Hybrid Particulate Collection Technologies

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Hybrid Particulate Control 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

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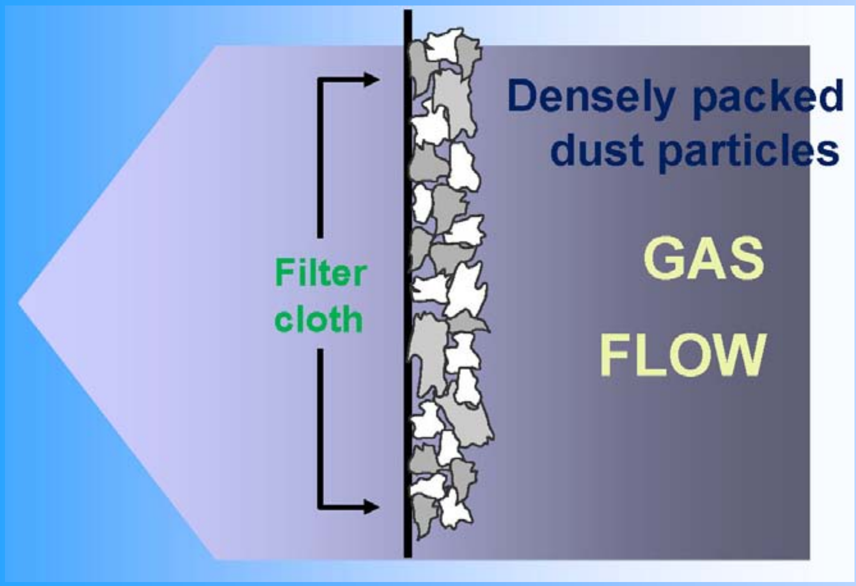
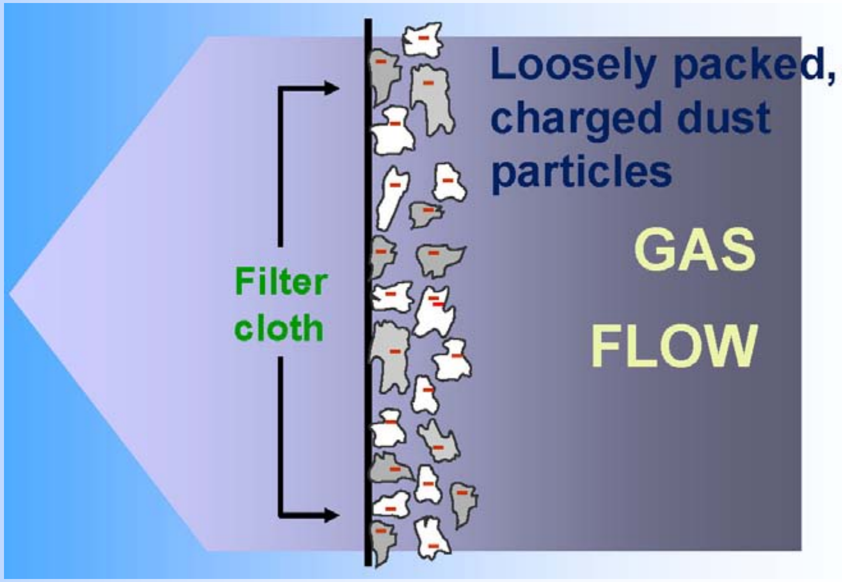
- Electrically-charged particles have been found to form highly porous dust layers in fabric filters
- Efforts to increase barrier filters efficiency without a corresponding increase in pressure loss have led to the development of electrostatically enhanced fabric filters and so-called hybrid devices

Electrostatically Enhanced FF's





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Hybrid Technologies

Hybrid Particulate Control Technologies

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- Compact Hybrid Particulate Collector (COHPAC)
- Advanced Hybrid
- Electrostatically Enhanced Fabric Filter (ESFF) or MAX9
- Multi Stage Collector (MSC™) Technology

Hybrid Particulate Control Technologies - COHPAC

- 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

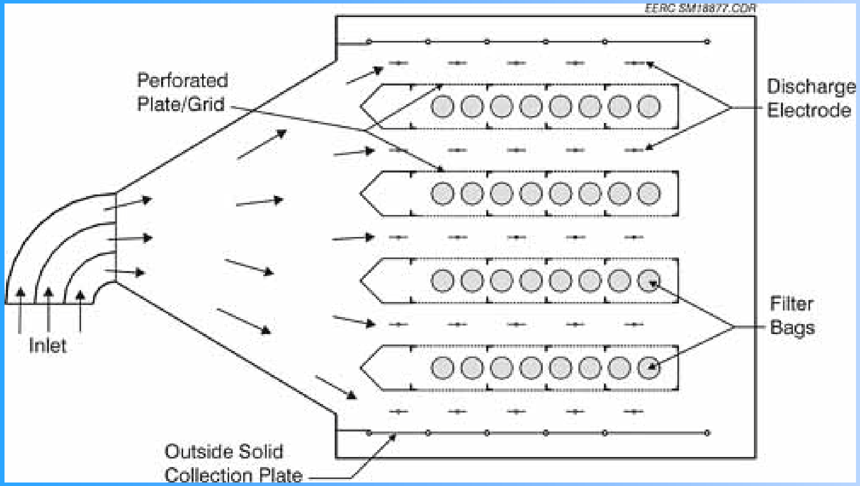
COHPAC I

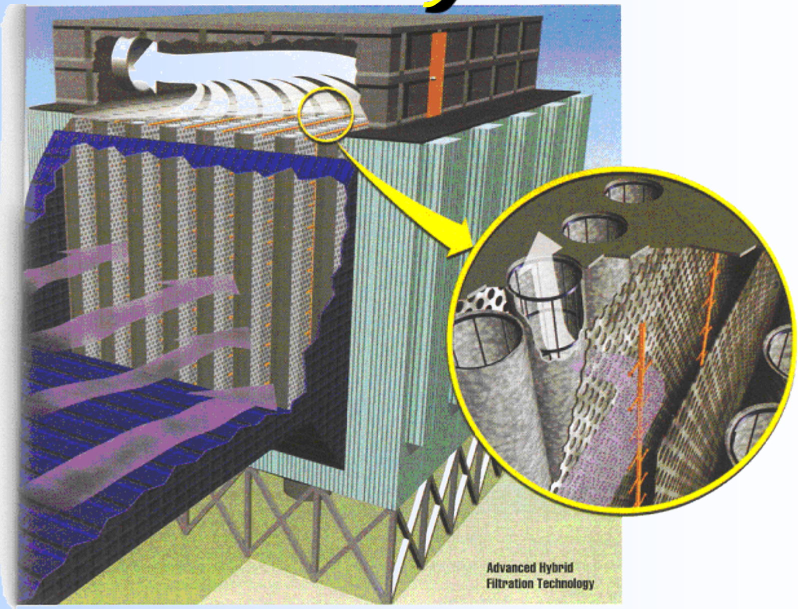
COHPAC II

Hybrid Particulate Control Technologies - Advanced Hybrid

- **Advanced Hybrid**
  - **This technology was patented by the University of North Dakota's Energy & Environmental Research Center (EERC). Its development was supported by DOE**

