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EVEN et al.(10) **Pub. No.: US 2018/0142413 A1**(43) **Pub. Date: May 24, 2018**(54) **NOZZLE BOX FOR AIR-BORNE
CONTINUOUS PAPER SHEET DRYING****Publication Classification**(51) **Int. Cl.**
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CPC **D21F 5/188** (2013.01)(71) Applicant: **SOLARONICS S.A.**, Armentières (FR)(72) Inventors: **Nicolas EVEN**, Houplines (FR); **James FARINHA**, Strazeele (FR)(73) Assignee: **SOLARONICS S.A.**, Armentières (FR)(21) Appl. No.: **15/580,035**(22) PCT Filed: **Jul. 6, 2016**(86) PCT No.: **PCT/EP2016/065969**

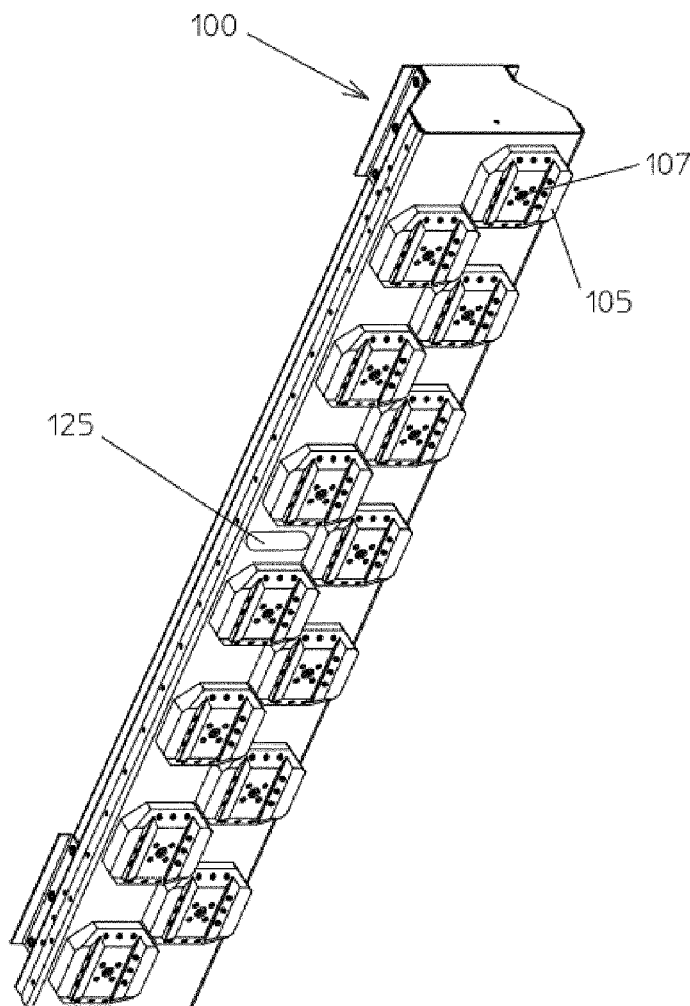
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(57) **ABSTRACT**

A nozzlebox for blowing hot gas in the convective drying zone of equipment for the continuous drying of air-borne paper sheets comprises at least one direct impingement nozzle for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried. The nozzle box comprises a plurality of inclined jet nozzles for ejecting jets of hot gas under an inclined angle with respect to the average plane of the paper sheet to be dried. At least two inclined jet nozzles are provided for which the plane comprising the vector representations of the jet directions of the at least two inclined jet nozzles does not comprise the vector representing the jet direction of a direct impingement nozzle.



