Oct. 9, 1945. W. H. CARRIER 2,386,292

DEHUMIDIFICATION METHODS AND MEANS

Filed April 10, 1941 3 Sheets-Sheet 1

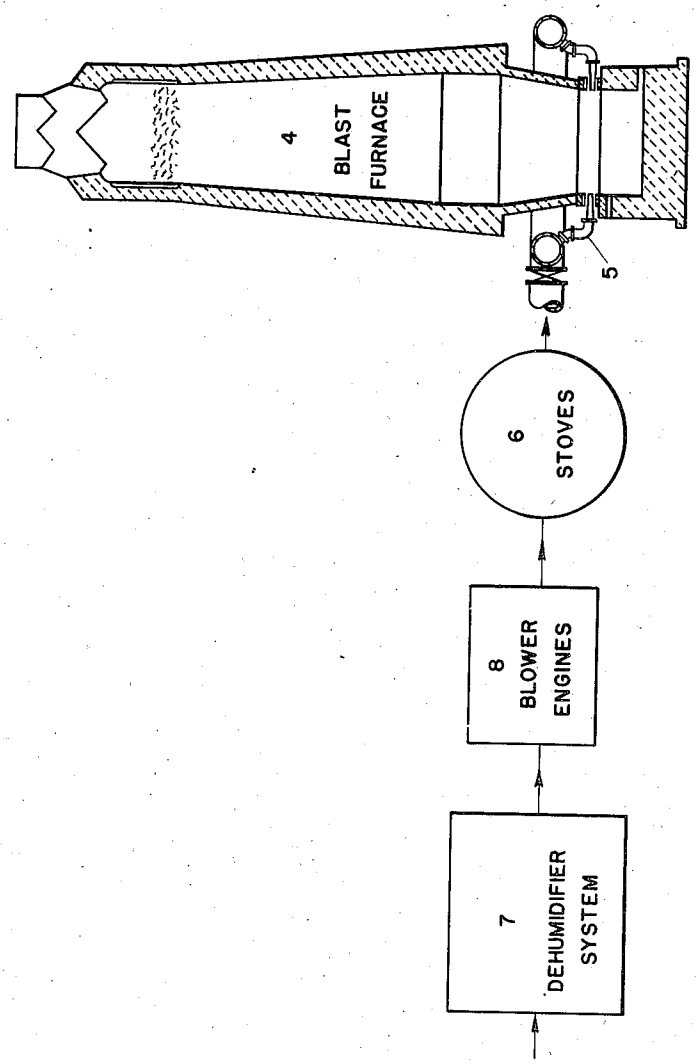


FIG. 1

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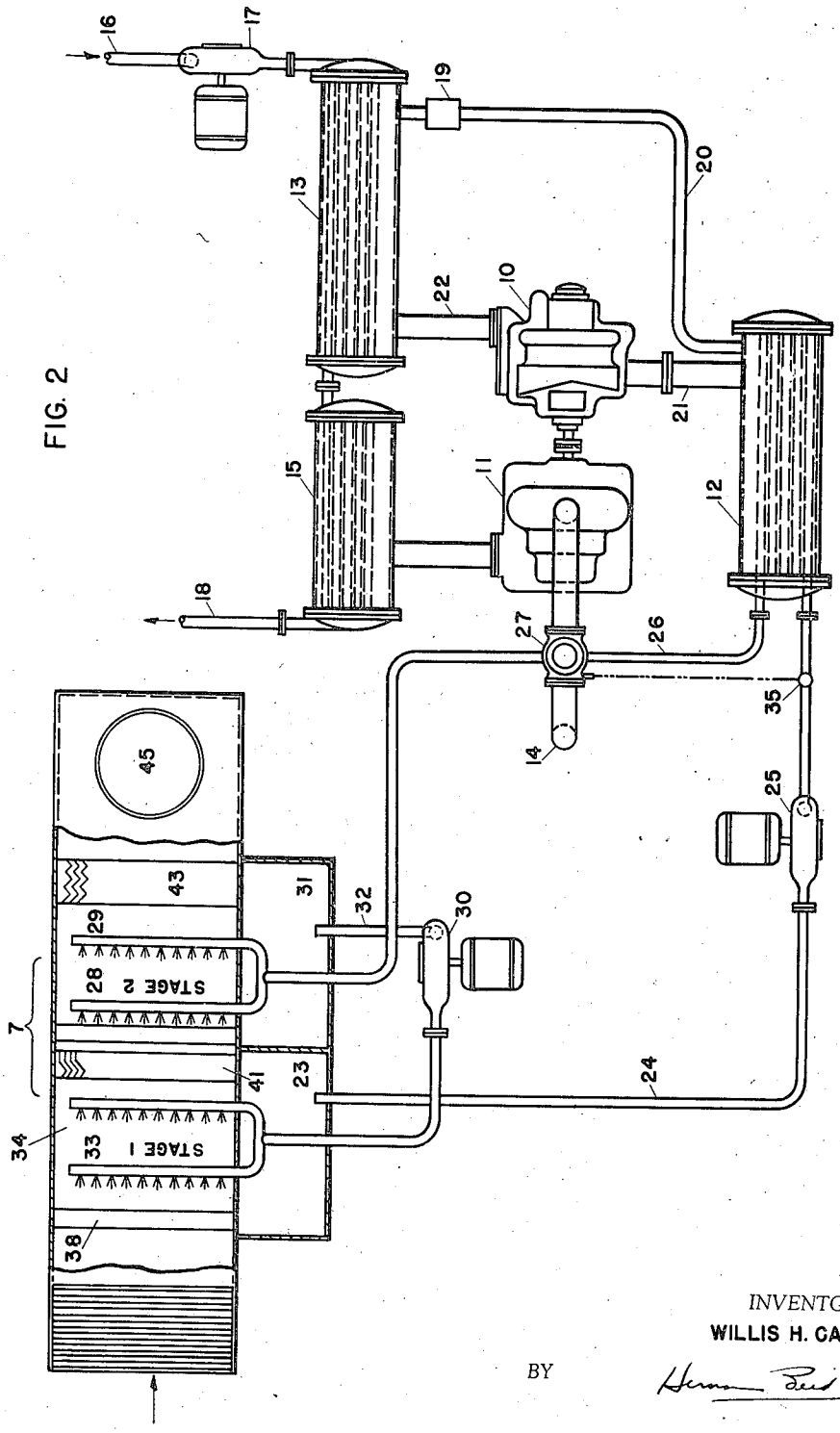
