Hybrid Particulate Collection Technologies
Fabric filters work well for many fly ashes as long as the cohesive strength of the fly ash is not too high or too low. However, highly cohesive fly ash can lead to problems with bag cleanability and high pressure drop, and fly ash with low cohesive strength can promote dust bleed through resulting in higher emissions.
Hybrid Particulate Control Technologies

- ESPs work well as long as the fly ash resistivity is in the correct range (from about $10^8$ to $10^{11}$ ohm-cm), but deteriorate significantly for high- or low-resistivity fly ashes.

- Additionally, neither of the technologies will work effectively with the submicron particulate matter for it shall pass straight though the filter material.
Hybrid Particulate Control Technologies

- Electrified charged particles have been found to form highly porous dust layers in fabric filters.
- 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.
Electrostatically Enhanced FF’s

Densely packed dust particles

Loosely packed, charged dust particles

Filter cloth
GAS FLOW
GAS FLOW
Hybrid Technologies
Hybrid Particulate Control Technologies

- Compact Hybrid Particulate Collector (COHPAC)
- Advanced Hybrid
- Electrostatically Enhanced Fabric Filter (ESFF) or MAX9
- Multi Stage Collector (MSC™) Technology
A combination Fabric Filter/ESP hybrid device has been developed by EPRI and is called the Compact Hybrid Particulate Collector (COHPAC):

- This device involves using pulse jet fabric filter to capture dust that escapes an ESP
  - COHPAC I involves placing a pulse jet filter downstream from an ESP
  - COHPAC II utilizes a fabric filter in place of the last field of an ESP
Hybrid Particulate Control Technologies - COHPAC

COHPAC I

COHPAC II
Advanced Hybrid

This technology was patented by the University of North Dakota’s Energy & Environmental Research Center (EERC). Its development was supported by DOE.
The internal geometry consists of alternating rows of ESP components (discharge electrodes and collecting plates) and filter bags within the collector.

The inlet flue gas is directed into the ESP zone, which removes most of the entrained dust prior to it reaching the filter bags.
Electrostatically-Stimulated Fabric Filters, ESFF (now marketed by GE-BHA under the trade name MAX-9) have been developed by EPA to reduce fabric filter pressure drop and particle penetration.
Hybrid Particulate Control Technologies - ESFF/MAX9
Multi-Stage Collector (MSC™)
Multi-Stage Collector - MSC™

United States Patent

Inventor: Henry Kripton

Assignee: Allied Environmental Technologies, Inc.

Multi-Stage Collector - MSC™

A multi-stage collector of the type used to collect particulate matter is shown in the drawings. The collector is a system designed to separate particles from a gas stream. The multi-stage collector is comprised of a plurality of parallel plates, each of which is designed to collect particulate matter from the gas stream. The collector is fabricated from corrosion resistant materials and is designed to operate under a wide range of conditions. The collector is capable of collecting particulate matter from a variety of environments.

Related United States Application:

Title: Multi-Stage Collector - MSC™

Inventor: Henry Kripton

Assignee: Allied Environmental Technologies, Inc.

Abstract:

A multi-stage collector of the type used to collect particulate matter from a gas stream. The collector is comprised of a plurality of parallel plates, each of which is designed to collect particulate matter from the gas stream. The collector is fabricated from corrosion resistant materials and is designed to operate under a wide range of conditions. The collector is capable of collecting particulate matter from a variety of environments.
The MSC™ assembly is made up from DEs placed between oppositely charged corrugated plates.

The DEs are followed by BFEs located in wide zones placed between the collecting electrodes.

Both the flat sides of each of the DEs, corrugated plates and the surfaces of the BFE form collecting surfaces where the electric field is relatively uniform.
The principal objective of the MSC™ design is to substantially improve fine particulate collection by:

- combining electrostatic charging, collection and filtration processes, and
- separating zones for particles charging and collecting
The MSC™ concept can be broadly summarized as a system in which multiple conventional stages are utilized.

