Nov. 22, 1949 H. A. THORNBURG 2,488,997

METHOD AND APPARATUS FOR COOLING

Filed March 23, 1945 2 Sheets-Sheet 1

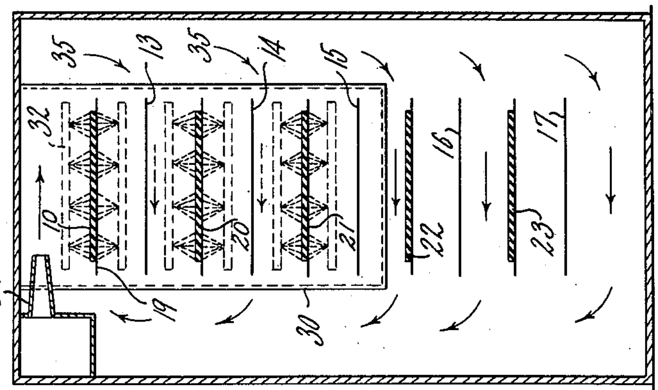

Fig. 2

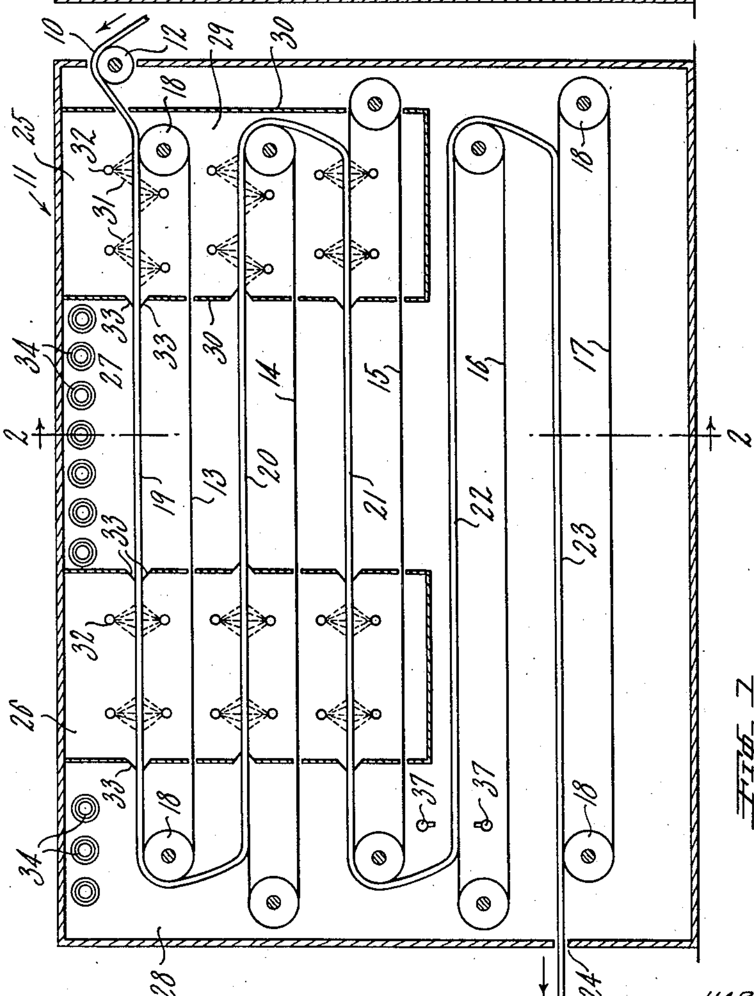

Fig. 1

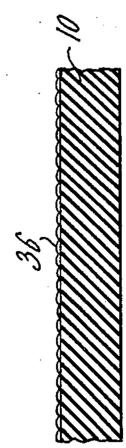

Fig. 3

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METHOD AND APPARATUS FOR COOLING

