Multi-Stage Collector (MSC™) Development

Henry V. Krigmont, QEP

Allied Environmental Technologies, Inc. 15182 Bolsa Chica Road, Suite D. Huntington Beach, CA 92649 USA

ABSTRACT

The Multi Stage Collector (MSC™) concept for ultra-fine particulate control offers significant improvements over current state-of-the-art technology. The new MSC™ design provides a synergistic combination of both single- and two-stage electrostatic precipitation while incorporating an additional collector-stage by filtering the gas exiting the collector through a barrier collector-zone. This arrangement ensures that essentially all dust would be detained in this final stage.

The MSC™ contains multiple narrow and wide zones formed by parallel corrugated plates. Enclosed in the narrow zones are discharge electrodes. These electrodes provide a non-uniform electric field leading to corona discharge. The corona discharge causes particulate matter in the gas flow to become charged. Wide regions contain barrier filters thus creating the two-stage precipitator with relatively uniform electric field. In these regions, particles are collected on both plates and on the porous barrier elements, which also act as the final filtering stage.

Results of the applications analyses and future development work are discussed. The gas flow analyses with an aid of the CFD model are presented below.

INTRODUCTION

The MSC™[1] offers a new method and design for collecting dust, fume, etc. for industrial gases, that is independent of electrical resistivity, thus it is especially beneficial when electrical resistivity of such dust or fume as precipitated, exceeds 10^{11} Ohm-cm or is extremely low, for example less than 10^4 Ohm-cm.

It is well known in the art how to build and use electrostatic precipitators. It is also known in the art how to build and use a barrier filter such as a baghouse. Further, it is known in the art how to charge particles and that charged particles may be collected in a barrier filter with lower pressure drop and emissions than uncharged particles collected for the same filtration velocity.

The MSC™ design will be most advantages when the material to be collected consists mostly of a sub-micron dust and/or fume. It also could be easily integrated with various catalysts or augmenting the corona discharge with high frequency alternating field as well as applications of the variety of dielectrically hindered (barrier) discharge for gaseous emissions collection.

BACKGROUND

Evolution of Electrostatic Precipitation

A typical electrostatic precipitator incorporates two zones:

- The charging zone, where the dust or aerosol particles are being charged, and
- The collecting zone, where the charged particles are being 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 precipitator design concepts: (i) a conventional electrostatic precipitator where both zones are combined in a single-stage, and (ii) so called two-stage design where these zones are separated.

The electrostatic precipitation process, in a case of high-resistance dusts, results in the reverse ionization (back corona) at the side of the collecting electrode at which the dust accumulates. As a result, positively charged dust particles may be released or formed by such reverse ionization and naturally (in a case when the discharge electrodes are negatively charged) such positively charged particles are repelled from the positively charged dust-collecting surfaces. As the gas stream passes between the "conventional" dust-collecting electrodes, particles, which pick up a positive charge by reverse ionization proximal to a collecting electrode, tend to move toward the next discharge electrode where they may pick up a negative charge and then move toward the collecting electrode where they may again pick up a positive charge, and so on.

Figure 1. Performance of the Laboratory Two-Stage Precipitator

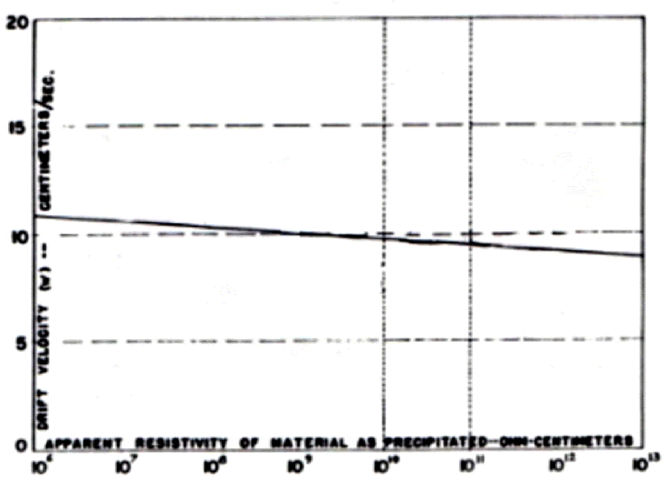
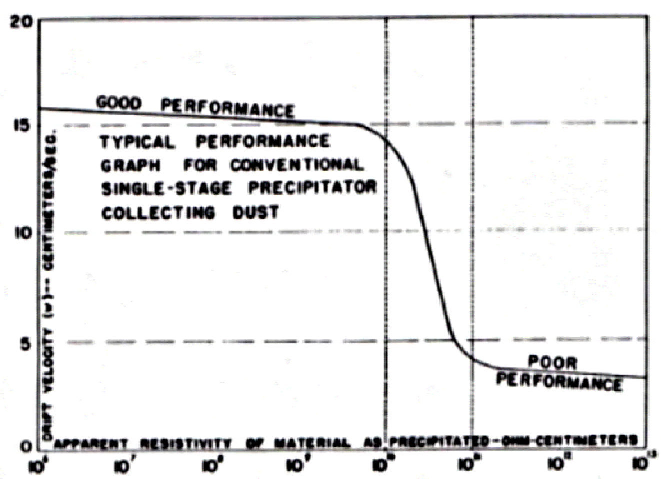


