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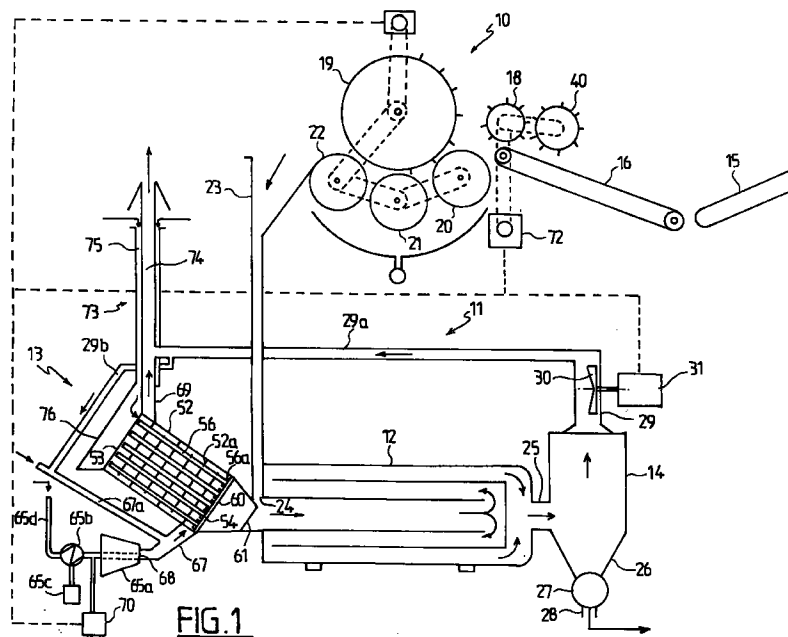
(54) Apparatus for drying crop material

(57) This invention relates to an apparatus for drying crop material which is particularly but not exclusively designed for drying alfalfa.

The apparatus according to the invention essentially comprises a tumbling cylinder (12) connected to fan means (30, 31), means (59) for feeding the crop material into the cylinder (12) for movement with the air inside, means (14) for receiving the dried material and the air from the cylinder (12) and for separating the dried material from the air, and heating means (13) for heating the air and crop material in the cylinder (12).

The heating means (13) comprise a heat

exchanger (52), means (76) for passing the air through a first path from an air inlet to the inlet (24) of the cylinder (12) and combustion means (65) for generating heat and combustion products and for passing them through a second path separate from the first one to heat the air in the first path, said apparatus including a flue (74) for receiving combustion products from the second path, the flue (74) having an air inlet jacket (75) at least partly surrounding it for entry of inlet air into the exchanger (52), such that the air is heated by the flue (74).



## Description

This invention relates to an apparatus for drying crop material which is particularly but not exclusively designed for drying alfalfa.

Alfalfa is a crop which has not been, up till now, utilized to its full extent and is often generally used simply as a feed material for animals. However alfalfa has significant potential in that it has a high nutrition content and if processed effectively can be used for a number of different end products.

It has been proposed previously to pass the alfalfa through a press which extracts juice which can be used separately and in addition provides a product which is compressed and of reduced moisture content for more effective drying. One example of press of this type is shown in United States Patent 4,125,070 (Besnard) and this includes a main press roller with a plurality of subsidiary rollers arranged at angularly spaced position around the main roller and each defining a nip with the main press roller for compressing the material and extracting juice. This press has however been of reduced effectiveness due to an inability to properly feed the material from a feed system into the nips.

The above press has been proposed for use with a previous dryer arrangement in which the compressed alfalfa is fed into a rotating drum. One example of a dryer of this type is shown in a brochure by M-E-C Company. The drum is horizontal with an inlet at one end and an outlet at an opposed end. A fan draws air through the drum so that the compressed crop material is deposited into the air stream passing through the drum at the inlet end of the drum and is carried through the drum to a separation cyclone at the outlet end of the drum. A combustion chamber is directly attached to the inlet end of the drum so that combustion products and heat are injected into the interior of the drum and are carried through the drum with the air stream and the crop material to be dried.

This proposed arrangement of the press and the drying apparatus has achieved some success. However the drawing apparatus also has some disadvantage in that the combustion products are directly carried into and mixed with the crop materials leading to an accumulation of benzopyrene and other combustion products in the crop materials which can be highly hazardous to the subsequent use or consumption of the product.

It is an object of the present invention to provide an improved drying section for the apparatus which avoids the contamination of the crop materials with combustion products such as benzopyrene.

According to the invention, there is provided an apparatus for drying crop materials comprising a tumbling cylinder having an inlet and an outlet, fan means for passing air through the tumbling cylinder from the inlet to the outlet, means for feeding the crop material into the inlet for movement with the air to the outlet for

drying the crop material within the tumbling cylinder, means for receiving the dried crop material and the air from the outlet and for separating the dried crop material from the air, and heating means for heating the air and crop material in the tumbling cylinder.

Such an apparatus is characterized in that the heating means comprise a heat exchanger having a first path therethrough separated from a second path therethrough, means for passing the air through the first path from an air inlet to the inlet of the tumbling cylinder and combustion means for generating heat and combustion products and for passing the heat and combustion products through the second path to heat the air in the first path whereby the air and crop materials are maintained separate from the combustion products, said apparatus including a flue for receiving combustion products from the second path, the flue having an air inlet jacket at least partly surrounding it for entry of inlet air into the heat exchanger, such that the air is heated by the flue in a heat exchange arrangement.

According to another feature of the invention, the heat exchanger includes a plurality of tubes extending from an inlet plenum to a discharge plenum, the discharge plenum being connected to the inlet of the tumbling cylinder.

According to another feature of the invention, the tubes are formed from ceramic material.

According to another feature of the invention, the tubes are formed from silicon carbide.

According to another feature of the invention, the tubes are arranged in array so as to extend in mutually parallel arrangement from the inlet plenum at one end to the discharge plenum at the other end, the tubes being arranged in rows lying in parallel planes, the tubes of alternate rows being offset relative to the tubes of the next previous row such that materials passing between two tubes of the previous row engage with the tubes of the alternate rows.

According to another feature of the invention, the heat exchanger is provided with a plurality of baffles a upon which the tubes are mounted and which are meant, on the one hand, to constitute a support for the tubes by maintaining them stationary and, on the other hand, to force the heated air and gases to circulate between said baffles and around the tubes.

According to another feature of the invention, the discharge plenum includes a rectangular end at the heat exchanger and converges inwardly therefrom to a circular end at the inlet of the tumbling cylinder.

According to another feature of the invention, the discharge plenum includes a plurality of baffles therein for causing rotation of the air passing through the discharge plenum relative to a central and longitudinal axis of the discharge plenum so as to generate rotation of the air as it enters the tumbling cylinder.

According to another feature of the invention, the tumbling cylinder has a horizontal axis with the inlet at one end thereof and the heat exchanger is arranged

such that the first path is inclined upwardly and away from the inlet end of the tumbling cylinder, the second path extending from an underside of the heat exchanger upwardly and toward the tumbling cylinder to said flue extending vertically upwardly from the heat exchanger, the combustion means being located at least partly underneath the heat exchanger so as to direct the combustion products upwardly into the second path of the heat exchanger.

According to another feature of the invention, the apparatus includes duct means for communicating air from the separating means to the flue.

According to another feature of the invention, the combustion means comprises a co-generation gas turbine having an output drive shaft and a combustion system arranged to generate rotation of the output drive shaft and heat, and this heat is communicated to the heat exchanger.

