We, CABOT CORPORATION, of 125 High Street, Boston, Massachusetts 02110, United States of America hereby apply for the grant of a Patent for an invention entitled:

METHOD AND APPARATUS FOR COOLING A HOT PARTICULATE-LADEN PROCESS STREAM

which is described in the accompanying complete specification. This application is a Convention application and is based on the application numbered 275,219 for a patent or similar protection made in United States of America on 19th June 1981.

My address for service is Messrs. Edwd. Waters & Sons, Patent Attorneys, 50 Queen Street, Melbourne, Victoria, Australia.

Dated this 17th day of June, 1982.

CABOT CORPORATION

James Murray

[Signature]

To: [To Whom]

[Signature]
In support of the Convention Application made by (1)

CABOT CORPORATION

(hereinafter referred to as the applicant) for a Patent 84988/82

for an invention entitled: (2)

METHOD AND APPARATUS FOR COOLING A HOT PARTICULATE-

LADEN PROCESS STREAM

I, (3) Samuel Barbin Coco, Jr.

of 125 High Street

Boston, Massachusetts, U.S.A.

do solemnly and sincerely declare as follows:

1. I am authorised by the applicant for the patent
to make this declaration on its behalf.

2. The basic application as defined by Section 141 of the Act was
made in (6) United States of America

on the 19th day of June 1981, by

ALLAN CLARK MORGAN

3. (5) ALLAN CLARK MORGAN, of 539 Concord Road,

Sudbury, Massachusetts, United States of America

is the actual inventor of the invention and the facts upon which the applicant
is entitled to make the application are as follow:

The applicant is the assignee of the said actual inventor

4. The basic application referred to in paragraph 2 of this Declaration
was the first application made in a Convention country in
respect of the invention the subject of the application.

DECLARED at Boston, Massachusetts, U.S.A.

this 19th day of May 1982.

CABOT CORPORATION

By Samuel B. Coco, Jr.
Sr. Vice President

The Commissioner of Patents.
Claim

1. A method for cooling a hot, particulate-laden gas stream in preparation for collection of the particulate component therefrom which comprises atomizing liquid water into said stream in such quantity as to extract heat from said stream by evaporation of the liquid water so atomized thereinto and cool said stream to a temperature above the dewpoint thereof, characterized in that said hot, particulate-laden gas stream is conducted through a relatively compact venturi-shaped conduit comprising an upstream convergent portion, a downstream divergent portion and a throat portion therebetween; accelerating said gas stream to a Mach number of at least about 0.25 in said throat portion and, in said throat portion, introducing substantially transversely into said gas stream said cooling water to be atomized as a plurality of streams thereof.
METHOD AND APPARATUS FOR COOLING A HOT PARTICULATE-LADEN PROCESS STREAM

The following statement is a full description of this invention, including the best method of performing it known to...
Method and Apparatus for Cooling a Hot Particulate-Laden Process Stream

The present invention relates broadly to cooling of particulate-laden process streams and is more specifically concerned with an integrated method and means for cooling hot, particulate-laden process streams and separating the particulate burdens therefrom by cloth filtration.

In many industrial processes products or by-products are produced in suspended particulate form, that is to say, in the form of a solid particulate matter component entrained in a hot gas stream component. For instance, furnace carbon blacks are produced by the thermal decomposition and/or partial combustion of hydrocarbonaceous feedstocks and are normally initially produced in the form of an aerosol or suspension of the particulate carbon black product in hot by-product flue gases. The carbon black process stream is quenched in the carbon black forming reactor to terminate the carbon forming reaction, further cooled and then treated by cloth filtration in order to collect the carbon black product. Some other exemplary industrial processes in which a hot particulate-laden process stream is cooled and then subjected to cloth filtration and to which the present invention may be employed with good effect are: treatment of coal fired power plant flue gases prior to filtration of the particulate burden therefrom, cooling of dry process cement calcining streams, cooling of calcined ore or rock dust containing streams and the like.

