March 5, 1957 D. BACHMANN ET AL 2,783,544

PROCESS AND APPARATUS FOR THE DRYING OF DAMP MATERIAL IN CURRENT DRIERS

Filed Aug. 16, 1954 2 Sheets-Sheet 1

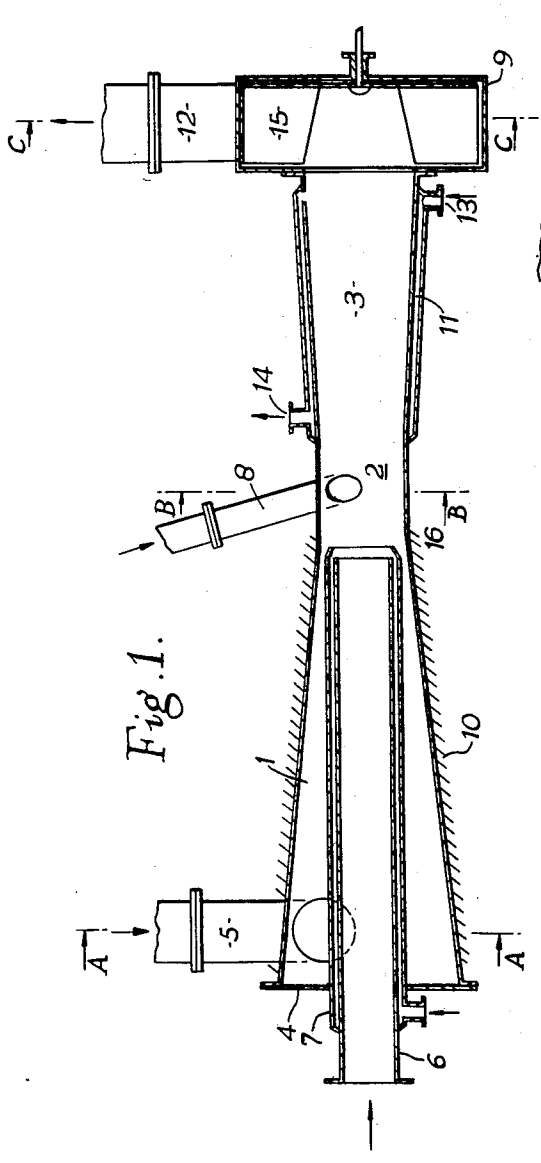

Fig. 1.

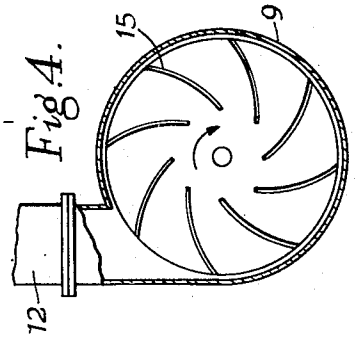

Fig. 4.

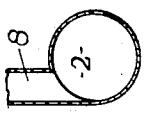

Fig. 3.

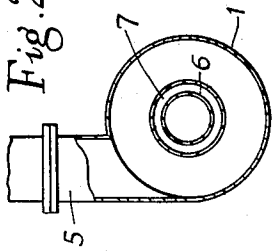

Fig. 2.

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PROCESS AND APPARATUS FOR THE DRYING OF DAMP MATERIAL IN CURRENT DRIERS

