A New Multi-Stage Collector (MSC™) Concept

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ABSTRACT

Several hybrid particulate collection systems integrating electrostatic precipitation with fabric filter collection have been under development for a number of years. Among major objectives of this work are reducing the size associated with a fabric filter (FF) while increasing the collection efficiency above that of an electrostatic precipitator (ESP). In most cases, the current approaches encountered different development issues:

- If the ESP and FF are in series, the ESP may selectively remove large particles resulting in high pressure drop across the FF;
- None of current hybrid collector designs is capable of effectively collecting bipolar charged particles, thus, performance continues to depend on particulate resistivity;
- A common issue is electrical discharge to the bags resulting in punctures.

A new hybrid particulate collector (Multi-Stage Collector or MSC™) is being developed that alleviates most of the issues sited above. The MSC™ technology provides an optimum combination of single- and two-stage electrostatic precipitation augmented by barrier filtration. This arrangement ensures that essentially all dust is retained within the collector.

The operation of the MSC™ is virtually independent of the collected material's electrical resistivity. Hence, its application will be especially beneficial when the electrical resistivity of the collected material either exceeds 10^{11} or it less than 10^{4} Ohm-cm levels.

Pilot results have shown collection efficiencies of 99.99% at face velocities (FV) of 8 ft/min.

INTRODUCTION

Popular devices currently used in industry to remove particulate matter from various process gases include Electrostatic Precipitators (ESPs) and Fabric Filters (FFs). While these devices are widely used, they have a number of shortcomings. The current work addresses these shortcomings through the development of a new concept for particulate removal and control: the Multi-Stage Collector (MSC™). The MSC™ concept is a patented process that entails a unique integration of both electrostatic precipitation and barrier filtration.[1,2] The MSC™ concept overcomes not only the shortcomings of conventional ESPs and FFs, but is also a technical improvement to hybrid ESP/FF concepts currently under development.

To date, (a) two patents had been issued for the MSC™ concept[1,2], (b) flow patterns through the

MSC™ device have been investigated using CFD modeling, (c) a pilot-scale MSC™ particulate collector has been fabricated and proof of concept tests have been performed.

Successful development of the MSC™ particulate collector will provide industry with a technologically advanced particulate removal device. Compared to current technologies, the MSC™ provides:

i. a more compact particulate collector

ii. a more energy-efficient particulate collector

iii. a device with a high particulate removal efficiency (99.99%) for all particle sizes including fine particles

iv. a particulate collection device whose collection efficiency is virtually independent of the particulate characteristics (i.e., size, electrical resistivity, etc.)

BACKGROUND

The most widely used methods to remove particulate matter from industrial process streams are ESPs and FFs. In addition, there are a number of developments underway of hybrid devices integrating ESP/FF concepts. To better understand why the MSC™ concept is a technical improvement over the current designs, it is appropriate to briefly review how each system works along with delineating their shortcomings.

Electrostatic Precipitation

A typical ESP incorporates two zones:

i. The charging zone, where the dust or aerosol particles are charged, and

ii. The collecting zone, where the charged particles are separated and transferred from the gas stream to a collecting electrode with subsequent removal into the collecting or receiving hoppers.

The arrangement of these zones led to two typical ESP design concepts: (a) a single-stage “conventional” ESP where both zones are combined in a common area, and (b) so called two-stage design where these zones are separated.

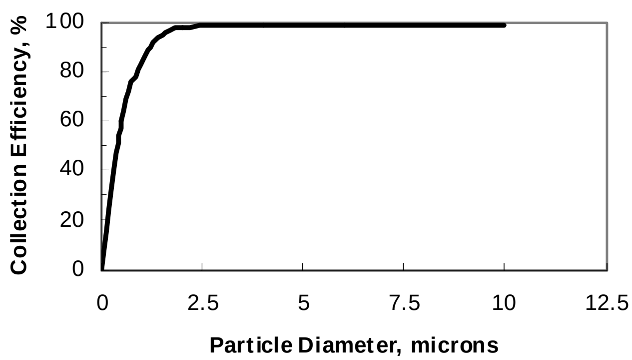
With high resistivity ash, a voltage drop occurs across the collected ash layer on the collection plates. This can cause an electrical breakdown resulting in a "back corona" or sparking through the dust layer resulting in re-entrainment. This back corona also results in a "bi-polar" distribution of charged particles. When this happens, the particles that are repelled, or re-entrained, from the collecting surfaces are carrying an opposite charge from the main inventory of entrained particles. None of the conventional ESPs, or the hybrid devices under development, can deal effectively with this bi-polar distribution of charged particles.

In the case of low-resistivity dust, a somewhat similar process takes place; however, due to an entirely different phenomena. Low resistivity dusts are known to quickly discharge; thus, they are repelled back to the gas stream nearly instantly upon contacting the collecting plates irrespective of their polarity. Viewed as a statistical phenomenon, particles of dust tend to move in a zig-zag fashion between the plane of the discharge electrodes and the collecting electrodes as the gas entrains such particles along the collecting path. The zig-zag movement is a phenomenon which is associated with both high- and low-resistance dusts.

Because of the zig-zag phenomenon, the effectiveness of dust collection is reduced, and hence the performance of a dust-collecting or dust-arresting assembly is significantly lower for high- or low-resistance dusts compared to dusts with normal electrical resistivity. The fact that ESP performance depends on the resistivity of the dust is one of the major shortcomings of this device. ESP collection efficiency is generally good if the ash resistivity is in the range of 10^4 to 10^{10} Ohm-cm. Performance degrades for higher or lower levels of ash resistivity[3].

