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(54) BOARD DRYING PROCESS AND DRIER

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(58) **Field of Search** 34/421, 422, 423, 34/446, 448, 450, 451, 459, 488, 489, 496, 500, 504, 619, 620, 623, 636, 637, 649, 651

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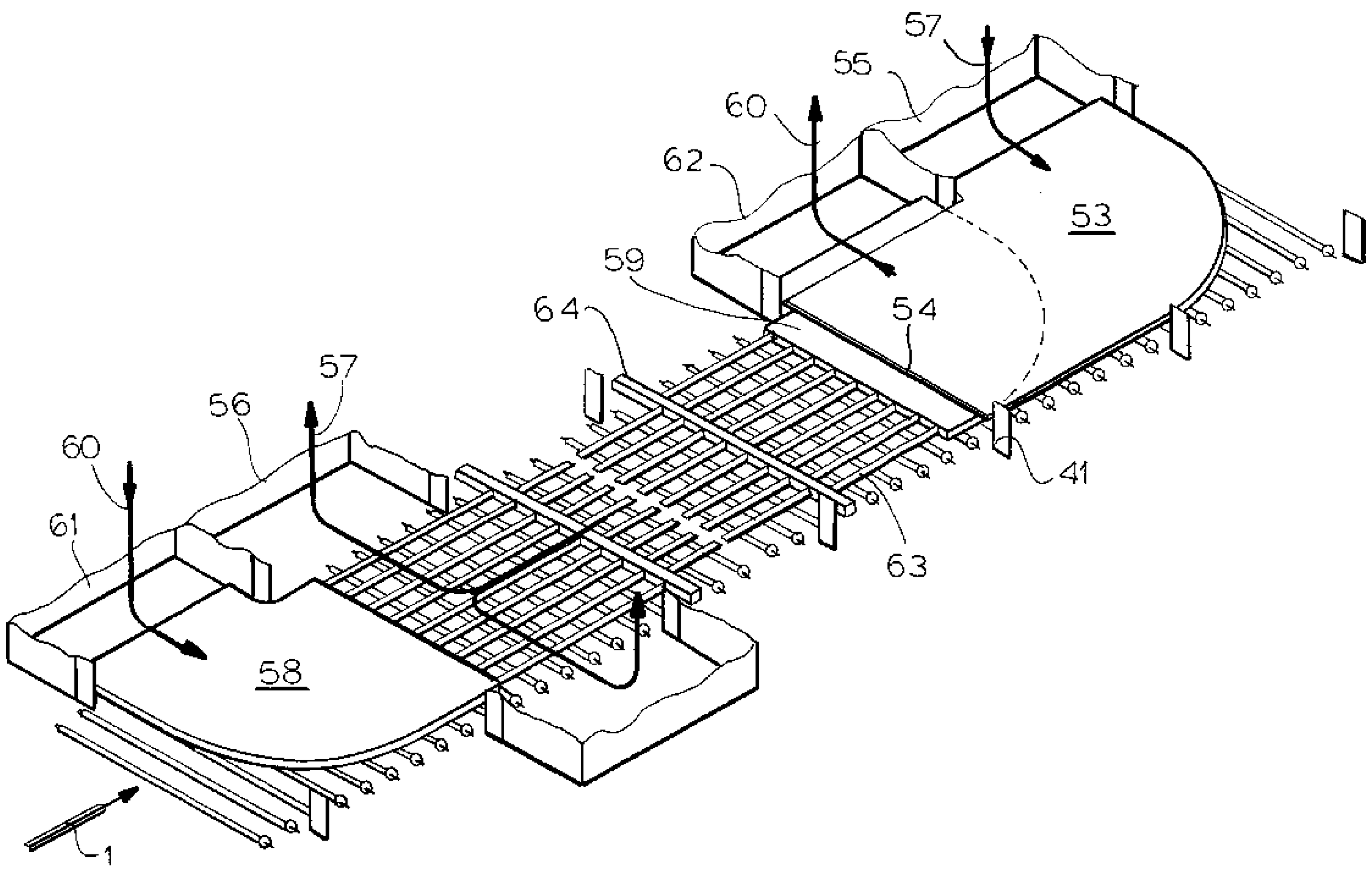
(57) ABSTRACT

In order to dry boards, the boards are guided on racks through a drier and brought into contact with drying air in two stages. In a stage A with a higher drying power, the drying air is supplied at a higher temperature and with an at least average humidity, and in the other stage B, it is supplied at an average temperature and with a low humidity. The waste heat of the outgoing air from stage A is used for preheating the drying air. This process should reduce the consumption of primary energy. For that purpose, a process is known that consists of also using the outgoing air condensation heat. This has the inconvenience, however, of requiring substantially more secondary energy, as important air mass flows are required to transfer heat because of the low condensation temperature. Primary energy should be reduced by using condensation heat without substantially increasing secondary energy requirements. According to the invention, the outgoing air from stage A is supplied to stage B through a heat exchanger arranged in the rack of the drier. The drying air of stage B is supplied in counter-current through the drier with a low humidity and temperature, so that the boards are dried in stage B both by condensation heat and by radiant heat. Thus only a reduced mass flow of drying air is required to transfer the condensation heat. The consumption of primary and secondary energy is low. This invention is suitable for drying boards as for buildings and gypsum plain boards or fiber boards.

22 Claims, 6 Drawing Sheets



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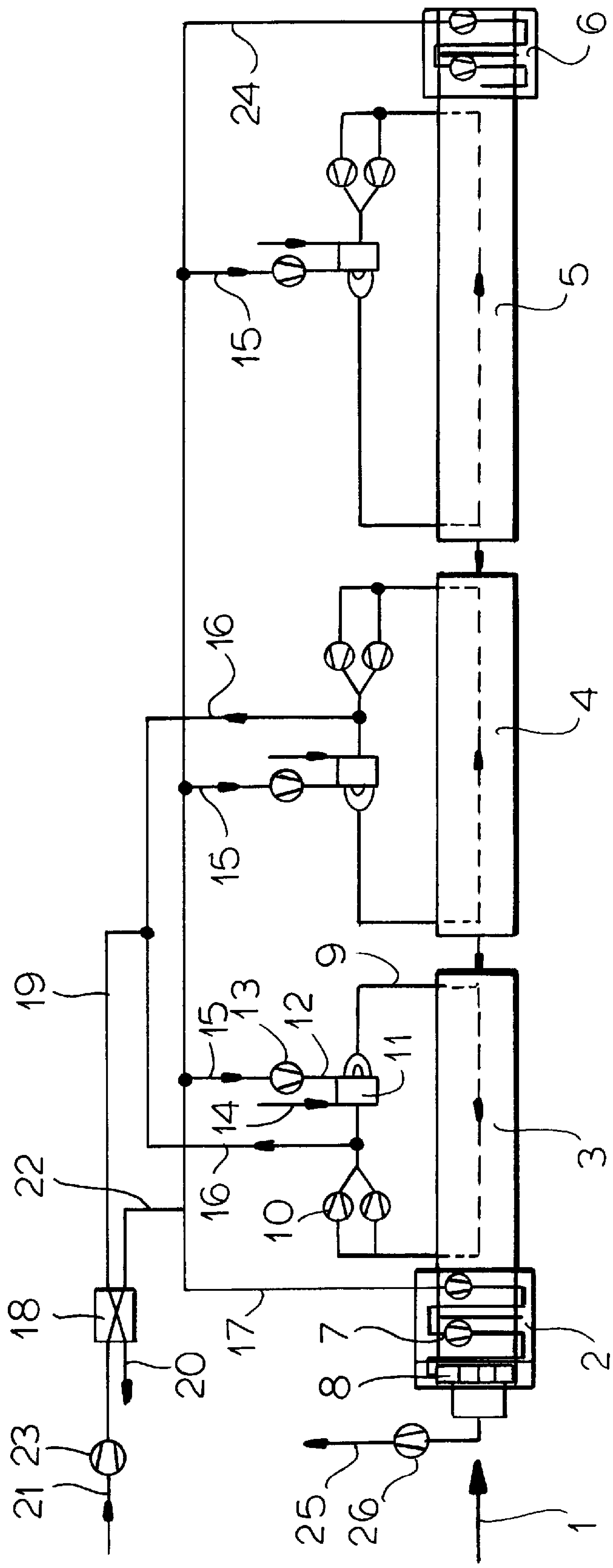