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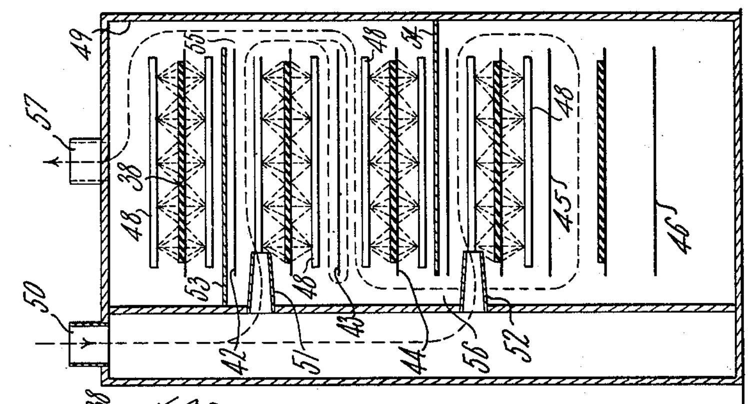

Fig-5

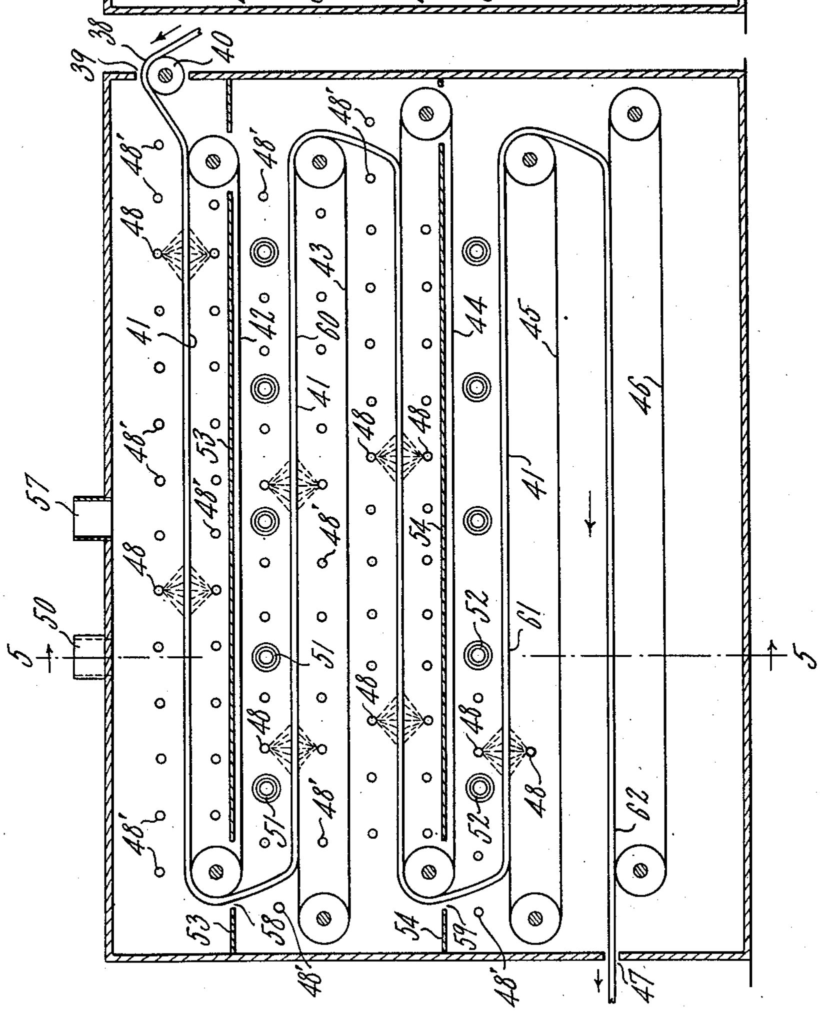

Fig-4

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METHOD AND APPARATUS FOR COOLING

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9 Claims. (Cl. 117—103)

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This invention relates to an improved method and apparatus for cooling materials by successively evaporating liquid films in intimate contact with the surface of said materials, and thereby utilize the latent heat of evaporation of the films of liquid as a means of absorbing at least 25% of the heat from the surface of the materials to be cooled and reducing the temperature of such materials so treated.