According to another feature of the invention, said combustion means comprises an air-water heat exchanger designed to effect a cooling of the air admitted in said turbine.

According to another feature of the invention, said heating means include a secondary heating source designed to be mixed with the heated air and the gaseous residues originating from the turbine.

According to another feature of the invention, said secondary heating source consists of finely divided coal that is sprayed in a hot air or vapour flow.

According to another feature of the invention, the apparatus includes a recycling means which contains the humid air originating from said means for separating the dried crop material from the air and which is connected to said secondary heating source.

According to another feature of the invention, the apparatus includes means for generating power from the shaft for communication to other elements of the apparatus.

According to another feature of the invention, the apparatus includes a press for receiving the crop materials and for extracting juice therefrom to form a compressed mass of the crop materials of reduced moisture content, the power from the output shaft being used to drive the press.

According to another feature of the invention, the apparatus includes an alternator driven by the output shaft.

According to another feature of the invention, the longitudinal axis of the output drive shaft is parallel to the axis of the tumbling cylinder.

According to another feature of the invention, the apparatus is of the type including a press for receiving the crop material for extracting juice therefrom to form a compressed mass of the crop materials of reduced moisture content.

Such an apparatus is characterized in that the press comprises a main press roller having a cylindrical surface surrounding its axis of rotation, a plurality of

subsidiary press rollers at angularly spaced positions around the main press roller such that each defines with the main press roller a respective nip, each of the rollers being rotatable about a respective axis with the axes parallel, means for feeding the material to the main press roller such that the material passes through each nip in turn, the main press roller having therein an array of axially and angularly spaced radially extending fingers rotatable with the roller about an axis offset from the axis of the roller, such that the fingers project outwardly from the surface of the roller at one part of said surface and are retracted into the roller at a second part of said surface, the fingers being arranged to engage the crop material ahead of the first subsidiary roller and to be retracted at least some of the nips.

According to another feature of the invention, the feeding means comprise a belt conveyor and a guide roller for compressing the crop materials onto the belt conveyor, the fingers being presented towards a discharge end of the belt conveyor for grasping the material discharged therefrom.

According to another feature of the invention, each subsidiary press roller comprises a plurality of parallel, coaxial, axially spaced disks and means mounting the disks in a stack such that edges of the disks lie in a cylindrical surface for defining said nip with said main press roller, the mounting means comprising a plurality of separate spacers, so as to define a path through the space between each disk and the next for passage of juice squeezed from the crop material, each disk being shaped so as to be thicker in an axial direction at the edge than at the area thereon between the edges, such that the space between each disk and the next is greater in the area between the edges.

According to another feature of the invention, the press comprises a main press roller having a cylindrical surface surrounding its axis of rotation, a plurality of subsidiary press rollers at angularly spaced positions around the main press roller such that each defines with the main press roller a respective nip, each of the rollers being rotatable about a respective axis with the axes parallel, and means for feeding the material to the main press roller such that the material passes through each nip in turn, each subsidiary press roller comprising a plurality of parallel, coaxial, axially spaced disk and means mounting the disk in a stack such that edge of the disks lie in a cylindrical surface for defining said nip with said main press roller, the mounting means comprising a plurality of separate spacer, so as to define a path through the space between each disk and the next for passage of juice squeezed from the crop material, each disk being shaped so as to be thicker in an axial direction at the edge than at the area thereon between the edges, such that the space between each disk and the next is greater in the area between the edges.

When processing high feed rates of material it is necessary to ensure that the juice extracted from the crop material is rapidly and effectively transported away

from the squeeze nip and accordingly it is another object of the present invention to provide an improved press roller design which allows rapid discharge of the juice.

One embodiment of the invention will now be described in conjunction with the accompanying drawings in which.

Fig. 1 is a schematic layout of the drying apparatus according to the present invention.

Fig. 2 is an enlarged isometric view showing schematically the construction of the heat exchanger of the drying system.

Fig. 3 is a cross-sectional view along the lines III-III of Fig. 2.

Fig. 4 is an isometric view showing schematically the discharge plenum of the heat exchanger of Fig. 2.

Fig. 5 is a schematic longitudinal cross sectional view of the press of Fig. 1.

Fig. 6 is a cross-sectional view along the lines VI-VI of Fig. 5.

In the drawings like characters of reference indicate corresponding parts in the different Figs.

The drying apparatus of Fig. 1 comprises a press generally indicated at 10 and a drying apparatus generally indicated at 11 including a tumbling cylinder 12, a heating section 13 and a separating section 14. In general, harvested crop material is supplied by a chute 15 onto a belt conveyor 16 which transports the crop material upwardly and toward the press 10 in an incline direction. The crop material passes under a guide roller 18 which forms a nip with an end of the belt 16 for discharging the crop material in a slightly compressed condition into the press 10.

The press 10 includes a main compression roller 19 and three subsidiary rollers 20, 21 and 22 arranged at angularly spaced positions around the main roller 19. The subsidiary rollers and the main roller each have an axis with the axes parallel so that the three subsidiary rollers each form a nip with the main roller through which the crop material can pass driven by rotation of the rollers. In between each nip roller and the next is provided a guide bar 17 to carry the material across the gap to ensure the material is properly fed into the next nip for crushing, the guide bar carrying a plurality of knives 171 projecting into engagement with the rollers and into the spaces between disks 201 of the rollers as shown in Fig. 5 and described hereinafter.

The squeezed and compressed crop material is discharged from the third nip between the main roller 19 and the subsidiary roller 22 and discharged into a chute 23 which carries the compressed crop material to the dryer section 11.

The tumbling cylinder 12 is horizontal and it provided with an inlet 24 at one end of the cylinder and with an outlet 25 at the opposed end. Within the cylinder 12 are provided guide walls defining a labyrinth arrangement so that the crop material together with transportation air is carried through the labyrinth arrangement

from the inlet 24 to the outlet 25. The cylinder 12 is mounted for rotation, so that the crop material is tumbled within the cylinder while it is transported in the transportation air stream.

At the outlet 25 is provided the separation section 14 in the form of a cyclone of conventional shape which causes the crop material and air stream to swirl within the cyclone 14 thus allowing the crop material to fall to a base 26 of the cyclone 14 for discharge through an air-lock 27 of the cyclone 14 into a collection duct 28. Simultaneously the air separated from the crop material moves upwardly into an outlet duct 29 at the top of the cyclone 14.

Air flow through the tumbling cylinder 12 and through the separation system 14 is generated by a fan 30 driven by a motor 31 mounted within the duct 29. This location of the fan 30 positions it at the coolest part of the air stream so that the fan 30 is not impacted by the highly heated air emerging from the heating section 13.

The heating section 13 generates heat which is applied to the air drawn into the inlet 24 of the tumbling cylinder 12 by the fan 30. The heated air thus drives the moisture out of the crop material with the moisture being carried through the duct 29 for discharge.

The arrangement described above constitutes a prior art arrangement and in particular the press described above is shown in United States patent 4,125,070 mentioned above.

