-load chamber and may be provided with an opening **24** at one side thereof through which the particles may be fed into the package unit. The portion C may also be provided with a so-called tear line **25**, which is intended to facilitate severing of the package unit when charging the same prior to the detonation sequence. The portion C may include volatile liquid. The portions A, B and C are made from a continuous tube and in this way form a string of units with equal division between the sealed ends thereof. As will be readily understood, all of said portions may be filled with explosive particles **23**. The tube preferably comprises a flexible material, such as a synthetic resin or aluminium and may be coiled on a roller, such as roller **12** in FIG. **1***a*. The package unit transporting and separating device **14** shown in FIGS. **1***a* and **1***b* is suitable for separating package units of the type shown in FIG. **3** and comprises a peg wheel **29**, the spacing between the pegs being the same as the spacing between the narrow sealed ends of the tubular package unit shown in FIG. **3**. The wheel **29** is arranged for rotation around a shaft **29***a*. Co-acting with the shaft **29***a* is a transmission device (not shown in Fig. **1***a*) which is arranged to co-act with a wheel **30**, which is arranged for rotation about a shaft **30***a*. The wheel **30** is provided with one or more knives **31** which are so guided that they are activated at each third spacing unit of the peg wheel, thereby to separate the package units A and B and C. As will be readily understood, the knives may also be arranged to sever each individual package unit, when each package unit contains explosive particles. FIG. **1***b* shows in larger scale the peg wheel **29** with associated pegs **29***b* and the package unit A, B and C shown in FIG. **3**. As will be seen, the packages separated by the knives **31** will fall down into the funnel **15**, through the safe-fall distance **11**.

In FIGS. **4***a* and **4***b* there is shown a package unit transporting and separating device **14** which is especially adapted to feed package units of the type illustrated in FIGS. **2***a* and **2***b*. To this end the device is provided with two wheels **26***a* and **26***b*. Each wheel has four cogs of mutually equal division corresponding to the distance between adjacent ampules in the string **13**. The string **13** is advanced via guide rollers **40***a* and **40***b*, which are adapted to orient the string **13** in relation to

the wheels **26***a* and **26***b*. The string portions **28***a* and **28***b* are bent off and accompany the rotation of said wheels **26***a* and **26***b*. The wheels **41***a* and **41***b* are biased against the wheels **26***a* and **26***b* and as a result of this arrangement the ampules containing explosive substance, shown in FIG. **4***a* and **4***b* by the reference numeral **18**, will be released from the string **13** in space **27**, whereupon the explosive substance **18** will fall down into the funnel **15**.

FIG. **4***b* shows in larger scale a number of the elements shown in FIG. **4***a*.

If it is now assumed that the package units shown in FIG. **3** fall into the space **9** in the conduit **2** at the same moment as the valve *e* and *d* are opened, the air contained in said units will expand to rupture said units, thereby allowing the particles in portion B of the package unit to fall into the curved portion **2***a* of the conduit **2**. If desired, the particles in the portion B of said package unit may be in paste form, i.e. a mixture of a volatile liquid and particles. In this instance, the paste will pass through the constrictions present between adjacent package units at the lower portion of the package unit portion B, as shown at **32**, in the form of a continuous string. This string is so brittle, however, that it is readily broken up upon falling into the curved portion **2***a* of the conduit **2**. The volatile component of the paste rapidly evaporates, leaving the particles relatively dry.

The valve *d* downstream of the feed chamber **10** is then closed in a known manner, whereafter air and a gaseous substance, for example gasol or propylene is supplied from the containers **5** and **7** respectively in a determined mixing ratio, e.g. 1:22.

The mixture ratio between the gaseous substance and oxygen such as atmospheric oxygen, can be selected in accordance with the desired detonation effect.

As previously mentioned, the valve *a* may conveniently be opened at the same time as valves *g* and *f* are opened, these latter valves being opened to give the mixture a predetermined air to gaseous substance relationship. The particles present in the space **9** will then be entrained with the gas flow into the chamber **1**, in which they are finely dispersed and suspended in said chamber until the explosive or detonation process takes place. Exploitation or detonation of the mixture in the chamber **1** is initiated by an electric spark, generated by the ignition device

The time at which the explosive or detonation process is initiated may be controlled by a programmed device. In this case, the process is controlled preferably automatically although in certain instances it may be more suitably to control said process manually.

The chamber 1 may have the form of an inverted box resting on the bottom of a liquid-filled vessel, or any other suitable form adapted to industrial requirements when it is required to compress and/or deform material by explosion techniques and for such processes as those which require a large energy output and a short explosive or detonation time. Examples of such processes include the instantantous compression of porous materials, such as wood for example, in conjunction with wood impregnation process, or deformation processes carried out within the microplastics industry.

