CHARACTERISTIC CAPACITY CURVE
FOR TYPICAL 3 STAGE STEAM EJECTOR

FIG. 6

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This invention relates in general to evaporative cooling under vacuum and more particularly to a continuous process suitable for the cooling of materials which are porous or have large surface areas exposed to the effect of an externally applied vacuum, e.g., certain fruit and vegetables and especially leafy vegetables.

In the conventional batch-type vacuum cooler used for leafy vegetables, a relatively large batch of produce is placed in a vacuum chamber and cooled by causing some of the moisture to flash off. At the end of the cooling period, the vacuum chamber must be relighted to the atmosphere and the doors of the chamber are opened so that the cooled batch may be removed and another batch inserted in the chamber. Since the dense, relatively dry portions of the vegetable do not cool as rapidly as the moist surface leaves, it is necessary to shut off the vacuum when the readily cooled portions approach the freezing temperature to prevent freezing of these portions, even though the denser or more inaccessible portions are not cooled to the desired temperature. If the vacuum chamber is isolated from the vacuum producer and the vegetable held for a long enough period for the temperature to equalize throughout the vegetable, the vacuum-producing unit is doing no cooling during this period.

Similarly running a conveyor through a suitable seal into a conventional batch vacuum cooler so as to eliminate opening and closing of the doors of the chamber and the consequent breaking of the vacuum appears to be an obvious solution to the difficulties mentioned above. But when such modifications are made in a batch vacuum cooler, it is found that the resultant continuously operating device is far less efficient than the batch vacuum cooler because the operation is carried out at the lower pressure and temperature prevailing at the completion of the cooling cycle rather than, as in the batch process, over a wide range in pressures and temperatures between the initial and high pressures and temperatures prevailing at the outset and the lower pressure and temperature at the finish. This follows from the fact that the available vacuum producing systems condense the vapors produced in the vacuum cooling process more efficiently at higher condensing temperatures and from the fact that such systems require less energy to compress the non-condensable gases to atmospheric pressure or greater (at which pressures they can be exhausted from the system) when the initial pressures from which these gases must be compressed are relatively high. Where a steam ejector system is used, a conventional and convenient vacuum producer, the vapors produced from the produce being cooled are compressed to high pressures and condensed at least cost where condensation can be effected with unrefrigerated water and the non-condensable gases compressed and exhausted to the atmosphere. The rate of gas and vapor removal of a given steam ejector system is considerably higher at pressures of steam temperature substantially in excess of the ultimate temperature of pressure prevailing within the vacuum chamber. For example, in the preferred embodiment to be described below, the capacity of the steam ejector system used for cooling lettuce from about 65° F to 33° F is, at a pressure of 0.62 inch Hg, about three times what it is at the 0.20 level. Thus, it will be appreciated that if the suggested modifications are made in the standard batch apparatus (a large tank) so as to allow for the entry of a continuously moving conveyor without the breaking of the vacuum seal, all of the water is flashed off at the 0.20 pressure level with the result that the steam ejector system is far less efficient.

Another problem stemming from the simple modification described above is that in the use of a large vacuum chamber, the chamber must be large enough that the vegetables continually passing there-through will be held within for a time sufficient for the temperature to equalize between the easily cooled portion (e.g. the leafy portions) and the more difficulty cooled portions (e.g. the stems or other relatively non-porous areas with relatively limited surface area). Further, every time a new portion of vegetables is inserted into the vacuum chamber, the moisture flashed off from the incoming warm vegetable condenses on the cold vegetables already in the chamber. To prevent these vegetables from warming up and leaving the chamber at too high a temperature, it is necessary to have a vacuum producer large enough to maintain the pressure in the chamber continually at the pressure corresponding to the final desired temperature of the vegetables leaving the vacuum chamber and also large enough to remove the air entering with the warm portion of entering vegetables. Finally, because the batch process removes air prior to the time of moisture volatilization, the partial pressure of the air is not present with the condensing water vapors in the condenser customarily used in conjunction with the vacuum producer with the result that maximum condenser efficiency is obtained. However, the modified process outlined above would result in moisture and air being removed simultaneously thus rendering the condensation of the water vapor less efficient since the partial pressure of the air would act to lower the temperature at which the water vapor could be condensed.

It is therefore the object of this invention to provide a vacuum process and apparatus for cooling relatively porous material and material of a relatively large surface area, which are thus amenable to vacuum cooling, which process and apparatus meet the objections to both the batch and continuous operations listed above.