The arrangement of the present device is modified relative to the prior art by the following features:

With regard to the press 10, the press is improved by an improved feeding system which allows the relatively bulky crop material, particularly alfalfa for which the present arrangement is particularly designed, to be fed properly into the nips between the rollers 20, 21 and 22 and the main roller 19. The feeding system is therefore improved by the addition of a guide roller 40 prior to the conventional feed roller 18. The guide roller 40 is of larger diameter than the feed roller 18 so as to constrain the crop material, particularly alfalfa, to pass initially under the guide roller 40 so that it can then be compressed to pass through the nip between the feed roller 18 and the end roller of the belt 16. The guide roller 40 is spaced from the surface of the belt 16 and carries fixed fingers 41 which grasp the crop material indicated at 42 and carry it under the guide roller 40 for feeding as a mat into the area underneath the feed roller 18.

The press is further improved by the addition of retractable fingers 43 mounted in the main press roller 19. The fingers 43 are arranged in rows and columns around the periphery of the roller 19 and are mounted in guide openings 44 in the periphery of the roller 19, so that the fingers 43 can be moved from a retracted position, as indicated at 43A, to an extended position as indicated at 43B. In order to obtain this movement, the fingers 43 are mounted on a shaft 45 which is offset from an axis 46 of rotation of the roller 19. The shaft 45

remains in fixed position relative to the axis 46 while the radially extending fingers 43 rotate with the roller 19. This causes the fingers 43 to move from a fully retracted position on the side of the axis 46 opposite to the shaft 45, and to a fully extended position on the side of the axis 46 which is the same as the shaft 45. In this arrangement, the fully extended position is arranged to be at or adjacent the feed roller 18, so that the crop material emerging from the nip under the feed roller 18 as indicated at 47 is grasped by the fingers 43 and carried into the nip between the rollers 19 and 20

As shown the nip area between the roller 20 and the roller 19 is larger than the nip area between the roller 21 and the roller 19. The fingers 43 are thus not fully retracted, as they pass through the nip area indicated at 20A of the roller 20, so that they insist in carrying the material through that nip area. However the nip area is sufficiently small to effect an initial crushing of the crop material, so it can then be carried by the guide plates 17 into the nip area 21A of the roller 21. The fingers 43 are fully retracted at the roller 21 so that the crop material can be fully crushed in that area and the juice squeezed from the material in the manner described in the above-mentioned patent.

In addition to the improvement to the feeding system for the crop material, the arrangement as shown further includes a juice collection system in the form of a cradle 50 mounted under the rollers 20, 21 and 22, so as to receive the juice dripping therefrom due to the crushing action between the rollers 20, 21 and 22 and the main roller 19. At the bottom of the cradle 50 there is provided a duct 51 into which the juice runs due to the concave curvature of the cradle 50, for transportation of the juice through the duct 51 to a collection and utilization system not forming part of the present arrangement.

In a yet further improvement as shown in Fig. 5, each subsidiary press roller 21, 21 or 22 comprises a plurality of parallel, coaxial, axially spaced disks 201 and means mounting the disks in a stack, such that the edges of the disks lie in a cylindrical surface for defining said nip with said main press roller 19, the mounting means comprising a plurality of separate spacers 202 so as to define a path through the space between each disk and the next for passage of juice squeezed from the crop material, each disk being shaped so as to be thicker in an axial direction at the edge 203 than at the area 204 thereon between the edges, such that the space 205 between each disk and the next is greater in the area between the edges than at the edges. This allows the juice extracted from the crop material to run quickly from the nip at the edge through the space between the disks for collection.

In one example, the press described above can process 17 tons per hour of crop material with a depth on the feed belt of 66 cm (approximately 26 inches), with the nips of the three subsidiary press rollers defining compression forces of 15 000 kg, 125 000 kg and 25

000 kg respectively.

Turning now to the heating system 13 of the drying apparatus 11, this is firstly modified relative to the conventional prior arrangement by the addition of a heat exchanger 52. The heat exchanger 52 is shown in more detail in Figs. 2, 3 and 4 and essentially comprises a first end plate 53 and a second end plate 54 which are spaced and parallel, with each of the end plate 53 or 54 having a plurality of holes 55 aligned in rows. The holes 55 are aligned in a first row 55A, a second row 55B, a number of intermediate rows, a penultimate row 55X and a last row 55Y. Each of the aligned holes 55 in the end plates 53 and 54 carries a tube 56 which has its ends mounted in the end plates 53 and 54 and extends therebetween as a continuous elongate cylindrical tube 56. The tubes 56 are formed from extruded ceramic material and particularly a recrystallized silicon carbide, and they are preferably twisted on their inner periphery in order to further enhance the heat exchange between the inner and outer spaces of the tubes 56.

Besides, the heat exchanger 52 is provided with a plurality of baffles 52a upon which the tubes 56 are mounted and which are meant, on the one hand, to constitute a support for the tubes 56 by maintaining them stationary and, on the other hand, to force the heated air and gases to circulate as slowly as possible between said baffles 52a and around the tubes 56. As can be seen in Figs. 1 and 3, the heated air and gases alternately impinge upon the first and the last rows 55A and 55Y of tubes 56.

Each tube 56 is provided at its end designed to be mounted into the second end plate 54 with a fixed collar 56a, whereas it is mounted free at its other end in order to allow some possible longitudinal dilatation of the same, thanks to a little space provided between said free end and the first end plate 53. Each collar 56a is inserted into the second end plate 54 and it is made up of a stack of plates forming also a support for the corresponding tube 56 and being tight as regards hot air. Further each collar 56a is provided with a joint being preferable made of asbestos.

Thanks to said collars 56a, the tubes 56 can be easily dismantled for the removal of residues, such as soots.

Preferably, the collars 56a are made of the same material as that of the tubes 56, namely a ceramic material.

Such a material is a fine grained, self bonded silicon carbide composition which can be formed into the relatively simple shape of a cylindrical tube 56. Such tubes 56 are self supporting with sufficient structural strength, to maintain structural stability across the space between the end plates 53 and 54. The porosity of the material is insufficient to allow significant communications of materials from outside the tubes 56 to their interior.

The heat exchanger 52 further includes side plates 57 and 58 thus defining a rectangular enclosure with the

end plates 53 and 54, which surrounds the array of tubes 56. This rectangular enclosure has an open bottom and an open top. Attached to the end plate 54 is a discharge plenum 59 which has a first end face 60 matching the dimensions of the end plate 54, so as to receive air passing through the tubes 56 into the discharge plenum 59. This discharge plenum 59 further includes a converging wall converging to a circular outlet 61. The plenum 59 thus has sheet metal walls shaped to converge from an initial rectangular shape to a final circular discharge shape. Within the plenum 59 are mounted four baffles 62, each having a leading edge 63 and a trailing edge 64 (see Fig. 3). Each leading edge 63 is located at the end 60 and each trailing edge 64 is located at the discharge opening 61. Each leading edge 63 is arranged at one side edge of the end 60 and it extends at right angles to that side edge across the end 60. Each trailing edge 64 is similarly arranged at the outside edge of the circular discharge opening 61 and it extends radially thereof.

It will be noted that the leading edge 63 of each baffle 62 is turned through 90° relative to the corresponding trailing edge 64. In addition, the baffle 62 which has its leading edge 63 at the top edge of the inlet opening 60 is smoothly curved, so that its trailing edge 64 is positioned at one side of the discharge opening 61. These baffles 62 thus contact air escaping from the tubes 56 and act to twist it as it passes through the discharge plenum 59, thus causing a rotation in the air as it exits through the discharge opening 61.

