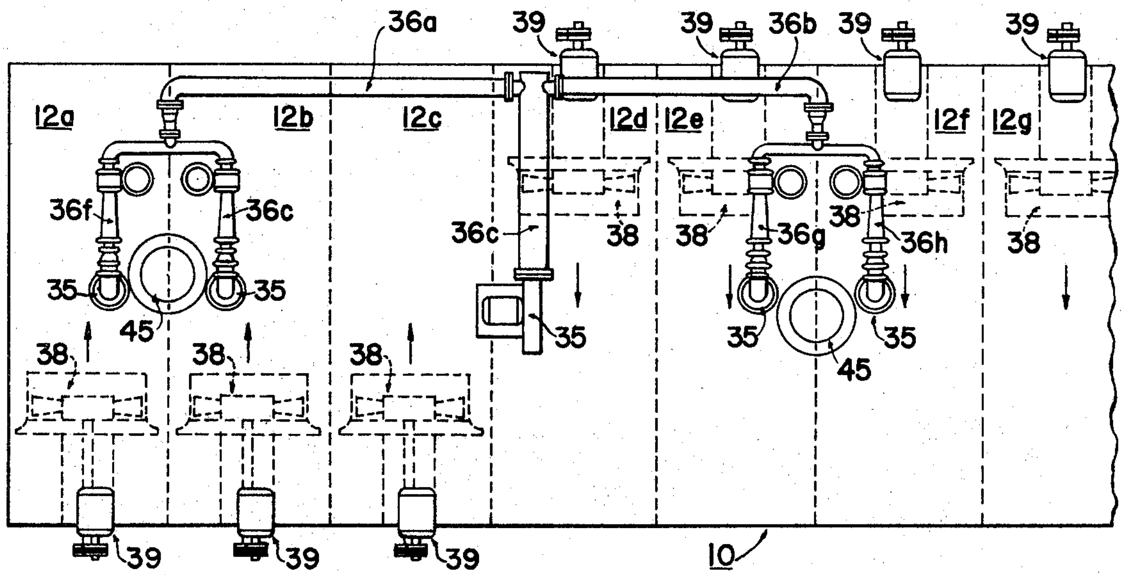
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36b
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12b
12c
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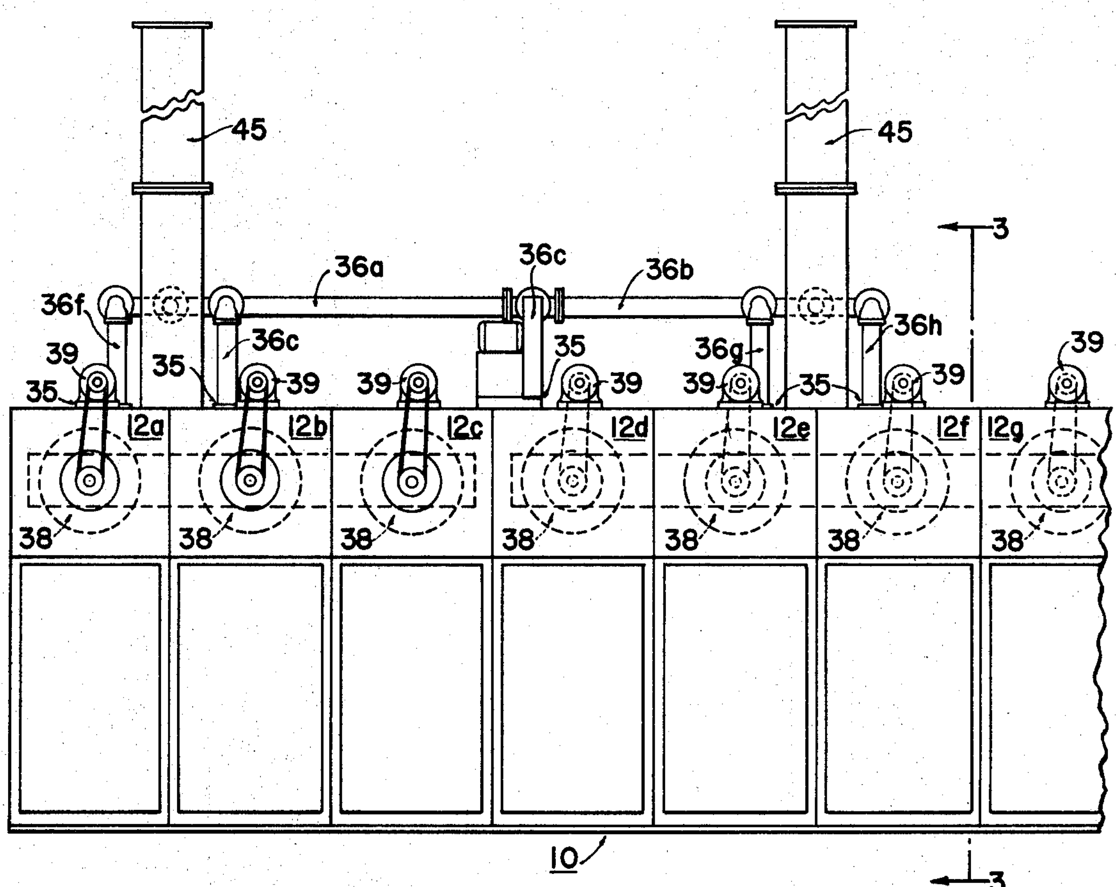
10