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DEHUMIDIFICATION METHODS AND MEANS

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FIG. 2



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DEHUMIDIFICATION METHODS AND MEANS

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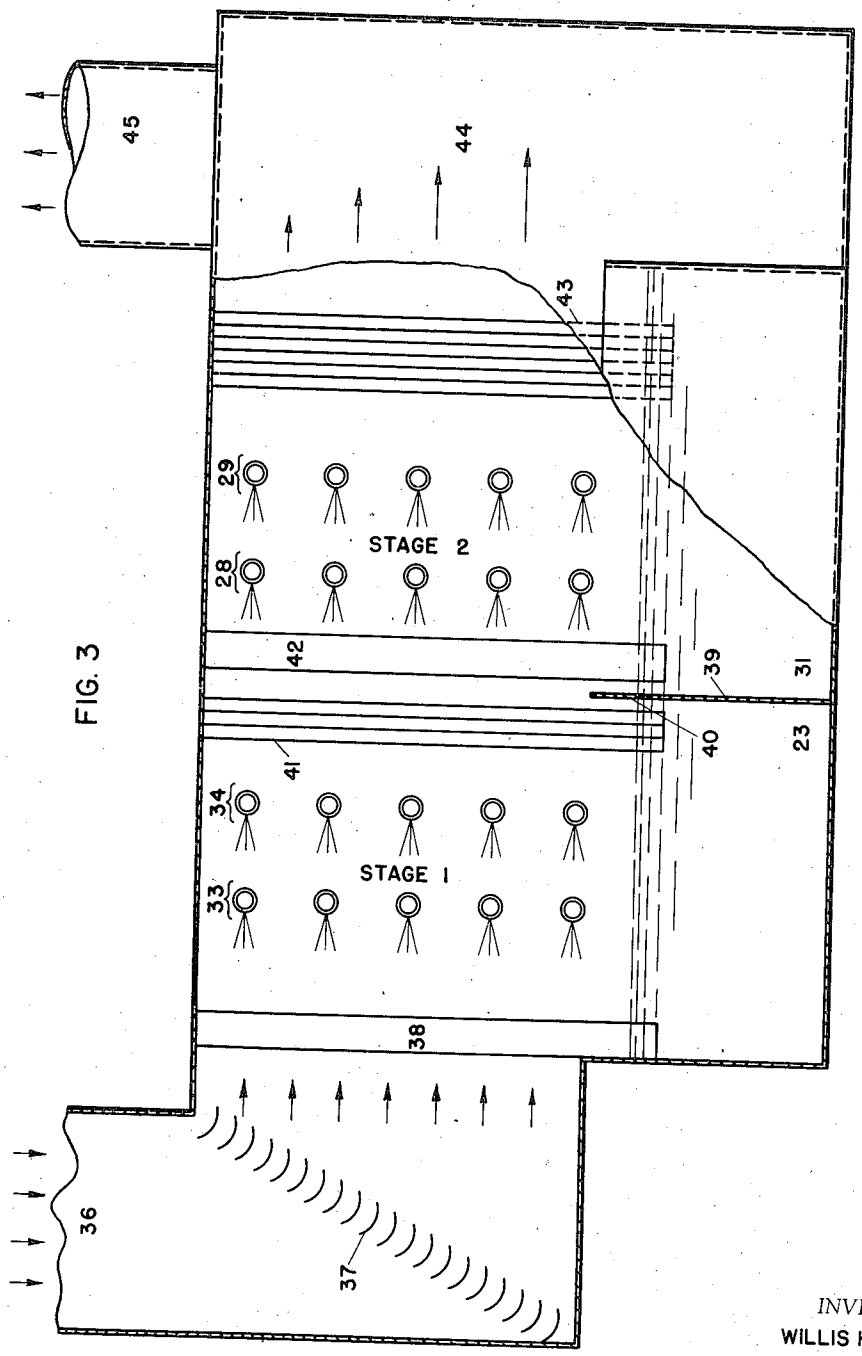