It is a further object of this invention to provide a continuous process and apparatus for cooling materials, especially vegetables, which, while enabling the continuous insertion into and removal of a product out of a vacuum chamber achieves the efficiency of the conventional batch process so far as the vacuum producer is concerned.

Another object of this invention is to provide a method and apparatus for treating materials which are amenable to vacuum cooling which involves the step-wise drawing of a vacuum on the material to be cooled and the step-wise releasing of the vacuum thereon whereby to facilitate passage of the product from the atmosphere into the machine and back out into the atmosphere again and also to achieve high efficiency.

In the drawings:

FIGURE 1 is a longitudinal sectional view of the machine of this invention, only a single conveyor-mounted basket being shown.

FIGURE 2 is an end elevational view taken along line 2—2 of FIGURE 1.

FIGURE 3 is an expanded view of the sprocket at one end of the machine showing the method of suspension of
the carrier baskets (which, for clarity and ease of representation, have been incompletely shown in FIGURE 1). FIGURE 4 is an expanded sectional view of a portion of the means providing a seal between the conveyor-mounted compartment ends walls and the conduit through which the walls advance.

FIGURE 5 is a sectional view on line 5—5 of FIGURE 1 with a conveyor-mounted basket being shown in place, the structural elements exterior to the conduit being omitted.

FIGURE 6 is a graph for a typical three-stage steam ejector wherein absolute pressure in inches of mercury is plotted against the rate of water removal, the figure demonstrating the desirability of operating a steam ejector at greater rather than lesser pressures.

Generally, this invention comprises, in its broadest embodiment, a continuous method and apparatus for cooling a material which is amenable to vacuum cooling, preferably leafy vegetables such as lettuce, cauliflower, spinach, celery or brussel sprouts. The method involves passing the material to be cooled into a vacuum zone which is in communication with a vacuum producer, the zone being maintained at a pressure, as determined by standard pressure-temperature conversion tables, equivalent to the temperature to which it is desired to cool the material. It is of critical importance that the vacuum zone be of a sufficiently small size relative to the total volume of gas, actual and potential (in the form of moisture) introduced with the product that the pressure within the vacuum zone rises substantially on entry of a batch of material to be treated. Thus, at the outset of the vacuum cooling operation, the temperature of a batch of produce entering the vacuum cooling chamber is substantially higher than the temperature ultimately to be obtained and, most important, sufficient moisture and gas finds its way into the vacuum cooling chamber with the product to allow the initial pressure therein immediately to rise to a level corresponding substantially to the initial product temperature desired, as determined from the standard pressure-temperature conversion tables of the Heat Exchange Institute, condenser section. The apparatus for performing this process is, in its essentials, a conveyor which is routed through a conduit, the conveyor having secured thereto and moving therewith spaced end wall sealing elements between which there is found sufficient room for placing a batch of material to be vacuum cooled. The vaccum zone is mounted upon a moving frame which is in turn mounted and driven through conduits 14 and 16 by motor 20. Reved around the sprockets 20 and 21 are the endless link chains 30.

FIGURE 1 shows only a single sprocket at either end of the machine and a single chain but, as can be seen in FIGURE 2, each sprocket is actually one of a pair with the result that four sprockets and a pair of parallel endless chains 32 are provided. Welded in such a fashion as to bridge the space between each chain are movable wall elements 32 which are discs of circumferences just slightly less than the internal circumferences of conduits 14 and 16. These movable wall elements or discs are of a substantial size, for example, of a 28” diameter, and hence it is desirable to provide auxiliary support means so that the discs 32 are not dragged through the conduits as dead weight but rather, to some extent, are supported. Shown are rollers 33, the supporting legs 34 of which are secured to flanges 35 in turn mounted on the faces of the discs 32. One of these rollers 33 supports the weight of a disc 32 when the disc is being moved through conduit 14 and the other supports the weight when said disc 32 is being advanced through the other conduit 16. As particularly seen in FIGURE 4, a suitable sealing means is required about the periphery of each disc. Circular elastomer flanges 36 and 37 are provided depending from both the lead and trailing edges of each disc 32. The flanges are held in place by means of suitable annular steel rings 38 which are bolted to each face of each disc 32. On alternate links are perpendicularly-mounted supports 40 to each of which is pivoted by means of pin 42 a support 44 for basket 46 (see FIGURE 3).