Typically, cloth filtration methods of commerce involve flowing a particulate-laden gaseous stream through one or more porous cloth or fabric filtration elements, said elements having a selected porosity or transmissibility which is, at once, sufficient to allow the gaseous component of the process stream to pass therethrough while being insufficient to allow passage of the particulate component. In consequence, the particulate component is separated from the gaseous component and is deposited on the upstream or
collection side of the cloth filtration elements. Means are usually provided by which to aid removal of the particulate burden from the filtration elements, such as by periodic repressurization or reversal of the gas flow therethrough, mechanical shaking or vibration thereof and the like. The thusly separated particulate burden is generally conducted into a collection hopper and is periodically removed therefrom for packaging and/or for such further processing as may be desired or necessary to provide a finished particulate product. In furnace carbon black processes of commerce, the so-called "fluffy" carbon black collected from the cloth filtration device may be subjected to such further treatments as: wet pelletizing; dry pelletizing; densing; calcining; surface oxidizing with air, ozone or mineral acids; milling, such as by pin milling, hammer milling or fluid energy milling; treating with surfactants, oils or oil emulsions and the like.

The cloth materials utilized to produce the filtration elements are usually composed of woven or unwoven textile fibers such as glass, cotton, wool, polyamide, polyester, polytetrafluoroethylene or blends thereof. Said materials are formed or sewn into the geometric shapes required of the particular cloth filtration device employed. One commonly employed filtration device is a so-called "bag filter", the cloth filtration elements of which are of long tubular shape. Other known cloth filtration devices employ cloth filtration elements in the forms of envelopes, sheets, bolts or disks. Certain other known cloth filtration devices employ cloth filtration elements which are essentially shapeless, the cloth filtration material merely being employed in the form of a stuffing or filler for a cartridge element through which the particulate-laden process stream is conducted.

Whatever the particular cloth filtration device used, however, it is essential that the particulate-laden process stream conducted thereinto have a temperature which is not
so high as to be deleterious to the cloth filtration elements thereof. Likewise, however, it is also important that the temperature of the process stream conducted into the filtration device be sufficiently high as to maintain the atmosphere within the device at above the dewpoint of the gaseous component of the process stream, thereby to mitigate against condensation of condensibles therefrom. Failure to maintain the former temperature criterion leads, of course, to excessively short cloth filtration element life. Failure to maintain the latter temperature criterion can lead to collection of adulterated and/or wetted particulate product and to blinding of the cloth filtration elements. In the case of furnace carbon black operations, the collection of wetted carbon black in the cloth filtration device not only adversely affects the efficiency of the collection step, but also can adversely affect the efficiency and quality of downstream finishing operations such as pelletizing, densing or chemical aftertreating of the collected carbon black and the quality and uniformity of the resulting finished carbon black product.

While it is possible to cool a hot, particulate-laden process stream to within the aforesaid temperature criteria by means of indirect heat exchangers, there arises the problem of efficient and economic operations of such heat exchangers. Normally, the goal temperatures for a particulate-laden process stream to be treated by cloth filtration will range from about 149°C to about 371°C. Indirect heat exchange is usually an economically justifiable method heat extraction only when the temperature drop to be achieved is relatively great, for instance, on the order of 300°C, or more, and when the hot process stream to be cooled is at a temperature of substantially above about 538°C. Thus, for example, to cool a 538°C particulate-laden process stream to about 260°C by an indirect heat exchange technique generally requires substantial and expensive equipment, the process economics of which are not usually justified even assuming complete
recoupment of the extracted heat energy. Moreover, indirect heat exchange equipment is usually adapted for operations under relatively static process conditions and is therefore, usually ill-adapted for reasonably precise control in response to changing process conditions. In view of these foregoing efficiencies, therefore, it is conventional practice in chemical plant operations to first extract and recoup as much heat from the hot process stream by indirect heat exchange as is economically feasible and, thereafter, to further quench the process stream to suitable cloth filtration temperatures by atomizing liquid water thereto.

This quenching of the process stream to suitable cloth filtration temperatures is normally undertaken by pressure or bi-fluid atomization of the liquid water into the process stream at some point relatively far upstream of the inlet of the cooled stream into the cloth filtration device. Atomization, as opposed to spraying, is undertaken in order to perform minute droplets which, of course, evaporate more quickly than the relatively large droplets producible by ordinary spraying techniques. The lengthy conduit interposed between the point of atomization of the cooling water into the process stream and the filtration device is provided for purposes of ensuring adequate time for the liquid water atomizate to evaporate completely prior to entry of the cooled process stream into the cloth filtration device. It is obvious, of course, that failure to completely evaporate the liquid water in the process stream can lead to difficulties similar to those which have hereinafter been discussed with respect to condensation of the gaseous component of the process stream within the cloth filtration device.

