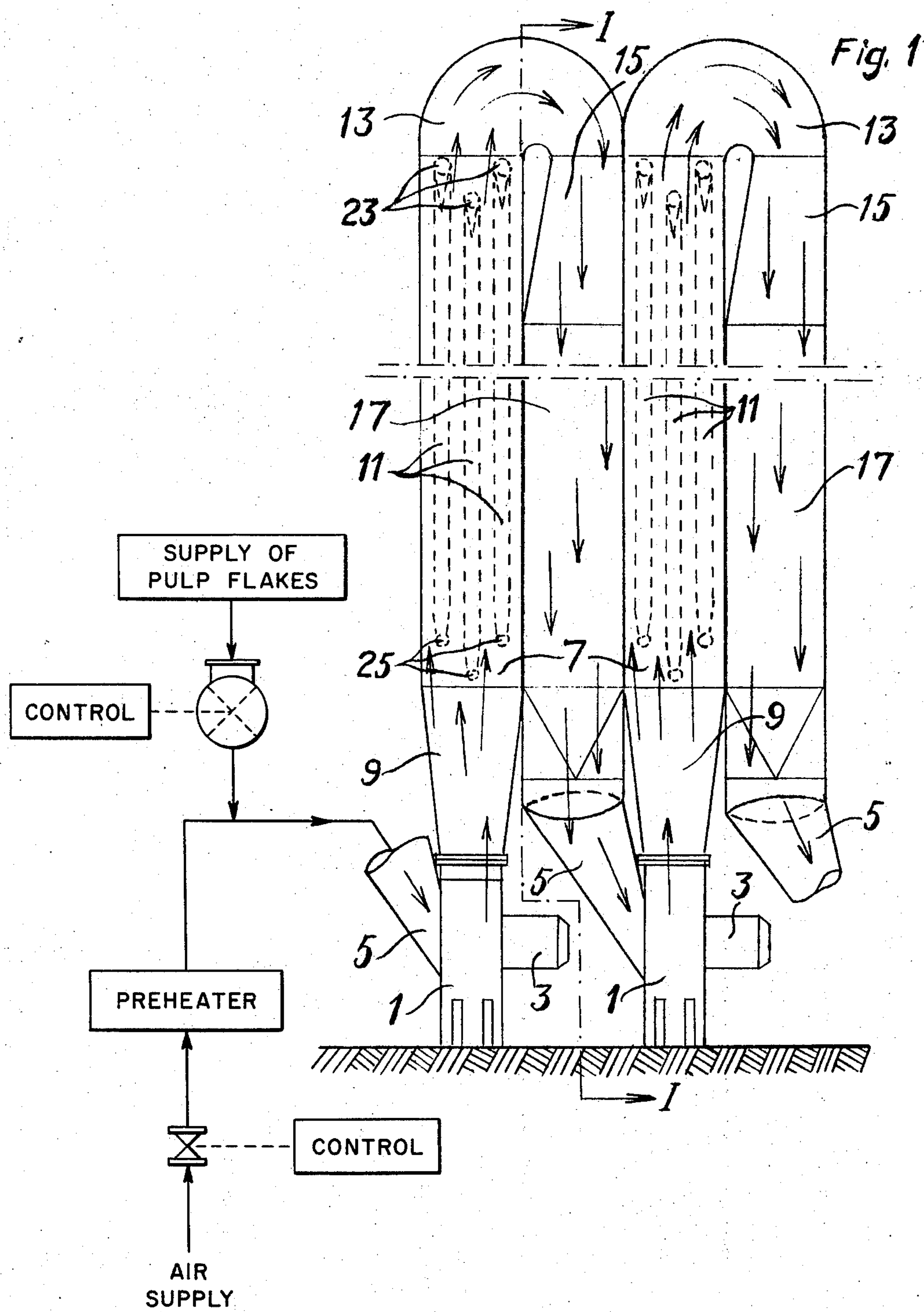