FIG. 3

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UNITED STATES PATENT OFFICE

2,386,292

DEHUMIDIFICATION METHOD AND MEANS

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Application April 10, 1941, Serial No. 387,948

4 Claims. (Cl. 62—176)

This invention relates to methods of and apparatus for conditioning air employed in the operation of blast furnaces.

In the smelting of ores, great quantities of air are necessarily employed. It is known that excessive moisture content of the air, as is prevalent under summer operating conditions, may at times reduce the capacity of a blast furnace as much as 15%. This is due to the fact that a blast furnace may be considered to be a gas producer, and as such it dissociates moisture introduced by the blast. This requires a considerable expenditure of energy supplied by the fuel and consequently leaves that much less fuel available for the smelting process. It should be noted that this expenditure of fuel is not utilized to any degree in removing or dissociating moisture contained in the coke or ore since such moisture is evaporated by the drying action of the blast furnace gases, after such gases leave the active smelting zone. Hence the use of fuel required for dissociating moisture is confined solely to the air used in the blast.

A principal object of the invention is to control the moisture content of the air employed in blast furnaces, whereby the air introduced will have substantially a constant absolute humidity, definitely established preferably at a point between 2½ and 3 grains per cubic foot of air. Since the air, under summer operating conditions, in most parts of the United States, often has an absolute humidity two or three times as great or even more, the result is that the introduction into the furnace of air with so small an amount of absolute moisture, may often effect an annual increase in capacity of a given furnace on the order of 7–10% without any increase in coke consumption. While this saving may be attributed to the elimination of the necessity for using up coke for dissociating moisture in the blast, another feature, of utmost importance, flowing from the use of air at a fixed moisture content, is that operations may always be carried forward on a fixed schedule as to time and loading, free of variations heretofore made necessary because of varying weather conditions resulting in air having widely different absolute humidities. Thus, the furnace need not be loaded with an excessive quantity of coke to take care of unforeseen burdens arising from high absolute humidities and as a result the utmost in ore loading is made possible. Also, the schedule of operations may attain a high degree of regularity with consequent greater capacity since the utmost in smelting is achieved in a minimum of time, and with a minimum of coke which need not be varied to compensate for variations in moisture content of the blast.

While a considerable amount of power is necessary to drive the refrigerating machines provided for effecting required dehumidification of the air, the power required for driving the fans or blowers serving the furnaces is reduced due to the reduction in weight of the air resulting from the precipitation of moisture therefrom, and applicant has found that no appreciable increase of power is required for driving both the blowers and the refrigerating machines over that required for operating the blowers alone when the air's moisture content is not removed.

