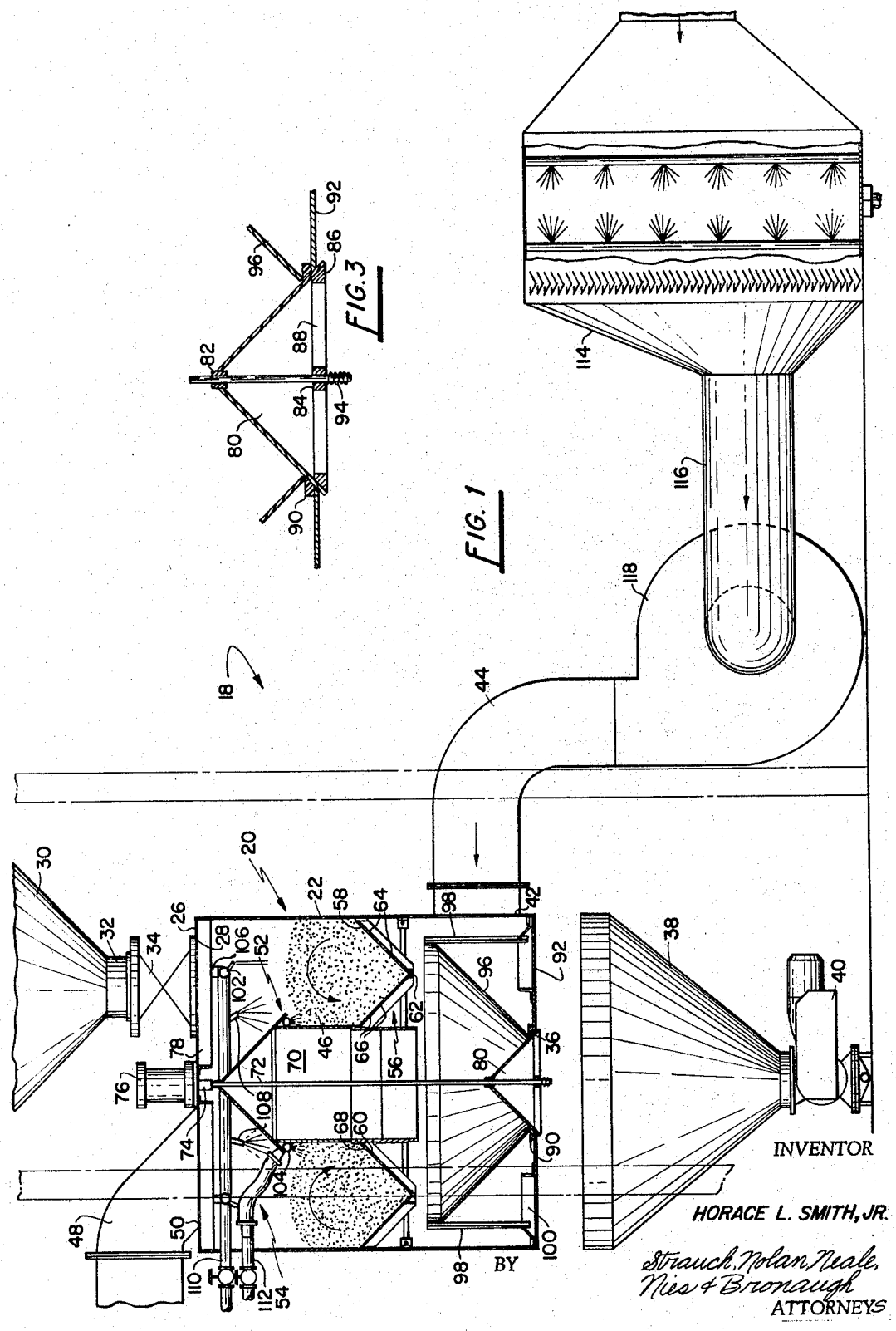
July 25, 1967 H. L. SMITH, JR 3,332,780

METHOD FOR COOLING ROASTED COFFEE

Filed Jan. 24, 1966 8 Sheets-Sheet 1



July 25, 1967 H. L. SMITH, JR 3,332,780

METHOD FOR COOLING ROASTED COFFEE

Filed Jan. 24, 1966 8 Sheets-Sheet 2

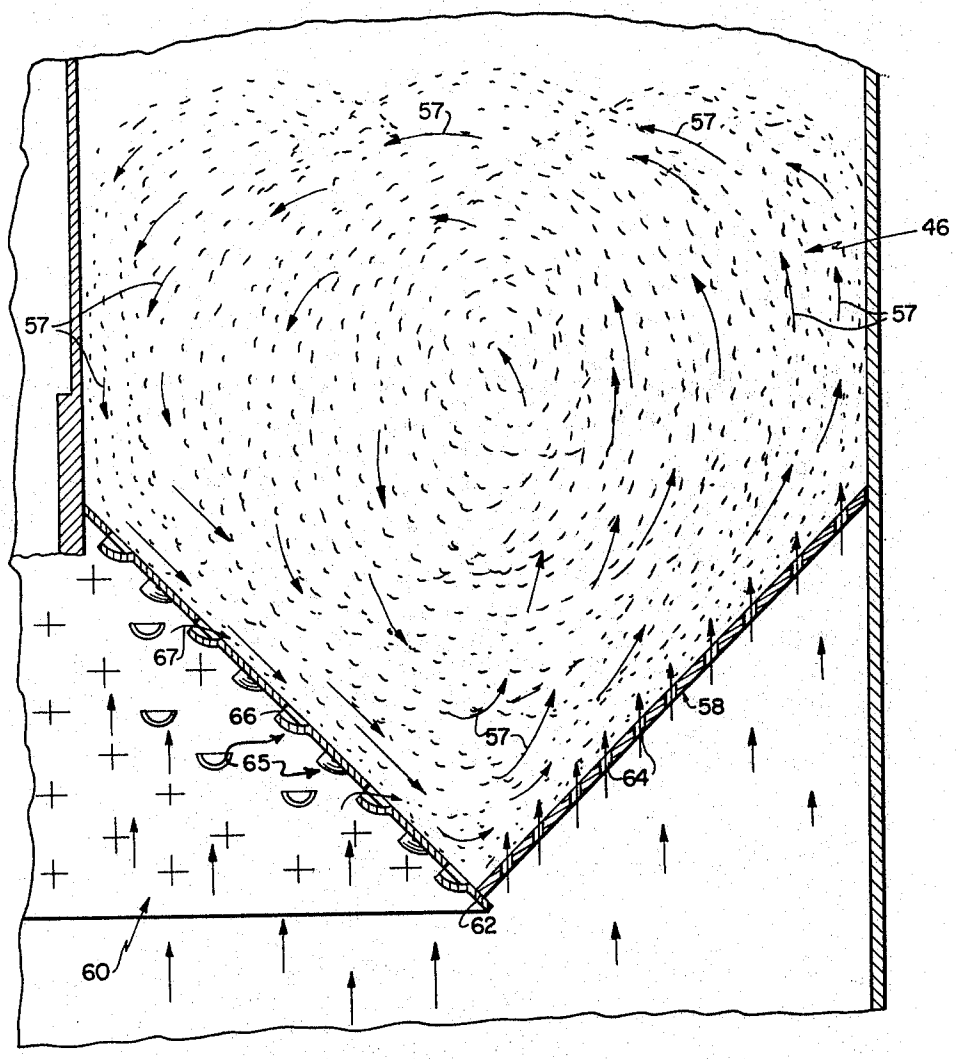


FIG. 2