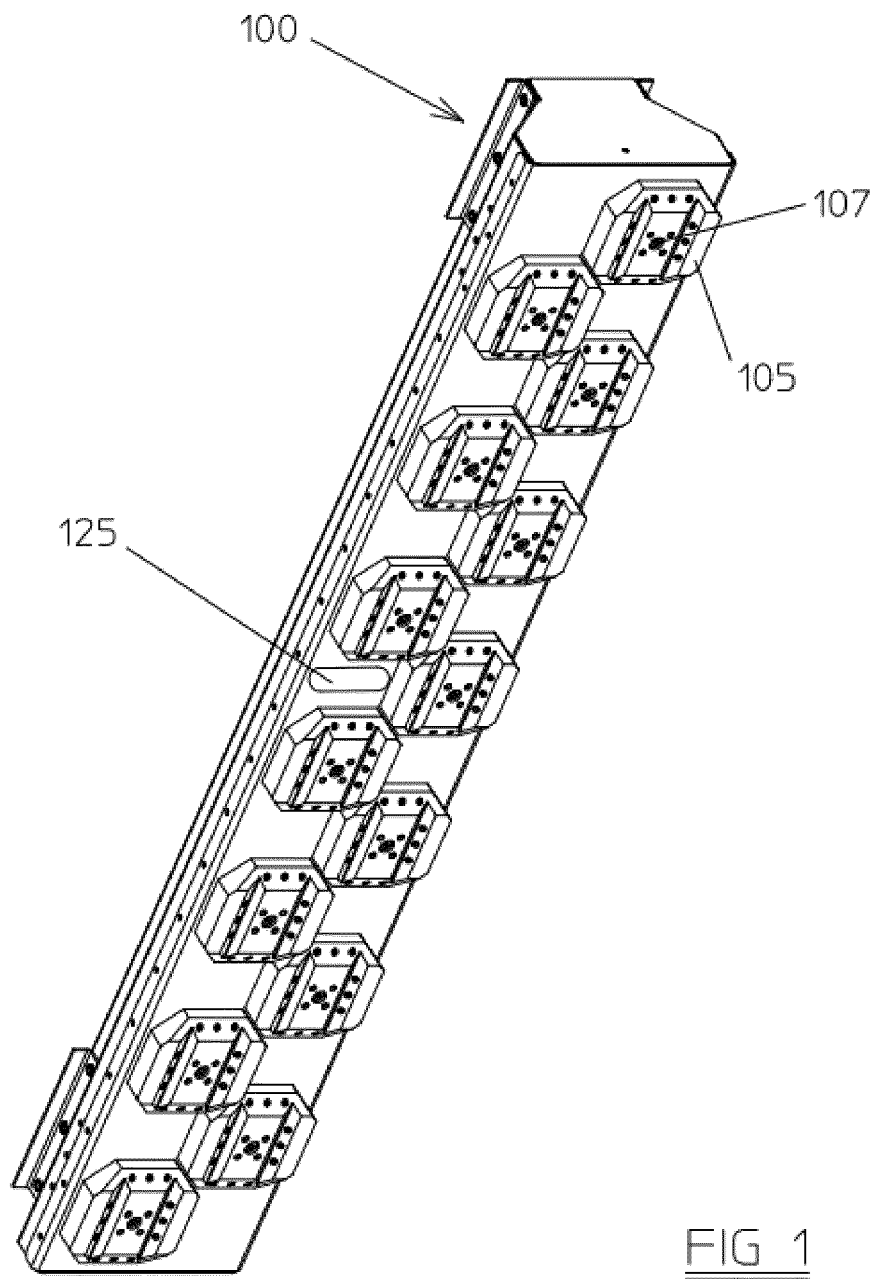


FIG 1

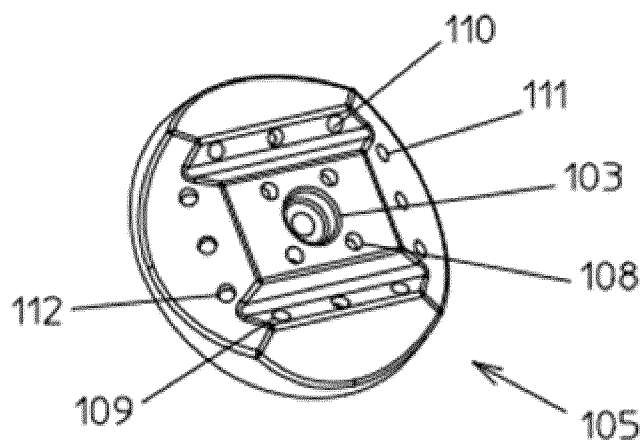


FIG 2

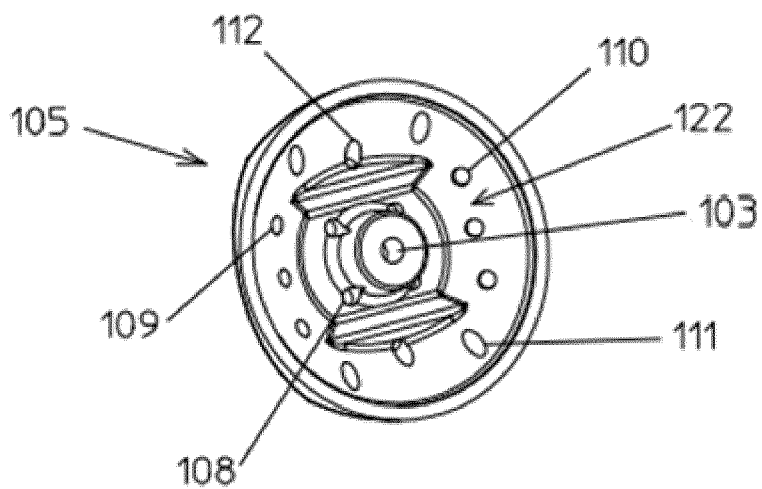


FIG 3

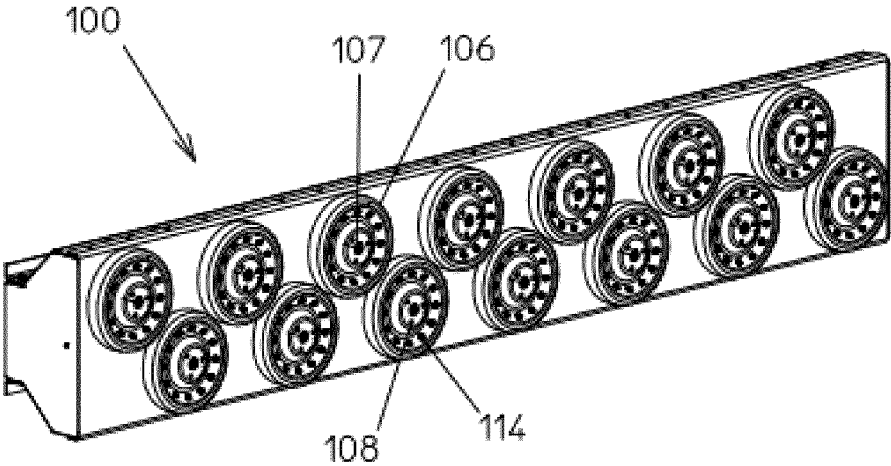


FIG 4

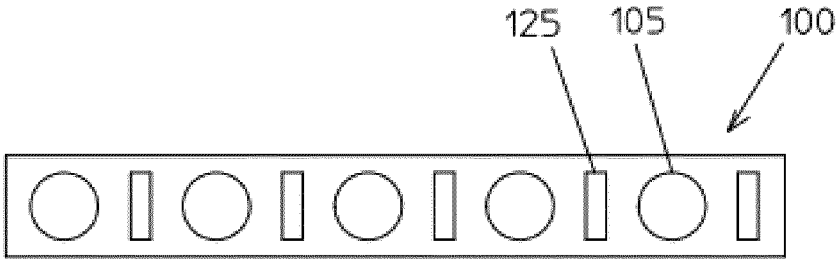


FIG 5

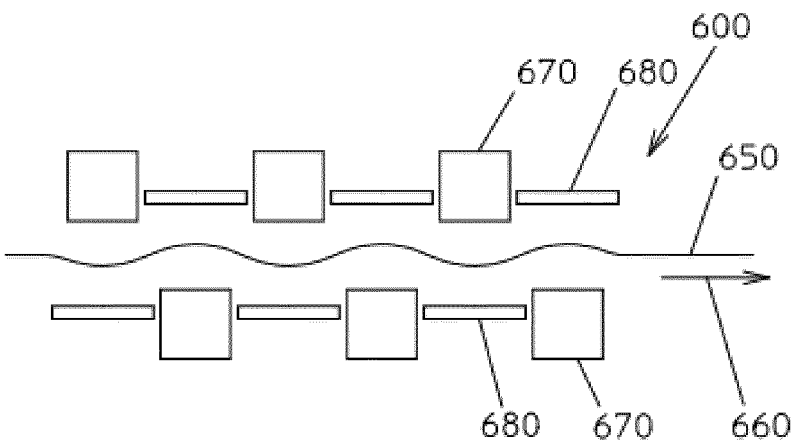


Fig. 6

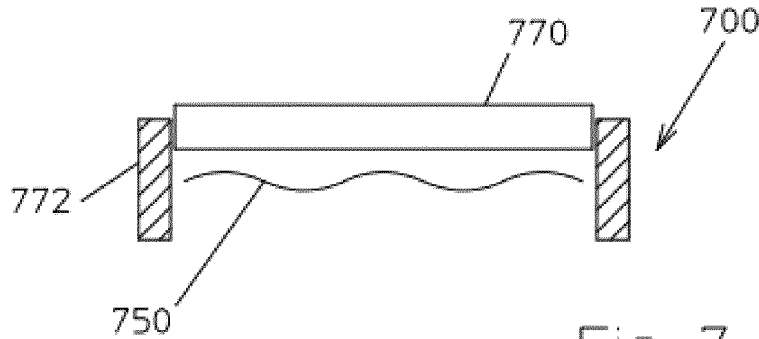


Fig. 7

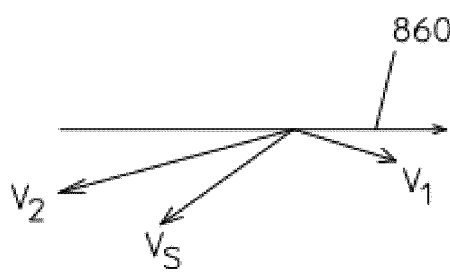


Fig. 8

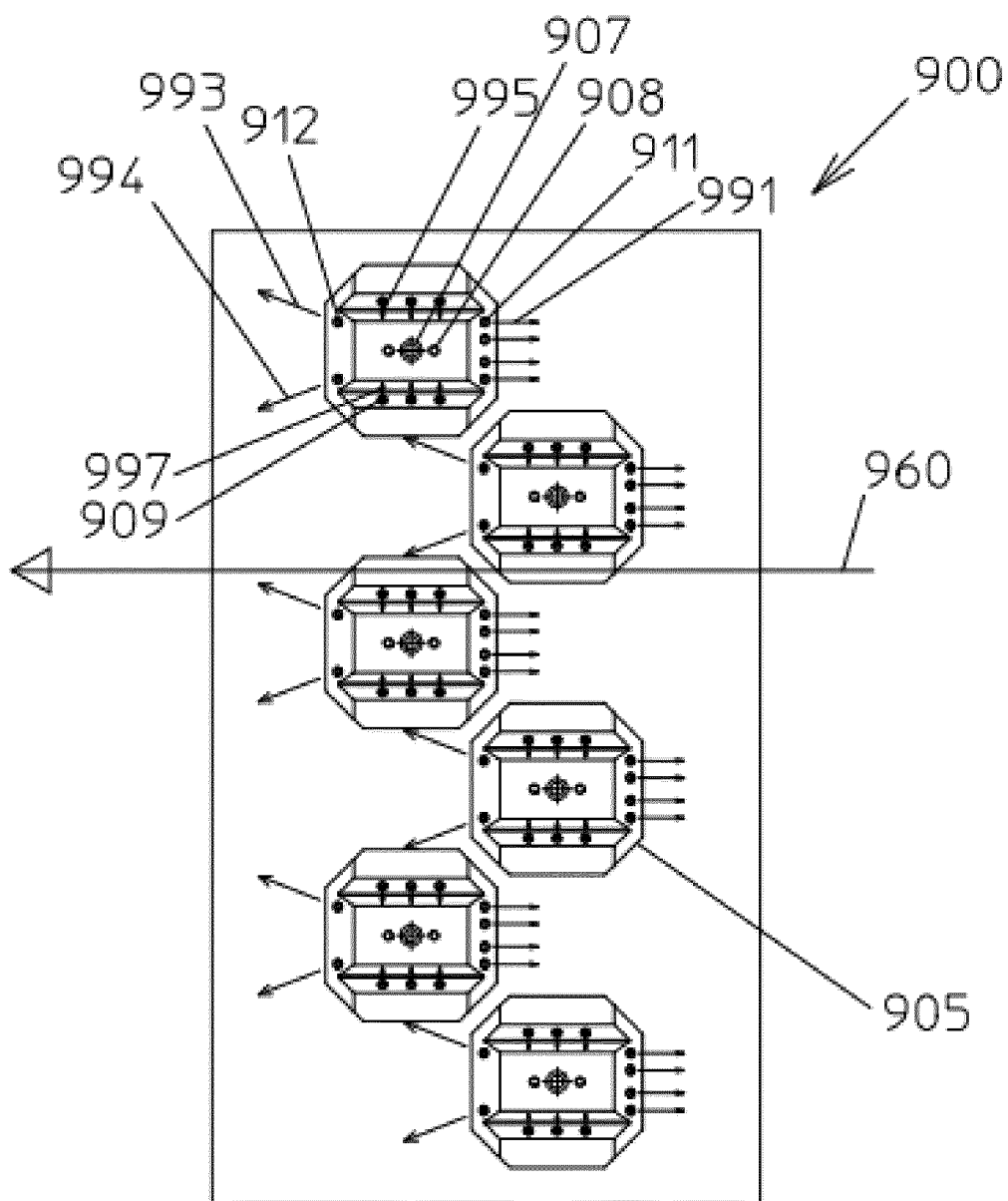


FIG 9

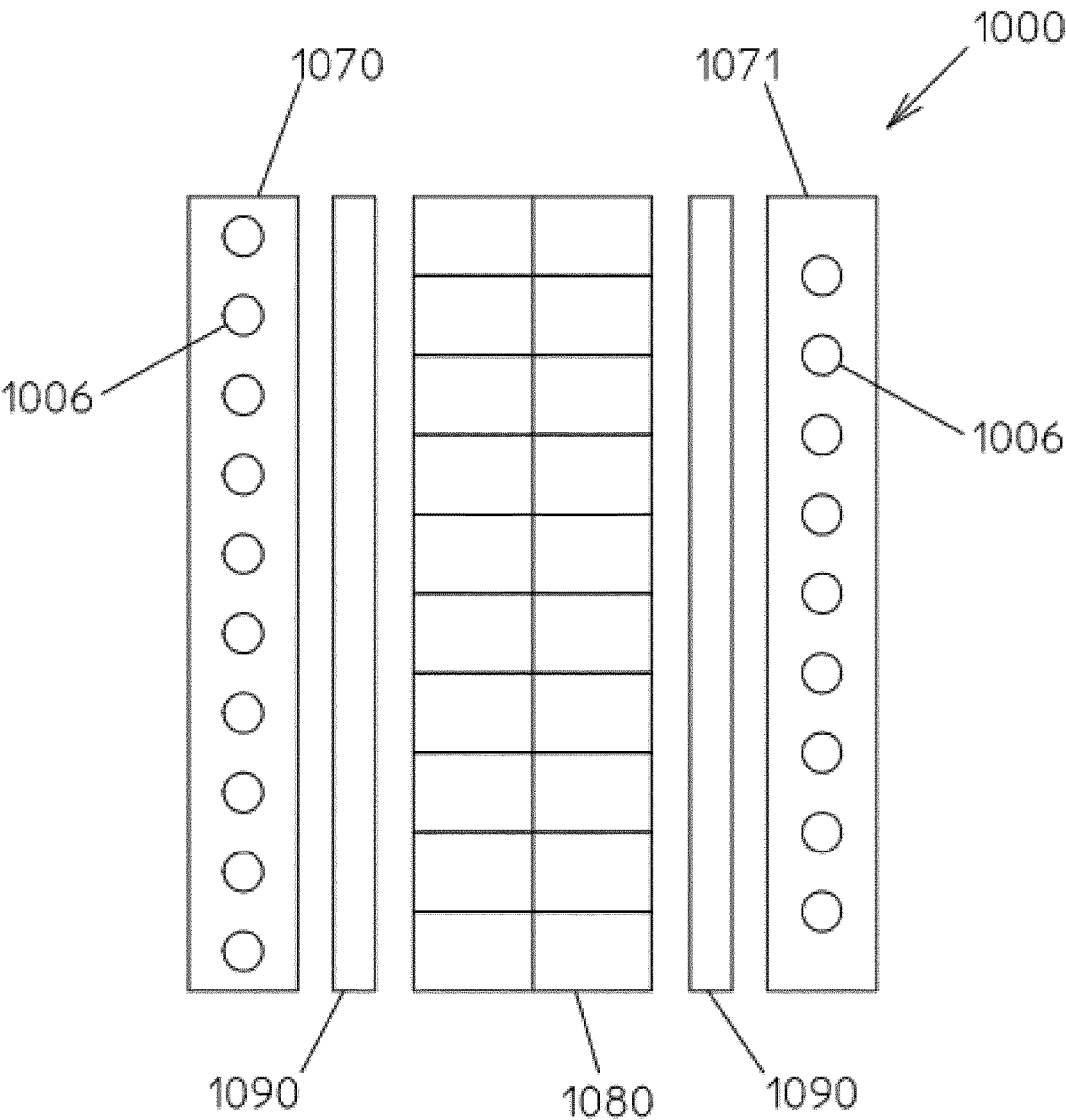


Fig. 10

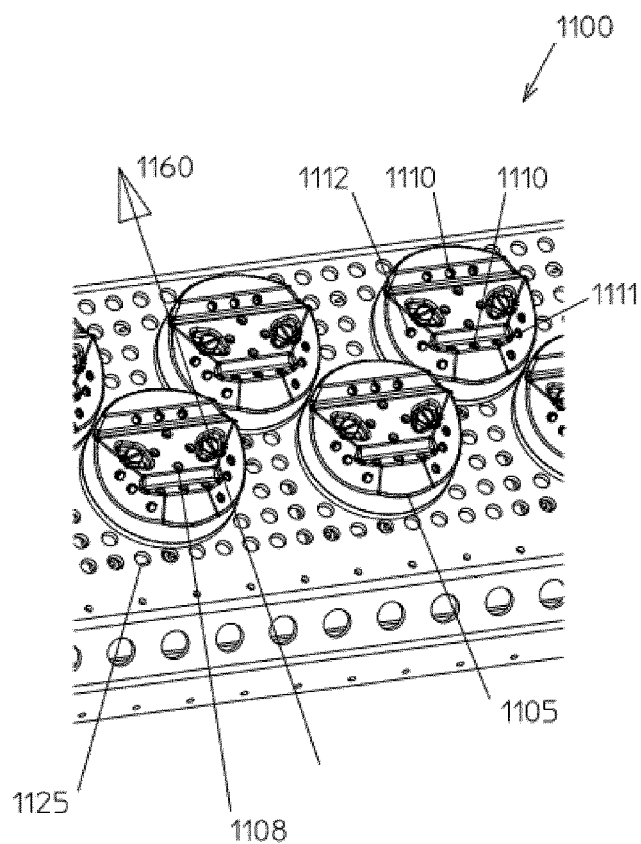


Fig. 11

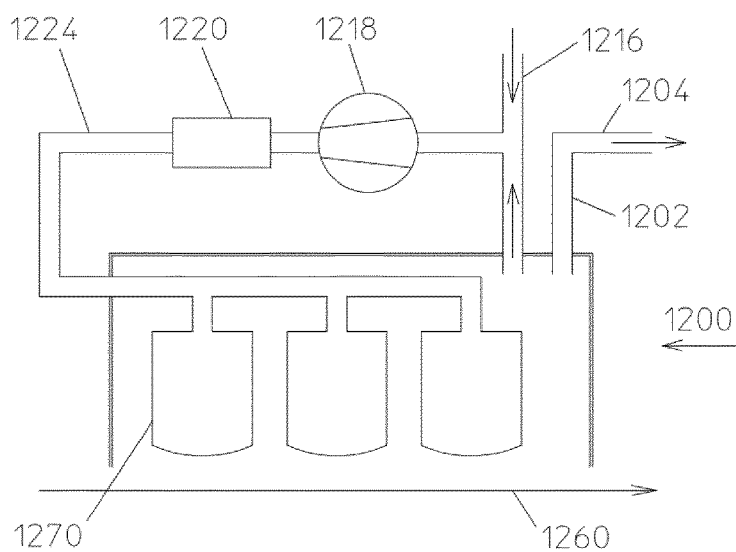


Fig. 12

NOZZLE BOX FOR AIR-BORNE CONTINUOUS PAPER SHEET DRYING

TECHNICAL FIELD

[0001] The invention relates to the technical field of nozzle boxes for continuous air-borne (or suspension) paper sheet drying equipment. The invention further relates to equipment for continuous air-borne drying of a paper or paper board sheet comprising such nozzle boxes; and to a method of operation of such equipment.

BACKGROUND ART

[0002] Air-borne or (suspension) paper or paper board sheet drying by means of convective drying or via combined radiant and convective drying is known. The paper sheet, e.g. a coated paper sheet, is borne or suspended by hot air used for drying, without the lateral selvages of the paper sheet being mechanically held in the drying chamber. Such drying systems have to provide efficient drying and correct air-borne suspension of the paper sheet being transported through the drying system.