Hybrid Particulate Control Technologies - Advanced Hybrid





- 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

Hybrid Particulate Control Technologies - ESFF/MAX9

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

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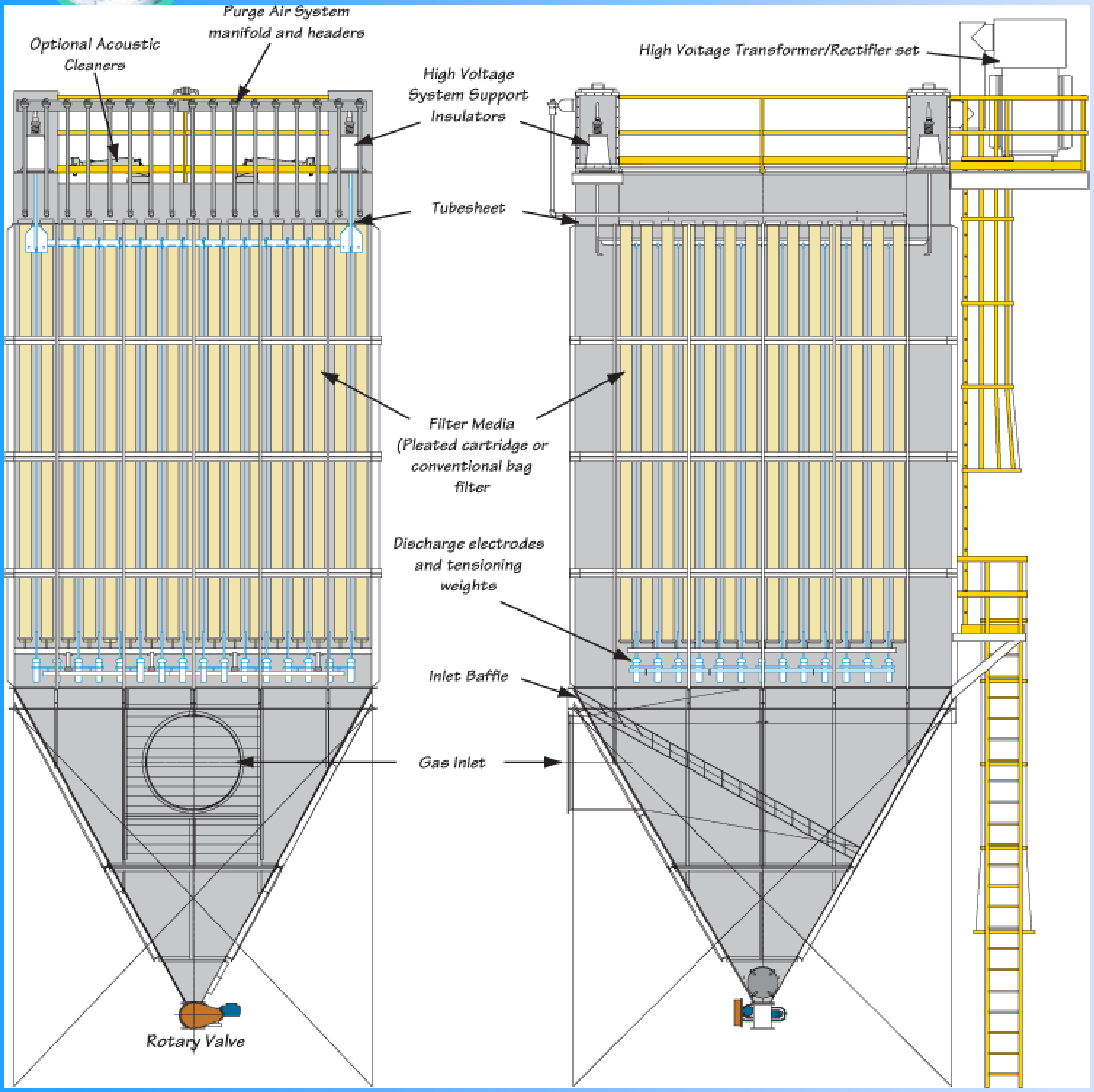
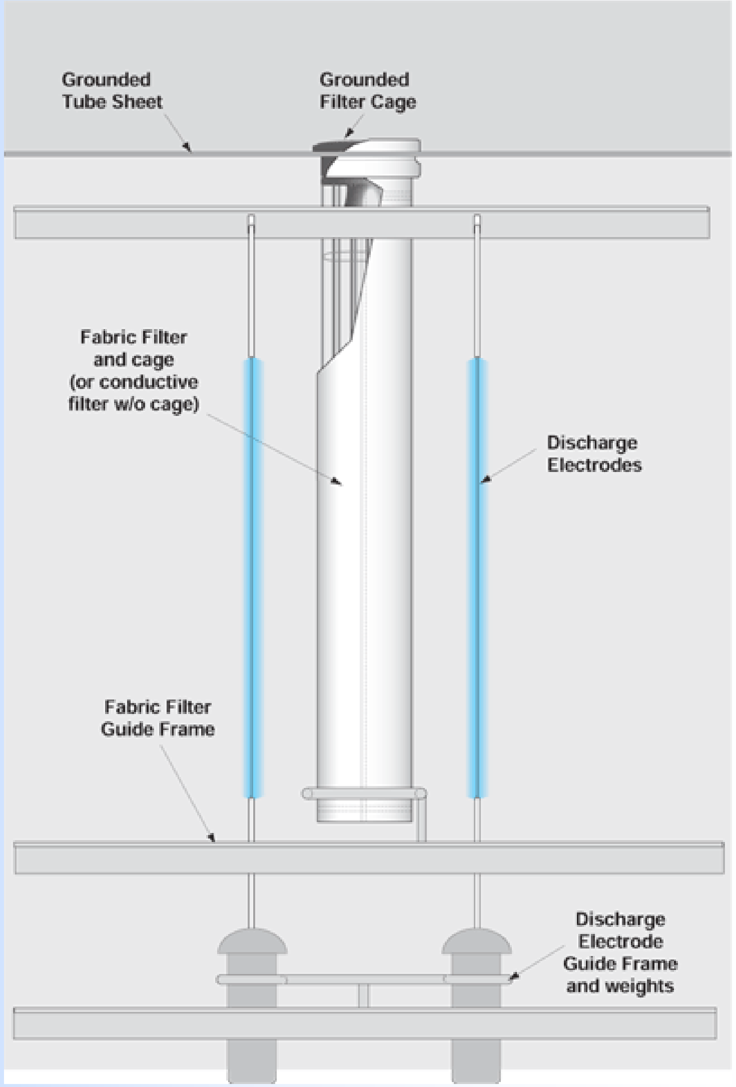




Multi-Stage Collector (MSC™)

Multi-Stage Collector - MSC™

US006524369B1

(12) **United States Patent**
Krigmont

(10) **Patent No.:** **US 6,524,369 B1**
(45) **Date of Patent:** **Feb. 25, 2003**

(54) **MULTI-STAGE PARTICULATE MATTER COLLECTOR**

(76) Inventor: **Henry V. Krigmont**, 3600 Marigold St., Seal Beach, CA (US) 90740

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/950,157**

(22) Filed: **Sep. 10, 2001**

(51) **Int. Cl.**[7] **B03C 3/155**; B03C 3/36

(52) **U.S. Cl.** **95/78**; 55/341.1; 55/372; 96/59; 96/62; 96/73; 96/87; 96/97

(58) **Field of Search** 96/55, 59, 62, 96/70, 73, 79, 86, 87, 97; 95/70, 78; 55/341.1, 361, 372