Figure 2. "Conventional" Precipitator Migration Velocity Relationship

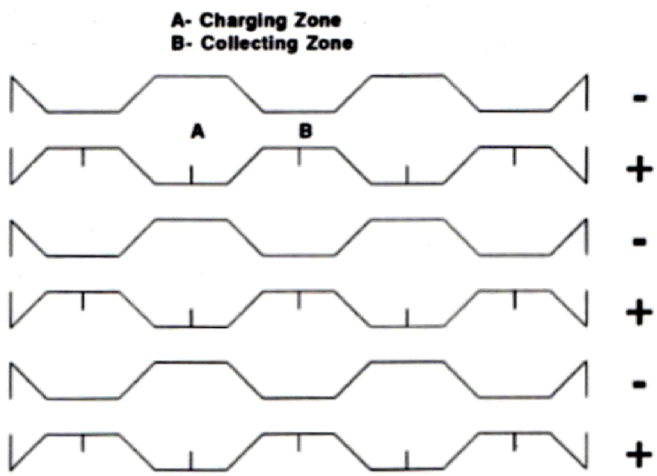


In a case of the low-resistivity dust, somewhat similar process takes place, however due to the entirely different phenomena. Low resistivity dusts are known for a quick discharging, thus, they would be repelled back to the gas stream nearly instantly upon contacting the collecting plates irrespective of their polarity. Viewed as a statistical phenomenon, therefore, 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 obviously reduced and hence the performance of a dust-collecting or dust-arresting assembly will be substantially lower for high- or low-resistance dusts than with normal resistance dusts.

Sproull[2] investigated a special two-stage electrostatic precipitator for high resistivity dusts collection application. The performance of this laboratory precipitator is illustrated in Figure 1. The paper compares performance of this special two-stage precipitator with a "conventional" single-stage design (Figure 2). If the resistivity of the material as precipitated is below 10^{10} ohm-cm, or if it can be reduced below this value easily, then a single-stage precipitator offers certain advantages (within certain particle size range). However, if the resistivity of the material as precipitated is between 10^{11} and 10^{12} ohm-cm most of the time, then the two-stage design offers certain advantages based on the reported laboratory data.

Figure 3. Two-Stage Electrostatic Precipitator



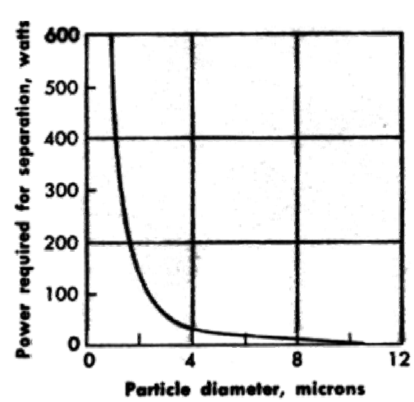
Krigmont[3] described an electrostatic precipitator, which utilizes the unique electrode design that provides for separate zones for aerosol particles charging and collection in a compact combined design (Figure 3). According to this design, the dust collecting assembly comprises of a system of bi-polar charged surfaces, which are constructed in such a way that they provide alternate separate zones for high-tension non-uniform and uniform electrostatic fields. The surfaces of the electrodes are of the design, which allows combining the charging, and collecting zones with non-uniform and uniform high-tension electric fields respectively in one common compact dust arresting assembly.

The spacing between the surfaces in the charging and collecting zones is different, wider in the charging or corona generating zones and narrow in the collecting ones where a uniform high-tension electric field is being required. A high voltage electric field of an adjustable (variable) frequency and/or alternating polarity could be applied to the dust arresting assembly to further improve collecting efficiency of bi-polar charged aerosol onto the surfaces of both plates, thus substantially increasing the effective collecting area.

Fine Particulate Collection in Electrostatic Precipitators

The energy requirements for operation of an ESP consist mainly of electricity demand for fan operation, electric field generation, and cleaning. It is evident that separation energies are larger for a given mass of fine particles because of their much greater dispersion. This is illustrated in the Figure 4[11], which gives the calculated power in watts expended to separate charged particles of various sizes from air stream of 100,000 cfm at a particle loading of 1 gr/ft^3. A power of about 500 W is needed to remove one-micron particles and only 5 W for the 10-micron ones. To summarize, ESP's power consumption ranges from 25 to 100 W/kacfm, with 40 W/kacfm being typical for the two-stage precipitators.

Figure 4. ESP Power Requirements



Barrier Filtration

Electric power utility as well as industrial user-companies are looking for ways to upgrade their pollution control equipment. One approach would be to replace the existing under-performing precipitator with a **B**arrier **F**ilter (BF) of conventional design (baghouse), which is generally accepted as an alternative to precipitators for collecting fly ash from flue gas. Conventional designs can be categorized as low-ratio baghouses (for example, reverse-gas and shake-deflate) and a relatively high ratio ones, so called pulsejet baghouses. BF's are generally operate at **F**iltration **V**elocities (FV) of 0.76 to 1.27 centimeters per second (1.5 to 2.5 ft/min), also defined as air-to-cloth ratio or volumetric flow rate of flue gas per unit of effective filter area (cubic feet of flue gas flow/min/square foot of filtering area). The pulsejet baghouses, on the other hand, generally operate at 1.52 to 3.05 centimeters per second (3 to 6 ft/min).

Baghouses generally have very high collection efficiencies (greater than 99.9%) independent of fly ash properties. However, because of their low filtration velocities, they are large, require significant space, are costly to build, and unattractive as replacements for existing precipitators. Reducing their size by increasing the filtration velocity across the filter bags usually results in unacceptably high pressure loss and outlet particulate emissions. There is also potential for "blinding" the filter bags - a condition where particles are embedded deep within the filter and reduce flow drastically.

A typical pulsejet baghouse includes a number of individual bags or filtration tubes about four to six inches in diameter, eight to twenty feet long, and are mounted within and suspended from a tube sheet[(4)]. The particulate dust is collected on the outside surfaces of the bags while the flue gas passes through the porous media to the inside, where it exits through the top of the bags into a clean air plenum and subsequently out the stack. Cages are installed inside the bags to prevent them from collapsing during the normal filtration process.

Because of the small bag spacing and forward filtration through the two rows of bags adjacent to the row being cleaned, much of the dust that is removed from one row of bags is simply recollected on the adjacent rows of bags. Thus, only the very large agglomerates of dust reach the hopper after supplying the burst of air through the bags. This phenomenon of re-dispersion and collection of dust after bag cleaning is a major obstacle to operating 'conventional' baghouses at higher filtration velocities.