As shown in Fig. 1, the discharge opening 61 is arranged so as to inject the air into the opening 24 of the tumbling cylinder 12. The air as it is injected therefore is twisted by the baffles 62 so that it is rotating within the tumbling cylinder 12, thus acting to mix the air to provide consistent temperature through it and at the same time acting to further mix the air and crop material as the crop material is fed through the chute 23 into the cylinder 12.

The heat exchanger 52 is heated by a heating system 65. The heating system 65 in the preferred arrangement comprises a cogeneration gas turbine 65a, one example of which is manufactured by Turbomeca of 64511 Bordes Cedex Franc having an associated company at Turbomeca Engine Corp. Grande Prairie Texas. Such a device is presently commercially available and provides the co-generation of heat and power through a gas turbine system 65a. Thus the co-generation gas turbine 65a includes a drive shaft 66 which is driven by the combustion of the gas within the gas turbine 65a and at the same time the combustion is used to generate significant temperature in the air driven through the gas turbine 65a. This gas turbine 65a is thus designed to generate heat and rotation rather than any significant longitudinal thrust.

If required in any particular installation, the co-generation gas turbine 65a can be replaced by a fuel or kerosine turbine, depending on the cost of each energy

source.

In the preferential embodiment of the invention represented at Fig. 1, there is also provided a heat exchanger 65b designed to effect a cooling of the air admitted in said turbine 65a, so as to weight such an air and therefore increase the ratio of oxygen available for the inherent combustion, because of a longer expansion during said combustion. As a consequence, this results in an enhancement of the thermal output and of the power efficiency of the co-generation gas turbine 65a.

Such a heat exchanger 65b is preferably of the type air-water, the water being previously cooled in a well 65c and being meant to cool the available air before its admission into the turbine 65a. Nevertheless, it is to be noted that said heat exchanger 65b could also be of the type air-air.

As can be seen in Fig. 1, there is provided an inlet duct 65d designed to receive an air flow for its injection into the exchanger 65b.

The heated air flow and the gaseous residues produced by the combustion are injected into the bottom open face of the heat exchanger 52 of Fig. 2 by a guide duct 67 which extends from a discharge mouth 68 of the gas turbine and diverges outwardly in the form of an inlet plenum. More precisely, said plenum has a circular open mouth at the discharge end 68 and a substantially rectangular discharge mouth that matches a part of the bottom open face of the heat exchanger 52 which corresponds to a first path existing between the second end plate 54 and the adjacent end baffle 52a.

Such a guide duct 67 is preferably made of ceramic, in order to prevent thermal losses between the turbine and the heat exchanger 52.

Besides, said guide duct 67 is preferably provided with an inlet duct 67a for the admission of a secondary heating source designed to be mixed inside the duct 67 with the heated air and the gaseous residues originating from the turbine, so as to increase the temperature within said duct 67. Advantageously, such a secondary source can consist of finely divided coal that is sprayed in a hot air or vapour flow into said duct 67a. Nevertheless, another quite non expensive energy source could be used for that secondary source, such as another fuel or an appropriate gas.

Indicatively, such a heated air, gaseous residues and coal particles can be characterized by a temperature substantially comprised between 1000° C. They are thus injected into the heat exchanger 52 so as to impinge upon the bottom row 55Y of tubes 56 inside the above-mentioned path. The air and the residues thus swirl around and pass between the tubes 56 of said path in the relatively narrow spaces between them and exit from the slots defined between the tubes 56, so as to impinge upon the next row 55X of tubes 56.

As can be seen in Figs. 2 and 3, it will be noted that the next row 55X is offset, so that each tube 56 of the row 55X lies between two of the tubes 56 of the row 55Y, to allow direct impingement of the air and the residues

onto the tubes 56. The same offset arrangement continues through the intermediate rows to the top row 55A of said path, so that the air and the residues that have impinged upon said top row 55A pass between the top end of said end baffle 52a and successively impinge upon the rows 55A, 55B, etc., 55Y inside a second path defined by said end baffle 52a and the adjacent one. Then the air and the residues pass between the bottom end of said adjacent baffle 52a and so on, until they can finally escape into a plenum 69 from the top row 55A of a last path existing between the other end baffle 52a and the first end plate 53.

The selection of the tubes 56 as defined above allows the use of the co-generation gas turbine and the also the high air temperature defined above, since the ceramic tubes 56 can accommodate such high temperatures without breakdown

The drive shaft 66 is connected to an alternator 70 which generates electric power for use in the remainder of the apparatus. Thus, the electric power from the alternator 70 is used to drive a motor 71 to the rollers of the press, a motor 72 to the belt 16 and feed roller system 18 and a motor 31 of the fan 30.

The drying apparatus 11 further includes a flue 74 and an inlet system 75 the whole system being generally indicated at 73. The flue 74 is connected to the plenum 69 and defines a cylindrical duct extending vertically upwardly from the plenum 69 for discharge of the heated air and of the residues of combustion to atmosphere. Thus, the plenum 69 is shaped to converge from the rectangular shape, at the upper end face of the last path of the heat exchanger 52, to a circular shape connected to the inlet end of the flue 74.

The duct 29 includes a portion 29a extending beyond the fan 30 and connected into the duct 74 at a position above the plenum 69. As can be seen in Fig. 1, the major part of humid air passing through the portion 29a is fed into the duct 74 for common discharge to atmosphere.

The inlet system includes an air inlet duct 75 which is in heat exchanging relation with the flue duct 74. In the arrangement as shown, the inlet duct 75 surrounds the flue duct 74 and contains a helical baffle (not represented) so as to cause the air to rotate around the flue duct 74 and to receive heat therefrom, for preliminary heating of the air which is fed to the inlet end of the tubes 56 of the heat exchanger 52. Thus the bottom end of the surrounding air inlet 75 includes a duct 76 which by passes the plenum 69 and is connected to the end plate 53 of the heat exchanger 52, so as to permit the discharge of the heated air from the duct 75 into the tubes 56.

It will be noted that the double-wall flue system 73, which allows a previous heating of the air injected into the outer duct 75, results in enhancing the thermal output of the heat exchanger 52. Moreover, the use of such a system 73 implies a lesser degree of thermal shocks inside the tubes 56 of the heat exchanger 52 than with

an apparatus of the prior art, thus enabling not to substantially affect the qualities of the product to be subsequently dried.

Besides, the drying apparatus 11 preferably includes a recycling duct 29b connected to the portion 29a of the duct 29, which contains the humid air originating from the cyclone 14, in order to contribute to the heating of the gaseous or vapour flow of sprayed coal that is injected into the duct 67a.

It will be noted that the heat exchanger 52 is inclined so that the tubes 56 inclined upwardly and rearwardly away from the inlet end 24 of the tumbling cylinder 12. Thus, the inlet end plate 53 of the heat exchanger 52 is raised above the discharge end plate 54. This allows the plenum 67 to be simple and relatively small, so that the gas turbine system 65 can be located in effect partly underneath the inclined heat exchanger 52. This keeps the heat generation system 65 to a compact construction.

The drying apparatus of the present invention therefore provides a very high efficiency, utilizing up to 80% of the energy in drying of the crop materials. It will be appreciated that drying requires a high energy input which can in many cases prevent the economic viability of the system. The present apparatus therefore provides a high efficiency which allows the economic viability of the processing alfalfa to allow the development of a number of alfalfa products, thus significantly increasing the commercial viability of this crop.

It appears that the final humidity rate of a crop material, such as Alfalfa, that has been dried with an apparatus according to the present invention is on average comprised between 60 and 65 %.

