

"HOPPER DRIER"

This invention relates to a hopper for supplying raw material to a molding machine, and more particularly to a hopper drier for drying granular synthetic resin material or the like to supply it to such
5 a machine.

Raw synthetic resin material used for molding products of synthetic resin such as plastics or the like is generally supplied in the form of pellets. As is well known, when pellets contain moisture
10 to more than a predetermined level, hydrolyzation takes place during the molding operation, resulting in the synthetic resin being deteriorated. As a result the molded products have reduced strength and ductility. Further, as the amount of moisture
15 in the pellets increases, the molten resin becomes fluid, which results in molten resin excessively filling the molding die whereby burrs are formed around the molded products, causing them to have an incorrect geometrical configuration, reduced
20 accuracy and a spoilt surface appearance. For this reason there is a necessity for sufficiently drying pellets prior to using the same. To meet this requirement it has been proposed that pellets be dried by using atmospheric air. However, it has been
25 found that this proposal was unacceptable for the reason mentioned below.

As is known, atmospheric air contains a certain amount of moisture. For example, if the air has a temperature of 20°C , an absolute pressure of 760mm
30 Hg and a relative humidity of 75%, the moisture contained in air of unit volume lm^3 amounts to 10.251 grams. If this wet air is introduced into a molding machine by operating a blower having a capacity of 2.5m^3 per minute, the result is that moisture
35 passes through the pellets at a rate of 2630.25 grams per hour. Then, in a case where nylon resin

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having a high moisture absorptivity is employed for a molding operation, moisture more than that removed by drying is supplied to the nylon pellets.

In view of these facts, in circumstances where drying is required at a high rate, it has been necessary to provide a hopper having a drier incorporated therein for drying pellets prior to delivering them to a molding machine.

To facilitate understanding of the present invention it will be helpful for a typical conventional hopper drier to be described below with reference to Fig. 1. As illustrated in the drawing, the conventional hopper drier includes a hopper housing 11 in which pellets to be supplied to a molding machine are stored, a dehumidified air preparing unit 12 for preparing dehumidified air to be delivered to the hopper housing 11, and a heating column 13 in which dehumidified air is heated up to an elevated temperature. Specifically, the dehumidified air preparing unit 12 includes two dehumidifying columns 14 and 15 with dehumidifying material therein, a heater 16 for drying dehumidifying material in the dehumidifying columns 14 and 15 with the aid of hot air having a temperature higher than 300°C to regenerate it, a cooling apparatus 17 for cooling dehumidifying material which has been regenerated by hot air, and three-way valves 18 for delivering only to one or other dehumidifying column air coming from the heater 16 and the cooling apparatus 17 and delivering to the heating column 13 air which has passed through the other dehumidifying column. The heating column 13 is provided with a heater 19 so that dry air introduced into the heating column 13 from the dehumidifying column 14 via the three-way valve 18, a blower 20, a filter 21 and a stop valve 22 is heated up to an elevated temperature and thereafter is delivered to the hopper drier housing 11 to dry pellets stored in the latter.

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After passing through the hopper drier housing 11, waste air is discharged into the outside environment via a discharging port 23. As illustrated in the drawing, a part of the waste air is introduced into
5 dehumidifying column 14 or 15 after it is cooled down in a cooling apparatus 24 and then it flows through a filter 25.

Next, when the three-way valve 18 is shifted, the dehumidifying column 15 initiates a so-called
10 regenerating cycle in which moisture absorbed in the dehumidifying material is removed. Namely, dry air taken from the dehumidifying column 14 by operating the blower 20 is caused to flow through the stop valve 26 and the cooling apparatus 17,
15 which is now kept inoperative, and is then heated in the heater 16. Thus heated air is delivered to the dehumidifying column 15 via the three-way valve 18 and thereby the dehumidifying material with moisture absorbed therein is dried. After
20 completion of dehumidification the heater 16 is turned off and the cooling apparatus 17 starts its operation to cool the dehumidifying material by allowing cooled dry air to flow therethrough. This is because of the necessity for cooling down the
25 dehumidifying material to a lower temperature close to room temperature, due to the fact that dehumidification fails to be achieved satisfactorily as long as dehumidifying material is kept hot. After the dehumidifying material has cooled down, the three-
30 way valve 18 is shifted so that dry air which has passed through the dehumidifying column 15 is introduced into the heating column 13. It should of course be understood that if air cooled in the cooling
apparatus 24 is to be utilized, it is caused to
35 flow into the dehumidifying column 15 via the filter 25. At this moment the dehumidifying column 14 initiates the same regenerating cycle as mentioned above with respect of the dehumidifying column 15.