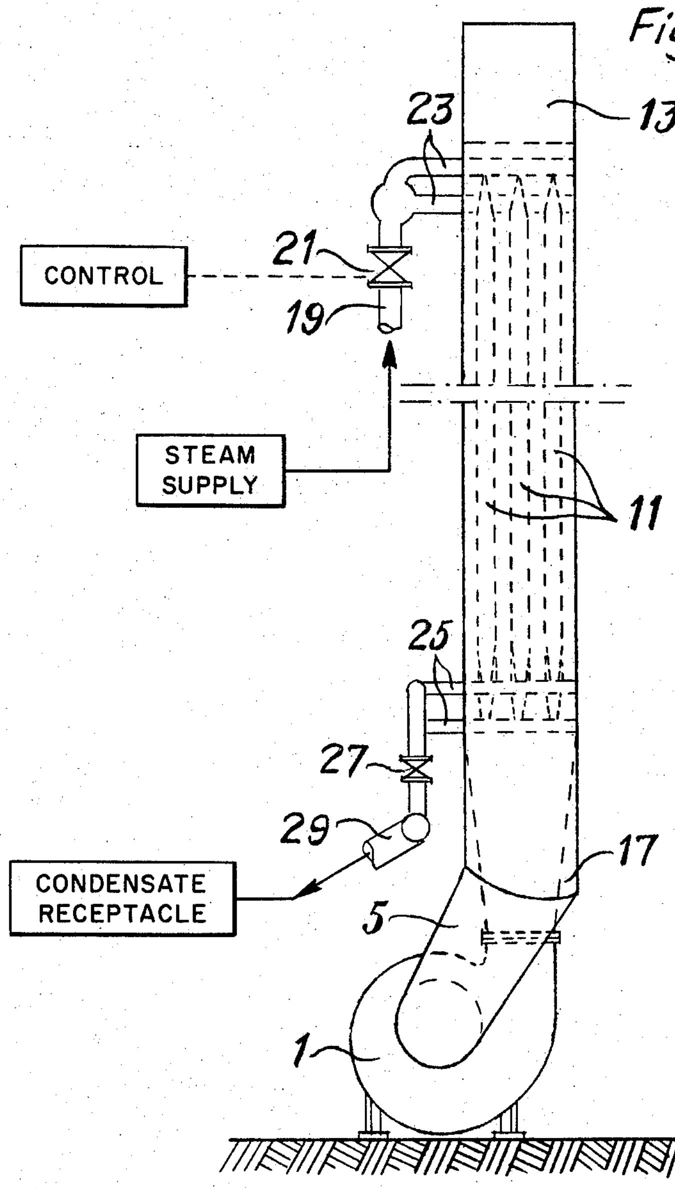