It is to be noted that the apparatus according to the present invention can either solely consist of the above-described press 10, or of a combination of said press 10 and of the drying apparatus 11.

Besides, the apparatus of the invention presents a wide scope of applications, apart from alfalfa products. For example, it can be designed for the drying of algae, fruits, beet pulps, grains, food liquids such as milk, sugar, etc.

Since various modifications can be made in my invention as herein above described, and many apparently widely different embodiments of same made within the spirit and scope of the claims without departing from such spirit and scope, it is intended that all matter contained in the accompanying specification shall be interpreted as illustrative only and not in a limiting sense.

## Claims

1. Apparatus for drying crop materials comprising a tumbling cylinder (12) having an inlet (24) and an outlet (25), fan means (30, 31) for passing air through the tumbling cylinder (12) from the inlet (24) to the outlet (25), means (59) for feeding the crop material into the inlet (24) for movement with

- the air to the outlet (25) for drying the crop material within the tumbling cylinder (12), means (14) for receiving the dried crop material and the air from the outlet (25) and for separating the dried crop material from the air, and heating means (13) for heating the air and crop material in the tumbling cylinder (12), characterized in that the heating means (13) comprise a heat exchanger (52) having a first path therethrough separated from a second path therethrough, means (76) for passing the air through the first path from an air inlet to the inlet (24) of the tumbling cylinder (12) and combustion means (65) for generating heat and combustion products and for passing the heat and combustion products through the second path to heat the air in the first path whereby the air and crop materials are maintained separate from the combustion products, said apparatus including a flue (74) for receiving combustion products from the second path, the flue (74) having an air inlet jacket (75) at least partly surrounding it for entry of inlet air into the heat exchanger (52), such that the air is heated by the flue (74) in a heat exchange arrangement.
2. The apparatus according to Claim 1, characterized in that the heat exchanger (52) includes a plurality of tubes (56) extending from an inlet plenum (76) to a discharge plenum (59), the discharge plenum (59) being connected to the inlet (24) of the tumbling cylinder (12).
  3. The apparatus according to Claim 2, characterized in that the tubes (56) are formed from ceramic material.
  4. The apparatus according to Claim 3, characterized in that the tubes (56) are formed from silicon carbide.
  5. The apparatus according to one of Claims 2 to 4, characterized in that the tubes (56) are arranged in array so as to extend in mutually parallel arrangement from the inlet plenum (76) at one end to the discharge plenum (59) at the other end the tubes (56) being arranged in rows (55A, 55B, 55X, 55Y) lying in parallel planes, the tubes (56) of alternate rows (55A, 55X) being offset relative to the tubes (56) of the next previous row (55B, 55Y) such that materials passing between two tubes (56) of the previous row (55B, 55Y) engage with the tubes (56) of the alternate rows (55A, 55X).
  6. The apparatus according to one of Claims 2 to 5, characterized in that the heat exchanger (52) is provided with a plurality of baffles (52a) upon which the tubes (56) are mounted and which are meant, on the one hand, to constitute a support for the tubes (56) by maintaining them stationary and, on the other hand, to force the heated air and gases to circulate between said baffles (52a) and around the tubes (56).
  7. The apparatus according to one of Claims 2 to 6, characterized in that the discharge plenum (59) includes a rectangular end (60) at the heat exchanger (52) and converges inwardly therefrom to a circular end (61) at the inlet (24) of the tumbling cylinder (12).
  8. The apparatus according to one of Claims 2 to 7, characterized in that the discharge plenum (59) includes a plurality of baffles (62) therein for causing rotation of the air passing through the discharge plenum (59) relative to a central and longitudinal axis of the discharge plenum (59) so as to generate rotation of the air as it enters the tumbling cylinder (12).
  9. The apparatus according to one of the preceding Claims, characterized in that the tumbling cylinder (12) has a horizontal axis with the inlet (24) at one end thereof and characterized in that the heat exchanger (52) is arranged such that the first path is inclined upwardly and away from the inlet end (24) of the tumbling cylinder (12), the second path extending from an underside of the heat exchanger (52) upwardly and toward the tumbling cylinder (12) to said flue (74) extending vertically upwardly from the heat exchanger (52), the combustion means (65) being located at least partly underneath the heat exchanger (52) so as to direct the combustion products upwardly into the second path of the heat exchanger (52).
  10. The apparatus according to one of the preceding Claims, characterized in that it includes duct means (29, 29a) for communicating air from the separating means (14) to the flue (74).
  11. The apparatus according to one of the preceding Claims, characterized in that the combustion means (65) comprises a co-generation gas turbine (65a) having an output drive shaft (66) and a combustion system arranged to generate rotation of the output drive shaft (66) and heat, characterized in that the heat is communicated to the heat exchanger (52).
  12. The apparatus according to Claim 11, characterized in that said combustion means (65) comprise an air-water heat exchanger (65b) designed to effect a cooling of the air admitted in said turbine (65a).
  13. The apparatus according to Claim 11 or 12, characterized in that said heating means (13) include a secondary heating source designed to be mixed

with the heated air and the gaseous residues originating from the turbine (65a).

14. The apparatus according to Claim 13, characterized in that said secondary heating source consists of finely divided coal that is sprayed in a hot air or vapour flow. 5
15. The apparatus according to Claim 13 or 14, characterized in that it includes a recycling means (29b) which contains the humid air originating from said means (14) for separating the dried crop material from the air and which is connected to said secondary heating source. 10
16. The apparatus according to one of the preceding Claims, characterized in that it includes means for generating power (70) from the shaft (66) for communication to other elements of the apparatus. 15
17. The apparatus according to one of the preceding Claims, characterized in that the apparatus includes a press (10) for receiving the crop materials and for expecting juice therefrom to form a compressed mass of the crop materials of reduced moisture content, the power from the output shaft (66) being used to drive the press (10). 20
18. The apparatus according to one of Claims 11 to 17, characterized in that it includes an alternator (70) driven by the output shaft (66). 25
19. The apparatus according to Claim 11, when Claim 11 is according Claim 9, characterized in that the longitudinal axis of the output drive shaft (66) is parallel to the axis of the tumbling cylinder (12). 30
20. The apparatus according to one of the preceding Claims, including a press (10) for receiving the crop material for extracting juice therefrom to form a compressed mass of the crop materials of reduced moisture content, characterized in that the press (10) comprises a main press roller (19) having a cylindrical surface surrounding its axis of rotation (46), a plurality of subsidiary press rollers (20, 21 and 22) at angularly spaced positions around the main press roller (19) such that each defines with the main press roller (19) a respective nip, each of the rollers (20, 21, 22) being rotatable about a respective axis with the axes parallel, means (15, 16, 17, 18) for feeding the material to the main press roller (19) such that the material passes through each nip in turn, the main press roller (19) having therein an array of axially and angularly spaced radially extending fingers (43) rotatable with the roller (19) about an axis offset from the axis (46) of the roller (19), such that the fingers (43) project outwardly from the surface of the roller (19) at one part of said surface and are retracted into the roller (19) at a second part of said surface, the fingers (43) being arranged to engage the crop material ahead of the first subsidiary roller (20) and to be retracted at least some of the nips. 35
21. The apparatus according to Claim 20, characterized in that the feeding means (15, 16, 17, 18) comprise a belt conveyor (16) and a guide roller (40) for compressing the crop materials onto the belt conveyor (16), the fingers (43) being presented towards a discharge end of the belt conveyor (16) for grasping the material discharged therefrom. 40
22. The apparatus according to Claim 20 or 21, characterized in that each subsidiary press roller (20, 21 or 22) comprises a plurality of parallel, coaxial, axially spaced disks (201) and means mounting the disks in a stack such that edges (203) of the disks (201) lie in a cylindrical surface for defining said nip with said main press roller (19), the mounting means comprising a plurality of separate spacers (202) so as to define a path through the space between each disk (201) and the next for passage of juice squeezed from the crop material, each disk (201) being shaped so as to be thicker in an axial direction at the edge (203) than at the area (204) thereon between the edges (203), such that the space between each disk (201) and the next is greater in the area (204) between the edges (203). 45
23. Apparatus for drying crop material comprising a press (10) for receiving the crop material for extracting juice therefrom to form a compressed mass of the crop materials of reduced moisture content, characterized in that the press (10) comprises a main press roller (19) having a cylindrical surface surrounding its axis of rotation (46), a plurality of subsidiary press rollers (20, 21, 22) at angularly spaced positions around the main press roller (19) such that each defines with the main press roller (19) a respective nip, each of the rollers (20, 21 or 22) being rotatable about a respective axis with the axes parallel, and means (15, 16, 17, 18) for feeding the material to the main press roller (19) such that the material passes through each nip in turn, each subsidiary press roller (20, 21 or 22) comprising a plurality of parallel, coaxial, axially spaced disks (201) and means mounting the disks (201) in a stack such that edges (203) of the disks (201) lie in a cylindrical surface for defining said nip with said main press roller (19), the mounting means comprising a plurality of separate spacers (202) so as to define a path through the space between each disk (201) and the next for passage of juice squeezed from the crop material, each disk (201) being shaped so as to be thicker in an axial direction at the edge (203) than at the area (204) thereon 50