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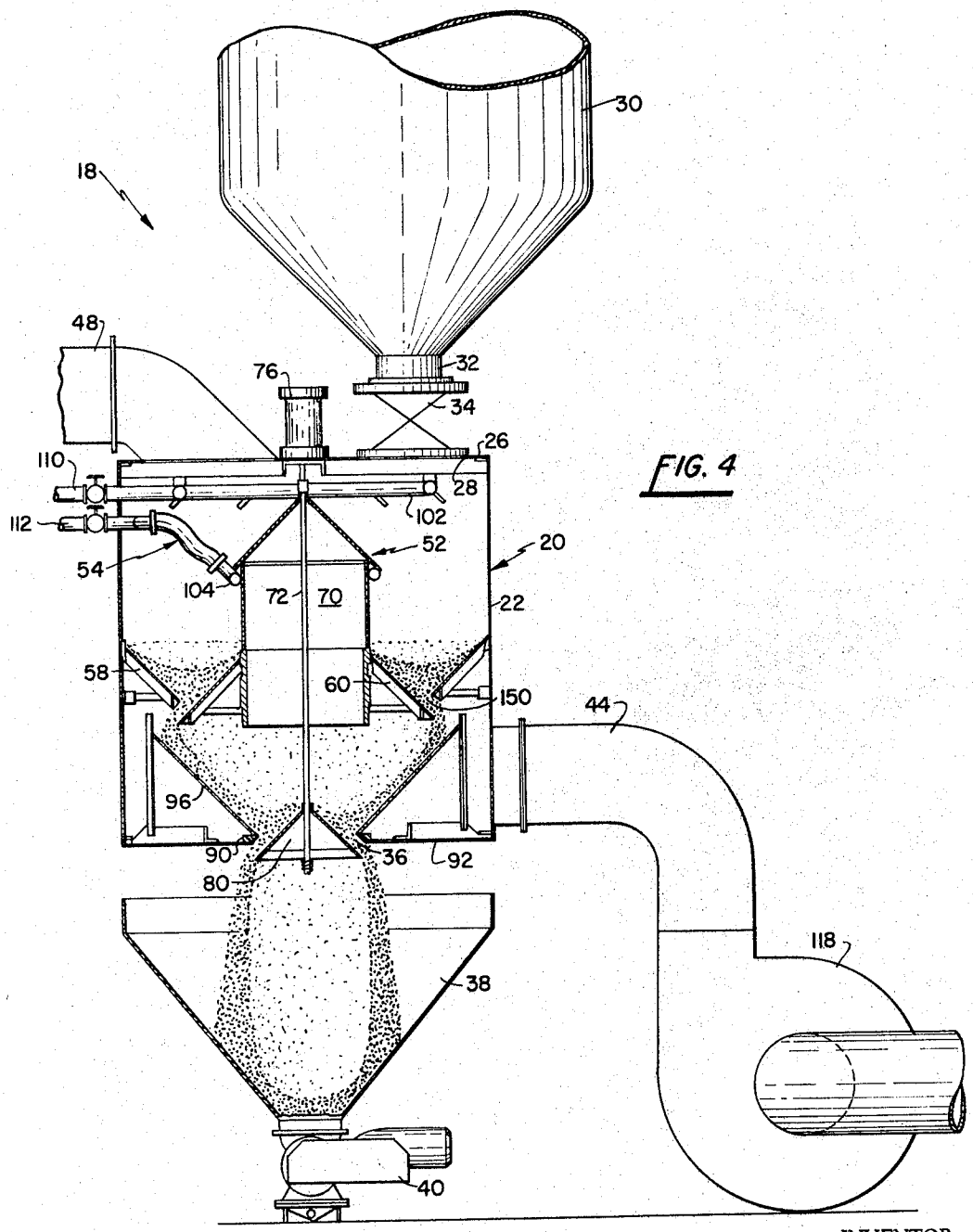


FIG. 4

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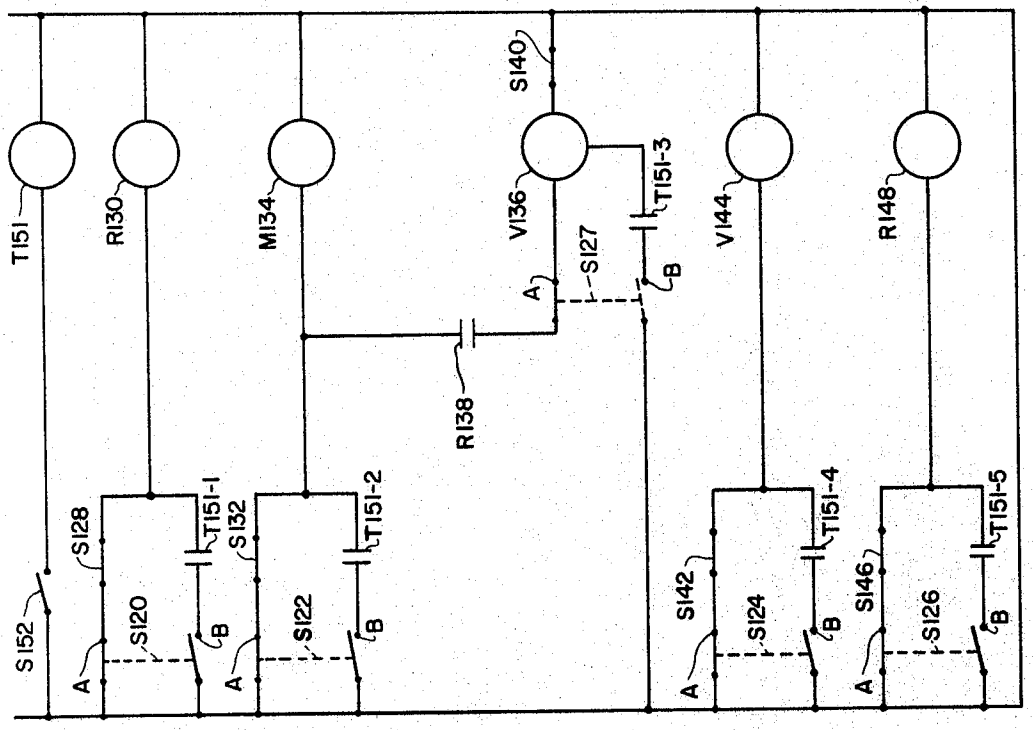


FIG. 5

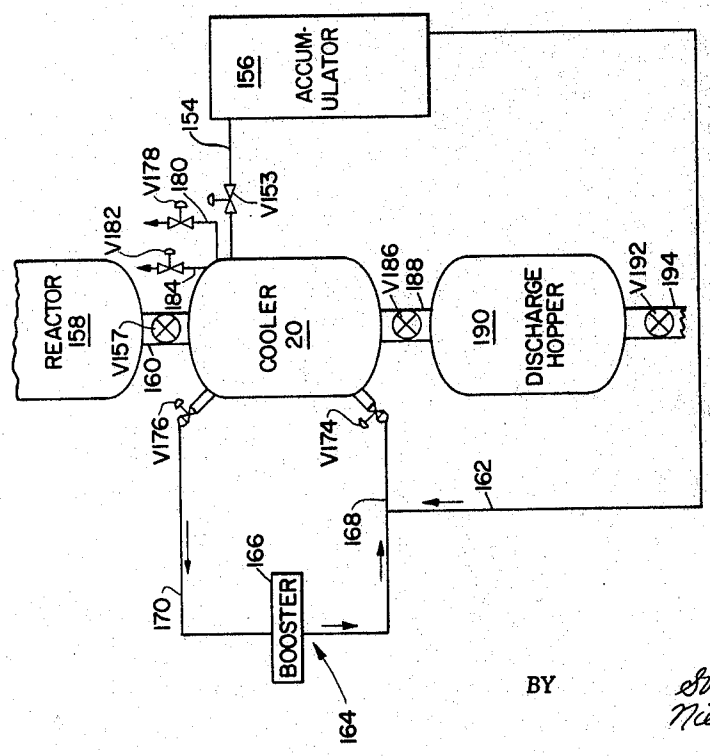


FIG. 8

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METHOD FOR COOLING ROASTED COFFEE