In a conventional configuration, ESPs will have a collection efficiency of nominally 99.5% to 99.9%. In addition, this collection efficiency is dependent on particle size. Figure 1 shows typical collection efficiency versus particle size relationship for an ESP. As can be seen, for sizes below 1 to 2 microns (µm), the collection efficiency rapidly degrades.

Figure 1. ESP Collection Efficiency as a Function of Particle Size



Fabric (Barrier) Filters

Electric power producers, as well as industrial-user companies, are looking for ways to upgrade current particulate control equipment. One approach is to replace existing under-performing ESPs with Fabric Filters (barrier filters). The Fabric Filters (FFs) are generally accepted as an alternative to ESPs for collecting fly ash from the flue gas. Conventional designs can be categorized as low air to cloth ratio baghouses (for example, reverse-gas and shake-deflate types) and relatively high air to cloth ratio FFs (so called pulsejet baghouses). Low air to cloth ratio FFs generally operate at Filtration Velocities (FVs) of 1.5 to 2.5 ft/min. The term Filtration Velocity (FV) and Air to Cloth (A/C) ratio are interchangeable where the A/C is the volumetric flow rate of flue gas per unit of effective filter area (cubic feet of flue gas flow/min per square foot of filtering area). The high-ratio, pulsejet (PJ) baghouses on the other hand, generally operate at Filtration Velocities of 3 to 6 ft/min.

FFs generally have very high collection efficiencies (greater than 99.9%) and the collection efficiency is largely independent of fly ash properties. However, because of their low filtration velocities, they are large, require significant space, costly to build, and thus generally unattractive as replacements for existing ESPs. Reducing their size by increasing the filtration velocity across the filter bags usually results in unacceptably high pressure drop and reduced collection efficiency. There is also potential for "blinding" the filter bags – a condition where particles become embedded deep within the filter and cannot be "cleaned" out of the filter material.

Hybrid Particulate Collectors

The traditional ESPs suffer from relatively low collection efficiency, particularly for fine particulates, and the performance depends on the electrical resistivity of the particulate that is being collected. While exhibiting a much greater collection efficiency that is largely independent of both particle size and property, the FFs provide a rather large pressure drop and are physically large devices.

In an effort to overcome the above deficiencies (i.e., increasing the collection efficiency without a corresponding increase in pressure drop and physical size), a number of efforts have been, and are currently, underway to develop hybrid particle collectors. These hybrid devices attempt to integrate electrostatic and fabric filtration into a single device. The MSC™ device, which is the subject of this paper, falls into this hybrid category.

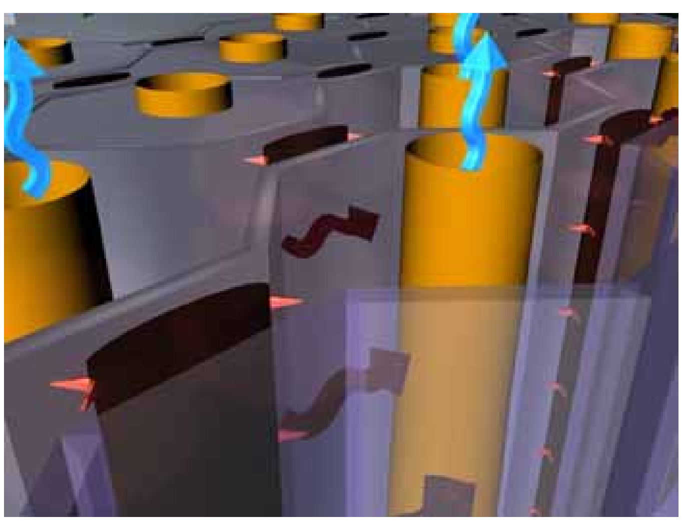
The hybrid particulate collection concepts of interest include:

i. Electrostatically enhanced Fabric Filter[3]
ii. COHPAC-1 and COHPAC-2 systems[4,5]
iii. Advanced Hybrid™[6]
iv. MSC™[1,2]

MSC™ Particulate Collector

The principal objective of the MSC™ design is to substantially improve fine particulate collection by combining electrostatic charging-collection and filtration processes not only by separating zones for particle charging and collecting, but by providing a new and unique collector design with improved efficiency for the collection of fine dust particles independent of their electrical properties. Figure 2 presents an artist's rendition of the MSC™ arrangement.

Figure 2. MSC™ Arrangement (Artist's Rendition)



The MSC™ design offers a compact arrangement. Each of the multiple stages utilizes an upstream stage consisting of a conventional electrostatic precipitator, followed by a downstream zone of parallel surfaces creating uniform electric field, followed by yet another stage, which incorporates conductive barrier-filter surfaces, again with a uniform electric field. By providing continuously repeated stages in series, the downstream zones effectively charge the particles that are either uncollected or re-entrained, and then collect those particles after they have been charged.

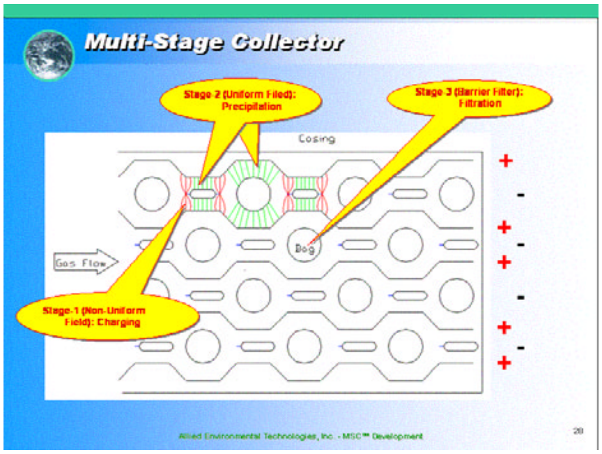
In the MSC™, particles are deposited onto the Barrier Filter Element (BFE) by two mechanisms, electrostatic and diffusional deposition, that take place in parallel. Collection by diffusion occurs because of both fluid motion and the Brownian (random) motion of particles. Diffusional collection effects are most significant for particles less than 1 micron (µm) in diameter. Another collection mechanism, direct interception, occurs when a particle comes within one particle radius of an obstacle. The path that the particle takes can be a result of inertia, diffusion, or fluid motion.