FIG.1A PRIOR ART

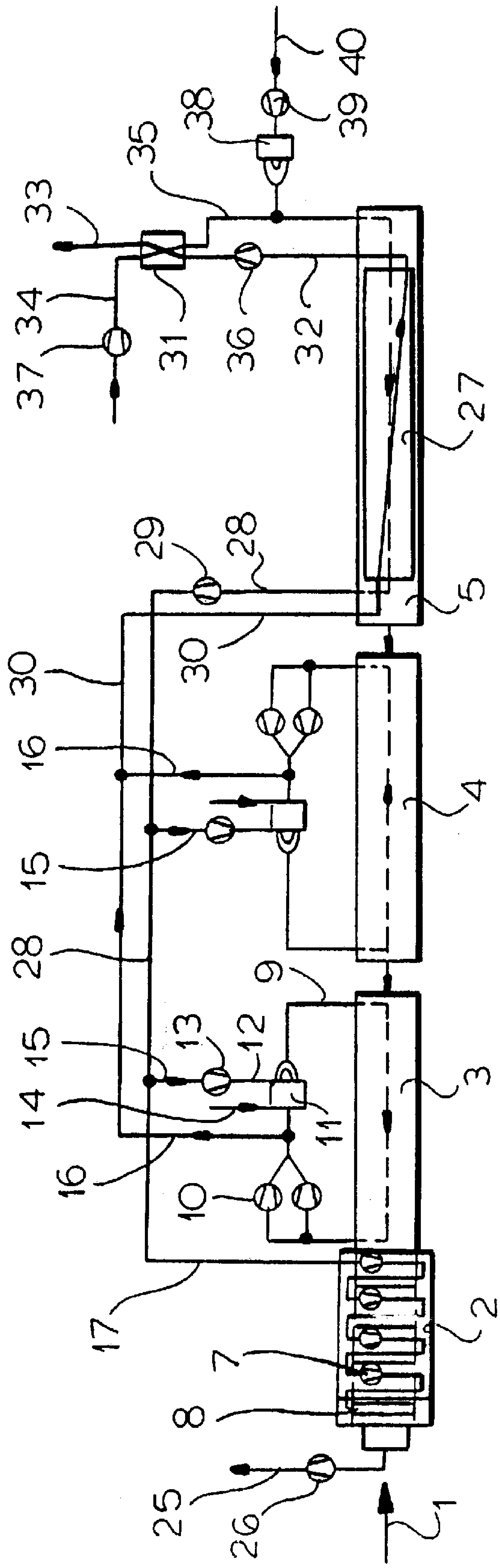
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FIG.1B