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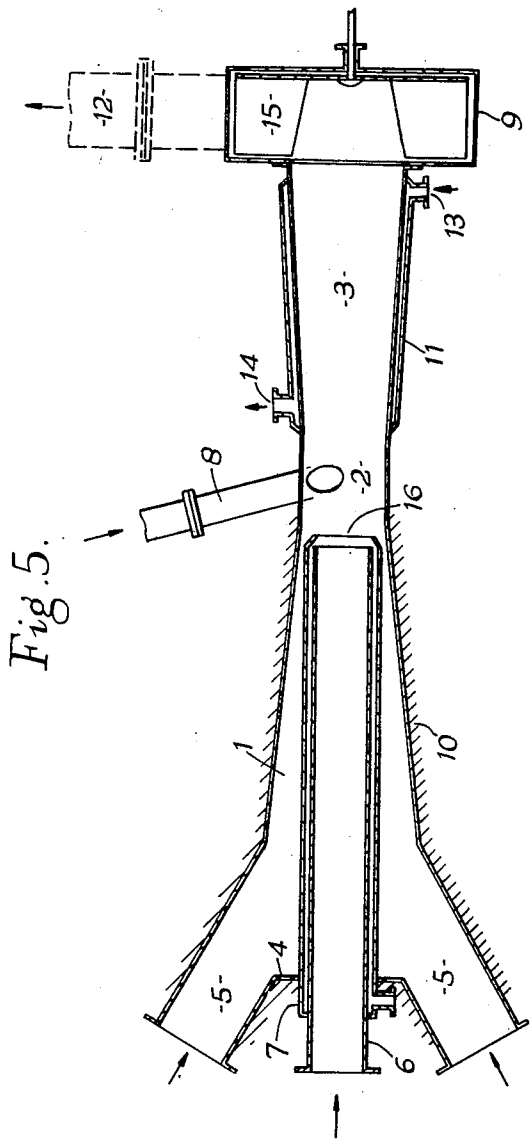

Fig. 5.

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PROCESS AND APPARATUS FOR THE DRYING OF DAMP MATERIAL IN CURRENT DRIERS

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8 Claims. (Cl. 34—10)

Methods of drying moist materials are known in which the moist material is introduced into a flow drier which is traversed by a current of hot air. The hot air current entrains the material over a certain distance, the moisture being dissipated from the material to the air. The separation of dried material and moist air is then carried out at the end of the drying tube by means of a cyclone or a dust filter. This known method is distinguished from other known drying methods by the very short drying period and is consequently particularly suitable for use with pulverulent and granular materials which are sensitive to temperature. The method is conducted as a single-stage or multi-stage method, according to the amounts of moisture initially in the product or the final moisture contents required in the dried material. It is obvious that when using a multi-stage working method, the installation is operated in such manner that the relative moisture content of the exhaust air of the first stage is as large as possible. The material resulting from the first stage then still has a correspondingly high moisture content, with which it is transferred into the second stage. In the second stage or, with installations operating with several stages, in the subsequent stages, the operation is carried out with correspondingly lower exhaust air saturations and higher exhaust air temperatures and it is therefore possible to adjust the required final moisture contents of the dried material.

While the specific heat requirement (cal./kg. of evaporated water) for the first stage assumes very low values, because of operating with high exhaust air saturations, the specific heat requirement is higher in the second stage or in the subsequent stages.

With this known method, the level of the hot air temperature entering the drier is dependent on the temperature sensitivity of the product to be dried; accordingly, only a slight temperature drop is available to the temperature-sensitive substances in the drying, so that the drying process is not economic.

The present invention has for its object to enable the drying to be carried out with substantially higher hot air temperatures than have been usual hitherto. This object is achieved according to the invention in that an air stream at relatively high temperature and an air stream at relatively low temperature are conducted through a treatment chamber on separate paths, but with the object of subsequent combination, the cooler air stream serving as carrier for the wet material and the hotter air stream having a temperature which is higher than the temperature which is permissible for the material to be dried.

This method of working provides the advantage that in the region of the mixing zone for the two hot air streams at different temperatures, a temperature is set in the treatment chamber which is lower than the theoretical mixing temperature. Since the wet material is located in the cooler air stream and this is gradually mixed with the

hot air stream, it is not possible for any overheating of the material to occur either ahead of, or even in the region of the mixing zone, because a partial evaporation of the moisture contained in the wet material constantly occurs during the process of mixing the hot air streams.

With the working method which has been described, a larger temperature drop is available for the drying process, whereby greater economy is produced.

The method according to the invention can also be carried into effect with particular advantage by a cooler stream of hot air being conducted as a vortex or envelope around a hot air stream and the wet material being supplied to the cooler air stream. This working method is particularly expedient when the drying process is to be carried out in two or more stages, the exhaust air, for example, of the last drying stage, being used as a current of cooling air for mixing with the current of hot air, for example, in the first drying stage. It has been shown in practice that the returned air does in fact always contain certain amounts of dust which can only be separated out by means of high-grade dust-extracting devices. If this does not take place, it is not possible for return air to be simply led back, when handling substances which are sensitive to temperature. Owing to eddy or vortex formations, depositions of product occur more specially at those walls which are located in the zone where the air currents at different temperatures are brought together, and these depositions result in damage or decomposition when the substances are sensitive to temperature.