between the edges (203) such that the space between each disk (201) and the next is greater in the area (204) between the edges (203).

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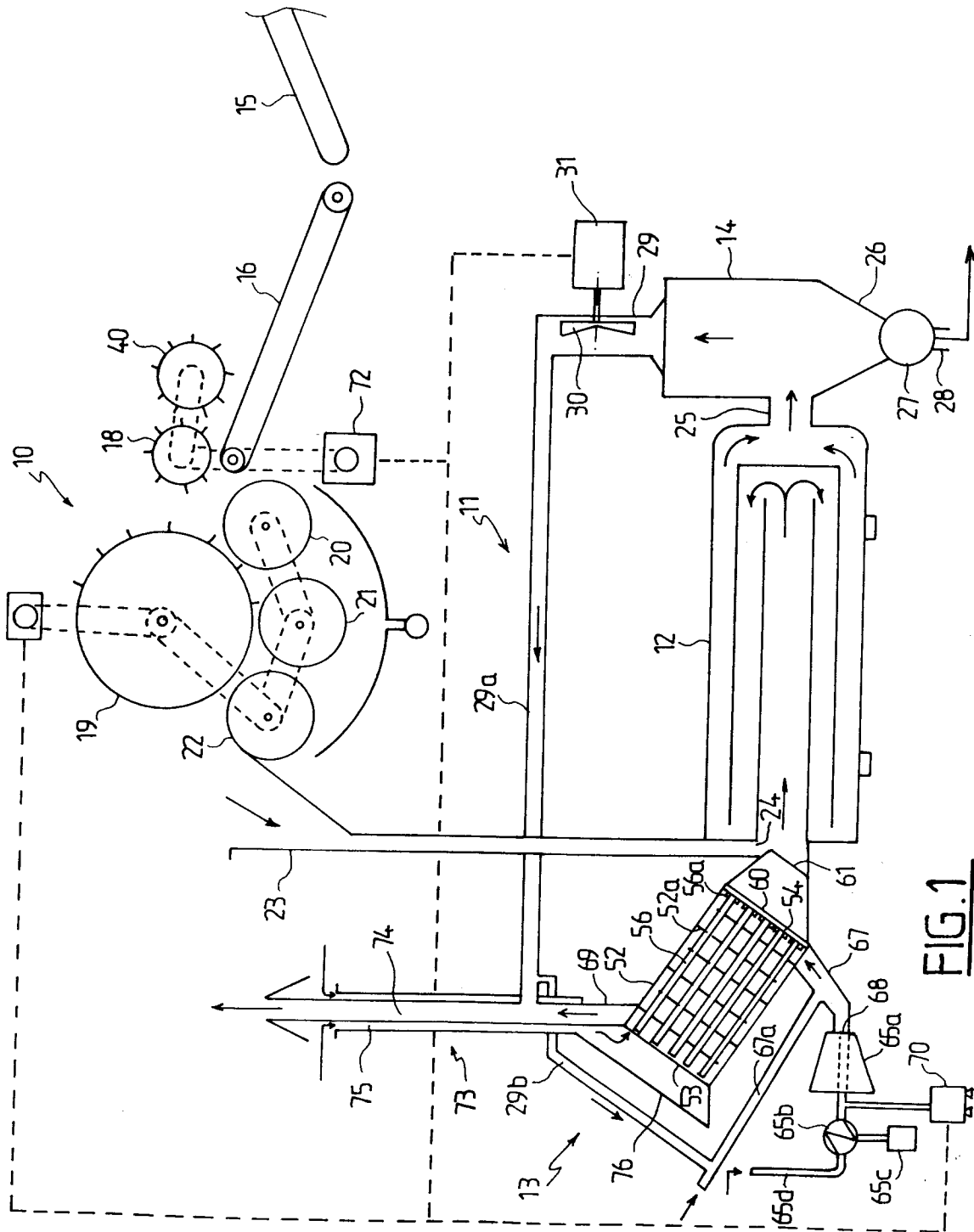