Fig. 1
13
15
13
23
15
17
11
11
17
SUPPLY OF
PULP FLAKES
CONTROL
25
7
9
9
5
5
3
5
1
3
1
PREHEATER
I
I
CONTROL
AIR
SUPPLY

Fig. 2


23
13
21
CONTROL
19
STEAM
SUPPLY
11
25
27
29
CONDENSATE
RECEPTACLE
17
5
1

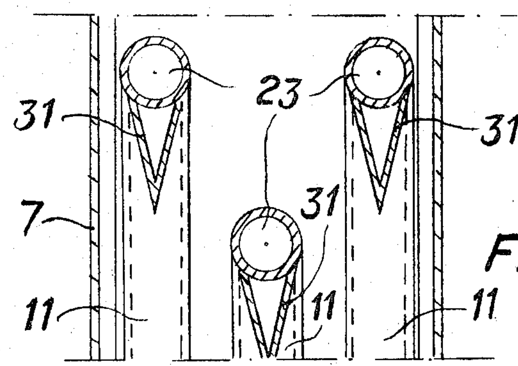


Fig. 3

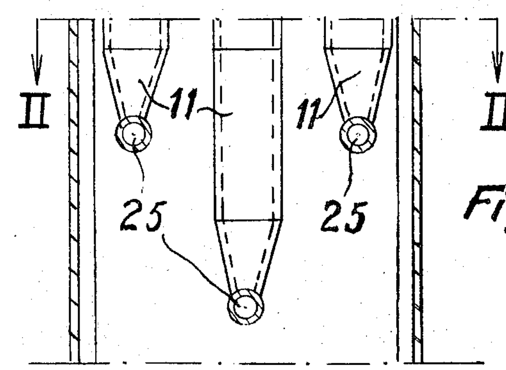


Fig. 4

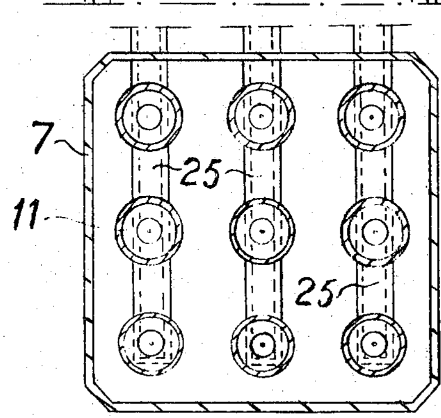


Fig. 5

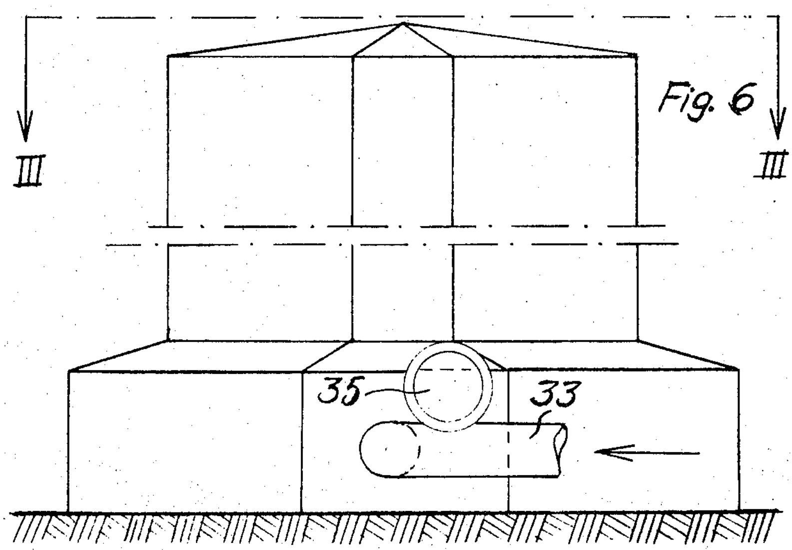


Fig. 6

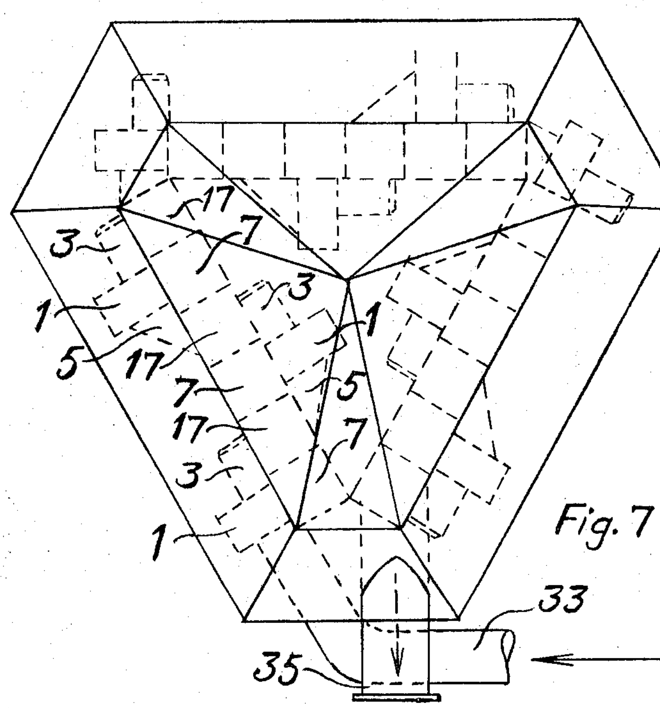


Fig. 7

3,808,093
Patented Apr. 30, 1974

3,808,093

METHOD AND APPARATUS FOR DRYING PULP INCLUDING HEAT EXCHANGE AND TEMPERATURE EQUALIZING ZONES

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Filed Feb. 15, 1972, Ser. No. 226,632
Claims priority, application Sweden, Apr. 6, 1971, 4,458/71
Int. Cl. F26b *3/10, 17/10*
U.S. Cl. 162—100 8 Claims

