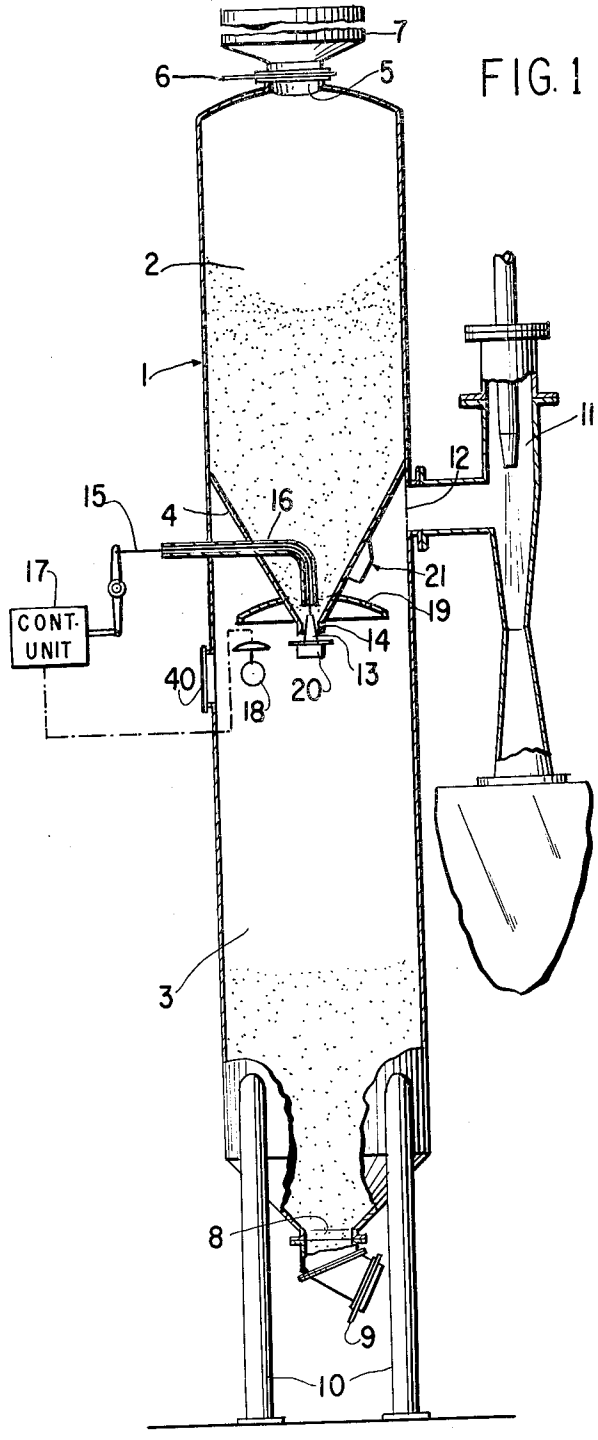
July 30, 1963 J. R. HIGHTOWER ETAL 3,099,138