The underlying reason for providing a relatively lengthy residence time after atomizing the liquid coolant water into the process stream resides in the fact that, as far as is known to applicant, neither bi-fluid nor pressure atomization techniques currently available in industrial
operations lend themselves to the performance of droplets of minute size over a sufficiently broad range of process conditions as to guarantee uniformly rapid and complete evaporation thereof within the process stream. In pressure atomization water is forced through a nozzle having a restricted orifice and the efficiency at which the injected water is fractured into droplets and the average size of the droplets so performed are largely dependent upon the orifice size of the atomizing nozzle and the pressure drop achieved across that orifice. In turn, the flow rate of water through an orifice of given dimensions is, of course, a function of the pressure drop, the higher the pressure drop the greater being the flow rate. Minor variation in any of the foregoing parameters has a very profound effect upon the uniformity and size of the droplets performed. For most industrial chemical plant installations the orifice size of a given pressure atomizing nozzle may be considered an invariant parameter. However, such is not normally the case with respect to flow rates and pressure drops. In industrial plant operations water line pressure and flow rate and the temperature and flow rate of the process stream to be quenched are normally subject to considerable variation. Where the hot process stream temperature and/or flow rate is altered, such as due to changes in reactor conditions in order to alter product properties, it is usually also necessary to alter the rate of quench water atomized into the process stream in order to attain the desired goal temperature preparatory to the cloth filtration treatment thereof. Thus, considerable variations in the water pressure delivered to the atomizing nozzles may occur incidentally or by design and can lead to periods of process operation wherein the pressure atomization nozzles are not and cannot be operated up to their design pressure drops and flow rates. Under such conditions, the droplets produced by pressure atomization techniques can be much enlarged and droplet uniformity diminished, thereby to require substantially increased residence times within the quenched
process stream so as to ensure complete evaporation of the water therein. Bi-fluid atomization nozzles employ motive gas to fracture a water stream into minute droplets within the nozzle and to project said droplets, entrained in the motive gas, into the process gas stream. In order to operate efficiently, such bi-fluid nozzles generally employ relatively large volume flow rates of the motive gas, which gas is not normally inherently available at the plant site and which gas, in any event, represents an added gas burden in the process stream which must ultimately be handled by the downstream cloth filtration device.

In order to maximize the residence time of the pressure or bi-fluid atomized quench water in the process stream, the customary approach, as mentioned, has been to interpose a large volume conduit or so-called "riser" between the point of atomization of the quench water into the process stream and the cloth filtration device. Under those conditions wherein the droplet size of the atomized quench water is relatively large, the evaporated rate thereof can be much reduced within the process stream flowing through the riser. In furnace carbon black operations such reduced evaporation rates can lead to increased opportunities for wetting and agglomeration of the particulate component of the process stream within the riser and the collection of a carbon black product having substantial quantities of hard coarse agglomerates therein. Moreover, in view of the fact that the process stream can often be highly corrosive, the riser conduit is often also required to be constructed of expensive corrosion resistant alloys. Nevertheless, the need for avoiding the presence of liquids within the cloth filtration device has heretofore outweighed the considerable economic penalties imposed by the construction and operations of a large volume corrosion resistant alloy riser preceding same and the danger of encountering the aforementioned phenomenon of particulate component agglomeration within the riser and, until the advent of the
present invention, industry has grudgingly accepted these
deficiencies so as to assure complete evaporation of the
quench water introduced into the process stream over a broad
range of process conditions.

In accordance with the present invention, many of the
aforementioned difficulties are either completely resolved
or are at least substantially ameliorated.

Objects of the Invention

It is a principal object of the invention to provide
a novel method for cooling a hot particulate-laden gas
stream.

It is another object of the invention to provide a
novel apparatus for cooling a hot, particulate-laden gas
stream.

It is another object of the present invention to
provide an improved integrated method for the separation of
the particulate component from a hot, particulate-laden
process stream.

It is another object of the present invention to
provide an improved integrated system for the separation of
the particulate component from a hot, particulate-laden
process stream.