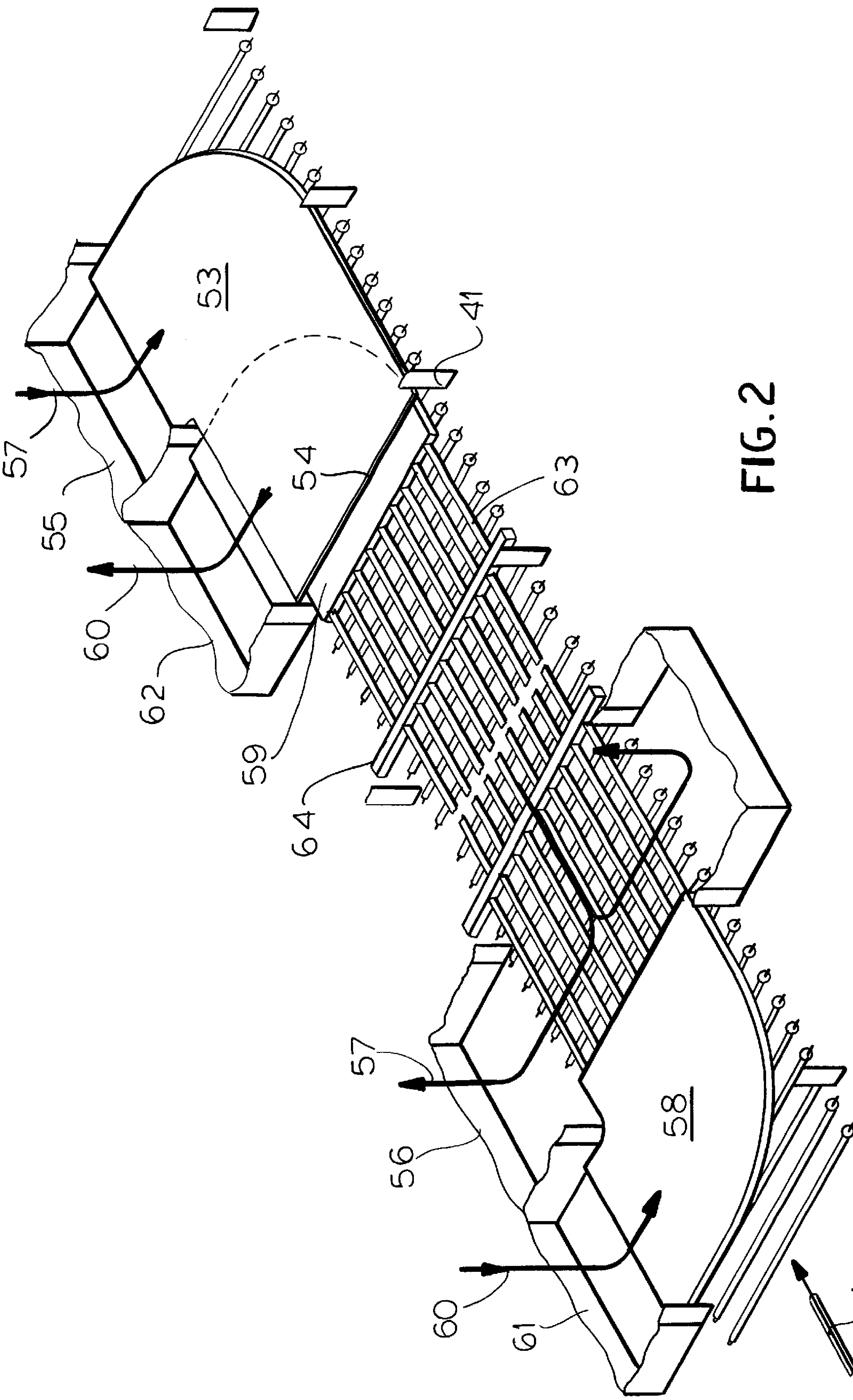

FIG. 2

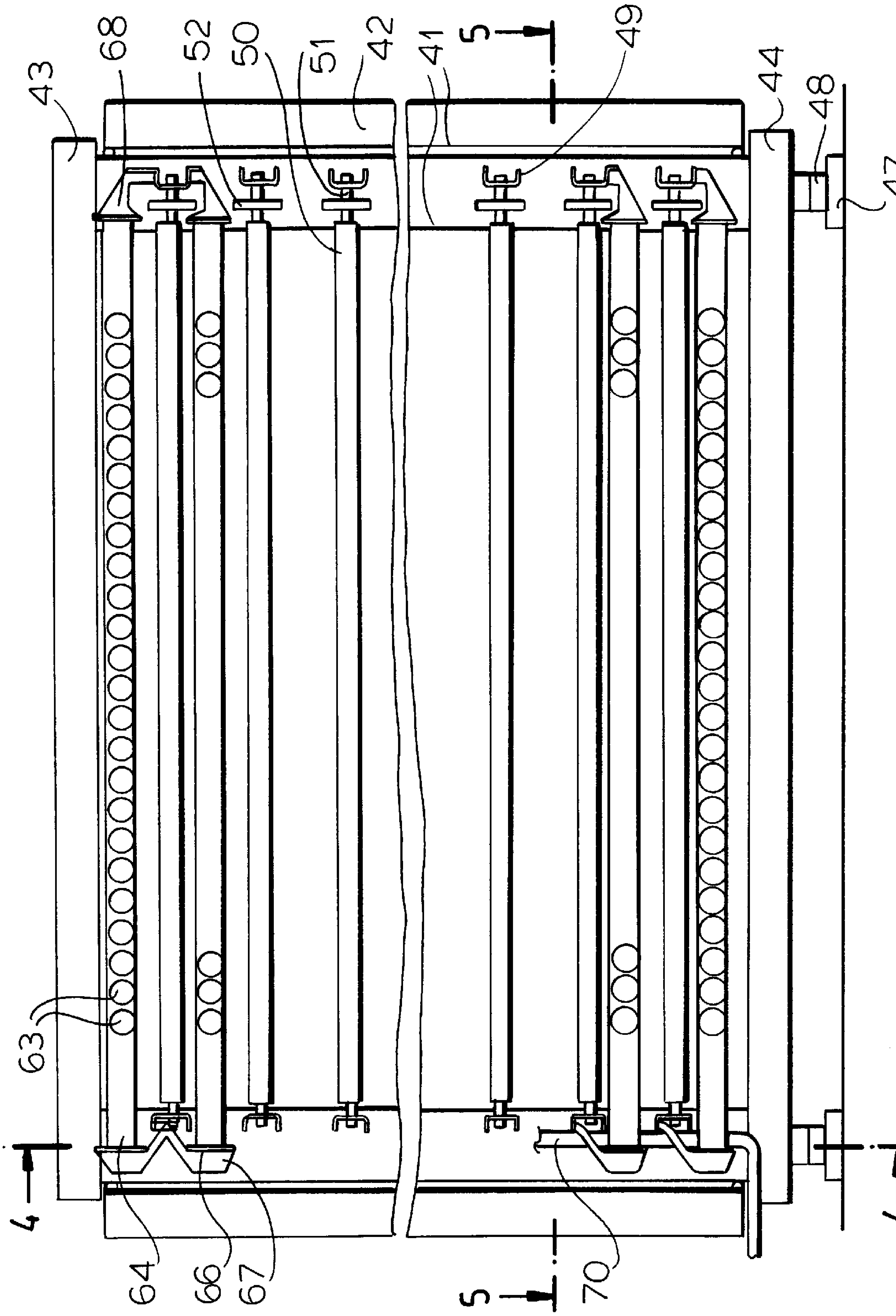

FIG.3

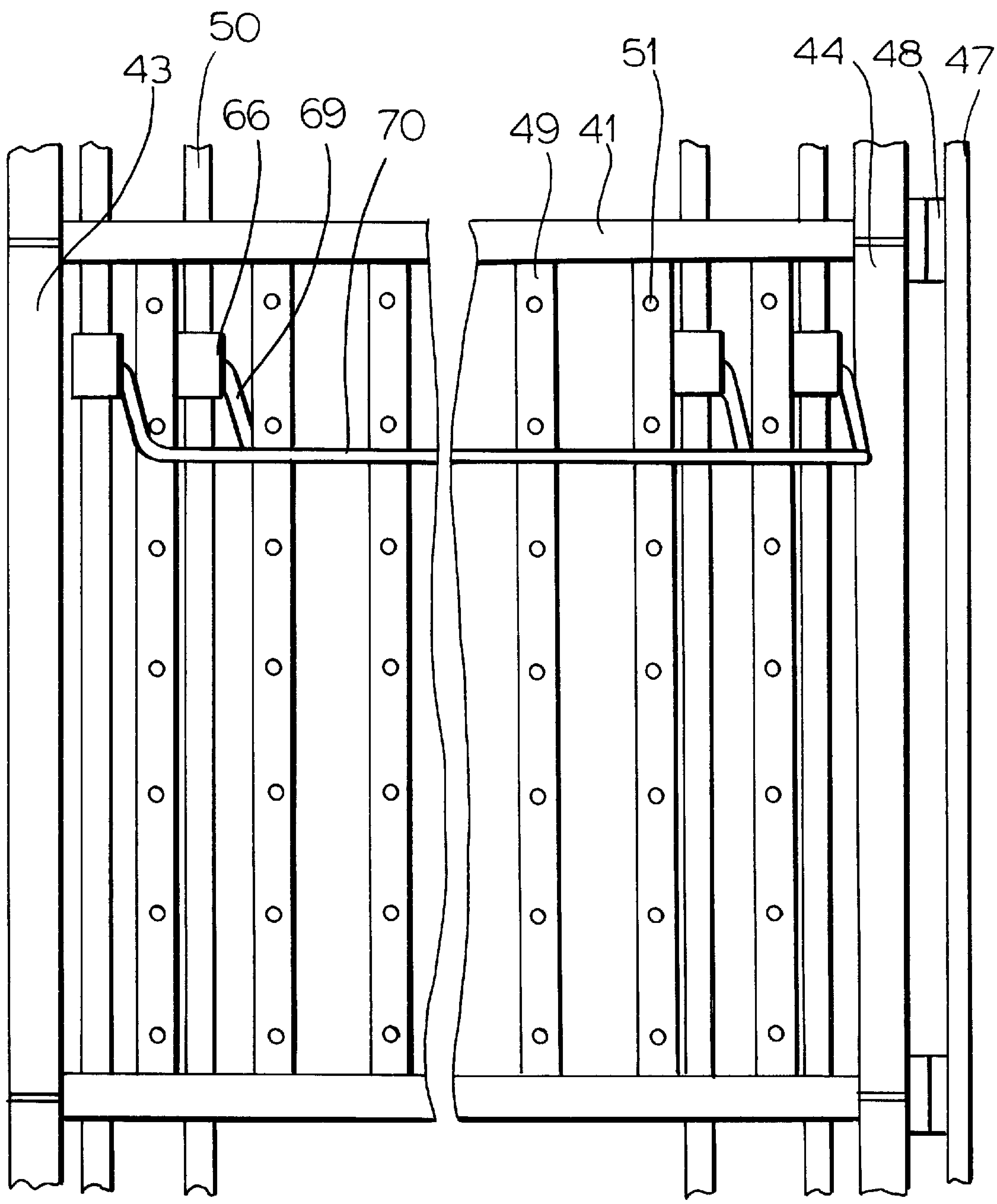

FIG.4

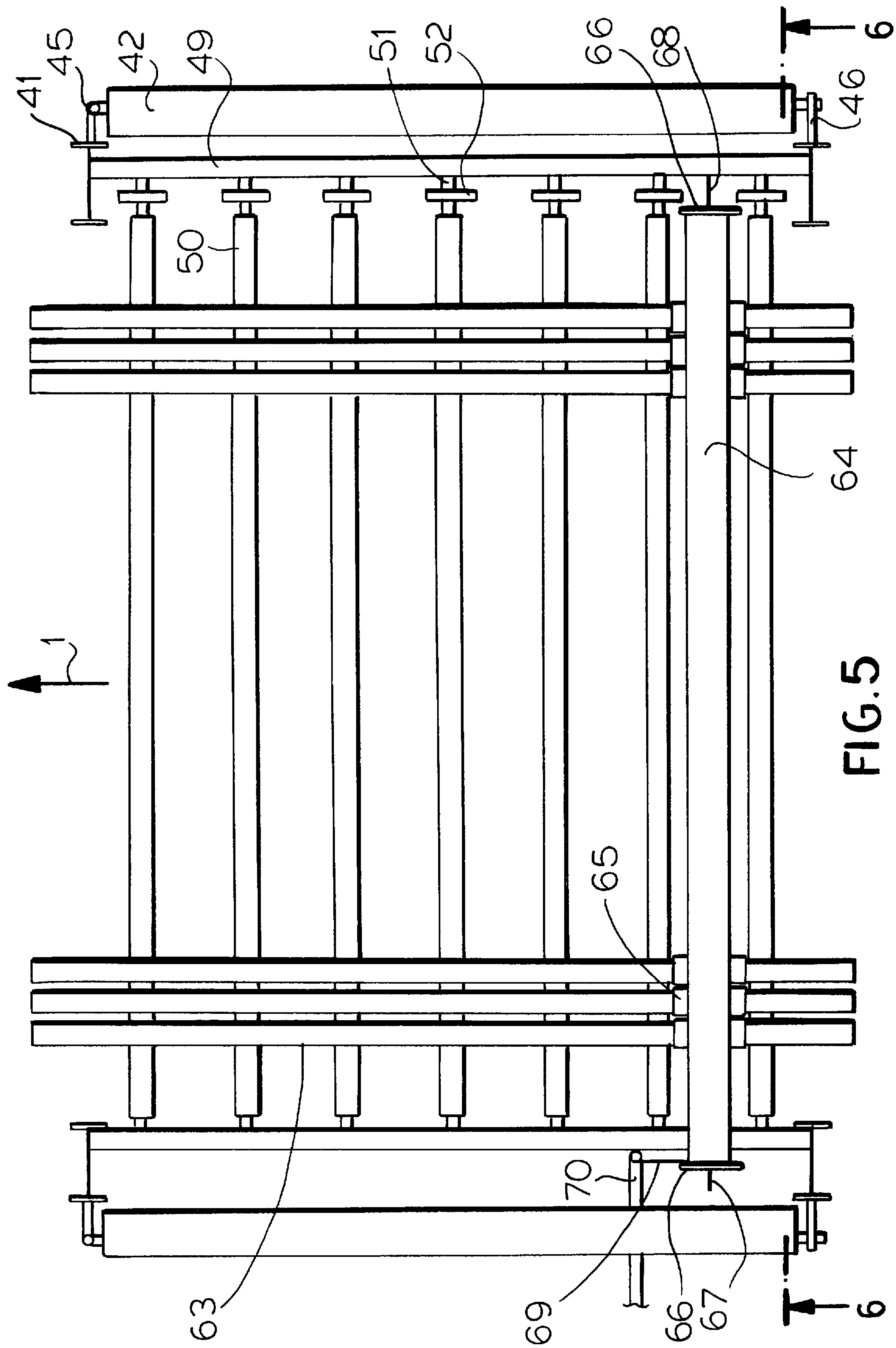

FIG. 5

BOARD DRYING PROCESS AND DRIER

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS REFERENCE TO RELATED APPLICATION

This is a national phase of PCT/EP94/102479 filed Jul. 27, 1994 which is based upon German national application P43 26 877.3 of Aug. 11, 1993 under the International Convention.

In the drying of boards, particularly building boards, such as gypsum plaster boards or mineral-fiber boards, the boards transported through a drier are brought into contact with heated air.

The supply of drying air can be done through longitudinal ventilation, cross ventilation or cross ventilation with nozzles. In the case of longitudinal ventilation the drying air is supplied at one end of the drier, or, when the latter is subdivided into several zone at one end of a zone, and evacuated at the opposite end.

In the case of cross ventilation the air is supplied at several locations on the sides of the drier and evacuated at the opposite sides, whereby it is possible to achieve larger mass flows of drying air through the drier. The largest air mass flows can be guided in the case of cross ventilation via nozzles through the so-called nozzle drier.

In most cases, an air recirculation process is used, wherein a large part of the drying air is recirculated. This drying air, also called recirculated air, is heated outside the inner drier space. Only a small part of the drying air is discharged as outgoing air and a part corresponding to the outgoing air is supplied from outside as fresh air.

For warming the drying air, e.g. through burners, optionally through damper registers, fuel i.e. primary energy is needed, and for the supply of air by fans electric energy, i.e. secondary energy is needed. The primary energy as well as the secondary energy, estimated to be three times as costly, should be kept as low as possible.

In the DE-Z Zement-Kalk-Gips, No. 8 1991, Pages 421 to 425 a process for the drying gypsum wall-building boards with cross ventilation is described, wherein a lower consumption of primary energy is achieved by using the condensation heat of the outgoing air. For this purpose in each of the two drier zones the hot air is cooled down in a heat exchanger arranged between the drier pipes for preheating of the hot air. Since the hot air, i.e. the drying air supplied to the board, is heated only to low temperatures, a large mass flow of drying air is needed. This leads to a relatively high consumption of secondary energy.

A further drying process wherein a low consumption of primary energy is achieved by using the condensation heat of the outgoing air is known from DE-A 26 13 512. This process is a two-stage process. In the first drying stage high temperatures and high air humidity are used and in the second drying stage low temperatures and low humidity are used. The drying efficiency of the first stage is two or three times greater than that of the second stage and the second drying stage is heated by the outgoing air of the first drying stage, due to the interposition of a heat exchanger. In both stages the drying air is supplied in a recirculation process, namely in the first drying stage in the form of a longitudinal ventilation and in the second stage in the form of cross ventilation with a large mass flow of recirculated air. The large recirculated air mass flow of the second stage and the resulting high consumption of secondary energy are the reasons why in practice this process has been replaced by the process of the invention.