CONTINUOUS COOLING METHOD AND APPARATUS

Filed April 28, 1961 2 Sheets-Sheet 1

FIG. 1



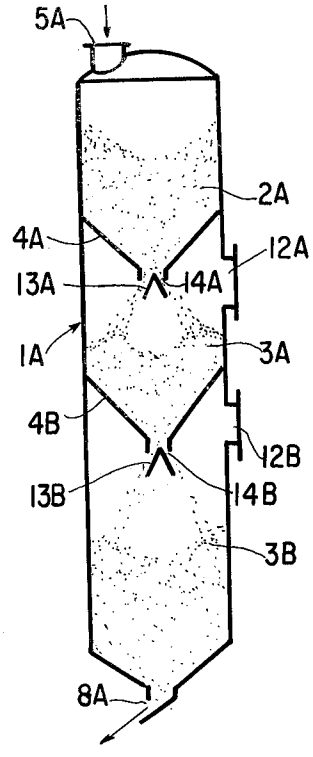


FIG. 2

INVENTORS
JOHN R. HIGHTOWER
JAMES T. REYNOLDS
BY
Hammond & Littell
ATTORNEYS

July 30, 1963 J. R. HIGHTOWER ETAL 3,099,138

CONTINUOUS COOLING METHOD AND APPARATUS

Filed April 28, 1961 2 Sheets-Sheet 2

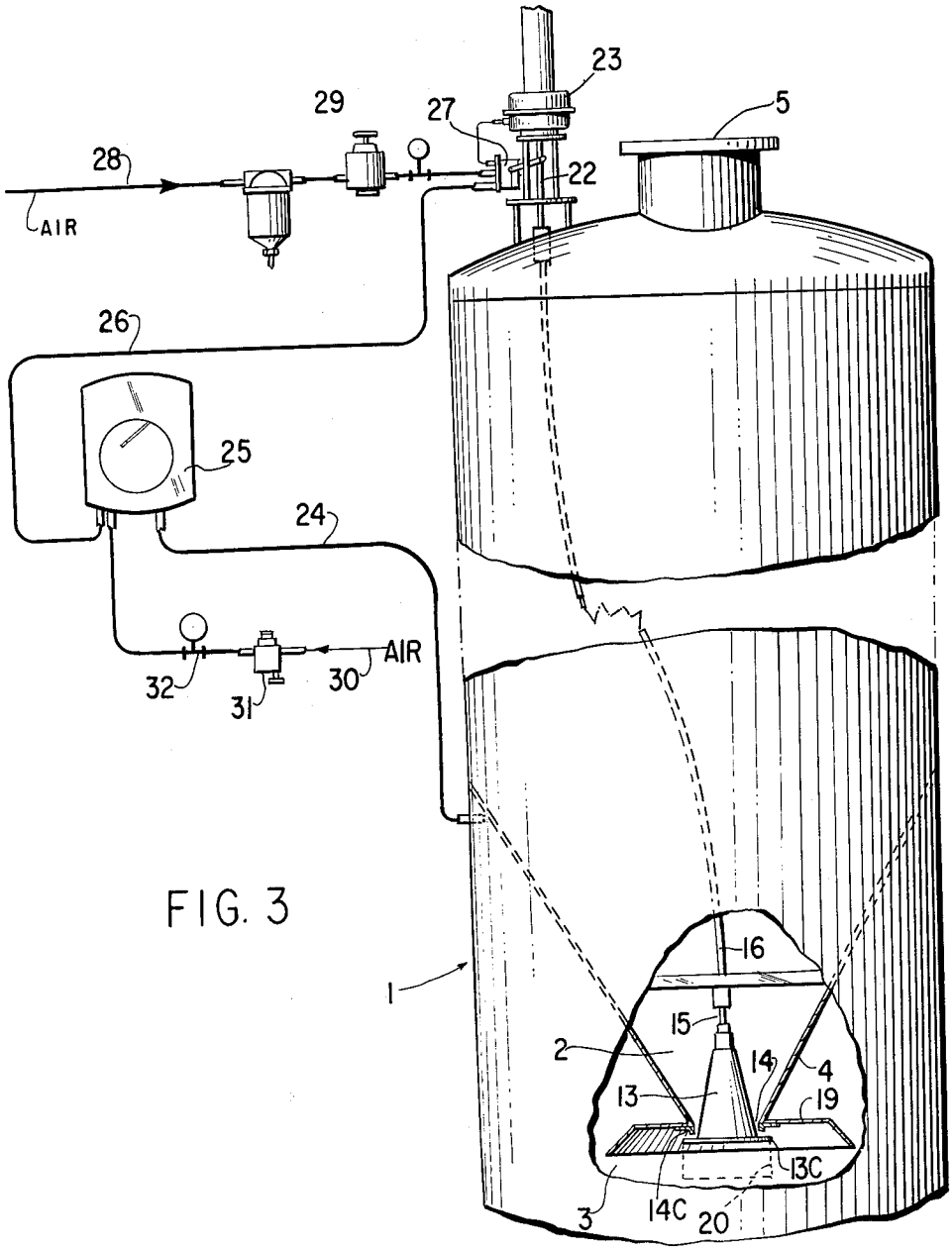


FIG. 3

INVENTORS
JOHN R. HIGHTOWER
JAMES T. REYNOLDS
BY
Hammond + Littell
ATTORNEYS

United States Patent Office 3,099,138 Patented July 30, 1963

3,099,138

CONTINUOUS COOLING METHOD AND APPARATUS

John R. Hightower, 3881 SW. Bridlemile Lane, Portland, Oreg., and James T. Reynolds, 2274 Woodland Terrace, Scotch Plains, N.J.

Filed Apr. 28, 1961, Ser. No. 106,227
5 Claims. (Cl. 62—63)

This invention relates to a method and apparatus for continuously cooling large quantities of sand and similar materials. It more specifically relates to the method of cooling sand in a vacuum apparatus wherein the sand is to be used in the formation of concrete structures where it is desired to have a lower concrete placement temperature. The invention further relates to controlling the flow of sand or other finely divided moist particles into a vacuum chamber.

In massive concrete structures, such as dams and the like, it is necesary to prevent the development of temperature cracks by placing the concrete so that it reaches its final set at a temperature as close as possible to its ultimate temperature in service, which ultimate temperature is determined by the service conditions and is normally controlled by the mean air and water temperature to which the dam or other structure is subjected in use.

Various methods of reducing the temperature of massive concrete structures have been used, such as limiting the size of the pourings of the individual sections, circulating cooling water through pipes imbedded in the concrete, cooling the mix by the use of ice water in the mixing operation, cooling the sand and/or aggregate by inundation in refrigerated water, cooling the aggregate by refrigerated air blast and other ways, but none of these methods has proven satisfactory for a number of reasons.