In the practice of the invention, an evaporative liquid is applied in a thin film to the surface of the material and it is quickly evaporated and carried off by the surrounding atmosphere. These operations are successively repeated until the material is reduced to the required temperature in a novel apparatus to be hereinafter described.

This invention is particularly applicable to cooling from above 70° F. water absorptive plastic sheet materials where the absorption of the water in a cooling water bath may be disadvantageous because of its injurious effect on the materials, or because of prolonged drying operations that may be required to eliminate the moisture. Heretofore, such materials have been cooled by circulating air over them. The transfer of heat from such materials to air is relatively slow as compared to the heat transfer from such materials to an evaporating film in direct contact with the materials. The thin films of liquid deposited on the surface of the materials in accordance with my invention do not penetrate into the body of the materials, because they are quickly evaporated by the effect of the heat within the materials and the non-saturated surrounding atmosphere. Also the heat transfer under such conditions is more rapid and efficient than in the case where the heat is transferred directly into the surrounding atmosphere. Therefore, in accordance with my invention the absorption of water into the materials by the immersion of the materials into the water is eliminated, and a more rapid cooling of the material can be obtained with the use of an atmosphere having a lesser temperature differential between it and the materials to be cooled.

The objects and advantages of this invention will be more clearly understood by referring to the following description and the accompanying drawings, in which:

Fig. 1 is a cross-sectional view of an apparatus embodying this invention and adapted to carry out the method;

Fig. 2 is a cross-sectional view of the apparatus, taken on line 2—2 in Fig. 1;

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Fig. 3 is a cross-sectional view of the material to be cooled illustrating the liquid film thereon;

Fig. 4 is a cross-sectional view of another form of an apparatus embodying this invention; and

Fig. 5 is a cross-sectional view of the apparatus shown in Fig. 4 and taken on line 5—5 of that figure.

As illustrated herein the material to be cooled is in the form of a continuous plastic rubber slab as it comes from a mill or extruder. The material is at an elevated temperature, and for example it may be at a temperature of 250° F. Referring to Fig. 1, the sheet material 10 to be cooled is led into the apparatus 11 over a roller 12 and is supported by a series of wire mesh conveyor belts 13, 14, 15, 16, and 17 or of any other type adapted to permit the free passage of air and water. The conveyor belts are supported at each end of their runs by means of rollers 18, which may be driven from drives located within or without the enclosure for the apparatus. The sheet material 10 is first deposited upon and passes along the top reach 19 of the belt 13 and then passes successively to the top reaches 20, 21, 22, and 23 of the belts 14 to 17, inclusive, and after having been reduced in temperature it passes out of the apparatus through an opening 24. In its travel, the material 10 passes successively through film applying stations 25 and 26 and film evaporating stations 27 and 28, which latter are arranged in a series with or interposed between the stations 25 and 26.

The film applying stations 25 and 26 are substantially alike, and only one of them will need to be described. The station 25 comprises a compartment 29 enclosed in walls 30 through which the material 10 on the conveyor belts 13, 14, and 15 is adapted to pass. The evaporative cooling liquid is applied in a thin film to the material 10 by fog sprays 31 which are directed to the upper and lower surfaces of the material from nozzles 32. As the material passes out of the compartment, any excess liquid is wiped off by rubber squeegees 33, which make contact with the upper surface of the sheet material 10, or the lower surface of the upper run of the belts.

As the material is passed into the evaporating station 27, a drying atmosphere, such as unsaturated air, is circulated about the material. The air is supplied from nozzles 34 and is caused to circulate about the material as shown by the arrows 35 in Fig. 2. The air may be discharged from the apparatus through any suitable openings, such as at the entry and exit of the material 10, or special openings provided therefor in the enclosure. The unsaturated air quickly or almost instantly evaporates the film and carries it off in the form of vapor.