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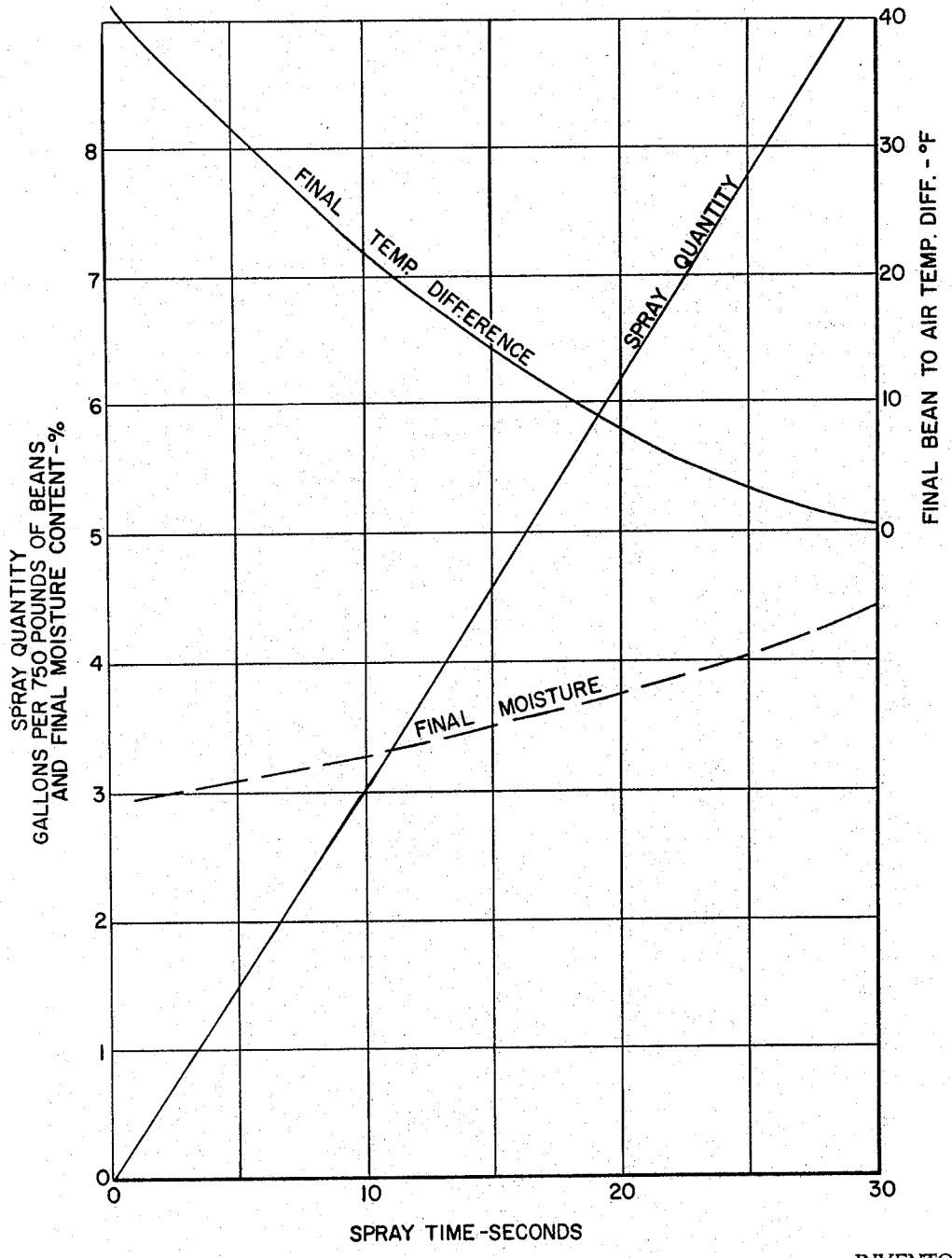


FIG. 6

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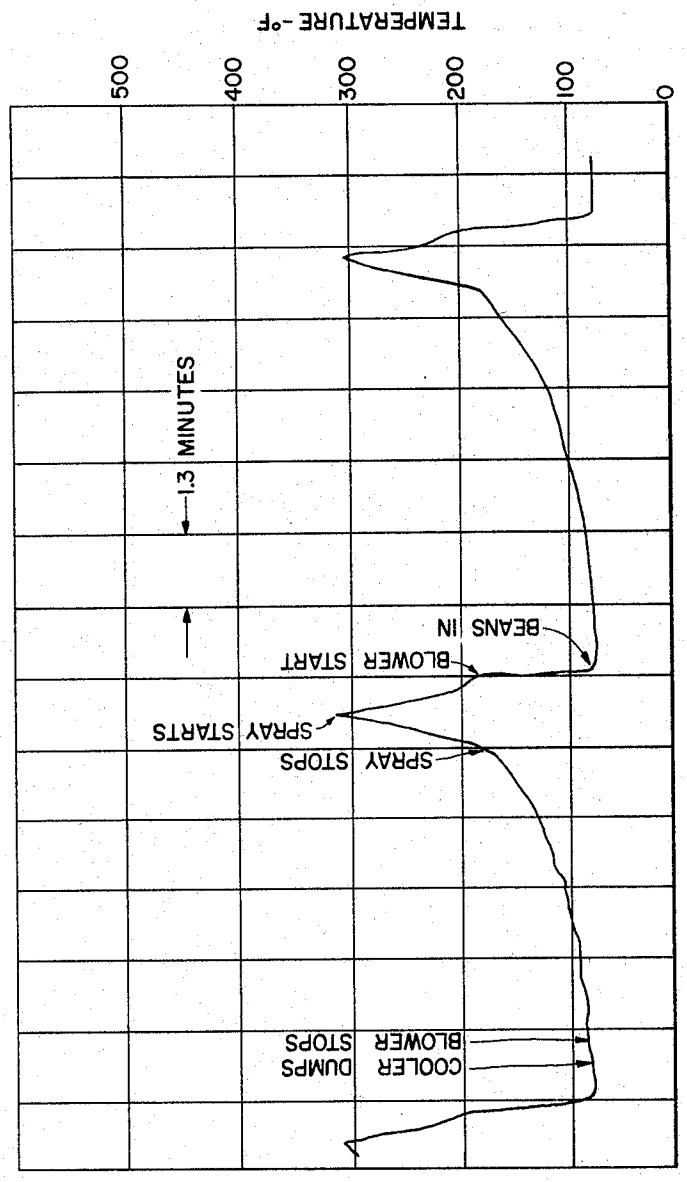


FIG. 7

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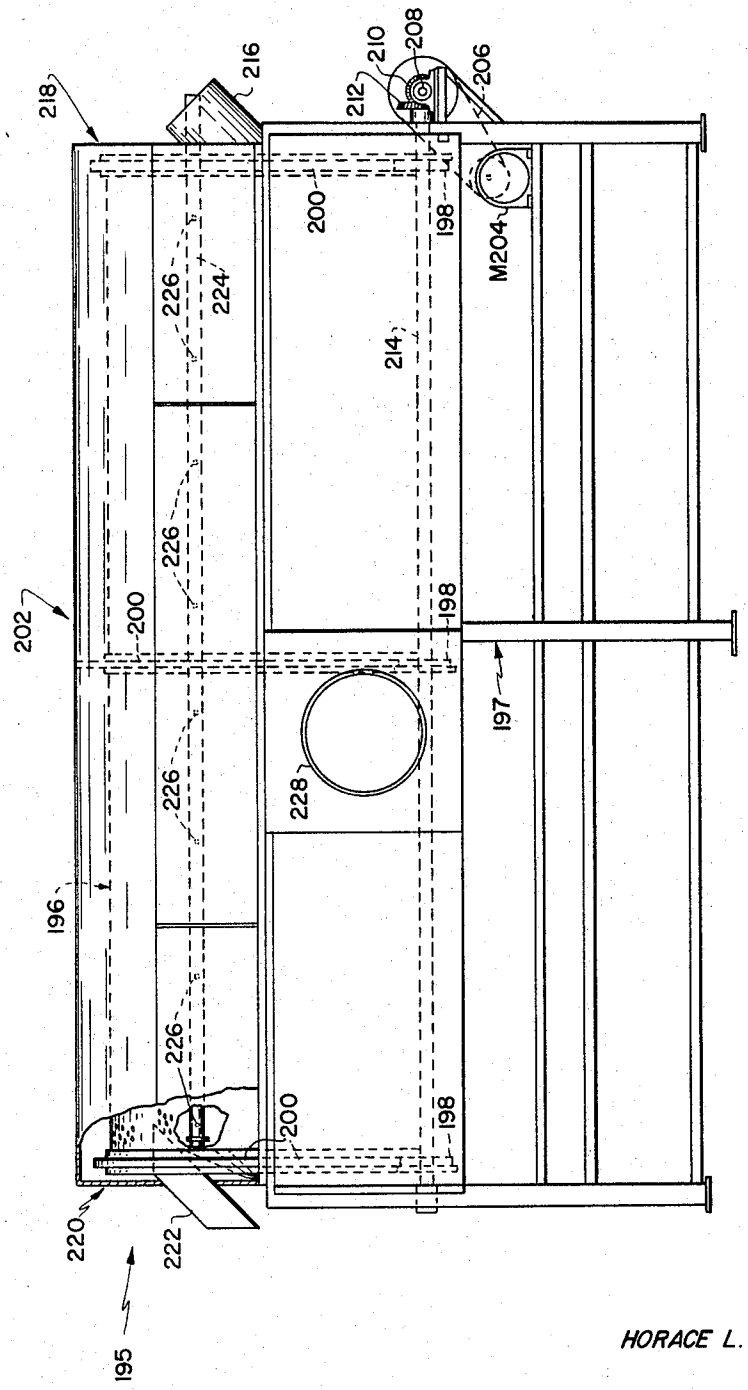


FIG. 9

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July 25, 1967 H. L. SMITH, JR 3,332,780