One of the objects of this invention is to provide a method and apparatus for continuously cooling sand for use in massive concrete structures for the purpose of lowering the placing temperature of the concrete.

A further object is to provide a method and apparatus for rapidly and accurately cooling moist finely divided particles of substantially uniform size of which sand is an illustration to a specific desired temperature.

Another object is to provide a method and apparatus for cooling a volume of sand or other finely divided moist material to a uniform temperature throughout the mass.

Still another object is to provide a method and apparatus for cooling a mass of sand or other finely divided moist material of substantially uniform size automatically by vacuum to a predetermined temperature.

A further object is to provide an apparatus for controlling the flow of sand or other finely divided moist material into a vacuum chamber to obtain continuous flow.

These and other objects of this invention will become apparent as the description thereof proceeds.

In general, our invention consists of passing the sand or other finely divided moist material of substantially uniform size to be cooled into a vacuum chamber as a continuously flowing, falling stream so that the individual sand particles are submitted to the vacuum action. Moisture on the sand particles is evaporated, thus cooling the particles.

The preferred apparatus for cooling the sand comprises a vertical cylindrical vessel divided into at least two compartments, one above the other, by an inverted cone structure cut off at the lower end to provide a circular opening. The upper compartment is the storage compartment and the lower compartment is the vacuum chamber where cooling takes place.

A throttling cone valve inserted into the opening of the conical divider is used to control the rate of flow of sand from the storage compartment to the vacuum chamber.

In this manner a uniform flow and rate of flow of the sand into the vacuum chamber is provided and at the same time each individual sand particle is subjected to the vacuum action while it is in free falling movement.