It is still another object of the present invention
to provide an improved integrated method and system for the
separation of furnace carbon black from a hot, furnace
carbon black-containing process stream.

Other objects and advantages of the present invention
will in part be obvious and will in part appear hereinafter.

Summary of the Invention

In accordance with the present invention, a hot,
particulate-laden gas stream is conducted through a
venturi-shaped conduit having a size and geometry adapted to
accelerate the process stream to a Mach number of at least
0.25. Within the throat portion of the venturi-shaped
conduit liquid water is injected substantially transversely
into said gas stream through a number of unrestricted orifices. By reason of the energetic flow of the process stream at the points of introduction of the liquid water thereinto, the plural streams of water are rapidly fragmented, disintegrated and sheared into uniform droplets of relatively minute size, thereby extracting heat from the gas stream by rapid evaporation of the thusly performed water droplets. The thus cooled gas or process stream is conducted through a cloth filtration device, whereby the particulate component is separated from the gaseous component.

Brief Description of the Drawing

Figure 1 hereof is a schematic diagrammatic flow sheet depicting, in solid lines, a cooling apparatus in accordance with the invention integrated into a typical furnace carbon black process line and, in dashed lines, a relatively comparatively scaled conventional prior art cooling apparatus.

Figure 2 hereof is a schematic, diagrammatic longitudinal sectional view of the embodiment of the cooling apparatus of the invention shown in Figure 1.

Figure 3 hereof is an enlarged schematic, diagrammatic longitudinal sectional view of a portion of the cooling apparatus shown in Figure 2.

Description of Preferred Embodiments

Referring now to Figure 1 hereof, a conventional furnace carbon black process line is depicted comprising major elements 1, 9, 14 and 15. A hydrocarbonaceous feedstock, combustion fuel and a gaseous oxidant (usually air) are introduced into a carbon black reactor 1. Therein the resulting mixture is ignited and the burning reaction mixture passed into refractory lined reaction chamber 5 wherein carbon forming conditions are maintained. Conventionally, the temperature within reaction chamber 5 is maintained at between about 1315°C and about 1760°C, the
exact temperature being primarily dependent upon the desired properties of the carbon black product. Control of the temperature within reaction chamber 5 is usually achieved by appropriate proportioning of the oxidant, fuel and feedstock delivered to reactor 1. Termination of the carbon forming reaction is initiated by a so-called "primary quench" wherein water is sprayed through nozzle 6 into the reaction mixture as it progresses through the downstream portion of reaction chamber 5. The rate at which the quench water is sprayed into the reaction mixture is approximately proportioned so as to rapidly reduce the temperature of the process stream to about 1204°C, or less. Since the thermal energy contained in the reaction mixture at this point in the process is relatively high, rapid evaporation of the primary quench water is inherently assured and the operations of the quench nozzle 6 are not normally critical.

The resulting process stream, comprising carbon black suspended in process flue gases, is then conducted from reactor 1 to an indirect heat exchanger 9 wherein said process stream is further cooled, usually to a temperature of between about 426°C and 648°C. Indirect heat exchanger 9 is conventionally cooled by the combustion oxidant employed in the carbon black forming process, thereby to preheat same prior to introduction into reactor 1 and thereby to recover substantial quantities of what would otherwise be waste heat and to improve the thermal efficiency of the overall process.

Separation of the carbon black from the process stream is conventionally undertaken in a cloth filtration device 15, such as a bag filter, whereby the process stream is conducted through porous cloth filtration elements adapted to retain the carbon black burden on the upstream side thereof while allowing the process gases to pass therethrough. The carbon black product separated and collected in cloth filtration device 15 is then packaged or otherwise treated as previously discussed herein.
In order to preserve the cloth filtration elements of the cloth filtration device 15, it is first necessary to further cool the still relatively hot process stream exiting indirect heat exchanger 9, usually to between about 149°C and about 371°C, the exact goal temperature being dictated largely by the dual considerations of the dewpoint of the gaseous component of the process stream and the thermal stability of the particular cloth filtration elements employed in cloth filtration device 15.