In the generic drying process known from the book "Trocknungstechnik" by K. Kroll and W. Kast, Third Volume, 1989, Pages 489 to 493, gypsum plaster boards which are guided through the drier on decks, are also dried in two stages at high temperature but at average humidity of the drying air in the first stage and with average temperature and low humidity of the drying air in the second stage. In the generic drier two zones are provided for performing the first stage and one zone is provided for performing the second stage. This and the higher temperatures of the drying air in the first stage lead to the assumption of a higher drying efficiency in the first stage. Due to the higher temperature of the drying air in the second stage when compared to DE-A 26 13 512, extremely large mass flows of recirculated air are avoided, so that this process leads to a low consumption of secondary energy. However the consumption of primary energy is relatively high.

In attempting to reduce the consumption of primary energy by using the condensation heat of the outgoing air, a general problem arises due to the fact that the waste heat of the outgoing air is available only at a low temperature level. Although a lower temperature of the drying air could be compensated by larger air mass flows, this would lead to a higher consumption of secondary energy, as described in the known process.

OBJECT OF THE INVENTION

It is therefore the object of the invention to provide an improved process and drier for the drying of plasterboard and the like with the lowest possible consumption of primary and secondary energy. Specifically with the invention the used primary energy should be kept as low as possible by using the waste heat and also the condensation heat of the outgoing air, without increasing the requirement for secondary energy due to the recirculation of large air mass flows.

SUMMARY OF THE INVENTION

The process for drying boards which are guided through a drier on decks, according to the invention, contacts the boards with drying air in two stages A and B, whereby in stage A the drying is carried out in a recirculated-air process with high temperature and at least average air humidity and with a drying capability which is two to four times higher than in stage B, and in stage B the outgoing air of stage A can be guided through a heat exchanger arranged in the decks of the drier and the drying air at a low temperature and low humidity can be guided in counterflow to the outgoing air of stage A.

In stage A, drying air at a temperature of 150° to 300° C. and an air humidity of 0.2 to 0.8 can be supplied, drying air at a temperature of 120° to 200° C. and an air humidity of 0.2 to 0.8 is discharged, and a part thereof is directed into stage B, and in stage B drying air is supplied in the form of longitudinal ventilation, whereby the drying air with a temperature of 20° to 80° C. and an air humidity of 0.005 to 0.015 is supplied and drying air at a temperature of 80° to 110° C. and an air humidity of 0.03 to 0.1 is discharged.