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,345,790	A	*	7/1920	Lodge	96/62
1,356,462	A	*	10/1920	Nesbit	96/87
2,654,438	A	*	10/1953	Wintermute	96/62
3,915,676	A		10/1975	Reed et al.	55/432 X
4,147,522	A		4/1979	Gonas et al.	55/467 X
4,354,858	A		10/1982	Kumer et al.	55/DIG. 5
4,357,151	A		11/1982	Helfritch et al.	55/302 X
4,375,364	A	*	3/1983	Van Hoesen et al.	96/87
4,411,674	A		10/1983	Forgal	55/304
4,904,283	A		2/1990	Hovis et al.	96/66
5,024,681	A		6/1991	Chang	95/70
5,066,313	A	*	11/1991	Mallory, Sr.	95/57
5,158,580	A		10/1992	Chang	95/70
5,217,511	A		6/1993	Plaks et al.	55/334 X
5,547,493	A		8/1996	Krigmont	96/54
5,547,496	A	*	8/1996	Hara	96/79
5,938,818	A		8/1999	Miller	95/63
6,152,988	A	*	11/2000	Plaks et al.	95/58

FOREIGN PATENT DOCUMENTS

JP 54-158770 A * 12/1979 .... 96/97

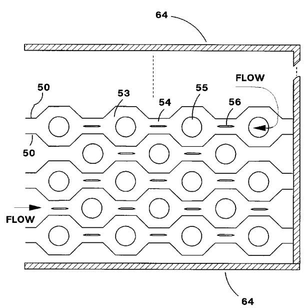
* cited by examiner

Primary Examiner—Richard L. Chiesa
(74) *Attorney, Agent, or Firm*—Clifford Kraft

(57) **ABSTRACT**

A multi-stage particulate matter collector of the type used to collect particles from waste industrial gas. The collector can contain multiple narrow and wide zones formed by a plurality of parallel corrugated plates. Contained in the narrow zones are elongated electrodes with sharp leading and/or trailing edges. These electrodes provide a non-uniform electric field near their sharp edges leading to corona discharge. The corona discharge causes particulate matter in the gas flow to become charged. The region in narrow zones away from the sharp edges of the electrodes resembles a parallel plate capacitor with relatively uniform electric field. In this region, particles can be collected on the plates and on the electrode. Wide regions can contain barrier filters (bag filters) with conductive surfaces. The electric field is also relatively uniform in this region causing electrostatic collection on the plates and filter surface. Gas exits the array through the sides of the barrier filters which provides additional highly efficient filtering.

28 Claims, 9 Drawing Sheets



US006932857B1

(12) **United States Patent**
Krigmont

(10) **Patent No.:** **US 6,932,857 B1**
(45) **Date of Patent:** **Aug. 23, 2005**

(54) **MULTI-STAGE COLLECTOR AND METHOD OF OPERATION**

(76) Inventor: **Henry Krigmont**, 3600 Marigold St., Seal Beach, CA (US) 90740

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/657,780**

(22) Filed: **Sep. 8, 2003**

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/353,155, filed on Jan. 28, 2003, now abandoned, and a continuation-in-part of application No. 10/400,324, filed on Mar. 26, 2003, now abandoned, which is a continuation-in-part of application No. 09/950,157, filed on Sep. 10, 2001, now Pat. No. 6,524,369.

(51) **Int. Cl.**[7] **B03C 3/155**; B03C 3/36

(52) **U.S. Cl.** **95/63**; 55/341.1; 55/361; 95/78; 96/55; 96/59; 96/62; 96/66; 96/73; 96/87; 96/97

(58) **Field of Search** 96/55, 57–59, 96/62, 70, 73, 79, 86, 87, 97, 66, 98, 99; 95/70, 78, 63, 69; 55/341.1, 361, 372, 379–382, 55/524

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,345,790	A	7/1920	Lodge	96/62
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2,654,438	A	10/1953	Wintermute	96/62
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4,874,586	A	10/1989	Szymanski et al.	55/380 X
4,904,283	A	2/1990	Hovis et al.	96/66

(Continued)

FOREIGN PATENT DOCUMENTS

JP 54158770 12/1979 .... 96/97

OTHER PUBLICATIONS

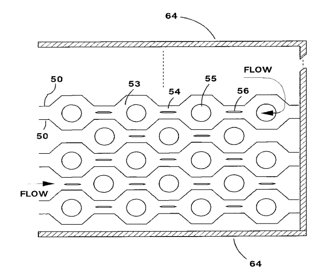
DOE/FETC/C-97/7284 RA. Dennis "US Dept. of Energy's High-Temp & High Pressure Particulate Cleanup for Advanced Coal-Based Power Systems", Jun. 8-13, 1997.

Primary Examiner—Richard L. Chiesa
(74) *Attorney, Agent, or Firm*—Clifford Kraft

(57) **ABSTRACT**

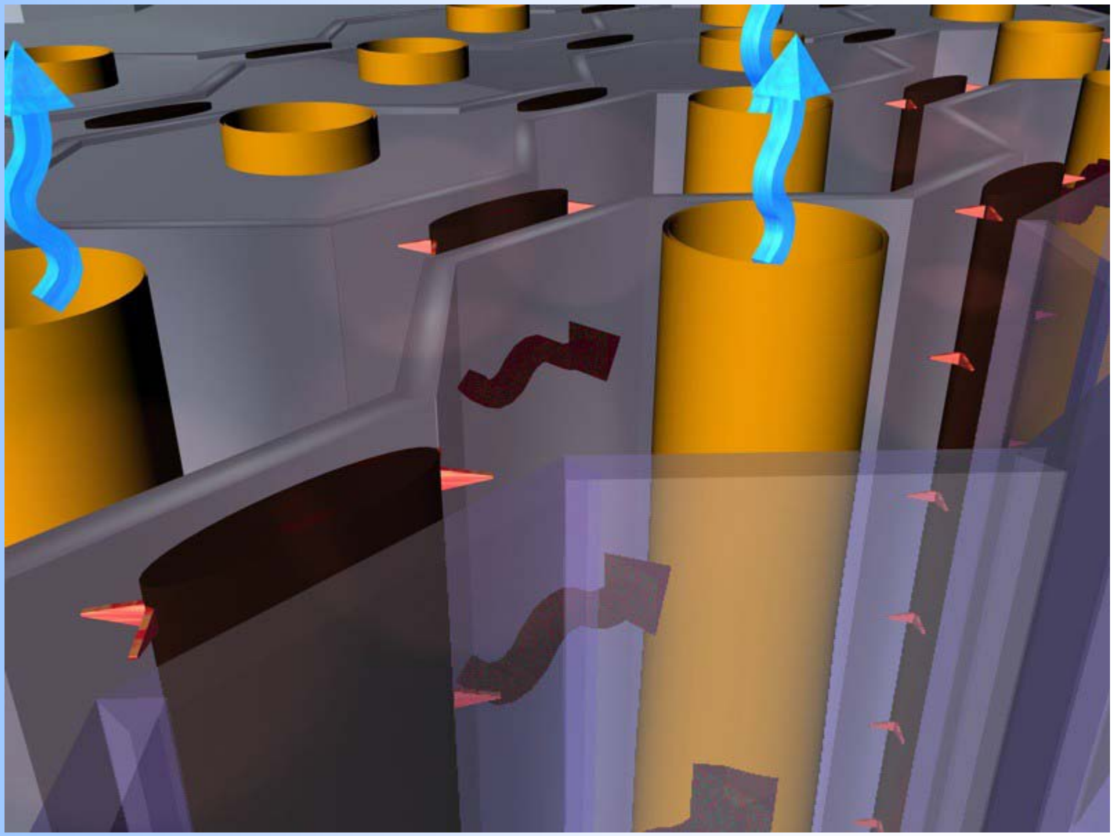
A multi-stage collector of the type used to collect particles from industrial gas. The collector can contain multiple narrow and wide zones formed by a plurality of parallel corrugated plates. Contained in the narrow zones can be elongated electrodes with sharp leading and/or trailing edges. These electrodes can provide a non-uniform electric field near their sharp edges leading to corona discharge. The corona discharge causes particulate matter in the gas flow to become charged. The region in narrow zones away from the sharp edges of the electrodes resembles a parallel plate capacitor with relatively uniform electric field. In this region, particles can be collected on the plates and on the electrode. Wide regions can contain barrier filters (bag filters) with conductive surfaces. The collector can also be used to clean inlet gas in gasification plants and to collect re-usable materials from a gas stream.