[0003] U.S. Pat. No. 3,823,488 discloses a suspension drier. The apparatus for full-width suspension guidance of a web of material on a fluid cushion includes a plurality of nozzle boxes located adjacent one another in a direction parallel to a plane in which a web of material is disposed. The nozzle boxes are formed with respective jet nozzles inclined transversely to the direction of travel of the web. Return flow channels are provided for removing fluid blown onto the web from the jet nozzles. The return flow channels are disposed alternately with the nozzle boxes in travel direction of the web. The return flow channels are open gaps defined by respective adjacent nozzle boxes. The inclined jet nozzles are disposed respectively at both sides of each of the return flow channels. The inclined nozzles can be slot nozzles or hole nozzles. The drying performance can be further increased if, in addition to the inclined jets, jets are also directed perpendicularly to the web of material and/or the opposing nozzle boxes.

[0004] U.S. Pat. No. 6,598,315B1 discloses a nozzle arrangement in an airborne web-drying apparatus for drying a coated paper web or the like. The nozzle arrangement comprises at least one overpressure nozzle, which is arranged to blow drying air both in the web's travel direction and against the web's travel direction. The nozzle arrangement comprises further a direct impingement nozzle combined with the exit side and/or the entrance side of the overpressure nozzle. In the direct impingement nozzle a plurality of nozzle slots or nozzle orifices are formed in order to blow drying air perpendicularly towards the web. The perpendicular distance from the nozzle surface of the direct impingement nozzle to the web is larger than the perpendicular distance from the supporting surface of the overpressure nozzle. Between successive nozzle arrangements in the direction of travel of the paper web, discharge passages are provided for the evacuation of wet air. A succession of nozzle arrangements with in between discharge passages are provided both above and below the air-borne paper web. Because of the generated air flows, the paper web undulates in the direction of transport of the paper web.

DISCLOSURE OF INVENTION

[0005] It is an objective of the invention to disclose a nozzle box for use in continuous paper sheet or paper board drying equipment that results in more efficient paper drying. It is an objective of the invention to disclose convective drying equipment comprising such nozzle box or nozzle boxes, resulting in more efficient paper drying.

[0006] The first aspect of the invention is a nozzle box for blowing hot gas in the convective drying zone of equipment for the continuous drying of air-borne paper sheets, e.g. for the continuous drying of air-borne coated paper sheets. For the invention, the term "paper sheets" has to be understood as including paper board. Preferably the nozzle box is provided for installation across the width of the continuous drying equipment. The nozzle box comprises at least one direct impingement nozzle for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried. The nozzle box comprises a plurality of inclined jet nozzles for ejecting jets of hot gas under an inclined angle with respect to the average plane of the paper sheet to be dried. With a plurality is meant at least two. The nozzle box comprises at least two inclined jet nozzles for which the plane comprising the vector representations of the jet directions of the at least two inclined jet nozzles does not comprise the vector representing the jet direction of a direct impingement nozzle. For this document, a vector indicates the direction in the three-dimensional space of the average jet of hot gas ejected by a nozzle. Where relevant, the magnitude of the vector equals the jet impulse of a nozzle when the nozzle is in use. The vector is to be considered independent from its origin, in the sense that vectors can be put at other origin points while maintaining their direction in the three-dimensional space. To evaluate whether or not three vectors (e.g. a vector representing the jet direction of an impingement nozzle and two vectors each representing the jet direction of one of two inclined jet nozzles) are within one plane, the three vectors are put in a same origin point and it is observed whether or not the three vectors when put in a same origin point are lying within one plane in the three-dimensional space.

[0007] Preferably, the nozzle box comprises a plurality of direct impingement nozzles for ejecting jets of hot gas perpendicular to the average plane of the paper sheet to be dried.

[0008] The nozzle box of the invention, when used in the convective drying zones in dryers for the continuous drying of air-borne paper sheets, has shown to result in more efficient drying compared to prior art nozzle boxes. The nozzle box provides the required combination of efficient drying, with correct suspension of the paper sheet by the hot gasses ejected by the nozzles of the nozzle box, without the paper sheet being held nor guided at its lateral edges by mechanical systems such as chain or pin systems. The nozzle box provides high convective power density. Although the successful results with the inventive nozzle box are not fully understood, it is believed that the existence of turbulences in several directions increases the drying efficiency. Furthermore, more uniform drying of the air-borne paper sheets can be obtained.

[0009] Nozzles, whether direct impingement nozzles or inclined jet nozzles can e.g. be provided as circular holes (or orifices) in plate material or in cast metal, or as slots in plate material or in cast metal, or as frustoconical jet nozzles.

[0010] Preferably, the angles of the jet direction of the inclined jet nozzles with respect to the jet direction of the direct impingement nozzle or nozzles are between 20 and 75°, e.g. 30°.

[0011] In a preferred embodiment, inclined jet nozzles are provided as through holes or through slits in inclined surfaces in the nozzles box, wherein the through holes or through slits are perpendicular to the inclined surface.

[0012] Preferably, the nozzle box comprises a hot gas chamber. The hot gas chamber is provided for supplying the at least one direct impingement nozzle and the plurality of inclined jet nozzles with hot gas to be ejected by the impingement nozzles and by the inclined jet nozzles.

[0013] In a preferred embodiment, inclined jet nozzles are provided in nozzle heads that are mounted in the nozzle box. Preferably, the nozzle heads are mechanically mounted, e.g. by means of bolts or rivets in the nozzle box. More preferably, the nozzle heads are mechanically replaceably mounted in the nozzle box, so that the nozzle heads can be replaced in the nozzle box. Nozzle heads can e.g. comprise cast metal parts, with the nozzles provided in the nozzle heads e.g. by means of drilling or machining holes and/or slots.

[0014] Preferably, the nozzle box comprises at least 3 (and preferably at least 4, more preferably at least 5, more preferably at least 6, more preferably at least 7, more preferably at least 8, more preferably at least 9, more preferably at least 10, more preferably at least 11, more preferably at least 12—e.g. 12) inclined jet nozzles, wherein each of the at least 3 (and preferably at least 4, more preferably at least 5, more preferably at least 6, more preferably at least 7, more preferably at least 8, more preferably at least 9, more preferably at least 10, more preferably at least 11, more preferably at least 12—e.g. 12) inclined jet nozzles has a vector representing its jet direction when in use; wherein each of the vectors of the at least 3 (and preferably at least 4, more preferably at least 5, more preferably at least 6, more preferably at least 7, more preferably at least 8, more preferably at least 9, more preferably at least 10, more preferably at least 11, more preferably at least 12—e.g. 12) inclined nozzles have a different direction in the three-dimensional space.

[0015] In a preferred embodiment, the inclined jet nozzles comprise or consist out of a first set of inclined jet nozzles and a second set of inclined jet nozzles. The first set of inclined jet nozzles are provided for blowing in a first direction; and the second set of inclined jet nozzles are provided for blowing in a second direction. The first direction is perpendicular to the second direction. Preferably, the first direction is—when the nozzle box is installed in the convective drying zone of equipment for the continuous drying of air-borne paper sheets—in the direction of transport of the paper sheet. And preferably the second direction is—when the nozzle box is installed in the convective drying zone of equipment for the continuous drying of air-borne paper sheets—in the direction transverse to the direction of transport of the paper sheet to be dried.

[0016] More preferably, the inclined jet nozzles comprise a third set of inclined jet nozzles and a fourth set of inclined jet nozzles. The third set of inclined jet nozzles are provided for blowing in a third direction and the fourth set of inclined jet nozzles are provided for blowing in a fourth direction. Preferably, the included angle between the first direction and

the third direction is 180°; and the included angle between the second direction and the fourth direction is 180°.

[0017] Preferably, the nozzle box comprises suction openings for the evacuation of gas. The nozzle box can e.g. comprise round suction openings and/or slit-shaped suction openings for the evacuation of gas.

[0018] A preferred nozzle box comprises a plurality of nozzle units over the nozzle box. Each of the units comprise

[0019] at least one—and preferably a plurality of—direct impingement nozzle for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried; and

[0020] a plurality of inclined jet nozzles, wherein inclined jet nozzles are provided for ejecting jets of hot gas under an inclined angle with respect to the average plane of the paper sheet to be dried.

[0021] At least two inclined jet nozzles of the nozzle unit are provided for which the plane comprising the vector representation of the jet directions of the at least two inclined jet nozzles does not comprise the vector representing the jet direction of a direct impingement nozzle of the nozzle unit. Preferably, nozzle units are provided as nozzle heads mounted in the nozzle box. Preferably, nozzle heads are mechanically mounted in the nozzle box, e.g. using bolts or rivets. Even more preferably, nozzle heads are mounted in a mechanically replaceable manner in the nozzle box, e.g. by means of bolts. Preferably, suction openings for the evacuation of gas are provided in the nozzle box between nozzle units. More preferably, round suction openings and/or slit-shaped suction openings for the evacuation of gas can be provided in the nozzle box between nozzle units; wherein nozzle units can be present as nozzle heads.