Hybrid Particulate Collection Technologies

Efforts to increase barrier filters efficiency without a corresponding increase in pressure loss have led to the development of electrostatically enhanced fabric filters and so-called hybrid devices. Chen[(5)], described a method for removing particulates from a gas stream by incorporating an electrostatic precipitator and a barrier filter arranged in series with the baghouse being downstream of the precipitator. Subsequently[(6)], the baghouse was located internally in an electrostatic precipitator. An alternative design was also described with the electrostatic precipitator and a baghouse sharing a common housing with a precharger situated downstream of the precipitator ahead of a baghouse.

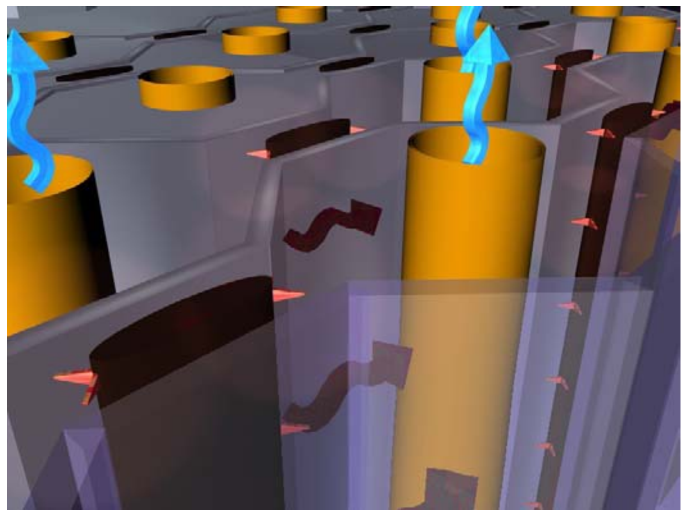
Miller[(7)] described an advanced hybrid particulate collector consisting of a chamber housing both baghouse filter elements and a section of an electrostatic precipitator situated between the rows of the filter elements. In this design, when the filter elements are being cleaned by pulsing air in a reverse direction, the dust dislodged from the bags is intended to be recaptured in the electrostatic precipitator section.

MULTI-STAGE COLLECTOR (MSC™)

MSC™ Concept

MSC™ is a new concept for particulate control. The intent of the MSC™ is to combine the best features of the two-stage ESP and a **B**arrier **F**ilter (BF). The MSC™ concept can be broadly summarized as a system in which multiple stages are utilized, with each stage performing a primary function and the multiple stages operating synergistically to provide significantly improved overall results. Figure 5 presents artist's rendition of the MSC™ conceptual arrangement.

Figure 5. MSC™ Conceptual Arrangement



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 particles charging and collecting, but, by providing new, unique collector design with improved efficiency to collect fine dust particles independent of their electrical properties.

The MSC™ offers a uniquely compact concept utilizing an upstream stage comprised of a conventional electrostatic precipitator, followed by a downstream zone of the parallel surfaces creating uniform electric field, followed by yet another stage, which incorporates barrier filter conductive surfaces of which provide a uniform electric field. Moreover, by providing continuously repeated stages in series, the downstream zones effectively charge and collect the particles that are either uncollected or reentrained and collect those particles after they have been charged.

Electrostatic Precipitation of Charged Particles on Porous Media Surface

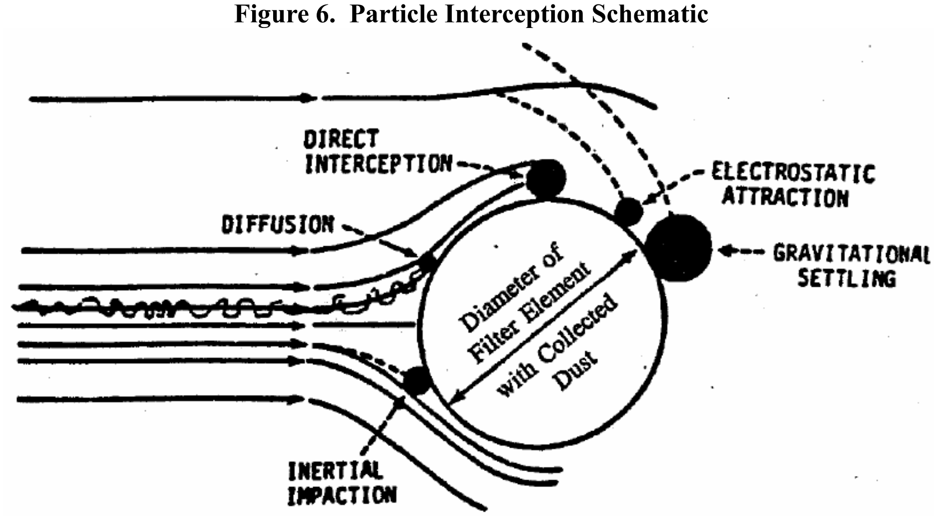
In the MSC™, particles are deposited onto the **B**arrier **F**ilter **E**lement (BFE) by two mechanisms: electrostatic and diffusional deposition that act simultaneously. Inertial impaction occurs as a result of a change in velocity between a fluid, such as air, and a particle suspended in the fluid. As the fluid approaches an obstacle it will accelerate and change direction to pass around the object. Depending on the mass of the particle, it may not be able to adapt to the fluid acceleration and a difference in velocity will develop between the particle and fluid stream. Inertia will maintain the forward motion of the particle towards the object, but the fluid will attempt to drag the particle around the obstacle. The resultant particle motion is a combination of these forces of fluid drag and inertia. This results in impaction for the particles where inertia dominates, and bypass for those particles overwhelmed by fluid drag[8].

Collection by diffusion occurs as a result of both fluid motion and the Brownian (random) motion of particles. Diffusional collection effects are most significant for particles less than 1 micrometer (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 ones because their charging probability in the corona field is too low. On the other hand, the diffusional collection efficiency of particles on fibers is high for small particles but low for the larger ones (Figure 6). Therefore, the simultaneous diffusional- electrostatic collection is a useful technique for efficient filtration of particles below 0.1µm.