On one hand, electrostatic deposition is effective for relatively large particles, but it is quite ineffective for the ultra-fine particles because their charging probability in the corona field is too low. However, the diffusional collection efficiency of particles on fibers is high for small particles but low for the larger ones. Therefore, the simultaneous diffusional-electrostatic collection is a useful technique for efficient filtration of ultra-fine particle sizes below 0.1 µm.

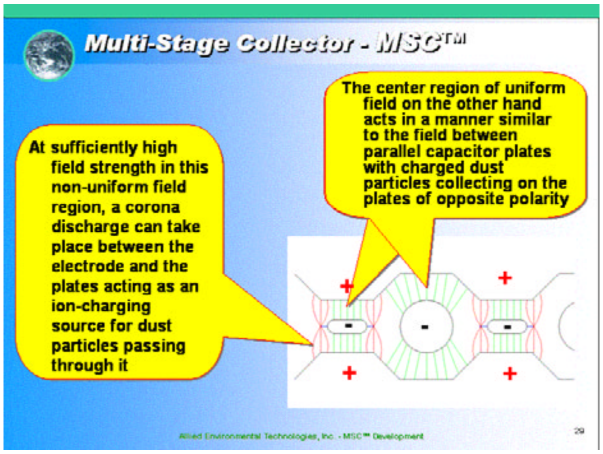
The MSC™ design (Figure 3a) consists of discharge electrodes (DE) placed between oppositely charged collection electrodes (CE). The discharge electrodes are followed by BFEs located in the wide zone placed between the collecting electrodes. Additionally, the surface of the BFEs can be made electrically conductive. The corrugated collecting plates are held at a first electrical potential while the discharge electrodes and the conductive surface of the BFE's are held at a second electrical potential. Both the flat sides of each of the discharge electrodes, corrugated plates and the surface of the BFEs form collecting surfaces where the electric field is relatively uniform.

Figure 3. MSC™ Operating Principals

(a) Overall MSC™ Arrangement



(b) Phenomena Occurring in a MSC™



The surfaces of the conductive BFEs are formed with electric field forming parts that may be suitably rounded and convex in the direction of the collecting electrode. The corrugated plate collecting electrodes are formed with narrow and wide sections to accommodate both the discharge electrodes and BFEs. By using an electrode with a cross-section that is relatively wide, a uniform electric field will form in the region of the center of the electrode, and a non-uniform field of high intensity can form at the sharp curvature of the leading and/or trailing edges.

At sufficiently high field strength in the non-uniform field region, a corona discharge can take place between the discharge electrode and the plates acting as an ion-charging source for dust particles passing through it (Figure 3b). The center region of uniform field on the other hand acts in a manner similar to the field between parallel capacitor plates with charged dust particles collecting on the plates.

The dust particles around the discharge electrodes (i.e., in the regions of the corona-generating points), which are charged to a negative polarity, are caught by the collecting electrode. Meanwhile, dust particles near the corrugated collecting plate electrode, which have been charged to a positive polarity by the positive ions resulting from reverse ionization, are collected by the uniform field-forming part of the discharge electrode and the conducting surfaces of the BFEs. Thus, the MSC™ collector can deal effectively with a bi-polar distribution of charged particles.

The spacing between the discharge points (corona sources) and collecting surfaces are wider in the charging, or corona generating zones, and narrower in the collecting zones where a uniform high voltage electric field is required. This feature allows for the use of a single high voltage power source for all zones). A high voltage electric field of an adjustable (variable) frequency and/or alternating polarity can also be applied to the device to further improve the collection efficiency of both positively- and negatively-charged particles onto the surfaces of the plates, thereby substantially increasing the effective collecting area. It should also be noted that all collection surfaces could be cleaned in a conventional manner such as by rapping or polarity reversal.

Another feature of the MSC™ is that the BFEs and the discharge electrodes (DEs) are grounded while the parallel-corrugated plates are suspended from the insulators. Consequently, by virtue of having the BFEs at the same potential as the DEs, the MSC™ design completely eliminates any potential sparks from the DEs toward the BFEs, thus eliminating any chance of causing fires and/or puncturing holes in the porous filter media. Hence, whether the MSC™ is powered by a "conventional" or an alternating power source, the BFEs remain protected from any sparks from the DEs irrespective of dust concentration.

PROOF OF CONCEPT PILOT TESTS

The overall technical objective of the Proof-of-Concept (POC) development phase is to experimentally demonstrate at a small pilot-scale the advantages of the MSC™ concept over conventional particulate collectors (i.e., ESPs, FFs, and other hybrid ESP/FF collectors). Specific questions to be answered during the POC pilot tests phase include:

i. Does the MSC™ device exhibit higher overall collection efficiency than other hybrid collectors (i.e., collection efficiency >99.9%)?

ii. Is the MSC™ collection efficiency independent of ash resistivity?

iii. Is the MSC™ collection efficiency of fine particles better than conventional technology?

iv. Can the overall size of the MSC™ device (i.e., high Air to Cloth ratio) be markedly smaller than conventional technology, for a given collection efficiency?

v. Can the MSC™ effectively collect a bipolar distribution of charged particles?

vi. Is the MSC™ device immune to back corona?

