May 23, 1944. F. OLSEN 2,349,300

EXPLOSIVE

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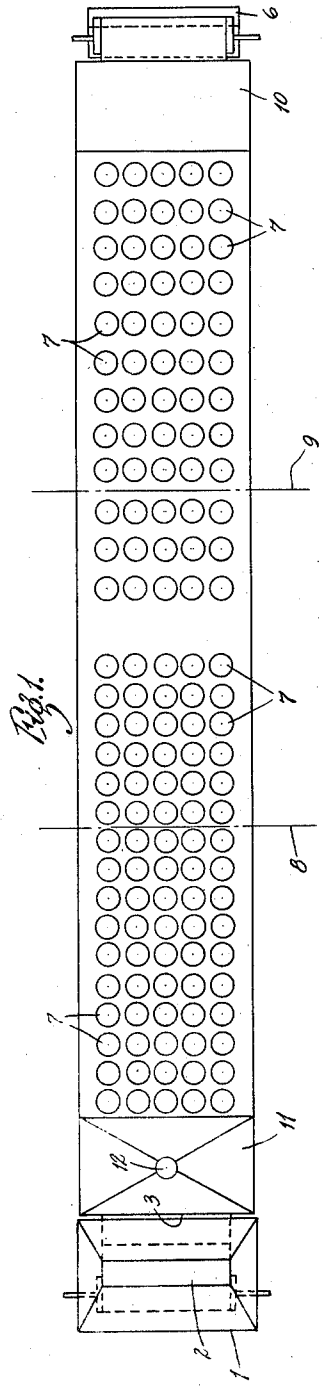

Fig. 1.

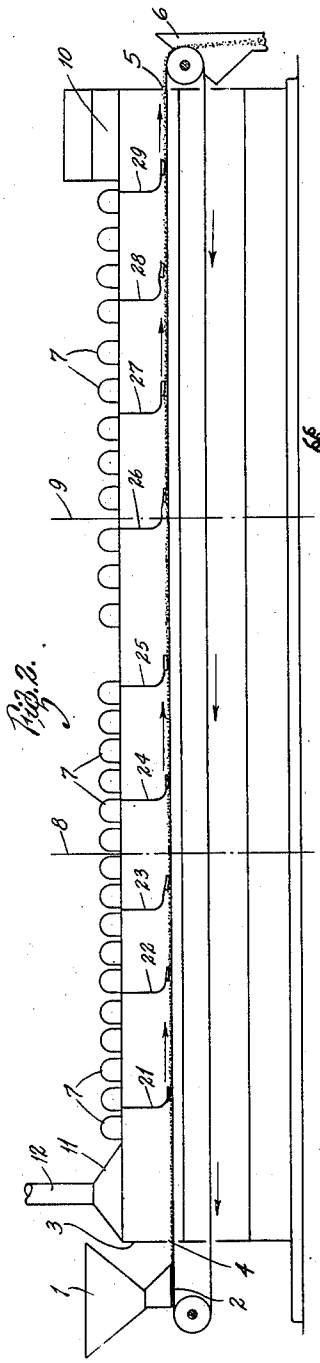

Fig. 2.

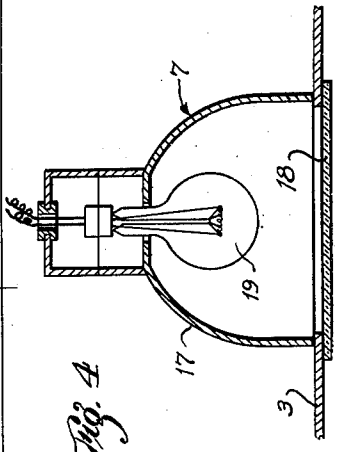

Fig. 4

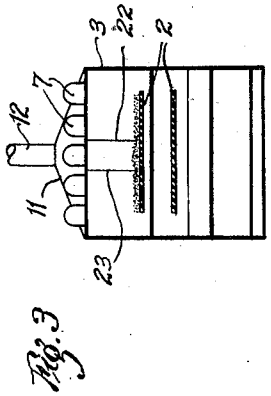

Fig. 3

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EXPLOSIVE

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4 Claims. (Cl. 34—39)

This invention relates generally to the manufacture of explosives, and particularly to a significant improvement in the drying operation required in the production of explosive substances.