The degree of vacuum used in the vacuum chamber depends on the desired final temperature of the sand. We have found that a vapor pressure of about 5 mm. Hg absolute will cool sand down to 36° F. The final temperature can be controlled by varying the rate of sand flow to suit the cooling range. Sand may readily be cooled from about 80° F. or above to about 32° F. by the method and apparatus of our invention. Generally, the sand will have about 4 to 8% moisture on it, although sand having lower or higher moisture content can be readily cooled as described herein. This method of cooling has a drying effect on the sand, since it evaporates the moisture from the sand grains. This provides an additional advantage since it causes better flow of the sand.

The vacuum may be produced by any known means, and we have found that a steam jet vacuum apparatus is quite satisfactory for our purpose. The vapor velocity is important to prevent sand carry-over. This velocity is dependent on the volume size of the vacuum chamber, and the apparatus is designed to obtain the desired rate of flow of vapor. A vapor velocity of from 10 feet per second up to about 40 feet per second has been found satisfactory. A baffle plate is used to prevent sand carry-over at the higher velocities.

In operation, moist sand is fed into the upper storage compartment through a top opening which is then sealed. During this loading the conical shaped throttle valve is closed. The vacuum chamber is then evacuated to the proper degree of vacuum, and the throttling valve is opened to permit the sand to flow into the vacuum chamber. The sand flows as a thin conical curtain of separated grains from around the throttling valve whereby the individual grains of sand are subjected to the vacuum. The circular opening between the upper and lower chambers and the throttling cone valve inserted in the opening may be varied by moving the throttling cone up or down relative to said opening. This controls the rate of flow of the sand.

The range of cooling and the end temperature are dependent on the vacuum and the amount of moisture evaporated from the sand. The percent of moisture on the sand initially has no effect on these factors. The amount of moisture on the sand does affect the sand's fluidability characteristics—sand with a relatively low moisture content flows more readily than sand with a high moisture content. The throttling valve compensates for this different flow characteristic. Thus, the desired vacuum in the lower chamber for obtaining a desired degree of cooling is maintained constant by adjusting the throttling valve and thus the rate of flow of the sand.

A low vacuum of about 50 mm. Hg is maintained in the upper feed chamber to prevent breakdown of flow near the end of the cooling cycle when very little sand is left in the feed chamber. After completion of the cooling cycle, the vacuum is broken and the cooled sand is removed from the lower chamber. In commercial operation, two cooling tanks may be used simultaneously so that sand is undergoing cooling in one while the other is being charged with sand. Thus, a continuous supply of cooled sand is available.

In another embodiment of our invention, sand may be continuously charged to the upper storage chamber of the sand tank, passed to the lower vacuum chamber and continuously withdrawn. For this embodiment, it is necessary to maintain a column of sand at least 22 feet high in the lower chambers and 5 to 10 feet in the upper chamber to serve as a vacuum seal. Another method is to use a rotating feed valve at the bottom thus cut-

ting the seal height to about 5 feet. Thus, it is not necessary to seal the top and bottom openings of the sand tank. In this way the cooling process is made completely continuous.

In a further embodiment of our invention, multiple, superimposed vacuum chambers are utilized in the sand tank. In this embodiment, the sand flows from the storage compartment to the first vacuum chamber, and then to a second vacuum chamber and to a third or fourth vacuum chamber, if desired. Each chamber has the same conical divider as described above and the same conical throttling valve. The advantages of multiple vacuum chambers is that the cooling is done in stages so that the vacuum required in upper chambers is less, the vacuum equipment required is smaller and less expensive, and the vacuum chambers can be smaller. Other embodiments of the invention and other means of uniformly feeding sand from a storage compartment to a vacuum compartment may, of course, be used but our preferred embodiments are herein described.

The method and apparatus of our invention may be more fully understood by referring to the drawing wherein:

FIG. 1 is a vertical elevation of a single stage vacuum sand cooler.

FIG. 2 is a diagrammatic vertical elevation of a multiple stage vacuum apparatus.

FIG. 3 is a partial vertical elevation showing in greater detail the throttle valve and the automatic instruments for controlling the throttle valve.