**The Prior Art**

Conventionally, this additional cooling or "secondary quench" of the furnace carbon black process stream preparatory to cloth filtration thereof is accomplished by conducting the partially cooled process stream from indirect heat exchanger 9 through a vertical, lengthy and large volume conduit or riser 14 while atomizing water into the upstream end portion thereof. For purposes of comparison, said riser 14 may, for example, typically have a length of about 30.48m, a diameter of about 1.524m and will usually be constructed of an expensive corrosion-resistant alloy. Stationed at the upstream end portion of riser 14 are one or more pressure or bi-fluid atomization nozzles 16 through which quench water is atomized into the process stream at a rate sufficient to cool the process stream to the selected goal temperature. The extensive portion of the riser 14 existing downstream from nozzles 16 is provided largely for purposes of ensuring sufficient resident time of the quenched process stream therein as to complete the evaporation of the quench water atomizate prior to entry of the process stream into cloth filtration device 15. For whatever reason, should the atomized water droplets be of a relatively large size say on the order of about 300 x 10^{-6} m or more, the evaporation rate thereof in the process stream will be relatively low, thereby creating significant opportunity for substantial contact of the suspended particulate component carbon black with liquid water during
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conveyance of the process stream through the riser 14. As mentioned previously, should such wetting of the carbon black particles occur, the wetted particles can then collide with one another to form coarse agglomerates. Also, the wetted carbon black particles can contact the walls of the riser 14, causing accretion and caking of carbon black thereon.

The Present Invention

In accordance with the present invention, referring now to the solid line portion of Figure 1 and to Figures 2 and 3, generally, and in all of which figures like reference numerals refer to like structures, the relatively hot, particulate-laden process stream exiting indirect heat exchanger 9 is conducted through a venturi-shaped conduit 20 having a geometry and shape adapted to accelerate said stream to a Mach number of at least about 0.25 within the throat portion 24 thereof. By "Mach number" is meant the dimensionless numerical quotient of the actual velocity of the process stream divided by the local velocity of sound within said stream. Thus, the Mach number of the process stream is both temperature and composition dependent and can be readily determined for any given set of circumstances by taking the temperature and composition of the particular process stream involved into full consideration. Desirably, the size and geometry of the venturi-shaped conduit 20 will be selected such as to accelerate the process stream to a Mach number of at least 0.4 within throat portion 24.

The venturi-shaped conduit 20 comprises a relatively rapid convergent upstream portion 22, a throat portion 24 and a relatively gently divergent downstream portion 26. In the particular embodiment of the invention shown in the drawing there is, centrally located along the longitudinal centerline of throat portion 24 a supply pipe 25 which terminates in an end-cap 27. Supply pipe 25 is braced in its central position by means of a strut 28 extending from the
wall of convergent portion 22 of the venturi-shaped conduit 20. End-cap 27 comprises a plurality of unrestricted orifices 29 which are radially oriented relative to the longitudinal centerline of the venturi-shaped conduit 20 and through which orifices 29 liquid quench water is introduced substantially transversely into the process stream flowing through throat portion 24. Control of the quench water flow rate through orifices 29 may be provided by the combination of water supply valve 50 and controller 51. Controller 51 receives process stream temperature data from outlet thermocouple $T_0$, integrates said data with respect to a preselected goal or set point temperature and responds by adjusting water supply valve 50 as necessary to obtain the set point temperature of the quenched process stream. Since the present invention depends primarily on the kinetic energy of the accelerated process stream to fracture the quench water into minute droplets and to disperse said droplets within said stream, the diameter(s) of unrestricted orifices 29 and the pressure (or flow rate) at which the quench water is supplied therethrough are subject to considerable variation and are normally non-critical as regards the performance of minute, uniform and rapidly evaporable droplets within the process stream. This beneficial feature of the present invention is a marked departure from the criticalities normally attendant operations of pressure or bi-fluid atomization nozzles of the prior art. Desirably, the number of diameter(s) of orifices 29 will be selected such that, under the contemplated range of quench water rates involved in the particular process under consideration, sufficient pressure will be developed at each of said orifices 29 as to project the resulting quench water stream therefrom into the process stream to at least a small distance from the surface of end-cap 27 prior to substantial disintegration and breakup of said quench water stream.