ABSTRACT OF THE DISCLOSURE

Pulp flakes are dried by entraining them in a flowing gas and conducting the gas-flakes mixture through a multiplicity of drying units, each of which includes a heat-exchanger section for transferring heat into the gas-flakes mixture and a temperature-equalizing section where the temperatures of the gas and flakes are brought into substantial equality. The concentration of pulp flakes in the gas is maintained at a level such that there is no more than about 0.35 kg. dry weight of pulp for each 1.0 kg. of gas. The supply of heat in the heat-transfer zone and the moisture content of the flakes and gas processed through the equipment are controlled so that the gas discharged from the device has a wet-bulb temperature not less than about 60° C. and a dry-bulb temperature of not greater than about 120° C. The heated portion of the flow path along which the gas-flakes mixture flows has a hydraulic diameter not greater than about 200 mm.

BACKGROUND OF THE INVENTION

This invention relates to a method and an apparatus for drying pulp flakes.

In so-called flash-drying of pulp, a fibrous suspension of pulp of relatively high consistency is formed into a fibrous web by de-watering and pressing, such as in a drum or roll press. The fibrous web is then broken up by a shredding device to form pulp flakes, which are dried by causing them to flow in a heated gas. Presently known methods and equipment for flash-drying of pulp flakes have numerous disadvantages. Generally, the efficiency of utilization of heat is low, inasmuch as large quantities of hot gas are required to conduct heat into the material to be dried. The inefficient utilization of heat is an especially great disadvantage in pulp mills requiring large amounts of hot water, which is usually the case in mills producing kraft pulp. In many flash-drying processes, there is a risk of the attainment of excessively high gas temperatures in drying that may very well cause deterioration in the quality of the pulp. The gas conveying systems in many known devices are subject to wide fluctuations in flow characteristics that result in frequent obstructions and blockages of the equipment and require the equipment to be shut down and the blockages cleared, to the serious detriment of efficient production.

SUMMARY OF THE INVENTION

There are provided, in accordance with the present invention, a method and an apparatus for flake drying pulp that overcome the disadvantages of presently known methods and equipment and offer significant advantages in their own right. In particular, the method and apparatus of the invention overcome many of the problems associated with the heat transfer conditions between a heated gas and pulp flakes by providing heat exchange in several separate zones along the path through which the pulp gas mixture is conveyed. The ratio of pulp flakes to gas and the properties of the conveying system are established and controlled to provide stable slow conditions that promote high efficiency of heat utilization and a minimum of risk of blockages in the equipment. The invention enables the pulp to be dried under suitable temperature conditions while producing a hot effluent gas that can be utilized efficiently in heating water for general use in other parts of the mill.

In accordance with the invention, the pulp flakes are entrained in a gas, air being quite appropriate, in an amount not greater than 0.35 kg. dry weight of pulp per 1.0 kg. of gas. Preferably the air or other gas is preheated prior to introducing the pulp flakes. The gas-flakes mixture is then conducted through a conduit system that is constructed to provide a multiplicity of units, each having a heat-transfer zone and a temperature-equalizing zone, arranged in series. In particular, each unit comprises a heat-transfer zone constituted by a length of conduit containing a heat exchanger, preferably in the form of a multiplicity of spaced-apart tubes extending parallel to the axis of the conduit and of appropriate length and surface area to provide a desired heat input in each zone. Preferably, the tubes are heated by conducting steam at a low saturation pressure in the range of from about 2 atmospheres to 12 atmospheres. As the mixture of pulp and flakes flows past the heat-exchanger section of each unit, heat is transferred into the gas and flakes. Each unit of the apparatus further includes a temperature-equalizing zone downstream from the heat-transfer zone. As the pulp flows through the temperature-equalizing zone of each unit, the temperatures of the flakes and the gas become substantially equalized, thus ensuring high efficiency and preventing the attainment of overly high gas temperatures. Consequently, the production of a high quality pulp is ensured.