As in FIGURE 5, opposed portions 30a and 30b of the chain are separated by roller 50. The overlapping links are secured together by pin 52 which passes through the individual links and the roller 50. A bushing 54 provides proper spacing for perpendicularly support 40 and basket support 44.

As seen in FIGURE 3, because the baskets are pivoted to the individual supports 40, the baskets swing under the influence of gravity so that the product remains upright as the endless link chains pass around the sprockets. The entire weight of the endless link chains, the baskets and material being cooled is sustained by the sprockets and discs 32 which ride within the conduits 14 and 16. Conduit 14 is provided with a small header 56 which, in turn, is in communication with a suitable vacuum source, not shown, such as a standard single-stage steam ejector. The passageways 57 in the conduit 14 preferably extend a substantial distance around the conduit and are enclosed by the collar 58, as better seen in FIGURE 2, for it is necessary that the passageways 57 be of a sufficiently narrow width that the leading and trailing edges of elastomer flanges 36 and 37 may bridge the entirety thereof as the leading disc 32 in the area designated C of FIGURE 1 passes over the passageway. This assures that pressure equalization between two adjacent chambers A and B will not occur. An additional header 59 of larger diameter is spaced therefrom and provided with a conduit leading to an additional higher vacuum source. This header 59 is also provided with a collar 60 which encloses the passageways 61. Both extend a substantial part of the distance about the periphery of conduit 14. The header is provided with a line 62 which is brought to its opposite end to header 18, thus to provide communication with the interior of the holding chamber 12. A check valve 63 is positioned in the line 62 between holding chamber 12 and the smaller zone designated "H".

The weight of the check valve must be carefully pre-determined, as will be described in detail hereinafter. The higher vacuum source may be a standard three-stage steam ejector. Suitable steam ejectors are those manufactured by the Croll-Reynolds Company of Westfield, New Jersey. FIGURE 7 is a characteristic capacity curve for a typical three-stage steam ejector of this type showing its greater efficiency at higher vacuum intake pressures.

Pressure equalization lines 64, 66, 68 and 70 join conduits 14 and 16. These must be placed as shown in FIGURE 1, viz., at such points that they are in a common position relative to the nearest disc 32. Each pressure equalization line, at the points where it enters the conduits 14 and 16, should be the narrower of the two lines which may be bridged by the elastomer flanges 37 and 38 to prevent adjacent zones in a single conduit from becoming equalized upon breaking of the seal between them. The equalizing lines are shown passing from the bottom of conduit 14 to the top of conduit 16, but this is shown merely for convenience; it is equally applicable to equalizing lines with the upper conduit 14 along one side thereof so that any water within the upper conduit 14 will not drain through the equalizing lines to the lower conduit 16.
but will be carried by the advancing discs 32 to a position beneath header 59 where such water will immediately be cooled to 33°F, thus to effect a first cleaning of heat by conduction from the material being cooled.

A feature necessary where it is desired to cool relatively non-porous objects such as melons is the spray system shown in FIGURE 1. A header 74 conveys cold water to a plurality of individual spray conduits 76 which supply the cold water to each of the zone chambers 45 to 58 formed when the conveyor-disc system is positioned as shown in FIGURE 1. Water is also conveyed into the large holding chamber 12. The spray heads mounted at the top of conduit 14 must be flush with the interior surface of the compartment or recessed therein somewhat so that the discs 32 may pass without impediment. The spray header 74 is connected to open tank 78 by means of conduit 80. The tank is provided with a float valve 82 which, in turn, permits the entry of additional water when required to hold the level at a predetermined point. Water is needed to compensate for the water carried off in the product and lost through evaporation. Since the tank operates at atmospheric pressure, any zone which is at a sufficiently lower pressure to compensate for the lift of the water and friction in the piping and spray system will receive water from the tank without the necessity of pumping. A pump could, of course, be inserted where it is desirable to use water spray in chambers at greater pressures than the differential between atmospheric and the pressure existing within the zone into which the water is being introduced.

As indicated, the water spray system is an optional feature and generally is required only where relatively dense products are to be cooled, which products are not ordinarily sufficiently cooled solely by the application of a vacuum. Such products are canteloupes, peaches, melons, pears and celery which are conventionally cooled by spraying them with cold water. In conventional machines, it is necessary to circulate large quantities of water to prevent an excessive temperature rise of the product as it is sprayed. The rate of heat conduction from the produce to the water depends upon the temperature difference between the produce and the water, lower water temperatures facilitating heat removal. The arrangement described above permits water to be held at the lowest possible temperature with relatively small quantities of water being circulated. That is, enough water is circulated to retain the surface of the produce in a wet condition while the constant evaporation of water from the surface of the produce facilitates heat removal.