Referring to FIG. 1 which illustrates one embodiment of our invention, the cooling apparatus comprises a vertical cylindrical tank 1 divided into an upper compartment 2 and a lower compartment 3, by an inverted conical wall 4. Tank 1 may be of steel welded construction or other suitable construction and includes structural bracing as well known in the art. An opening 5 is provided for charging sand into storage compartment 2, and may be vacuum-tight closed by any suitable means, such as slide valve 6. A charge hopper 7 may be provided for storing sand delivered to the tank while a cooling cycle for said is in progress. An opening 8 for withdrawing cooled said from vacuum chamber 3 is provided and this opening may also be vacuum-tight closed by suitable means such as gate 9. Suitable closed manholes indicated at 40 may be provided for access to the interior of the tanks. Tank 1 is supported by legs 10.

Vacuum is produced in the lower chamber 3 by any suitable vacuum apparatus. In FIG. 1, a jet vacuum pump 11 mounted at opening 12 into vacuum chamber 3 provides the vacuum pressure. This pump may be of any commercial design capable of furnishing the desired vapor velocity to produce the degree of vacuum desired, such as a Croll-Reynolds 24 inch Booster ejector.

Throttling valve 13 is of a conical shape and fits within the circular opening 14 of conical wall 4. Valve 13 may be raised and lowered by cable 15 moving in tube 16 which is suitably sealed where it passes through the walls of the tank and at the ends where the cable extends beyond the tube to maintain the vacuum in chamber 3. Valve 13 is preferably adjusted by automatic controls illustrated generally as control unit 17 operating cable 15 through any suitable mechanism. The control unit 17 is in turn actuated by the sensing element 18 within the vacuum chamber 3. These control instruments are standard products and are described below in greater detail.

A baffle 19 is provided around the base of cone 4 and above opening 14 to prevent sand from being carried over in the vapor stream and out of opening 12 into the vacuum apparatus 11.

A vibrator 20 is attached to throttling cone 13, and a vibrator 21 is attached to the lower side of conical wall 4. These vibrators are preferably electrically operated, suitable electric connections being provided therefor, and they agitate the cone 13 and wall 12 while the sand

is flowing through opening 14 and make possible an even, uninterrupted sand flow. This is important since irregular feeding results in changes in the vapor volume. If the flow of sand slows, this lowers the vapor volume, thus a greater amount of moisture is evaporated from each sand grain, cooling the sand too much and causing freezing. If the flow rate of sand increases, the vapor volume is increased, causing less evaporation of moisture from the sand and not producing the desired cooling effect. The relation between the vapor flow and the vacuum depends upon the capacity of the vacuum pump being used.

In FIG. 2 an apparatus for performing our sand cooling method in plural stages is diagrammatically shown. This apparatus consists of a vertical tank 1A, storage compartment 2A and vacuum chambers 3A and 3B, formed by conical walls 4A and 4B, respectively. An opening 5A is provided for charging sand, and an opening 8A is provided for withdrawing cooled sand. The openings 14A and 14B into vacuum chambers 3A and 3B are controlled by cone throttle valves indicated diagrammatically at 13A and 13B, respectively. The apparatus of FIG. 2 is similar to that of FIG. 1, with multiple vacuum chambers instead of a single vacuum chamber and the cone valves 13A and 13B are operated in a manner similar to that shown with reference to cone valve 13 in FIG. 1. The advantage of multiple chambers is that the temperature of the sand is brought down in stages so that the degree of vacuum required in each chamber is less than the vacuum required in the single vacuum chamber of FIG. 1. The vacuum apparatus required is, therefore, smaller and less expensive. In use, for example, the sand may be cooled from 80° F. or above to about 45° F. in vacuum chamber 3A and from 45° F. to around 25° F. in vacuum chamber 3B.

