(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 316 576 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.05.2011 Bulletin 2011/18

(51) Int Cl.:
B03C 3/155 *(2006.01)* ***B03C 3/017*** *(2006.01)*
B03C 3/019 *(2006.01)*

(21) Application number: **09174340.1**

(22) Date of filing: **28.10.2009**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR
Designated Extension States:
AL BA RS

(71) Applicant: **Alstom Technology Ltd**
5400 Baden (CH)

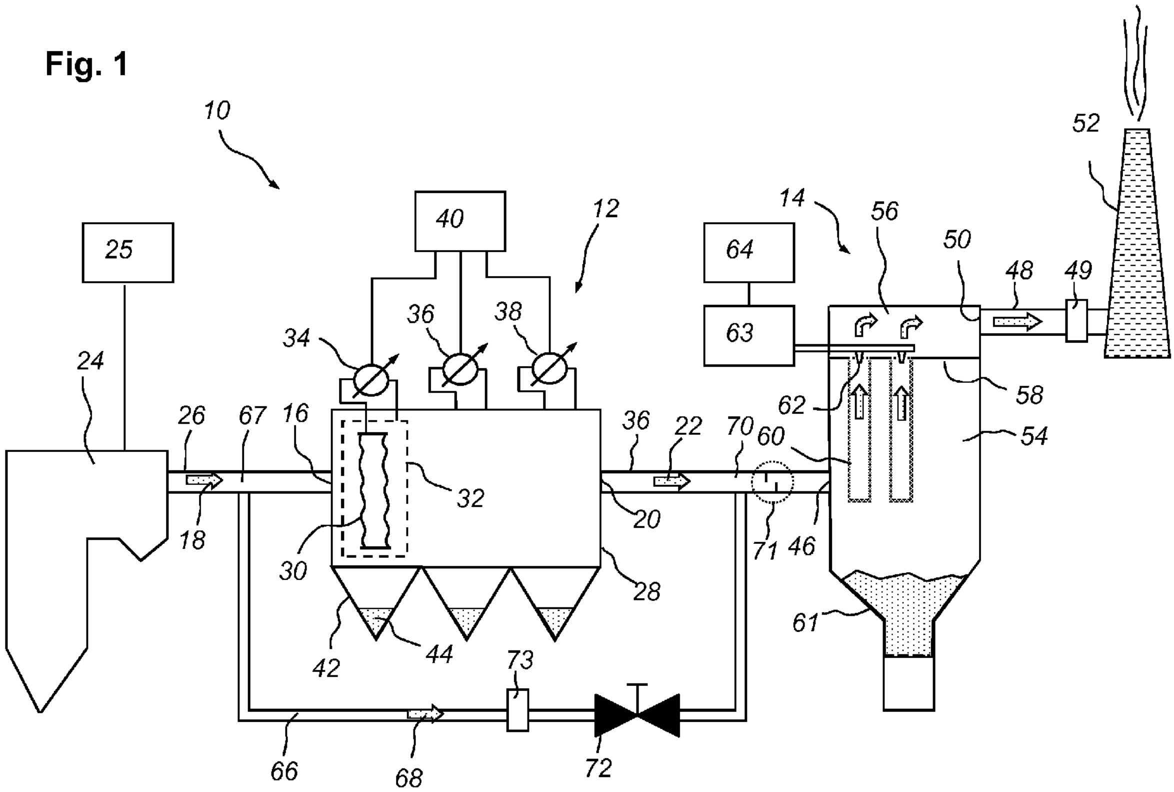
(72) Inventor: **Bäck, Andreas**
352 40 VÄXJÖ (SE)

(74) Representative: **Simonsson, Erik**
Awapatent AB
P.O. Box 99
351 04 Växjö (SE)

(54) **Hybrid dust particulate collector system**

(57) A method for removing dust particles from a raw gas stream (18), which comprises raw gas dust particles, in a hybrid dust particulate collector system (10) comprising an electrostatic precipitator (12), and a barrier filter (14) located downstream, with respect to a gas flow direction through the system (10), of said electrostatic precipitator (12), comprises
cleaning at least a major portion of the raw gas stream (18) in the electrostatic precipitator (12), so as to obtain an ESP cleaned gas stream portion (22), and
transferring a bypass fraction of said raw gas dust particles to a bypass fraction return region (70) located in or downstream of an outlet (20) of said electrostatic precipitator (12), and upstream of said barrier filter (14), said bypass fraction having a coarser dust particle composition compared to the composition of dust particles remaining in the ESP cleaned gas stream portion (22).

Fig. 1



EP 2 316 576 A1

Description

Field of the invention

[0001] The present invention relates to a hybrid dust particulate collector system comprising an electrostatic precipitator and a barrier filter located downstream of said electrostatic precipitator. The invention also relates to a method for removing dust particles in such a hybrid particulate collector.

Background of the invention

[0002] In boilers and other types of combustion plants, there is often a need for removing particulate matter, such as fly ash, from flue gas generated in the combustion process. US patent no. 5,024,681 discloses a method for removing particulates from a gas, the method comprising the steps of first passing the gas and the particulates through a conventional electrostatic precipitator (ESP) whereby 90-99% of said particulates are removed, and then passing the remaining particulates and said gas leaving said ESP to a barrier filter placed downstream of said electrostatic precipitator.

[0003] A particulate removal system requires periodic maintenance and consumes energy during operation; hence, there is a need to reduce the energy consumption and ease the maintenance demand of such systems. There is also a constant strive to increase the total particulate collection efficiency of hybrid particulate collector systems.

Summary of the invention

[0004] It is an object of the present invention to solve, or at least mitigate, parts or all of the above mentioned problems. To this end, there is provided a method for removing dust particles from a raw gas stream, which comprises raw gas dust particles, in a hybrid dust particulate collector system comprising an electrostatic precipitator (ESP), and a barrier filter located downstream, with respect to a main gas flow direction through the system, of said electrostatic precipitator, the method comprising cleaning at least a major portion of the raw gas stream in the electrostatic precipitator, so as to obtain an ESP cleaned gas stream portion; and

transferring a bypass fraction of said raw gas dust particles to a bypass fraction return region located in or downstream of an outlet of said electrostatic precipitator, and upstream of said barrier filter, said bypass fraction having a coarser dust particle composition compared to the composition of dust particles remaining in the ESP cleaned gas stream portion.

[0005] The "coarseness" of a dust particle composition is defined by the mass mean diameter D_{MMD} of a dust sample having that dust particle composition. The mass mean diameter D_{MMD} of a dust sample comprising n particles is calculated as

$$D_{MMD} = \frac{\sum m_i d_i}{\sum m_i}$$

where d_i and m_i refer to the diameter and mass of each particle i for i=1 to n of the sample. The higher the mass mean diameter D_{MMD} of a dust sample, the coarser the dust particle composition of that sample. In more general terms, this means that the more of the total dust particle mass *M* carried by a gas stream that is represented by larger particles, the coarser is the composition of the dust particles carried by that gas stream.

[0006] D_{MMD} may also be accurately approximated by making the sums not over individual particles, but over particle size intervals.

[0007] The relatively coarse raw gas dust particles transferred to the bypass return region will thereby build up a relatively porous and permeable dust cake on the barrier filter. Compared with the compact, relatively impermeable dust cake formed by an ESP cleaned gas stream alone, a porous dust cake formed with the aid of a coarse bypass fraction dust particles may allow a longer interval of cleaning of the barrier filter. Less frequent cleaning of the barrier filter reduces the wear on the barrier filter, and hence prolongs its service interval. Less frequent cleaning may also reduce the total particulate emission to the ambient air, since an emission dust peak is often observed in the cleaned flue gas immediately after cleaning the barrier filter. Furthermore, a more porous dust cake may result in a lower gas pressure drop over the barrier filter. This reduces the amount of energy required for forcing the gas through the barrier filter.

[0008] According to one embodiment, said bypass fraction is carried to said bypass fraction return region by a non-ESP cleaned bypass portion of said raw gas stream. By carrying the bypass fraction by means of the raw gas itself, no designated conveyors for transporting the bypass fraction are needed.

[0009] By way of example, said non-ESP cleaned bypass portion may be transferred from a bypass entry region upstream of the electrostatic precipitator to said bypass fraction return region by means of a bypass duct. A duct may easily be dimensioned to fit the exact bypass needs of existing installations, such that retro-fits of the invention are facilitated.

[0010] As another alternative, said non-ESP cleaned bypass portion may be transferred to said bypass fraction return region via a bypass path through an inactive portion of said electrostatic precipitator, such that said non-ESP cleaned bypass portion is transferred through the electrostatic precipitator without being cleaned by means of an electric field. Evidently, this is a very inexpensive and compact embodiment. Furthermore, by only temporarily de-activating at least a portion of the electrostatic precipitator so as to create said bypass path, the bypass through the electrostatic precipitator may be opened and closed at will, for example by switching off or switching on bus sections.

[0011] According to one embodiment, said bypass fraction comprises a portion of the dust particles separated from the ESP cleaned gas stream portion in a first field of the electrostatic precipitator. The first field of the electrostatic precipitator typically removes the coarsest particles from the raw gas stream. By returning a portion of the coarse particle fraction collected in the first field, an even more porous dust cake may be obtained on the barrier filter.

[0012] Preferably, said bypass fraction of said raw gas dust particles amounts to 2 - 30%, by mass, and more preferably 3 - 20% by mass, of the total amount of dust particles in the raw gas stream. Within this range, the benefit of the dust removal in the ESP is still maintained at an attractive level, while the dust entering the barrier filter has a particle size composition that allows forming a porous dust cake.