The outgoing air leaving the heat exchanger in stage **[**A**]** *B* can be directed into a heat exchanger for preheating the drying air of stage B.

The drying air of stage A, guided as recirculated air, can be heated by at least one burner, the drying air discharged from stage B being directed towards the burners. Advantageously the boards are at first dried in a preliminary drying stage, are subsequently dried in stage A and are .finally dried in stage B.

Alternatively the boards are dried at first in stage B and subsequently in stage A.

A drier for drying boards, with a conveying device for transporting boards arranged on decks through the drier, can have a section A with at least one zone, which has a supply device, an evacuation device and a recirculated-air channel with conveying means and a heating device for recirculated air, as well as means for the supply of incoming air and means for the discharge of outgoing air, and a section B with a supply device for drying air and an evacuation device for drying air which are arranged at opposite ends of the drier.

A heat exchanger can extend in the decks above the conveying device through the section B of the drier, and can have a supply device and an evacuation device which are arranged at opposite ends of the drier, whereby the supply device of the heat exchanger is connected with at least one means for discharging the outgoing air of section A. The supply device of the heat exchanger and the supply device for the drying air of stage B can be arranged at opposite ends of the drier.

The drier can have a heat exchanger for preheating the drying air of section B, whose supply line is connected to the evacuation device of the first-mentioned heat exchanger. The heating installation of section A can consist of burners and the evacuation device for drying air of section B can be connected with the incoming air lines of a burner.

The conveying device can have roller conveyors or belt conveyors. The first-mentioned heat exchanger can have tubes running parallel to the travel direction. The tubes can be interrupted by collectors arranged transversely to the travel direction and to which they are connected.

In stage B the outgoing air of stage A with a high water vapor content, guided through the heat exchanger, is cooled down by the drying air with a lower temperature to the point that a part of the water vapor condensates.

The waste heat and condensation heat of the outgoing air of stage A reach the inside of the drier in the immediate environment of the boards to be dried and are transmitted to the boards in the form of radiation and convection heat. Heating devices arranged outside the drier are not required. Pipes for the recirculated air can be simplified or saved.

By using also the condensation heat, which is made possible by the low temperature of the drying air cooling the heat exchanger and the at least average air humidity of the outgoing air of stage A, the primary energy is intensively utilized.

Due to the fact that the drying air is guided in counterflow to the outgoing air of stage A guided through the heat exchanger, cooler drying air meets already cooled outgoing air. This insures the widest possible condensation of the water vapors contained in the outgoing air and improves the utilization of primary energy. The intensive utilization of the primary energy leads to considerable savings of primary energy.

Generally in stage B the drying is done at the most with one half of the drying power of stage A. Thereby a part of the heat is transferred to the boards through heat radiation, due to the arrangement of the heat exchanger in the decks of the drier. Therefore for the transfer of the second part of the heat through convection only a relatively small amount of drying heat is required. The secondary energy required for guiding this relatively low amount of drying heat is considerably lower in the process of the invention than the one needed in processes with similar low consumption of primary energy.

Therefore in the process of the invention the primary energy is utilized to the largest possible extent, without substantially increasing the need for secondary energy.

In stage A the drying can take place according to the recirculated-air process, whereby drying air with a temperature of 150° to 300° C. and an air humidity of 0.2 to 0.8 is supplied and drying air with a temperature of 120° to 200° C. and an air humidity of 0.2 to 0.8 is discharged. A part of this drying air is drawn from stage A as outgoing air and guided into the heat exchanger of stage B. In stage B the drying air is supplied through longitudinal ventilation, whereby drying air with a temperature of 20° to 80° C. and an air humidity of 0.005 to 0.015 is supplied and drying air at a temperature of 80° to 110° C. and an air humidity of 0.03 to 0.1 is discharged.

With the drying power of stage A which is two to four times higher and the foregoing process parameters, the primary energy is optimally used with the lowest possible consumption of secondary energy.

In comparison to the prior art process, the process of the invention can dispense with the burner used in the third zone of the prior art process.

The mass flow needed in the process of the invention is even smaller than in the stage B, i.e. in the third zone of the prior art process. The process parameters make possible such a reduced mass flow of the drying air in stage B, that the drying air can be supplied in the form of a simple longitudinal ventilation, i.e. the recirculation of the drying air and therefore the recirculated-air pipes can be fully dispensed with. The total amount of secondary energy needed in the process of the invention, taking into consideration the additionally required electric energy for guiding the outgoing air of stage A through the heat exchanger of stage B, is approximately as great as in the prior art process.

Since due to the heat exchanger surfaces the flow cross section in the inner space of the drier is also reduced, the smaller mass flow of drying air can be guided past the boards at a flow velocity which is almost equal to stage A.

The invention can utilize a preheating of the drying air supplied to stage B in a second heat exchanger outside the-drier, through which the outgoing air leaving the stage B is guided.

The heat contained in the drying air discharged from stage B is used by directing the drying air to the burners of stage A.

The process is particularly suited for drying gypsum plaster boards, which towards the end of the process are not supposed to be exposed to very high temperatures, because of the danger of gypsum calcination. Therefore after a preliminary drying, the boards are dried at first at high temperatures in the stage A and subsequently at lower temperatures in stage B. Besides this temperature course favors the starch migration which is needed for good cardboard bonding.

The alternative approach is particularly suited for drying boards, e.g. mineral-fiber boards, which could also be exposed in a dry state to higher temperatures. In this process the boards are predried in stage B and in stage A are dried to ultimate humidity. In this temperature course the drying takes place at high temperature differences of drying air and boards, which leads to a particularly efficient utilization of primary energy.

A roller-conveyor drier or a belt drier according to the invention can have several roller conveyors or belts arranged on top of each other, is particularly well suited for incorporating a heat exchanger which thereby extends in the decks above roller conveyors or belts.

The heat exchanger can have heat exchanger tubes running parallel to the conveying device or can have heat exchanger plates. The advantage of the tubes is a lesser danger of contamination of the heat exchanger, while the plates are easier to mount.

When the heat exchanger is equipped with tubes, these are advantageously interrupted by collectors arranged transversely to the conveying direction, whereby the tubes are connected to these collectors. In the collectors the condensate can be collected and discharged from there. In certain cases the collectors also facilitate the cleaning of the tubes, since through them cleaning devices can be introduced into the tubes.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects, features, and advantages will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

The invention is further explained with the aid of an example schematically represented in the drawing.

FIG. **1**A is a process flow diagram of the **[**invention**]** *prior art*;

FIG. **1**B is a process flow diagram of the **[**prior art**]** *invention* (top).

FIG. **2** shows a deck of section B of the drier according to the invention in a perspective view;

FIG. **3** is a cross section through the drier in section B:

FIG. **4** is a side view of a segment along lines **4**—**4** in FIG. **5**;

FIG. **5** is a vertical cross section through a segment of the drier in section B along lines **6**,**6**.

SPECIFIC DESCRIPTION

A drier is provided with a conveying device for the transport of boards arranged on decks through the drier. The drier can be built as a roller-conveyor drier or a belt drier, whereby the conveying device has several roller conveyors or conveyor belts arranged one on top of another.

In the following with the aid of the process flow diagram in FIG. **1**A first a prior art drier and subsequently a drier according to the invention for drying gypsum plaster boards is described.

The prior art drier shown in FIG. **[**1B**]** *1A* is subdivided in the travel direction of the boards into

- a preliminary drying section **2** with two nozzle areas,
- a section A with two zones **3**, **4**, longitudinally ventilated according to the air recirculation process,
- a section B with a zone **5** longitudinally ventilated according to the air recirculation process and
- a supplementary drying section **6** with two nozzle areas.

In each of the nozzle areas of the preliminary and supplementary drying sections **2**, **6**, the drier has a cross ventilation with nozzles and a fan **7**. In the introductory part of the preliminary drying section there is also a suction device **8** for drying air.