Each stage performing its primary function, and

Multiple stages operating synergistically to provide significantly improved performance.
The MSC™ offers a uniquely compact concept utilizing:

- a stage comprised of a conventional ESP
Multi-Stage Collector - MSC™

Stage-1 (Non-Uniform Field): Charging
The MSC™ offers a uniquely compact concept utilizing:

- an upstream stage comprised of a conventional ESP,
- followed by a zone of parallel surfaces creating uniform electric field
Multi-Stage Collector - MSC™

Stage-1 (Non-Uniform Field): Charging

Stage-2 (Uniform Filed): Precipitation

Gas Flow
The MSC™ offers a uniquely compact concept utilizing:

- an upstream stage comprised of a conventional ESP,
- followed by a downstream zone of the parallel surfaces creating uniform electric field,
- followed by yet another stage, which incorporates barrier filter surfaces of which provide yet additional zone with uniform electric field.
Multi-Stage Collector - MSC™

Stage-1 (Non-Uniform Field): Charging

Stage-2 (Uniform Filed): Precipitation

Stage-3 (Barrier Filter): Filtration
Multi-Stage Collector - MSC™

Stage-1 (Non-Uniform Field): Charging

Stage-2 (Uniform Field): Precipitation

Stage-3 (Barrier Filter): Filtration
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 of opposite polarity.

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.
MSC™ Effectively Deals with Bi-Polar Charges

Negatively Charged Particles

Positively Charged Particles

- electron

- molecule

- particle
MSC™, by providing continuously repeated stages in series, ensures that the downstream zones effectively re-charge and re-collect the particles that are either uncollected or reentrained.
**MSC™ Pilot Tests**

Field Off

Field On
**MSC™ Pilot Tests: Pressure Drop Characteristics**

- **Pulse Jet Mode**
- **MSC™ Mode**
- **MSC Electric Field Energized**

- **MSC dP**
- **Current (mA)**

*Allied Environmental Technologies, Inc. - MSC™ Development*
MSC™ Pilot Tests: Pressure Drop Characteristics

![Graph showing pressure drop characteristics over elapsed time for MSC Mode and Pulse Jet Mode.](image_url)
MSC™ Pilot Tests: Collection Efficiency

Collection Efficiency, %

MSC Mode
Pulse Jet Mode

Elapsed Time, hr:min

0:00 1:12 2:24 3:36 4:48

99.70 99.75 99.80 99.85 99.90 99.95 100.00
MSC™ Pilot Tests: Emissions

Particle size, microns
Cumulative Mass, lb/hr

Inlet
Pulse Jet Mode
MSC Mode
MSC™ Pilot Tests: Penetration vs. Particle Size

![Graph showing Penetration vs. Particle Size for MSC™ and PJ.](image)

Penetration, %

Particle Size, microns

MSC
PJ

Allied Environmental Technologies, Inc. - MSC™ Development
MSC™ Proof of Concept Pilot

Sparking Between the Discharge and Collecting Electrodes.
Corona Discharge
MSC™ Proof of Concept Pilot

Sparking Between the Discharge and Collecting Electrodes.
Fundamental Differences
It is well-known fact that the electrical charge imparted on the aerosol particles is proportional to the applied electrical field and the particle size.

Furthermore, the effective migration velocity, which determines the collection efficiency, is also proportional to the applied electrical field that moves the charged particulate from the gas stream towards (a) collecting plates and (b) bags.

Therefore, in order to effectively charge and collect the sub-micron particulate, the collecting device must provide:

- Effective, and rapid particulate charging, and
- To be able to operate with the extremely high electrical field.
Space charge is a phenomenon, which could be defined as a charge present in the inter-electrode space (between two or more oppositely charged electrodes) due to the flow of ions, or a cloud of the charged particles.

Since the mobility of the charged dust is much lower than the mobility of the ions and electrons, the cloud of charged dust represents a significant increase in space charge, which tends to quench the corona current.
The space charge imposed by the cloud of the charged particulate matter, however, would be greatly dependent on the particle size distribution, for the same particulate mass could be represented by a few big particles or a large number of the smaller ones.

This would present even more problems when dealing with the cloud of the charged fumes or smoke with MMD of less than 1 micron (sub-micron range).