Fig. 1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3

Fig. 2

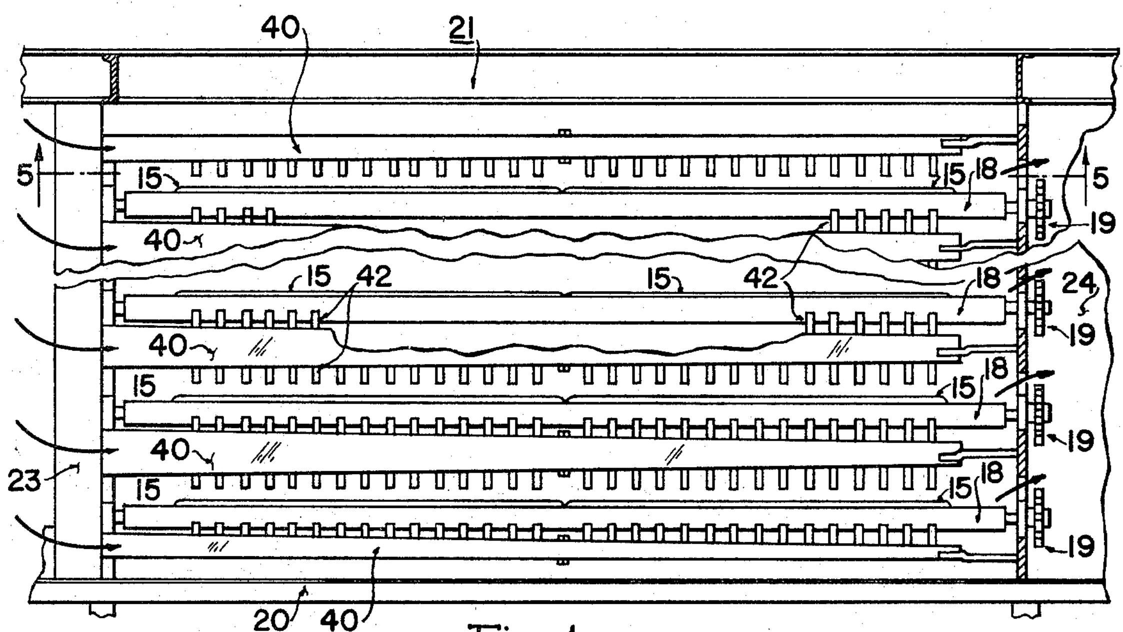


Fig. 4

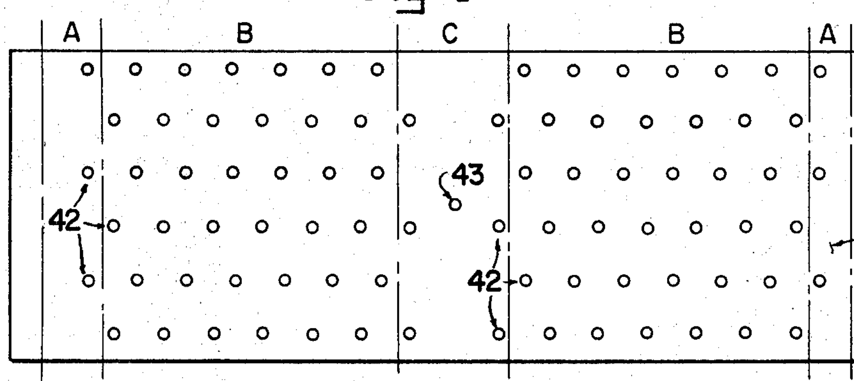


Fig. 5

Fig. 3

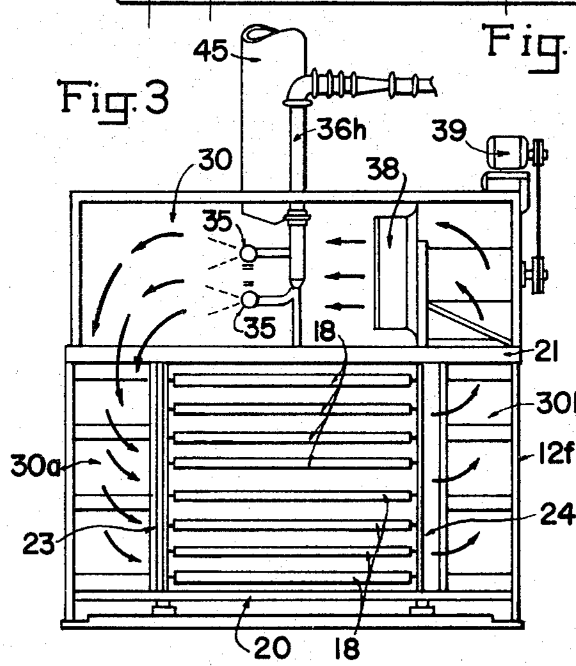
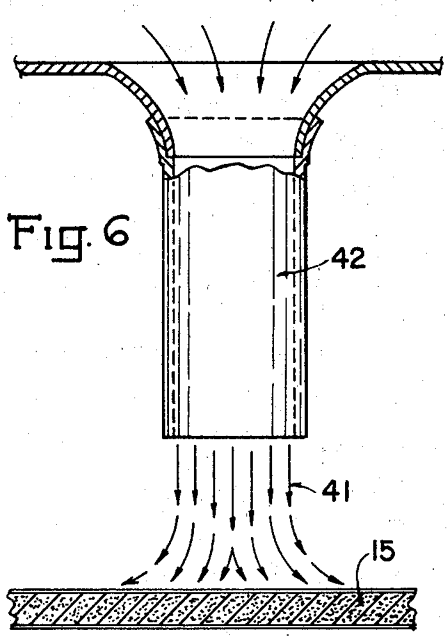