The included angle of divergence of the divergent portion 26 of the venturi-shaped conduit 29 is generally
non-critical. However, it is preferred that said angle of divergence reside within the range of between about 6 and about 14° and, even more preferably, in the range of between about 7 and about 10°. By adherence to these preferred limits said divergent portion 26 will generally act as a diffuser, thereby to minimize the pressure drop generated across conduit 20 for a given acceleration of the process stream and to extend the length over which said process stream maintains high velocity. In another preferred embodiment of the invention at least the divergent portion 26 of venturi-shaped conduit 20 is thermally insulated, such as by means of lagging 30. Said insulation 30 serves to reduce the thermal deposition driving forces of the hot process stream, which forces might otherwise tend to cause at least some deposition of the particulate component thereof on the surfaces immediately downstream of throat portion 24.

In another preferred embodiment of the invention the upstream end of convergent portion 22 of the venturi-shaped conduit 20 is fed by a short length of conduit 18 containing flow-rectifying means 19 therein. The provision of such flow rectifying means immediately prior to the venturi-shaped conduit 20 minimizes turbulences and eddy currents within the process stream as it approaches said conduit 20, thereby to ensure efficient acceleration therein.

In view of the extremely rapid disintegration and evaporation of the quench water introduced into the process stream in accordance with the invention, both the venturi-shaped conduit 20 and the conduit 31, which defines the communication between the downstream end of said conduit 20 and the inlet of cloth filtration device 15, can be substantially more compact, on an equal process scale basis, than the riser type secondary quenching systems of the prior art. This represents a substantial advantage occurring to the practice of the present invention since, as previously indicated, the secondary quench riser systems of the prior
art usually involve apparatuses of relatively very large lengths and volumes. Utilizing the process and apparatus of the present invention since, as previously indicated, the secondary quench riser systems of the prior art usually involve apparatuses of relatively very large lengths and volumes. Utilizing the process and apparatus of the present invention, for example, a furnace carbon black process stream of the same type contemplated in the sizing of the riser 14 previously discussed herein in the paragraph entitled, "The Prior Art", can be effectively cooled to goal temperature in a venturi-conduit 20 of the present invention having inlet and outlet diameters of about 0.8128m, a throat diameter of about 0.4064m and an overall length of between about 3.6576m to about 4.572m. The length of volume of conduit 31, moreover, is dictated substantially only by the need for fluid-tight communication of the cooled process stream into the cloth filtration device 15. Moreover, the apparatus of the invention need not be oriented vertically as in the risers of the prior art, but rather may be subjected to whatever orientation thereof may present itself as appropriate based on considerations of available space and efficient plant layout.

Additionally, the present invention exhibits substantially less sensitivity to process stream inlet temperature variation than does the prior art riser technique employing pressure atomizing of the quench water. Utilizing the latter prior art method a decrease in the inlet temperature of the process stream fed to riser 14 of about 38°C, for example, reduces the rate of water required to be pressure atomized into the process stream to attain goal temperature by about 20%. If the water pressure is reduced so as to adjust the rate of water flow downwardly by 20%, however, the average droplet size of a pressure-atomized spray is markedly increased as is the residence time required to evaporate such larger droplets and the volume of downstream enclosing conduit required to provide such increased residence time.
In consequence, the particulate component is separated from the gaseous component and is deposited on the upstream or

target of the present invention and is deposited on the upstream or

achieved complete evaporation of the droplets. Thus, unlike prior art riser systems, little or no additional length or volume of downstream conduit need ordinarily be built into the apparatus of the present invention simply to provide an adequate residence time buffer for complete quench water evaporation in response to temperature and flow changes in the process and quench water streams. Also, while the shearing and disintegration of the quench water introduced into the process stream in consequence of the practice of the present invention may be termed a type of bi-fluid atomization, the motive gas for the atomization of the quench water is not an external diluent, the process stream and motive gas being one and the same entity. Thus, the present process and system avoids further dilution of the process stream and the need for augmentation of the gas handling capacity of the cloth filtration device.

While for purposes of illustration the present invention has been described hereinbefore in detail only with respect to a furnace carbon black process line and only in terms of ultimate separation of the particulate component by cloth filtration, it is obvious that the present invention can be beneficially applied to many other chemical process lines wherein it is required to cool a hot gaseous process stream containing particulate solids suspended therein.