Another object of the invention is to control the absolute humidity of air introduced into a blast furnace so that the furnace temperature may not be affected due to change in moisture burden. The quality of smelted iron, particularly with respect to silicon content, depends in great measure on the furnace temperature. While the temperature is affected by changes in burden, it is also affected by variations in moisture content of the blast, so that the production of iron meeting exact standards of composition has not only been made difficult but costly without a means, such as that provided by applicant, for regulating the moisture content of the blast.

Another object of the invention is to enable centrifugal fans or blowing engines to operate with stabilized displacement and at consequent stabilized speeds. By providing air substantially at a constant temperature and with a constant moisture content, the weight of air supplied to the inlet sides of the fans or blowing engines remains substantially the same. Applicant provides a simple means for controlling and metering the weight of air at all times.

Applicant's system for controlling the air fed to the blast may readily be combined with existing furnaces and air blowing engines, so that the benefits of greater furnace capacity, better quality iron, and more efficient and simplified operation may be attained in a very short time and at relatively small cost compared to that required, for example, for providing additional smelting capacity.

To achieve these and other benefits, applicant provides a combination of apparatus incorporating the following principal features: (*a*) a spray type dehumidifier in which "fogging" is substantially eliminated, and an actual dewpoint attained within a few degrees of the refrigerant temperature (*b*) a multi-stage pumping system

serving a series of sprays in a dehumidifier in combination with a cooling circuit of a refrigeration system (c) a variable speed refrigerating machine and (d) a variable speed governor for controlling the operation of the refrigeration system responsive to changes in temperature of the water leaving the refrigerating machine en route to the dehumidifier. By correlation of these elements, a constant minimum dewpoint may be maintained with great accuracy, and maximum simplicity, economy and reliability. Of primary importance, is that in this system moisture variation due to varying entrainment is eliminated; and the control is largely self-regulatory.

Considering the drawings:

Fig. 1 is intended diagrammatically to illustrate the essential elements of a "dry-blast" system or blast furnace arrangement equipped with a source of supply of air adapted to be furnished at a desired rate and containing a constant and predetermined amount of moisture per unit of volume, normally about 2.85 grains per cubic foot of air;

Fig. 2 illustrates diagrammatically an air conditioning system capable of supplying air in desired volume and at a desired condition, for use in the blast furnace and;

Fig. 3 illustrates diagrammatically a section of the washer employed in the system of Fig. 2.

First considering the smelting process, and as is well known to those skilled in the art, the furnace 4 is charged at the top in the usual manner with the burden consisting of ore, coke, fluxes, etc. The wind or blast enters the furnace through the tuyères 5 immediately above the hearth. In prior practice it was customary to load an excess of coke with respect to the tonnage of ore to compensate for a possible rise in moisture content in the air of the blast. Otherwise, it was necessary to vary the temperature of the hot blast fed to the furnace, and in this connection it is necessary to provide an additional 25 to 50° for each grain of moisture per cubic foot of air. This requires an appreciable reserve capacity in the stoves 6 where the air, in the usual manner, is preheated to a temperature above 1000° before being delivered to the furnace. If no such reserve capacity is available, or if no excess of coke in the furnace is available, there is danger of the furnace growing "cold," with attendant serious loss in production, and expense. This becomes apparent when it is realized that the heat absorbed by one pound of moisture vapor to produce its dissociation amounts to 2850 B. t. u. and this requires added fuel. Since the quantities involved are enormous, with the wind required for a furnace of about 500 tons capacity per day amounting to about 50,000 cubic feet of air per minute (or 2700 tons of air per day, which means over 5 tons of air per ton of iron produced) it will be seen that the savings flowing from reduction of moisture content of the air are very appreciable. Each grain saved per cubic foot per minute amounts to more than 5 net tons of water per day. Since it is not uncommon on humid summer days to have nine or more grains per cubic foot, the elimination of six grains per cubic foot, results in preventing over 30 tons of water from entering each furnace.