In FIGURE 3, an automatic control system for maintaining the desired vacuum in chamber 3 is shown. As in FIG. 1, a throttling valve cone 13 fits within opening 14, a flanged ring 14C is attached to the lower side of baffle 19, and a plate 13C is attached to the base of cone 13. Plate 13C makes contact with ring 14C when throttle valve 13 is completely closed thus making a vacuum tight fit while vacuum chamber 3 is being brought to the proper degree of vacuum. Both plate 13C and ring 14C are preferably rubber covered.

Throttle valve 13 is controlled by cable 15 which moves within tube 16. Cable 15 is attached to stem 22 of an actuator 23. The actuator may be of any given type and we have found that an air valve motor such as a Foxboro No. 160 Stabiflow Motor is quite suitable for this purpose. The operation of motor 23 is brought about by a change in the pressure in vacuum chamber 3 which is transmitted through line 24 to a pressure controller 25 of any suitable type such as a Foxboro M/40 absolute pressure recording controller. The change in pressure in vacuum chamber 3 is transmitted by pressure controller 25 through line 26 to motor 23 thereby actuating stem 22 to move cable 16 to raise or lower throttle cone 13. Opening 14 is then made larger or smaller to increase or decrease the flow of sand to return the degree of vacuum to the proper predetermined level.

A valve positioner 27 may be attached to stem 22 of motor 23, for example, a Foxboro Type C Valvactor. The valve positioner functions on the impulse received from the pressure in line 26, to deliver air to pneumatic motor 23 from line 28 and brings about a smoother functioning of motor 23. The air supply in line 28 is regulated by an air set 29 such as the Foxboro Air Set B–110–AS, including filter, pressure regulator and gauge. Pressure controller 25 is kept in balance by air line 30 regulated by pressure regulator 31 such as a Foxboro Type 67 FR combination pressure regulator and filter, and gauge 32.

By the use of the above described control system, the degree of vacuum in chamber 3 may be maintained con-

stant and sand cooled to a preselected desired temperature.

While we have described a specific pneumatic control system, it will be obvious that other control systems could be used including electrical control systems.

The method of our invention will be further illustrated by the following examples. It will be understood that these examples are set forth solely for the purpose of enabling persons skilled in the art to better understand and practice the invention and are not intended to be limitative.

Example I

Commercial washed masons sand was sucked to the upper storage chamber **2** of a two-compartment sand tank 15 feet high and 54 inches in diameter through a 3 inch line by pulling a vacuum with a Croll-Reynolds 6 inch Evactor steam jet vacuum pump. At the same time the sand was sucked up, it was heated by bleeding steam into the 3 inch line. After the sand was in the top chamber **2**, the Evactor was turned off and closed, after which the high vacuum system consisting of a 24" x 16" single nozzle cast iron booster was turned on and allowed to bring the pressure in the lower vacuum chamber **3** down to approximately .2 inch Hg pressure, at which point the various sand control devices were put into operation. The length of the run was timed and the vacuum and temperatures were noted and recorded.

During the cooling run, the vacuum was controlled by manipulating the position of the valve cone **13**. A dibutylphthalate gauge was used to measure the vacuum during this test, both the upper cone vibrator and the spindle cone vibrator were on. The test run consisted of cooling 5100 pounds of sand in 4¾ minutes from 80° F. to an average of 32° F., by keeping the absolute pressure gauge at 4½ to 5 millimeters Hg pressure. This was an overall rate of 65,000 pounds an hour and the figured vapor load, 650 pounds an hour, checked closely with the vacuum on the capacity curve of the 24 inch booster used for the test. The calculated velocity of sand flow was about 550 feet per second.

Through a 16 inch plexiglass port in the side of the tank the action of the sand was observed. As soon as the sand stopped flowing, the vacuum was immediately turned off so as not to allow the sand further time to cool. As soon as the equipment was turned off the vacuum in the chamber **3** was broken and a 16 inch manway into chamber **3** was opened. The sand was leveled off in the lower chamber and its height measured to determine the volume of sand cooled. Also thermometers was placed at various positions in the sand, to determine the temperature. The temperature was found to be 32° F. without a variance of more than 1° throughout the sand mass.