Fig. 6



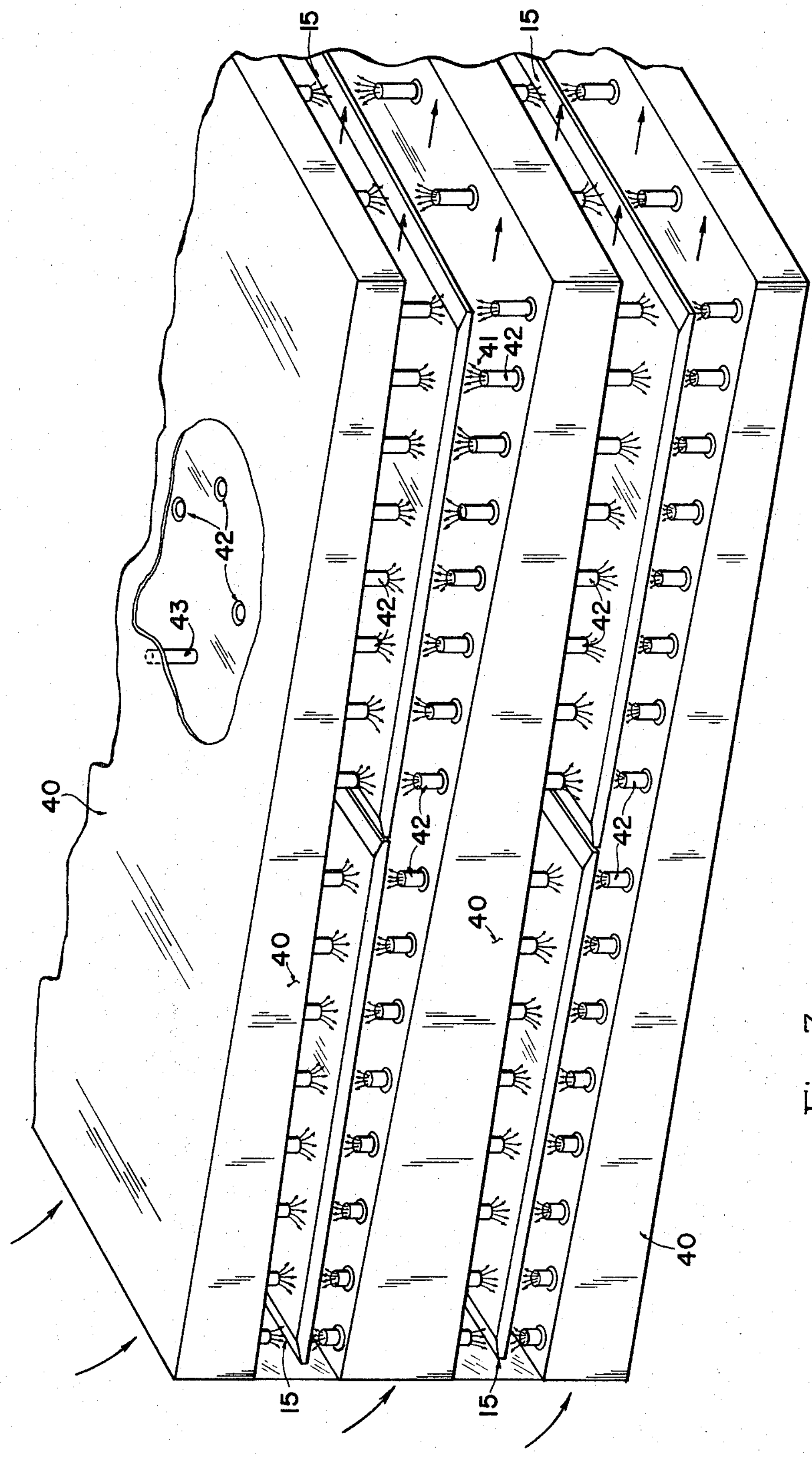


Fig. 7

United States Patent Office

3,529,357

Patented Sept. 22, 1970

3,529,357

METHOD AND APPARATUS FOR HIGH-SPEED DRYING OF GYPSUM BOARD

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Filed Sept. 20, 1968, Ser. No. 761,220
Int. Cl. F23b *3/04, 9/00*
U.S. Cl. 34—23 6 Claims

ABSTRACT OF THE DISCLOSURE

A compact, multi-tiered continuous-type gypsum drier comprising an insulated multi-zone drying chamber in which a heated air drying medium is directed through a plurality of staggered jet nozzles at high temperature (300–1,000° F.) and high velocity (2,500–10,000 feet per minute) to impinge normally against the respective major surfaces of a moving gypsum board strip. After impingement on the gypsum strip the drying medium is swept laterally to the direction of the movement of the gypsum material and then recirculated in relatively short closed loops which lie in perpendicular planes relative to the longitudinal direction of strip travel. The jet nozzles, though spaced over the width and length of the gypsum strip passing through the chamber, are clustered towards the center band of the strip so as to prevent overdrying of the edges of the gypsum board. Uniform velocity and temperature at the point of impingement of the drying medium on the gypsum strip is maintained over the width thereof by lateral tapering of the jet nozzle air boxes and by alternating the direction of lateral circulation flow in successive drier zones.

BACKGROUND OF THE INVENTION

This invention relates to an apparatus and method for the high-speed drying of gypsum board and similar mineral products in which excess moisture is removed from a moving strip of wet processed material by the controlled application of a heated air medium. More particularly, the present invention employs an insulated drying chamber having a plurality of jet nozzles directing high-temperature air at extremely high velocity to impinge at right angles against the top and bottom surfaces of a moving horizontal strip of gypsum board. Whereas the exemplary embodiment of the invention