METHOD FOR COOLING ROASTED COFFEE

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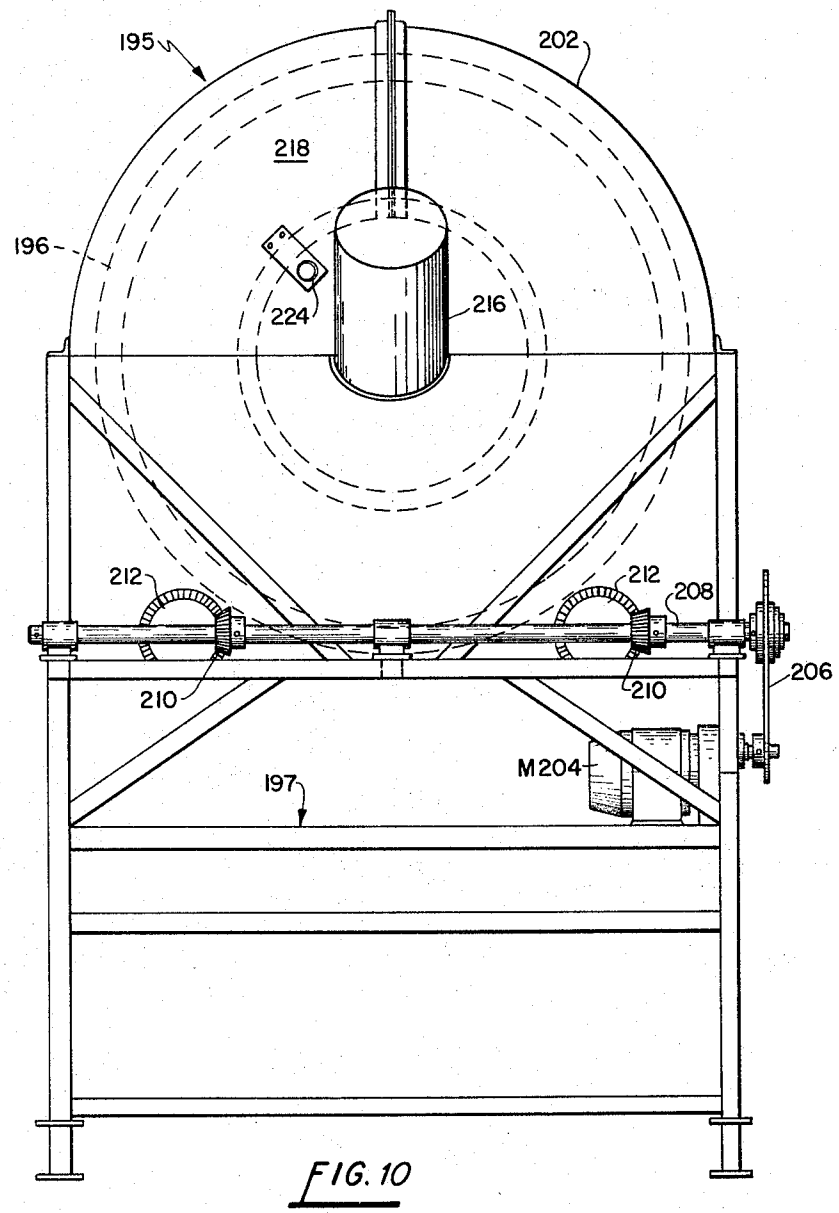


FIG. 10

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United States Patent Office 3,332,780 Patented July 25, 1967

3,332,780

METHOD FOR COOLING ROASTED COFFEE

Horace L. Smith, Jr., Richmond, Va., assignor to Hupp Corporation, Cleveland, Ohio, a corporation of Virginia

Filed Jan. 24, 1966, Ser. No. 522,503
6 Claims. (Cl. 99—68)

This application is a continuation-in-part of application No. 425,702 filed Jan. 15, 1965, by Horace L. Smith, Jr., for Apparatus and Method.

The invention disclosed herein relates to the cooling of particulate solids and, more specifically, to novel, improved methods of cooling particulate solids.

One particularly important application of the present invention is the cooling of roasted coffee beans. The principles of the present invention will, for the most part, be developed by relating them to this exemplary application of the invention. It is to be understood, however, that this invention has far greater utility. The ensuing discussion of the invention is therefore intended to be illustrative and not limiting with respect to its scope, which is defined only by the appended claims.

At the end of a roast, coffee beans have a temperature throughout of several hundred degrees Fahrenheit. Therefore, unless the roasted beans are cooled rapidly, the residual heat in the beans will prolong the roast even though no external heat is applied to the beans. The result will be a heavy roast which is undesirable because of lower yields and lower soluble solids content and because coffee brewed from the beans will have a poor aroma and bitter taste.

In the past, arrest of the roast has typically been effected by dumping water on the roasted beans as they lie in the roaster or a cooler as described in U.S. Patent No. 2,278,473 issued April 7, 1942, to Musher for Coffee, for example. A major drawback of this method of quenching the roast is the lack of uniformity in the application of the water to the beans. Consequently, the beans are not uniformly cooled and do not have uniform characteristics; and coffee brewed from them is of relatively poor quality.

Another disadvantage of this method of quenching a roast is that heat is inefficiently transferred from the beans to the cooling fluid. Cooling therefore proceeds slowly and with low efficiency.

Other methods of quenching the roast have heretofore been proposed. For example, U.S. Patents Nos. 3,122,439 and 2,857,683 suggest fluidizing the roasted coffee with a fluid which will extract heat from the beans. This technique also results in nonuniform cooling because, as pointed out in application No. 425,702, the particles are virtually stagnant in a fluidized bed; and the fluidizing fluid increases in temperature as it passes upwardly through the bed. Consequently, the particles in the lower part of the bed will be cooled much more rapidly than those in the upper part of the bed.

A further disadvantage of the fluidized bed method of cooling is that, because the cooling fluid is utilized to fluidize the bed, this fluid must be gaseous. Gases have comparatively poor heat transfer characteristics. Consequently, these processes are relatively inefficient. Further, because of their poor heat transfer characteristics, gases employed in practical volumes are incapable of arresting the roast with sufficient rapidity to prevent a heavy roast.

U.S. Patent No. 2,716,936 to Kopf suggests yet another process for cooling roasted coffee beans. In the Kopf process the beans are cooled with a fluid which includes the volatiles evolved from the coffee beans during the roast. As discussed in application No. 425,702 I have found that coffees such as Robustas, for example, can be substantially upgraded in quality by driving off certain

volatile substances during the roast and then removing these substances from the system so that they are not restored to the roasted beans. This benefit is completely lost in the Kopf process in which these volatiles are recirculated into contact with the roasted beans and materially lower their quality.

A further important disadvantage of the Kopf process is that the volatiles Kopf utilizes as a cooling fluid exit from the roaster at a temperature of several hundred degrees Fahrenheit (Kopf speaks of a temperature of 410°). To reduce the volume of volatiles necessary for cooling from such temperatures to a sufficiently low temperature that they could cool the roasted beans to room or a similarly low temperature would be impractical.

I have discovered that the disadvantages of the prior art cooling methods described above can be avoided by employing a novel technique in which the roasted beans are simultaneously agitated or circulated and sprayed with an inert quenching liquid [1] until the temperature of the beans is reduced to a temperature sufficiently low to arrest the roast. While the beans are being sprayed a fluid medium is also preferably circulated through the beans to increase the speed of the quench by absorbing heat from the beans. It is preferred that the fluid medium be at least partially saturated with the quenching liquid to maximize its heat absorbing capacity. After the roast is arrested, cooling of the beans may be continued until the desired final temperature is reached by maintaining the circulation of the beans and continuing to contact them with the fluid cooling medium.

Water is preferably employed as the quenching liquid because of the minimal expense involved. In addition, the use of water as the quenching fluid makes it possible to vary the moisture content of the cooled beans so that this parameter will be at the optimum.

The advantages of the present invention can be realized to a considerable extent by mechanically effecting a continuous circulation of the roasted beans while they are being cooled. I have now discovered, however, that my novel cooling technique can be even more effectively carried out by producing the circulation of the beans by the novel fluid-solids contact technique described in my parent application. In applying this technique to the cooling of particulate solids, I utilize the cooling medium to fluidize and rotate the bed of roasted beans while they are being sprayed to arrest the roast and during the remainder of the cooling cycle. The fluid medium therefore both produces the necessary circulation of the solids and also extracts a considerable amount of heat from them.

One advantage of this cooling technique over that disclosed in my parent application in which circulation of the beans is effected mechanically is that there is a much more rapid circulation or turnover of the beans being cooled than can be produced by mechanical circulation or agitation. As a result, there is greater uniformity of contact between the beans and the quenching liquid and the fluid cooling medium. Therefore, the beans are more uniformly cooled by application of the principles of the present invention; and the final product is more uniform. This is extremely important because, as discussed above, uniformity of the roasted coffee is a major goal in the roasting of coffee.

Uniformity of cooling is further enhanced in the technique disclosed herein because, due to the rapid circulation of the beans, cooling of all of the beans starts virtually simultaneously and with all of the beans subjected to exactly the same conditions.

[1] By "inert" gas, liquid, or fluid is meant one which will not adversely affect the quality of the beans or other solids with which it comes in contact.

Another important advantage of this invention is that, because of the more intimate contact between the beans and the fluid medium, the beans can be cooled to a temperature more closely approaching the ambient temperature of the fluid medium than has heretofore been possible in a cooling cycle of reasonable duration.