This quick or so-called "flash" evaporation of the liquid in contact with the surface of the material, utilizes the latent heat of evaporation of the film for extracting the heat from the material.

The sheet material 10 next passes by the squeegees 33 into the film applying station 26 where it is treated in the same manner as described in reference to station 25. The material then passes by the next advanced squeegees 33 into the next evaporating station 28, where the film is dried in the same manner as described in reference to the evaporating station 27. The material 10 successively passes through the stations and its temperature is progressively reduced as each film is evaporated from the material 10. The thickness of the film 36 is relatively thin as shown in Fig. 3. Its thickness is preferably no greater than a film retained by the surface tension of the cooling liquid. Where the term "thin film" occurs, it means a film no greater in thickness or depth than that retained as a result of the surface tension of the liquid on a rough or smooth surface, whether in a horizontal or vertical position, and whether the film is applied in the form of a spray, or by dipping and draining the material. In the final drying operation, a strong drying current of air may be directed upon the top and bottom surfaces of the material by the nozzles 37 to insure complete dryness.

The modified form of the apparatus disclosed in Figs. 4 and 5 is adapted to cool the material 38 as it moves continuously through the apparatus, or to cool the material in a step by step movement therethrough. The apparatus will first be described in reference to the continuous movement. The warm sheet material 38 to be cooled is led into the apparatus through an opening 39 over a roller 40 and onto the top reach 41 of a conveyor belt 42. Then it is led successively to the top reaches 41 of the belts 43, 44, 45 and 46. The material 38 passes from the belt 46 out of the apparatus through an opening 47 at a reduced temperature. Transversely extending rows of fog spray nozzles 48 are arranged above and below the sheet material 38 and are spaced along its path of travel for the purpose of depositing thin films of liquid on the top and bottom surfaces of the material. Additional spray nozzles 48′ are incorporated in the apparatus for a purpose to be hereinafter described. After each film of the desired thickness is deposited upon the surface it is evaporated by the effect of the heat imparted thereto by the material 38 and a non-saturated atmosphere circulated in contact therewith, before the next film is applied. Ordinarily the thickness of the films is controlled by the sprays 48, but if desired squeegees or pressure rollers may be used for that purpose.

The path of travel of the material 38 in the apparatus is enclosed by walls 49. The air for evaporating the films of liquid is supplied to the enclosure under a suitable pressure through an inlet duct 50. The air is discharged from the duct 50 into the enclosure through an upper set of air circulating nozzles 51, and a lower set of air circulating nozzles 52. As shown in Figure 4, the nozzles 51 and 52 are arranged so that the incoming streams of air flowing therefrom do not fall directly upon the sprays of fog delivered by the fog spray nozzles 48. Therefore the fog will fall or impinge upon the surface of the material 38 and form a film thereon before it is evaporated by the incoming streams of air. In order to increase the capacity of a given quantity of air to conduct heat away from the material 38 and to vaporize the films of liquid or absorb moisture, the incoming air is circulated around the cooler portions of the material 38 first, and then progressively circulated around the warmer portions of the material. This increase in the capacity of the air to absorb heat and moisture results from the air being heated to the highest temperature by the hottest portion of the incoming material 38 and from the air being capable of absorbing more moisture at the increased temperature. With this in view baffles 53 and 54 are provided to cause the incoming air from the nozzles 51 and 52 to progressively circulate over the films in a direction from the cooler portions of the material 38 towards the warmer portions of such material. The incoming material 38 above the baffle 53 is the hottest, and it is progressively cooled in the compartment between the baffles 53 and 54 and the compartment below the baffle 54. The baffle 53 is positioned above the nozzles 51 and is attached to the wall of the duct 50, and a space or opening 55 is provided between the edge of the baffle 53 and the wall 49 so that the air delivered by the nozzles 51 can pass over the hottest portion of the material 38 after having circulated about the cooler portions on the upper reaches of the belts 43 and 44, which are positioned between the baffles 53 and 54. The baffle 54 is placed immediately above the nozzles 52 so as to separate the incoming air of those nozzles from the air delivered by the nozzles 51, until the air from the nozzles 52 has circulated about the cooler runs of the material 38 on the top reaches 41 of the belts 45 and 46. The baffle 54 is attached to the wall 49, and a space or opening 56 is provided between the edge of the baffle 54 and the wall of the duct 50, so as to permit the air from the nozzles 52 to pass by the baffle 54 and mix with the air discharged from the nozzles 51, after the air from the nozzles 52 has been first circulated around the cooler portions of material 38 carried by the belts 45 and 46. The air from the nozzles 52 commingles with the air from the nozzles 51 in the compartment between the baffles 53 and 54 and is further heated, thereby increasing its capacity to take up additional moisture. The commingled air passes through the opening 55 around the baffle 53 in the compartment above the latter baffle, where the temperature of the atmosphere is the hottest. Consequently, the air in the compartment above the baffle 53 will become additionally heated and will be capable of taking up additional moisture and will have a further cooling effect on the first and top run of the material 38, although the film of liquid deposited by the nozzles 48 in that compartment may not be completely evaporated. The moisture laden atmosphere is discharged through the outlet 57.