To cool dehumidifying material in the dehumidifying columns 14 and 15 usually takes longer than two hours, although this varies in dependence on the amount of dehumidifying material to be cooled.

5 Further, in the illustrated case, another drawback is that a large amount of electric power is consumed because the heater 16 requires 6 KW, the cooling apparatus 3 KW and the heater 19 in the heating column 13, 3 KW. Also, where waste air to be discharged
10 through the discharging port 23 is reused, there is a necessity for installing the cooling apparatus 24 to cool hot waste air in order to assure that the dehumidifying material functions properly. Thus, a large amount of thermal energy is consumed
15 in vain. Moreover, mechanical driving energy is required for operating the cooling apparatus 24.

Thus the present invention has been made with the foregoing background in mind and its main object is to provide an improved hopper drier in which
20 the above-mentioned drawbacks are removed or at least reduced, which is relatively simple in structure, and which assists energy saving.

According to the present invention there is provided a hopper drier comprising;

25 a hopper drier housing, for containing granular material of synthetic resin to be supplied to a molding machine for example, said hopper drier housing being formed with a dry hot air introducing port at a lower part thereof and two discharging ports
30 at an upper part thereof, one of said discharging ports being in communication with the suction side of a blower,

first and second dehumidifying means for containing dehumidifying material for dehumidifying air
35 to be supplied to the hopper drier housing, each of said dehumidifying means having a first introducing and discharging port which is in communication with a source of compressed air via first valve means

and a second introducing and discharging port which is in communication via second valve means with an air delivery pipe for delivering dehumidified air to the hopper drier housing,

5 a heating column of which one end is in communication with the delivery side of the said blower and of which the other end is in communication with the said introducing port of the hopper drier housing, said heating column including a heating pipe extending
10 about the heating column for preheating dehumidified air of which one end is connected to the said air delivery pipe, a nozzle connected to the other end of said heating pipe to supply into the heating column dehumidified air which has been preheated while flowing
15 through the heating pipe, and a heater disposed in the heating column to heat up to a predetermined temperature the mixture of air discharged through said nozzle and air blown from the blower, and

 said first valve means being arranged so that
20 when compressed air is supplied into either of said dehumidifying means via said first port waste air is discharged from the other dehumidifying means to the outside environment, and said second valve means being arranged so that when dehumidified air is delivered
25 from either of said dehumidifying means to the said delivery pipe, a part of such dehumidified air is introduced into the other dehumidifying means.

 In a preferred embodiment of the invention the hopper drier housing is provided with an one-way valve
30 in the other of its said discharging ports so arranged that only a volume of air equal to that of air supplied through the said nozzle is discharged to the outside environment via the one-way valve. Thus, air pressure in the hopper drier housing is maintained substantially
35 constant at all times. Further, the second valve means may include, associated with each said dehumidifying means, a one-way valve adapted to permit flow there-

through only of air coming from the said second introducing and discharging port to the said delivery pipe and to prevent air from flowing in the opposite direction, and an orifice disposed in parallel with said one-way valve to permit restricted flow of air coming from the delivery pipe to the said second introducing and discharging port.

In operation of a hopper drier constructed in the above-described manner, compressed air introduced into either of the dehumidifying means via the first valve means is dehumidified therein, dehumidified air is preheated while it flows through the heating pipe, and thereafter preheated air is introduced into the heating column through the nozzle. The heating column is supplied with hot air at the upper part thereof which is delivered from the hopper drier housing by operating the blower, so that it is mixed with air which is delivered through the nozzle and thereby the mixture has a reduced absolute temperature. However, the mixture is heated up to a predetermined temperature again by means of a heater in the heating column and it is then introduced into the hopper drier housing. The one-way valve disposed at the upper part of the hopper drier housing serves to allow a volume of air equal to that of air supplied through the nozzle to be discharged therethrough to the outside environment so that highly dried hot air is supplied into the heating column at all times with the aid of the blower. Since dry air supplied through the nozzle is preheated by means of the heating pipe, the heater incorporated in the heating column consumes a much reduced amount of electric power. Further, a part of the dry air dehumidified in one or other of the dehumidifying means is introduced into the other dehumidifying means via the said orifice so as to dry dehumidifying material in the other dehumidifying means. When it is found that the one dehumidifying means has

reduced dehumidifying capability, the first valve means is shifted so that the other dehumidifying means is brought into use.