Stable flow conditions in the equipment are maintained by controlling a combination of factors. As already mentioned, the ratio of pulp flakes to gas is held below 0.35 kg. of pulp, dry weight, per 1.0 kg. of gas. It has been found that a pulp loading significantly above that limit increases the likelihood of formation of fiber networks or agglomerates. In addition, the cross-section of the conduit system is dimensioned and shaped so that the velocity profile at any zone in the system does not have any unstable parts of the same order of size as the flocs or aggregations of pulp that tend to form in the system due to the inherent property of fibrous pulp flakes to form networks or flocs. It has been found that the flocs or aggregations of pulp flakes generally have a size on the order of 50 mm. to 100 mm., a range which corresponds roughly to the unstable part of a velocity profile in a conduit having a hydraulic diameter of about 200 mm. Accordingly, an important feature of the invention is the construction of the flow system such that the hydraulic diameter at any heated zone in the system does not exceed about 200 mm.

In order for the heat in the effluent gas leaving the equipment to be utilized economically for heating water for general use in the mill, the ratio of pulp to gas is controlled so that, taking into account the moisture content of the pulp, the rate of introduction of moisture into the system is sufficient to produce an effluent gas from the equipment having a wet-bulb temperature of not less than about 60° C. At the same time, the input of heat to the system and the rate of heat transfer in the several units are controlled so that the dry-bulb temperature of the gas does not exceed 120° C. It has been found that dry-bulb temperatures higher than 120° C. present some risk of impairment of the quality of the pulp.

In a preferred embodiment of the apparatus, the conduit system is formed by a multiplicity of laterally adjacent, generally parallel conduit sections. Alternate ones of the conduit sections contain the heat exchangers and the remaining sections constitute at least portions of the temperature-equalizing zones. Adjacent pairs of heat-transfer sections and temperature-equalizing sections are connected together by elbows to place the temperature-equalizing section downstream of the corresponding heat-transfer section in each unit. The cross-sectional area of each elbow decreases in proportion to the distance of any given cross-section from the upstream end to ensure against the establishment of a stagnation zone at the downstream, radially inward end of the elbow and thus prevent turbulence and back flow and a possibility of an unstable flow condition and possible blockage of the conduit. Preferably, the flow of the gas-air mixture is augmented periodically by conducting the mixture through conveyor fans. Such fans may be located near the downstream end of each temperature-equalizing zone of the system. The conveyor fan may provide the connection between each adjacent pair of units in the system. Advantageously, the conduit sections are oriented vertically with the elbows uppermost and the conveyor fans lowermost. In that case, the fans are conveniently and readily mounted on footings, which is of considerable advantage from the point of view of an efficient structural arrangement.

The initial cost of the equipment is significantly less than previously known equipment for flash-drying of pulp, primarily because heating takes place at several stages with temperature equalization between the heat-transfer stages. Consequently, the quantities of gas to be handled will be small, and the conveyor fans and other components of the equipment may be commensurately small and thus of lower cost.

A unit having conveyor sections arranged vertically in parallel, side-by-side relation occupies a minimum of space and is structurally durable. The equipment can be located outside with appropriate coverings required only for the motors and instrumentation. This means further savings in cost.

The method and apparatus can readily be used with a gas other than air, for example a chemically inert gas, such as air having its oxygen content removed. The liquid removed during the drying process can be extracted readily, for example, by the acetone extraction process.

DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be made to the following description of an exemplary embodiment, taken in conjunction with the figures of the accompanying drawings, in which:

FIG. 1 is a side-elevational view of two units of the embodiment, the view being in generally schematic and diagrammatic form and showing a center portion of the equipment broken out to reduce the height of the figure;

FIG. 2 is an end view in elevation of the apparatus of FIG. 1, the view being taken generally along a broken plane, as represented by the lines **1—1** in FIG. 1, and in the direction of the arrows;

FIG. 3 is a side view in section of the upper portion of a heat-exchanger section of a unit of FIGS. 1 and 2, the view being on a somewhat larger scale than FIGS. 1 and 2;

FIG. 4 is a side view in section of the lower portion of a heat-exchanger section of a unit, also on a larger scale than FIGS. 1 and 2;

FIG. 5 is a top view in cross-section taken through a heat-exchanger section of one of the units of the embodiment of FIGS. 1 and 2;

FIG. 6 is a side-elevational view of a complete installation constructed with a multiplicity of units of the form shown in greater detail in FIGS. 1 and 2, the center portion of the installation being broken away to reduce the vertical height of the figure; and

FIG. 7 is a top view of the equipment illustrated in FIG. 6, as designated by the lines **3—3**, and the direction of the arrows in FIG. 6.