20 Claims, 15 Drawing Sheets



Multi-Stage Collector - MSC™

- 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



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Multi-Stage Collector - MSC™

- **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**

Multi-Stage Collector - MSC™

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- 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

Multi-Stage Collector - MSC™

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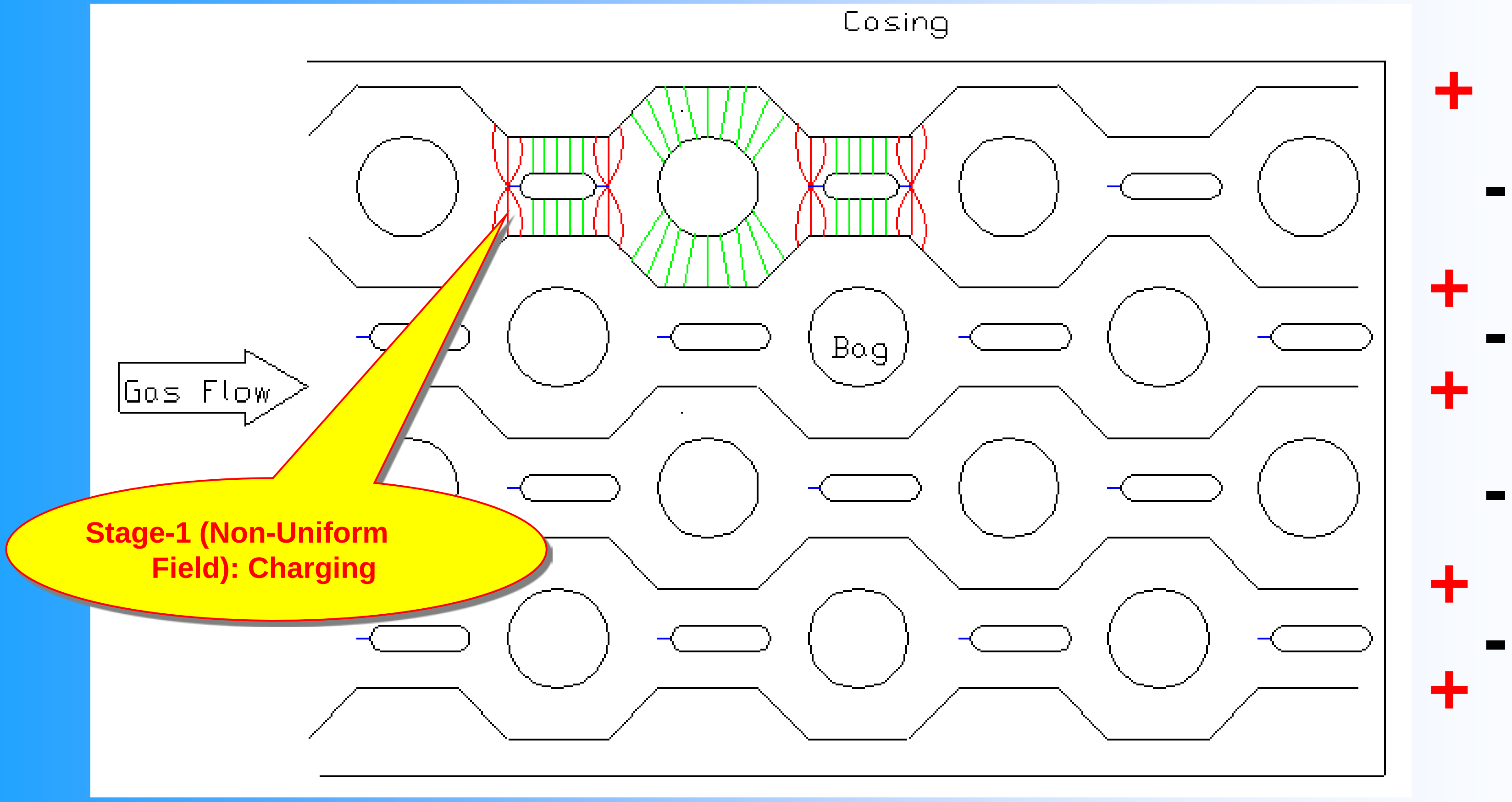
- **The MSC™ offers a uniquely compact concept utilizing:**
  - **a stage comprised of a conventional ESP**

Multi-Stage Collector - MSC™



Multi-Stage Collector - MSC™

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- 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™

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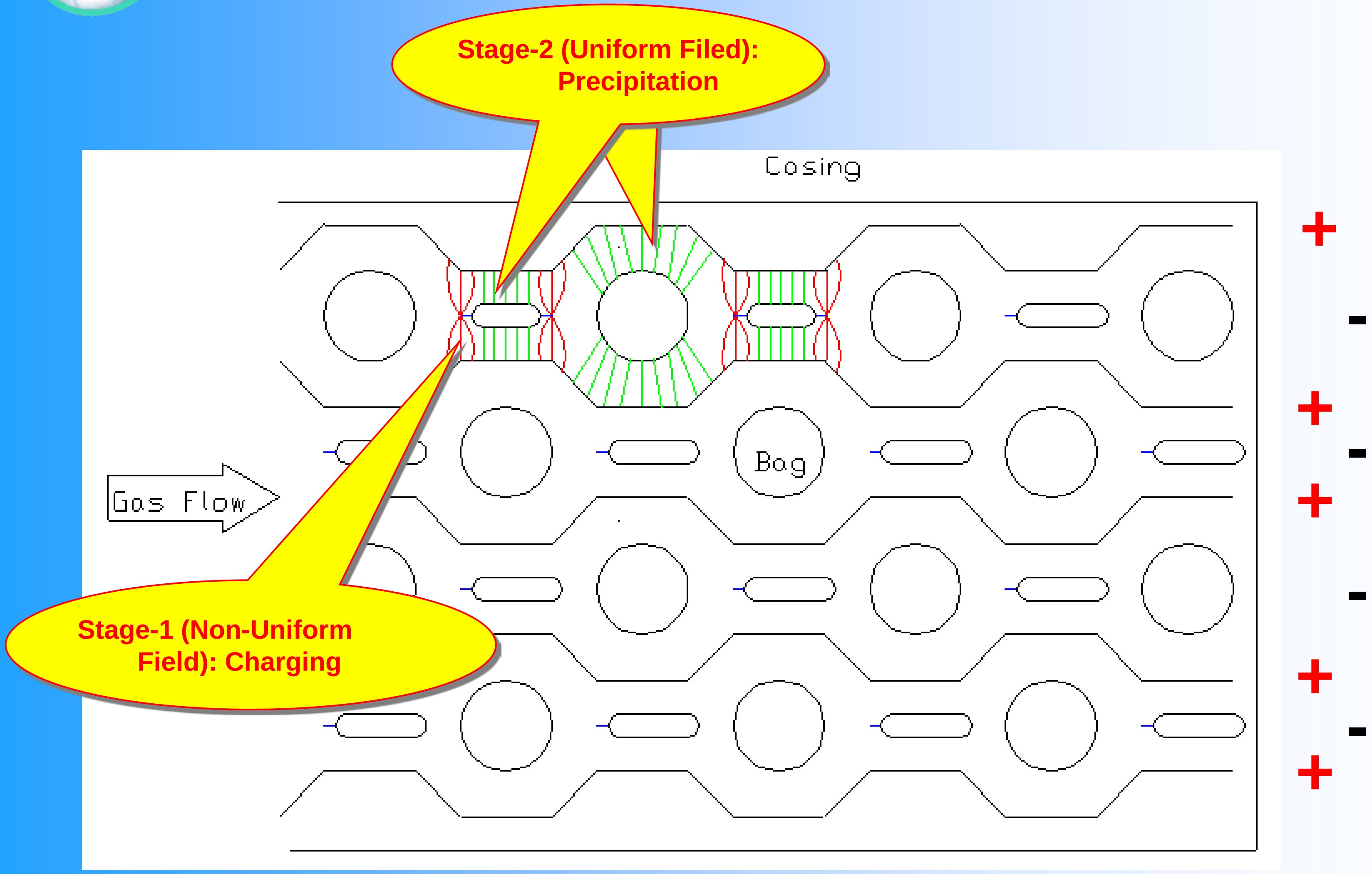