In each of the zones **3**, **4**, **5** of sections A and B the drier has a supply device, an evacuation device and a recirculation channel **9** with conveying means and a heating device for the recirculated air.

The supply and evacuation devices are arranged respectively at opposite ends of a zone **[**2,**]** **3**, **4**, *5* whereby in the travel direction **1** of the boards the supply device of the first zone **3** is arranged at the end of zone **3** and the supply devices of the second and third zone **4**, **5** are arranged at the beginning of each of the zones **4**, **5**.

In the respective recirculated air channel **9**, which connects the evacuation device with the supply device of a zone **3**, **4**, **5** the conveying means and the heating device are arranged one after the other, starting from the evacuation device. In each zone two fans **10** connected in parallel are provided as conveying means for the recirculated air. Each of the heating devices has a burner **11** for oil or gas, an air connection **12** with a fan **13** and a fresh air connection **14**. Instead of direct heating it is also possible to provide indirect heating, whereby the heating device can have damper registers, e.g. with thermal oil.

Air supply lines **15** for the air supply of zones **3**, **4**, **5** are connected to the fans **13** for the burners **11**. Air outlet lines **16** for the outgoing air of the first and second zones **3**, **4** branch out respectively between the fans **10** and the burners **11** of the recirculated air channels **9**.

An air supply line **17** is connected to the fan **7** of the second, i.e. last nozzle area of the preliminary drying section **2**.

The drier has also a heat exchanger **18** arranged outside the inner drier space, with supply and outlet lines **19**, **20** for outgoing air and supply and outlet lines **21**, **22** for fresh air.

The outgoing-air lines **16** of the two zones **3**, **4** are connected to the supply line **19** for outgoing air. The outgoing line **20** for outgoing air ends in a chimney not shown in the drawing.

In the supply line **21** for fresh air a fan **23** is arranged. The outlet line **22** for fresh air branches out into the incoming air lines **17**, **15** of the preliminary drying section **2** and of the three zones **3**, **4**, **5** and in an incoming air line **24** which leads to the fan **7** of the second, i.e. last nozzle area of the supplementary drying section **6**.

An outgoing air line **25** with a fan **26** leads outward from the preliminary drying section **2**.

The zones **3**, **4**, of section A and the zone **5** of section B of the drier are connected to each other so that an air exchange is possible between them.

The drier of the invention illustrated in diagram of FIG. **[**1A**]** *1B* is subdivided into

- a preliminary drying section **2**
- a section A with two zones **3**, **4** and
- a section B with one zone **5**.

In contrast to the prior art drier, its preliminary drying section **2** has four nozzle areas. A supplementary drying section is not provided.

The construction of the preliminary drying section **2** and of the section A with the two zones **3**, **4** correspond with the generic drier.

However in section B, i.e. in zone **5**, the drier has

- only one supply device and one evacuation device for drying air, i.e. it has no recirculated air channel, and
- one heat exchanger **27** with a supply device and an evacuation device.

The supply and evacuation devices of the heat exchanger **27** and for the drying air are respectively arranged at opposite ends of zone **5**, whereby the supply device of the heat exchanger **27** and the evacuation device for drying air at the beginning of zone **5** are arranged in the travel direction **1** of the boards.

The evacuation device for drying air is connected with an air line **28**, wherein a fan **29** is arranged, and which branches out into the incoming air lines **15** for the incoming air of zones **3**, **4** of section A and the incoming air line **17** of the preliminary drying section **2**.

In the supply device of the heat exchanger **27** ends an air line **30** for the outgoing air of section A, to which the outgoing air lines **16** of the first and second zone **3**, **4** of section A are connected.

In addition the drier has a heat exchanger **31** for preliminary heating of the fresh air, i.e. the drying air supplied to section B, with incoming and outgoing lines **32**, **33** for the outgoing air and with incoming and outgoing lines **34**, **35** for fresh air.

The supply line **32** for outgoing air is connected to the evacuation device of the heat exchanger **27** and is provided with a fan **36**. The outlet line **33** for outgoing air ends in a chimney which is not shown in the drawing.

In the supply line **34** for fresh air a fan **37** is arranged. The outlet line **35** for fresh air leads to the supply device for the drying air of section B. In the outlet line **35** ends a line **40** provided with a burner **38** and a fan **39**, for preheating the fresh air at the start of the drier and for regulating the temperature of the fresh air.

The zones **3**, **4**, **5** of the drier are subdivided into fields by vertical supports **41** arranged on both sides (see FIG. **2**). The supports **41** consist for instance of double T-sections (FIGS. **3**, **4**, **5**).

Each field has two side walls **42**, a ceiling **43** and a bottom **44**. The side walls **42**, the ceiling **43** and the floor **44** are built as double walls and provided with insulating material. They are fastened to the supports **41**, whereby the side walls **42** are fastened for instance via hinges **45** to the rear supports **41** and via closures **46** to the front supports **41**.

Underneath the supports **41** on the bottoms **44** legs **48** are mounted, which are provided with rollers and guided in a support rail **47**. On each side of the drier, between every two supports **41**, roller supports **49** arranged on top of each other and fastened to the supports **41** extend horizontally. The roller supports **49** consist for instance of U-shaped sections, whose bottoms are arranged vertically and whose arms are pointing outward. Between two roller supports **49** located on both sides at the same level, horizontal, cylinder-like rollers **50** of a roller conveyor, arranged in succession, extend transversely to the travel direction **1**. Each of the roller conveyors arranged on top of each other form the bottom of a rack wherein the boards are transported.

The rollers **50** are provided at their ends with pivots **51**, by means of which they are supported in the roller supports **49**. On one side (in the example on the right side seen in the travel direction **1**) sprockets **52** are located on the pivots **51** in front of the roller supports **49**. A driven chain (not shown in the drawing) is guided over these sprockets **52**. A chain can extend for instance over the entire conveying length of the drier and can drive the rollers of two superpositioned decks, in that in the lower deck it is guided above the rollers **50** over the chain wheels **52** and in the rack located thereabove it is guided underneath the rollers **50** over the chain wheels **52**.

In the first and last fields of zones **3**, **4** of section A there are also the supply device and the evacuation device for the recirculated air, whereby the supply device is located in the last field of the first zone and in the first field of the second zone **4** and the evacuation device is correspondingly located in the first field of the first zone **3** and in the last field of the second zone **4**.

FIG. **2** shows the layout of the supply and evacuation devices for drying air, as well as the arrangement of the heat exchanger **27** in a deck.

In the section B in zone **5** the supply device for drying air extends over the last two fields. The evacuation device for drying air is arranged in the second field. The supply device for the heat exchanger **27** is located in the first field and its evacuation device is located in the second last field of zone **5**.

In each rack the supply device for drying air has in the upper deck area a plate-like nozzle **53**, extending over two fields and over the entire width of the roller conveyor, which has a lateral opening (not visible) for the incoming drying air and an opening **54** pointing into the deck against the travel direction **1** for the exiting drying air. The nozzles **53** are provided with baffle plates on the inside.

The supply device for drying air has on each side of the drier an incoming air channel **55** extending over the length of the last field and the entire height of the drier and wherein end the lateral openings of the nozzles **53**. In the second field of the section B, the evacuation device has a corresponding outgoing air channel **56**. The flow direction of the drying air is indicated by arrows **57**.

The supply and evacuation devices of the heat exchanger **27** have respectively in each deck plate-like nozzle **[57** [sic]**]** *59* and **58**, arranged above the roller conveyor. The nozzles **58** and **59** are also provided with baffle plates on the inside. Each nozzle **58** has a lateral opening for the entering outgoing air and each nozzle **59** has a lateral opening for the exit of the outgoing air. The flow direction of the outgoing air is indicated by arrows **60**. Each of the lateral openings of the nozzles **58**, **59** also ends in a channel **61**, **62**, which extends over the entire length of the corresponding field and over the entire height of the drier.