[0013] Preferably, the method comprises adjusting the amount of bypass fraction to be transferred to the bypass fraction return region to a selected amount of bypass fraction. By adjusting the amount, it is possible to adapt the amount of bypass fraction to the particular process conditions.

[0014] According to one embodiment, the method comprises controlling, based on an event in equipment downstream or upstream of the electrostatic precipitator, the amount of bypass fraction to be transferred to the bypass fraction return region. Thereby, it is possible to adjust the amount of bypass fraction in response to changing process conditions.

[0015] According to one embodiment, the transfer of said bypass fraction is controlled based on the initiation of a cleaning of the barrier filter, such that the barrier filter is primed by the bypass fraction. Some types of barrier filters are particularly sensitive to blinding just after having been cleaned. According to this embodiment, a protective porous dust cake may be built up rapidly, before the barrier filter has been exposed to large amounts of the fine particles entrained in the ESP cleaned gas stream.

[0016] According to another aspect of the invention, parts or all of the above mentioned problems are solved, or at least mitigated, by a hybrid dust particulate collector system for removing dust particles from a raw gas stream, which comprises raw gas dust particles, the system comprising an electrostatic precipitator and a barrier filter, said barrier filter being connected downstream of said electrostatic precipitator, the electrostatic precipitator being configured for cleaning at least a major portion of the raw gas stream so as to obtain an ESP cleaned gas stream portion, the system comprising

a transferring device configured for transferring a bypass fraction of said raw gas dust particles to a bypass fraction return region located in or downstream of an outlet of said electrostatic precipitator, and upstream of said barrier filter, the transferring device being configured to transfer a bypass fraction that has a coarser dust particle composition compared to the composition of dust particles remaining in the ESP cleaned gas stream portion.

[0017] Again, the "coarseness" of a dust particle composition is defined by the mass mean diameter D_{MMD} of a dust sample having that particle size composition.

[0018] The relatively coarse raw gas dust transferred by the transferring device to the bypass return region will build up a relatively porous and permeable dust cake on the barrier filter. Compared with the compact, relatively impermeable dust cake formed by an ESP cleaned gas stream alone, a porous dust cake formed with the aid of a coarse bypass fraction may allow a longer interval of cleaning of the barrier filter. Less frequent cleaning of the barrier filter reduces the wear on the barrier filter. Less frequent cleaning may also reduce the total particulate emission to the ambient air, since an emission dust peak is often observed in the cleaned flue gas immediately after cleaning the barrier filter. Furthermore, a more porous dust cake may result in a lower gas pressure drop over the barrier filter. Thereby, the amount of energy required for forcing the ESP cleaned gas through the barrier filter is reduced.

[0019] According to one embodiment, said transferring device is configured to transfer said bypass fraction to said bypass fraction return region carried by a non-ESP cleaned bypass portion of said raw gas stream.

[0020] According to one embodiment, said transferring device comprises a bypass duct, connecting a bypass entry region upstream of the electrostatic precipitator to said bypass fraction return region. The bypass duct may, according to a particular embodiment, be provided with a control valve, such that the transfer of a bypass fraction may be initiated or adjusted at will.

[0021] According to one embodiment, said transferring device comprises a bypass path through an inactive portion of said electrostatic precipitator, such that said non-ESP cleaned bypass portion may be transferred through the electrostatic precipitator without being cleaned by means of an electric field.

[0022] The transferring device may according to a particular embodiment further comprise a controller, which is configured to, during operation of the hybrid dust particulate collector system, temporarily de-activate at least said portion of the electrostatic precipitator, such that said non-ESP cleaned gas stream portion may be transferred through the electrostatic precipitator without being cleaned.

[0023] According to one embodiment, said transferring device comprises a bypass duct, connecting a dust collecting hopper of a first field of the electrostatic precipitator to said bypass fraction return region, said bypass duct being configured for transferring collected dust that has been separated from said ESP cleaned gas stream to said bypass return region.

[0024] Preferably, said transferring device is adapted for transferring 2 - 30%, by mass, and more preferably, 3 - 20% by mass, of the total amount of dust particles in the raw gas stream.

[0025] According to one embodiment, said transferring device comprises a control system for controlling the transfer of the bypass fraction to the bypass fraction return region. The control system is, according to an embodiment, configured to control, based on an event in equipment downstream or upstream of the electrostatic precipitator, the amount of bypass fraction to be transferred to the bypass fraction return region. According to one particular embodiment, the control system is configured to initiate a transfer of said bypass fraction based on the initiation of a cleaning of the barrier filter, such that the barrier filter is primed by the bypass fraction.

[0026] According to one embodiment, said electrostatic precipitator and said barrier filter are comprised in the same housing. This embodiment is particularly well suited for compact installations.

[0027] Further objects and features of the present invention will be apparent from the description and the claims.

Brief description of the drawings

[0028] The above, as well as additional objects, features and advantages of the present invention, will be better understood through the following illustrative and non-limiting detailed description of preferred embodiments of the present invention, with reference to the appended drawings, where the same reference numerals will be used for similar elements, wherein

Fig. 1 is a diagrammatic side view of a first embodiment of a hybrid dust particulate collector system;
Fig. 2 is a graph illustrating an exemplary shift in dust size composition;
Fig. 3a is a diagrammatic side view of a second embodiment of a hybrid dust particulate collector system;
Fig. 3b is a diagrammatic top view of the ESP of the hybrid dust particulate collector system of fig. 3a;
Fig. 4 is a flow chart, illustrating a method for removing dust particles from a raw gas stream;
Fig. 5 is a flow chart, illustrating a method for removing dust particles from a raw gas stream; and
Fig. 6 is a diagrammatic side view of a third embodiment of a hybrid dust particulate collector system.

Detailed description of the exemplary embodiments

[0029] Fig. 1 illustrates a first embodiment of a hybrid dust particulate collector system 10 as seen from the side and in cross-section. The system 10 of fig. 1 comprises an electrostatic precipitator (ESP) 12, which is connected in series with a barrier filter 14. The barrier filter 14 illustrated in fig. 1 is in this example a fabric filter of the baghouse filter type described in more detail in US 4,336,035.

[0030] The ESP 12 has an ESP inlet 16 for raw, dust particle laden gas 18, and an ESP outlet 20 for ESP cleaned gas 22, from which most of the dust particles have been removed. The raw gas 18 may, for instance, be flue gas from a boiler 24, in which a fuel such as coal is combusted. The boiler 24 of fig. 1, which is controlled by a boiler control system 25, is connected to the ESP 12 via a raw gas duct 26.

[0031] The electrostatic precipitator 12 has a casing 28 in which a first field, a second field, and a third, and last, field, are provided. Each field is provided with a number of discharge electrodes, of which twp discharge electrodes 30 are shown in Fig. 1, and a number of collecting electrode plates, of which one collecting electrode plate 32 is shown in Fig. 1, as is known in the art, for instance from US patent No 4,502,872. In fig. 1, only the electrodes of the first field of the ESP 12 are illustrated for reasons of clarity. Typically, the collecting electrodes 32 are kept at ground potential, while the discharge electrodes 30 operate at a positive or negative potential of several kV.

[0032] Each of the ESP fields is provided with current from an electric power supply. In fig. 1, the first field of the ESP 12 receives an electrode current from a first electric power supply 34, the second field receives current from a second electric power supply 36, and the third field receives current from a third electric power supply 38. The output current of each electric power supply 34, 36, 38 is controlled by a control system 40. The control system 40 also controls rapping of the collecting electrode plates 32, in the manner well known to those skilled in the art.

[0033] Each field of the ESP 12 is also provided with a hopper 42, which is arranged below that field's respective collecting electrode plates 32, such that, when the collecting electrode plates 32 are rapped, collected dust particles will fall from the collecting electrode plates into the hopper 42. Collected dust 44 is removed from the hopper 42 and disposed of elsewhere.

[0034] The bag filter 14 is provided with a bag filter inlet 46, which is connected to the ESP outlet 20 via a duct 36, and a bag filter outlet 50, which is connected via a clean gas duct 48 to a stack 52 for emitting clean flue gas to the ambient air. The bag filter 14 is further provided with an inlet compartment 54, which communicates with the bag filter inlet 46 so as to receive ESP cleaned gas 22 from the ESP 12, and an outlet compartment 56, which communicates with the clean gas duct 48 via the bag filter outlet 50. The clean gas duct 48 may comprise an optional fan 49 for drawing the gas through the bag filter 14. The two compartments 54, 56 are separated by a wall 58, which is configured so as to allow gas to pass from the inlet compartment 54 to the outlet compartment 56 only via a filter fabric. In the particular example shown in fig. 1, the filter fabric consists of a number of filter bags 60, only two of which are shown for reasons of clarity. Dust remaining in the ESP filtered gas stream will thereby be collected on the outside of the filter bags 60, and eventually form a dust cake on the surface of the filter bags 60. After a period of operation of the bag filter 14, this dust cake will have been built so thick and compact that it will blind the filter bags 60, and thereby induce a significant pressure drop over the bags 60. Therefore, the filter bags 60 are periodically cleaned by clean air pulses directed, with respect to the flue gas flow, in the reverse direction through the filter bags 60, such that the dust cake is forced to release from the filter bags 60 and fall down into a hopper 61. To this end, clean air nozzles 62, fed by a pressurized air tank 63, are arranged at each filter bag 60. The pulsing of clean air is controlled by a barrier filter control system 64. The pulsed air cleaning is, according to established art, typically performed sufficiently often to keep the pressure drop over the filter bags 60 reasonably low, but unnecessary cleaning is avoided. Cleaning by pulsed air too often consumes energy and exposes the filter bags to excessive mechanical wear. Furthermore, the dust cake also contributes significantly to the total filtering effect of the bag filter 14; when the dust cake is removed, the cleaning efficiency of the bag filter is temporarily somewhat reduced.