Multi-Stage Collector - MSC™

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- 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™

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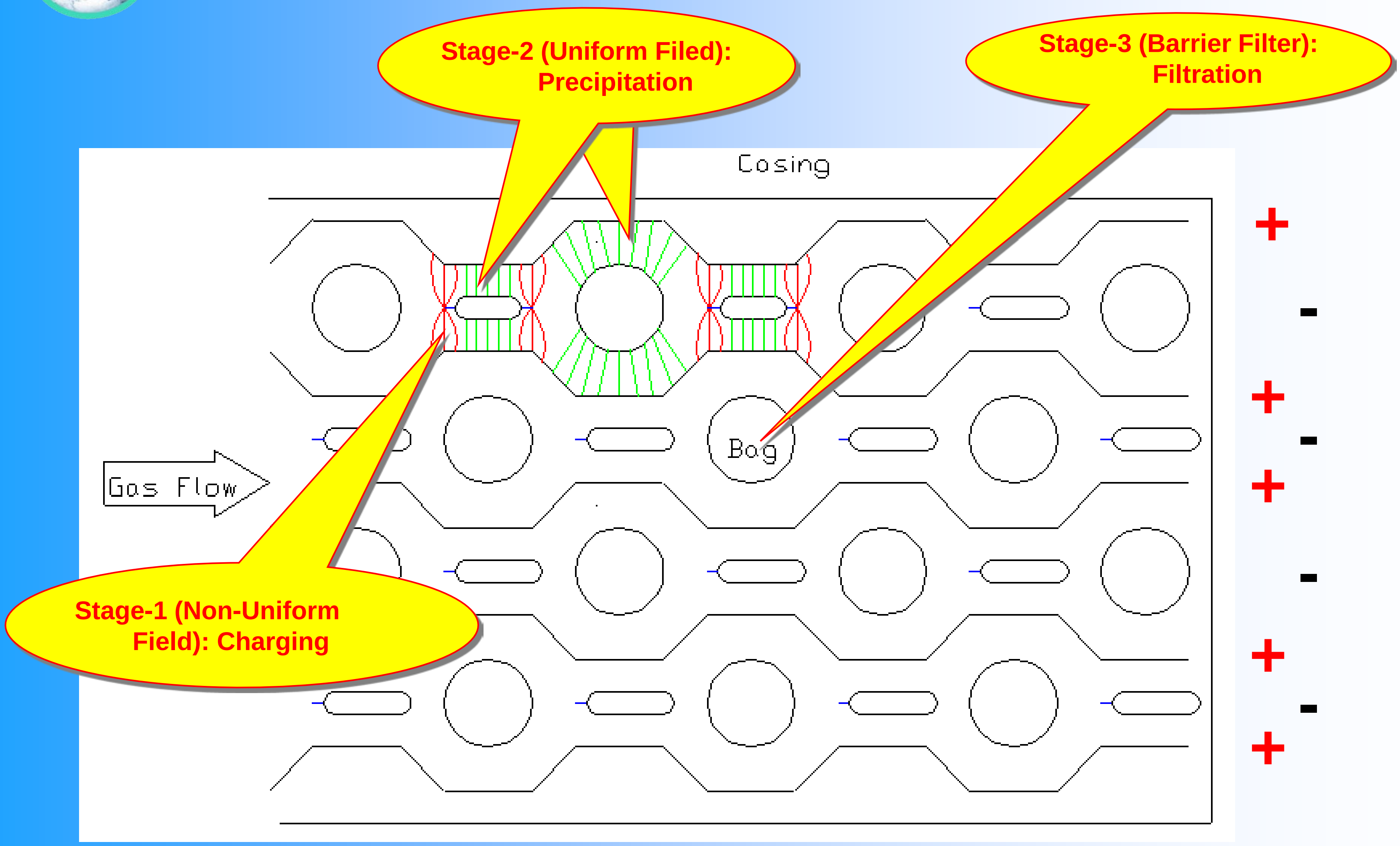
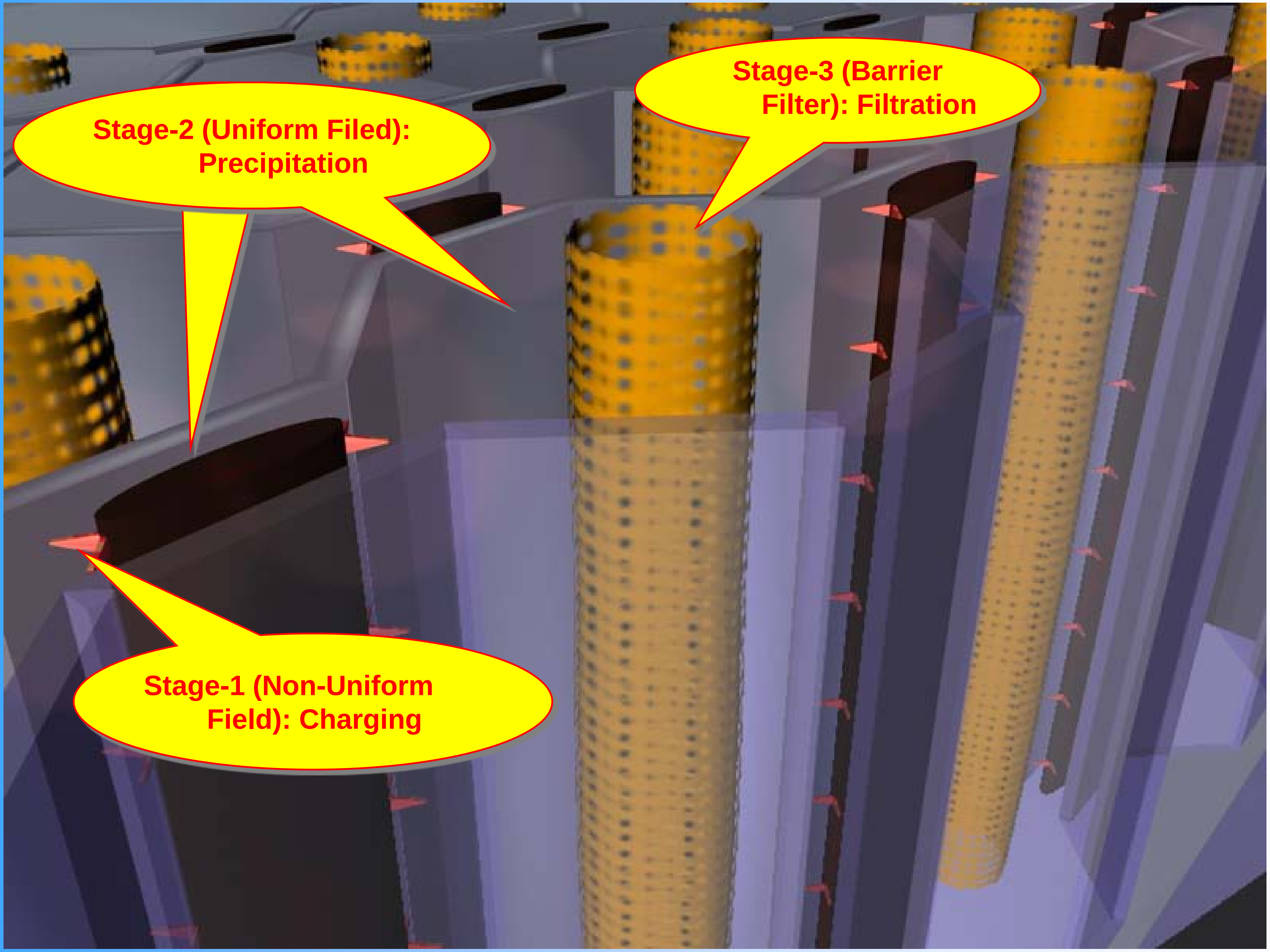