The step of drying has been an essential part of the manufacture of explosives required to have a minimum content of moisture and/or other volatile matter, such as organic solvents. Heretofore, the methods which have been available for the removal of volatile matter from explosives have been fraught with disadvantageous features, particularly the exceedingly long drying period required and the necessity for spacing the buildings in which the drying is accomplished inconveniently large distances apart, which not only results in the waste of a considerable proportion of the plant area but also requires the erection and maintenance of extended steam, air and power lines.

Thus, in the manufacture of smokeless powder grains, the final drying operation, which has generally been used and considered most satisfactory, involved storing the grains on trays in drying chambers, through which warm air at a temperature up to 55° C. was circulated, for periods varied from several days to 90 days or more, depending upon the size of the grains and the desired residual content of moisture and other volatile matter. Frequently, this operation has been preceded by an extended water-dry treatment, carried out by storing the powder in suitable vessels and circulating warm water heated to a temperature up to 55° C. therethrough for at least several days. This has generally followed a previous solvent-recovery step, in which the powder, while contained in a suitable bin or vessel, was treated with warm air from which the solvent was subsequently condensed by cooling and recovered for re-use.

Likewise, extended drying periods have heretofore been required in the manufacture of explosives such as the aromatic nitro compounds, for example trinitrophenylmethylnitramine (tetryl), trinitrotoluene, trinitroresorcin, picric acid, and ammonium picrate. As an illustration, in order to reduce the moisture content of tetryl from 25% to the desired residue of less than 0.1%, it has been necessary to store the explosive in trays within a drier chamber through which air heated to a temperature of 70° C. was circulated for a minimum period of 45 hours.

One unavoidable consequence of this prior method of drying was the necessity for storing large weights of explosive undergoing the drying treatment in the individual dry-houses. For reasons of safety, it has been considered essential to segregate each of such buildings in order to minimize the chances of having an accidental explosion in one of the drier chambers spread throughout the entire drying installation of the plant. The minimum distance of separation between buildings depends upon the character and amount of the explosive under treatment and may be computed by the use of formulas or taken from tables compiled as a result of previous experience. It will readily be apparent, however, that for a plant of given capacity of explosives, the plan of having only a small quantity of explosives stored in any one building would have the disadvantage of requiring a very large number of small dry-houses, while, if the capacity of the individual dry-houses is increased, this is necessarily accompanied by an increase in the area segregated for this purpose, since larger distances must then be provided between the units.

In view of the serious disadvantages which have long been recognized in the prior art batch drying methods, it is not surprising that numerous attempts have heretofore been made to improve the safety and economy of this operation. Some of these efforts have been directed toward the development of a continuous process for the drying of explosives, but have been unsuccessful in the provision of a procedure overcoming the above-mentioned disadvantages. One of the principal reasons for such failure has been the inherent difficulty of supplying the requisite amount of heat throughout the mass of explosive being treated. These materials, particularly in the dried or partly dried state, are exceedingly poor conductors of heat and also, very unfavorable conditions of heat transfer are encountered when attempts are made to supply heat to such a mass by means of a heated plate or belt or by means of a heated gaseous medium. Furthermore, when the explosive produced is in the form of very small particles, as is generally the case with the aromatic nitro explosives, gaseous drying media cannot be employed at high velocity, since otherwise, particles of the material under treatment become entrained with the gas.

It is an object of this invention to provide a method for drying explosives which overcomes the disadvantages of prior methods.

A further object of this invention is the provision of a method whereby the drying of explosives is facilitated and expedited.

Another object of this invention is to provide a process for drying explosives whereby increased safety and economy of operation may be secured.

It is also an object of this invention to provide a process for drying explosives which enables the operation to be carried out continuously.

A further object of the invention is the provision of a process for drying explosives whereby a high rate of production may be secured while only a limited amount of explosive is maintained under treatment in any one unit at any given time.

Other objects will appear from the following detailed description.

In accordance with this invention, generally stated, the foregoing objects may be accomplished by subjecting the explosive material to be dried to the action of controlled near infra-red radiation. When granular explosives containing volatile matter are passed in thin layers through a bath of such radiation, properly controlled, the volatile matter may be rapidly and efficiently removed without adversely affecting the stability or other chemical or physical properties of the explosive.