Example II

The apparatus was the same as used in Example I. Separate runs were made with various settings of the throttling cone to determine as near as possible the actual setting of the cone with various discharge sand temperatures. The distance of the cone **13** from the opening **14** was obtained by marking the cable **15** and measuring it in each instance. These cone distances were as follows:

Cooling Range (initial and final temp. of sand, ° F.)	Distance	Area Around Periphery of Cone, sq. inches
85° to 35°	⅜ of an inch	2.9
85° to 40°	⅝ to ¾ of an inch	3.46
85° to 27°	¼ of an inch	2.35

The sand velocity for this size opening was approximately 540 feet per second. The flow of the sand was even whether the cone vibrators were full on or half on. However, if the vibrators were turned off completely, the flow of sand was noticeably erratic. At the lower flow rates, if the vibrators were not on, the sand flow was irregular flowing from first one side of the cone and then the other; whereas with the vibrator on, the flow of the sand was uniform around the cone and was much smoother.

It was apparent from the tests that the sand did not flow into a vacuum as it would under atmospheric conditions. That, in fact, due to the high velocity flow of the vapor, it exploded into the vacuum chamber and could not be contained in any of the conventional types of sand feeders but could be controlled by the conical throttling device of the invention or similar throttling devices. It was found that the sand under normal atmospheric conditions would not flow through the size opening necessary to control the flow under vacuum, even vibrators on. From the throttling openings, the calculated sand velocity was found to be approximately 550 feet per second. With the throttling cone valve, it is possible to obtain consistent sand temperature no matter what the cooling range is, or the moisture content. Also by resetting the controls, it was possible to obtain various sand temperature, again independent of cooling range or moisture control. The variable in this control is the rate of cooling the sand which will vary with the cooling range. To insure continuous and steady flow a vibrator should be used on the underside of the throttling cone, also on the side of the upper chamber cone.

Within the limits of the test equipment, it was found that the terminal difference between the sand temperature and the corresponding vapor pressure was less than 1° F., and in some instances it indicated that there was a slight negative terminal difference. This, of course, would mean that the vapor pressure of the moist sand was less than that of water. Although this might be the case, the point was not checked further. It was noted, however, that it was possible to cool sand to 25° to 27° F. without having it freeze together. The type of sand use in this test was also commercial standard washed masons sand.

It was originally felt that the vapor velocity through the tank should be approximately 10 feet per second, to insure separation of the sand and the vapor thus preventing sand carry-over. With this in mind a vapor bleed was installed to the 24 inch booster so that the capacity of the apparatus could be decreased. It was found, however, that even with full booster capacity which gave vapor velocities up to 40 feet per second, the sand would not carry-over if proper deflecting baffles were used.

Example III

A two-compartment tank 67 feet high and 11 feet, 6 inches in diameter was charged with 202,000 pounds of sand at an initial temperature of 80° F. in the storage compartment. The openings were sealed, and the vacuum was brought to 4.5 mm. Hg absolute in the vacuum chamber after about 10 minutes. The automatic controls were set so that the 4.5 mm. Hg pressure was maintained in the cooling chamber. The vapor flow was 7800 pounds of steam per hour. After 50 minutes, the entire volume of sand was cooled to a temperature of 36° F. While we prefer to use a conical control valve operating in a circular opening because uniform increase and decrease in the size of the opening can thereby be made, any other shape of control valve which will provide uniform feeding of the sand may be used. The term "sand" as used herein is intended to be illustrative of an application of our invention, it being understood that other finely divided moist particles may be cooled by the process and apparatus of this invention.

While we have set forth specific embodiments and preferred modes of practice of our inventive method and apparatus, it will be understood that the invention is not limited thereby, and that various changes and modifica-

tions may be made without departing from the spirit of the disclosure or the scope of the appended claims.