5 An embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, in which:-

Figure 1 is a system flow chart schematically illustrating the construction of a typical conventional hopper drier; and

10 Fig. 2 is a system flow chart schematically illustrating the construction of a hopper drier in accordance with the invention.

The conventional apparatus of Fig.1 have already been described, referring now to Fig. 2, two dehumidify-
15 ing columns 32 and 33 are shown which are filled with dehumidifying material. As is apparent from the drawing, both the dehumidifying columns 32 and 33 are the same in structure and therefore description will be made below only with respect to the dehumidify-
20 ing column 32. The dehumidifying column 32 has a first introducing and discharging port 34 formed at the bottom thereof and a second introducing and discharging pipe 35 is vertically inserted through the dehumidifying column 32 in such a manner that
25 its open end is located at the upper part of the latter. The pipe 35 is projected downwardly of the dehumidifying column 32 until it is in communication with a bypass pipe 39 with an orifice 38 disposed midway thereof and moreover it is in communication
30 with a main pipe 42 with a one-way valve 41 disposed midway thereof. The one-way valve 41 (the second valve means referred to above) is designed in the conventional manner such that fluid discharging from the pipe 35 is allowed to flow but fluid flow
35 from the main pipe 42 is prevented. The lower end part of the bypass pipe 39 is jointed to the lower end part of the main pipe 42. The main pipe 42 for each of the dehumidifying columns 32 and 33

is in communication with a delivery pipe 43 at the bottom thereof. There is provided a three-way valve 37 (the first valve means already referred to) of which a second port is in communication with a connection pipe 36 for the dehumidifying column 32 and of which a third port is in communication with a connection pipe 44. The latter extends to a compressor which is not shown in the drawing so that compressed air which has been dehumidified and cooled is introduced into either of the dehumidifying columns 32 and 33 by selectively shifting the three-way valve 37. As will be readily seen from the drawing, compressed air delivered through the connection pipe 44 is introduced into the dehumidifying column 32 via the three-way valve 37 and the connection pipe 36 and after completion of dehumidification compressed air is delivered to the delivering pipe 43 via the pipe 35 and the one-way valve 41. A part of the compressed air in the delivery pipe 43 is introduced into the dehumidifying column 33 via the orifice 38 while the one way valve 41 in the main pipe 42 is kept closed under the influence of the pressure of compressed air active in the opposite direction. Thus, no compressed air is introduced into the dehumidifying column 33 through the main pipe 42. After passing through the dehumidifying column 33 compressed air is delivered to the three-way valve 37 via the connection pipe 36 and it is then discharged into the outside environment via a discharging pipe 45. Namely, the working state as illustrated in Fig.2

represents the dehumidifying column 32 being kept in the normal working cycle while the dehumidifying column 33 is kept in the regenerating cycle.

5 The delivery pipe 43 extends further to the right as seen in the drawing until it is jointed to a heating pipe 48 which is spirally wound round a heating column 47 disposed by the side of a hopper
10 dryer housing 46. The lower end part of the heating column 47 is in communication with the lower end part of the hopper dryer housing 46 via a filter 49 located therebetween. On the other hand, the upper end part of the heating column 47 is in communication with the upper end part of the hopper dryer housing 46 via a blower 51 located above the heating
15 column 47 and a filter 52 housed in the upper end part of the hopper dryer housing. The heating pipe 48 extends further upwardly while spirally winding round the heating column 47 until it reaches a nozzle 53 which is opened toward the interior of the heating
20 column 47. A heater 54 is housed in the heating column 47 so as to heat dry compressed air which has been blown into the latter through the nozzle 53 whereby dried hot air is delivered to the hopper drier housing 46. The hopper drier housing 46 is
25 provided with a one-way valve 55 at the upper end thereof which is opened to the outside environment so that a part of the hot air is discharged to the outside through the one-way valve 55.

Next, operation of the hopper drier of the present invention as constructed in the above-described manner will be described below.