DESCRIPTION OF EXEMPLARY EMBODIMENT

Referring to FIGS. 1 and 2 of the drawings, reference numeral **1** designates centripetal fans that are driven by motors **3** and have generally conical inlet pipes **5** connected to the suction sides of the fans. The output side of each of the fans is connected by a tapered outlet duct section **9** to the lower end of a vertical conveyor duct section **7**. The conveyor duct **7** is generally square in cross-section (see FIG. 5) and contains a heat-exchanger unit composed of a multiplicity of spaced-apart pipes **11** that extend parallel to the axis of the duct **7**. Connected to the top of each duct **7** is a 180° elbow duct **13** that connects the upper end of the duct **7** to the upper end of a tapered duct section **15**. Each duct section **15** is connected at its lower end to a duct section **17**, which is also oriented vertically, is of substantially square cross-section and is laterally adjacent the section **7**. The lower portion of the duct section **17** is constructed to transform the cross-section of the duct system from square to substantially circular, and the circular lower end of the section **17** is connected to the conical inlet **5** of an adjacent fan **1**.

As will be described in more detail below, and as illustrated in FIGS. 6 and 7 of the drawings, the duct sections **9, 7, 13, 15, 17** and **5** constitute one unit of a multiple unit system composed of several of the basic units mounted adjacent each other and connected to each other in series. The major portion of each duct section **7** constitutes a heat-transfer zone of each unit, and the duct sections **13, 15, 17** and **9** constitute a temperature-equalizing zone of each unit.

The elbow **13** is constructed with a varying cross-sectional area that provides a smooth reduction in area from its upstream end to its downstream end so that the outlet area is about 30% to 40% less than the inlet area. The reduction occurs at the inner periphery of the bend and eliminates a stagnation zone that would exist in an elbow of uniform cross-sectional area, thereby eliminating eddy currents and turbulence that would disrupt flow and possibly cause blockage of the duct.

FIG. 1 of the drawings illustrates schematically a supply system for delivering a mixture of gas, such as air, and pulp flakes into the first unit of the apparatus. Air is supplied from the atmosphere through a control valve that can be set to regulate the amount of air, is conducted through a preheater and thence through appropriate piping into the inlet **5** of the fan **1** of the first unit. Pulp flakes delivered from the pulp de-watering and pressing equipment, appropriately shredded into flakes, are fed, such as by a rotary feeder, into the inlet pipe. The rate of feed of the pulp flakes is controlled either by controlling the output of the press and shredding device or by controlling the rotary feeder, the latter form of control being illustrated in the drawing.

FIG. 2 illustrates schematically the supply of steam from a source through an inlet pipe **19**, a control valve **21** and branch lines **23** leading to the upper ends of the heat exchanger pipes **11**. The steam condenses in the pipes, and the condensate is drawn off through outlet manifolds **25**, a valve **27** and an outlet **29** to an appropriate condensate receptacle or other processing equipment.

As shown in FIG. 3, the inlet manifolds **23** to the heat exchanger pipes **11** have V-shaped deflectors **31** mounted on their under sides to divert the flow and maintain smooth flow conditions. As shown in FIG. 4, the lower ends of the steam pipes **11** are tapered, and the condensate manifold outlets are of relatively small diameter. Therefore, relatively smooth flow conditions exist at the lower ends of the heat-exchanger section. It will also be observed from FIGS. 3 and 4 that the tops and bottoms of the pipe sets are staggered vertically, again to enhance the flow conditions in the heat exchanger sections.

Referring to FIGS. 6 and 7, an exemplary embodiment of a complete installation of the apparatus of the invention consists of nine units of the form described above and illustrated in some detail in FIGS. 1 to 5. The nine units are arranged in a triangular configuration with three units along each side of the triangle. The gas-pulp flake mixture is conducted to the first unit through an inlet **33**, passes in series through the units along the leg of the system shown at the left of FIG. 7, is conducted to the top three units, beginning with the left-most unit, and finally is conducted through the series of three units along the right leg of the triangle in FIG. 7. The dry flakes and exhaust gases are discharged through an outlet conduit **35**. The apparatus illustrated in FIGS. 6 and 7 is provided with an appropriate cover structure, but as already mentioned, it would be appropriate to provide covers only for the fans and instrumentation of the device, the conduits being left exposed.