Figure 4. View into Bottom of the Pilot MSC™ Unit

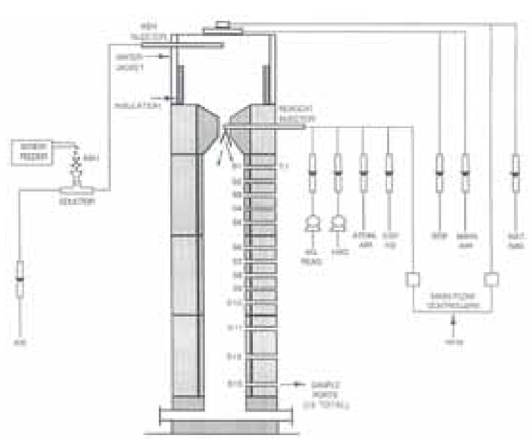
The Proof-of-Concept development phase is being done using a working prototype of the MSC™ that was designed to operate with face velocities (FV) in the range of 3.59 to 28.73 ft/min range. Pilot data for design of the equipment was based on computer simulations, engineering calculations, and previous conceptual analyses. Figure 4 presents a view of the Pilot MSC™ with the hopper removed. The Pilot MSC™ consists of two (2) rows of barrier filters (bags) with four (4) bags in each row for a total of eight (8) bags. The two rows of bags are placed between three (3) corrugated collecting plates. The Pilot MSC™ design data are presented in Table 1. At this scale, it is possible to satisfy most of the important dimensions such as electrode spacing, BFE diameter, and spacing along each row. The most important dimensions to simulate are the discharge point-to-plate parallel surface spacing in the narrow and wide zones, the discharge point-to-BFE spacing, and the BFE diameters, so these dimensions are similar to that of a full-scale unit. This approach simulates the geometric arrangement in a full-scale MSC™ and facilitates testing the effect of cleaning adjacent BFEs. Furthermore, testing at different FVs can easily be accomplished by either removing BFEs or by blocking an entire gas passage. Sight ports are installed at various locations to facilitate visual inspection and video monitoring of the BFEs, as well as the discharge and corrugated plate electrodes during normal filtration and cleaning cycles.

Table 1. Pilot MSC™ Design Data

			Simulated Performance Data	
			250,000 Btu/hr	
			English	Metric
Design Inlet Conditions	Temperature	Deg. F - C	300.0	148.9
	Flue Gas Moisture	%	8.50	8.50
	Flue Gas Flow, dry	cfm - Nm^3/s	33	0.016
	Flue Gas Flow, wet	cfm - Nm^3/s	36	0.017
	Flue Gas Flow, actual	acfm - m^3/s	61	0.029
	Gas Passages per Compartment	No.	2	2
Barrier Filter Data	Barrier Filter Diameter	inch - cm	4.00	10.16
	Barrier Filter Length	ft. - m	2.00	0.61
	No. of BF's per Gas Passage	**No.**	**4**	**4**
	Filtration Velocity (FV)	**ft/m - m/s**	**3.64**	**0.02**
ESP Zones Data	Electrical Gap in Charging Zone	in - mm	1.50	38
	Electrical Gap in Uniform Field Zone	in - mm	1.00	25.40
	Electrical Gap in Barrier Filter Zone	in - mm	1.00	25.40
	Effective Length of Collecting Electrodes	ft. - m	4.26	1.30
	Number of DE per Gas Passage	No.	4	4
	Effective Height	ft. - m	2.00	0.61
Design Details	Effective Electrode Collecting Area in ESP Zones per Compartment	sq. ft. - m2	39.40	3.66
	Total Collecting Area per Compartment	sq. ft. - m^2	56.16	5.22
	Total Collecting Area	sq. ft. - m^2	56.16	5
	Effective SCA	sq. ft./k acfm - $m^2/m^3/s$	920.95	181.27
	Effective Face Velocity in Charging Zone	ft./s - m/s	1.02	0.31
	Effective Face Velocity in Barrier Zone	ft./s - m/s	1.52	0.46

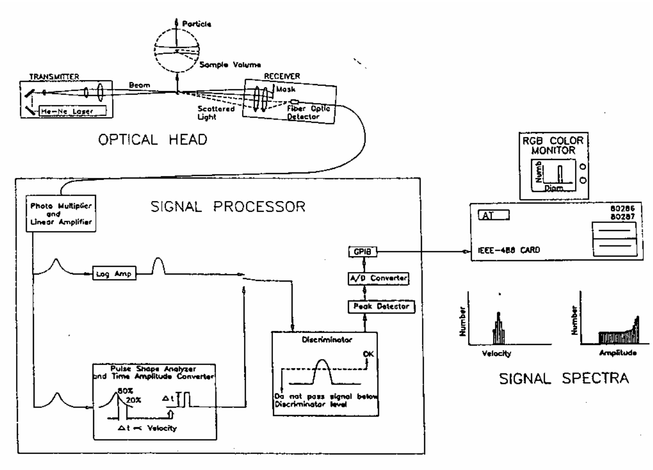
Flue gas from a natural gas fired combustor is used to supply ash-laden flue gas to the MSC™ pilot unit. This facility has been used for a wide variety of studies ranging from fundamental studies of the measurement of N_2O in combustion systems and SNCR chemistry, to the characterization of dry SO_2 removal processes. A schematic of the overall pilot-scale facility used for these tests is shown in Figure 5.