[0022] Preferably, when nozzle units and/or nozzle heads are used, the nozzle units or the nozzle heads comprise a hot gas chamber. The hot gas chamber is provided for supplying the at least one direct impingement nozzle and the plurality of inclined jet nozzles with hot gas to be ejected by the direct impingement nozzles and by the inclined jet nozzles. Means, e.g. tubes or pipes, are provided in the nozzle box to supply hot gas to the hot gas chambers. More preferably a hot gas chamber in the nozzle box is arranged to provide hot gas to the hot gas chambers of each of the multiple of nozzle units. The nozzle units can be present as nozzle heads. Nozzle heads can e.g. comprise cast metal parts, with the nozzles provided in the nozzle heads e.g. by means of drilling or machining holes and/or slots.

[0023] Preferably, the nozzle units of the nozzle box have identical nozzle configurations. The nozzle units can be present as nozzle heads.

[0024] In preferred embodiments, sharp angles of nozzle units or nozzle heads are avoided in order to prevent the risk of damaging the paper in case of unplanned contacts.

[0025] In a preferred embodiment, nozzle units are linearly aligned on the nozzle box, preferably such that when installed in a drying apparatus, the nozzle units are provided linearly aligned over the width of the drying equipment.

[0026] In a preferred embodiment, nozzle units are provided staggered over the nozzle box, preferably such that when installed in a drying apparatus, the nozzle units are provided staggered over the width of the drying apparatus. In an exemplary embodiment, the first, third, fifth nozzle unit in a nozzle box are linearly aligned; and the second nozzle unit is staggered between the first and third nozzle unit; the fourth nozzle unit is staggered between the third

and the fifth nozzle unit. The even numbered nozzle units are linearly aligned; and the odd numbered nozzle units are linearly aligned, but each in a staggered position compared to the even numbered nozzle units. Preferably, at least part of the nozzle units comprise inclined jet nozzles for which the jet direction is oriented towards spaces in between the nozzle units. Preferably in such an embodiment, the even numbered nozzle units comprise inclined jet nozzles for blowing into the direction of the space between the even numbered nozzles. And preferably in such an embodiment, the odd numbered nozzle units comprise inclined jet nozzles for blowing into the direction of the space between the odd numbered nozzles.

[0027] In a preferred embodiment, the nozzle unit comprises at least 3 (and preferably at least 4, more preferably at least 5, more preferably at least 6, more preferably at least 7, more preferably at least 8, more preferably at least 9, more preferably at least 10; more preferably at least 11, more preferably at least 12—e.g. 12) inclined jet nozzles, wherein each of the at least 3 (and preferably at least 4, more preferably at least 5, more preferably at least 6, more preferably at least 7, more preferably at least 8, more preferably at least 9, more preferably at least 10, more preferably at least 11, more preferably at least 12—e.g. 12) inclined jet nozzles has a vector representing its jet direction when in use; wherein each of the vectors of the at least 3 (and preferably at least 4, more preferably at least 5, more preferably at least 6, more preferably at least 7, more preferably at least 8, more preferably at least 9, more preferably at least 10, more preferably at least 11, more preferably at least 12—e.g. 12) inclined jet nozzles have a different direction in the three-dimensional space.

[0028] When nozzle units are present as nozzle heads, preferably, the nozzle head comprises a hot gas chamber. The hot gas chamber is provided for supplying the at least one direct impingement nozzle and the plurality of inclined jet nozzles with hot gas to be ejected by the impingement nozzles and by the inclined jet nozzles. Means, e.g. tubes or pipes, are provided in the nozzle box to supply hot gas to the hot gas chambers of the nozzle heads. More preferably, the nozzle head comprises a metal body, wherein the metal body at least partly encompasses the hot gas chamber. Even more preferably, the nozzle head is fully made out of metal.

[0029] When nozzle units are present as nozzle heads, preferably, the nozzle head comprises a body out of cast metal. Preferably the impingement nozzles and/or the inclined jet nozzles are provided as drilled or machined holes and/or slots in the body. Preferably the body at least partly encompasses a hot gas chamber in the nozzle head.

[0030] In a preferred nozzle box comprising nozzle units (and possibly wherein the nozzle units are present as nozzle heads), the at least one direct impingement nozzles are provided in the central section of the nozzle unit; and the inclined jet nozzles surround the at least one direct impingement nozzles.

[0031] In a preferred embodiment, at least part of—and more preferably all—the inclined jet nozzles surrounding the at least one direct impingement nozzles are provided for blowing inwards towards the at least one direct impingement nozzle.

[0032] In a preferred embodiment, a first part of the inclined jet nozzles surrounding the at least one direct impingement nozzles are provided for blowing inwards towards the at least one direct impingement nozzle. A second

part of the inclined jet nozzles surrounding the at least one direct impingement nozzles are provided for blowing in the direction away from the at least one direct impingement nozzle.

[0033] In a preferred embodiment, the inclined jet nozzles within a nozzle unit are provided so that when the inclined jet nozzles are in operation, the hot gas jets of the inclined jet nozzles are present in equi-angularly distributed planes perpendicular to the nozzle box.

[0034] In a preferred embodiment the nozzle box comprises suction openings for the evacuation of gas and the nozzle box comprises a plurality of nozzle units over the nozzle box. Preferably, suction openings for the evacuation of gas are provided in the nozzle box between nozzle units.

[0035] In a preferred embodiment, where nozzle units are provided staggered over the nozzle box, such that when installed in a drying apparatus, the nozzle units are provided staggered over the width of the drying apparatus, suction openings or groups of suction openings are also staggered over the nozzle box, alternating with nozzle units.

[0036] In a preferred embodiment, the nozzle box comprises a plurality of nozzle heads. Each of the nozzle heads comprises a plurality of, e.g. four, direct impingement nozzles for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried. The direct impingement nozzles are preferably provided such that some lines in the direction of the nozzle box that coincide with the width direction of the paper sheet to be dried cross only one direct impingement nozzle of a nozzle head, while other lines in the direction of the nozzle box that coincide with the width direction of the paper sheet to be dried cross two direct impingement nozzles of that same nozzle head, and while other lines in the direction of the nozzle box that coincide with the width direction of the paper sheet to be dried cross no direct impingement nozzles of that same nozzle head. Such arrangement of the direct impingement nozzles has shown to provide better uniformity of heat transfer by the direct impingement nozzles to the paper sheet to be dried. Preferably, each of the nozzle heads comprises one or more than one series of inclined jet nozzles, wherein each of the series of inclined jet nozzles comprises a number of inclined jet nozzles provided on a straight line. More preferably, at least one series of inclined jet nozzles, and e.g. two series inclined jet nozzles are aligned on a line in the direction of the nozzle box that coincides with the width direction of the paper to be dried. In a more preferred embodiment, two series of inclined jet nozzles are aligned on a line in the direction of the nozzle box that coincides with the width direction of the paper to be dried; of which one series of inclined jet nozzles is provided for blowing in the direction of movement of the paper sheet to be dried; and the other series of inclined jet nozzles is provided for blowing in the direction opposite to the direction of movement of the paper sheet to be dried. More preferably, the nozzle head comprises in addition at least one series, and e.g. two series, of inclined jet nozzles that are aligned on lines that make an angle between 10 and 80 degrees with the direction of the nozzle box that coincides with the width direction of the paper sheet to be dried.

[0037] The second aspect of the invention is an equipment for continuous air-borne drying of a paper sheet, e.g. of a coated paper sheet, e.g. of paper board, e.g. of coated paper board. The equipment comprises a nozzle box as in the first aspect of the invention. The nozzle box spans the width

available in the equipment for the transport of the paper sheet. Preferably, nozzle units are provided in the nozzle box across the width available in the equipment for the transport of the paper sheet, so that the nozzles in nozzle units, e.g. in nozzle heads, in the nozzle box can address the full width of paper sheet to be dried.

[0038] Preferably, the equipment comprises more than one nozzle box as in the first aspect of the invention. Preferably, a first set of nozzle boxes as in the first aspect of the invention is provided above the plane available for transport of the paper sheet; and a second set of nozzle boxes according to the first aspect of the invention is provided below the plane available for the transport of the paper sheet.

[0039] Preferred equipment comprises rows of infrared emitters, e.g. premix gas fired infrared emitters, and nozzle boxes as in the first aspect of the invention in between rows or combinations of rows of infrared emitters.