Alonso[9] reported superior performance of an electrostatic precipitator in which the collector electrode has been substituted by series of wire screens transposed to the gas flow. The particles deposition by diffusion was highly efficient for particle diameters in the range of a few nanometers. The larger particles were collected by conventional electrostatic deposition. The combination of both mechanisms led to high particle collection for the whole particle size range below 0.1µm.

Figure 6. Particle Interception Schematic



Mermelstein[10] conducted a study to investigate the effect of using stainless steel fibrous and porous filters as the ground electrode of a point-to-plate electrostatic precipitator on particle penetration. The effect of filter medium structure and pore size on particle removal has been investigated as a function of particle size, for particles in the range of 0.03-1µm and FV in the range of 15-75 cm/s (29-147 ft/m). The application of the electrical field decreased particle penetration by a factor of 6 to 54. The experiments confirmed that sub-micron particles were captured in the first few layers of the filters by the action of electrostatic forces.

MSC™ Design

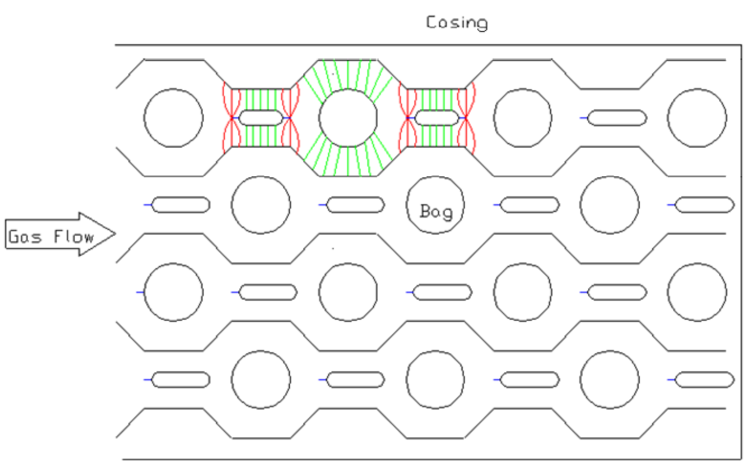
The MSC™ assembly is made up from discharges electrodes placed between oppositely charged electrodes. The discharge electrodes are followed by **B**arrier **F**ilter **E**lements (BFE) located in the wide zone placed between the collecting electrodes, the surface of the BFE can be made conductive. The corrugated 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 surfaces of the BFE form collecting surfaces where the electric field is relatively uniform.

The surfaces of the conductive BFE's are formed with electric field forming parts that may be suitably rounded and convex in the direction of the collecting electrode (Figure 7). The corrugated plate collecting electrodes are formed with narrow and wide sections to accommodate both the discharge electrodes and BFE's. By using an electrode with a cross-section that is relatively wide, a uniform electric field can form in the region of the center of the electrode, and a non-uniform field of high intensity can form at the sharp leading and/or trailing edge.

At sufficiently high field strength in this non-uniform field region, a corona discharge can take place between the electrode and the plates acting as an ion-charging source for dust particles passing through it. 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 were charged to 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 conveniently collected by the uniform field-forming part of the discharge electrode and the conducting surfaces of the BFE's.

Figure 7. High Tension Electric Fields in the MSC™



The spacing between the discharge points (corona sources) and collecting surfaces are different, wider in the charging or corona generating zones and narrow in the collecting ones where a uniform high voltage electric field is required. This feature allows for the use of a single high voltage power source for all electrostatic fields (in all zones). A high voltage electric field of an adjustable (variable) frequency and/or alternating polarity could also be applied to the dust arresting assembly to further improve collecting efficiency of bipolar charged aerosol onto the surfaces of both plates, thus, substantially increasing the effective collecting area. It should be noted that all collection surfaces can be cleaned in a conventional manner such as by rapping, polarity reversal, or by other means.

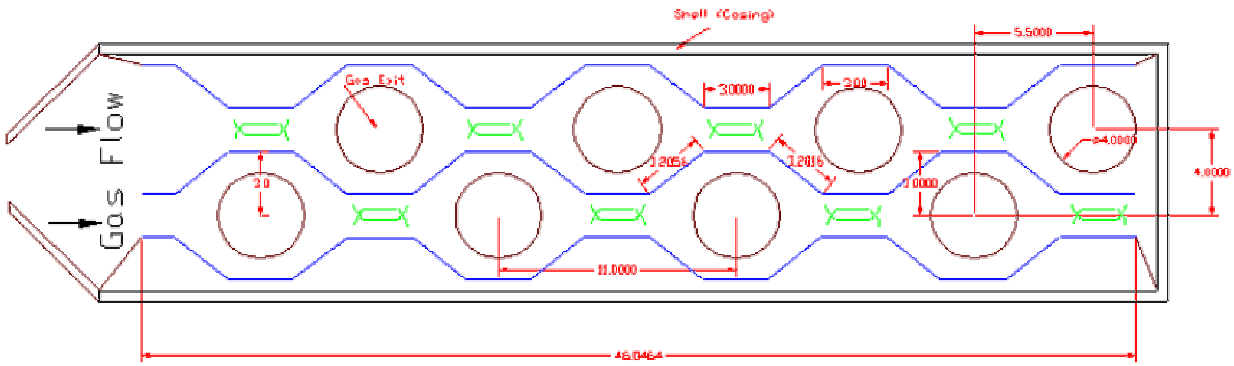
Furthermore, another unique feature is that the MSC™ is engineered in such a way that the BFE and the DE are grounded while the parallel corrugated electrodes are suspended from the insulators. By virtue of having the BFE's at the same potential as the DE's, the MSC™ design completely eliminates any potential sparks from the DE toward the BFE, thus eradicating any chances of causing fires and/or puncturing holes in the porous barrier media. Hence, whether the MSC™ is powered by a "conventional" or an alternating power source, the BFE's remain protected from any sparks from the DE irrespective of dust concentrations

DEMONSTRATION MSC™

A working prototype of the MSC™ (**D**emonstration **MSC**, or **DMSC**) was designed to operate with the **F**ace **V**elocity (FV) in the 3.59 – 28.73 ft/min (0.02-0.15 m/s). DMSC was designed to elicit sufficient data for scale-up of the MSC™ concept. Design of the equipment was based on computer simulations, engineering calculations, and previous conceptual analyses. Figure 8 presents a preliminary MSC™ pilot design. The pilot MSC™ consists of two (2) rows of barrier filters (bags) four (4) bags each for a total of 8 bags and three (3) collecting corrugated plates.