[0035] Bag blinding may in general terms be described as the condition where the dust cake obstructs the gas passage through the filter bags. A particular type of bag blinding occurs when fine particles penetrate deep into the fabric of the filter bags; a relative small amount of fine dust may be sufficient to cause a significant blinding of the bags. Hybrid particulate collector systems of prior art are based on the paradigm that the more particles that are removed in each consecutive filter, the better. Therefore, in a hybrid system of prior art, all the raw gas is passed through, and cleaned by, the ESP. However, the ESP not only removes particles; it also changes the particle size composition, since larger particles have a higher tendency to be collected by the ESP. The particle size composition of the fraction remaining in the ESP cleaned gas stream therefore has a higher relative portion of fine particles, and is more prone to blind a filter bag than the particle size composition of a raw, non-ESP cleaned gas stream. The higher blinding effect of the ESP cleaned gas stream is attributed to the fact that fine particles are prone to penetrate deep into the fabric of the filter bags, and also to the fact that fine particles tend to form a more compact dust cake than coarse particles do. Coarse particles, on the other hand, do not penetrate deep into the fabric of the filter bags, and even prevents penetration of fine particle into the fabric of the filter bags. The bag blinding contribution of sub-micron particles, i.e. fine particles having a diameter of less than about 1 μm, is particularly severe.

[0036] Coarse dust particles, in particular particles having a diameter of more than about 30 μm, tend to form a very porous dust cake, which not only allows a high gas flow therethrough, but is also capable of adsorbing a relatively large amount of finer dust particles. In other words, the presence of very coarse particles downstream of the ESP may be particularly beneficial for the dust collecting efficiency of the barrier filter; an ESP induced change of particle size composition of the gas stream may therefore reduce the dust collecting efficiency of the barrier filter.

[0037] In order to mitigate those problems, the hybrid particulate collector system of fig. 1 comprises a bypass duct 66 connected between the raw gas duct 26 and the ESP cleaned gas duct 36. The bypass duct 66 operates so as to allow a non-ESP cleaned bypass portion 68 of the raw gas stream 18, said bypass portion 68 carrying a bypass fraction of the dust in the raw gas stream 18, to bypass the ESP 12, and mix with the ESP cleaned gas stream 22 in a bypass fraction return region 70 downstream of the ESP 12. The bypass fraction of the dust in the raw gas stream 18, said bypass fraction being carried through the bypass duct 66 by the bypass portion 68 of the raw gas stream 18, enters the bypass duct 66 in a bypass entry region 67 located in the raw gas duct 26, and therefore has essentially the same particle composition, with respect to size, as the raw gas stream 18 in the raw gas duct 26.

[0038] The ESP cleaned gas stream 22 leaving the ESP 12 via the ESP outlet 20, on the other hand, carries mainly relatively fine dust particles, since the ESP 12 by its fundamental operating principles removes coarse particles more efficiently than it removes fine particles. By mixing the fine dust particle fraction of the ESP cleaned gas stream 22 with the relatively coarser bypass fraction carried by the bypass portion 68 of the raw gas stream 18, the dust entering the bag filter 14 will form a more porous dust cake on the filter bags 60 than would the fine dust of the ESP cleaned gas stream 22 alone. In other words, the blinding of the filter bags 60 will be reduced thanks to the coarser dust composition entering the bag filter 14.

[0039] The bypass duct 66 may be provided with an optional control valve 72, for controlling the amount of raw gas to be bypassed, and hence, also for controlling the amount of dust that will be bypassed to a location downstream of the ESP 12 completely unaffected by the ESP 12. The control valve 72 may, by way of example, be a damper of any of the types known to those skilled in the art. The bypass duct may also be provided with an optional fan 73, for maintaining the flow of the bypass portion 68 of the raw gas stream 18 at a high speed. For some types of raw gas dust compositions, the use of a fan may be beneficial to assure that the coarsest dust particles of the bypass fraction do not fall down onto the floor of the bypass duct 66, but are maintained in the bypass flow all the way to the bypass fraction return region 70. The fan 73 may also be used instead of, or in combination with the valve 72 for controlling the bypass flow rate through the bypass duct 66. Preferably, about 70-98%, and more preferred, about 80-97% of the raw gas stream 18 in the raw gas duct 26 is passed through and cleaned by the ESP 12, while the remaining about 2-30%, or more preferred, 3-20%, of the raw gas stream 18 in the raw gas duct 26 is bypassed via bypass duct 66 to the bypass fraction return region 70 downstream of the ESP 12.

[0040] Fig. 2 illustrates a numerical example, based on results from actual measurements at a coal-fired plant. The numerical example illustrated in Fig. 2 assumes a 97% (by dust mass *M*) dust removal efficiency of the ESP 12, and a bypass portion 68 of the raw gas stream 18 amounting to 7 % of the raw gas stream 18. The bypass portion 68 of the raw gas stream 18 is assumed to carry a bypass fraction having an identical composition, with respect to particle size, as the raw gas stream 18. The graph of fig. 2 illustrates the dust mass *M* as a function of the particle diameter d; more precisely, the dust mass *dM* per logarithmic diameter interval *d(log(d)),* passing a respective portion of the hybrid particulate collector 10 per time unit, is plotted against the logarithm of the diameter, *log(d).* The respective curves illustrate the total mass of raw gas dust particles 19 carried by the raw gas stream 18 from the boiler; the mass of the bypass fraction 17 carried by the bypass portion 68 of the raw gas stream 18; the mass of the fines dust fraction 21 remaining in the ESP cleaned gas stream 22; and the total mass of the mixed dust particle fraction 23, i.e. the sum of the fines dust fraction 21 and the bypass fraction 17, entering the bag filter 14 downstream of the bypass fraction return region 70. A fines dust fraction 21 comprising 3% by mass of the raw gas dust entering the ESP 12 exits the same, carried by the ESP cleaned gas stream 22. In the bypass return region 70, the fines dust fraction 21 is mixed with the bypass fraction 17, which corresponds to 7% of the raw gas dust 19, so as to form a mixed fraction 23. As can be seen in fig. 2, in the fines dust fraction 21 carried by the ESP cleaned gas stream 22, more than 10% of the particle mass belongs to the submicron size fraction having a diameter d below 1 μm *(log(d)<0).* On the other hand, in the mixed fraction 23, downstream of the bypass return region 70, less than 5% of the particle mass belongs to the size fraction having a diameter below 1 μm. As for the relative content of very coarse dust particles, belonging to the size fraction having a diameter d of more than 30 μm *(log(d)<1.5),* the difference between the fines fraction 21 and the mixed fraction 23 is even more striking; a large portion of the mixed fraction 23 consists of very coarse dust particles, whereas the fines fraction 21 contains very little such coarse dust particles. In other words, the dust carried by the flue gas stream will, downstream of the bypass fraction return region 70, behave essentially as a raw gas stream with respect to filter bag blinding, while at the same time comprising less than 10% of the dust mass initially carried by the raw gas stream 18.

[0041] Referring again to fig. 1, an additional effect of bypassing a bypass portion 68 of the raw gas stream 18 is that in the bypass fraction return region 70, the bypass fraction, which is carried by the bypass portion 68 of the raw gas, will be mixed with the fines fraction of electrically charged fine dust particles remaining in the ESP cleaned gas portion 22. When the mixing of the two fractions occurs, fine dust particles, being electrostatically charged after having passed the ESP 12, will agglomerate with uncharged, bypassed, relatively coarse particles, so as to form even coarser, agglomerated particles. The agglomerated particles are held together by electrostatic forces, van der Waals forces, and other colloidal forces, to the effect that the fine particles attached to such agglomerated particles are prevented from penetrating deep into the fabric of the filter bags. This effect contributes even further to increasing the porosity of the dust cake on the filter bags 60. In order to improve the mixing of the ESP cleaned gas stream 22 with the bypass portion 68 of raw gas, the duct 36 is provided with an optional static mixer 71 just downstream of the bypass return region 70. The static mixer 71 of fig. 1, which could just as well have been located within the bypass return region 70, is shown as a set of two mixer blades inside the duct 36, even though many different types of static mixers are well known to those skilled in the art.

[0042] Fig. 3a is a diagrammatic side view of a second embodiment of a hybrid dust particulate collector system 10. The system 10 of fig. 3a comprises an electrostatic precipitator (ESP) 12, which is connected in series with a bag filter 14, in a manner similar to what is described above with reference to fig. 1. The ESP 12 has an ESP inlet 16 for raw, dust particle laden gas 18, and an ESP outlet 20.

[0043] Similar to the ESP 12 of fig. 1, the electrostatic precipitator 12 of fig. 3a is divided into consecutive fields, the operation of which may be controlled independently. In fig. 3a, the ESP 12 is divided into two fields: a first field, and a second, last field. Each field is provided with a number of discharge electrodes 30 and a number of collecting electrode plates 32, as will be further elucidated below with reference to fig. 3b. In fig. 3a, only one collecting electrode 32 and two discharge electrodes 30 are, for reasons of clarity, schematically illustrated in only the first field of the ESP 12.