According to the invention, a two-stage drying process with return of the exhaust air may be carried into practice without difficulty, because the quantities of extremely fine material contained in the cooler air current are positively conducted to the cooler outside walls and mixed with the wet material. As a result, complicated and expensive dust-extracting devices for the returned air are superfluous and the heat content of the returned air less saturated with moisture may be fully utilised for the drying of the first stage.

In the case wherein the cooler air stream is conducted as an eddy current around the hotter air stream, it is expedient to select for the outer cooler air stream an axial velocity which is greater than that of the hot air stream, so that the latter is partially broken up in an inward direction by eddy formation. By this means, an intial thorough mixing of the hot air with the cooler air current takes place in an extremely short time.

In order to carry into effect the method according to the invention which has been described above, it is expedient to use a treatment chamber which is similar to a Venturi tube. The air currents are conducted through the latter in such manner that the cooler air is supplied at the beginning tangentially or axially, the hot air is supplied through an axial tube up to the narrowest point of the chamber and the wet material is preferably also supplied to the narrowest point. At the opposite end, the venturi-like member terminates on the suction side of a high-speed fan, which may also be constructed in known manner as a disintegrator, to the exhaust pipe of which is connected a drying tube.

One advantage of the tangential introduction of the cooler air is that dust of the product which may perhaps be contained therein is extensively centrifuged out towards the wall, so that by supply of wet material, the latter becomes mixed with the dry dust and the mixture of product is moved along a spiral path on the wall. By means of this step, the results obtained are firstly that the wall temperature after the point of introduction of the hot air is kept low and, secondly, no appreciable quantities of product are able to pass directly into the stream of hot air and thus be heated to an impermissibly

high temperature. To protect the extremely fine dry dust which is in the return air or circulating air and which is not centrifuged out, the hot air inlet pipe has placed around it a jacket through which small quantities of cooling air are drawn.

With this constructional form of the invention, it is essential that the product to be dried does not come into direct contact with the stream of hot air, since it mainly slides in spirals on the inside wall of the mixing member, which in turn is additionally cooled by the cooler air vortex. As a result of this step, the wall temperature is kept cool in the dangerous zone of the hot air inlet. A considerable drop in temperature is already caused by evaporation of moisture in the treatment chamber. The final lowering of the temperature, however, takes place after the intimate thorough mixing of moist material and dry air in the fan or disintegrator itself. Consequently, the temperature drops to such an extent that with sticky or thermo-plastic substances, any dust of the product is not subject to the danger of damage in a drying tube connected on the output side.

For the purpose of explaining the flow conditions proposed according to the invention, reference is made to Figures 1 to 5, which illustrate two constructions by way of example, and also the method of operation. In the drawings:

Figure 1 is a longitudinal section of one apparatus;

Figure 2 is a cross-section at the point of introduction of the returned air on the line A—A of Figure 1;

Figure 3 is a cross-section at the narrowest point on the line B—B of Figure 1;

Figure 4 is a cross-section through the fan or disintegrator; and

Figure 5 is a longitudinal section of an apparatus in which cooler air is guided as a sheathing or envelope.

Referring to Fig. 1:

The treatment chamber, consisting of a member similar to a Venturi tube, is composed of a frustoconical inlet section **1**, a cylindrical section **2** and a frustoconical outlet section **3**. The member is so formed that the cylindrical section **2** connects the smallest cross-sections of the frustoconical sections **1** and **3**. The frustoconical discharge section **3** terminates at the fan or disintegrator **9**, to the pressure pipe of which there is connected a drier tube **12**. As shown in Figure 2, the return air is introduced through a tube **5** tangentially into the inlet section **1** acting in the manner of a cyclone. A pipe **6** for introducing hot air and a pipe **7** for introducing the cooling medium, for example, air, are arranged coaxially of the inlet section **1** and are carried by a cover **4**. The pipe **6** projects into the inlet section **1**, expediently as far as the cylindrical section **2**, the inlet section preferably being provided with insulation **10** over its entire length. Arranged on the inlet section **1** is the cylindrical section **2**, into which one or more connections **8** for the supply of wet material are adapted to open tangentially or radially, as shown in Figure 3.