Thus, applicant provides a system of air moisture control, generally designated by numeral 7 for regulating the moisture content of air delivered to the blowing engines or the like 8, from which the air enters the stoves and then the furnace in the usual manner. The consequence of providing system 7 is to enable at all times the charging of an exact tonnage of ore and coke, without regard to unforeseen changes in weather conditions, so that the blast of air at an assured and constant condition will cause the production of a constant quantity of iron per unit of time. Since the charge must be introduced some 10 to 12 hours before it reaches the hearth, it is evident that with all factors predetermined, operations may proceed at maximum efficiency with the furnace at full productive capacity. For every grain of moisture removed per cubic foot of air, a saving of about 48–50 pounds of coke per ton of iron is effected. For every six grains removed, as is the case under summer operating conditions, about 300 pounds of coke per ton of iron are saved. Thus not only can the furnace be operated with assured regularity, but more ore may be safely charged and more iron produced with less coke. Actual operations with applicant's system over extended test periods, with charges employing varying grades of ores, shows an increase in iron production of approximately 10% with a decrease in consumption of coke of approximately 10%.

Considering the system for producing the dry blast, as illustrated in Fig. 2, numeral 10 designates a centrifugal refrigerating compressor adapted to be driven by steam turbine 11, to which steam is supplied at a desired pressure from any available source 14. Cooler 12 is operatively associated with compressor 10, and although it is diagrammatically illustrated as a separate piece of apparatus, it is usually combined in a unitary assembly with the compressor, and this is often also the case with refrigerant condenser 13. Steam condenser 15 serves turbine 11. A common water supply from source 16 is routed by motor driven pump 17 through condensers 13 and 15 in series, and then delivered through discharge line 18 to a cooling tower for reuse in the system, or wasted.

The refrigerant circuit is from compressor 10 to condenser 13 through discharge line 22 where the refrigerant is liquefied in the usual manner; then from condenser 13 through trap 19 and supply line 20 to cooler 12 where it is evaporated; and then in gaseous state from cooler 12 back to the compressor through suction line 21.

The water circuit is as follows: from sump 23 of the first stage of dehumidification apparatus 7 through suction line 24 to motor driven pump 25, then through cooler 12 discharge line 26, control 27, to banks of spray 28 and 29 in the second stage of apparatus 7. Motor driven pump 30 then withdraws the water from sump 31 of the second stage through suction line 32, delivering it to banks of spray 33 and 34 of the first stage of apparatus 7, and dropping to sump 23.

Sumps 23 and 31 in practice constitute water tanks under the respective dehumidifier stages. The pumps 25 and 30 are designed to deliver the water handled by them to the respective sprays served by them at 25 pounds pressure.

The air flow through apparatus 7 in countercurrent relationship with reference to the direction of discharge of the water from sprays 28, 29, 33 and 34. The proportions of weight of air routed through apparatus 7 with respect to the weight of water delivered through the sprays is such that substantially 80% of the required cooling effect of the air is accomplished in the first stage of apparatus 7. To obtain this result applicant supplies approximately .7 pound of water per pound of air to each bank of spray nozzles, or

approximately 1.4 pounds of water per pound of air in each stage.

This relationship produces an overall rise in water temperature of approximately 10° when a corresponding amount of air is cooled through a range of 40° in wet bulb temperature, for example, from 80° to 40°. The ratio of .7 pound of water per pound of air in each bank of sprays may be varied, within limits, yet permit achieving good results. In practice, the range may be between one-half to one pound of water supplied to each bank of sprays per pound of air passing through apparatus 7 at normal capacity.

The optimum air velocity through the apparatus is between 400 and 600 feet per minute. Where a surge in flow is encountered, as when reciprocating blowing engines are employed, the maximum practical velocity is less than that which may safely be employed when continuous air flow is provided as where turbo compressors are used for providing the blast. Such operation will prevent entrained moisture from being carried through the eliminators.

Control 27 is specially adapted to provide water at a desired temperature to apparatus 7 to assure delivery therefrom of air leaving the second stage at a predetermined dewpoint. In connection with control 27, the operation of centrifugal compressor 10 is significant. Compressor 10, in practice, produces a difference in temperature between evaporator and condenser, depending upon the speed of operation of the compressor. Considerable changes in capacity of the compressor can occur at a given temperature difference without greatly affecting the speed of the compressor. However, the rate of flow of heat in the water cooler 12, as well as in condenser 13, depends upon the difference in temperature between the water and the refrigerant on opposite sides of the finned heat transfer surfaces provided therein. Thus, it is possible to change the load on the compressor as well as the temperature, merely by changing the speed of the compressor, which may be brought about by regulating the operation of turbine 11.