The term "near infra-red radiation" refers to radiation characterized by a wave-length between about 6,000 and 20,000 Angstrom units, such as is obtainable by the use of commercially available infra-red ray carbon or tungsten-filament electric bulbs. Such lamps are characterized by emitting radiation largely within the above stated limits of wave-length. For the purpose of the present invention, the most useful portion of the radiation will generally be that characterized by wave-lengths between 3,000 and 20,000 Angstrom units.

It has been found that explosive substances which are characterized by the presence of nitro or nitrate groups are to a large extent transparent in very thin layers to radiation of the above-described character, whereas practically complete absorption and conversion to heat result when water and the common organic solvents are subjected to radiation of wave-lengths greater than 3,000 Angstrom units. Advantage is taken of this behavior, in the process of this invention, in facilitating the transfer of energy from top to bottom of the layer of granular explosive under treatment, as well as to the interiors of the individual particles or grains of the explosive. This factor contributes largely toward enabling the drying operation (with near infrared radiation) to be carried out rapidly, so that temperatures may be employed which could not be tolerated with other types of heat transfer. For example, in the case of smokeless powder drying, it is entirely satisfactory and, indeed, advantageous, to subject the powder (under near infrared radiation) to temperatures in excess of the temperature (65° C.) usually employed in surveillance tests.

The radiant energy is apparently most readily absorbed and converted to heat in regions of the explosive which contain volatile matter and is accordingly most effective where it is most needed. Likewise, since the energy is transferred in the form of penetrating radiation, the serious obstacle of poor heat transfer, which greatly decreases the efficiency of drying processes in which reliance is had on heating by means of a heated gas or metal belt or tray, is not encountered in the process of this invention. In contrast to the prior drying methods, in which the transfer of heat to the interior of the mass of explosive material becomes increasingly more difficult as the drying progresses, the present process offers the unique advantage of providing conditions wherein the penetration of energy may be facilitated to an increasing extent as the drying proceeds. This is of particular significance in view of the recognized fact that the removal (by the means hitherto employed) of the last percent or so of volatile matter from explosives, generally proves to be the most difficult.

In accordance with the present process, it has been found essential that the explosive material to be dried be supplied in relatively thin layers and that relative motion be provided between the explosive and the source of radiation. Preferably, the explosive material is caused to pass through a bath of radiation by depositing a thin layer on a moving endless belt, which passes through one or more irradiated zones; whereby, deleterious effects due to the incomplete uniformity of distribution of the radiation are avoided and uniform drying results and safety of operation are secured.

The intensity of radiation, the dimensions of the radiation zone, and the distance from the radiators to the surface of the moving layer are coordinated to achieve a temperature (at the top surface of the layer) which will accomplish the desired drying. Such a temperature, in the case of smokeless powder may be 65 to 75° C., as high as 95° C. in the case of dinitromethylaniline, or as high as 110° C. for tetryl; it being understood that it is desirable to employ the highest temperature which is consistent with reasonable stability and safety considerations for the particular explosive being treated.

The depth of the layer being irradiated depends upon the character of the explosive, the moisture content and the temperature of treatment. In the case of smokeless powder, it is desirable to treat in layers having a thickness of about ½ inch or less, with dinitromethylaniline about ⅛ inch and tetryl about ¼ inch. The speed at which the layer is moved through the irradiation zone also depends upon other factors, such as the moisture content, the temperature and the thickness of the layer, but particularly upon the length of the irradiation zone, as the controlling element is the elapsed time of irradiation rather than speed of travel. This may be 1–2 hours for smokeless powder, 3–4 hours for tetryl, or as little as 5 minutes for dinitromethylaniline.

Another factor which must be considered in determining the temperatures, layer depths and irradiation time of any given explosive is the character of the conveyor member, particularly its heat conductivity and light reflecting characteristics. For example, a white rubber conveyor belt contributes definitely toward the achievement of uniformity of heating. Furthermore, while the invention is disclosed herein with particular reference to layers of material in which the relation of the grains in the layer is substantially constant throughout the treatment, it is evident that suitable agitators or conductor blades may be provided for turning or causing intra-layer migration of the grains during treatment. While such intra-layer migration enables thicker layers of material to be treated, and enables the drying to be accomplished with lower temperatures in some instances, care must be exercised not to utilize devices which will induce such intra-layer migration when the explosive is of a character in which friction due to movement of one grain over another may cause detonation.