disclosed herein relates to the drying of gypsum board, in which a layer formed of a wet gypsum and binder composite is first sandwiched within a paper wrapping and then dried, it is to be understood that these teachings are also applicable to the high-speed treatment of mineral board and other similar mineral materials such as lime, plaster of Paris, clay, asbestos, etc. which, together with suitable binders added for strength and stability, are formed into strips or sheets and then subjected to drying or heat curing.

Gypsum board, often referred to as wallboard, is comprised of a layer of gypsum and binder material which while wet is first wrapped within a paper covering and thereafter dried to form the finished product. The great bulk of gypsum or wallboard is cut into 4 x 8 foot panels from continuous four-foot wide strips in which, for building construction purposes, the lateral edges are tapered to a bevel commencing approximately 1½ inches from the edges.

Conventionally, the technique for drying gypsum board material utilizes single or multi-tiered systems in which the heated air flow is recirculated through the drying chamber in a longitudinal direction, that is, parallel with the direction of movement of the gypsum strip or strips through the system. In these prior art systems the air flow

pattern at the interface of the board surfaces is always horizontal and parallel to the strip direction. Typically, a drying system would be comprised of several isolated temperature zones, each providing a region of different environmental temperature conditions for removal of excess moisture from the gypsum product.

Because of the great length of these earlier systems (sixty to one hundred fifty feet in length), together with the long air flow circulation paths within the individual chamber zones, moisture uniformity is quite difficult to obtain in the resultant product. In particular, because of the lengthy air flow patterns, a considerable drop in temperature occurs from the point at the inlet side of the chamber where the heated air enters and the outlet side where the air exits.