[0044] As is best shown in Fig. 3b, which is a schematic top view of the electrostatic precipitator 12 of fig. 3a, each field is, in this example, divided into three parallel independent units, called bus-sections. A bus-section is defined as an individual unit of the ESP 12, having its own electric power source for supplying current to the electrode(s) of that bus section. In the example of fig. 3a-b, the first field has three parallel bus-sections 74a-c, and the second field also has three parallel bus sections 76a-c.

[0045] Each bus-section 74a-c, 76a-c is provided with discharge electrodes 30 and collecting electrode plates 32. Each of the bus-sections 74a-c, 76a-c is also provided with an independent electrical current source 34a-c, 36a-c, each of which applies a current and a voltage between the respective discharge electrodes 30 and the collecting electrode plates 32 of that specific bus-section 74a-c, 76a-c. Each of the current sources 34a-c, 36a-c is individually controlled by a control system 40 (fig. 3a).

[0046] All electrodes 30, 32 are arranged in a housing 28, which comprises an inlet funnel 27 and an outlet funnel 29.

[0047] Similar to the system described above with reference to fig. 1, the precipitator 12 of fig.3a-b is configured so as to receive a raw gas stream 18 from a raw gas duct 26. The division of the ESP 12 into parallel, individually controlled bus sections 74a-c, 76a-c makes it possible to render a selected path 74b, 76b through the ESP 12 inoperable. This may be done, e.g., by adjusting the current and voltage across the electrodes of a subset 74b, 76b of the bus-sections 74a-c, 76a-c, to zero. Thereby a bypass portion 68 of the raw, non-ESP cleaned gas stream 18, which carries a bypass fraction of the dust from the raw gas stream 18, may pass along the de-activated path 74b, 76b of the ESP 12 without being cleaned by the ESP 12. The bypass dust fraction carried along the de-activated path 74b, 76b of the ESP 12 by the bypass portion 68 of the raw gas stream 18 has essentially the same particle composition, with respect to size, as the raw gas stream 18 in the raw gas duct 26.

[0048] The bypass portion 68 is mixed with the ESP cleaned gas stream 22 in a bypass fraction return region 70 downstream of the electrodes 30, 32 of the ESP 12; in this example, the bypass fraction return region 70 is located in the outlet 20 of the ESP 12. The outlet 20 of the ESP 12 is defined as the location immediately downstream of the electrodes 30, 32 of the last field of the ESP. In the example shown in fig. 3b, this means that the outlet 20 is located upstream of the outlet funnel 29 of the ESP 12.

[0049] By mixing the fine dust particle fraction of the ESP cleaned gas stream 22 with the relatively coarser bypass fraction of the bypass portion 68 of the raw gas stream, the dust entering the bag filter 14 will form a more porous dust cake on the filter bags 60 than would the fine dust of the ESP cleaned gas stream 22 alone. In other words, the de-activated path 74b, 76b through the ESP 12 of fig. 3a-b has essentially the same function as the bypass duct 66 of fig. 1.

[0050] The bus-sections to be de-activated are selected by a control system 40, or by an operator, such that a selected amount 68 of raw gas is passed through the ESP 12 without being cleaned. Preferably, about 70-98%, and even more preferred, 80-97%, of the raw gas in the raw gas duct 26 is cleaned by the ESP 12, while the remaining about 2-30%, or more preferred, 3-20% of the raw gas in the raw gas duct 26 is bypassed via de-activated bus-sections 74b, 76b to the bypass fraction return region 70.

[0051] A person skilled in the art is aware that, in order to de-activate a bus-section, it is not necessary to lower the applied voltage and current over the electrodes of that bus-section to zero; it is sufficient to lower it to a value below a selected maximum value, at which maximum value that bus-section is rendered essentially inoperable with respect to dust removal efficiency.

[0052] Similarly, it is not necessary that the bypass path 74b, 76b be arranged in separate bus-sections provided with individual electric power sources 34b, 36b. An alternative would be to connect the electrodes of the bypass path 74b, 76b, via a respective de-activation switch, to the power sources 34a, 36a. In this manner, the electrodes of the bypass path 74b, 76b may be operated as slaves to the bus sections 74a, 76a during times when no bypass path is desired. Whenever a bypass path is desired, the electrodes of the slave section 74b, 76b may be de-activated by disconnecting them from the power sources 34a, 36a by means of the de-activation switches.

[0053] If a permanent bypass path is desired, it is possible to, during construction of the ESP, reserve a bypass path through the ESP 12 by simply omitting to provide a portion of the ESP 12 with discharge electrodes, and preferably also shielding this path from any portions of the ESP 12 that are operable for cleaning gas. This alternative may also be attractive for retrofits to existing installations. However, the ability to open or close a bypass path at will during operation of the filter also opens up additional possibilities, as will be further elucidated below.

[0054] As can be seen in fig. 3a-b, the control system 40 for controlling the operation of the electrodes 30, 32 of the bus-sections 74a-c, 76a-c is also connected to a control system 64 for controlling the cleaning of the filter bags 60 of the bag filter 14. Instead of continuously bypassing a bypass portion 68 of the raw gas stream 18, it is sometimes preferred to vary the fraction of bypassed dust in a time-dependent manner. By way of example, it may be beneficial to bypass a coarse bypass fraction of dust immediately after cleaning the filter bags 60, such that when the dust starts to deposit again on the clean filter bags 60, a layer of coarser dust will be deposited first. By priming the filter bags 60 in this way, they will be less sensitive to blinding by finer dust fractions received from the ESP. A method for operating the hybrid dust particulate collector system of figs 3a-b so as to prime the filter bags 60 with relatively coarse dust particles will now be described with reference to fig. 4.

[0055] In step 110, the bag filter controller 64 initiates cleaning of at least a portion of the filter bags 60 of the bag filter 14, e.g. by releasing a jet of compressed air, via the clean air nozzles 62, into the filter bag(s) 60 to be cleaned. This event triggers, in step 112, a bag filter cleaning signal to be sent to the ESP controller 40, which in this example also acts as a bypass controller, such that the ESP controller 40 will be made aware that the filter bags 60 are now clean and exposed to being blinded by fines dust.

[0056] Based on the bag filter cleaning signal, the ESP controller 40, in step 114, opens a bypass path through the ESP 12 to the bypass return region 70 by de-activating all the bus-sections 74a-c, 76a-c, i.e. the entire ESP 12.

[0057] In step 116, the bypass path is kept open during a bypass time, such that a selected bypass portion 68 of the raw gas stream 18, carrying a bypass fraction of dust, may pass. This bypass fraction, having a dust particle composition than the dust carried by the ESP cleaned gas coarser stream 22 prior to de-activating the ESP 12, will now prime the cleaned filter bags 60.

[0058] After having allowed the bypass portion 68 to pass the bypass path, i.e. the ESP 12, the bus-sections 74a-c, 76a-c are once again re-activated so as to resume normal, dust-removing operation of the ESP 12.

[0059] In order to bypass a suitable bypass portion 68 of raw gas to the bypass return region 70, the bypass time, i.e. the duration of the bypass, is preferably based on the bypass frequency, which in the example above is identical to the bag filter cleaning frequency. Preferably, the bypass time is selected so as to keep the bypass open between 2 and 30%, and more preferred, between 3 and 20 % of the time.

[0060] As an alternative to bypassing the entire flue gas flow through the ESP, it is also possible to de-activate only a few bus-sections, corresponding to the desired gas flow capacity of the bypass path, when opening the bypass. By way of example, when opening the bypass path in step 114, the bypass path may be limited to bus-sections 74b, 76b by disabling only the power supplies 34b, 36b. Furthermore, it is also possible to open an already existing bypass path, such that an already existing bypass flow is increased, or close a bypass, such that the bypass flow is reduced. In other words, an already open bypass may be opened even further, or a degree of opening of an open bypass may be reduced without completely shutting the bypass.

[0061] In hybrid particulate systems having a long distance from the ESP 12 to the bag filter 14, it may be beneficial to initiate the cleaning of the bag filter 14 a short period of time after opening the bypass path, such that the bypass fraction will arrive to the inlet compartment 54 of the bag filter 14 just in time for the cleaning of the bag(s) 60.

[0062] As can be seen in fig. 3a-b, the control system 40 for controlling the operation of the electrodes 30, 32 of the bus-sections 74a-c, 76a-c is also connected to the boiler control system 25. The opening and closing of a bypass path may thereby also be controlled based on events taking place in the boiler 24 (fig. 1). Such events may be, by way of example, events that effect the composition of raw gas dust particles carried by the raw gas stream 18, such that a change in the bypass flow is motivated. One particular example is the start-up of a coal fired boiler, using oil as a start-up fuel for pre-heating the boiler. Oil combustion may produce finer dust particles than coal combustion; bypassing of oil combustion flue gas to a barrier filter is therefore in most cases not desired. Furthermore, the flue gas from oil combustion may contain residues of oil aerosol, which may clog the filter bag material of a bag filter 14 and thereby permanently damage the filter bags 60. Fig. 5 illustrates an example of a start-up procedure for operating the hybrid dust particulate collector system 10 of figs 3a-b.

[0063] In step 210, the boiler control system 25 transmits a start-up warning signal to the ESP controller 40, so as to notify the ESP controller 40 that the boiler 24 (fig. 1) will undergo a start-up procedure.

[0064] Based on the start-up warning signal, the ESP controller in step 212 verifies that the ESP 12 is in operation and that any bypasses are closed. The ESP controller 40 transmits a verification signal to the boiler control system 25.

[0065] In response to the verification signal, the combustion in the boiler 24 is, in step 214, initiated by the boiler control system 25 or by an operator. In this step, the boiler 25 is started using an oil based fuel.