Its design data are presented in the Table 1. At this scale, it will be possible to satisfy most of the important dimensions such as electrode spacing, **B**arrier **F**ilter **E**lement (BFE) diameter and spacing in a row. The most important dimensions to simulate are the discharge point-to-plate, parallel surfaces spacing in the narrow and wide zones and discharge point-to-BFE spacing, as well as the BFE diameter so these dimensions are similar to that of a full-scale unit. This approach simulates the geometric arrangement in a full-scale MSC and would facilitate testing the effect of cleaning adjacent BFE's. Furthermore, testing at different **F**ace **V**elocities (FV) could easily be accomplished by either removing BFE's or by blocking a gas passage. Sight ports will be installed at strategic locations to facilitate visual inspection and video monitoring of the BFE's, discharge and corrugated plate electrodes during normal filtration and cleaning cycles. The DMSC vessel will be heat-traced and insulated for precise temperature control.

Figure 8. Demonstration MSC™



Experimental Work (Test Plan)

Cold-Flow Shakedown Testing

The primary purpose of the cold-flow testing with air is to verify and properly adjust the pulse-cleaning parameters and flow to achieve the best interaction between the electrostatic and barrier filtration zones. Reentrained dust will be injected into the carrier air upstream of the DMSC, operating at a pre-selected FV, until the BFE reach a desired pressure drop. The dust feed will then be stopped until the compartments clear of suspended dust to enhance visual observation of the cleaning phenomenon. Tests will be conducted with the electric field on and off and with different polarities and frequencies to document the benefit of the electric field for BFE cleaning. Independent variables to be adjusted during this cold-flow testing will include pulse pressure, pulse volume or duration, applied voltage and its polarity, and dust type. The primary dependent variables will be pressure drop before and after cleaning and a visual subjective evaluation of the cleaning dynamics. Only limited outlet particulate emission measurements will be conducted to verify that collection efficiency is a minimum of 99.99%. The expected duration for each test condition will be approximately 1 hour. Approximately 6 to 8 test conditions will be evaluated each day and approximately 10 test days are planned.

Fundamental Principles Evaluation

This phase will consist of the fundamental principles evaluation. It will include corona and uniform electric fields study within the MSC™ geometry and comparing it with the "base-line" literature data. Some additional experimental work might be scheduled on as needed basis.

Flue Gas Testing

For this task the combustor will be fired on gas with coal-ash for DMSC testing. The main variables will be FV ratio, electrical field strength, and polarity. The eventual commercial success of the MSC™ will depend upon the FV ratio, since that is the main factor determining the size and cost of a full-scale MSC™. All tests will be conducted at DMSC operating at typical flue gas parameters. Each test will include inlet and outlet EPA Method 5 dust-loading measurements and continuous outlet measurements with suitable in-situ CEM instrumentation.

Long-Term Testing

Subsequently, several long-term tests are planned to evaluate the long-term DMSC operation over multiple cleaning cycles. The main variables will include FV ratio and electrical parameters. Extensive inlet and outlet particulate measurements will be completed to thoroughly document the performance of the DMSC as a function of time. Ultimate and proximate analyses will be conducted on the coal for each run, and major elemental analysis will be completed on the fly ash. Two of the tests will each include several inlet and several outlet Method 29 trace element measurements to evaluate the collection efficiency of arsenic, cadmium, chromium, lead, mercury, nickel, and selenium. Trace element analysis for these seven elements will also be conducted on the coal for each of the tests Method 29 sampling is conducted.

Table 1. Pilot MSC™ Design Data

UNIT ID === >			Simulated Performance Data 250,000 Btu/hr	
			English	Metric
Standard Conditions	Temperature	Deg. F. - Deg. C	32	0
	Pressure	Hg - mm. H2O	29.92	760
Design Inlet Conditions	Temperature	Deg. F - C	300.0	148.9
	Flue Gas Moisture	%	8.50	8.50
	Site Elevation	ft - m	50	15
	Boiler Design Heat Input[1]	MBtu/hr - kCal/hr	0.25	63
	Coal Heat Value	Btu/lb	12,060	6,700
	Natural Gas Burn Rate[1]	lb/hr - kg/hr	15	9
	Flue Gas Flow, dry	scf/100 ft^3 of NG (based on comb.calcs)	13,027	
	Flue Gas Flow, dry	cfm - Nm^3/s	33	0.02
	Flue Gas Flow, wet	cfm - Nm^3/s	36	0.02
	Flue Gas Flow, actual	acfm - m^3/s	60	0.03
	Fly Ash	gr./scf - g/Nm^3, wet	0.00	0.00
	Concentration	gr./acf - g/m^3	0.00	0.00
General MSC Design Data	MSC's per Installation	No.	1	1
	Compartments per MSC	No.	1	1
	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**
	Barrier Filter Area	ft^2 - m^2	2.09	0.19
	No. of BF's per Gas Passage	**No.**	**4**	**4**
	Total Barrier Filter Area	ft^2 - m^2	16.76	1.56
	Filtration Velocity (FV)	ft/m - m/s	3.59	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
	Effective Length of Collecting Surface on DE	ft. - m	0.33	0.10
	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. - m2	56.16	5.22
	Total Collecting Area	sq. ft. - m2	56.16	5.22