In the instant application, the aforesaid characteristic of the centrifugal compressor may be utilized to control the temperature of the water delivered to the sprays by means of a very simple speed control of the compressor, actuated by the temperature of the water leaving cooler 12. In practice, control 27 governs the speed of turbine 11 by regulating the admission of steam thereto from source 16. Since the turbine is coupled to the compressor, this control effectively governs the speed of the compressor. However, since the total load, as it varies, affects the dewpoint of the air delivered from apparatus 7, and since it is desired to keep the variation within exceedingly small limits it is necessary to reset control 27 as the total load varies. The change in total load may be measured by the change in temperature of the water from sump 23 being returned to the cooler. Thermostat 35, reflecting the change in total load on the system, serves to reset control 27 whereby the speed of the compressor will be varied and the temperature of water delivered correspondingly varied to compensate for changes in total load. As a result, the dewpoint of the outgoing air may be maintained substantially constant.

To illustrate the operation of the control, it may be assumed that the spread between the temperature of the air leaving the second stage and the temperature of the water from the cooler delivered to the second stage is 2°, which is the actual condition as it exists at maximum load. Under practical operating conditions the water temperature entering the second stage may be 38° for a 40° dewpoint of the leaving air at maximum load. The water returning from the first stage to the cooler is 48° or 10° higher than the water leaving the cooler. At half load, however, the rise in water temperature is 5° and the spread between the leaving air and the entering water is only 1°. Therefore, for a 40° dewpoint of leaving air, the water temperature leaving the cooler and entering the second stage, under half load conditions, would be 39° and the water temperature leaving the first stage and entering the cooler would be 44°. Therefore, thermostat 35 causes control 27 to be raised or reset 1° for every 4° rise in entering water temperature where the total rise in water temperature at full load is 10°.

Obviously, the resetting of control 27, which may be accomplished manually as well as automatically, is regulated so that the degree of reset is proportionate to the change in water temperature entering the cooler. Thus, if the rise in water temperature is 12° instead of 10° at full load, then the control would be reset 1° for every 5° rise in the temperature of the water leaving the dehumidifier apparatus 7 and entering the cooler 12.

By means of this system of control of the temperature of the leaving water, utilizing a reset operated by or in accordance with variations in the temperature of the water entering the cooler, it is possible precisely to control the dewpoint of the air leaving apparatus 7; and this may be done by controls located at the refrigerating machine, although this is often installed in a separate building removed from the apparatus 7.

Fig. 3 illustrates in greater detail the dehumidifier arrangement employed. The air to be conditioned is preferably drawn in from outdoors through a vertically disposed inlet 36. The intake chamber may be provided with an air distributor 37 consisting of a series of blades for causing the air to flow uniformly in a horizontal direction into the first spray chamber or first stage of the dehumidified apparatus. As was already noted, the first stage of air cooling constitutes the second water pumping stage; and the second stage of air cooling constitutes the first water pumping stage. Each spray chamber or stage is provided with two banks of sprays. These sprays are of the centrifugal type in which the water is discharged in opposition to the direction of air flow. To prevent the spray carrying within the air inlet 36 a series of baffle plates or eliminators 38 are positioned at the entrance to the first spray chamber. These are vertical plates so designed and arranged as to effect a uniform lateral distribution of the air throughout the chamber. These plates serve a special purpose in uniformly distributing the air in order more effectively to obtain a uniform dewpoint temperature and prevent "fogging" of the air passing through the chamber.

Stages one and two in effect constitute two compartments. A single water tank is provided below the two compartments but this contains a vertical partition 39 which divides the tank into two parts. An equalizer opening 40 in partition 39 permits water to flow from one of the tank compartments to the other whenever there is a difference in pumping capacity of the two pumps. Such difference in pumping capacity will cause a change in level and this in turn causes a flow

through opening 40 and prevents failure of the pumping system or overflow of one of the tanks which might otherwise occur.

At the discharge end of the first spray chamber or first stage is positioned a three-bend eliminator 41 and at the entrance to stage 2 is positioned a series of baffles 42. Eliminators 41 effectively remove entrained moisture from air leaving stage 1 this moisture draining into sump 23. Baffles 42 prevent spray from carrying through beyond stage 2, the water from these baffles dripping into sump 31. Baffles 42 are also designed to distribute uniformly the air entering stage 2, and this is of importance in securing a uniform dewpoint and in preventing "fogging" of the air. At the discharge end of stage 2 is positioned a six-bend eliminator 43 which effectively prevents any entrained moisture from being carried from the second stage into the exit or plenum chamber 44. The air from the plenum chamber goes through discharge conduit 45 to the blowing engines 8, and from there to stoves 6 and blast furnace 4, as is well known in the art.