The invention will be better understood from the following example. A machine is provided having discs of about 28" outside diameter spaced 28" apart, each disc being fitted with elastomer seals 36-37 bridging a total of about 3". The elastomer seals are suitably prepared from a polyvinyl chloride material such as the B. F. Goodrich "Plastisol" compound 370 CA 77. The endless conveyor is advanced at the rate such that one entire batch-sized zone passes a given point in six seconds. A box of moist lettuce containing 24 heads is placed within one of the baskets at the feed end and advanced through the machine. The temperature of the lettuce will generally be about 65°F, though it may be as high as about 85°F. The lettuce enters the flared-mouth upper conduit 14 at atmospheric pressure, roughly 30 inches of mercury, and when it reaches the point of the basket shown in FIGURE 1, it is substantially sealed from the atmosphere. As soon as this compartment A passes over the first equalizing pipe it will be connected with compartment R which is shown in FIGURE 1 as being under a pressure of 19.68 Hg absolute. Consequently when compartment A at 30.00" and compartment R at 19.68" are equalized they will both reach a pressure of 24.84" assuming the compartments have the same volume and there is no leakage of air in or out of either compartment from any other source.

Compartment A which is now at 24.84" will eventually reach zone B and will equalize with one of the lower chambers which will be at 14.52" whereupon both chambers will come to 19.68". Then the lower chamber will then equalize with a lower zone at 9.36" giving two zones at 14.52". The upper zone at 14.52" continues to the right, and equalizes with a zone on the lower row at 4.2" giving two zones with pressures of 9.36". The zone in the upper row now passes under the primer 58 where its pressure is lowered to 5.2". It then continues to the right and equalizes with a lower row zone at 3.2" giving two zones at 4.2". The upper zone at 4.2" then equalizes with a lower zone of 2.2" giving two zones of 3.2". The diagram shows this position as zone E and zone O. The upper row zone of 3.2" then proceeds to the right and equalizes with a lower zone at 1.2" giving two zones at 2.2". The upper row zone at 2.2" continues to the right and equalizes with a lower zone of 2.2" giving two zones of 1.2", then comes under the three-stage ejector vacuum system where its pressure is lowered to 2", causing moisture in the product to flash off after which the zone passes through the holding chamber where it is held at 2", finally reaching the zone L on the diagram and eventually is equalized with an upper zone at 2.2", making two zones at 1.2" and proceeds to the left through a series of equalizations already described, finally reaching the position R on the diagram where it has a pressure of 19.68", then 0.0" and then vented to atmosphere where it occupies position S on the diagram.

Any number of equalization stages may be provided. The effect of additional lateral equalization conduits positioned before header 56 is to increase the length of conduits 14 and 16 while lessening the amount of air the low vacuum ejector must remove. For optimum results, the volume which is in direct communication with chamber D should be such that as disc 32 passes beneath the header 59, the pressure at the vacuum intake of the three-stage ejector will rise to a level which corresponds roughly to the prevailing temperature of the product, as read from the aforementioned pressure-temperature conversion table. Hence, if the product enters the cooler at a field temperature of about 65°F, the pressure on the product immediately after it passes beneath the lead wall of header 59 shown in FIGURE 1 almost immediately falls to a pressure corresponding to the temperature of the product (62°F at 63°F) causing moisture to flash off the product. The rate the pressure is lowered further depends on the capacity of the three-stage ejector to remove the water vapor flashed off. The speed of the conveyor is maintained to suit the capacity of the ejectors so the pressure will be at the final desired pressure by the time the following seal of the volume being cooled passes beyond the wall of header 59. If the temperature of the product is at a field temperature of 85°F it would have flashed slightly during the step previously mentioned (when a zone at 2.2" equals a zone at 2", yielding two zones at 1.2"). Under these conditions the 85°F product cools to 84.6°F; when the seal passes the wall of header 59 the pressure under the header at 2.2" rises while the pressure in the 1.2" zone falls causing moisture to flash off as soon as the pressure drops below 1.2". Further reduction in pressure proceeds in accordance with the capacity of the three-stage ejector as previously described. It should be noted that in the case of the 85°F product with the particular pressures described in the example, lowering the temperature 4°F during the equalizing step is accompanied by a corresponding rise in temperature of the product in the 20° zone. This is undesirable and in normal operation is prevented by regulating the pressure under the primer so that the equalizing step just prior to passing under header 59 will be slightly above the pressure corresponding to the saturation temperature of said zone.