Another important advantage of cooling coffee in accord with the principles of the present invention is that there is more intimate contact of the fluid cooling medium and the quenching liquid with the beans. This increases the transfer of heat from the beans to the quenching liquid and fluid medium and therefore reduces the time required to quench the roast. The improved heat transfer characteristics also result in increased efficiency in the cooling process.

An additional important advantage of effecting circulation of beans in the manner just described is that there is a very low pressure drop through the bed of beans so that the power required to circulate the fluid medium is, relatively speaking, very low. This can result in substantial cost savings.

A related advantage is that, with the bean surfaces moist, the mass transfer conditions are such that there is a highly efficient evaporative cooling effect.

Yet another important advantage of cooling roasted coffee in accord with the principles of this invention results from the use of the same fluid medium to fluidize and rotate the bed of beans being cooled and to cool the beans. This simplifies the cooling apparatus and eliminates the energy input required to effect circulation mechanically, reducing he cost of building, operating, and maintaining the cooling apparatus.

Still another important advantage of the present invention is that the liquid sprayed onto the beans is rapidly evaporated as long as the bean temperature is above 212° F. in the case of a water spray, for example. Such evaporation is accomplished by conversion of sensible heat in the beans into latent heat of vaporization, which rapidly reduces the beam temperature by extracting large amounts of sensible heat from the beans.

A further advantage of the present invention is that roasted coffee beans cooled in accord with its principles have a much longer shelf life than beans with the same moisture content cooled by other methods.

Still another advantage of this invention is that beans can be roasted in accord with the principles thereof both at atmospheric and superatmospheric pressure. Cooling techniques and apparatus in accord with the present invention are also much much flexible and versatile than those heretofore known. Other important advantages of the present invention, attributable primarily to the preferred method of effecting circulation of the beans, are identical to those discussed in parent application No. 425,702.

From the foregoing, it will be apparent that the principles of the present invention are applicable to the cooling of particulate solids generally and are not limited in usefulness to the cooling of roasted coffee beans. Therefore, to the extent that other applications of the present invention are not expressly excluded from the appended claims, they are fully intended to be covered therein.

One important object of the present invention is accordingly the provision of novel improved methods of cooling particulate solids, which are particularly applicable to the cooling of roasted coffee beans and the like, but are also applicable to the cooling of other materials.

Other important and related but more specific objects of the present invention include the provision of methods of cooling particulate solids:

(1) Which are capable of more rapidly reducing the temperature of the particulate solids than has heretofore been possible and are therefore capable of substantially reducing the residual-heat induced changes which occur in heretofore known processes and apparatus.

(2) Which, when applied to the cooling of roasted coffee beans and like solids, are capable of materially increasingly yields, the quality of the final product, and the soluble solids content in comparison to what is obtainable when heretofore known cooling techniques are employed.

(3) Which are capable of more uniformly cooling the solids and therefore producing a more uniform product than is possible by techniques heretofore known.

(4) Which provide a more efficient transfer of heat from the solids being cooled than is obtained in previously known processes.

(5) Which avoid contamination of the solids being cooled with substances such as violatiles driven off in a previous heating step which would adversely affect the properties of the finished product.

(6) In which circulation of the solids being cooled is first effected and in which a quenching liquid is then distributed onto the solids to rapidly decrease the solids temperature and thereby minimize residual-heat induced changes in the solids.

(7) In which a single fluid medium is used both to maintain a continuous rapid circulation of the solids being cooled and to cool the solids.

(8) Capable of cooling solids at lower cost than has heretofore been possible.

(9) Which are capable of utilizing low cost media such as water and air to cool the solids to ambient temperatures, but which can utilize other liquids and fluid media, if desired.

(10) Which, when used for the cooling of roasted coffee beans, produce a product having a longer shelf life than roasted beans of similar moisture content cooled by other methods.

(11) Can be employed to cool solids both at atmospheric and superatmospheric pressures.

Other objects, further advantages, and additional novel features of the present invention will be apparent from the appended claims and as the ensuing detailed description and discussion proceeds in conjunction with the accompanying drawing, in which:

FIGURE 1 is a section through apparatus for cooling particulate solids in accord with the principles of the present invention;

FIGURE 2 is a fragment of FIGURE 1, to an enlarged scale, showing details of a flow control assembly employed in a reaction vessel incorporated in the apparatus of FIGURE 1;

FIGURE 3 is a sectional view, to an enlarged scale, of the lower end of the reaction vessel;

FIGURE 4 is a view similar to FIGURE 1, showing certain components in the reaction vessel positioned to discharge cooled solids from the vessel;

FIGURE 5 is a schematic illustration of a control system for the cooling apparatus of FIGURE 1;

FIGURE 6 is a graph illustrating the effect of spraying a quenching liquid on the solids being cooled in accord with the principles of the present invention;

FIGURE 7 is a reproduction of a temperature record strip chart showing the changes in temperature which occur in the reaction vessel during the cooling cycle;

FIGURE 8 is a diagrammatic illustration of a second form of apparatus for cooling particulate solids in accord with the principles of the present invention including a reaction vessel of the type illustrated in FIGURE 1 for cooling particulate solids under pressure;

FIGURE 9 is a side view of a third form of cooling apparatus utilizing the principles of the present invention in which circulation of the solids being cooled is produced mechanically; and

FIGURE 10 is an end view of the cooling apparatus of FIGURE 9.

Referring now to the drawing, FIGURE 1 illustrates apparatus 18 for cooling roasted coffee beans or other particulate solids [2] including a reaction vessel 20 con-

structed in accord with the principles of the present invention. Reaction vessel **20** has a vertically elongated cylindrical shell **22** which, in one actual embodiment of the present invention, is 70.5 inches in diameter and 90 inches high.

In this particular embodiment of the present invention, cooling is effected at atmospheric pressure. Therefore, shell **22** may be fabricated of relatively light gauge sheet metal.

The top wall **26** of shell **22** is provided with an inlet **28** through which the roasted coffee beans enter reaction vessel **20** from a roasting vessel **30** connected to the reaction vessel by a dump conduit **32**. A dump valve **34** controls the flow of roasted beans from roaster **30** into reaction vessel **20**.

In the lower end of reaction vessel shell **22** is a centrally located aperture or dump opening **36** through which the cooled beans are discharged into a hopper **38**. The beans are removed from the hopper as by a pneumatic conveyor **40** for packaging, grinding, or other further treatment.

A second aperture **42**, also formed in the lower portion of the reactor shell, accommodates an inlet conduit **44** for a fluid cooling medium. The fluid thus supplied to the reaction vessel passes upwardly through the bed **46** of beans being cooled and is exhausted from the reaction vessel through an outlet conduit **48** extending through an aperture **50** in the top wall **26** of shell **22**.

In addition to the components just described, reaction vessel **20** has a dump mechanism **52** for discharging the cooled beans through dump opening **36**, a spray system **54** for distributing an inert liquid medium onto the beans in the reaction vessel, and a fluid distributing and directing or flow control assembly **56**, which also supports the beans while they are being cooled.

Flow control assembly **56** directs the fluid medium entering the reaction vessel into the bed of beans **46** in such a manner as to fluidize the bed of beans and rotate the fluidized bed by circulating the beans in paths in which they move upwardly in the peripheral regions of the reaction vessel, inwardly toward the center of the reaction vessel in the upper part of bed **46**, downwardly in the central regions of the reaction vessel, and outwardly in the lower part of the bed as shown by arrows **57** in FIGURE 2. The circulation of the beans being cooled through the path just described is of extreme importance inasmuch as this pattern of circulation provides intimate, uniform contact between the beans and the fluid medium. Even more important, this pattern of circulation ensures intimate contact and uniform distribution of the inert liquid distributed through spray system **54** onto the beans to arrest the roast.

Referring specifically to FIGURE 2, flow control assembly **56** includes an outer frustoconical flow plate **58** bolted or otherwise fixed to the interior of reaction vessel shell **22** and an inner frustoconical flow plate **60** adapted to engage the lower edge of flow plate **58** to support the bed of solids **46**. Outer flow plate **58** is constructed to direct 60–70% of the fluid entering the reaction vessel through inlet conduit **44** in a generally vertical direction upwardly through the bed of solids **46**. In the embodiment of the present invention mentioned above, outer flow plate **58** is fabricated from 0.125 inch thick 304 or 316 stainless steel. The upper surface of flow plate **58** is at an angle of 45° to the horizontal. Its inner edge defines a circular opening **62** which is concentric with the centerline of the reaction vessel and through which inner flow plate **60** extends.