[0040] Preferred equipment comprises one or a plurality of nozzle boxes. Means are provided for suction of hot gas through suction openings—e.g. round suction openings or slit shaped suction openings—in the nozzle boxes (e.g. between nozzle units or between nozzle heads) and/or between nozzle boxes. Means are provided to collect the sucked gas into piping. Preferably, piping is provided to evacuate part of the sucked gas out of the equipment. Means are provided for the supply of fresh air into the equipment, wherein the freshly supplied air is mixed with sucked gas. Piping is provided to recirculate at least part of the sucked gas back, together with the freshly supplied air, to the one or to the plurality of nozzle boxes for being blown onto the paper sheet to be dried by the direct impingement nozzles and by the inclined jet nozzles of the nozzles boxes. Means are provided to heat the mixture of sucked gas and freshly supplied air before it is supplied to the nozzle box(es). Such means can e.g. be a heat exchanger or a gas burner. Such gas burner can be provided such that the combustion gas of the gas burner is added to the mixture of sucked gas and freshly supplied air. Means (e.g. dampers) are provided in the piping to control the flows of the gases.

[0041] In a preferred embodiment, the equipment comprises suction openings for the evacuation of gas. In a preferred embodiment, the equipment comprises in the direction of movement of the paper sheet, a number of nozzle boxes; and between nozzle boxes, gas fired infrared emitters. Suction openings are preferably positioned between a nozzle box and gas fired infrared emitters.

[0042] In preferred equipment, one or more than one nozzle boxes are provided such that the vector sum of the vectors representing the jet direction and having as magnitude the jet impulse of the inclined jet nozzles of the nozzle box points in the opposite direction of the direction of transport of the paper sheet through the drying equipment.

[0043] Preferred equipment comprises a multiple number of nozzle boxes as in the first aspect of the invention. At least two consecutive nozzle boxes comprise nozzle units that are staggered when comparing the positions of the nozzle units in the first nozzle box of the two consecutive nozzle boxes with the positions of the nozzle units in the second nozzle box of the two consecutive nozzle boxes. Preferably, a range of infrared emitters—more preferably gas fired infrared emitters—is positioned between the two consecutive nozzle boxes. Even more preferred is when between a nozzle box and a range of infrared emitters, suction openings are provided for the evacuation of gas.

[0044] The third aspect of the invention is a method for continuous drying of a paper sheet (e.g. a coated paper sheet, e.g. a paper board, wherein equipment for continuous drying is used as in the second aspect of the invention. The method comprises the step of transporting a paper sheet, e.g. a coated paper sheet, through the equipment in order to dry the paper sheet in the equipment for continuous drying. The paper sheet is air-borne in the equipment without the selvedge of the paper sheet being held by mechanical means. The paper sheet undulates in the direction of transport of the paper sheet through the drying equipment. And the paper sheet undulates in the direction perpendicular to the direction of transport of the paper sheet through the drying equipment. Preferably, the speed of the paper sheet transported through the drying equipment is at least 50 m/min, more preferably at least 150 m/min, more preferably is at least 300 m/min, and preferably more than 500 m/min. Preferred ranges are between 300 and 2500 m/min, more preferred ranges are between 500 and 1500 m/min.

[0045] In a preferred method, the vector sum of the vectors representing the jet direction and having as magnitude the jet impulse of the inclined jet nozzles of the nozzle box, points in the opposite direction of the direction of transport of the paper sheet through the drying equipment.

[0046] Preferably, the mass per unit of time of hot gas ejected by the inclined jet nozzles of a flow box in the direction opposite to the movement of the paper sheet is more than 10% higher than the mass per unit of time of hot gas ejected by the inclined jet nozzles of the flow box in the direction of the movement of the paper sheet; and more preferably more than 20% higher, more preferably more than 50% higher, more preferably more than 75% higher, even more preferably more than 100% higher. Preferably, the mass per unit of time of hot gas ejected by the inclined jet nozzles of a nozzle box in the direction opposite to the movement of the paper sheet is less than 150% higher than the mass per unit of time of hot gas ejected by the inclined jet nozzles of the nozzle box in the direction of the movement of the paper sheet.

BRIEF DESCRIPTION OF FIGURES IN THE DRAWINGS

[0047] FIG. 1 shows an example of a nozzle box as in the first aspect of the invention.

[0048] FIGS. 2 and 3 respectively show the front and back view of a nozzle head that can be used in the invention.

[0049] FIG. 4 shows an example of a nozzle box as in the first aspect of the invention.

[0050] FIG. 5 shows yet another example of a nozzle box as in the first aspect of the invention.

[0051] FIG. 6 shows the section in paper transport direction; and

[0052] FIG. 7 shows a cross section in the traverse direction of an example of equipment for the continuous air-borne drying of a paper sheet comprising nozzle boxes as in the first aspect of the invention.

[0053] FIG. 8 shows the vectors representing the jets of the inclined jet nozzles of one of the nozzle boxes of the equipment of FIGS. 6 and 7.

[0054] FIG. 9 shows another example of a nozzle box as in the first aspect of the invention.

[0055] FIG. 10 shows an embodiment of equipment for continuous air-borne drying of a paper sheet according to the second aspect of the invention.

[0056] FIG. 11 shows an embodiment of a nozzle box as in the first aspect of the invention.

[0057] FIG. 12 shows air dryer equipment according to the second aspect of the invention.

MODE(S) FOR CARRYING OUT THE INVENTION

[0058] FIG. 1 shows an example of a nozzle box 100 as in the first aspect of the invention. The nozzle box 100 is provided for blowing hot gas in the convective drying zone of equipment for the continuous drying of air-borne paper sheets (including paper board), e.g. for the continuous drying of air-borne coated paper sheets; and is provided for installation across the width of the continuous drying equipment. The nozzle box 100 comprises a plurality of nozzle units 105 over the nozzle box. In the example, the nozzle units 105 are nozzle heads 105, that are removably mounted by means of a bolt 107 and nut onto the nozzle box 100. It is also possible that the nozzle units are integrally formed out of the material of the nozzle box. In the example—although not necessarily for the invention, all nozzle heads of the nozzle box have identical nozzle configurations. The nozzle heads 105 are provided staggered over the nozzle box, such that when installed in a drying apparatus, the nozzle units are provided staggered over the width of the drying apparatus. In the example, the first, third, fifth nozzle unit in the nozzle box are linearly aligned; and the second nozzle unit is staggered between the first and third nozzle unit; the fourth nozzle unit is staggered between the third and the fifth nozzle unit. The even numbered nozzle units are linearly aligned; and the odd numbered nozzle units are linearly aligned, but each in a staggered position compared to the even numbered nozzle units. The nozzle units comprise inclined jet nozzles for which the jet direction is oriented towards spaces in between the nozzle units. The even numbered nozzle units comprise inclined jets for blowing into the direction of the space between the even numbered nozzles. The odd numbered nozzle units comprise inclined jets for blowing into the direction of the space between the odd numbered nozzles.

[0059] Other arrangements of the nozzle units or nozzle heads in the nozzle box are possible however, e.g. the nozzle units or nozzle heads can be linearly aligned on the nozzle box, e.g. such that when installed in a drying apparatus, the nozzle units are provided linearly aligned over the width of the drying apparatus.

[0060] FIGS. 2 and 3 respectively show the front (FIG. 2) and back (FIG. 3) view of a nozzle head 105 used in the exemplary nozzle box 100 of FIG. 1. The nozzle head 105 comprises a drilled hole 103 that allows mounting the nozzle head by means of a bolt and nut replaceably into a nozzle box. The nozzle head 105 comprises four direct impingement nozzles 108 for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried. The nozzle head 105 comprises twelve inclined jet nozzles 109, 110, 111, 112, provided for ejecting jets of hot gas under an inclined angle with respect to the average plane of the paper sheet to be dried. Inclined jet nozzles 109 and 111 are provided for which the plane comprising the vector representation of the jet directions of the inclined jet nozzles 109 and 111 does not comprise the vector representing the jet direction of the direct impingement nozzles 108 of the nozzle unit. On the other hand, the plane formed by the vector representations of the jet directions of the inclined jet

nozzles 111 and 112 comprises the vector representing the jet direction of the direct impingement nozzles 108 of the nozzle unit. In the nozzle box head 105, although not necessary for the invention, the direct impingement nozzles 108 are provided in the central section of the nozzle head 105. The inclined jet nozzles 109, 110, 111, 112 surround the direct impingement nozzles 108. Inclined jet nozzles 109 and 110 are provided for blowing inwards towards the direct impingement nozzles 108. The inclined jet nozzles 109, 110, 111, 112 surround the direct impingement nozzles 108. Inclined jet nozzles 111 and 112 are provided for blowing in the direction away from the direct impingement nozzles 108.

[0061] At the inside of the nozzle head 105, a hot gas chamber 122 is provided (see FIG. 3).