[0066] In step 216, the bypass path is kept closed, i.e. all bus sections 74a-c, 76a-c of the ESP 12 are kept operational, while the boiler 24 is running on oil or a mixture of oil and coal.

[0067] In step 218, the boiler control system 25 switches over the boiler 24 to coal combustion. After having verified that stable, normal operation of the boiler has been obtained, i.e. that the boiler 24 has been running on 0% oil for a predetermined period of time, the boiler control system 25 transmits a normal operation verification signal to the ESP controller.

[0068] Based on the normal operation verification signal from the boiler control system 25, the ESP controller 40, in step 220, opens a bypass path through the ESP, e.g. by de-activating the bus-sections 74b, 76b. The bypass path thus formed will now allow a bypass portion 68 of the raw gas stream 18, said bypass portion 68 carrying a bypass fraction of dust, to bypass the ESP 12 and be mixed with the ESP cleaned gas stream 22 in the bypass return region 70.

[0069] Using this start-up procedure, it is possible to avoid transferring a potentially harmful bypass fraction of the raw gas dust while the boiler operates on oil. This is of particular use in a hybrid dust particulate collector system optimized for cleaning of flue gas from a coal combustion process.

[0070] The above methods described with reference to figs 4-5 are merely based on examples of situations in which it may be desirable to control the bypass based on events taking place in equipment upstream or downstream of the hybrid particulate collector 10. It is appreciated that many such situations will be apparent to a person skilled in the art; by way of example, it may also be desirable to decrease a bypass flow during soot-blowing of the boiler 24. Another situation when it is desirable to reduce, or even close, the by-pass is when it has been detected that one or several of the filter bags 60 has been damaged, such damage of one or several of the filter bags 60 being detected by the control system 64, or by a detected dust particle level in the stack 52 passing a predetermined threshold value.

[0071] Evidently, the methods described above with reference to figs 4-5 are not limited to use in conjunction with the hybrid dust particulate collector system of figs 3a-b; they may advantageously also be combined with the embodiment of fig. 1. To this end, the bypass control valve 72 of fig. 1 may be configured so as to respond to control signals from any of the control systems 25, 40 or

64. The methods may also be combined with the embodiment that will now be described with reference to fig. 6.

[0072] The hybrid dust particulate collector system 10 of fig. 6 comprises an electrostatic precipitator (ESP) 12, which is connected in series with a bag filter 14, in a manner similar to what is described above with reference to figs 1 and 3a-b. The ESP 12 has an ESP inlet 16 for a raw, dust particle laden gas stream 18, and an ESP outlet 20 for an ESP cleaned gas stream 22.

[0073] Similar to the electrostatic precipitators of figs 1 and 3a-b, the electrostatic precipitator 12 of fig. 6 is divided into consecutive fields, the operation of which, even though this is not necessary, may be controlled independently. In fig. 6, the ESP 12 is divided into two fields: a first field, and a second, last field. Each field is provided with a number of discharge electrodes 30 and a number of collecting electrode plates 32; again, only the electrodes 30, 32 of the first field of the ESP 12 are schematically illustrated for reasons of clarity. Electrical power is supplied to the first field by means of a first power supply 34, and to the second field by means of a second power supply 36. The first field of the ESP 12 is further provided with a first field hopper 41, which is arranged below the first field's collecting electrode plates 32, such that, when the first field's collecting electrode plates 32 are rapped, a collected portion of raw gas dust particles 44 will fall from the collecting electrode plates 32 into the first field hopper 41. Also the second field is provided with a hopper 42.

[0074] As explained above with reference to fig. 1, the ESP 12 by its fundamental operating principles removes coarse particles more efficiently than it removes fine particles. This means that the collected portion 44 of raw gas dust particles, which are collected by the first field, are coarser than the dust particles collected by the second field, which in turn are coarser than the fine dust particles remaining in the ESP cleaned gas stream 22. In fact, the particle composition of the collected portion 44 is typically even coarser than the composition of the particles entrained with the raw gas stream 18.

[0075] The hybrid dust particulate collector system 10 of fig. 6 is provided with a bypass duct 66, which is connected between the first field hopper 41 and a bypass fraction return region 70. The bypass duct 66 is configured so as to transfer a bypass fraction of the collected portion 44 of raw gas dust particles collected by the first field of the ESP 12. In order to facilitate the transfer, the bypass duct is provided with a compressed air blower 72, for blowing the bypass fraction of said raw gas particles along the bypass duct 66 to the bypass fraction return region 70. By returning a portion of the coarse fraction 44 collected in the first field to the bypass fraction return region 70, an even more porous dust cake may be obtained on the bag filter 14 than would be possible using raw gas dust carried directly by a bypass portion 68 of the raw gas stream 18.

[0076] In the embodiments described hereinbefore, with reference to figs 1-5, the amount of dust to be transferred to the bypass return region 70 may be controlled by varying the flow rate of a raw gas bypass portion 68, e.g. by varying the flow through a control valve or the size of a bypass path through an ESP. In the embodiment of fig. 6, the amount of dust to be transferred to the bypass return region 70 may be controlled, by way of example, by feeding collected dust 44 to the compressed air blower 72 at a selected rate. A person skilled in the art understands that there are many alternatives to an air blower 72. By way of example, a screw conveyor may be used, or the collected dust may be transported by the force of gravity on a fluidized bed conveyor to the bypass fraction return region 70.

[0077] In summary, a hybrid dust particulate collector system, comprising an electrostatic precipitator in series with a bag filter, for cleaning a flue gas stream, is disclosed above. The system is provided with bypass means for bypassing a coarse fraction of the dust contained in the flue gas stream to a location downstream of the electrostatic precipitator. The coarse fraction comprises a mass percentage of dust particles falling below 1 μm in diameter that is lower than the mass percentage of dust particles falling below 1 μm that remains in the fines dust fraction carried by gas cleaned by the electrostatic precipitator. Preferably, the coarse fraction also comprises a mass percentage of dust particles exceeding 30 μm in diameter that is higher than the mass percentage of dust particles exceeding 30 μm that remains in the fines dust fraction carried by gas cleaned by the electrostatic precipitator. By transferring a coarse bypass fraction of the dust particles to a bypass return region downstream of the electrostatic precipitator, a lower pressure drop over the bag filter may be obtained. This provides for energy savings, as less energy is required to draw the gas flow through the bag filter. Furthermore, it is possible to prolong the cleaning intervals of the bag filter, which will in turn reduce the wear on the filter fabric, and/or reduce the total particulate emission.

[0078] The invention has mainly been described above with reference to various exemplary embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

[0079] For example, in the examples above, a fabric filter of bag filter type is operated so as to accumulate dust on the outside of the filter bags. The filter may also be operated in the reverse direction, i.e. so as to accumulate dust inside the bags in the manner well known to those skilled in the art. Instead of, or in combination with bag filters, also other types of fabric filters, as well as barrier filters in general, can be used to implement the invention. One example of such barrier filters is ceramic filters of the type described in US 4,862,813. Furthermore, the invention may be used in combination with boilers for combusting many different types of fuel, such as coal, waste, peat, and biomass fuel, such as wood chips. In fact, the invention is not limited to cleaning flue gas from a boiler; also other types of dust-laden gas, emanating from other types of processes, including metallurgical processes, may be cleaned by means of the invention.

[0080] Even though, in the embodiments described in detail hereinbefore, the electrostatic precipitator and the barrier filter are illustrated as separate components, they may also be arranged in the same housing. And even though the boiler, ESP, and barrier filter controllers 25, 40, 64 are illustrated as separate components, they may, in fact, be implemented on the same printed circuit board, in the same computer, or in the same software on the same computer. The controllers 25, 40, 64 may also, for that matter, be separated into more than three separate control units.

[0081] A bypass fraction may be transferred through one or several bypass ducts, through one or several inactivated paths in an ESP, or through a combination of bypass ducts and inactivated paths, to an arbitrary number of bypass fraction return regions downstream of the active parts of the ESP.

Claims

1. A method for removing dust particles from a raw gas stream (18), which comprises raw gas dust particles, in a hybrid dust particulate collector system (10) comprising an electrostatic precipitator (12), and a barrier filter (14) located downstream, with respect to a main gas flow direction through the system (10), of said electrostatic precipitator (12), the method comprising
cleaning at least a major portion of the raw gas stream (18) in the electrostatic precipitator (12), so as to obtain an ESP cleaned gas stream portion (22), and being **characterized in**
transferring a bypass fraction of said raw gas dust particles to a bypass fraction return region (70) located in or downstream of an outlet (20) of said electrostatic precipitator (12), and upstream of said barrier filter (14), said bypass fraction having a coarser dust particle composition compared to the composition of dust particles remaining in the ESP cleaned gas stream portion (22).

2. A method according to claim 1, wherein said bypass fraction is carried to said bypass fraction return region (70) by a non-ESP cleaned bypass portion (68) of said raw gas stream (18).

3. A method according to claim 2, wherein said non-ESP cleaned bypass portion (68) is transferred from a bypass entry region upstream of the electrostatic precipitator (12) to said bypass fraction return region (70) by means of a bypass duct (66).

4. A method according to claim 2, wherein said non-ESP cleaned bypass portion (68) is transferred to said bypass fraction return region (70) via a bypass path through an inactive portion (74b, 76b) of said electrostatic precipitator (12), such that said non-ESP cleaned bypass portion (68) is transferred through the electrostatic precipitator (12) without being cleaned by means of an electric field.

5. A method according to claim 4, further comprising temporarily de-activating at least a portion (74b, 76b) of the electrostatic precipitator (12), so as to create said bypass path.