It is also possible to supply the wet material through a slot, the length of which corresponds to the diameter of the cylindrical tube. The discharge section **3**, which follows after the cylindrical section **2** may have a jacket **11** for cooling air or cooling liquid, which is introduced at **13** and discharged at **14**. The discharge section **3** opens on the suction side of the fan or disintegrator **9**, the rotating vanes **15** of which rotate in the same direction as, or in the direction opposite to, the return air vortex. The cooling air pipe **7** expediently projects a little beyond the mouth of the hot air tube **6** at the point **16**, whereby the cooling air is drawn in and, in addition, the material is prevented from coming into direct contact with the opening of the hot air pipe **6**.

If it is intended completely to break up the current of hot air before the opening into the disintegrator, it may be expedient to make the frustoconical discharge section **3** cylindrical or even nozzle-shaped, or to extend it in this form. The opening angles of the frustoconical inlet and discharge sections are adapted in each case to the properties of the material to be dried. Similarly, the velocities of the hot air current and the axial velocity of the cooler air are suitably adapted to the prevailing conditions.

Figure 5 shows another apparatus in longitudinal section. In this case, the return air, circulating air or fresh air is supplied through pipe sections **5** arranged in Y-formation. Due to this method of introduction of the air, no rotation of the cooler air takes place, but it merely surrounds the hot air current entering through the tube **6** in the form of a cooler envelope. In other respects, the apparatus is made in a manner similar to that shown in Figure 1. In the constructions shown in Figures 1 and 5, the wet material is supplied at the narrowest part of the apparatus but it is also quite possible for the wet material to be already supplied beforehand to the return air by means of a separate fan or disintegrator fitted in the pipe for the cooler air, in which case pipe connections **8** for the supply of the wet material are superfluous. This latter arrangement may be of particular advantage with materials which are very sensitive to temperature, since, owing to its low saturation, the return air is still able to absorb water from the wet material and is thereby able to be cooled to the region of the dew point. The temperature is prevented from dropping below the dew point by a moderate heating of the return air pipe.

The method and the apparatus according to the invention may be used both with single-stage driers and with multi-stage driers. With materials which are not very sensitive to temperature, it is perhaps also possible to work with a direct flame instead of the centrally-introduced hot air, in which case, for example, fuel gas will be supplied through the pipe **6** and the air for combustion through the pipe **7** shown in Figure 1.

The method which has been described above and the apparatus as illustrated for carrying the method into effect may be modified in many ways within the scope of the invention. For example, the method is not restricted to the use of only two air currents at different temperatures; it is in fact possible to use several air currents which are at different temperatures.

The invention has been described above with reference to the use of air but it is also possible to use other gases in place of air. For example, when drying products which are sensitive to oxygen or with which there is a danger of gas/dust explosions, it may be expedient to use nitrogen, carbon dioxide or superheated steam instead of air. If it is desired to reach particularly high temperatures, there may with advantage be employed gases which are obtained by combustion of solid, liquid or gaseous fuels.

A wide variety of moist substances can be dried in a satisfactory manner with the method according to the invention; for example, minerals, rocks and earths, peat, chemicals of inorganic or organic origin, foodstuffs, wood products, cellulose products, and plastic manufactured by polymerisation and polycondensation, and others.

Example

If a thermoplastic plastic with a lower softening temperature in the region of 60° C. is to be dried, then this is only possible with comparatively low air temperatures which must be in the region of, or just above, the softening temperatures, if the drying process is carried out intermittently or continuously with the use, for example, of a known hurdle-type drying chamber using circulatory air. With this arrangement, it is frequently necessary to use drying periods of hours up to several days. With such long drying times, a certain damage may occur, even with comparatively low temperatures, which in certain cases may even be below the softening tem-

perature. Furthermore, such a drying process is uneconomical.