The apparatus illustrated in the drawings has the following mode of operation:

A string of package units containing explosive particles **23, 18**, is fed from the reel **12** to the package unit separating device **14**, the arrangement being such that the severed units fall into the funnel **15**. The packages fall from the funnel **15** into the space **9**, which may be placed under a pressure below the prevailing ambient pressure, whereupon a combustible gaseous substance is fed from the gas container **5** to the space **9** together with oxygen to cause the exploxive particles to move along the conduit **2**, through valve *a* into the chamber **1**. The particles are of such size that they are maintained suspended in the aforementioned combustible substance and the resultant mixture of explosive particles and combustible substances is ignited by means of the ignition device **4**.

Because the explosive particles are encased in their respective package units prior to leaving the space **9**, there is less risk of unintentional explosion or detonation of said particles due to extraneous sources.

As previously mentioned, the processes may be controlled by programmed mechanism located at a central operation station, as may also the duration of each process, together with the time interval between successive explosions or detonations. The valves and devices employed during the chamber charging and process may be electrically or hydraulically controlled.

The invention is not restricted to the embodiments described and illustrated but may be modified within the scope of the following claims.

The explosive particles may comprise a single explosive substance or may comprise a number of explosive substances. For example the particles may comprise 75 percent nitroglycerine in 25 percent kieselguhr, aluminium powder or the like.

The used explosive substance may be of the primary and/or secondary type. It is suggested to use penta erytritol tetra nitrat having a particle size or fineness of grain within the range 0.03–0.01 mm, aluminium powder within the range 10–20 m or magnesium powder within the range 5–10 m. It is known that powder with a size within the lower range is causing a higher detonation velocity than powder with larger size.

The initiation of the mixture may be caused by an electric spark, heated surfaces or laser beam. When using an electric spark it is suitable to have the electrodes on a distance exceeding 0.2 mm. The minimum energy may in a propane-oxygen-nitrogen gas mixture be about 0.002 mJ. Other mixtures will need other values in the minimum energy consumption.

In the description used expression "explosion" is meant that the velocity of the burning is lower than that of the sound and the used expression "detonation" is meant that the velocity of the burning is higher than that of the sound. By using this invention it is a desire to have explosion with a high velocity of the burning and may therefor be close to the detonation.

I claim:

1. A method for exploding or detonating a combustible gaseous substance at atmosphere pressure comprising

a. charging to an combustion chamber combustion ingredients consisting of

a1. a combustible gaseous substance,

a2. oxygen, preferably in the form of air,

a3. particles of an explosion substance,

b. obtaining a mixture of said ingredients in said chamber, and

c. igniting said mixture to explode or detonate the same.

2. A method for exploding or detonating a combustible gaseous substance at atmospheric pressure, com-

prising packaging determined quantities of explosive particles in unit packages, feeding said packages to a vacuum chamber, placing said chamber under a pressure below the prevailing ambient pressure thereby to release said particles from said packages, feeding to said chamber a combustible gaseous substance and oxygen, preferably in the form of air in a determined substance-to-air ratio, causing said substance, said oxygen and said explosive particles to pass into said combustion chamber to provide a mixture therein, and igniting said mixture to explode or detonate the same.

3. A method according to claim **1,** wherein the size of said explosive particles is such as to enable said particles to be suspended in said gaseous combustible substance and oxygen, preferably in the form or air.

4. An apparatus for exploding or detonating a combustible substance at atmospheric pressure, comprising:

a. an combustion chamber,
b. a source of gaseous, explosive substance,
c. an oxygen source,
d. a source of explosive particles,
e. means for charging to said combustion chamber said gaseous substance, said oxygen and said explosive particles to form a mixture therein, and
f. means for exploding said mixture in said combustion chamber.

5. An apparatus according to claim **4,** wherein said source of explosive particles comprises a plurality of rupturable explosive particle unit packages.

6. An apparatus according to claim **4,** wherein said rupturable unit packages are in the form of coherent strings of packages, and wherein means are provided for serving said strings to form separate unit packages.

7. An apparatus according to claim **4,** wherein means are provided to receive unit packages so as to rupture the same, said means being connected to said oxygen source and said explosive substance source.

8. An apparatus according to claim **7,** wherein said unit package receiving means has the form of a vacuum chamber.,

9. An apparatus according to claim **4,** wherein said explosive substance source and said oxygen source communicate with a common supply pipe, and wherein valve means are provided to regulate the feed of said substance and said air to said supply pipe.

10. An apparatus according to calim **6,** wherein said severing means has the form of a rotatable wheel provided with string serving means spaced at determined distances apart.

11. An apparatus according to claim **4,** wherein the means for exploding said mixture is connected to a programmed explosion sequence initiating device.

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