6. A method according to claim 1, wherein said bypass fraction comprises a portion of the dust particles (44) separated from the ESP cleaned gas stream portion (22) in a first field of the electrostatic precipitator (12).

7. A method according to any of the previous claims, wherein said bypass fraction of said raw gas dust particles amounts to 2 - 30%, by mass, of the total amount of dust particles in the raw gas stream (18).

8. A method according to any of the previous claims, further comprising adjusting the amount of bypass fraction to be transferred to the bypass fraction return region (70) to a selected amount of bypass fraction.

9. A method according to any of the previous claims, further comprising controlling, based on an event in equipment (24, 25, 14, 64) downstream or upstream of the electrostatic precipitator (12), the amount of bypass fraction to be transferred to the bypass fraction return region (70).

10. A method according to claim 9, wherein the transfer of said bypass fraction is controlled based on the initiation (110) of a cleaning of the barrier filter (14), such that the barrier filter (14) is primed by the bypass fraction.

11. A hybrid dust particulate collector system for removing dust particles from a raw gas stream (18), which comprises raw gas dust particles, the system (10) comprising an electrostatic precipitator (12) and a barrier filter (14), said barrier filter (14) being connected downstream of said electrostatic precipitator (12), the electrostatic precipitator (12) being configured for cleaning at least a major portion of the raw gas stream (18) so as to obtain an ESP cleaned gas stream portion (22), the system being **characterized in**
a transferring device configured for transferring a bypass fraction of said raw gas dust particles to a bypass fraction return region (70) located in or downstream of an outlet (20) of said electrostatic precipitator (12), and upstream of said barrier filter (14), the transferring device being configured to transfer

a bypass fraction that has a coarser dust particle composition compared to the composition of dust particles remaining in the ESP cleaned gas stream portion (22).

12. A hybrid dust particulate collector system according to claim 11, said transferring device being configured to transfer said bypass fraction to said bypass fraction return region (70) carried by a non-ESP cleaned bypass portion (68) of said raw gas stream (18).

13. A hybrid dust particulate collector system according to claim 12, wherein said transferring device comprises a bypass duct (66), connecting a bypass entry region upstream of the electrostatic precipitator (12) to said bypass fraction return region (70).

14. A hybrid dust particulate collector system according to claim 13, wherein said bypass duct (66) is provided with a control valve (72).

15. A hybrid dust particulate collector system according to claim 11, wherein said transferring device comprises a bypass path through an inactive portion (74b, 76b) of said electrostatic precipitator, such that said non-ESP cleaned bypass portion (68) may be transferred through the electrostatic precipitator without being cleaned by means of an electric field.

16. A hybrid dust particulate collector system according to claim 15, wherein said transferring device further comprises a controller (40), which is configured to, during operation of the hybrid dust particulate collector system (10), temporarily de-activate at least a portion of the electrostatic precipitator (12) so as to create said bypass path, such that said non-ESP cleaned gas stream portion (68) may be transferred through the electrostatic precipitator without being cleaned.

17. A hybrid dust particulate collector system according to claim 11, wherein said transferring device comprises a bypass duct (66), connecting a dust collecting hopper (41) of a first field of the electrostatic precipitator to said bypass fraction return region (70), said bypass duct (66) being configured for transferring collected dust (44) that has been separated from said ESP cleaned gas stream (22) to said bypass return region (70).

18. A hybrid dust particulate collector system according to any of the claims 11-17, wherein said transferring device is adapted for transferring 2 - 30%, by mass, of the total amount of dust particles in the raw gas stream (18).

19. A hybrid dust particulate collector system according to any of the claims 11-18, said transferring device further comprising a control system (40) for controlling the transfer of the bypass fraction to the bypass fraction return region (70).

20. A hybrid dust particulate collector system according to claim 19, said control system (40) being configured to control, based on an event in equipment (24, 25, 14, 64) downstream or upstream of the electrostatic precipitator (12), the amount of bypass fraction to be transferred to the bypass fraction return region (70).

21. A hybrid dust particulate collector system according to claim 20, said control system (40) being configured to control said transfer of said bypass fraction based on the initiation (110) of a cleaning of the barrier filter (14), such that the barrier filter (14) is primed by the bypass fraction.

22. A hybrid dust particulate collector system according to any of the claims 11-21, wherein said electrostatic precipitator (12) and said barrier filter (14) are comprised in the same housing.

Fig. 1

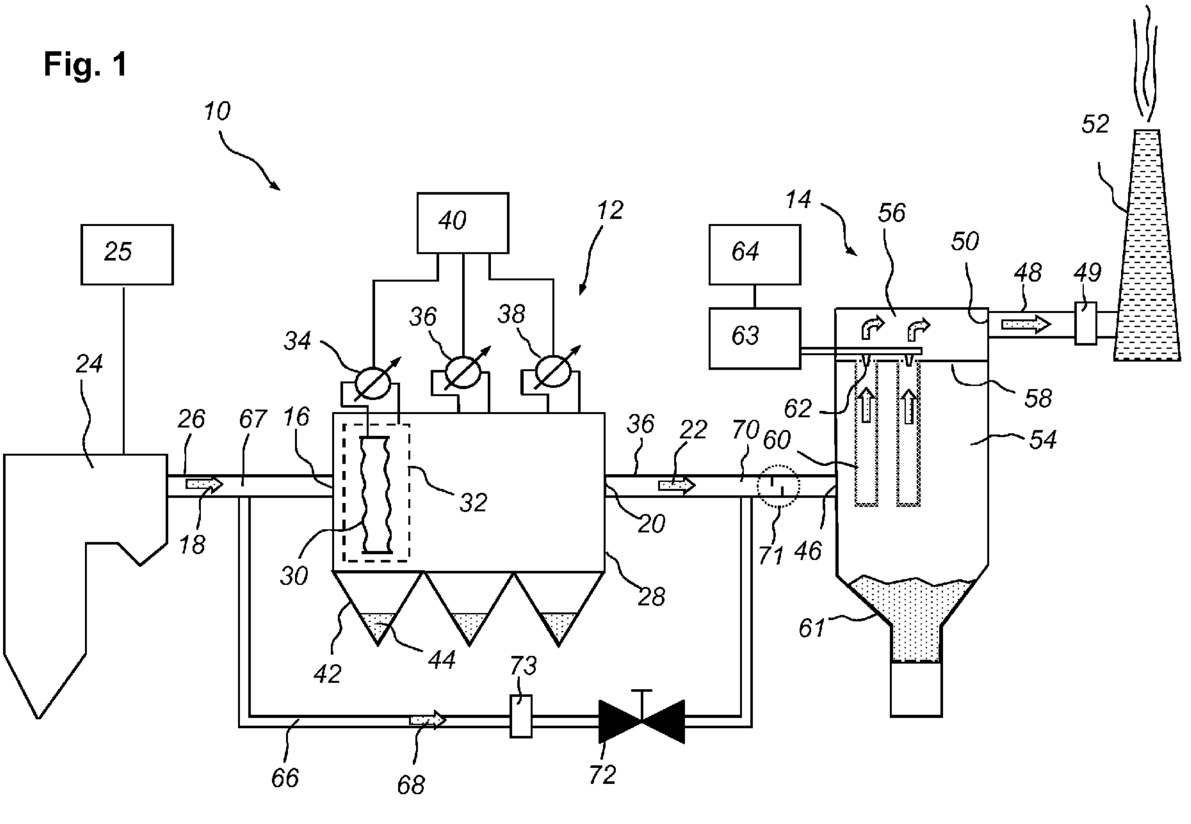

10
12
14
16
18
20
22
24
25
26
28
30
32
34
36
38
40
42
44
46
48
49
50
52
54
56
58
60
61
62
63
64
66
67
68
70
71
72
73