Multi-Stage Collector - MSC™



Multi-Stage Collector - MSC™

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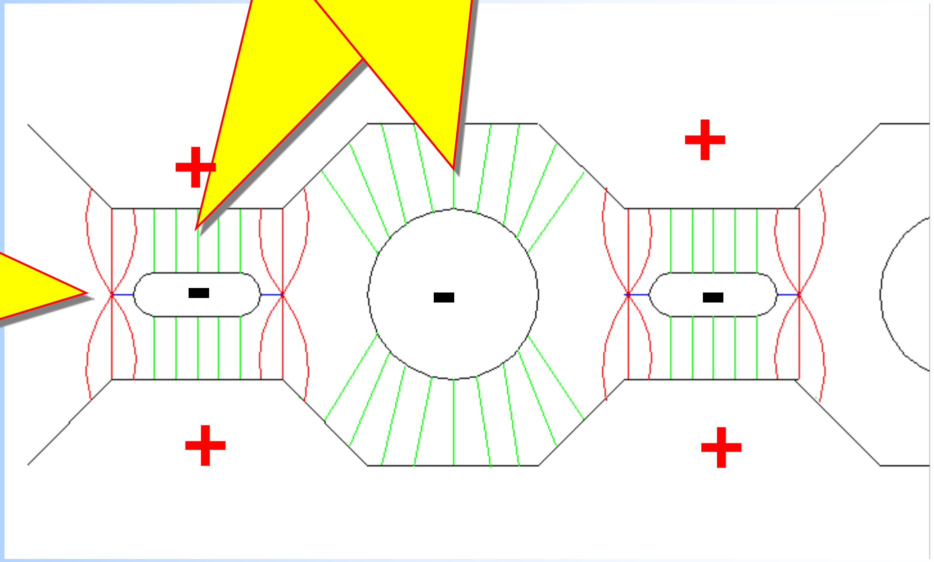
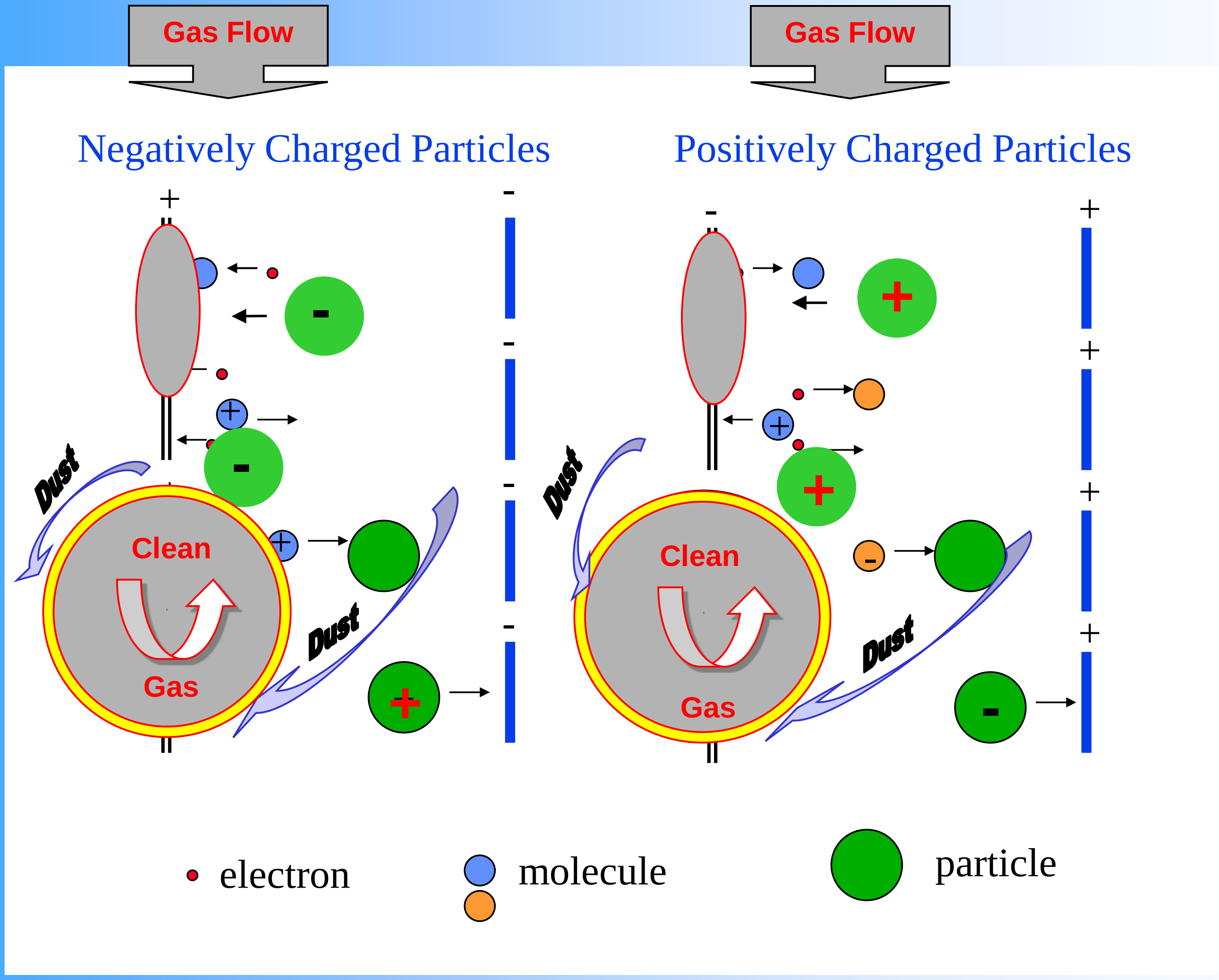
The center region of uniform field on the other hand acts in a manner similar to the field between parallel capacitor plates with charged dust particles collecting on the plates of opposite polarity