In order to cut down on the size of the drying system and to speed up the drying process, attempts have been made to increase somewhat the temperature of the drying medium at the entrance side of the drying chamber so that the air flow, though considerably cooled after traversing the length of the chamber, would still remain at sufficient temperature level for effective drying. However, the application of highly heated air at the relatively constricted entrance area of the drying chamber frequently creates an over-dried condition in the thin tapered edges of the gypsum board. On the other hand, when entrance temperatures are reduced in order to prevent deleterious edge softening, then oftentimes the central portion of the board is inadequately dried and sufficient excess moisture remains in the wet center portion to render the board unacceptable as a commercial product. The limitation on entrance temperature level, together with the considerable cooling which results as the drying medium travels its longitudinal path through the drying chamber, requires that the gypsum board strip either proceed relatively slowly through the drier or the chamber be very long in order that the dwell time of the gypsum therein be adequate for sufficient drying to be achieved. Thus in order to obtain reasonably high production speeds (110 feet per minute) it is necessary in conventional systems for the drying chamber, which typically is comprised of three or more sepaarte longitudinal air flow zones, to extend for three hundred seventy feet or more.

Because of the criticality required in balancing the drying environment throughout the length of the drying chamber so that both the central and edge portions of the gypsum board are dried to a uniform moisture content, existing systems usually cannot maintain consistent performance over a continuous high-speed production run. The result is that, with prior art systems, a considerable portion of the gypsum board production is not commercially acceptable for construction purposes because of nonuniform drying, and must either be culled and scrapped or cut up and used as damage to protect shipments.

SUMMARY OF THE INVENTION

It will be seen from the foregoing discussion that the soft edges and wet center problems encountered in the drying of gypsum board with prior art systems result principally because of the severe temperature gradient created by the lengthy flow path for the heated air medium which parallels the travel of the board material through the drying chamber. Also, because of the relatively low air temperatures and velocities used, the moisture is removed from the board quite slowly and therefore a drying chamber of considerable length is necessary in order to provide adequate dwell time of the material in the drier at production speeds.

In the novel gypsum drier design of the present invention a faster and more uniformly controlled removal of moisture is effected from the wet gypsum board strip through the use of a plurality of high-velocity air jets spaced throughout the drying chamber and directing high-temperature heated air normal to the surfaces of the gypsum board strip. For an equivalent production speed the overall length of the drier chamber may be substantially reduced over conventional designs because of the more efficient moisture removal provided by the jet drying action. Further, the recirculatory paths for the heated air flow are arranged in planes perpendicular, rather than parallel, to the longitudinal direction of board movement—thereby resulting in a greatly reduced path length for the air flow and an essentially constant temperature environment throughout the length of a drying zone.

The jet nozzles are disposed to direct air vertically against both the upper and lower surfaces of the moving horizontal gypsum strip and, though spaced throughout the drying chamber, are reduced in number at the location points opposing the edge areas of the strip in order to prevent overdrying of these thin critical areas.

In an exemplary embodiment described herein, the invention is in the form of a multi-zone, eight-deck drier, the eight tiers of gypsum board strips being driven through the insulated drying chamber by horizontal roll-type conveyors. The drying air medium is directly heated in the respective zones by a plurality of gas-fired burners to various temperatures within the range 300–1,000° F. and is circulated by a corresponding set of fans mounted on top of the drying chamber arranged to circulate the air flow in a series of short closed loops disposed transverse to the direction of board movement. The air flow velocity through the jet nozzle system is maintained uniform along the width of the chamber by the utilization of tapered air boxes, and the direction of lateral air flow is reversed in successive zones of the drying chamber, both expedients serving further to minimize any irregularities or unevenness in board moisture content.

It is therefore a principal objective of the present invention to provide a novel method and apparatus for effecting improved high-speed production drying of gypsum board and similar mineral products.

It is a further important objective of the present invention to provide a novel method and apparatus for production drying of gypsum board wherein more uniform drying and moisture content control are obtained, with minimal overdrying of the edges or underdrying of the center portion of the material.

It is a still further objective of the present invention to significantly reduce the size and length of a continuous high-speed gypsum board production drier by the utilization of heated air flows at temperatures and velocities substantially in excess of those heretofore employed.

It is a principal feature of the present invention that drying of gypsum board is effected by the application of high-velocity, high-temperature jet air flows directed normally to the respective major surfaces of the moving strip material.