As an illustrative example, globular smokeless powder grains of the type disclosed in United States Patent 2,027,114 may be dried in accordance with this invention by treatment of a continuously moving thin layer with near infrared radiation, utilizing the apparatus shown somewhat diagrammatically in the accompanying drawing, in which:

Figure 1 is a plan view of a drying apparatus provided with near infrared radiators according to the present invention.

Figure 2 is a view in side elevation, with the near side removed, of the apparatus shown in Figure 1.

Figure 3 is a single line cross-sectional view of the drying apparatus shown in Figure 2.

Figure 4 is a detail view in cross-section, showing one of the radiators and its arrangement relative to the housing of the drying apparatus.

Powder grains containing about 12% volatile matter, consisting of moisture and residual organic solvent, are charged into the hopper 1 arranged to deposit the same in a layer across the width of belt 2. The belt, carrying the substantially uniform layer of grains enters the drying chamber 3 through a suitable slit 4.

The drying chamber 3 may consist of an elongated enclosed space, of which the belt 2 forms the bottom, and externally insulated hinged members the sides, and the ends of which are closed excepting for the slits 4 and 5 through which the belt enters and leaves. In the top of the drying chamber a plurality of radiators 7 are arranged in banks.

The radiators 7 are preferably arranged as a plurality of zones, whereby the control of temperature is facilitated, each zone of radiators being separately controllable independently of the other zones. The radiators may consist of 250 watt, 115 volt infrared bulbs provided with tungsten, carbon, or other suitable filament, each being furnished with a reflector of suitable shape and surface characteristics, such as of plated gold or aluminum. Preferably, the radiators are so adjusted in the reflectors 17 that the radiation on the belt, 18 inches below the mouths of the reflectors, is diffuse. The reflector mouths are covered by a layer of material 18, such as a mica sheet, which is transparent to the desired radiation, to prevent any possible access of explosive dust or gas mixture to the heated surface of the lamps 19 or, in case of breakage, of heated fragments of glass or filament to the layer of explosive material. An installation comprising 140 lamps arranged in three distinct control zones has been found effective, the lamps being more densely grouped in the zone between the hopper 1 and line 8 than in the zones between lines 8 and 9 and to the right of line 9.

The endless belt 2 may be of any suitable material and is preferably provided having a surface which reflects the impinging radiation so as to minimize the chances for an undue rise in temperature. A white rubber composition belt, $\frac{3}{16}$ inch thick, 4 ft. wide, and travelling over pulleys 39 feet apart between centers, has been found satisfactory. Continuous travel of the belt at the desired slow rate may be accomplished by rotating the discharge-end pulley by means of an electric motor, through reduction gears and an adjustable drive of known type.

The temperature of the material on the belt 2 within the drying chamber 3 may be controlled at the desired value by means of thermocouples and associated control apparatus. Thus, nine thermocouples, 21 to 29, inclusive, may be distributed in the chamber so as to contact the uppermost surface of the layer of powder grains. The central couple in each zone may be connected with a recording and controlling potentiometer, by means of which temperature readings may be taken at frequent intervals and, whenever necessary, a relay, turning the lamps in any one zone on or off, may be operated. The remaining six couples are connected to selector switches and thereby to an indicating potentiometer, permitting the measurement of the temperature, whenever desired, at any of the six points. Switches may also be provided for controlling the successive rows of lamps.

It may be desirable to provide a gentle circulation of air or other gas over the grains in order to remove the vaporized volatile matter. This may be accomplished by passing a slow current of warm air into drying chamber 3 by means of a duct 10 located at the discharge end, through the chamber 3, and out through a hood 11 located at the charging end and provided with a stack 12. The vapor discharged through stack 12 may be subjected to solvent recovery treatment if that should be desired.

Excellent results have been obtained by adjusting the depth of the powder grain layer at close to ¼ inch, and the speed of travel of the belt such that 95 minutes are required for passing through the radiation chamber (approximately 30 feet), the temperature being maintained at close to 72° C. Under these operating conditions, a unit of this type reduces the moisture and volatile content of globular smokeless powder grains, of about 0.020 inch diameter and 0.950 gravimetric density, from 12% to not more than 0.9% at the rate of 60 pounds per hour. When the initial content of volatile matter amounts to 8–10%, the capacity of each unit as described above is increased to at least 80–85 pounds per hour of smokeless powder containing about 1.1 to 1.2% residual volatile matter.