In each rack the nozzle **59** of the evacuation device of heat exchanger **27** is arranged underneath the nozzle **53** of the supply device for drying air and projects somewhat under the nozzle **53**. The nozzle **58** of the supply device is arranged at the same level as the nozzle **59** of the evacuation device. In addition the heat exchanger **27** has tubes **63** and collectors **64** arranged at the same level.

The arrangements of the heat exchanger **27**, consisting of a nozzle **58**, tubes **63**, collectors **64** and a nozzle **59** in the decks extend approximately over the entire length of the roller conveyor (whereby in FIG. **2** only every third **[**roller**]** *tubes* **63** is indicated). Such an arrangement is also located underneath the lowest deck. In FIGS. **3** to **5**, which show the inner drier space in section B, the heat exchanger **27** is shown only in two uppermost decks, in the lowest deck and underneath the lowest deck. Thereby in the second uppermost rack and in the lowest rack only a few tubes **63** are shown.

The tubes **63** extend parallelly to the travel direction **1** from the nozzle **58** of the supply device to the nozzle **59** of the evacuation device, to which they are respectively connected. The tubes **63** are interrupted by the collectors **64** arranged transversely to the travel direction **1**, to which they are connected by detachable connection elements **65** (shown only in FIG. **5**).

The nozzles **58** and **59** are closed towards the inner space of the drier, with the exception of openings for the tubes **63**. For the uniformization of the radiation onto the plates, the tubes **63** can be staggered transversely to the travel direction **1** by half the distance between tubes. They can have a smooth surface and can be made of stainless steel, aluminum, galvanized or flame-aluminized sheet metal.

The collectors **64** can also be made of the same materials. They are for instance arranged at equal intervals, whereby a collector **64** is located in each field. However the distance between the collectors **64** can also be different, according to the degree of contamination of the tubes for instance, and can amount up to two to four field lengths. In these cases the tubes **63** between collectors **64**, e.g. in the fields without collectors, are held by supports (not shown in the drawing).

The for instance box-shaped collectors **64** with rectangular cross section and rounded edges are provided with two lateral covers **66** which can be unscrewed. They are fastened to the roller supports **49** via mountings **67, 68** fastened to the covers **66**. The mountings **67, 68** consist for instance of metal sheet plates widening towards the covers **66**. They can also consist of sections.

Via discharge lines **69** connected to the bottom of collectors **64**, the collectors **64** are connected to a vertical drainage pipe **70**. The drainage pipes **70** abut for instance via a siphon in a drainage channel or via a drainage channel in a water recipient with a water column of for instance 30 mm. In FIG. **3** the drainage pipe **70** is shown only in the lower decks.

The cross section of the tubes **63** is round. It can also be oval or elliptic, in order to increase the horizontal radiation surface.

Instead of tubes **63** the heat exchanger **27** can also have plates connected to the nozzles **58, 59**, which are for instance arranged one on the other and supported fieldwise and are provided with cleaning devices.

The width of a roller conveyor is of about 3 to 4 meters, the length of a field for instance 2.40 m. In each field there are five to seven rollers **50** arranged one after the other. The length of each of the zones **3, 4** of section A equals 20 m, the length of zone **5** of section B 50 to 70 m. The drier has 12 decks. The number of decks can vary between 8 and 14.

According to the invention during operation the boards are continuously moved on decks through the drier, by means of the driven rollers **50** of the roller conveyors. Depending on the size of the inner drier space and the width of the boards, two to four boards are arranged next to each other. Thereby the boards are successively brought into contact with the drying air in a stage A and a stage B. In this example for drying the gypsum plaster boards they are first dried in a preliminary drying stage.

Before drying the humidity of the boards amount to 45% (kg water per kg dry substance in %) and their temperature is 40° C. through the already initiated setting of the gypsum.

In the preliminary drying stage the boards run through four nozzle areas of the preliminary drying section **2**. The supply of drying air takes place in cross countercurrent with respect to the travel direction **1**, namely in the form of cross ventilations with nozzles arranged one after the other, whereby the drying air is supplied to the last nozzle area and is discharged by the exhaust **8** at the beginning of the first nozzle area. The drying air discharged from the zone **5** of section B and directed to the preliminary drying section **2** has an air humidity of 0.04 to 0.05 (kg water per kg dry air) and a temperature of 100° C. After running through the preliminary drying section **2**, the humidity of the boards amounts to 42% and their temperature to 60° to 70° C.

In stage A the boards run through the first and second zone **3, 4** of section A and are thereby brought into contact with drying air at a flow velocity of approximately 7 to 15 m/s. In each of the two zones **3, 4** the supply of drying air takes place in the form of a longitudinal ventilation according to the recirculated-air process, whereby the drying air is supplied from the recirculated-air channels **9** through the supply devices of zones **3, 4** and after passing through the zones **3, 4** it is discharged through the evacuation device into the recirculated-air channels **9**, where it is reheated. The supplied drying air has an average humidity of 0.3 to 0.5 and a high temperature of about 260° to 280° C. The discharged drying air has a slightly higher humidity also of 0.3 to 0.5 and a temperature of for instance 170° C.

In the first zone **3** of section A the drying air is supplied in countercurrent with respect to the travel direction **1** of the boards and in the second zone **4** it is guided in the same direction as the travel direction **1**. The drying air supplied to the second zone **4** can have a slightly higher temperature and a slightly lower humidity than the drying air supplied to the first stage. Besides with the aid of fans **10, 13** of stage A and the fans **29, 36** of stage B the pressure conditions in the air systems are set so that a certain amount of drying air from zone **5** of section B flows into the zone **4** of section A, and from the zone **4** of section A into the zone **3** of section A.

In section A the boards are dried to a humidity of 10 to 12%. The temperature continues to be approximately 100° C.

In stage B the boards run through the zone **5** of section B. The supply of drying air takes place in the form of a longitudinal ventilation in countercurrent to the travel direction **1** of the boards. Besides in stage B the outgoing air of stage A is guided through the heat exchanger **27** arranged in the decks of zone **5** in the same flow direction as the travel direction **1**. This way the drying air of stage B and the outgoing air of stage A are guided in countercurrent to each other.

The outgoing air of stage A is aspirated from the recirculated-air channel **9** of zones **3, 4** between the fans **10** and the burners **11** and directed through the lines **16** and **30** to the supply device of the heat exchanger **27**. It is fed via nozzles **58** into the tubes **63**, traverses the tubes **63** and the collectors **64** and is discharged via the nozzles **59** of the evacuation device of heat exchanger **27**. Thereby a part of the water vapor contained in the outgoing air condensates. The condensate is collected in collectors **64** and directed via the drainage lines **69** to the drainage pipe **70** and the drainage channel.

From the discharge device of the heat exchanger **27** the outgoing air is guided via the discharge line **35** through the heat exchanger **31** to the chimney. In the heat exchanger **31** fresh air aspirated from the outside by the fan **37** is heated and supplied to the via the discharge line **35** to the supply device for drying air.

When the drier is started, optionally fresh air aspirated by the fan **39** is heated in burner **38** and directed via the discharge line **35** to the supply device for drying air. The burner **38** can also be used for regulating the temperature of the drying air fed to the supply device.

The drying air supplied through the nozzles **53** of the supply device has a humidity corresponding to the normal humidity of the ambient air of 0.005 to 0.015 and a temperature of e.g. 60° C. While passing through the zone **5** of section B the humidity of the drying air increases to 0.04 to 0.05 and its temperature increases to about 100° C. This drying air is discharged through the discharge channel **55** of the evacuation device and supplied to the burners **11** of the zones **3, 4** of section A via the air lines **28** and the incoming air lines **15** to the burners **11** of zones **3, 4**, and over the air line **28** and the incoming air line **17** to the preliminary drying section **2**, as already mentioned.