Figure 5. Pilot-Scale Apparatus: Combustor, MSC™, and Ancillary Equipment



The pilot-scale combustor fires natural gas into a water-cooled combustion section. The gas temperature leaving the burner section is controlled by the firing rate and water-cooled inserts. The air and natural gas flow to the burner and combustion section are controlled with valves and monitored with rotameters. Fly ash from selected utility boilers is pneumatically injected into the natural gas combustion products at the venturi throat section, downstream of the combustion section (Figure 5). The ash is metered with a gravimetric feeder and injected through a water cooled probe For the results reported in this paper a high resistivity PRB coal ash was used.

Figure 6. Schematic of the PCSV Instrument

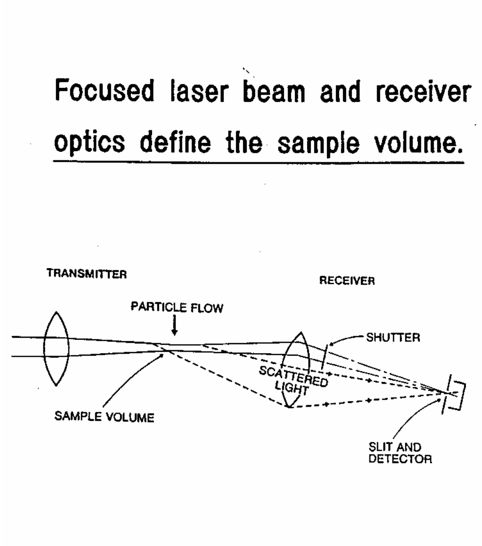


The particulate loading and size distribution entering and leaving the Pilot MSC™ unit were measured using a Process Metrics laser-based PCSV analyzer[7]. Figure 6 shows a schematic of the PCSV setup. The PCSV principle of operation is based on measuring the light scattered by single particles moving through the sample volume of a focused laser beam. The laser beam is brought to a focus midway between the transmitter and receiver tubes of the optics. The particle-sensing region or sample volume is defined by the dimensions of the laser beam at the focus point and by the receiver aperture. Figure 7 shows a schematic (not to scale) of the sample volume region. Particles may pass anywhere along the length of the laser beam. However, only those particles passing through the sample volume scatter light that is collected by the receiver. The PCSV technique is based on classical, near-forward light scattering techniques, which have been shown to be minimally sensitive to particle shape and refractive index.

As particles pass through the sample volume, light scattered in the near forward direction is collected by the receiver lens and focused onto a fiber optic cable. The fiber optic cable conducts the scattered light pulses from the optics to the detector in the signal processor where the pulses are analyzed.

For each scattered light pulse, the signal processor measures the peak signal intensity (related to particle size), and the signal width (related to particle speed). Since the laser light intensity varies across the measurement volume, a particle trajectory through the center of the measurement volume results in a much higher signal intensity than does a particle trajectory near the boundary. Therefore, the amplitude of the scattered light signal depends not only on the particle size, but also on its trajectory. Once a large number of scattered light signals are collected, the software uses an intensity deconvolution algorithm to determine the absolute particle concentration, particle size distribution, and average particle speed. The intensity deconvolution algorithm is based on the statistical analysis of a large number of individual events, which in this case are the individual scattered light signals from single particles passing through the measurement volume. This analysis has the advantage that no assumptions are required about the shape of the size distribution. This size distribution is obtained directly from the experimental data.

Figure 7. Schematic of PCSV Sample Volume



In order to cover the wide dynamic range in concentration and size, logarithmic scales are used. Two laser beams are used to span the entire size range. One beam measures the smaller particle sizes, from about 0.3 to 2-3 µm. A second beam measures the larger particle sizes, from about 3 to 100-200 µm. The exact particle size ranges depend on the laser beam focus dimensions and the particle concentration. At higher particle concentrations where the two sizes ranges do not overlap, an interpolation is made between the two size ranges. The total distribution is the combination of two independent measurements using the two laser beam diameters, which differ by a factor of 10. The congruence of these two independent measurements is a significant consistency check for the PCSV.

Demonstration MSC™ Start-Up and Shake-Down Tests

The pilot MSC™ device has been setup as shown in Figure 5. Prior to running the ash-loading tests with the natural gas combustion products, a series of tests were run to characterize the voltage-current (V-I) response of the pilot-scale unit. Two independent high-voltage power supplies with the ability to provide both positive and negative voltage were utilized to charge the corrugated plates. The goals of these shakedown tests were two-fold. The first was to evaluate the electrical clearances in the pilot-scale unit and to identify any plate/electrode/BFE alignment issues that would result in premature sparking. Once any alignment issues were identified and corrected, the V-I response of the unit was fully characterized.