[0062] The hot gas chamber is provided for supplying the at least one direct impingement nozzle and the plurality of inclined jet nozzles with hot gas to be ejected by the impingement nozzles and by the inclined jet nozzles. A hot gas chamber in the nozzle box is arranged to provide hot gas to the air chambers of each of the multiple of nozzle heads.

[0063] Optionally, suction openings 125 for the evacuation of gas can be provided in the nozzle box 100 between nozzle heads 105 (see FIG. 1).

[0064] FIG. 4 shows another example of a nozzle box 100 as in the first aspect of the invention. The nozzle box 100 is provided for blowing hot gas in the convective drying zone of equipment for the continuous drying of air-borne paper sheets, e.g. for the continuous drying of air-borne coated paper sheets; and is provided for installation across the width of the continuous drying equipment. The nozzle box 100 comprises a plurality of nozzle units 105 over the nozzle box. In the example, the nozzle units 106 are nozzle heads 106, that are removably mounted by means of a bolt 107 and nut onto the nozzle box 100. It is also possible that the nozzle units are integrally formed out of the material of the nozzle box. In the example—although not necessarily for the invention, all nozzle heads of the nozzle box have identical nozzle configurations. The nozzle heads 106 are provided staggered over the nozzle box, such that when installed in a drying apparatus, the nozzle units are provided staggered over the width of the drying apparatus. Other arrangements of the nozzle units or nozzle heads in the nozzle box are possible however, e.g. the nozzle units or nozzle heads can be linearly aligned on the nozzle box, e.g. such that when installed in a drying apparatus, the nozzle units are provided linearly aligned over the width of the drying apparatus.

[0065] The nozzle heads 106 comprise direct impingement nozzles 108 for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried. Each nozzle head 106 comprises twelve inclined jet nozzles 114, provided for ejecting jets of hot gas under an inclined angle with respect to the average plane of the paper sheet to be dried. In the nozzle box head 106, although not necessary for the invention, the direct impingement nozzles 108 are provided in the central section of the nozzle head 106. The inclined jet nozzles 114 surround the direct impingement nozzles 108. The inclined jet nozzles 114 are provided so that when the inclined jet nozzles 114 are in operation, the jets of the inclined jet nozzles 114 are present in equi-angularly distributed planes perpendicular to the nozzle box 100. Each of the twelve inclined jet nozzles 114 has a vector representing its jet direction when in use; wherein each of

the vectors of the twelve inclined jet nozzles **114** has a different direction in the three-dimensional space.

[0066] At the inside of the nozzle head **106**, a hot gas chamber is provided. The hot gas chamber is provided for supplying the at least one direct impingement nozzle and the plurality of inclined jet nozzles with hot gas to be ejected by the impingement nozzles and by the inclined jet nozzles. A hot gas chamber in the nozzle box is arranged to provide hot gas to the air chambers of each of the multiple of nozzle heads.

[0067] Optionally, suction openings for the evacuation of gas can be provided in the nozzle box **100** between nozzle heads **106**. Alternatively, in the drying equipment specific suction boxes can be mounted aligned with the nozzle box or nozzle boxes.

[0068] FIG. 5 shows yet another example of a nozzle box **100** as in the first aspect of the invention. The nozzle box **100** comprises nozzle units **105** that are linearly aligned on the nozzle box, such that when installed in a drying apparatus, the nozzle units **105** are provided linearly aligned over the width of drying apparatus. Optionally, the nozzle box is provided with suction units **125** in between nozzle units.

[0069] FIG. 6 shows the section **600** in paper transport direction; and FIG. 7 shows a cross section **700** in the traverse direction of an example of equipment for the continuous air-borne drying of a paper sheet (e.g. a coated paper sheet) comprising a plurality of nozzle boxes **670**, **770** as in the first aspect of the invention (e.g. as shown in the examples of FIG. 1 or FIG. 4). The nozzle boxes **670** span the width available in the equipment for the transport of the paper sheet **650**, **750**. The nozzle boxes **770** are mounted laterally in support structures **772**. In the example, a first set of nozzle boxes as in the first aspect of the invention is provided above the plane available for transport of the paper sheet; and a second set of nozzle boxes according to the first aspect of the invention is provided below the plane available for the transport of the paper sheet. The coated paper sheet **650** moves through the equipment in the direction indicated by arrow **660**. Although not necessary, the equipment comprises rows of infrared emitters **680**, e.g. premix gas fired infrared emitters, in between nozzle boxes **670**.

[0070] The paper sheet **650**, **750** is air-borne in the equipment without the selvedge of the paper sheet being held by mechanical means. The paper sheet **650**, **750** undulates in the direction of transport of the paper sheet through the drying equipment. And the paper sheet **650**, **750** undulates in the direction perpendicular to the direction of transport of the paper sheet through the drying equipment.

[0071] FIG. 8 shows the vectors representing the jets of the inclined jet nozzles of one of the nozzle boxes of the equipment of FIGS. 6 and 7. Arrow **860** shows the direction of transport of the paper sheet through the drying equipment. Vector V_1 represents the sum of the vectors of the inclined jet nozzles of one nozzle box that have a jet component in the direction of transport of the paper sheet through the equipment; vector V_2 represents the sum of the vectors of the inclined jet nozzles of the same nozzle box that have a jet component in the direction opposite to the direction of transport of the paper sheet through the equipment. Vector V_s is the sum of vectors V_1 and V_2 and has a component in the direction opposite to the direction of transport of the paper sheet through the drying equipment.

[0072] FIG. 9 shows another example of a nozzle box **900** according to the first aspect of the invention. The nozzle box

900 is provided for blowing hot gas in the convective drying zone of equipment for the continuous drying of air-borne paper sheets, the direction of movement of the paper sheet with respect to the nozzle box **900** is indicated by arrow **960**. The nozzle box **900** comprises a plurality of nozzle units **905** over the nozzle box. The nozzle units **905** are nozzle heads **905** which are removably mounted by means of a bolt **907** and nut onto the nozzle box **900**. The nozzle heads **905** are provided staggered over the nozzle box, such that when installed in a drying apparatus, the nozzle units are provided staggered over the width of the drying apparatus. Each nozzle head **905** comprises two direct impingement nozzles **908** for ejecting hot gas perpendicular to the average plane of the paper sheet to be dried. The nozzle head **905** comprises inclined jet nozzles **909**, **911**, **912**, provided for ejecting jets of hot gas under an inclined angle with respect to the average plane of the paper sheet to be dried. Inclined jet nozzles **909** are provided for ejecting hot gas jets in the transverse direction of the direction of movement of the paper sheet; vectors **995** and **997** show the direction of the ejection of the jets by the inclined jet nozzles **909**. Four inclined jet nozzles **911** are provided for ejecting jets in the direction indicated by arrows **991**; which is a direction opposite to the direction of movement of the paper. Two inclined jet nozzles **912** blow in the direction indicated respectively by arrow **993** and **994**, which make acute angles with the direction of movement of the paper sheet; the two inclined jet nozzles **912** blow away from each other. The provision of inclined jet nozzles **912** of which the jets make an acute angle with the direction of movement of the paper sheet; and wherein the two inclined jet nozzles **912** blow away from each other has shown to result in improved drying efficiency of paper sheet.

[0073] The inclined jet nozzles **912** are provided in the cast nozzle head **905** by drilling a skew orifice. All of the inclined jet nozzles in the nozzle head **905** are provided in the cast nozzle head via drilling orifices of the same diameter. All of the inclined jet nozzles **909**, **911**, **912** are supplied with hot gas from the hot gas chamber inside the nozzle head **905**. Therefore, the mass of hot gas ejected per unit of time is the same for each of the inclined jet nozzles **909**, **911**, **912**. The result is that the mass of hot gas ejected per unit of time in the direction opposite to the movement of the paper sheet is larger than the mass of hot gas ejected per unit of time in the direction of the movement of the paper sheet; such arrangement has shown to provide higher efficiency of the drying equipment.

[0074] FIG. 10 shows an embodiment **1000** of equipment for continuous air-borne drying of a paper sheet according to the second aspect of the invention. The equipment **1000** comprises a multiple number of nozzle boxes **1070**, **1071** as in the first aspect of the invention. Two consecutive nozzle boxes **1070**, **1071** comprise nozzle units **1006** that are staggered when comparing the positions of the nozzle units in the first nozzle box of the two consecutive nozzle boxes with the positions of the nozzle units in the second nozzle box of the two consecutive nozzle boxes. A range of infrared emitters **1080**—preferably gas fired infrared emitters—is positioned between the two consecutive nozzle boxes **1070**, **1071**. Between a nozzle box and a range of infrared emitters, suction openings **1090** are provided for the evacuation of gas.