It will be evident to those skilled in the art that various additional controls will be provided, and this is well within the ordinary engineering skill. For example, the fan motors may be controlled to vary the speed of the fans and therefore the flow rates in various units of the equipment. Temperature and humidity detecting devices will be employed throughout to assist in controlling the equipment.

In operation, air is introduced at a controlled rate through the preheater into the inlet **5** of the first fan **1** (see FIGS. 1 and 7). Pulp flakes are supplied at an appropriate rate to the incoming air flow. The ratio of pulp flakes to incoming air should not exceed 0.35 kg. of pulp flakes per 1.0 kg. of air, a ratio that has been found to reduce significantly a risk of excessive floccing or agglomeration due to the formation of fiber networks and loss of fiber mobility. The ratio of pulp to air is also controlled to introduce sufficient moisture into the system to ensure that the gas exhausted from the device is of relatively high humidity, as mentioned above.

The pulp-flakes mixture is propelled by the fan **1** of the first unit upwardly through the heat-exchanger section of that unit where heat is transferred from the pipes into the mixture of air and pulp flakes. As already mentioned, the steam condenses in the pipes and is withdrawn through the condensate collector pipes **25**. The predominate heat transfer is into the air rather than into the flakes and, accordingly, the mixture leaves the heat exchanger with the air at a significantly higher temperature than the flakes. The mixture passes around the elbow **13** and downwardly through an open vertical conduit that constitutes the major portion of a heat-equalization zone in each unit. During the passage of the mixture through the temperature-equalizing section, heat exchange takes place between the air and the pulp flakes, thereby to reduce substantially the temperature differential. Equalization of the temperature of the gas and the temperature of the air is assisted by a velocity increase at the downstream end of the elbow, a velocity decrease as the cross-section expands through the tapered conduit section **15** and another velocity increase through the conical inlet **5** to the fan and at the outlet from the fan.

The above process is repeated in each unit of the equipment, the pulp-flakes mixture passing from the delivery fan into the heat-exchanger section and through the temperature-equalizing section of each unit and passing through the several units in series. At each unit, additional heat is added and additional moisture removed from the flakes. Between each input of heat in the heat-exchanger units, temperature equalization occurs, thus precluding the establishment of excessively high air temperatures in the equipment. As the material leaves the last unit through the outlet **35**, the air has a wet-bulb temperature of at least 60° C. and a dry-bulb temperature not in excess of about 120° C. The mixture, after discharge through the outlet pipe, may be conducted through a cyclone or cyclone system, or other appropriate separation devices, for removing the dried pulp flakes from the moist air. The air may be conducted to water heating equipment and represents a source of useful heat for general purposes, particularly the heating of water for general mill use.

It is evident that the processing conditions in the equipment may vary significantly, depending upon the characteristics of the pulp and the results desired. An example of a process applied to a particular product follows.

For the production of ADT pulp supplied in the form of flakes de-watered and pressed into a web and then shredded into small flakes having a dryness of 48%, a nine-stage unit of the form illustrated in FIGS. 6 and 7 of the drawings may be used. Each heat exchanger has a height of 15 meters and provides a total heat exchange area of 3000 sq. meters for the total of nine stages, the heat exchanger area being equally divided among the nine stages. The temperature-equalizing sections of each unit have a height of 18 meters. In addition, the lower portion of each heat exchanger section provides an additional temperature-equalizing zone having a height of approximately three meters. The steam tubes in each heat exchanger are arranged with a center-to-center spacing of 90 mm., and have external diameters of 50 mm.