Figure 8. Demonstration MSC™ Electrical Clearances Evaluation

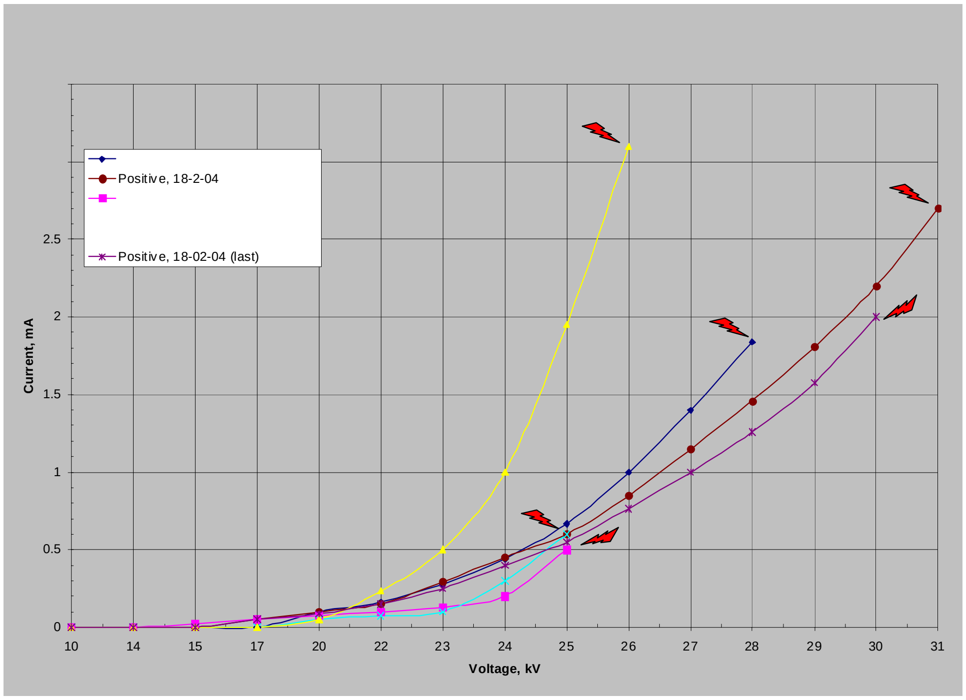


Figure 8 presents the results of the initial V-I characterization of the pilot MSC™. The initial tests were run in the positive corona mode, and the maximum voltage attainable prior to the onset of sparking was 28 kV. These initial tests were run with the hopper, inlet, and all inspection panels removed so that the areas of sparking could be identified and subsequently addressed. Figure 9 illustrates the sparking phenomena occurring between a discharge electrode and a plate.

Figure 9. Sparkling at the Top of the Electrode System

Following optimization of the electrical clearances, the maximum achievable voltage increased to 30 to 31 kV as shown by the positive corona results. Subsequent to optimizing the pilot unit in the positive corona mode, a series of tests were also run where a negative voltage was applied to the plates. As shown in Figure 8, sparking occurred at lower voltages in the negative corona mode.

Overall, the shake-down tests indicated the V-I performance of the pilot MSC™ to be better in the positive, rather than negative, corona mode.

Initial MSC™ Collection Efficiency and Pressure Drop Tests

A short series of tests were run to compare the particulate collection efficiency and pressure drop characteristics of the MSC™ concept to that of a conventional pulsejet fabric filter. These tests were run by operating the pilot MSC™ with the electric field energized (MSC™ mode), and un-energized (pulsejet mode). For both sets of tests, the pilot MSC™ was supplied with ambient air at an air-to-cloth ratio of approximately 8.0 (total of six bags in operation). Fly ash obtained from a Powder River Basin (PRB) coal-fired boiler was injected into the air stream ahead of the pilot MSC™ at a loading rate typical of that for a full-scale PRB-fired utility boiler (nominally 2 gr/scf).

Figure 10. Photographs Through the Observation Window Below the Electrodes and Bags

(a) MSC™ Field Off **(b) MSC™ Field Energized (27 kV/0.5 mA)**

Before presenting quantitative results, the difference in the "MSC™" mode and "pulse jet" mode is illustrated in Figure 10. This figure shows photographs taken through the observation window in the hopper region for both modes of operation. As can be seen in the photograph on the left, Figure 10a Pulse Jet Mode, a cloud of particulate can be seen throughout the hopper region. When the field is energized, Figure 10b - MSC™ mode, the area immediately clears up. Presumably, the improvement was due to the fact that a large fraction of the particulate mass was collected electrostaticly on the plates, rather than on the fabric filter elements. This phenomenon was verified via visual observations made through the view ports installed on the rear wall of the pilot-scale unit (i.e. the wall opposite the dirty-gas inlet). In the pulsejet mode, large quantities of suspended ash particles were clearly visible in the passages between the fabric filter elements, as well as in the hopper area below. Energizing the electric field immediately resulted in a significant reduction in the visible amount of suspended fly ash particles in these areas.

The improved performance can also be seen in the pressure drop characteristics and cleaning intervals. This is shown in Figure 11 where the pressure drop versus time is shown for a period of 16 hours. During this period, a cleaning cycle was initiated when the pressure drop reached 8 inches H_2O. For the first hour, the unit was run in the pulse jet mode and as can be seen, a cleaning cycle was initiated about every 10 minutes. When the electric field was energized and the unit operated in the hybrid MSC™ mode, a cleaning cycle was only initiated about every one and one half hours.

The next series of tests characterized the collection efficiency of the two operating modes. In each operating mode (MSC™ and pulsejet), the fabric filter bags were first cleaned down to a pressure drop level of 0.5 to 0.7 inches H_2O. Fly ash injection was then initiated, and the PCSV instrument utilized to monitor the outlet mass loadings and size distribution until the pressure drop reached a level of 8.0 inches H_2O.