COMPUTATIONAL FLUID DYNAMICS MODELING

In order to evaluate the MSC™ design, a detailed analysis of fluid dynamic flow was performed. **C**omputational **F**luid **D**ynamics (CFD) simulation was conducted for the pilot MSC™ consisting of four (4) rows of barrier filters (bags) four (4) bags each for a total of 16 bags and five (5) collecting corrugated plates. A 3-D view of the CFD model is depicted on Figure 9. The MSC™ operation was simulated for three (3) operating conditions with the gas flows of 0.24, 0.47, and 0.69 m^3/s at 149 ºC (500, 1,000, and 1,500 acfm at 300 ºF) for the filtration velocity in the range of 5 – 15 cm/s (10-30 ft/m). The operating pressure drop supplied by the bags was assumed about 6 inches of water. The simulation utilized body-fitted grid approach, which allows the use of non-orthogonal grids that can accurately represent geometry of the simulated object. The computational grid is presented on Figure 10.

Figure 9. CFD Model 3-D View

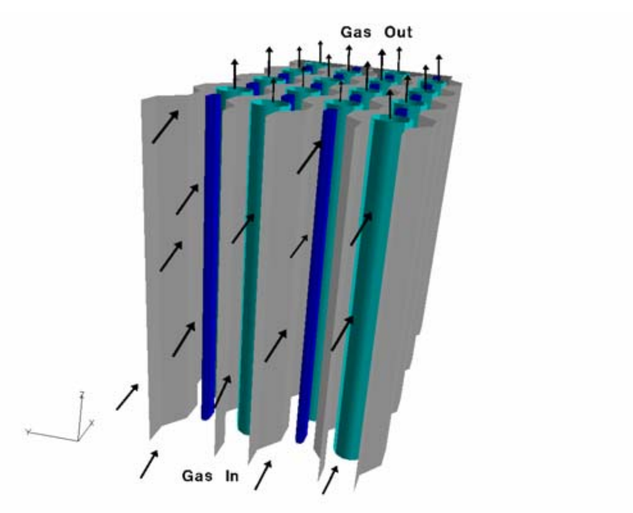
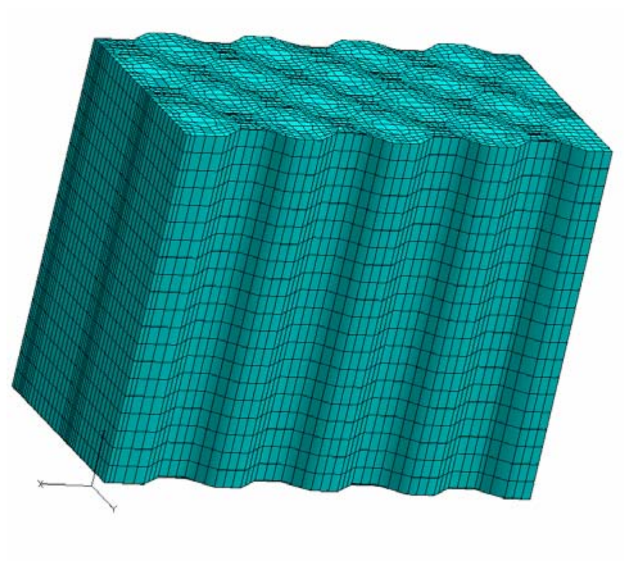


Figure 10. CFD Model Computational Grid



The simulation was carried out using standard k-e turbulence model with the logarithmic wall functions. The turbulence intensity at the MSC™ inlet was assumed to be 5 %. Since the pressure drop inside MSC™ is small with respect to the atmospheric pressure, the equation of state of the gas used in the simulation was the one of the constant-density gas. The bags were simulated as the porous media of the constant resistance, which was adjusted to ensure pressure drop of 6 inches of water for the gas flow simulated.

The computational results, including the three-dimensional distribution of the flue gas velocity (flow) are illustrated graphically in Figure 11 through Figure 14. Figure 11 and Figure 12 represent velocity distribution vectors for a gas flow of 1,000 acfm, while Figure 13 and Figure 14 represent velocity distribution vectors at the gas flow of 1,500 acfm inside the MSC™ pilot. As it could be seen on figures presented, the flow distribution inside MSC™ pilot is uniform without any major stagnation or recirculation zones.

APPLICATIONS

One of the most important MSC™ design improvements is very high collection efficiency in a submicron (ultra-fine) region, which extends its potential use to a wide variety of the fine particulate/dust collection applications (Figure 15).

Particularly the MSC™ could find its use within the following areas/applications:

- Ultra clean exhaust gases: "Vision 21"
- Integrated Gasification Combined Cycle (IGCC): super-clean de-dusting process (synthetic) gases from the gasification equipment prior to the introduction into the combustion turbine
- Industrial mineral processing industries:
    - In-process capture of the expensive product material and return to the process, i.e. metals, rock-dust, gold, etc
    - Post-processing super-clean de-dusting prior to exhaust to the atmosphere.
- Ultra-clean air de-dusting in high-tech, medical, biological and other similar applications.
- Multi-pollutant applications (SOx, NOx, Hg, etc.) via integrating (or impregnating) catalyst materials or augmenting the corona discharge with high frequency alternating field as well as applications of the variety of dielectrically hindered (barrier) discharge.

The MSC™ design is superbly compact and warrants very high efficiencies in the sib-micron/ultra-fine particulate range. Hence, it may be also suitable for the combustion turbine inlet air cleaning.