Assuming further that the mobility of the particulate is somewhat similar, the cloud of the finer charged matter could present a barrier (or obstacle) to the ions in their quest to carry charges from one electrode to the other. Hence, the other phenomenon called “corona quenching.”
MSC™ & Hybrid Technologies – Fundamental Differences

- It is necessary to operate the corona discharge electrodes at an electrical operating voltage above the corona onset voltage.

- The corona onset voltage is that voltage at which the gas immediately adjacent to the corona discharge electrode starts to ionize because of the very high electric field formed at the curved surface, which then transfers the charge to the particles.
MSC™ & Hybrid Technologies – Fundamental Differences

COHPAC

- ESP & PJBH in Series
- Very Limited Dust Cake Electrostatic Enhancement
- Selected Collection of the Large Fractions in the ESP Impacts the Dust Cake Performance
- All High Resistivity Problems Remain (Back Corona, etc.)
MSC™ & Hybrid Technologies –
Fundamental Differences

Advanced Hybrid

- ESP & PJBH in Series
- The Main Idea of the Advanced Hybrid Operation Predicated on the Dust PRE-COLLECTION in the ESP Section
  - All High Resistivity Problems Remain (Back Corona, etc.)
  - As soon as the corona quenching phenomena settles in, the precipitator section efficiency would significantly diminish, thus the overall unit performance
MSC™ & Hybrid Technologies – Fundamental Differences

Advanced Hybrid

- Very Limited Dust Cake Electrostatic Enhancement
  - especially after switching to the tri-electrode geometry to prevent sparking to the bags

- Selected Collection of the Large Fractions in the ESP Impacts the Dust Cake Performance
**MSC™ & Hybrid Technologies – Fundamental Differences**

**ESFF/MSX9**

- The corona onset voltage is a function of the gas temperature and density, corona discharge electrode diameter, its distance from the bags, and the surface roughness of the electrode.

- The corona onset voltage for an electrode increases with its diameter and distance from the bags, and decreases with the surface roughness.
In this device the charging electrodes are located in the very proximity to the bags, hence to eliminate the chance of the sparking towards the bag, which would cause the bag puncture, the high voltage has to be reduced to the minimum possible.

Therefore, if the space charge occurs, instead of the increasing the applied voltage to overcome the charged particulate cloud, the system would have to reduce the voltage in order not to overcome the sparking threshold.

Hence, defeating the effective sub-micron particles charging and collection.
The MSC™ is engineered in such a way that the BFE and the DE are grounded while the 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 virtually eliminates any potential sparks from the DE toward the BFE.

Contrary to other technologies, whose performance is greatly dependent on the dust resistivity and could be virtually “halted” when back corona develops, the MSC™ offers an efficient collection mechanism for the bi-polar particles. Thus, in effect, making it virtually independent of the dust (product) electrical resistivity.
The high voltage in the MSC™ device is not limited by the sparking towards the bags.

Hence, it could operate with the maximum possible applied high electric field to ensure the most effective sub-micron particulate charging and collection.

Furthermore, by utilizing combination of the single- and two-stage electrostatic precipitation, the MSC™ technology offers the best possible combination of the non-uniform and uniform high-tension electric fields for the most efficient aerosol charging and collection.
Independent Research
Multi-Stage Collector - MSC™

Korea Institute of Energy Research
Multi-Stage Collector - MSC™

Korea Institute of Energy Research
Multi-Stage Collector - MSC™

Korea Institute of Energy Research

![Graph showing filtration time vs. pressure drop](image_url)
Multi-Stage Collector - MSC™

Korea Institute of Energy Research

![Graph showing collection efficiency over time for plain and corrugated plates](image)

- Plain plates
- Corrugated plates

Collection efficiency, %

Time, min

0 7 14 21 28 36 43 50

99 99.1 99.2 99.3 99.4 99.5 99.6 99.7 99.8 99.9 100
Multi-Stage Collector - MSC™

Korea Institute of Energy Research

(a) Collection efficiency, %

ESP+FF: 99.912
Only FF: 99.832
Only ESP: 98.33

Corrugated plates

(b) Collection efficiency, %

ESP+FF: 99.976
Only FF: 99.903
Only ESP: 98.546

Plain plates
Multi-Stage Collector - MSC™

Korea Institute of Energy Research

Fractional collection efficiency, %

Particle aerodynamic diameter, µm