Instead of providing a thermostatic device for resetting control 27, a recorder may be employed for noting the dewpoint of the air delivered from the second stage. When an undesirable variation occurs an operator may then manually reset control 27. The control, which reflects the temperature of the water delivered from the cooler 12 will then, responsive to its new setting, cause the turbine to increase or reduce the speed of the compressor until the water temperature from the cooler satisfied the new setting.

With applicant's method of control overspeeding of the compressor and undercooling of the spray water which might result in a freezing condition within the cooler is prevented, since the water temperature is controlled without any cycling or surging of temperatures, either of the water or of the dewpoint of the leaving air.

Since the invention exemplified by the system disclosed may be practiced with modifications in design of apparatus as well as in the method of operation employed, obvious variations are intended to be covered, and the terms of the appended claims are not intended to be limited to the specific combination and steps employed.

I claim:

1. A method of treating air for use in a blast furnace wherein the condition of the air delivered to the furnace is regulated consisting in cooling the air from its entering condition to a predetermined final condition where it contains substantially 3 grains of moisture per cubic foot of air, accomplishing a preponderant percentage of desired cooling of the air in a first air treating stage, spraying water in said first stage, proportioning in said first stage the weight of air and weight of water spray to produce said preponderant percentage of desired air cooling, accomplishing said last mentioned step by spraying between one-half pound and one pound of water per bank of sprays per pound of air passing through said first stage, utilizing at least two banks of spray in said first stage, and accomplishing the balance of desired air cooling by passing the air from the sprays of the first stage to other sprays in a second stage.

2. A method of treating air for use in a blast furnace wherein the condition of the air delivered to the furnace is regulated consisting in cooling the air from its entering condition to a predetermined final condition at substantially 40° F., passing the air to be conditioned through a plurality of stages of conditioning arranged in series, each of which provides two banks of spray and substantially complete elimination of entrained moisture from the air as the air leaves each stage, providing a rise in the temperature of the water for the sprays after it passes through all stages of approximately 10° F. for a drop in the temperature of the air after it passes through all stages of approximately 40° F., said water flowing from the final stage to the first stage in counterflow relationship to the passage of the air through the stages accomplishing substantially 80% of said rise in water temperature and drop in air temperature in the first of the stages of conditioning by supplying approximately .7 pounds of water in each of the banks of spray per pound of air passing through the sprays, routing the air through the sprays at a velocity between 400 and 600 feet per minute, and regulating the temperature of the water serving the sprays to maintain a definite number of grains per cubic foot of air leaving the final stage of conditioning.

3. A method of treating air for use in a blast furnace wherein the condition of the air delivered to the furnace is regulated consisting in cooling the air from its entering condition to a predetermined final condition in a plurality of stages, accomplishing approximately 80 per cent of desired conditioning of the air in a first air treating stage, accomplishing the balance of desired conditioning of the air in a remaining air treating stage eliminating entrained moisture at the discharge side of each stage and preventing fogging of air passing through the stages, cooling water for delivery to said last mentioned stage and thereafter to said first air treating stage, measuring the dewpoint of the air subsequent to treatment in said last stage, and controlling the temperature of the water fed to said stages responsive to variations in temperature of the water leaving the first stage whereby the dewpoint of the air delivered from said last stage is maintained substantially constant.

4. A system for treating air for use in a blast furnace consisting of a first conditioning chamber, a second conditioning chamber, a plurality of sprays within each of said chambers, means located at the discharge ends of each chamber for eliminating entrained moisture from air leaving each chamber, a centrifugal refrigeration machine, means for driving said machine at varying speeds, a cooler served by said machine, means for routing water from the cooler to the second chamber, from the second chamber to the first chamber and from the first chamber to the cooler, pumps suitably provided in combination with said water circuit for feeding the water delivered to said sprays at a pressure of approximately 25 pounds whereby approximately .7 pounds of water is delivered to each of several banks of sprays in each of said chambers per pound of air passing through said chambers, routing air initially through the first chamber and then through the second chamber at a velocity between 400 and 600 feet per minute, regulating the temperature of the water delivered from the cooler by means located in a line discharging from the cooler and in a second line leading to the cooler, said second means regulating the action of the first means.

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