FIG. 1

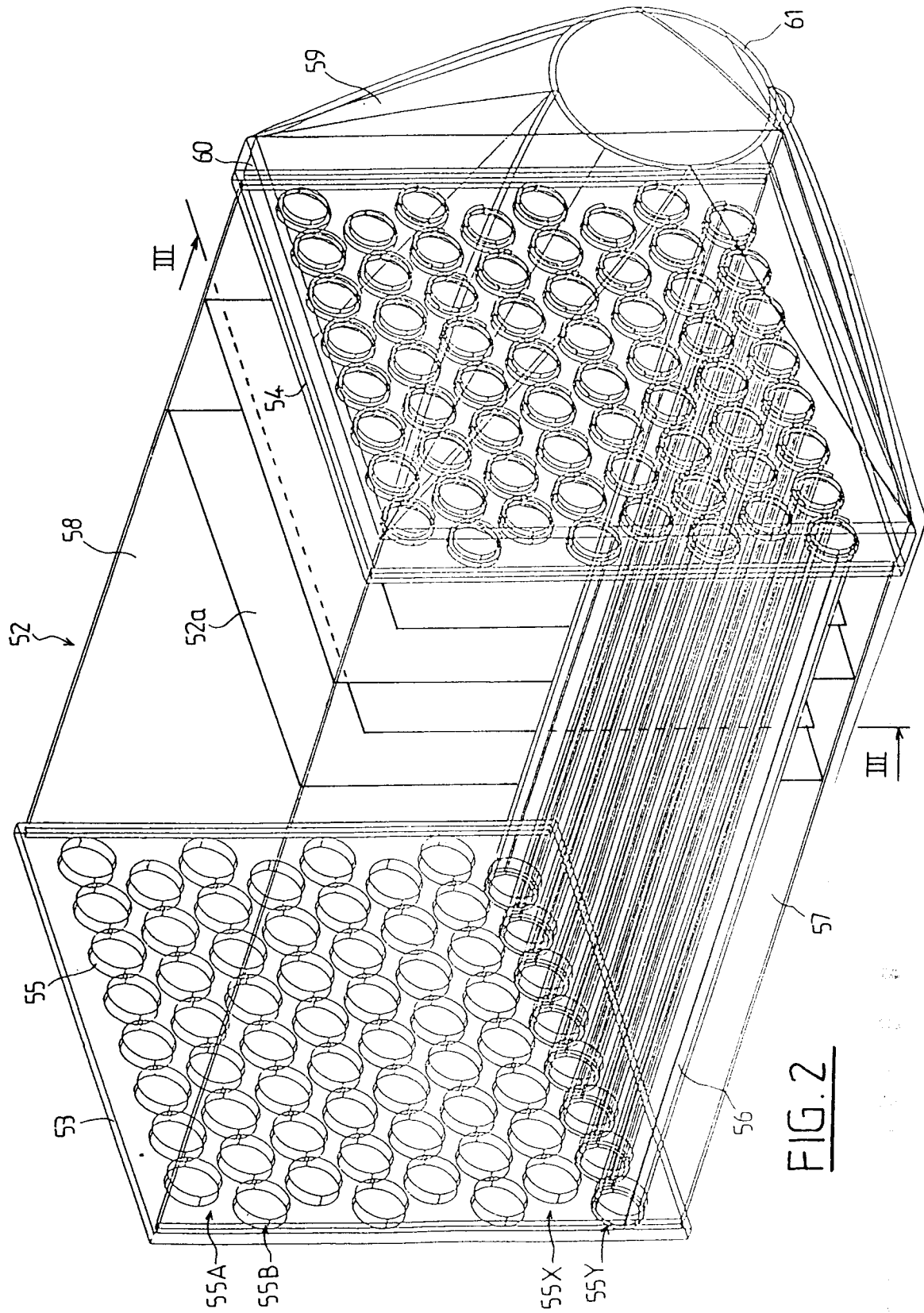


FIG. 2

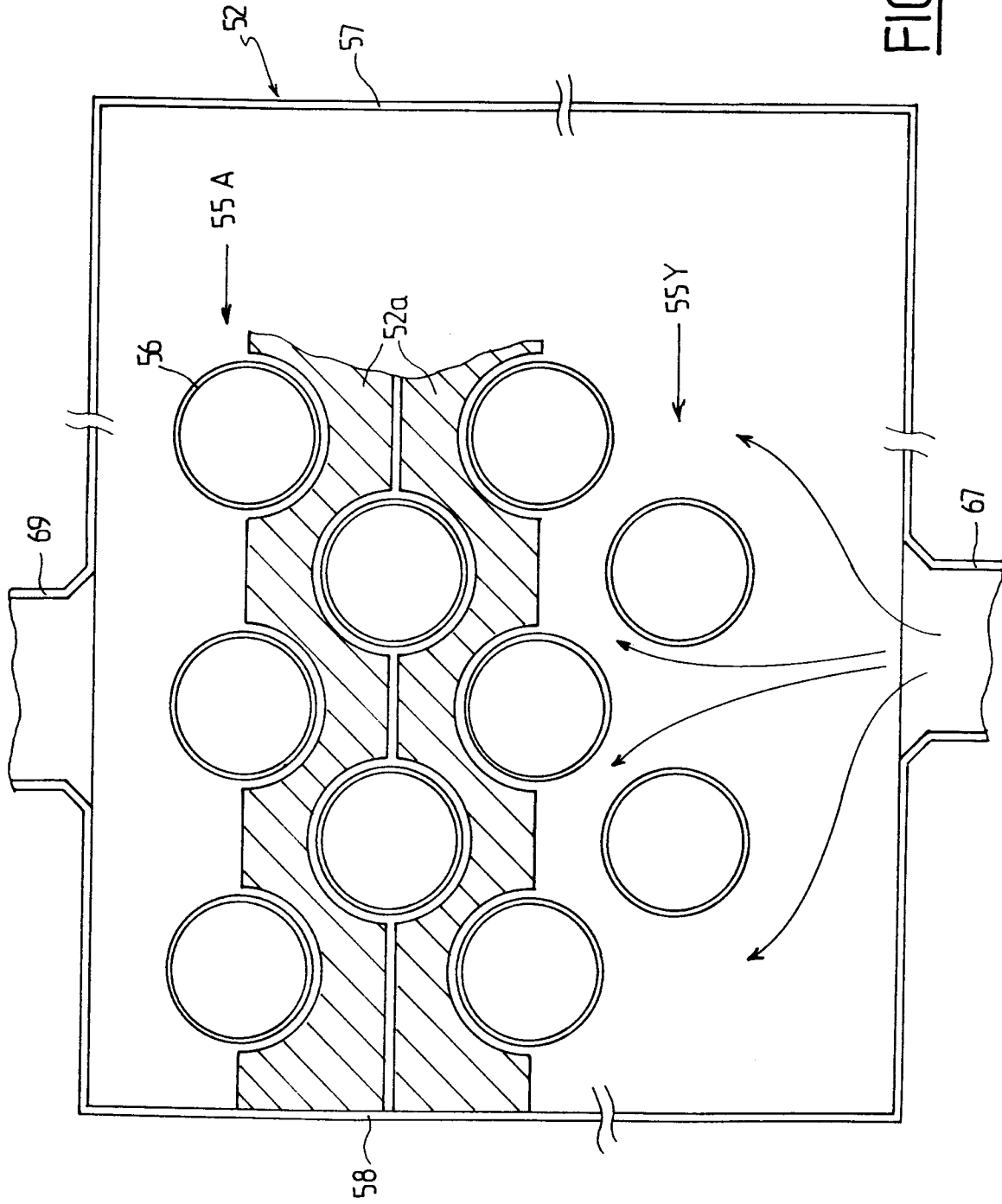


FIG. 3

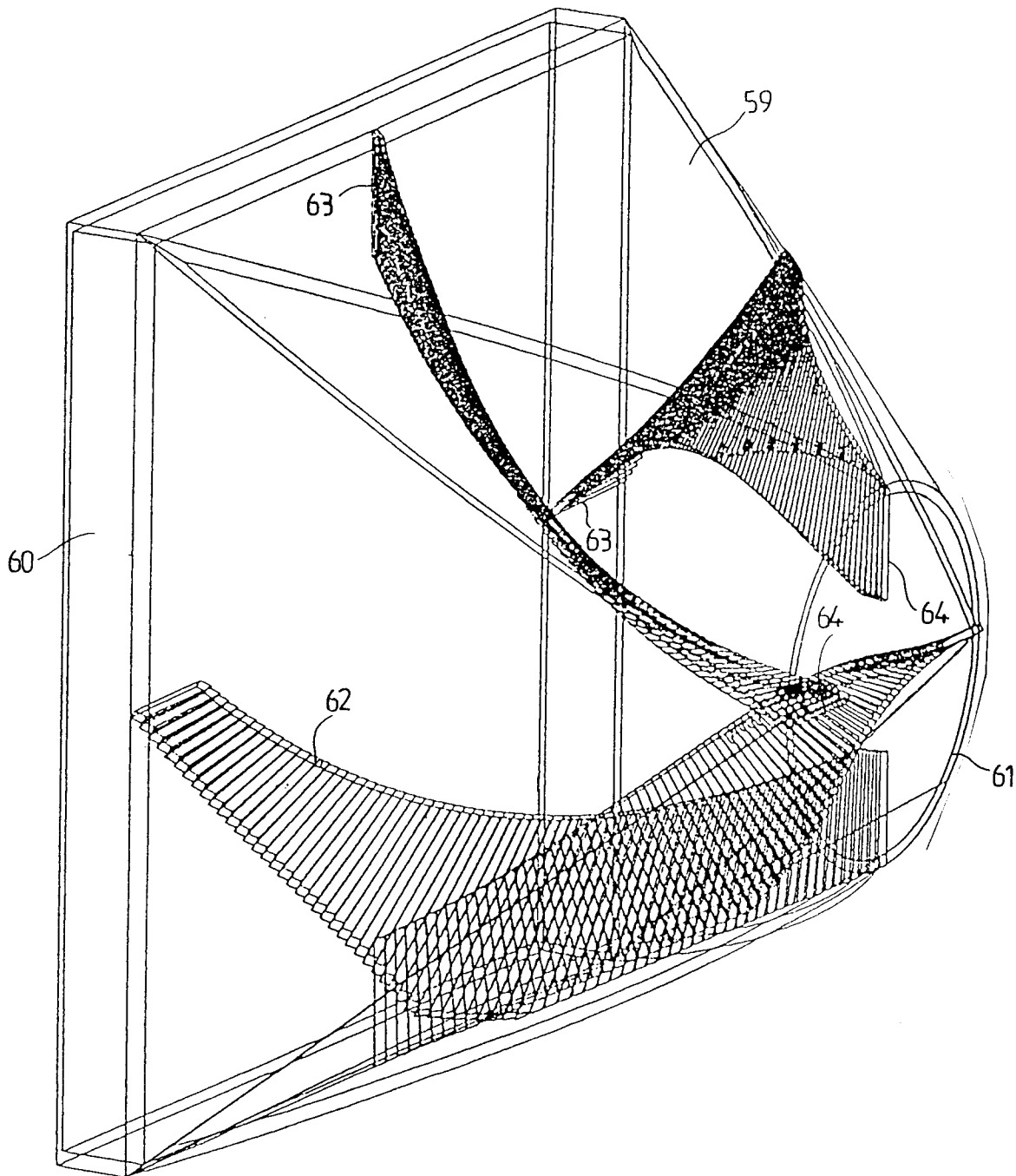


FIG. 4

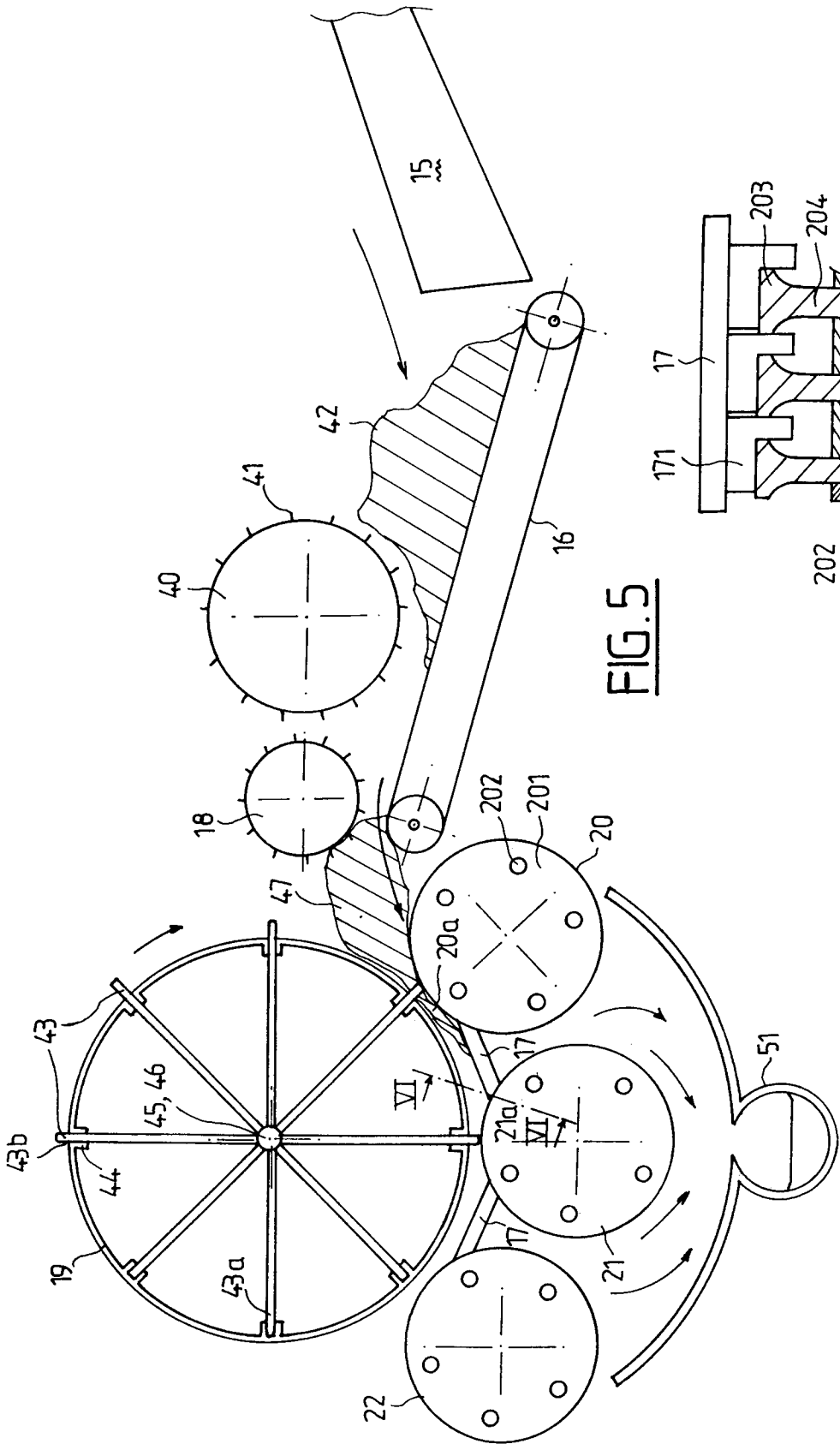


FIG. 5

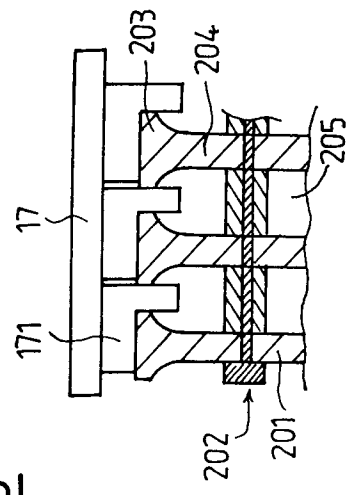


FIG. 6



European Patent  
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Application Number  
EP 97 46 0005

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	WO 91 07631 A (CIMBRIA UNIGRAIN LTD. A/S)	1	F26B11/04
A	* the whole document *	2,10	F26B23/02
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		17 June 1997	SILVIS, H
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