Air flow conditions are maintained in the equipment to provide a velocity of about 25 meters per second in the square cross-section ducts. Steam is delivered to the system at 3 kp./cm.^{2}. Ambient air is drawn in at 20° C. and is preheated in the preheater unit to about 110° C. The incoming air cools upon contact with the incoming pulp flakes through a temperature of approximately 60° C. The first heat exchanger raises the temperature of the air to about 85° C. and the air and flakes equalize in the temperature-equalizing section of the first unit to about 50° C. The heat exchanger of the second unit raises the air temperature to about 90° C., and the temperature is equalized at about 58° C. In the third stage, the temperature of the air is raised to about 96° C. and the pulp and air temperatures equalize at about 64° C. Similar increments of heat input and equalization occur in the remaining stages so that the final stage provides a heating of the air to about 120° C. and a temperature equalization of between the temperature of the pulp and the air at about 100° C. The pulp leaves the equipment with a dryness of about 90%.

The above-described embodiment and example of the invention are intended to be merely exemplary, and many variations and modifications may be made by those skilled in the art without departing from the spirit and scope of the invention. All such variations and modifications are intended to be included in the scope of the invention, as defined in the appended claims.

What is claimed is:

1. A method of drying pulp flakes comprising the following steps: (1) entraining the pulp flakes in a gas in an amount not greater than about 0.35 kg. dry weight of pulp to 1.0 kg. of gas, (2) establishing and maintaining a flow of the gas-flakes mixture along a confined path having a hydraulic diameter not exceeding about 200 mm. at any heated region thereof, (3) transferring heat into the gas-flakes mixture in a heat transfer zone along the path, (4) substantially equalizing the temperatures of the gas and the flakes in a temperature-equalizing zone of the path downstream from the heat-transfer zone, (5) repeating steps (3) and (4) in successive series of heat-transfer and temperature-equalizing zones, and (6) controlling the supply of heat in the heat-transfer zones and the moisture content of the flakes and gas so that the gas discharged from the final temperature-equalizing zone has a wet-bulb temperature not less than about 60° C. and a dry-bulb temperature of not greater than about 120° C.

2. A method according to claim **1** and further comprising the step (7) of preheating the gas prior to step (1).

3. A method according to claim **1** and further comprising the step (8) of imparting kinetic energy to the gas-flakes mixture at least at one zone along the confined path.

4. A method according to claim 3 wherein kinetic energy is imparted to the gas-flakes mixture following each step (4) and prior to each step (3).

5. Apparatus for drying pulp flakes comprising a conduit system defining a confined path for a flow of pulp flakes entrained in a gas, means for establishing a flow of pulp flakes entrained in a gas through the conduit system, a multiplicity of heat exchangers in the conduit system for transferring heat into the gas-flakes mixture in heat-exchanger zones, and at least one blower in the conduit system for imparting kinetic energy to the gas-flakes mixture, the conduit of the conduit system having a hydraulic diameter not exceeding about 200 mm. in any heat-exchanger zone along its length and including a plurality of laterally adjacent, generally parallel conduit sections, alternate ones of said conduit sections containing spaced-apart heat exchangers and the remaining intervening conduit sections defining at least portions of temperature-equalizing zones located between successive heat-exchanger zones and downstream from each heat exchanger for substantial equalization of the temperatures of the flakes and the gas prior to entry into the next heat-exchanger zone, pairs of conduit sections being interconnected by elbows at one end and constituting units each containing one of the heat-exchanger zones and one of the temperature-equalizing zones, the downstream end of each of said units being connected in series by one of said at least one blower with the upstream end of a succeeding adjacent unit, each heat exchanger including a plurality of tubes carrying a heating medium, the tubes being located within and oriented generally parallel to one of said alternate conduit sections.

6. Apparatus according to claim 5 and further comprising means for controlling the supply of pulp flakes and gas to the conduit to maintain an amount of flakes not greater than 0.35 kg. dry weight for each 1.0 kg. of gas.

7. Apparatus according to claim 6 and further comprising means for controlling the supply of heat to the heat exchangers and the moisture content of the gas and flakes processed in the apparatus to provide in the gas leaving the last temperature-equalizing zone a wet-bulb temperature of not less than 65° C. and a dry-bulb temperature of not greater than 120° C.

8. Apparatus according to claim 5 wherein the cross-sectional areas of each elbow diminish smoothly in relation to the distance in the downstream direction from the upstream end.

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U.S. Cl. X.R.

34—10, 57 A; 162—232