In the operation of the method in connection with the continuously moving material 38 through the apparatus disclosed in Figs. 4 and 5, the hot sheet material 38 in the compartment above the baffle 53 is sprayed by two rows of fog spray nozzles 48 above and below the sheet during the continuous travel of the material. The film deposited by the first row will immediately flash into vapor, if the temperature of the material is sufficiently high. As many more additional rows of spray nozzles are provided as may be necessary to deposit films that may be carried by the material through an opening **58** in the baffle **53** to the compartment below. Any films carried to that compartment or deposited on the material therein are evaporated in succession by the heat of the material **38** and the air from the nozzles **51** or the air commingled therewith from the nozzles **52**. The air is directed over the films as indicated by the arrows in Fig. 5, and each film is substantially evaporated before the next is applied. The sheet material then passes through the opening **59** in the baffle **54** and on to the top reach **41** of the belt **45**. Any film remaining thereon is evaporated by air from the first of the air nozzles **52**, and then a succeeding film is deposited by the next spray nozzles **48**. A series of air nozzles **52** following the last row of spray nozzles **48** is provided in order to insure the complete evaporation of the last film of liquid applied.

The operation of the apparatus shown in Figs. 4 and 5 will now be described for cooling the material in a step by step movement through the apparatus. This method is best suited for cooling material which is intermittently delivered from a mill in batches. Each batch is introduced into the apparatus in a continuous movement and then it remains at rest for a period before the next batch is introduced. This intermittent introduction of the batches one after the other produces a step by step movement of the material through the apparatus in each step of which the batches are moved forward an amount substantially equal to the length of the batch being introduced.

The apparatus shown in Fig. 4 is designed to hold three batches of material when it is fully loaded. When loaded, the last batch in extends from the right end of belt **42** to the point **60** on the belt **43**; the next preceding batch extends from the point **60** to the point **61** on the belt **45**; and the next preceding batch extends from the point **61** to the point **62** on the belt **46**.

During the movement of the material **38** in the apparatus, the nozzles **48** opposite the material and shown to be in operation are continued in operation as in the continuous movement of the material through the apparatus, and air is preferably delivered continuously from the nozzles **51** and **52** all of the time the material is inside the apparatus. As the two batches of the material last introduced remain stationary between their steps of movement, substantially their entire top and bottom surfaces are intermittently covered with the thin film of liquid by the combined simultaneous action of the fog spray nozzles **48** and **48'** opposite such surfaces. The nozzles are turned on and off in groups adapted to cover the separate batches, and the film deposited by each group is evaporated before the next film is deposited. The application and evaporation of the films are repeated at each step until the temperature of the material **38** has been reduced the desired amount at the particular stage to cause a progressive reduction in its temperature as it passes through the apparatus and so that the batch of material ready to leave the apparatus may be discharged at the desired low temperature.