Dehumidified compressed air supplied from
5 a compressor via the connection pipe 44 is introduced
into the dehumidifying column 32 via the three-way
valve 37 so that it is dehumidified further therein
with the aid of dehumidifying material 31. Compressed
10 air which has been dried is delivered to the delivery
pipe 43 via the pipe 35 and the one-way valve 41.
After passing through the delivery pipe 43 it enters
the heating pipe 48 and it is then introduced into
the heating column 47 through the nozzle 53. The
15 heating column 47 is heated up to an elevated temperature
by a combination of hot air flowing therethrough
and heater 54 whereby air in the heating pipe 48
is heated by heat radiated from the heating column
47. Thus, hot compressed air is blown into the
20 heating column 47. After it is dried and heated
up further to an elevated temperature in the heating
column 47, it is introduced into the lower part
of the hopper dryer housing 46 via the filter 49
so as to dry pellets held in the hopper drier housing
46. As air flows up through the hopper drier housing
25 46 while drying pellets, it becomes humidified.
Thus, a volume of air equal to the volume of air
blown through the nozzle 53 is discharged to the
outside via the filter 52 and the one-way valve
55, whereas a residual volume of air is delivered
30 to the heating column 47 again with the aid of the
blower 51 and is mixed

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with dried hot air blown through the nozzle 53 so that the mixture is reheated by the heater 54. Reheated dry hot air is introduced into the hopper drier housing 46 again.

5 As it passes through the hopper drier housing, it is considerably cooled down to a temperature which measures about 80% of the initial temperature of hot air supplied from the heating column 47, wherein the aforesaid temperature varies in dependence
10 on the volume of pellets stored in the hopper drier housing 46. Provided that hot air supplied from the heating column 47 has a temperature of 100°C, return air entering the blower 51 has a temperature of about 80°C. Due to this fact there is required
15 only a sufficient amount of thermal energy to heat up air by an extend^e of about 20°C, once adjustment has been made in the beginning time of operation, so as to supply to the hopper drier housing 46 hot air having a temperature of 100°C.

20 On the other hand, the one-way valve 41 for the other dehumidifying column 33 is kept closed under the influence of the pressure of compressed air coming from the one dehumidifying column 32 so that compressed air is inhibited from flowing
25 into the dehumidifying column 33 via the one-way valve. However, a part of the dry compressed air is allowed to enter the dehumidifying column 33 at its upper end and it is utilized to carry out a regenerating cycle for drying the dehumidifying
30 material 31. Thus supplied dry air is caused to flow downwardly from the upper end part of the dehumidifying column 33 and

thereafter it is discharged into the outside environment via the port 34, the connection pipe 36, the three-way valve 37 and the discharging pipe 45. Accordingly, the hopper drier is operated such that dry air is

5 supplied to the heating pipe 48 from the one dehumidifying column 32 while a part of the dry air coming from the latter is introduced into the other dehumidifying column 33 so as to dry dehumidifying material 31 at a lower temperature. When it is found that

10 the dehumidifying column 32 has reduced dehumidifying capability, the three-way valve 37 is shifted immediately in such a manner that the one dehumidifying column 32 undertakes the regenerating cycle and the other dehumidifying column 33 which has completed the

15 dehumidifying operation undertakes the normal working cycle.

Next, explanation will be made below as to whether or not dry hot air can be produced by mixing very highly dried air with air having moisture absorbed

20 in the hopper drier housing 46. For instance, 6,6 nylon resin of 50 Kg having a moisture of 0.3% contains a moisture of 150 grams. Incidentally, the moisture content recommended by suppliers is about 0.1%.

25 To allow 50 Kg resin having a moisture of 0.3% to be dried to a level of 0.1% moisture for three hours it is necessary to expel moisture at a rate of 33.3 grams per hour. Now, it is assumed that the hopper drier including the hopper drier housing 46, the heating column 47 and the blower 51 has a working

30 volume of 110 litres and 50 kg resin in the form of

pellets has a volume of about 90 litres. Further, it is assumed that air having a dew point of -53°C is supplied at a rate of 5.4 m^3 per hour and air in the hopper drier housing 46 has a dew point of -20°C at a time when heating is initiated. If resin is filled at a volume rate of 60%, it has a net volume of 54 litres and therefore the hopper drier has a space volume of 56 litres. Thus, air having a dew point of -20°C contains a moisture of 0.049476 grams in the aforesaid space volume of 56 litres.