Flow apertures **64** are drilled or otherwise formed in flow plate **58**. In the actual reaction vessel just described, there are 6,080 0.136 inch diameter apertures in the outer flow plate. The apertures are drilled at an angle of 45° to the upper surface of the flow plate so that, with the flow plate installed in reaction vessel **20**, apertures **64** are vertically oriented. The apertures are arranged in circular and radial rows and are spaced so that the effective hole spacing is uniform over the entire plate. That is, the holes are located so that the product of the radial spacing dimension and the circumferential spacing dimension is essentially constant. In this particular flow plate, the product of the radial and circumferential spacing dimensions is equivalent to 0.45 square inch for each hole location. This provides a uniformly distributed flow through outer flow plate **58**.

Inner flow plate **60** is also of frustoconical configuration, but in typically fabricated of somewhat thinner material (0.0625 inch in the illustrated embodiment) than the outer flow plate. At predetermined intervals, louvers **65** are punched or otherwise formed in flow plate **60**, providing flow apertures **66** having a width of 0.625 inch and a depth of 0.094 inch through the plate. Louvers **65** direct the treating fluid flowing upwardly in the lower part of the reaction vessel through nozzle plate apertures **66** into a downwardly and outwardly inclined path as shown by arrows **67** in FIGURE 2. In the range of approximately 30–40% of the treating fluid is discharged into the bed of solids being treated through inner flow plate **60**. To insure proper rotation of bed **46**, louvers **65** are formed so that they will direct the fluid flowing through apertures **66** at an angle of 30° or less to the upper surface of inner nozzle plate **60**.

In the embodiment of this invention mentioned previously, the radial distance between adjacent rows of louvers **65** is 1¾ inches; and the apertures **66** in each row are evenly spaced and are approximately 1⅜ inches apart.

Flow plates of the type described above are disclosed in greater detail in copending application No. 425,702, together with other forms of flow plates which may be used if desired instead of those described above. Reference may be made to the latter application if deemed necessary for a more complete understanding of the present invention.

Like outer plate **58**, inner flow plate **60** is oriented with its upper surface **68** at an angle of approximately 45° to the horizontal when installed in reaction vessel **20**. The angle the nozzle plates make with the horizontal may be increased but should not be decreased substantially below 30°. This is to insure that the angle the upper surfaces of the flow plates make with the horizontal exceeds the angle of repose of the beans or other product being treated. If it does not, the product will not slide off the nozzle plates when dump mechanism **52** is operated to discharge the treated product from the reaction vessel.

For the foregoing it will be apparent that both the flow through apertures **64** in outer flow plate **58** and the flow through apertures **66** in inner flow plate **60** have large velocity components tangential to the fluidized rotating bed. This provides rapid and complete circulation of the solids in the rotating bed through paths of the configuration described above.

Inner nozzle plate **60** is fixed, as by welding, to the lower end of a vertically extending sleeve **70** incorporated in dump mechanism **52**. The upper end of sleeve **70** is fixed, as by welding, to a shaft **72** connected to the piston rod **74** of a hydraulic motor **76** supported from the top wall **26** of reaction vessel shell **22** by a framework **78**.

In addition to hte components just described, dump mechanism **52** includes a conical closure member **80** slidably mounted on shaft **72** at the lower end thereof by journal bearings **82** and **84** (see FIGURE 3). Journal bearing **82** is fastened, as by brazing, directly to the closure member. Journal bearing **84** is attached to the closure member by a support structure including a circular bar **86** fastened to the closure member and radial bars **88** extending from bar **86** to the journal bearing. Closure

[2] In the ensuing detailed description, exemplary embodiments of the present invention, will be described exclusively in conjunction with their application to the cooling of roasted coffee beans for the sake of convenience. Such description is intended to be illustrative and not limiting.

member 80 is adapted to engage a circular soft rubber gasket 90 fixed to the bottom wall 92 of reaction vessel shell 22 around dump opening 36 to seal the opening.

To seat closure member 80 against gasket 90, a compression spring 94 is journalled on the shaft, to which one end of the spring is attached. Compression spring 94 biases the closure member against gasket 90 to provide a tight seal. To insure that closure member 80 remains properly seated against gasket 90 during the cooling cycle, compression spring 94 is selected so that the upward force it exerts against the closure member will be greater than the downward force exerted by the gaseous medium in the reaction vessel.

Dump mechanism 52 also includes an inverted, frustoconical guide 96 for directing the cooled beans into dump opening 36 when reaction vessel 20 is dumped. The lower inner end of guide 96 is fastened, as by welding or brazing, to the bottom wall 92 of the reaction vessel. At its upper end, guide 96 is supported by vertical standards 98 fastened, at their lower ends, to a reinforcing framework 100 of structural members fixed to the bottom wall of the reaction vessel.

The remaining important feature of reaction vessel 20 is spray system 54, which includes two horizontally disposed circular headers 102 and 104 adjacent the top wall 26 of reaction vessel shell 22. As shown diagrammatically in FIGURE 1, spray header 102 is supported from the top wall 26 of the reaction vessel by a bracket 106 formed of structural members. Located at intervals of typically 45° along header 102 are spray nozzles 108. In one commercial application of the principles of the present invention, this gives a spacing between nozzles of approximately 9$\frac{3}{16}$ inches.

Header 102 is connected to a source of inert liquid medium, generally water, by conduit 110. The water or other liquid flows through the conduit header 102 and out nozzles 108 onto the beans in reaction vessel 20 in the form of a fine mist. As the beans in the reaction vessel are being continuously circulated by the gaseous medium supplied through conduit 44 as they are sprayed, there is a uniform application of the liquid medium to the beans and intimate contact of the liquid with the beans. This results in uniform rapid cooling of the beans and a consequent quick arrest of the roast with the advantages discussed above.

A relatively large volume of water is discharged through nozzles 108 in order to rapidly cool the beans. As the temperature of the beans decreases, it may be desirable to reduce the rate at which the inert liquid medium is added to the beans to insure, for example, that they have the proper moisture content when cooled but do not have wet surfaces. This is accomplished by terminating the flow of liquid medium through nozzles 108 at a predetermined point in the cooling cycle and distributing the remainder of the liquid medium onto the beans through header 104. Header 104 is connected to the source of inert liquid through inlet conduit 112. Header 104 may be provided with the same type of nozzles (not shown) as header 102; or, as an alternative, nozzles may be drilled in the header. In either case, the nozzles are preferably equidistantly spaced around the periphery of header 104 and are oriented to direct the liquid flowing through the header onto the bed 46 of beans being cooled.

In addition to effecting circulation of the beans being cooled in the manner described above, the fluid medium supplied to the reaction vessel is also employed in conjunction with the sprays just discussed to cool the beans. To increase the heat absorbing capacity of the fluid medium an air washer 114, connected by a conduit 116 to the inlet of the blower 118 by which the fluid medium is supplied to the reaction vessel, may be employed. Air washer 114 is of conventional construction. For this reason and because its details are not part of the present invention, it is not considered necessary to describe it in detail herein.

In the actual embodiment of the present invention under discussion, air washer 114 decreases the temperature of the fluid medium (in this case air) from 95° F. to 78° F. and increase its moisture content from 0.0166 pound of water per pound of dry air to 0.0208 pound of water per pound of dry air, materially increasing its capacity to remove heat from the beans being cooled.

The operation of the cooling apparatus just described can best be summarized by reference to FIGURES 1 and 5, the latter of which is a simplified schematic of the cooling apparatus control system. Referring now to these figures, the cooling apparatus is preferably constructed so that the various steps in the cooling cycle may be controlled manually or automatically. In the ensuing description of a typical cooling cycle, manual operation of the system will be assumed for the sake of convenience.

Manual control is provided by moving selector switches S120, S122, S124, S126, and S127 to the manual position in which contacts A are closed and contacts B open. The switches are shown in this configuration in FIGURE 5. Switch S128 is then closed, energizing relay R130. This, in a manner described in detail in parent application 425,702, opens dump valve 34 and energizes the dump mechanism (not shown) in roasting vessel 30, discharging a batch of roasted beans from the latter through dump conduit 32 into reaction vessel 20. Switch S128 is then opened, deactivating the dump mechanism and closing dump valve 34.

With the hot roasted beans (typically at a temperature of up to 400° F.) in the cooling apparatus, switch S132 is closed, energizing the motor M134 of blower 118. As described above, this causes blower 118 to supply a fluid medium to the reaction vessel to effect and maintain a circulation of the beans therein and to cool the beans.

As shown in FIGURE 5, a solenoid valve V136 in the inlet conduit 110 to spray system header 102 is connected to the lead to blower motor M134 through a conventional delay type relay R138. Accordingly, after the delay set into relay R138 has elapsed, valve V136 is energized, permitting the inert liquid medium to flow into header 102 and through nozzles 108 onto the circulating beans in reaction vessel 20. This delay is on the order of 40 seconds in one actual cooling system constructed in accord with the principles of this invention. The delay can be varied as desired for different applications of the invention.