Figure 11. 3-D Velocity Distribution

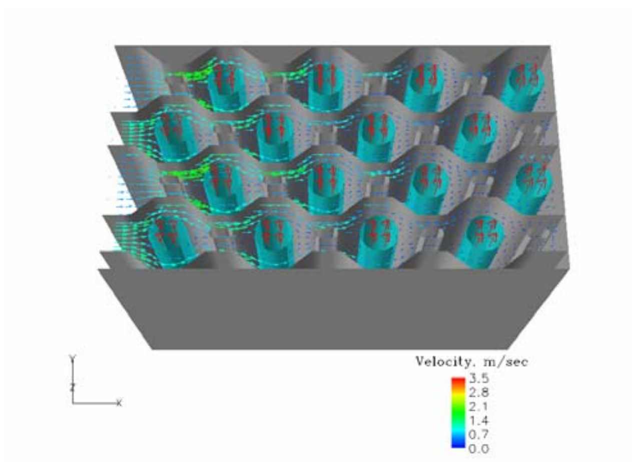


Figure 12. Velocity Distribution

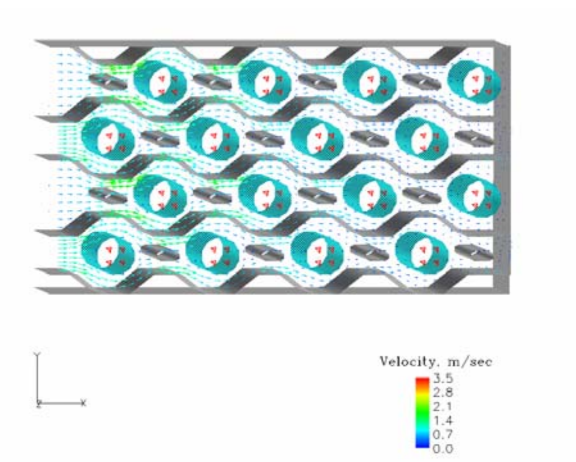


Figure 13. 3-D Velocity Distribution

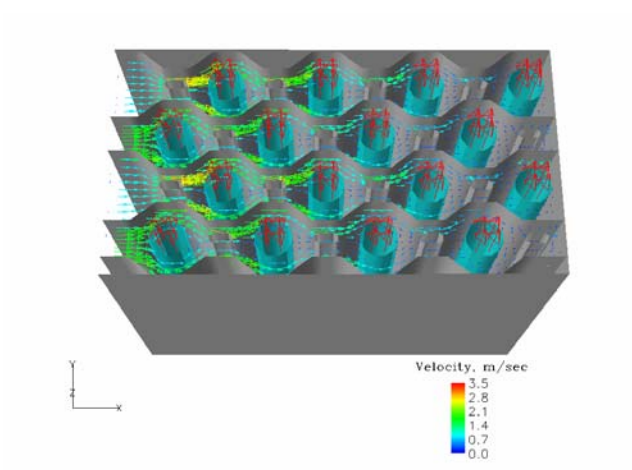
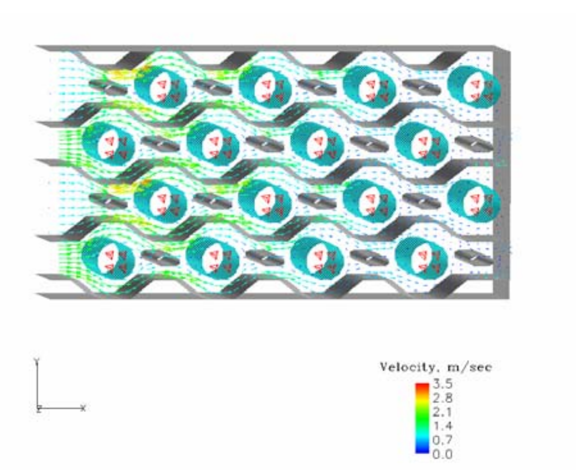
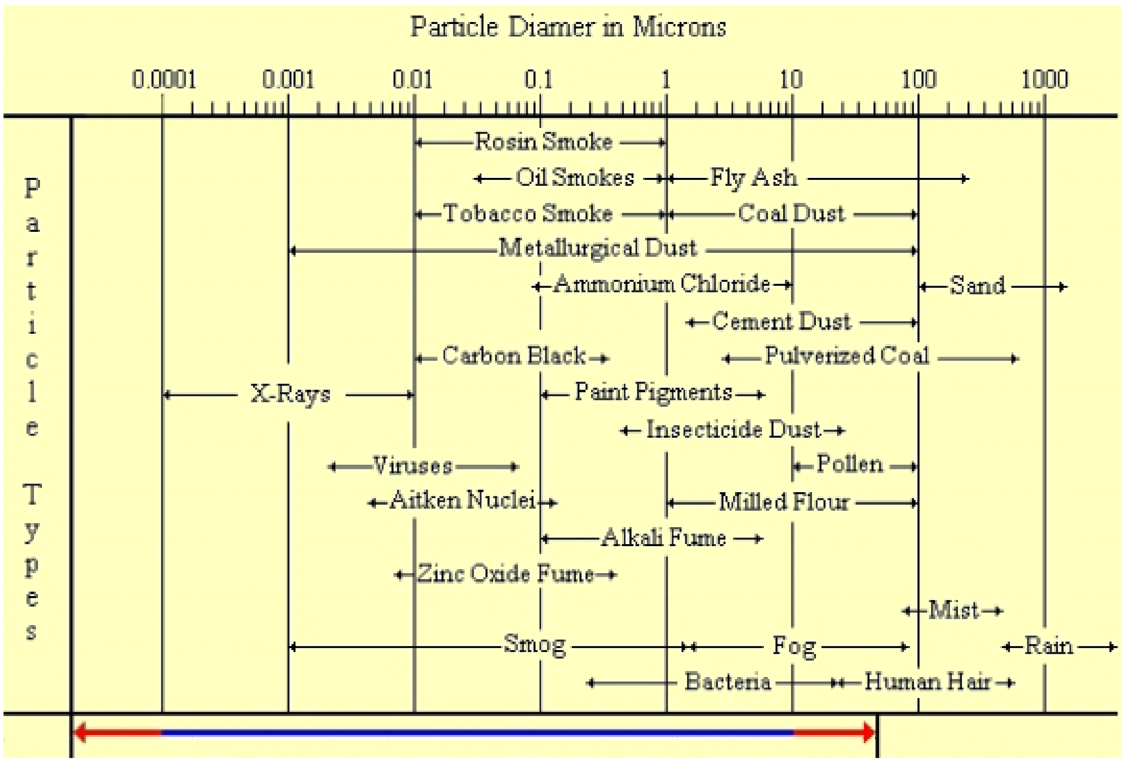


Figure 14. Velocity Distribution



Additional applications, for example, unique ability to generate ozone to promote oxidation process of the gaseous components and introduce it in either "dirty" or "clean" gases (or both) should be evaluated and may result in yet another beneficial use.