Since the amount of air to be discharged is equal to the amount of air introduced into the hopper drier, air is discharged to the outside environment through the one-way valve 55 at a rate of 5.4 m^3 per hour. A number of experiments reveal that air has a dew point of $+5^{\circ}\text{C}$ for the initial period of 2.5 hours when it is discharged through the piled layer of 6,6 nylon. Thus, moisture contained in air, that is, moisture to be expelled is 36.7092 grams. On the other hand, very highly dried air having a dew point of -53°C has a moisture of 109.69 grams when it is introduced at a rate of $5.4 \text{ M}^3/\text{Hr}$. Since moisture expelled every hour is 36.56556 grams which is obtainable from an arithmetic calculation of $36.7092 - 0.14364 = 36.56556$, it results that moisture expelled for three hours amounts to 109.69 grams. This means that a hopper drier of the present invention mounted for a certain molding machine adapted to consume pellets at a rate of 15 Kg per hour assures that pellets are conditioned to a dried state suitable for a

molding operation within three hours and moreover the dried state is maintained while pellets to be dried are charged into the hopper drier as the dried pellets are consumed.

5 Further, it is found that the hopper drier of the invention consumes a total electric power less than 2.9 Kw/Hr because the heater for preparing dry air consumes less than 1 Kw/Hr of electric power, the compressor for supplying dehumidified air less
10 than 1.5 Kw/Hr and the blower less than 0.4 Kw/Hr. This means that remarkable energy saving can be achieved by employing the hopper drier of the invention. Another advantageous feature of the invention is that the cooling capacity required for a room having
15 the hopper drier mounted therein can be substantially reduced because the amount of heat radiated from the heating column is inhibited to less than about 20% of the total inputted heat owing to the arrangement of the heating coil spirally wound round the heating
20 column.



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Claims

1. A hopper drier comprising;

a hopper drier housing, for containing granular material of synthetic resin to be supplied to a molding machine for example, said hopper drier housing being
5 formed with a dry hot air introducing port at a lower part thereof and two discharging ports at an upper part thereof, one of said discharging ports being in communication with the suction side of a blower,

first and second dehumidifying means for contain-
10 ing dehumidifying material for dehumidifying air to be supplied to the hopper drier housing, each of said dehumidifying means having a first introducing and discharging port which is in communication with a source of compressed air via first valve means and
15 a second introducing and discharging port which is in communication via second valve means with an air delivery pipe for delivering dehumidified air to the hopper drier housing,

a heating column of which one end is in communica-
20 tion with the delivery side of the said blower and of which the other end is in communication with the said introducing port of the hopper drier housing, said heating column including a heating pipe extending about the heating column for preheating dehumidified
25 air of which one end is connected to the said air delivery pipe, a nozzle connected to the other end of said heating pipe to supply into the heating column dehumidified air which has been preheated while flowing through the heating pipe, and a heater disposed in
30 the heating column to heat up to a predetermined temperature the mixture of air discharged through said nozzle and air blown from the blower, and

said first valve means being arranged so that
when compressed air is supplied into either of said
35 dehumidifying means via said first port waste air



is discharged from the other dehumidifying means to the outside environment, and said second valve means being arranged so that when dehumidified air is delivered from either of said dehumidifying means to the said delivery pipe, a part of such dehumidified air is introduced into the other dehumidifying means.

2. A hopper drier as claimed in claim 1, wherein the hopper drier housing is provided with a one-way valve in the other of its said discharging ports, said one-way valve serving to discharge air to the outside environment at a rate substantially equal to that at which air is supplied through the said nozzle.

3. A hopper drier as claimed in claim 1 or 2, wherein the said second valve means includes, associated with each said dehumidifying means, a one-way valve adapted to permit flow therethrough only of air coming from the said second introducing and discharging port to the said delivery pipe and to prevent air from flowing in the opposite direction, and an orifice disposed in parallel with said one-way valve to permit restricted flow of air coming from the delivery pipe to the said second introducing and discharging port.

4. A hopper drier as claimed in any of claims 1 to 3, wherein the said first introducing and discharging port is disposed at the lower part of each said dehumidifying means and the second introducing and discharging port is disposed at the upper part of the same.

5. A hopper drier substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.