Also, while the present invention has been described hereinbefore with respect to certain preferred embodiments thereof, it is to be noted that the foregoing description is intended to be illustrative in nature and not as being limiting of the invention. For instance, while the specific apparatus shown and described comprises a centrally located
end-cap 27 within the throat portion 24 of venturi-shaped conduit 20, which end-cap 27 serves as the final element for the introduction of the quench water into the process stream, it is obvious that other functional equivalents of this arrangement can be achieved. For instance, the means to introduce the quench water can also take the form of a plurality of radial quench water orifices penetrating through the enclosing wall and positioned about the periphery of throat portion 24 of venturi-shaped conduit 20. Said orifices may then be enclosed by a common manifold equipped with a water supply line thereto.

Obviously, many other suitable alternative and equivalent constructions of the apparatus and method of the invention will suggest themselves to those of skill in the art and it should be understood that all such changes, alterations, modifications and the like are intended to fall within the essential spirit and scope of the invention as defined in the appended claims.
of which are not usually justified even assuming complete

CLAIMS
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method for cooling a hot, particulate-laden gas stream in preparation for collection of the particulate component therefrom which comprises atomizing liquid water into said stream in such quantity as to extract heat from said stream by evaporation of the liquid water so atomized thereinto and cool said stream to a temperature above the dewpoint thereof, characterized in that said hot, particulate-laden gas stream is conducted through a relatively compact venturi-shaped conduit comprising an upstream convergent portion, a downstream divergent portion and a throat portion therebetween; accelerating said gas stream to a Mach number of at least about 0.25 in said throat portion and, in said throat portion, introducing substantially transversely into said gas stream said cooling water to be atomized as a plurality of streams thereof.

2. The method of Claim 1 wherein, in said throat portion, said hot, particulate-laden gas stream is accelerated to a Mach number of at least about 0.4.

3. The method of Claim 1 wherein said liquid water is introduced substantially transversely and outwardly into said gas stream from a centrally located element within said throat portion, said element having a plurality of radially oriented unrestricted orifices.

4. The method of Claim 3 wherein the rate of water introduced from said element is sufficient to project each of the resulting streams of liquid water into said gas stream to at least a small distance from the surface of said element prior to substantial disintegration and breakup thereof.

5. The method of Claim 1 wherein said downstream
divergent portion has an included angle within the range of about 6° and about 14°.

6. The method of Claim 1 wherein at least the downstream divergent portion of said venturi-shaped conduit is thermally insulated.

7. The method of Claim 1 wherein, substantially immediately preceding introduction of the hot, particulate-laden gas stream into the convergent upstream portion of the venturi-shaped conduit, the flow of said gas stream is rectified to reduce eddy currents and turbulences therein.

8. The method of any of Claims 1 through 7, inclusive, wherein said hot, particulate-laden gas stream is a furnace carbon black process stream.

9. An integrated method for the separation of a particulate component from a hot, particulate-laden gas stream which comprises cooling said hot, particulate-laden gas by atomizing liquid water into said stream, thereby to extract heat from said stream by evaporation of the liquid water so atomized thereinto, and then conducting the thusly cooled particulate-laden stream through a cloth filtration device, the quantity of water so atomized being sufficient to cool the stream to a temperature sufficiently low as to prevent damage to the cloth filtration elements of said device but being sufficiently high as to maintain the atmosphere within said device at above the dewpoint of the gaseous component of said particulate-laden gas stream, characterized in that said hot, particulate-laden gas stream is cooled by conducting same through a relatively compact, venturi-shaped conduit comprising an upstream convergent portion, a downstream divergent portion and a throat portion therebetween; accelerating said stream to a Mach number of at least about 0.25 in said throat portion and, in said
agglomeration within the filter and, until the advent of the

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throat portion, introducing substantially transversely into said gas stream, a plurality of streams of said water to be atomized, the rate of liquid water so introduced being proportioned to cool said stream to within the afore-described limits.

10. The integrated method of Claim 9 wherein, in said throat portion, said hot, particulate-laden gas stream is accelerated to a Mach number of at least about 0.4.

11. The integrated method of Claim 9 wherein said cloth filtration device is a bag filter.

12. The integrated method of Claim 9 wherein said liquid water is introduced substantially transversely and outwardly into said gas stream through a centrally located element within said throat portion, said element within said throat portion, said element having a plurality of radially oriented unrestricted orifices.