Figure 11. Pressure Drop Characteristics; Pulse Jet and MSC Mode

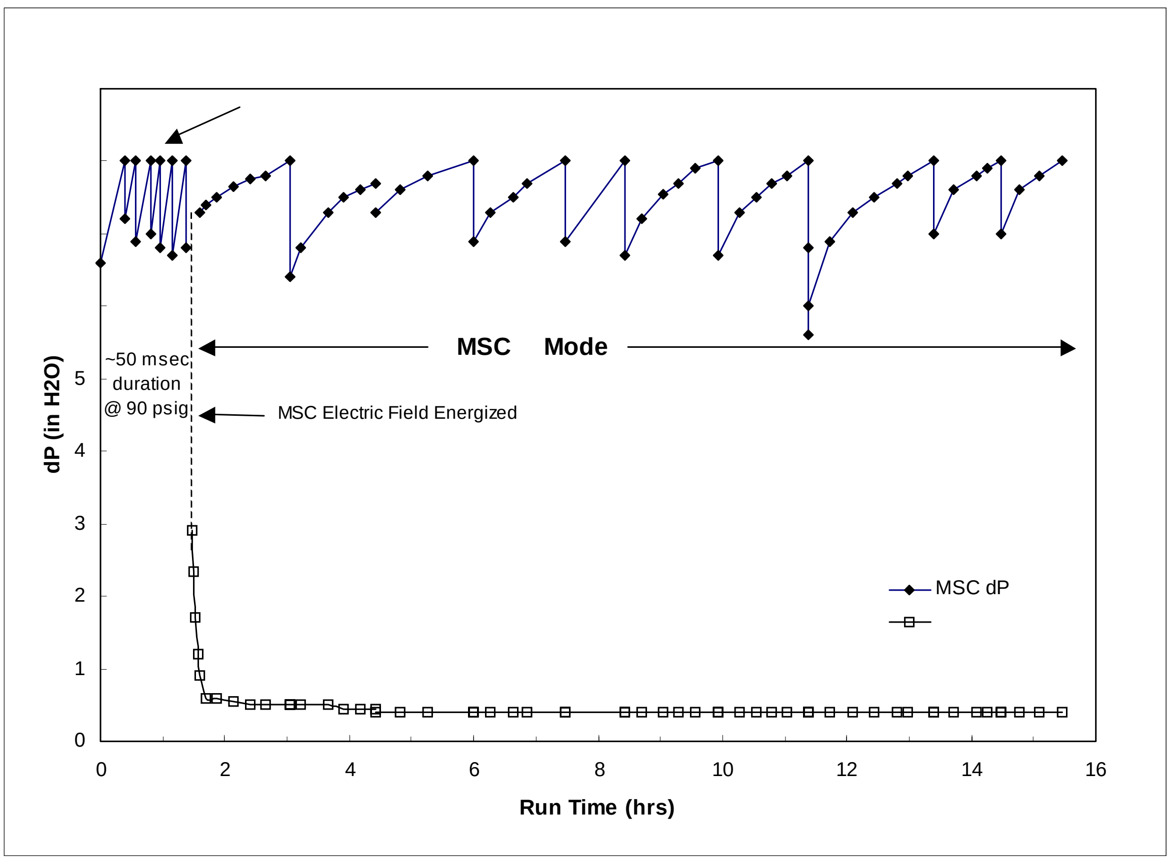


Figure 12 shows the pressure drop results for both sets of tests. With the electric field off, the pressure drop increased at a rapid rate, reaching 8.0 inches H_2O in less than one hour. In contrast, with the electric field energized (MSC™ mode), the pressure drop increased at a much slower rate requiring approximately 4.5 hours to reach 8.0 inches H_2O.

For each of the time periods shown in Figure 12, the PCSV was used to measure the collection efficiency. These results are shown in Figure 13. With the electrical field off, the particle collection efficiency improved from 99.71 to 99.81% as the pressure drop increased, but then the efficiency began to decline as the differential pressure approached 8 inches H_2O. With the electrical field energized (MSC™ mode), the particle collection efficiency was markedly higher than those for pulsejet operation, 99.99%. Further, the collection efficiency was essentially constant over the entire range of pressure drop up to 8.0 inches H_2O.

Figure 12. Rate of Pressure Drop Increase from Clean Condition (Pulse Jet and MSC™ Mode)

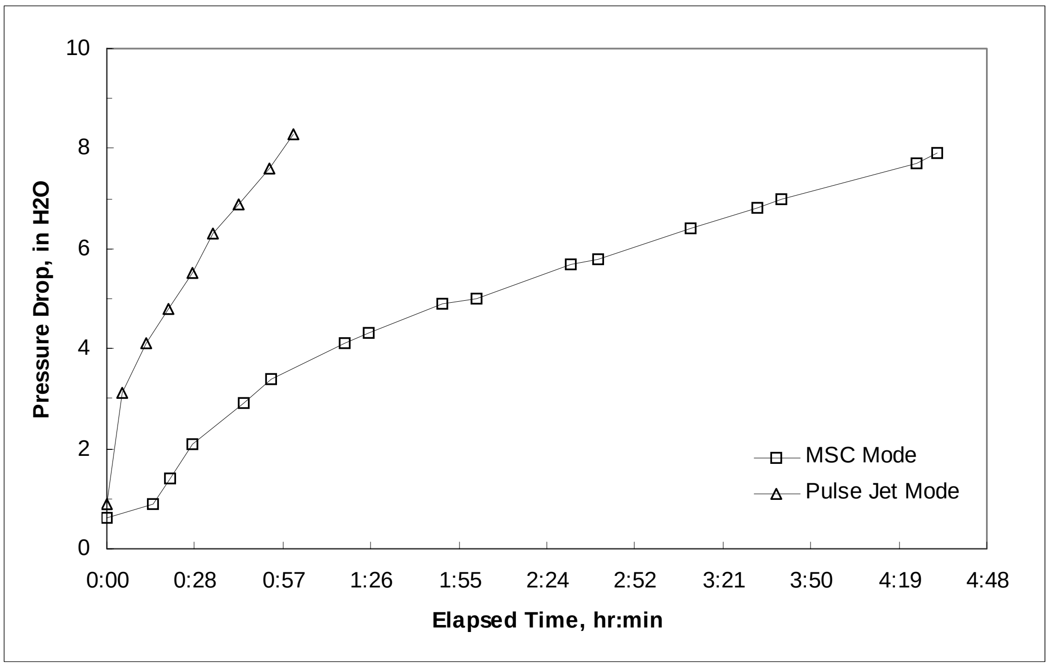


Figure 14 shows the particle size distributions measured with the PCSV instrument. The inlet showed a mass mean diameter of about 38 microns. In the pulse jet mode, the largest particle size that was measured was 17 microns. In the MSC™ mode the largest particle size was only 7 microns. The higher collection efficiency in the MSC™ mode is also apparent in Figure 14.