The amount of liquid supplied to the material **38** is successively reduced as the temperature of the material falls in the successive stages of cooling. The amount of liquid delivered in these stages may be controlled by reducing the flow of the liquid to the sprays, or by changing the length of time the sprays remain turned on. It

is desirable not to spray the batch which is ready to leave the machine, and it is acted on only by the unsaturated air in order to insure complete dryness of the material **38** as it passes through the exit **47**.

This invention is particularly applicable to the cooling of slabs of rubber coming from a mixer in a raw or unvulcanized state and which is capable of absorbing moisture. The rubber is tacky in that condition, and in order to reduce its tackiness so that it will not adhere to any surface upon which it is deposited after leaving the apparatus herein described, the surfaces of the rubber slab are coated with an adhesive preventing material as it passes through the apparatus. Such material is referred to as a lubricating material, and may consist of ordinary washing soap, or other similarly acting materials used by the rubber industry and which will not readily settle out of the liquid applied to the rubber slab. In accordance with my invention, the lubricant may be mixed with the water used to form the evaporative films on the surface of the rubber, and after the liquid is evaporated, the lubricant remains on the surface of the sheet material. The lubricant may be mixed in the desired quantity with the water in order to deposit the desired quantity on the surface of the material. It is preferable, however to increase the concentration of the lubricant and use it only in a limited number of rows of spray nozzles in order to control the deposit of lubricant on the surface of the material.

It has been found that my apparatus and process operates efficiently with water as a film forming agent and with atmospheric air as a film evaporating or absorbing agent for cooling rubber slabs, and that the average temperatures of the water and the air encountered throughout the United States during all of its seasons can be employed efficiently. As an example in the operation of my apparatus and process, a slab of rubber ¼ inch thick, 5 feet wide, weighing 400 lbs., and having a specific heat of .5 will be delivered per minute and may be cooled from 250° F. to 110° F. when the distance traveled by the rubber is such that it remains in the apparatus for approximately 3.2 minutes. That requires the removal of 28,000 B. t. u. per minute. Such removal is effected by vaporizing 26 lbs. of water with 3300 lbs. of air at the average summer temperature of water at 54° F. and at the average summer outdoor atmospheric conditions of air at 95° F. dry bulb, 75° F. wet bulb, 40% relative humidity, 66.8° F. dew point, and containing 98.5 grains H_2O per lb., a total heat of 37.66 B. t. u. per lb., and weighing 1 lb. per 14.3 cu. ft. In such example the outlet temperature rose only 1° F. dry bulb and the air had a relative humidity of 59%. In this example approximately 97% of the heat was absorbed by the latent heat of evaporation of the liquid. It will be understood that as the outside air approaches saturation, less fog spray will be required. However, if no fog spray had been used and the air in the above given condition had been relied upon to remove all of the heat from the rubber in the above case, approximately 18,820 lbs. of air would have been required with a rise in temperature of 5° F. dry bulb between the atmospheric air inlet and outlet. The relative humidity at the outlet would have been 34.5%. It will thus be seen that a considerable increase in the volume of air circulated is required where air only is employed as a cooling agent, and that due to its lower relative humidity at the outlet the rate of conduction of heat is lower than in the case of the higher outlet humidity produced by the fog spray.