In FIGURE 1, zone H is just leaving the small vacuum chamber and would be at that point at a pressure approximately 2.0 Hg absolute corresponding to about 33°F.
The check valve 33 would be open under these conditions and the holding chamber would also be at the above pressure. As the chamber H moves to the right the elastomer seal 36-37 (which has been shown a bit wider than the opening) will reach a position where the opening is blocked off momentarily and at that time the vacuum will be removing vapors from the holding chamber and the check valve will, of course, again be wide open. As zone G comes under the opening the pressure in the vacuum chamber will immediately rise to some point between the .2" and the 1.2" which zone G had prior to coming under the vacuum. Under these conditions the check valve will close preventing any moisture flushing off of the product in the zone G from passing into the holding chamber where it would condens on produce already cooled, consequently adding heat to the produce already cooled. The check valve prevents this.

This check valve is adjusted so that it opens by its own weight when the pressure in the holding chamber and in the small cooling zone H are equal and closes at any time there is a very slight difference in pressure. It closes when the small cooling zone H is at a pressure (equivalent to just less than 1.5° F.) than the holding chamber 12.

The lettuce then advances into the large equalization chamber 12 which is provided to allow the stems and other denser, more difficultly cooled portions to reach a temperature closely approximating that of the leafy portions. Chamber 12 is of substantial size so as to provide a throughput time adequate to permit heat to pass by conduction from the more difficultly cooled portions, such as lettuce butts, while at the same time periodically removing moisture, thus keeping the easily cooled portions of the lettuce at the desired final temperature. In other words, heat passes from the butt of the lettuce to the leaves with the result that the leaves warm up slightly, causing further moisture to evaporate therefrom, thus cooling the leaves back to approximately 33° F. Thus, when the lettuce reaches the volume labeled "L" of FIGURE 1, the entire body of the lettuce, both butt and leaves, has been cooled to the final temperature.

Substantial variations are possible in the pressures and temperatures employed, for it is apparent that the general principles involved may be utilized to cool any product which is amenable to vacuum cooling to less than 212°. Obviously, where one is cooling a product from a temperature above 212° to a level of 212°, the product may simply be opened to the atmosphere and the water present allowed to flash off without concern for matters of vacuum chamber efficiency. When emerging from the chamber 12, the temperature of the lettuce, including the stem, is within a range of about 33° F. to 35° F. and at a pressure of about 0.18-0.20° Hg absolute. Some cooling would be obtained quite irrespective of the material being treated so long as care is taken that in the high vacuum zone, the entry of produce to be cooled is also accompanied by such a rise in pressure (somewhat over a three-fold increase in the preferred process described above) that the pressure therein is roughly equivalent to or somewhat greater than the saturation temperature which corresponds to the entering product temperatures. If a four-stage steam ejector is substituted for the three-stage steam ejector noted earlier, it is possible to use the apparatus as a freezer, the principles outlined earlier continuing to be applicable. The produce may also be blanked prior to cooling and freezing in accordance with conventional practice.

From the foregoing, it will be seen that the preferred structure of this invention enables the continuous passage of a product through a vacuum chamber while making possible the separate removal of air entering with the product before the moisture therein is evaporated whereby to obtain maximum efficiency of operation of the condenser system. The equalization system provided assures that the cool product obtains most of its air from the incoming compartments prior to its return to the atmosphere, thus resulting in far greater efficiency than if air for the exciting compartments is provided directly from the atmosphere itself.

To compensate for variations in weight and temperature of entering produce, the speed of the endless-link chains carrying the vacuum-tight compartment seals is varied. The speed given earlier is suitable for lettuce entering at a field temperature of about 65° F., but it is apparent that speed variations will be necessary where products are treated which are cooled with greater difficulty. It is also obvious that the type of vacuum producer may be varied, though, in any event, it is essential that there be only a small chamber on the vacuum intake side of the vacuum producer.

Other apparatus set-ups for achieving the method disclosed are possible whereby to practice the process without the use of the conduits disclosed.