In stage B, for drying the boards the heat is transferred to the boards through convection, as well as through radiation.

In the heat transfer through convection the boards are brought into contact with the drying air which was preheated in the heat exchanger **31** and which is heated inside the drier through contact with the heat exchanger surfaces of the heat exchanger **27**. Through a reduced mass flow of the drying air at a reduced flow cross section, the flow velocity is also set at 7 to 15 m/s. Due to the low temperature level there is no danger of the boards being overdried by heat radiation.

The heat transfer through radiation takes place over the heat exchanger surfaces of the heat exchanger **27** arranged in the decks of the drier, i.e. through nozzles **57** of the supply device, the tubes **[60]** *63*, the collectors **61** and the nozzles **58** of the discharge device.

The heat amounts transferred to the boards by convection and radiation are approximately equal. Thereby the boards are dried to a humidity of ≦0.3%. When they leave section B their temperature is 60° C., so that cooling or compartimentalization are no longer needed.

We claim:

1. A recirculated-air process for drying boards comprising the steps of:

(a) advancing a plurality of heated wet boards in succession along a board path in a travel direction through at least one first heating section and a drying section *having a first heat exchanger in decks thereof*;

(b) passing an incoming drying air having a first relatively low temperature and first air humidity along an air path in counterflow to the travel direction after passing through [a first heat exchanger provided in decks of] the drying section;

(c) [branching a portion of the] *passing* drying air from said [first heat exchanger] *drying section* into the heating section for encountering and heating the boards releasing a humidity, so that the drying air in said heating section [has] *develops* a humidity above that of the incoming air;

(d) thereafter evacuating [the] drying air from the heating section and conveying evacuated air in the travel direction toward the drying section, said evacuated air having a second temperature and second humidity higher than said first temperature and humidity of said incoming drying air;

(e) passing the evacuated air in the travel direction through the first heat exchanger in the drying section; and

(f) feeding a fresh drying air having a third temperature and humidity less than said first air temperature and humidity of said incoming drying air through said [first heat exchanger] *drying section* in the counterflow, so that the fresh air substantially reaches the first temperature and the first humidity of step (b) [upon heat exchanging with the evacuated air in said first heat exchanger].

2. The process defined in claim **1** wherein

said process further comprising the steps of:

discharging said evacuated air at the temperature from 80° to 110° C. and humidity from 0.03 to 0.1 downstream from said exchanger along said board path, and

discharging said incoming air at the first temperature from 150° to 300° C. and first humidity from 0.2 to 0.8 at a location [upstream from] *in* said heating section along said board path, said portion of the drying *air* being evacuated in step (d) at the second temperature from 120° to 200° C. and *at a* second humidity from 0.2 to 0.8 before entering said heat exchanger in step (e).

3. The process defined in claim **2** wherein [part of the portion of] the evacuated air discharged *from the heating section* upon leaving the heat exchanger is directed to another heat exchanger downstream of said first heat exchanger in said drying section for heating said fresh air before the latter enters said [first heat exchanger] *drying section* in step (e).

4. The process defined in claim **1** wherein said step (c) further [comprising] *comprises* a step of additional heating of the [potion] *portion* by a burner located along said *air* path in said heating section.

5. The process defined in claim **1** wherein said step (a) [including] *includes* a step of preliminary heating where said plurality of boards is initially heated and dried.

6. A drier comprising:

conveying means for advancing a plurality of wet and heated boards along a board path through at least one heating station and a drying station in one direction, said heating station being located upstream from said drying station;

pump means for passing a fresh drying air [having a first relatively low temperature and first air humidity] in a second direction opposite said travel direction and located downstream from said drying station, said fresh drying air becoming an incoming drying air having a [second] temperature and humidity upon leaving [an elongated heat exchanger located in] said drying station *which is formed with an elongated heat exchanger*;

said heating station including:

first supply means for branching said incoming drying air [into] *in* the [first] *heating* station for encountering said plurality of boards,

first evacuating means for pumping [said] drying air out of the heating station and conveying evacuated air in the second direction towards said drying section, said evacuated air having a third temperature and second humidity higher than said first and second temperatures and humidity of said fresh drying air and said incoming drying air;

said drying station being provided with second evacuating means spaced [upstream] *downstream* from said heat exchanger and being in flow communication with said first supply means for evacuating the fresh drying air from said [heat exchanger] *drying station* and for passing the incoming drying air along said second direction, said fresh drying air being in counterflow with said evacuated air from said heating station in said heat exchanger, said first temperature and humidity of said fresh air being lower than said second temperature and humidity of said incoming drying air.

7. The drier defined in claim **6** further comprising a heater located between said pump means and said heat exchanger.

8. The drier defined in claim **6** wherein said heating station further comprises a burner preheating said incoming air.

9. The drier defined in claim **6** wherein said conveying means includes roller conveyors.

10. The drier defined in claim **6** wherein said first heat exchanger is provided with a plurality of tubes lying parallel to said travel direction of the boards, and

a plurality of collectors spaced apart and connecting said tubes and running transversely to said travel direction.

11. The drier defined in claim **6** wherein said conveying means includes belt conveyors.

12. The drier defined in claim **6** wherein said heat exchanger [which] extends in decks above said conveying means.

13. A method of drying boards, comprising the steps of:

(*a*) *passing boards to be dried in succession through a first drying stage A and a second drying stage B;*

(*b*) *in said first drying stage A, passing a supplied hot drying air into contact with said boards to remove moisture from said boards and produce an outgoing moist air of a higher humidity than the supplied air;*

(c) in said second drying stage B, passing said outgoing air through a heat exchanger in a deck in radiation heat-exchanging relationship with said boards and collecting condensate from said heat exchanger while discharging an outgoing moist air from the heat exchanger in stage B; and

(d) simultaneously with step (c) in said second drying stage B, passing a supplied drying air into convection heat-exchanging relationship with said boards.

14. The method defined in claim 13 wherein said outgoing air of step (b) is passed through said heat exchanger in said second drying stage B in the direction of movement of said boards therethrough.

15. The method defined in claim 14 wherein said supplied drying air in step (d) is passed through said second drying stage B in a direction opposite to movement of said boards therethrough.

16. The method defined in claim 15 wherein the supplied drying air of stage B is heated before it is passed into convection heat-exchanging relationship with said boards.

17. The method defined in claim 15, further comprising the step of passing said supplied drying air of stage B and said outgoing moist air from the heat exchanger in stage B in heat exchange in another heat exchanger.

18. The method defined in claim 16 wherein steps (c) and (d) are so carried out that heat amounts transmitted to the boards by the radiation and the convection are approximately equal.

19. The method defined in claim 16 wherein said outgoing air of higher humidity is produced by using the supplied drying air of stage B, after convection heat-exchange with said boards in stage B as a part of the hot drying air passed into contact with said boards in stage A as the supplied hot drying air therein.

20. The method defined in claim 19 wherein said supplied hot drying air of stage A is heated by combustion.

21. The method defined in claim 20 wherein a part of the drying air for stage B is passed into a preliminary drying stage for said boards.

22. A drier comprising:

conveying means for advancing a plurality of wet boards along a board path through at least one first station A and one second station B in a travel direction in which said station B is being located downstream from said first station A including:

first supply means for passing hot drying air into contact with said plurality of boards to remove moisture from said boards and produce a moist air in said first station A;

first evacuating means for pumping said moist air out of the first station A and for passing said moist air towards said second station B, said second station B being provided with an elongated heat exchanger, said means of station A for passing moist air towards said second station B being in flow communication with said heat exchanger of station B;

means for collecting condensate from said heat exchanger while discharging an outgoing air therefrom;

pump means for supplying a fresh incoming air to said station B and passing said incoming air into convection heat-exchanging relationship with said boards in a direction opposite said travel direction; and

second evacuating means being in flow communication with said first supply means of station A for passing said incoming air of said station B to the supplied hot drying air of station A.

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