We claim:

1. A method for controlling the flow of sand into a vacuum chamber and simultaneously subjecting said sand to a vacuum within said chamber which comprises flowing said sand through a circular opening at the bottom of an inverted conical enclosure into said vacuum chamber, said circular opening being constricted by the insertion therein of a conical throttling valve to form an annular area through which the sand flows, while simultaneously submitting said inverted conical enclosure and said throttling valve to vibrating action and simultaneously subjecting said sand flowing through said opening and into said vacuum chamber to a vacuum while the separate particles of sand are falling through the space in the top of said vacuum chamber.

2. The method for controlling the flow of moist sand into a vacuum chamber to obtain continuous, even flow of sand and of simultaneously subjecting said sand to a vacuum within said chamber which comprises flowing said sand through a circular opening at the bottom of an inverted conical enclosure into said vacuum chamber, said circular opening being constricted by the insertion therein of a conical throttling valve to form an annular area through which the sand flows, simultaneously submitting said inverted conical enclosure and said valve to vibrating actions, and moving said valve to adjust the size of said annular area to obtain a desired rate of flow and simultaneously subjecting said sand flowing through said opening and into said vacuum chamber to a vacuum while the separate particles of sand are falling through the space in the top of said vacuum chamber.

3. Apparatus for cooling sand, which comprises a vertical cylindrical shell, at least one inverted conical divider within said shell to form a superimposed storage compartment and at least one lower vacuum chamber, a circular opening in said divider, vibrating means on said divider, throttling valve means to constrict said divider opening, vibrating means on said valve means, means to raise and lower said throttling valve means, means to charge sand into and seal said storage compartment, means to remove sand and seal said vacuum chamber, and means to impress a vacuum on said vacuum chamber.

4. A method for controlling the flow of moist sand into a vacuum chamber to obtain continuous, even flow of sand and of simultaneously subjecting said sand to a vacuum within said chamber which comprises flowing said sand through a circular opening at the bottom of an inverted conical enclosure into said vacuum chamber, said circular opening being constricted by a throttling valve to form an annular area through which the sand flows, simultaneously submitting said inverted conical enclosure and said valve to vibrating actions, and moving said valve to adjust the size of said annular area to obtain a desired rate of flow and simultaneously subjecting said sand flowing through said opening and into said vacuum chamber to a vacuum while the separate particles of sand are falling through the space in the top of said vacuum chamber.

5. Apparatus for cooling sand, which comprises a vertical cylindrical shell, at least one inverted conical divider within said shell to form a superimposed storage compartment and at least one lower vacuum chamber, a circular opening in said divider, vibrating means on said divider, throttling valve means to constrict said divider opening, vibrating means on said valve means, means to raise and lower said throttling valve means, means to charge sand into and seal said storage compartment, means to remove sand and seal said vacuum chamber, and means to impress a vacuum on said vacuum chamber.

References Cited in the file of this patent

UNITED STATES PATENTS

1,086,950	Stanton	Feb. 10, 1914
1,570,795	Tainton	Jan. 26, 1926
1,920,107	Richardson	July 25, 1933
1,991,733	Dean	Feb. 19, 1935
2,064,609	Humble	Dec. 15, 1936
2,073,553	Dienst	Mar. 9, 1937
2,227,634	Dalin	Jan. 7, 1941
2,283,319	Dienst	May 19, 1942
2,348,559	Morrow	May 9, 1944
2,386,052	Lundy	Oct. 2, 1945
2,569,085	Wood	Sept. 25, 1951
2,602,498	Overton	July 8, 1952

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,099,138 July 30, 1963

John R. Hightower et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, lines 42 and 43, for "said", each occurrence, read -- sand --; column 5, line 50, for "was" read -- were -- column 6, line 41, for "use" read -- used --.

Signed and sealed this 25th day of February 1964.

(SEAL)
Attest:

ERNEST W. SWIDER

Attesting Officer

EDWIN L. REYNOLDS

Acting Commissioner of Patents