Obviously, many modifications and variations may be made without departing from the spirit and scope of this invention, and therefore only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. A process for cooling a material which is amenable to vacuum cooling comprising: passing said material in a moist condition into a vacuum zone maintained at a predetermined gas pressure, said predetermined pressure being the pressure equivalent to the saturation temperature corresponding to the ultimate material temperature desired, said material, prior to entering said vacuum zone, being under a pressure in excess of that required to permit the said moisture to flush off therefrom, said vacuum zone being sufficiently small that on entry of the material to be treated therein, the gas pressure within said vacuum zone rises to a level substantially equivalent to the saturation temperature which corresponds to the entering material temperature, exhausting gas from said zone while retaining said material in said zone until the gas pressure again reaches said predetermined pressure.

2. Apparatus for cooling material which is amenable to vacuum cooling comprising: a generally U-shaped conduit; a first vacuum source in communication with the interior of said conduit at an intermediate point substantially removed from the open end of one leg of said U-shaped conduit, the vacuum intake of said vacuum source being immediately adjacent said intermediate point of said conduit; sealing means for forming a substantially vacuum-tight seal with the conduit internal walls on either side of a material to be cooled; a second and lower vacuum source in communication with the interior of said conduit at a point between the first vacuum source and the second leg of said U-shaped conduit; means for moving said sealing means and said material to be cooled through said conduit simultaneously; and at least one pressure equalizing conduit positioned between the open ends of said U-shaped conduit and the point of communication of said second vacuum source providing communication between both arms of said generally U-shaped conduit.

3. The structure of claim 2 wherein two of said equalizing conduits provide communication between the interior of the arms of said U-shaped conduit at points between the point of communication of said second lower vacuum source and the open ends of said conduit.

4. An apparatus for cooling material which is amenable to vacuum cooling comprising: a generally U-shaped conduit having parallel conduits; a large, sealed tank positioned at one end of said conduits, said conduits being in communication with the interior of said tank; a first vacuum source in communication with the interior of the first of said conduits at a point intermediate the said tank and the open end of said conduit, the vacuum intake of said vacuum source being immediately adjacent said intermediate point of said conduit; sealing means for forming a substantially vacuum-tight seal with the conduit internal walls on either side of the...
material to be cooled; means for moving said sealing means and material to be cooled through said first conduit, through said sealed tank and thereafter through the second of said conduits; and a second lower vacuum source in communication with the interior of said first conduit at a point spaced between the said first vacuum source and the end of said first conduit; and vacuum means in communication with the interior of said tank, said vacuum means being capable of creating a vacuum within said tank at least as low as that created by said lower vacuum source at its point of communication with the interior of the said first conduit.

5. The structure of claim 4 wherein means are provided for spraying water into the first of said conduits.

6. The structure of claim 4 wherein at least one pressure equalizing conduit provides communication between the interior of each of said conduits at a point intermediate the ends of said conduits and the point of communication of said second vacuum source.

7. The structure of claim 6 wherein two pressure equalizing conduits are provided, both being positioned intermediate the open ends of said conduits and the point of communication of the said second vacuum source.

8. An apparatus for cooling material which is amenable to vacuum cooling comprising: a conduit having a feed end and a discharge end; a first vacuum source in communication with the interior of said conduit at a point spaced from said feed end, the vacuum intake of said vacuum source being immediately adjacent said spaced point; sealing means for forming a substantially vacuum-tight seal with the conduit internal walls on either side of the material to be cooled; a second and lower vacuum source in communication with the interior of said conduit at a point between the first vacuum source and the discharge end of said conduit; means for moving said sealing means and said material to be cooled through said conduit simultaneously; and at least one pressure-equalizing line extending from a point between the feed end of the said conduit and the said second and lower vacuum source to a point positioned between the said discharge end and the said second vacuum source; and means for spraying water into the interior of the said conduit at a point between the said feed end of the said conduit and the said second vacuum source.

9. An apparatus for cooling material which is amenable to vacuum cooling comprising: a conduit having a feed end and a discharge end; a first vacuum source in communication with the interior of said conduit at a point spaced from said feed end, the vacuum intake of said vacuum source being immediately adjacent said spaced point; sealing means for forming a substantially vacuum-tight seal with the conduit internal walls on either side of the material to be cooled; a second and lower vacuum source in communication with the interior of said conduit at a point between the said first vacuum source and the said second vacuum source.

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