Fig. 2

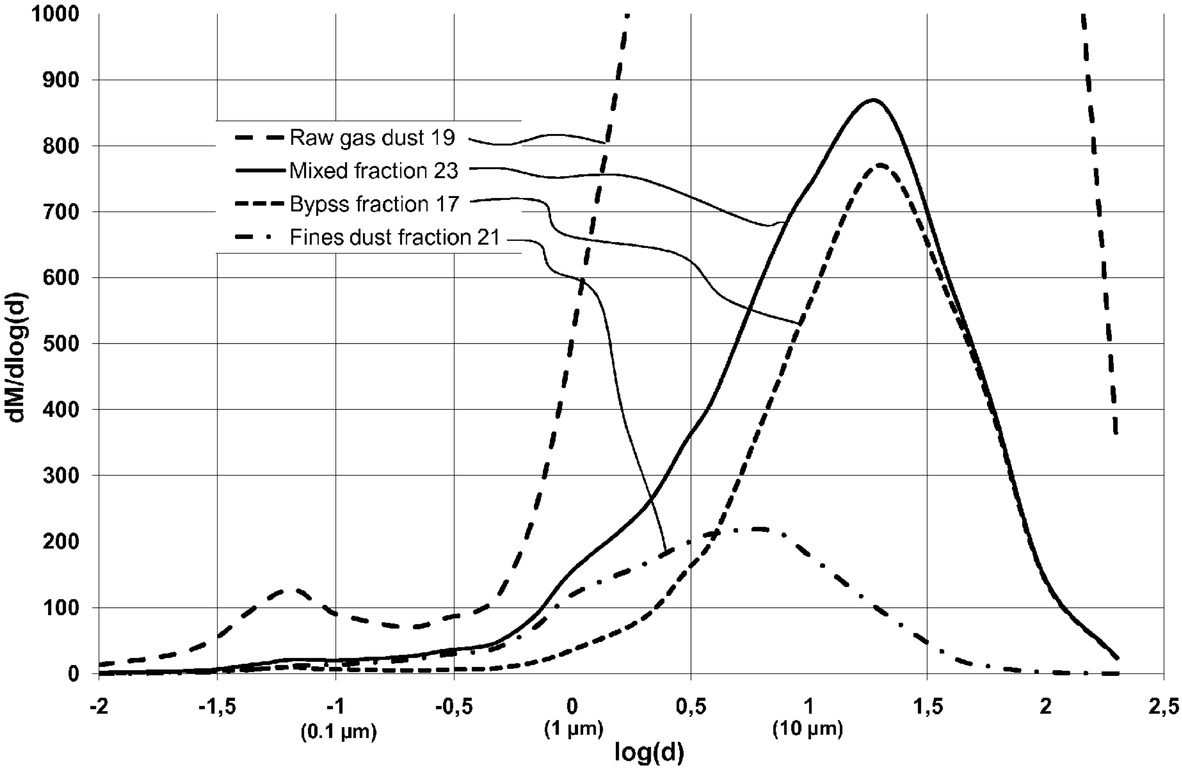

1000
900
800
700
600
500
400
300
200
100
0
dM/dlog(d)
Raw gas dust 19
Mixed fraction 23
Bypss fraction 17
Fines dust fraction 21
-2
-1,5
-1
(0.1 µm)
-0,5
0
(1 µm)
0,5
1
(10 µm)
1,5
2
2,5
log(d)

Fig. 3a

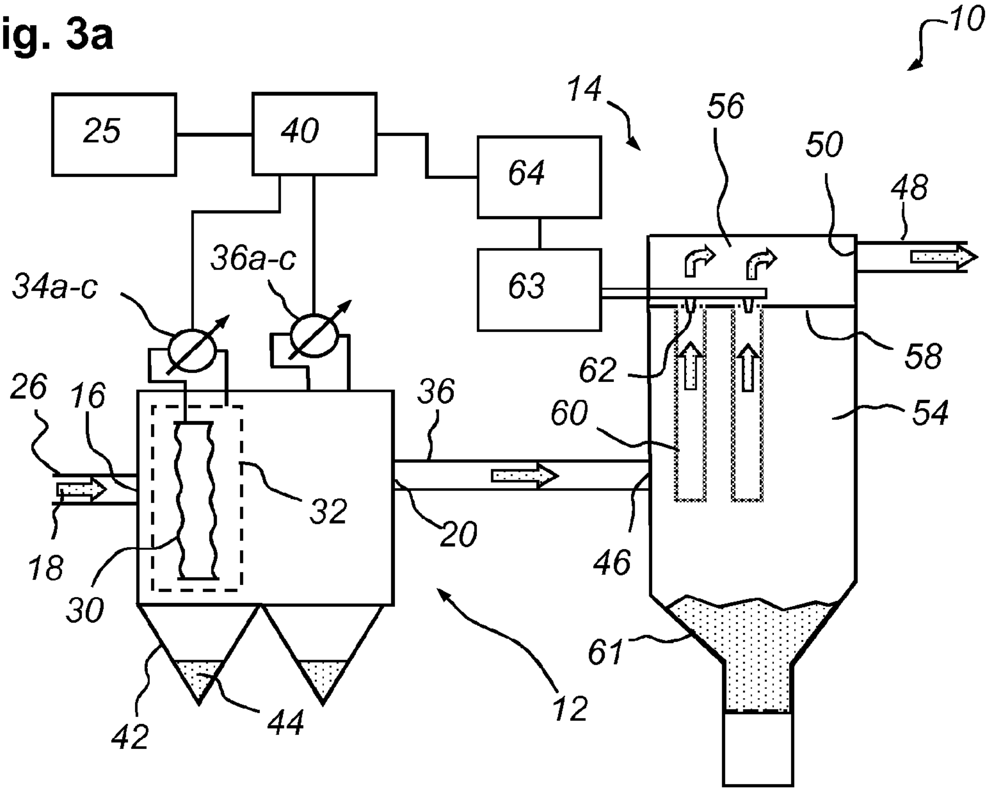

10
14
25
40
64
63
56
50
48
34a-c
36a-c
58
62
26
16
36
60
54
32
20
46
18
30
61
12
42
44

Fig. 3b

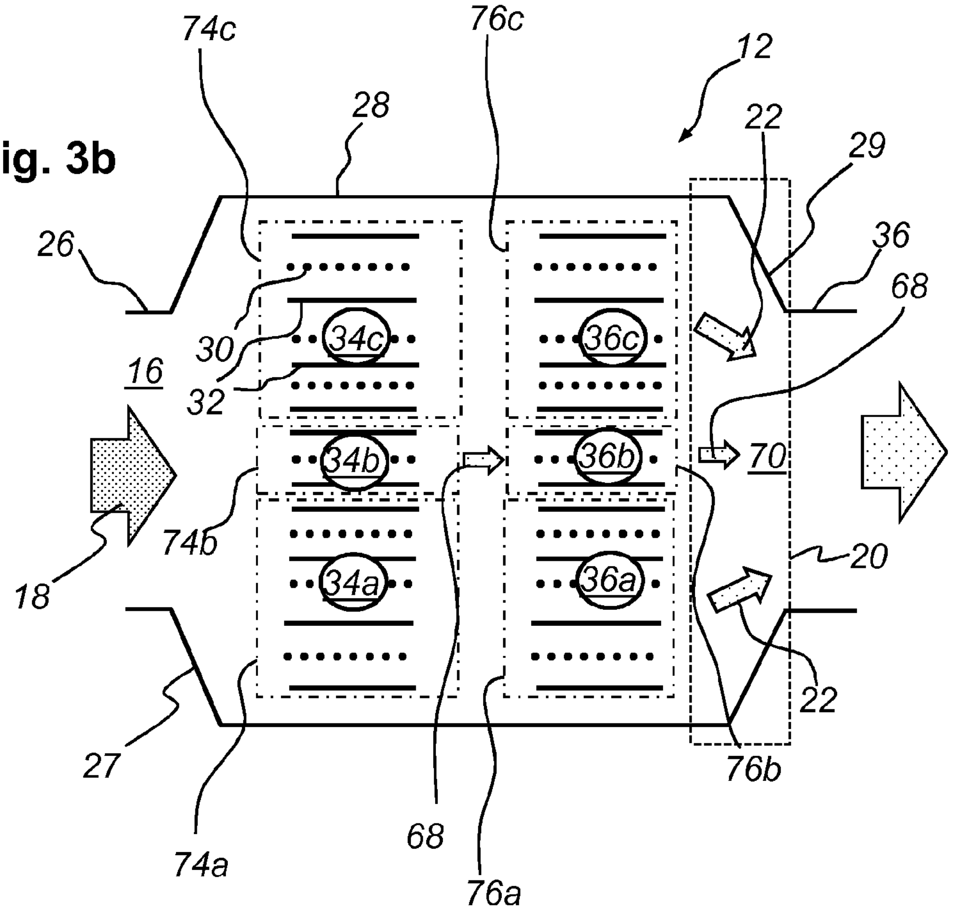

74c
76c
12
28
22
29
26
36
68
30
34c
36c
16
32
34b
36b
70
74b
34a
36a
20
18
22
27
76b
74a
68
76a

Fig. 4

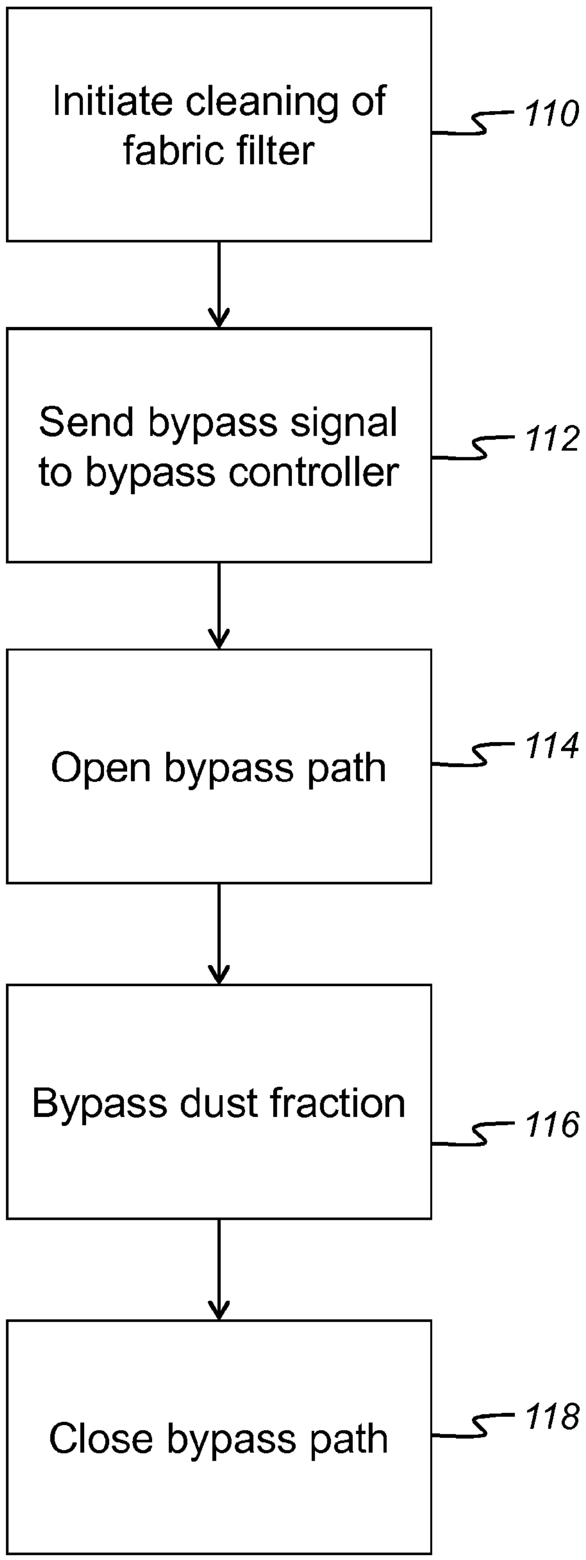

Initiate cleaning of fabric filter
110
Send bypass signal to bypass controller
112
Open bypass path
114
Bypass dust fraction
116
Close bypass path
118