[0075] FIG. 11 shows another embodiment of a nozzle box as in the first aspect of the invention. The nozzle box **1100**

is provided for blowing hot gas in the convective drying zone of equipment for the continuous drying of air-borne paper sheets, the direction of movement of the paper sheet with respect to the nozzle box **1100** is indicated by arrow **1160**. The nozzle box **1100** comprises a plurality of nozzle units **1105** over the nozzle box. The nozzle units **1105** are nozzle heads **1105** which are removably mounted onto the nozzle box **1100**. The nozzle heads **1105** are devoid of sharp angles in order to prevent the risk of damaging the paper in case of unplanned contacts between the paper to be dried and the nozzle head. The nozzle heads **1105** are provided staggered over the nozzle box, such that when installed in a drying apparatus, the nozzle units are provided staggered over the width of the drying apparatus. Each of the nozzle heads comprises four direct impingement nozzles **1108** each for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried. The direct impingement nozzles are provided such that some lines in the direction of the nozzle box that coincide with the width direction of the paper sheet to be dried cross only one direct impingement nozzle of a nozzle head, while other lines in the direction of the nozzle box that coincide with the width direction of the paper sheet to be dried cross two direct impingement nozzles of that same nozzle head, and while other lines in the direction of the nozzle box that coincide with the width direction of the paper sheet to be dried cross no direct impingement nozzles of that same nozzle head. Such arrangement of the direct impingement nozzles has proven to provide better uniformity of heat transfer by the direct impingement nozzles to the paper sheet to be dried.

[0076] Each of the nozzle heads comprises four series of inclined jet nozzles, wherein each of the series of inclined jet nozzles comprises a number of inclined jet nozzles provided on a straight line. Two series of inclined jet nozzles **1110** are each aligned on a line in the direction of the nozzle box that coincides with the width direction of the paper to be dried; of which one series is provided for blowing in the direction of movement of the paper sheet to be dried; and the other series is provided for blowing in the direction opposite to the direction of movement of the paper sheet to be dried.

[0077] The nozzle head comprises in addition two series of inclined jet nozzles **1111**, **1112** that are each aligned on a line that makes an angle of e.g. 60° with the direction of the nozzle box that coincides with the width direction of the paper to be dried.

[0078] Each of the nozzles—direct impingement nozzles as well as inclined jet nozzles—are provided in the nozzle head as drilled round openings perpendicular to the surface of the nozzle head where the round opening has been drilled.

[0079] Between the nozzle heads, the nozzle box is provided with suction openings **1125** for the evacuation of gas.

[0080] The nozzle box arrangement of FIG. **11** has shown particularly beneficial results in terms of drying efficiency of coated paper sheets, thanks to the particular arrangement of the direct impingement nozzles and of the inclined jet nozzles.

[0081] FIG. **12** shows hot air dryer **1200** equipment according to the second aspect of the invention. The hot air dryer equipment **1200** comprises a housing **1201** and a plurality of nozzle boxes **1270** according to the first aspect of the invention. Means are provided for suction of hot gas through suction openings—e.g. round suction openings or slit shaped suction openings—in the nozzle boxes (e.g. between nozzle units or between nozzle heads) and/or

between nozzle boxes. Means are provided to collect the sucked gas into piping **1202**. Preferably, piping **1204** is provided to exhaust part of the sucked gas out of the equipment. Means are provided for the supply of fresh air into the equipment, wherein the freshly supplied air—introduced via piping **1216**—is mixed with sucked gas. Piping **1224** is provided to recirculate—e.g. by means of a fan **1218**—at least part of the sucked gas back, together with the freshly supplied air, to the one or to the plurality of nozzle boxes for being blown onto the paper sheet to be dried by the direct impingement nozzles and by the inclined jet nozzles of the nozzles boxes. Means **1220** are provided to heat the mixture of sucked gas and freshly supplied air before it is supplied to the nozzle box(es). Such means can e.g. be a heat exchanger or a gas burner. Such gas burner can be provided such that the combustion gas of the gas burner is added to the mixture of sucked gas and freshly supplied air. Means—not shown in FIG. **12**—e.g. dampers are provided in the piping to control the flows of the gases in the different pipes or tubes.

1. Nozzle box for blowing hot gas in the convective drying zone of equipment for the continuous drying of air-borne paper sheets, the nozzle box comprises

at least one direct impingement nozzle for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried; and

a plurality of inclined jet nozzles, wherein inclined jet nozzles are provided for ejecting jets of hot gas under an inclined angle with respect to the average plane of the paper sheet to be dried;

wherein at least two inclined jet nozzles are provided for which the plane comprising the vector representations of the jet directions of the at least two inclined jet nozzles does not comprise the vector representing the jet direction of a direct impingement nozzle.

2. Nozzle box as in claim 1, wherein the nozzle box comprises at least three inclined jet nozzles, wherein each of the at least three inclined jet nozzles has a vector representing its jet direction when in use; wherein each of the vectors of the at least three inclined jet nozzles has a different direction in the three-dimensional space.

3. Nozzle box as in claim 1,

wherein the inclined jet nozzles comprise or consist out of a first set of inclined jet nozzles and a second set of inclined jet nozzles;

wherein the first set of inclined jet nozzles are provided for blowing in a first direction; and

wherein the second set of inclined jet nozzles are provided for blowing in a second direction;

and wherein the first direction is perpendicular to the second direction.

4. Nozzle box as in claim 1, wherein the nozzle box comprises suction openings for the evacuation of gas.

5. Nozzle box as in claim 1, wherein the nozzle box comprises a plurality of nozzle units over the nozzle box, wherein each of the units comprises

at least one direct impingement nozzle for ejecting a jet of hot gas perpendicular to the average plane of the paper sheet to be dried; and

a plurality of inclined jet nozzles, wherein inclined jet nozzles are provided for ejecting jets of hot gas under an inclined angle with respect to the average plane of the paper sheet to be dried;

wherein at least two inclined jet nozzles of the nozzle unit are provided for which the plane comprising the vector representation of the jet directions of the at least two inclined jet nozzles does not comprise the vector representing the jet direction of a direct impingement nozzle of the nozzle unit.

6. Nozzle box as in claim 5, wherein suction openings for the evacuation of gas are provided in the nozzle box between nozzle units.

7. Nozzle box as in claim 5, wherein nozzle units are provided as nozzle heads mounted in the nozzle box.

8. Nozzle box as in claim 5, wherein the at least one direct impingement nozzles are provided in the central section of the nozzle unit; and

wherein the inclined jet nozzles surround the at least one direct impingement nozzles.

9. Nozzle box as in claim 8,

wherein a first part of said inclined jet nozzles are provided for blowing inwards towards the at least one direct impingement nozzle;

and wherein a second part of said inclined jet nozzles are provided for blowing in the direction away from the at least one direct impingement nozzle.

10. Nozzle box as in claim 5, wherein the inclined jet nozzles within a nozzle unit are provided so that when the inclined jet nozzles are in operation, the jets of the inclined jet nozzles are present in equi-angularly distributed planes perpendicular to the nozzle box

11. Equipment for continuous air-borne drying of a paper sheet, comprising a nozzle box as in claim 1, wherein said nozzle box spans the width available in the equipment for the transport of the paper sheet.

12. Equipment as in claim 11, wherein one or more than one nozzle box as in claim 1 is provided such that the vector sum of the vectors representing the jet direction and having

as magnitude the jet impulse of the inclined jet nozzles of the nozzle box points in the opposite direction of the direction of transport of the paper sheet through the drying equipment.

13. Equipment as in claim 11, wherein the equipment comprises a multiple number of nozzle boxes as in claim 10; and

wherein at least two consecutive nozzle boxes comprise nozzle units that are staggered when comparing the positions of the nozzle units in the first nozzle box of the two consecutive nozzle boxes with the positions of the nozzle units in the second nozzle box of the two consecutive nozzle boxes.

14. A method for continuous drying of a paper sheet, wherein an equipment for continuous drying is used as in claim 11;

wherein a paper sheet is transported through the equipment in order to dry the paper sheet in the equipment for continuous drying;

wherein the paper sheet is air-borne in the equipment without the selvedge of the paper sheet being held by mechanical means;

wherein the paper sheet undulates in the direction of transport of the paper sheet through the drying equipment;

and wherein the paper sheet undulates in the direction perpendicular to the direction of transport of the paper sheet through the drying equipment.

15. Method as in claim 14, wherein the vector sum of the vectors representing the jet direction and having as size the jet impulse of the inclined jet nozzles of the nozzle box, points in the opposite direction of the direction of transport of the paper sheet through the drying equipment.

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