When using known flow driers with a single-stage or multi-stage arrangement, it is certainly possible to raise the drying air temperature to about 120° C. with products having the above mentioned softening temperature, since in this case there is a brief drying time and the particle temperature does not exceed the cooling limit temperature, above all in the first section of the drying. However, if the drying temperature is raised to above 120° C., caking of the product on the walls is observed owing to overheating of the wall surfaces, and this caking leads first of all to sintering and finally even to decomposition of the product.

Satisfactory drying, even of substances sensitive to high temperatures, is however produced with the method according to the present invention.

If the mixing zone proposed according to the invention is connected ahead of the fan or disintegrator of the drier, it is possible for the thermoplastic material to be dried without caking on the wall surfaces of the mixing apparatus, fan or disintegrator and drier tube when using a return air temperature of about 60° C. and a hot air temperature of 250° C. (with equal quantities of return air and heating air and a theoretical mixing temperature of about 155° C.). In this case, the temperature in the region of the wall of the discharge section **3** of the mixing apparatus, when measured along the jacket, is only about 80–120° C.; the temperature in the mean axis of the mixing apparatus, measured from the hot air inlet to just in front of the inlet to the disintegrator, drops in this test from 250° C. to 140° C., it not being possible to determine any product in the current of hot air. The above-mentioned theoretical mixing temperature of 155° C. is not reached at any point in the mixing apparatus, since a certain water evaporation and thus drop in temperature takes place. The residual thorough mixing takes place in the fan or disintegrator **9**, whereby the temperature, measured just above the discharge pipe of the disintegrator into the drier pipe **12**, drops to about 65° C. Since the entire process up to this measurement position is completed in about $\frac{1}{50}$ to $\frac{1}{100}$ of a second, there is no unfavourable effect on the material. It is surprising that the product dried in this manner has higher thermostability than the product dried in the manner which was formerly usual. Furthermore, the product is obtained in a very constant form.

The temperatures indicated in the example must be determined from case to case for each product. The velocity of the return air in this experimental arrangement is about 25 m./sec. in the tangential inlet pipe and is increased to 45 m./sec. in the nozzle-like admission section as far as the narrowest point. The hot air flows through the central pipe at a velocity of 25 m./sec. About 5% of the quantity of hot air is delivered as cooling air through the jacket of the hot air supply pipe.

We claim:

1. In a flow current method of drying moist material, directing a first current of relatively high temperature gas to flow through a generally tubular treatment chamber relatively centrally thereof; directing a second current of relatively low temperature gas to flow through said chamber between said first current and the walls of said chamber and in contact with said walls and causing said second current to flow as a swirling envelope surrounding said first current; introducing the moist material into said second current; and ultimately mixing the gas from said two currents and said material.

2. A method according to claim 1, wherein the moist material is supplied to said second current before the two gas currents are brought together.

3. A method according to claim 1, wherein the moist material is introduced after the two gas currents have been brought together and at a point at which the gas from said second current is still substantially at a lower temperature than the gas in said first current.

4. A method according to claim 1, wherein said first current is introduced centrally into a chamber having the general shape of a venturi tube through a jacketed supply pipe charged with cooling medium, into which chamber it issues from the supply pipe at the point of narrowest cross-section, the gas forming said second current being supplied to said chamber ahead of the outlet of said first current gas from its supply pipe, and the wet material being supplied as an envelope around said first current, the mixture of gas and material being mixed thoroughly and then entering a drier pipe.

5. A method according to claim 3, wherein said second gas current has an axial velocity which is greater than that of said first gas current.

6. In a flow current drying apparatus, a member having the general shape of a venturi tube and providing a chamber comprising a frustoconical inlet section, a frustoconical discharge section and an intervening cylindrical section connecting the smallest cross-sections of said inlet and discharge sections; a tube projecting centrally into said inlet section and terminating substantially at the inner end thereof for introducing relatively high temperature gas centrally into said chamber; means for introducing relatively low temperature gas into said chamber through said inlet section between said tube and the walls of said inlet section; means for introducing moist material to be dried into said cylindrical section; and a disintegrator for receiving the gas and material from said discharge section.

7. Apparatus as set forth in claim 6, in which said tube is provided with a cooling jacket.

8. Apparatus as set forth in claim 7, in which said cooling jacket projects beyond the inner end of said tube and is constricted at its inner projecting end.

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