Fig. 5

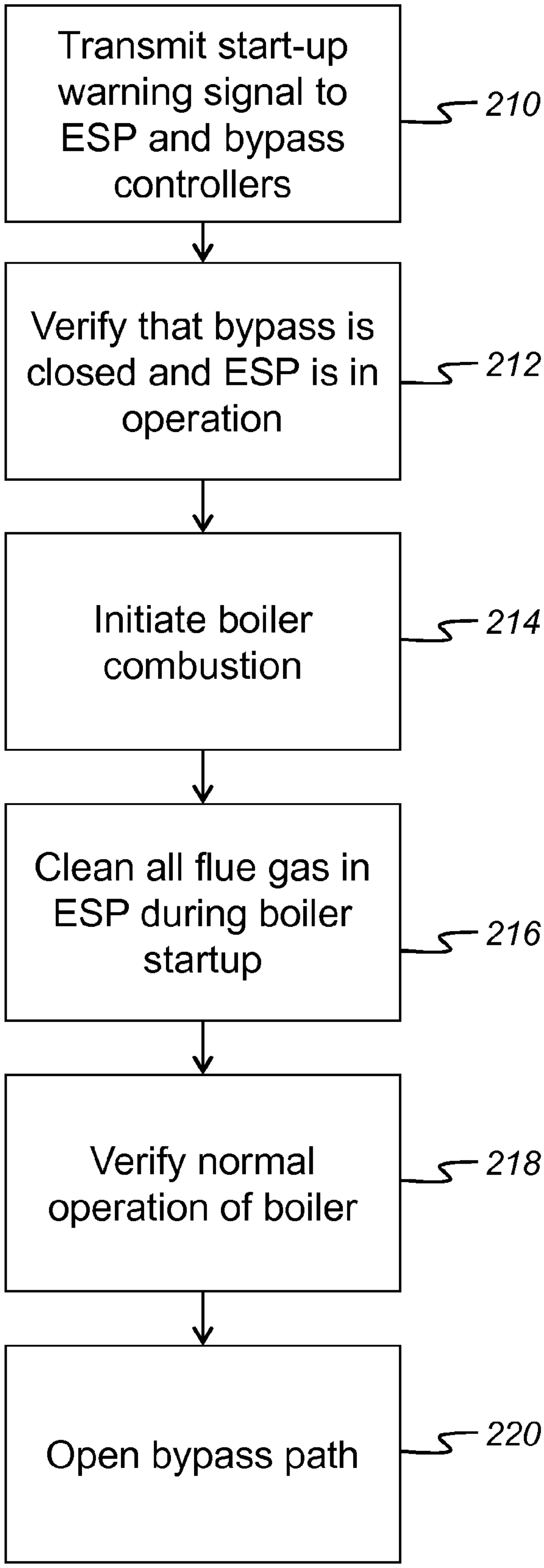
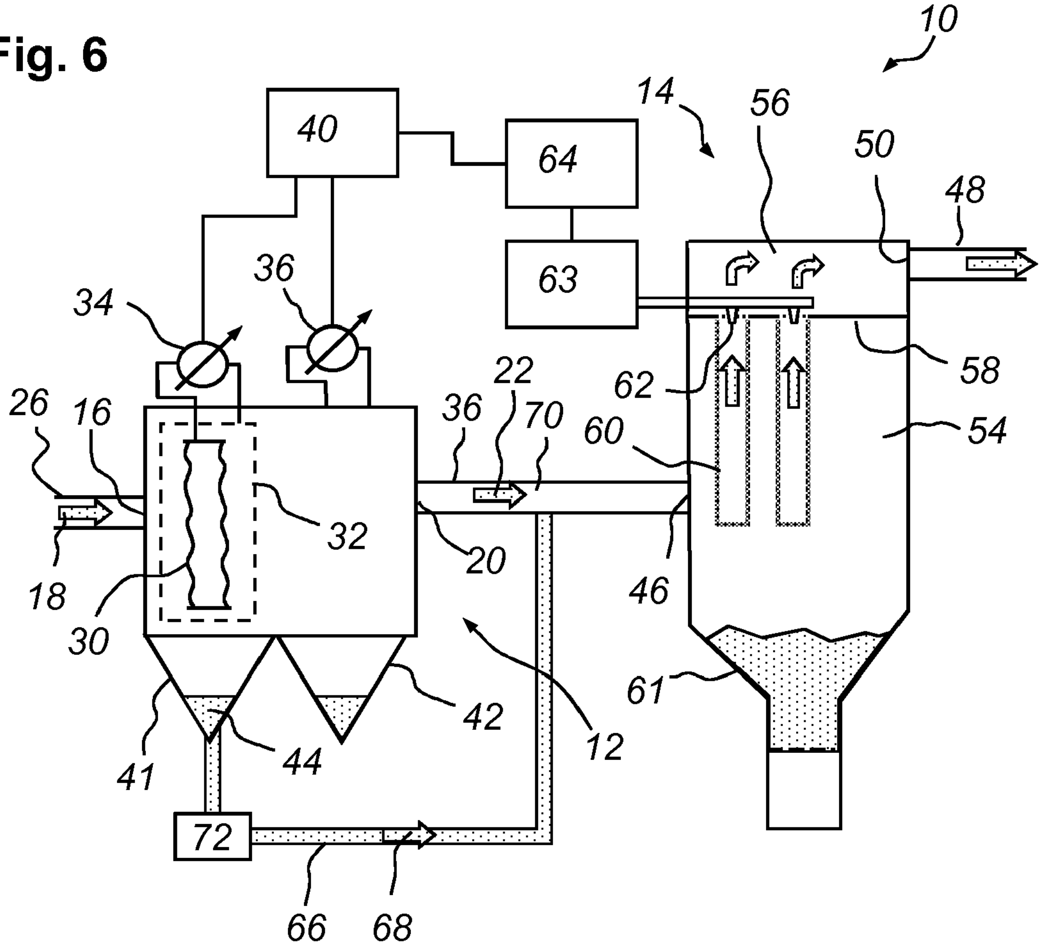

Transmit start-up warning signal to ESP and bypass controllers
210
Verify that bypass is closed and ESP is in operation
212
Initiate boiler combustion
214
Clean all flue gas in ESP during boiler startup
216
Verify normal operation of boiler
218
Open bypass path
220

Fig. 6


10
14
56
50
48
40
64
63
36
34
58
62
22
26
16
36
70
60
54
32
20
18
46
30
12
61
42
44
41
72
66
68

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 09 17 4340

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP 2008 012060 A (DAIKIN IND LTD) 24 January 2008 (2008-01-24) * paragraph [0029] * -----	1-22	INV. B03C3/155 B03C3/017 B03C3/019
X	DE 42 08 204 C1 (METALLGESELLSCHAFT AG, 6000 FRANKFURT, DE) 18 March 1993 (1993-03-18) * figure 2 * -----	1-22	
X	US 4 317 661 A (SASAOKA RYOSUKE ET AL) 2 March 1982 (1982-03-02) * figures 9,10 * -----	1,11	
Y	US 3 733 784 A (ANDERSON W ET AL) 22 May 1973 (1973-05-22) * figure 1 * -----	1-22	
Y	US 5 024 681 A (CHANG RAMSAY [US]) 18 June 1991 (1991-06-18) * abstract * -----	1-22	TECHNICAL FIELDS SEARCHED (IPC)
Y	US 4 871 515 A (REICHLE ERNST-MICHAEL [DE] ET AL) 3 October 1989 (1989-10-03) * figure 6 * -----	1-22	B03C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	3 March 2010	Demol, Stefan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
&: member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 17 4340

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

03-03-2010

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
JP 2008012060	A	24-01-2008	NONE			
DE 4208204	C1	18-03-1993	EP	0561433	A1	22-09-1993
US 4317661	A	02-03-1982	DE	2810735	A1	28-09-1978
			FR	2383707	A1	13-10-1978
			GB	1587983	A	15-04-1981
US 3733784	A	22-05-1973	CA	980267	A1	23-12-1975
			JP	48044868	A	27-06-1973
US 5024681	A	18-06-1991	AT	150986	T	15-04-1997
			CA	2046877	A1	16-06-1991
			DE	69030376	D1	07-05-1997
			DE	69030376	T2	23-10-1997
			EP	0458955	A1	04-12-1991
			JP	4505419	T	24-09-1992
			WO	9108838	A1	27-06-1991
US 4871515	A	03-10-1989	DE	3723544	A1	26-01-1989
			EP	0299197	A2	18-01-1989
			JP	1047463	A	21-02-1989

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 5024681 A **[0002]**
- US 4336035 A **[0029]**
- US 4502872 A **[0031]**
- US 4862813 A **[0079]**