It is another distinctive feature of the present invention that the heated air flow, used for drying of the gypsum board strip, is recirculated in closed paths of relatively short length disposed in planes perpendicular to the longitudinal direction of strip movement.

Still another distinctive feature of the present invention is the provision of a tapered construction for the laterally-arranged jet-nozzle air box sections by means of which the jets of heated air are maintained at uniform velocity over the width of the gypsum strip.

It is a principal advantage that the continuous high-speed gypsum board drying system of the present invention consistently produces a high quality gypsum board of controlled and uniform moisture content.

The foregoing and other objectives, features and advantages of the present invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary top plan view of an illustrative embodiment of the drier system of the present invention showing a portion of the longitudinal length of the drying chamber thereof, but with the remainder being identical and repetitive of the portion shown.

FIG. 2 is a front elevational view of the drying chamber shown in FIG. 1.

FIG. 3 is a cross-sectional view of the drying chamber taken along the lines **3—3** of FIG. 2.

FIG. 4 is an enlarged cross-sectional view, partially broken away, showing a detail portion of that shown in FIG. 3.

FIG. 5 is a plan view, taken along the lines **5—5** in FIG. 4, showing the arrangement and location of the jet nozzles on one of the air box modular sections of the drier system.

FIG. 6 is an enlarged detail view showing the jet nozzle construction and air flow configuration at the point of impingement on the gypsum strip.

FIG. 7 is a partially fragmentary, perspective view, on greatly enlarged scale, of a portion of a set of respective modular air box sections schematically illustrating the air flow configuration across the face of the gypsum strip.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, particularly FIGS. 1–4, there is depicted a gypsum drier system constructed according to the teachings of the present invention. The drier system is comprised of a thermally insulated chamber, generally designated as **10**, which in one typical embodiment consists of some fifteen modular six-foot long sections, each generally similar to the seven sections shown, **12*a*** . . . **12*g***, totaling some 90 feet in length. In processing, the wet gypum board material, after some preliminary conventional drying is fed in the form of strips of up to twenty-four foot length to the chamber inlet on the left-hand side of FIGS. 1 and 2. The material travels horizontally through the chamber **10** toward the right, emerging in a dry state after passing through a number of serially-connected modular sections **12*a*** . . . **12*n***.

As best shown in the cross-sectional views of FIGS. 3 and 4, illustrating a typical modular chamber section **12*f***, the drying chamber is exemplarily designed to handle eight decks of gypsum board strips and is sufficiently wide to carry on each tier two four-foot wide strips in near abutting arrangement, so that in toto the drier system has the capacity for processing simultaneously sixteen four-foot wide strips of gypsum board material. Each of the strips **15** is conveyed horizontally through the core of the drying chamber **10** by means of conventional roll-type conveyors **18** which are driven by an associated side-mounted chain-and-sprocket arrangement **19** from a suitable motor transmission means (not shown). The multi-tiered conveyor **18** and associated drive **19** are supported within the core of the chamber by a box-like skeletal framework comprised of horizontal members **20**, **21** and vertical supports **23**, **24**.

Encircling the interior core opening through which the tiers of gypsum board strip are advanced through the chamber section is a C-shaped plenum passage **30** which, together with the chamber core, provides a circular path for closed circulation of the driving medium. Tracing the flow path of the air within the chamber section, as schematically indicated by the arrows in FIG. 3, the air is first pressurized by the turbofan **38**, which is driven by an associated belt and motor **39**, and then heated to a suitable temperature within the range 300–1000° by a burner **35** supplied with gas from a pressurized line source (not shown) over a piping network **36*a*** . . . **36*h***. After heating, the air is forced laterally by the fan across the top of the plenum chamber, and then downward into the left vertical portion 30*a* of the C-shaped passage. Referring now particularly to FIGS. 4 and 5, the heated air next passes into the respective inlets of a plurality of laterally-extending hollow rectangular air boxes **40** associated with respective tiers of the conveyor **18**. The heated air exits from the air boxes at high velocity through a plurality of jet nozzles **42** spaced in a staggered arrangement over the top and bottom surfaces thereof. (As indicated in FIG. 4, the respective topmost and bottommost air boxes in the tier arrangement have their jet nozzles **42** disposed on only one surface thereof, whereas the intermediate air box sections are provided with jet nozzles on both of their respective major surfaces.)