In one actual and exemplary embodiment of the present invention, which is designed to cool approximately 750 pounds of roasted coffee beans at a time, the spray is preferably maintained for a period of 20–40 seconds and the flow regulated so that at least 0.70 and preferably on the order of 0.90 gallon of water per 100 pounds of roasted beans or more is sprayed on them. The spray is then stopped by opening switch S140 to de-energize solenoid valve V136.

The roasted beans are sprayed in the manner just described to quench arrest the roast at a definite point and to control the moisture content of the roasted beans, as mentioned previously. That the spray just described is effective to rapidly terminate the roast is apparent from FIGURE 7 which shows that, in one exemplary roast, the temperature of the beans being cooled was reduced from 310° F. to 180° F. in approximately 33 seconds. At this lower temperature, the heat remaining in the beans will not cause undesired changes in their characteristics.

Quenching of the roast is extremely important since it has been found that a variation of 5–10 seconds in a roast having a duration of five to six minutes or longer will affect the characteristics of the roasted beans to such an extent that the difference in flavor of coffee brewed from them is readily detectable by the average coffee drinker. Because of the rapidity with which the beans are cooled by spraying them in the manner described above, such variations in the duration of the roast, caused

in heretofore known processes by residual-heat induced changes, are avoided.

In the present invention a spray is particularly effective because the fluid medium has a very low velocity above the bed of beans or other solids. Therefore, there is virtually no tendency for the gaseous medium to blow the spray of liquid away from the beans as occurs in some heretofore known cooling apparatus.

As discussed previously, in the conventional process water is dumped on the roasted beans as they lie in a quiescent mass in the bottom of the roasting vessel or a cooler. A typical African bean roasted and quenched in this conventional manner has a yield loss of 15–16 percent. By roasting the same beans in the manner described in parent application No. 425,702, but without a quenching spray, this loss is reduced to 11.5–12 percent. By adding a spray of the type described above to add moisture to the roasted beans in a uniformly applied fine mist, the loss is further decreased to less than 10 percent. This gives the process disclosed herein an important economic advantage over the conventional process.

There is another extremely important advantage to quenching the roasted coffee beans in the manner just described. In conventional processes, the shelf life of the roasted product is approximately inversely proportional to its moisture content. That is, as the moisture content is increased, the shelf life of the roasted product is proportionately decreased. Unexpectedly, it has been found that coffees roasted and then cooled in accord with the present invention have a much longer shelf life than the same coffees roasted and cooled in the conventional manner, even though those roasted by the present process have a much higher moisture content.

As mentioned briefly above, in some applications of the present invention it may be preferable to diminish the volume of the spray after the beans have been partially cooled. In such cases, the spray through nozzles **108** is interrupted in the manner just described; and switch **S142** is closed to energize and thereby open a solenoid valve **V144** in the inlet conduit **112** to spray system header **104**. This permits the inert liquid to flow through conduit **112** into the spray header and through the nozzles of the latter onto the rapidly circulating beans in reaction vessel **20**. Termination of this spray is effected by opening switch **S142** to de-energize and thereby close solenoid valve **V144**.

As discussed above and shown in FIGURE 7, the beans in reaction vessel **20** are typically at a temperature on the order of 180° F. when the distribution of inert liquid onto the beans is terminated. The beans are cooled from this temperature to a temperature typically on the order of 80° F., i.e., room temperature, by continuing the circulation and cooling of the beans with fluid cooling medium supplied to reaction vessel **20** by blower **118**. As shown by FIGURE 7, this may take on the order of 5–6 minutes after the spray is terminated for a 750 pound batch of beans for which the time-temperature record of FIGURE 7 is typical.

Blower **118** is then stopped by opening switch **S132**, which de-energizes blower motor **M134**; and switch **S146** is closed. Closing of switch **S146** energizes a solenoid **R148**, admitting an operating fluid to hydraulic motor **76** in a conventional manner (not shown). Upon energization, hydraulic motor **76** moves dump sleeve **70** together with conical inner flow control plate **60** and closure member **80** from the positions shown in FIGURE 1 to the dump positions shown in FIGURE 4. This allows the cooled beans in reaction vessel **20** to flow through the annular gap **150** between inner and outer flow plates **58** and **60** into frustoconical guide **96** and out the dump opening **36** in the bottom wall **92** of reaction vessel shell **22** into hopper **38**.

Switch **S146** is then opened, de-energizing solenoid **R148**. This so actuates hydraulic motor **76** as to move dump sleeve **70** and shaft **72** in the opposite, upward direction, engaging inner flow plate **60** with outer flow plate **58** and seating closure member **80** against the rubber gasket **90** around dump opening **36**. Upward movement of shaft **72** and dump sleeve **70** may be terminated in any desired manner such as by the use of limit switches (not shown), for example.

As shown in FIGURE 7, the whole sequence of events in the cooling cycle is typically completed on the order of 6½ minutes.

The cooling cycle can be controlled automatically as well as manually. For automatic operation, selector switches **S120**, **S122**, **S124**, **S126**, and **S127** are thrown to "Auto" so that their A contacts are open and their B contacts are closed. Operation of the various cooling system components is then under the control of a timer **T151** through the opening and closing of its contacts **T151–1** . . . **T151–5**. The operation is identical to that described above except that delay relay **R138** is not employed in the energization of solenoid valve **V136** inasmuch as its function is performed by timer **T151**. Timer **T151** may be energized by closing normally open switch **S152** although, in actual practice, it will normally be activated by the energization of a relay (not shown) incorporated in a control system such as that shown and described in detail in parent application No. 425,702.

As mentioned previously, one of the important features of the novel cooling apparatus **18** described above is that the cooling can be closely controlled to thereby accurately regulate the characteristics of the cooled coffee beans. This is apparent from FIGURE 6 which shows the effect which the duration of the spray has on the final moisture content of the cooled beans and on the temperature differential between the ambient atmosphere and the beans being cooled when the spray is stopped. As shown by this figure, necessary adjustments in the moisture content of the beans can be made by varying the duration of the spray. The curves in FIGURE 6 are for one particular system in which 750 pound batches of coffee beans are cooled. These curves may vary for other specific applications of the principles of this invention.

This figure also shows that the temperature differential between the ambient atmosphere and the sprayed beans can be reduced to as low as is necessary to prevent residual-heat induced changes in the beans by varying the duration of the spray. It will therefore be apparent that further advantages of the novel cooling apparatus described herein reside in its versatility and the control over the final cooled product that it affords.

In much of the foregoing description, it has been presupposed that cooling apparatus **18** was operated at atmospheric pressure. Coffee roasted for brewing in the conventional manner is normally cooled at atmospheric pressure because beans roasted under superatmospheric pressures do not expand or develop. Therefore, such coffees have a high bulk density in comparison to the conventionally roasted product. Consequently, coffee cooled under pressure has a lower volume/weight ratio than that cooled at atmospheric pressure, which is disadvantageous in marketing the roasted coffee.

The disadvantage in cooling coffee at atmospheric pressure is that yields are lower than are obtained by cooling under pressure. Therefore, pressure cooling is preferably employed for applications such as the manufacture of instant coffee where the higher bulk density of the pressure cooled coffee sent to the extraction columns is not a factor.

Moreover, it has now been found that both the advantages of pressure cooling and development of the beans may be obtained by cooling the beans under pressure, slowly reducing the pressure in the cooling vessel to an intermediate pressure (as discussed in parent application No. 425,702 this pressure may typically be 25–50 p.s.i.g. or as high as 250 p.s.i.g.), and then quickly venting the cooling vessel from the intermediate to atmos-

pheric pressure. This process of cooling provides yields equivalent to those obtained by conventional pressure cooling and, in addition, provides controlled development of the roasted beans.

With the few simple modifications illustrated diagrammatically in FIGURE 8, the cooling apparatus 18 described above may be readily adapted for cooling roasted beans at superatmospheric pressure. Referring now to be the latter figure, the reaction vessel 20 diagrammatically illustrated in this figure may be identical to the reaction vessel 20 described above except for the conventional modifications such as a thicker shell necessary to adapt it to withstand above atmospheric pressures. The reaction vessel is pressurized to the desired cooling pressure (which is preferably generally equal to the roasting pressure which may be as high as on the order of 300 p.s.i. as discussed in copending application No. 425,702) by opening a valve V153 in a conduit 154 connecting cooler or reaction vessel 20 to an accumulator 156. Dump valve V157 is then opened, permitting the roasted beans to flow from roaster or reactor 158 to cooler 20 through transfer conduit 160. Valve V157 is then closed, which isolates reactor 158 from cooler 20.