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



Multi-Stage Collector - MSC™

- 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

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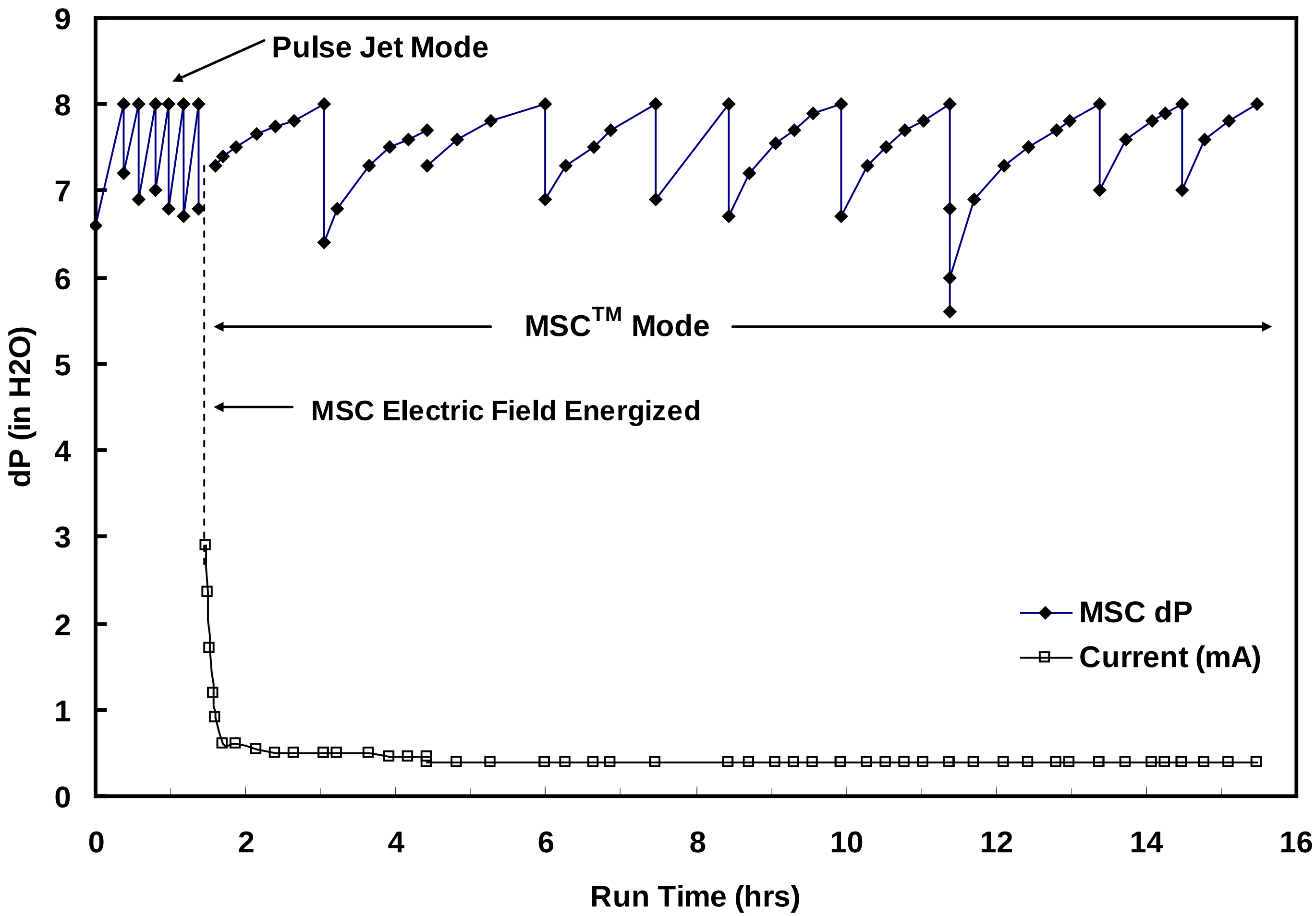
Field Off

Field On

MSC™ Pilot Tests: Pressure Drop Characteristics



MSC™ Pilot Tests: Pressure Drop Characteristics

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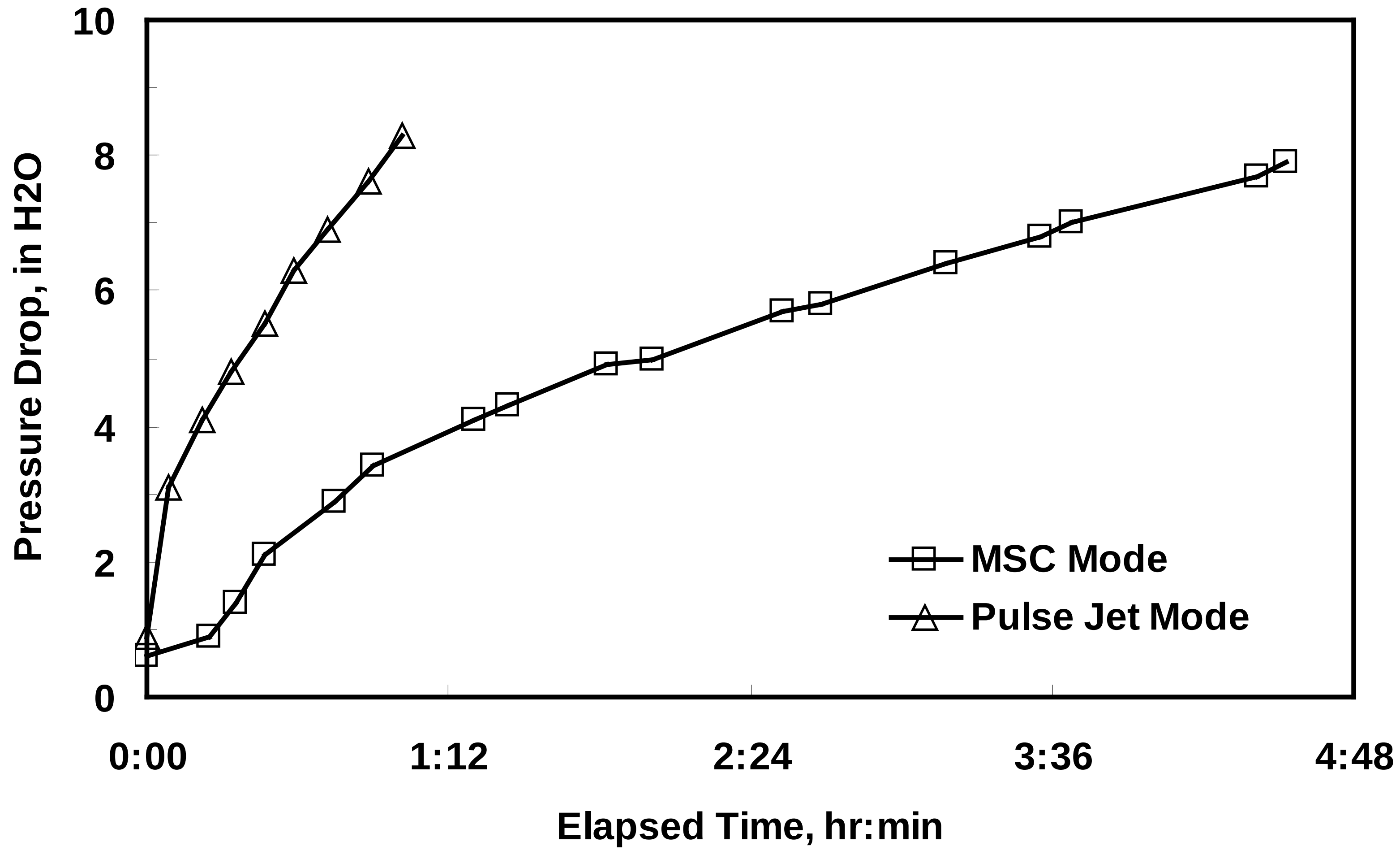