As schematically illustrated in FIGS. 6 and 7, the heated air emerges from an individual jet nozzle **42** at high velocity, typically 2,500–10,000 linear feet per minute, to impinge perpendicularly to the horizontal surface of the moving gypsum strip **15**. The high-velocity, high-temperature jet action produces an efficient and rapid drying of the wet gypsum board material and, because of the disruption of the interface boundary layer which occurs due to the sharp right-angle impingement of the jet stream on the flat surface of the strip, the drying action is extremely thorough. The high air temperatures used, which are considerably above those conventionally employed in gypsum driers, are not injurious because the moisture is rapidly drawn from the interior of the gypsum material and quickly evaporated from the surface, thereby providing a cooling effect which protects the board from injury or discoloration.

After impingement on the gypsum strip material the air flow is swept laterally across the surface thereof (toward the right in FIG. 3) and exhausted from the core area into the right vertical portion 30*b* of the C-shaped plenum passage, and thereafter drawn upward toward the inlet ide of the turbofan **38** to complete the circulation path. Moisture carried away from the gypsum material in the drying process and collected in the gaseous medium is exhausted to the atmosphere through the vent stack **45**.

The flow of the drying gaseous medium at the critical point where the jet stream **41** impinges upon the surface of the gypsum strip **15** is schematically illustrated in the detail view of FIG. 6 and the perspective view of FIG. 7. As represented by the arrowheads, after impact the jet stream, now containing vaporized moisture drawn from the strip, sweeps out laterally to the right to exit from the core area of the chamber. In order to maintain uniformity in the velocity of the air flow **41** emanating from the respective jet nozzles **42**, each of the air boxes **40** is tapered inward along its length so as to reduce the cross section and thereby maintain the pressure head constant as the entering air stream flows deeper into the air box. Thus, as illustrated in FIG. 7, as the air stream proceeds in from the left-hand or inlet side, each of the air boxes **40** tapers gradually inward to a reduced cross section. This tapered air box configuration serves to maintain the resultant exit jet stream velocity constant over the lateral length of the air box section, and thus prevents the possibility of any uneven drying occurring along the width of the gypsum strip. In order to compensate for the lateral inward taper of the air box sections **40** away from the plane of the gypsum strip material **15** so as to thereby maintain the jet stream velocity constant at the point of its impingement with the material, it is advisable to provide as shown the jet nozzles **42** with a gradually increasing axial length as their position becomes more remote from the inlet side of the air box.

As previously mentioned, one of the more significant advantages of the present invention is the rapid drying which is achieved through the use of high-velocity, high-temperature jet streams directed perpendicularly to the plane of the moving gypsum strip. However, in order to prevent overdying of the thin beveled edge portions of the gypsum board which detrimentally results in a so-called "soft edge" condition, the density of the jet nozzle grouping on the portions of the section box opposing the edges of the gypsum board strips is reduced so that the drying action along the edge bands of each strip is considerably decreased. Thus, as shown in the plan view of FIG. 5, there is an evenly spaced, staggered arrangement of the jet nozzles **42** over the portions of the air box face opposing the major part of the lateral surface of each of the two abutting gypsum strips. This central band B corresponds to about 85–90 percent of the board's surface where the layer is of uniform thickness. However, at the edge bands A and C on either side of the two gypsum strips the number of nozzles whose jets are directly against the strip edge portions is greatly reduced to prevent overdrying. (**43** is not a nozzle but instead a central supporting spacer post for the hollow air box section.)

As previously stated, a typical gypsum drying system would consist of additional numbers of modular chamber sections **12** in addition to the seven shown. In one typical installation some fifteen of these modular chambers are serially connected so that the resulting drying chamber area has an overall length of some ninety feet. As is conventional, the temperature environment within the drying chamber is not maintained constant over its length, but is instead broken down into three or four zones of differing temperatures so as to optimize the moisture removal process and the curing of the material. Thus, in the portion of the overall chamber system shown in FIGS. 1 and 2, the seven modular sections **12***a* . . . **12***g* are divided into two temperature zones with separate drying environments being maintained therein. Sections **12***a* . . . **12***c* comprise the first zone, and the remaining four modules **12***d* . . . **12***g* serve as a second zone, with each of the zones being maintained under respective environmental conditions by associated controlled means (not shown).

A principal feature of the present invention is that the direction of lateral air flow of the drying medium over the surface of the gypsum strip is reversed in successive temperature zones. Thus, as shown by the arrows in the top view of FIG. 1, in the first temperature zone comprised of chamber sections **12***a* . . . **12***c* the air flow across the top of the plenum is from bottom to top, resulting in a cross-circulation flow across the surfaces of the tiered gypsum board strips which, when looking at a right-hand end view, is from right to left or clockwise. However, in the second temperature zone, chamber section **12***d* . . . **12***g*, the direction of flow is reversed so that the cross-circulation lateral air flow across the surfaces of the tiered strips is from left to right or counter-clockwise as shown in FIG. 3. This reversal of cross-circulation directional flow virtually eliminates any irregularity in drying action across the surface of the board by compensating for any gradient effects due to cooling or moisture saturation which would otherwise be present as the drying medium sweeps laterally across the strip.