CONCLUSIONS

The MSC™ hybrid collector incorporates design features that overcome shortcomings of electrostatic precipitators and fabric filters as well as hybrid concepts under development. The MSC™ provides for a small footprint (high filtration velocity), collection efficiency that is independent of electrical characteristics of the ash, and is able to deal with a bipolar distribution of charged particles.

The pilot scale tests have shown a collection efficiency of 99.99% with a high resistivity PRB ash (compared to 99.8% when operated in a pulse jet mode. The rate of pressure drop increase was also much slower in the MSC™ mode 0.5 inches H_2O to 8 inches H_2O in 4.5 hours compared to one hour in the pulse jet mode.

Figure 13. Collection Efficiency Characteristics: Pulse Jet and MSC™ Mode (PRB Fly Ash)

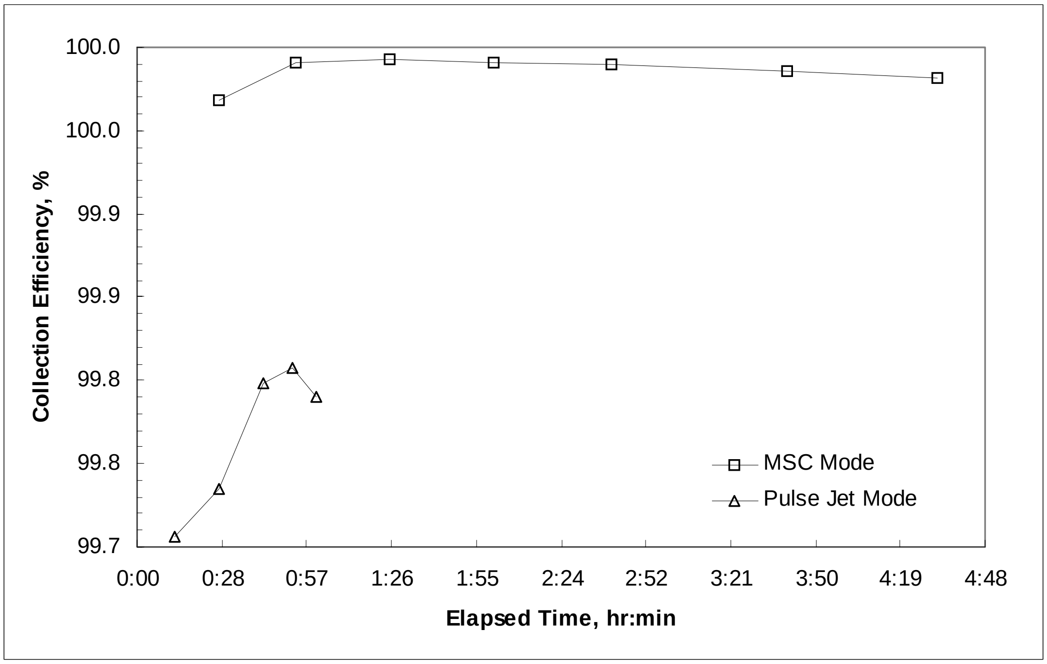
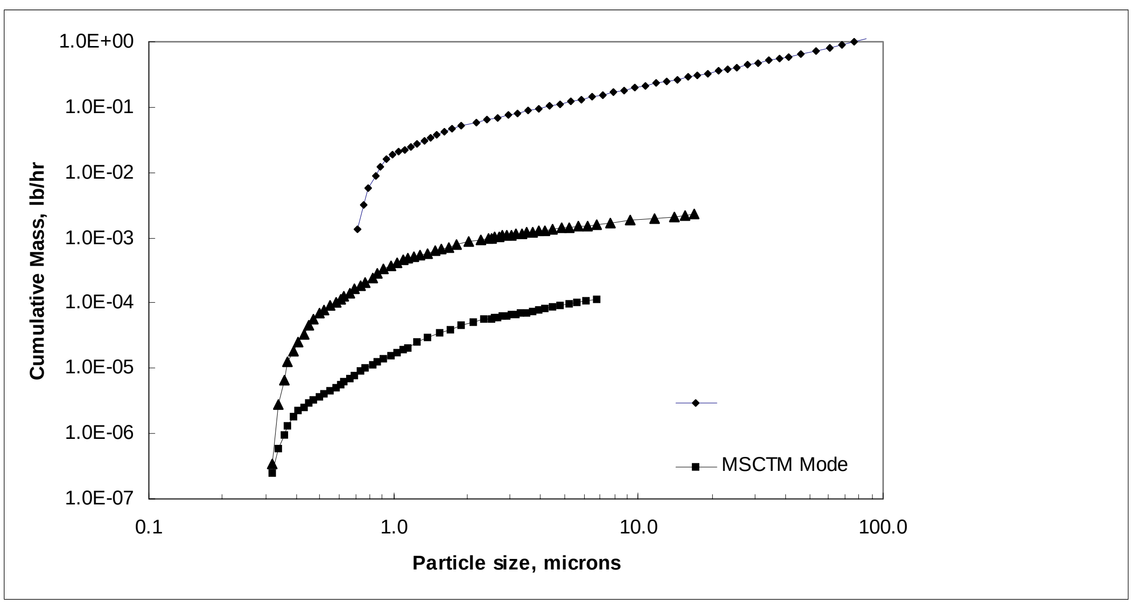


Figure 14. Particle Size Measurements: Inlet and Outlet



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