Figure 15. MSC™ Particulate Matter Collection Range(12)



Case Study

A case study was conducted in order to evaluate suitability and size requirements of the MSC™ for the "conventional" ESP retrofitting. The goal of the study was to evaluate whether it would be possible to fit the required barrier filter area and the respective ESP equipment in the existing casing without its major refurbishing.

A 500 MW boiler-unit firing a sub-bituminous coal was selected. The existing three (3) filed ESP had two (2) casings, four (4) cells each with 20 gas passages on 229 mm (9 inch) centers. The collecting plates were 3.66 m (12 feet) long and 9.14 m (30 feet) high. This geometry resulted in a SCA of 38.87 $m^2/m^3/s$ (197 ft^2/kacfm) at a gas flow of 826 m^3/s (1,750,000 acfm) at 149 ºC (300 ºF).

Table 2 presents the results of the simulation. Assuming that the MSC™ will be able to operate with the FV in the 5 - 6 cm/s (10 - 12 ft/m) range a reasonably suitable retrofit seems possible. Naturally, as the MSC™ operation is independent of the fly ash resistivity, there will be no need to evaluate the fly ash resistivity and the requirements for the flue gas conditioning (FGC). Hence, this boiler would be an ideal user for the "spot" coal. Furthermore, as it was discussed previously, the expected system performance should be within the "Vision 21" range; hence the expected outlet emissions should satisfy requirements of any local air pollution control regulatory office.

SUMMARY

The MSC™ technology is a novel, compact multi-stage collector for collecting dust, fume, etc. from industrial gases, which is independent of electrical resistivity. This design should be particularly advantageous when the material to be collected consists mostly of a sub-micron and ultra-fine dust or fume.

Table 2. Simulated Performance Data for a 500 MW Boiler-Unit

ITEM	UNITS	SIMULATED PERFORMANCE DATA			
		Case A		Case B	
Barrier Filter Dia.	cm - inch	15.24	6	12.7	5
Gas Flow	m^3/s - acfm	826	1,750,000	826	1,750,000
MSC™	Systems	2	2	2	2
Compartments per MSC™		6	6	6	6
Compartment Length	m - ft	6.1	20	6.1	20
Compartment Width	m – ft	3.66	12	3.66	12
Effective Height	m – ft	7.32	24	7.32	24
Barrier Filter Elements		14 x 24		16 x 27	
No. of Barrier Filter elements per Compartment		336	336	432	432
Barrier Filter Area per Compartment	$m^2 – ft^2$	1,177	12,667	1,261	13,572
Barrier Filter Face Velocity	cm/s – ft/m	5.81	11.52	5.46	10.75
Total Collecting Area	$m^2 – ft^2$	29,485	317,376	32,950	354,673
Effective SCA	$m^2/m^3/s$ – ft^2/kacfm	34.74	176	38.82	197

The MSC™ concept offers significant improvement over conventional ESP's and BF's. It will be especially beneficial when electrical resistivity of such dust or fume as precipitated, exceeds 10^{11} Ohm-cm, or is extremely low, for example less than 10^4 Ohm-cm. Furthermore, this design will be particularly advantageous when the material to be collected consists of a sub-micron dust and/or fume or when it is required that exhaust must attain "super-clean" levels, for example the "Vision 21" (≤ 0.005 lb/MBtu) or hot fuel gas clean-up upstream of the combustion turbine.

The MSC™ design is free of the detrimental characteristics of the single-, and two-stage electrostatic precipitators, as well as known electrostatically enhanced barrier filters design:

- it continuously offers ample supply of the ions for aerosol particles charging,
- by virtue of the unique design offers improved collection efficiency, and
- it also incorporates an additional collector-stage by filtering the gas exiting the collector through the barrier collector zone

Additionally, by integrating one of the stages with catalytical materials, the MSC™ may become an "ultimate" multi-pollutant emissions control apparatus.

The MSC™ design provides an optimum combination of not only single-and two-stage ESP, but also incorporates an additional collector stage by filtering the gas exiting the collector through a BFE's, which, in essence, is the only way for the gases to "escape" or exit from the collector. The MSC™ arrangement assures that essentially all dust (either uncollected in electrostatic collection zones or being reentrained in the gas stream during the rapping and/or BFE-cleaning steps) would be detained in this final stage. Finally, in the event the BFE gets "punctured" or simply leaks, the overall MSC™ performance would suffer less, due to the remaining ESP collection phenomena.

Operational Enhancements Offered by MSC™

- MSC™ solves the problem of excessive fine-particle emissions with conventional dedusting technology.
- MSC™ greatly reduces the problem of higher emissions from conventional fabric filters and hybrid devices in the event of partial breaking, leakage or any malfunctioning parts of the systems.
- MSC™ solves the problem of sparking and bags damaging in the hybrid particulate collectors.
- MSC™ overcomes hurdles that prevent operation of pulsejet filters at high filter velocity ratios.
- MSC™ requires significantly less BFE surface area than conventional barrier filter. Consequently, the lower vessel size required to accommodate the MSC™ may result in the lower capital and operating costs.

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KEY WORDS

Electrostatic, precipitator, barrier filter, baghouse, multi-stage, fine particulate