13. The integrated method of Claim 12 wherein the rate of water introduced from said element is sufficient to project each of the resulting streams of liquid water into said gas stream to at least a small distance from the surface of said element prior to substantial disintegration and breakup thereof.

14. The integrated method of Claim 9 wherein the temperature of the cooled gas stream is continuously monitored and wherein the rate of water introduced into the hot, particulate-laden gas stream is adjusted in response thereto.

15. The integrated method of Claim 9 wherein said downstream divergent portion has an included angle within the range of between about 6 and about 14°.
16. The integrated method of Claim 9 wherein at least the downstream divergent portion of said venturi-shaped conduit is theremally insulated.

17. The integrated method of Claim 9 wherein, substantially immediately preceding introduction of the hot, particulate-laden gas stream into the upstream convergent portion of the venturi-shaped conduit, the flow of said gas stream is rectified to reduce eddy currents and turbulences therein.

18. The integrated method of any of Claims 9 through 17, inclusive, wherein said hot, particulate-laden gas stream is a furnace carbon black process stream.

19. An integrated system for the separation of a particulate component from a hot, particulate-laden gas stream comprising a conduit adapted to receive a hot, particulate-laden gas stream therethrough and means to atomize liquid water into said gas stream flowing through said conduit, thereby to cool same by evaporation of the atomized liquid water therein, and a cloth filtration device to receive the thusly cooled particulate-laden gas stream from said conduit and to separate the particulate component from the gaseous component thereof, characterized in that said conduit comprises a relatively compact venturi-shaped conduit having an upstream convergent portion, a downstream divergent portion and a throat portion therebetween, said venturi-shaped conduit being of a size and shape adapted to accelerate a hot, particulate-laden gas stream to a Mach number of at least about 0.25 within the throat portion thereof and means to introduce a plurality of streams of liquid water substantially transversely into said gas stream in said throat portion at a rate proportioned to cool said gas stream sufficiently to prevent damage to the cloth filtration elements of said cloth filtration device but to maintain the temperature of the atmosphere within said cloth
filtration device at about the dewpoint of the gaseous component of the cooled gas stream.

20. The integrated system of Claim 26 wherein said cloth filtration device is a bag filter.

21. The integrated system of Claim 26 further including flow rectifying means located substantially immediately upstream from said upstream convergent portion of said venturi-shaped conduit, said flow rectifying means being adapted to reduce eddy currents and turbulences in the hot, particulate-laden gas stream.

22. The integrated system of Claim 26 wherein said downstream divergent portion of said venturi-shaped conduit has an included angle within the range of about 6° and about 14°.

23. The integrated system of Claim 26 wherein said means to introduce a plurality of streams of liquid water comprises an element located centrally within said throat portion of said venturi-shaped conduit, said element comprising a plurality of radially oriented unrestricted orifices, and a water supply pipe in communication with said element, said supply pipe extending through a sidewall of said venturi-shaped conduit.

24. The integrated system of Claim 26 including temperature sensing means (T) located between the downstream end of said venturi-shaped conduit and the inlet to said cloth filtration device valve means to control the rate of liquid water introduced into the gas stream in said throat portion and controller means communicating with said temperature sensing means (T) and being operative to control said valve means in response to the sensed temperature of said temperature sensing means (T).
25. The integrated system of Claim 27 wherein the size and shape of said venturi-shaped conduit is adapted to accelerate the hot, particulate-laden gas stream to a Mach number of at least about 0.4 within the throat portion thereof.

26. The integrated system of Claim 26 wherein at least the downstream divergent portion of said venturi-shaped conduit is thermally insulated.

27. The integrated system of Claim 26 wherein said downstream divergent portion of said venturi-shaped conduit has an included angle within the range of between about 6 and about 14°.

28. The integrated system of any of Claims 26 through 27 inclusive, further comprising an indirect heat exchanger communicating with and being located upstream from said venturi-shaped conduit and a furnace carbon black reactor communicating with and being located upstream from said indirect heat exchanger.

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The included angle of divergence of the divergent portion 26 of the venturi-shaped conduit 29 is generally
and the volume of downstream enclosing conduit required to provide such increased residence time.