It is to be understood that the cooler the temperature of the air directed upon the material, the less liquid film will be required to remove a given quantity of heat from the material in a given time in the operation of this process. When the point is reached where less than 25% of the heat transferred from the body to be cooled is absorbed by the latent heat of evaporation of the film, it is more economical to dispense with the application of the film and use air only for cooling because the volume of air required at the lower temperatures is relatively small. The following is an example of an air condition where it is desirable to dispense with the application of the liquid film to the rubber slab above: 60° F. dry bulb, 56° F. wet bulb, 80% relative humidity, 53.8° F. dew point, and containing 61.5 grains of H_2O per lb., a total heat of 23.7 B. t. u. per lb., and weighing 1 lb. per 13.25 cu. ft.

While I have shown the preferred forms of my invention herein, it will be understood that changes in details may be made without departing from the spirit of the invention and the scope of the appended claims.

Having thus described my invention, what I claim and desire to protect by Letters Patent is:

1. The method of transferring heat from a body of tacky plastic heated material comprising the steps of repeatedly and intermittently spraying a thin film of liquid containing a lubricating agent to the surface of the body and at a lower temperature than said body, quickly evaporating the liquid in intimate contact with said surface between the applications of said films, whereby at least 25% of the heat transferred from said body goes into supplying the latent heat of evaporation of the liquid and the lubricant contained therein is deposited upon said surface.

2. The method of reducing the temperature of successive batches of plastic sheets comprising successively passing the batches in series through cooling zones in a step by step movement, continuously applying thin films of liquid to said sheets at spaced stations in the first of said zones and evaporating said films between said stations during the movement of said batches, intermittently applying thin films of liquid to said sheets in other of said zones and evaporating each film before the next film is applied while said batches remain stationary in said zones.

3. An apparatus for cooling sheet material comprising fog sprays arranged in groups, said groups being arranged in series and adapted to deposit individual films of liquid on to the surface of the sheet material, means for circulating a gaseous atmosphere over said films between each group of said fog sprays to evaporate each film before the next one may be applied, means for directing said gaseous medium progressively from the coolest portions of said sheet material towards the hottest portions of said sheet material, and means for conveying said material in position to be operated upon by said spray and circulating atmosphere.

4. The method of transferring heat from a flat sheet-like body comprising the steps of repeatedly and intermittently spraying a thin film of liquid onto the surfaces of said body on each side thereof and at a temperature lower than said body, quickly evaporating the films in intimate contact with said surfaces by the heat of said body and in the presence of an atmosphere capable of absorbing the vapors of said liquid, and controlling the intermittent application of the films to permit the film deposited on a surface to be substantially evaporated before the next film is applied to the same surface.

5. An apparatus for cooling sheet material comprising an open mesh support for said material, means for applying successive thin films of liquid to a surface area on each side of said material on said support, and means for quickly evaporating the film on said surface area before another is applied to that area.

6. An apparatus for cooling sheet material comprising an open mesh support for said material, means positioned on opposite sides of said support for spraying successive thin films of liquid on a surface area on each side of said material on said support, and means for quickly evaporating the film on said surface area before another is sprayed on that surface.

7. An apparatus for cooling sheet material comprising an open mesh movable support for said material, film applying units arranged in series along the path of said support on each side thereof, film drying units alternating with said film applying units for quickly drying the films deposited by said film applying units before another film is applied to same surface area, and means for moving said support past said film applying and drying units.

8. An apparatus for cooling sheet material comprising alternately arranged spraying and drying compartments, means for conveying the sheet material in succession through said compartments, means in said spraying compartment for spraying liquid upon the surfaces of the sheet material therein, means for passing currents of air over the sheet material in said drying compartments to evaporate the liquid sprayed on the sheet before it is carried into the succeeding spraying compartment.

9. An apparatus for cooling sheet material comprising alternately arranged spraying and drying compartments, means for conveying the sheet material in succession through said compartments, means in said spraying compartment for spraying liquid upon the surfaces of the sheet material therein, means for wiping excess liquid from the surface of said material as it leaves the spraying compartments, means for passing currents of air over the sheet material in said drying compartments to evaporate the liquid sprayed on the sheet before it is carried into the succeeding spraying compartment.

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