From the foregoing description, taken together with the schematic illustrations of the air flow circulation, it will be recognized that, in contradistinction to conventionla prior art drying systems wherein the air flow parallels the longitudinal movement of the strip through the chamber, the air flow in the present scheme follows a lateral circulatory path of very short length, sharply reducing the magnitude of any temperature or humidity gradient in the drying medium. This greatly increases the effectiveness of the drying action and materially speeds up the drying of the gypsum board material, while minimizing any irregularity or unevenness in the moisture content of the finished board product.

By way of contrast to gypsum board dryer systems heretofore employed, an operative embodiment of a mult-tiered drier system constructed according to the teachings of the present invention which was recently installed in a commercial gypsum plant is now satisfactorily processing sixteen strips of four-foot wide gypsum board on a continuous production run basis at the rate of 110 feet per minute with far better quality control in contrast to a drying chamber of conventional design requiring 40 percent greater length for the same production capacity.

What is claimed is:

1. Apparatus for simultaneously heat-treating a multiple number *n* of layers of substantially impervious planar material having substantial cross-sectional thickness comprising: a plurality of modular sections coupled together to form a longitudinally-extending heat-insulated chamber having a core opening extending as a tunnel through the length thereof; means for horizontally supporting said layers in spaced relationship within said chamber tunnel core and for advancing said layers therethrough; and each of said modular sections having $n+1$ number of laterally-extending hollow air boxes positioned in a vertical stack transversely across said core opening and interdigitally spaced with respect to said layers, each of said air boxes having a plurality of nozzles disposed in a spaced array horizontally thereover for directing jets of high-temperature, high-velocity air to impinge normally against respective major surfaces of said material layers, with the intermediate ones of said air boxes having said nozzles disposed on both upper and lower horizontal surfaces thereof, means for coupling a source of pressurized heated air to the respective inlets of said air boxes, and means directing said air jets, after impingement against said respective major surfaces, laterally and unidirectionally across said surfaces in a sweeping motion for exit from said core.

2. An apparatus as set forth in claim **1** wherein the air stream in at least one of said respective modular sections, after impingement on said material, flows laterally and unidirectionally across the major surfaces thereof in a counter direction to that of corresponding air streams in others of said modular sections.

3. Apparatus for drying gypsum board material comprising: a longitudinally-extending heat-insulated chamber having a core opening extending as a tunnel through the length thereof, drive means for advancing said material horizontally through said chamber tunnel core, a plurality of nozzles arranged in a spaced array throughout said chamber and coupled to a source of pressurized heated air for directing jets of high-temperature air at high velocity

substantially perpendicularly to the major surfaces of said material advancing through said tunnel, and means for directing said air jets, after impingement on said material, to flow laterally across the major surfaces thereof in a unidirectional sweeping action transversely to the directon of movement of said material.

4. A method for heat-treating gypsum board material of the type having tapered lateral edges comprising the steps of: advancing said material in direction of its strip length through a controlled environmental region, subjecting said material within said region to a plurality of jet streams of high-velocity, high-temperature air directed substantially perpendicularly to the major surfaces of said moving strip, with the number of jet streams impinging against the thin edge portions of said material as it travels through said environmental region being substantially less than the corresponding number of jets impinging against the remaining portion of said material.

5. The method set forth in claim **4** further characterized in that said jet streams impinge on said material at a temperature not less than 300° F. and at a linear velocity not less than 2,500 feet per minute.

6. The method set forth in claim **4** further characterized in that said jet streams, after impingement on said gypsum board material, flow laterally across the major surfaces thereof in a sweeping action transervsely to the direction of movement of said material through said environmental region.

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EDWARD J. MICHAEL, Primary Examiner

U.S. Cl. X.R.

34—148

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,529,357 Dated September 22, 1970

Inventor(s) Henry W. Schuette et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 2, line 36, after "or" insert --that--;
43, correct spelling of "separate";
54, for "damage" substitute--dunnage--.

Col. 4, line 39, change "length" to --lengths--.

Col. 5, line 37, change "ide" to --side--.

Col. 6, line 47, change "section" to --sections--;
lines 59-60, correct spelling of "conventional".

Col. 8, lines 5-6, correct spelling of "direction";
line 26, correct spelling of "transversely".

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NOV 24 1970

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Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents

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USCOMM-DC 60376-P69
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