Accumulator 156 is connected through a conduit 162 to a circulation system 164 which includes a booster or circulator 166 and supply and return conduits 168 and 170 connected to cooler 20. Circulation of the cooling fluid is initiated by opening valves V174 and V176 in supply and return conduits 168 and 170, permitting booster 166 to circulate the fluid from conduit 162 through supply conduit 168 into and upwardly through the beans in cooler 20. From cooler 20, the cooling fluid flows through return conduit 170 to exhaust or into a heat exchanger (not shown) where it is cooled so that it may be recirculated.

At the same time that or after the flow of cooling fluid through cooler 20 is initiated, a valve V178 may be opened to slowly vent cooler 20 through a conduit 180 to an intermediate pressure, typically on the order of 25–50 p.s.i.g. When the intermediate pressure is reached, a valve 182 is opened, rapidly venting cooler 20 from the intermediate to atmospheric pressure through a conduit 184. The vent valves may be closed when the pressure in cooler 20 reaches atmospheric to prevent air from entering the cooler, if desired.

The venting of cooling apparatus 18 in the manner described above is employed in the roasting of coffee intended to be brewed by conventionel techniques to develop the beans. In the roasting of beans for the manufacture of instant coffee, such venting may be omitted and the coffee cooled to its final temperature at the initial pressure.

In pressure cooling as in cooling at atmospheric pressure, water or other inert liquid is sprayed on the beans in the form of a fine mist as described above to arrest the roast and to control the moisture content of the roasted beans.

After the beans have cooled, a valve V186 in a transfer conduit 188 between cooler 20 and a discharge hopper 190 is opened, and dump mechanism 52 is activated as described above. This permits the cooled beans to flow by gravity from cooler 20 into the discharge hopper, which, if desired, may be pressurized in the manner described in copending application No. 425,702.

Valve V186 is then closed and a valve V192 is opened to permit the roasted and cooled beans to flow from discharge hopper 190 through conduit 194 onto a suitable conveyor (not shown).

As mentioned above, the advantages of the present invention may be realized to a considerable extent in coolers of the type illustrated in FIGURES 9 and 10 and identified by reference character 195. In this type of cooler the continuous circulation of the beans as they are being cooled is effected manually. For the most part, the details of cooler 195 are not critical to the practice of the present invention; and, moreover, coolers similar in many respects to that illustrated in FIGURES 9 and 10 are commercially available. Therefore, it is not believed necessary to describe the details of this cooler herein.

Briefly, however, this apparatus includes an elongated, cylindrical, cooling vessel or reel 196 rotatably supported from a frame 197 by car wheels or rollers 198 at the ends and the center of the cooler. The illustrated cooler 195 has a reel formed of 11 gauge, perforated, galvanized iron and is 16 feet long with an internal diameter of 60 inches. Cast iron rings 200, assembled on reel 196, engage car wheels 198 and prevent reel 196 from moving longitudinally relative to cooler frame 197. Reel 196 is surrounded by a sheet metal housing 202. The details of housing 202 are not critical in the practice of the present invention and may be varied as desired.

Reel 196 is rotated at a speed of approximately 17 revolutions per minute by an electric motor M204 mounted on frame 197 and connected through a belt drive 206 to a shaft 208 rotatably supported from the framework 197 of the cooler. Bevel pinions 210, fixed to shaft 208, mesh with and rotate bevel gears 212 which, as shown in FIGURE 9, drive the shaft 214 on which car wheels 198 are mounted. The car wheels engage the cast iron rings 200 at the ends and center of the reel and rotate it by friction.

As shown in FIGURES 9 and 10, the beans to be cooled are dumped into reel 196 through a galvanized inlet chute 216. A helical guide (not shown), extending from one end of the reel to the other and fastened to the inside of the reel, distributes the beans from the inlet end 218 of cooler 195 to discharge end 220 as reel 196 rotates. At the discharge end of the cooler, the beams are discharged from reel 196 through a chute 222 by a bucket type unloader (not shown).

After the roasted beans are dumped into cooler 195, they are sprayed with a fine mist of water[3] as described previously to arrest the roast and to control the moisture content of the beans. For this purpose, cooler 195, which is otherwise of generally conventional construction, is provided with a spray system including an elongated pipe or header 224 extending longitudinally through reel 196. Located at intervals of typically 21.5 inches along header 224 are spray nozzles 226. Header 224 is connected to a source of water or other liquid, the liquid flowing through header 224 and out nozzles 226 onto the beans in the form of a fine mist. As the beans in the bed of beans in reel 196 are continuously agitated and circulated while the liquid is being sprayed, the foregoing system provides a uniform application of liquid to the beans.

In one actual cooler of this type, the spray is preferably maintained for a period of 8–10 seconds and the flow through header 224 regulated to that at least 1.0 and preferably on the order of 1.1 gallons of water per 100 pounds of roasted beans or more is sprayed on them. The roasted beans are sprayed in the manner just described to arrest the roast at a definite point and to control the moisture content of the roasted beans, as mentioned previously.

The beans in reel 196 are also cooled by blowing air or other fluid through the perforated reel for approximately 3–5 minutes. For this purpose, cooler housing 202 is provided with an air inlet 228 and a similar air outlet (not shown) on the opposite side of the housing. Cooling air flows in inlet 228, through reel 196 and the charge of beans therein, and out the exhaust opening.

[3] Sodium bicarbonate or other alkaline materials may be added to water used as a quenching medium in this or any other embodiment of the present invention, if desired, to reduce the acidity of the roasted product although such treatment may normally not be required in roasting coffee in accord with the principles of the present invention.

A fan or blower (not shown) is provided to effect the flow of cooling air through the cooler. This fan may be of any desired construction.

Many modifications may be made in the illustrated embodiments of the present invention in addition to those discussed above. To the extent that such modifications are not expressly excluded from the appended claims, they are fully intended to be covered therein.

As discussed above and from the foregoing description of exemplary applications of the present invention, it will also be readily apparent to those skilled in the arts to which the present invention pertains that its principles and the illustrated apparatus can be used to cool particulate solids other than coffee beans. All such applications of the present invention and processes employing its principles are also intended to be covered by the appended claims unless expressly excluded therefrom.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. The process of cooling coffee beans and similar particulate solids, comprising the steps of:

(a) first effecting a continuous movement of the solids to be cooled with a fluid at a temperature lower than that of the solids by effecting a flow of the fluid medium through a bed of said solids, a first part of the fluid medium being directed upwardly through the outer regions of the bed, said upwardly directed part of the fluid medium having a sufficiently large vertical component to transport the particles upwardly in the outer regions of the bed, and the remainder of the fluid medium being directed into the lower inner part of the bed and toward the periphery thereof, said peripherally directed part of the fluid medium having a sufficiently high lateral flow component to cause outward movement of the particles in the lower part of the bed; and then,

(b) while maintaining said circulation, distributing an inert liquid medium onto said solids to rapidly reduce the temperature of said solids and thereby minimize residual-heat induced changes therein.

2. The process of cooling coffee beans and similar particulate solids, comprising the steps of:

(a) pressurizing the environment in which said solids are located;

(b) effecting a continuous movement of the solids to be cooled with a fluid at a temperature lower than that of the solids by effecting a flow of the fluid medium through a bed of said solids, a first part of the fluid medium being directed upwardly through the outer regions of the bed, said upwardly directed part of the fluid medium having a sufficiently large vertical component to transport the particles upwardly in the outer regions of the bed, and the remainder of the fluid medium being directed into the lower inner part of the bed and toward the periphery thereof, said peripherally directed part of the fluid medium having a sufficiently high lateral flow component to cause outward movement of the particles in the lower part of the bed;

(c) while maintaining said circulation, distributing an inert liquid medium onto said solids to rapidly reduce the temperature of said solids and thereby minimize residual-heat induced changes therein;

(d) slowly reducing the pressure on the solids being cooled to an intermediate pressure above atmospheric pressure while they are being cooled; and then

(e) quickly reducing the pressure on said solids from said intermediate presssure to atmospheric pressure to effect a controlled developmentof said solids.

3. The process of cooling coffee beans and similar partciulate solids with a fluid at a temperature lower than that of the solids by effecting a flow of the fluid medium through a bed of said solids, a first part of the fluid medium being directed upwardly through the outer regions of the bed, said upwardly directed part of the fluid medium having a sufficiently large vertical component to transport he particles upwardly in the outer regions of the bed, and the remainder of the fluid medium being directed into the lower inner part of the bed and toward the periphery thereof, said peripherally directed part of the fluid medium having a sufficiently high lateral flow component to cause outward movement of the particles in the lower part of the bed.

4. The process of claim **1** wherein the flow of said fluid medium is continued after the distribution of the inert liquid medium onto the solids has been completed to further reduce the temperature of said solids.

5. The process of claim **1**, together with the step of increasing the relative humidity of said fluid medium before it is passed through said solids to thereby augment its heat absorbing capabilities.

6. The process of claim **1**, together with the step of maintaining the solids under a superatmospheric pressure while they are cooled.

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