Dinitromethylaniline may be dried in the above-described apparatus from a moisture content of about 5% to about 0.1% by subjecting the material in a layer ⅛ inch thick to irradiation by the infrared lamps for a period of 5 minutes, the operation of the lamps being controlled to maintain a temperature of 95° C. in the air space just above the product being treated. Under these conditions, each unit is capable of yielding at least 150 pounds of dried product per hour. Other operating conditions may be employed to attain this or higher production capacity; for example, the use of thicker layers, higher temperatures, and different rates of belt travel may so be coordinated as to attain such results.

In another embodiment illustrating the drying of dinitromethylaniline, this material having a moisture content of 30% may be fed into the above-described apparatus as a uniform layer, $\frac{1}{16}$ inch in thickness, and passed therethrough in 8 minutes. By maintaining a temperature of 85° C. in the charging zone and 120° C. in the discharging zone, a product having a residual moisture content of 0.4% is obtainable at a production rate of 75 pounds per hour.

As another example, tetryl, having a moisture content of 7 to 12%, may be dried in accordance with the present invention by depositing it upon the belt in a layer about ¼ inch thick; controlling the temperature at the top surface of the layer to about 110° C. and adjusting the speed of the belt to a rate that about 3½ hours is re-

quired for movement through the irradiation zone. Under these conditions, a single unit of the character hereinbefore described is capable of drying 1,200 pounds of tetryl to a moisture content of 0.03 to 0.05% in the twenty-four hour period. Using the same conditions as above indicated, excepting that the irradiation period is reduced to two hours, 2,100 pounds of tetryl can be dried in twenty-four hours to a final moisture content of 0.1%.

As a further example of the drying of smokeless powder, globular grains of about 0.035 inch diameter may be dried from a content of 9.8% volatile matter to not more than 1.2% at a production rate of over 50 pounds per hour, the drying temperature being controlled at about 75° C. and the optimum layer thickness in this case being about 3/8 inch.

The optimum conditions for the drying of any given granular explosive material may vary with the grain size and density but can readily be established by determining the capacity of the apparatus at various layer thicknesses at the desired operating temperature, the speed of travel of the conveying belt being adjusted to accomplish the required extent of drying.

The expression "nitro explosive" is used in the appended claims in a sense which is inclusive of the several organic explosive materials herein specifically referred to, to-wit, smokeless powder (nitrocellulose), tetryl, trinitrotoluene, trinitroresorcin, picric acid, ammonium picrate and dinitromethylaniline.

Having thus described the invention, what I claim is:

1. In the manufacture of explosives, the process of drying wet granular organic nitro explosive material, comprising, feeding the wet material upon a conveyor, moving the laden conveyor through an enclosure irradiated with near infrared light of an intensity such as to maintain a temperature of at least 65° C. at the upper surface of the grains on the conveyor, moving the conveyor at a rate such that the grains remain in radiation zone for at least five minutes, and discharging the material from the conveyor at the end of the enclosure.

2. In the manufacture of explosives, the process of drying wet smokeless powder grains, comprising, feeding the wet grains upon a conveyor, moving the conveyor through an enclosure irradiated with near infrared light of an intensity such as to maintain a temperature of 65–75° C. at the upper surface of the grains on the conveyor, and moving the conveyor at a rate such that the powder grains remain in the irradiation zone from one to two hours.

3. In the manufacture of explosives, the process of drying wet granular dinitromethylaniline, comprising, feeding the wet grains upon a conveyor, moving the conveyor through an enclosure irradiated with near infrared light of an intensity such as to maintain a temperature of approximately 95° C. at the upper surface of the grains on the conveyor, and moving the conveyor at a rate such that the grains remain in the irradiation zone for at least five minutes.

4. In the manufacture of explosives, the process of drying wet granular tetryl, comprising, feeding the wet grains upon a conveyor, moving the conveyor through an enclosure irradiated with near infrared light of an intensity such as to maintain a temperature of approximately 110° C. at the upper surface of the grains on the conveyor, and moving the conveyor at a rate such that the grains remain in the irradiation zone from two to four hours.

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