MSC™ Pilot Tests: Collection Efficiency

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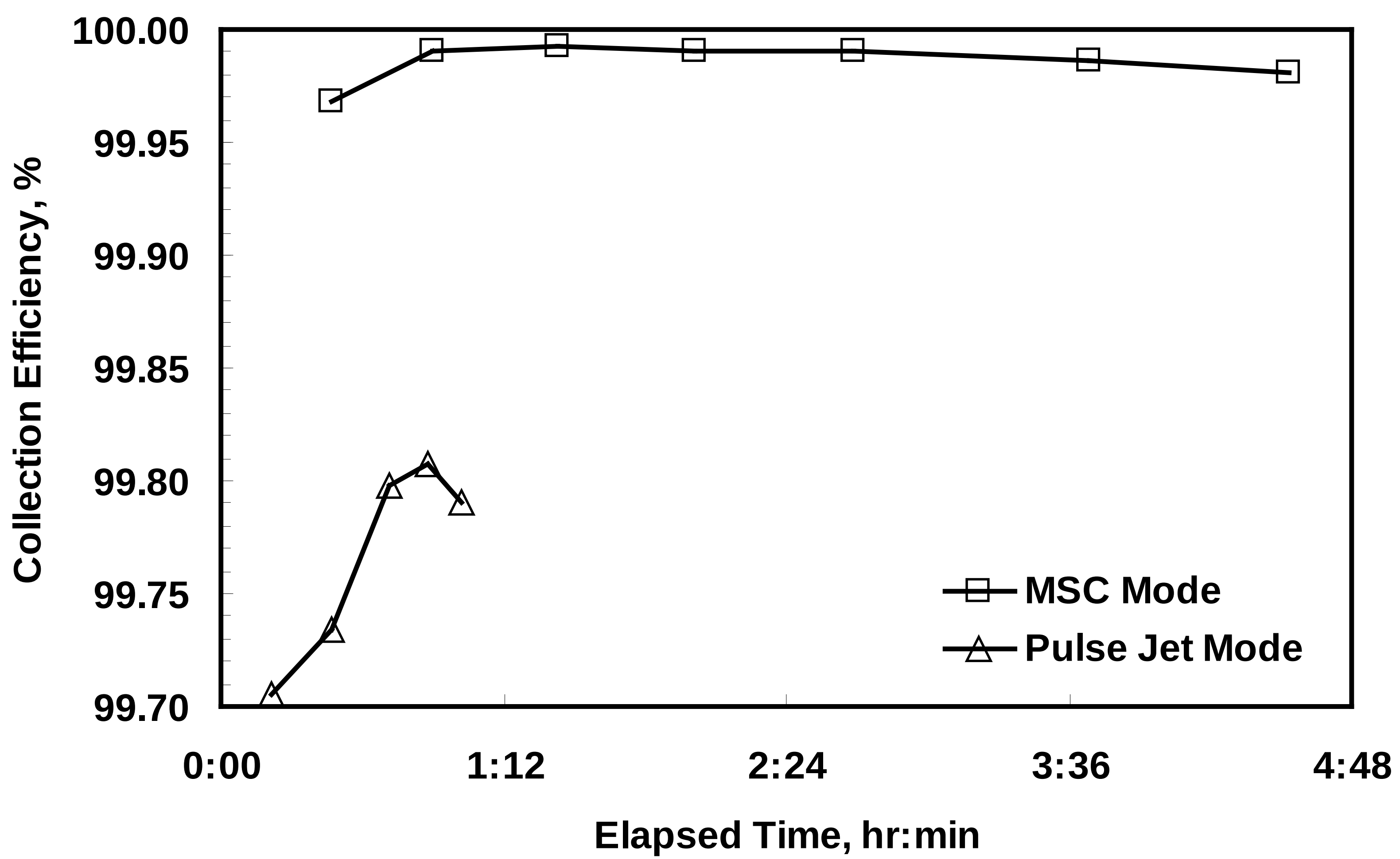

MSC™ Pilot Tests: Emissions

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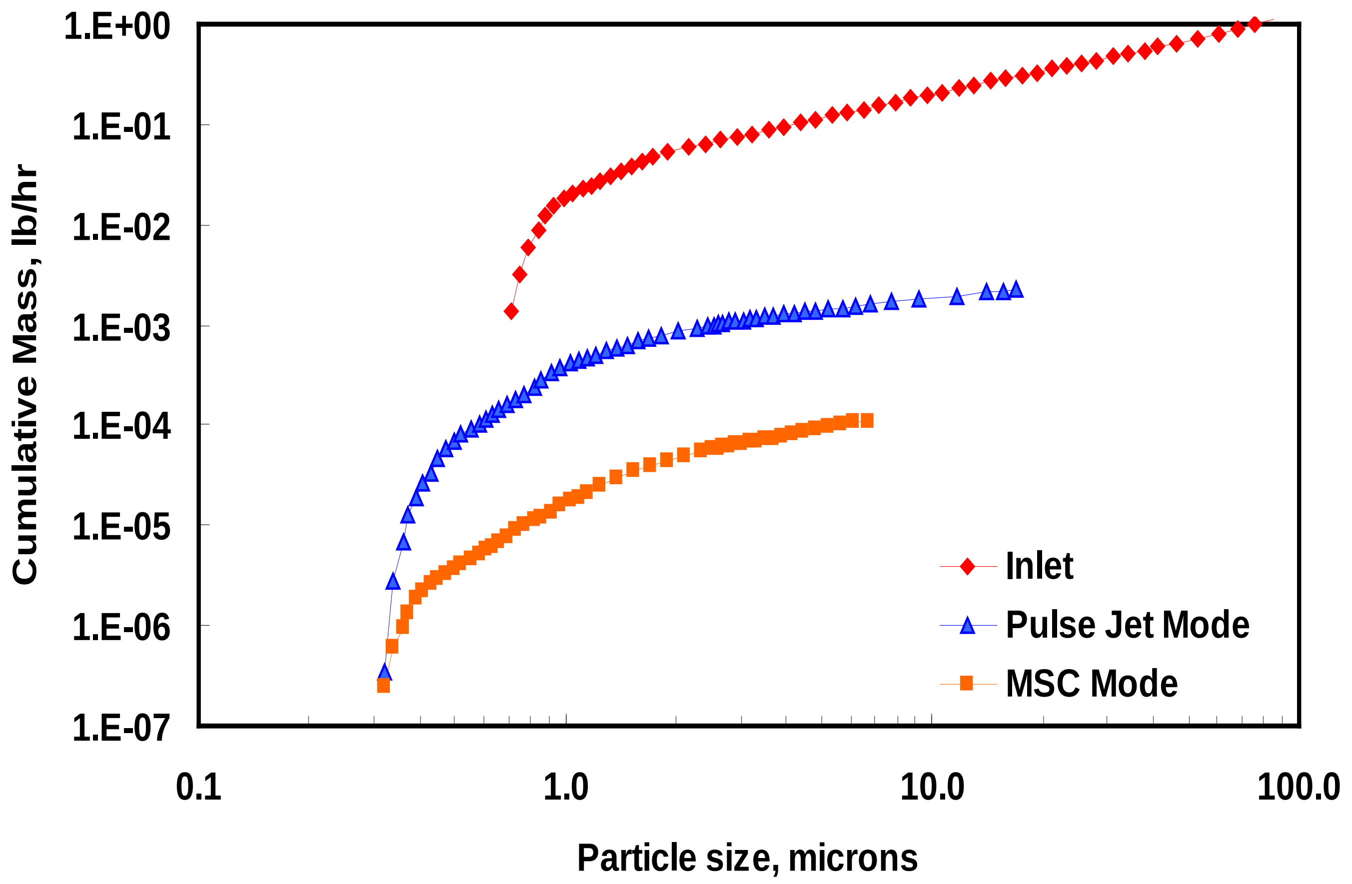
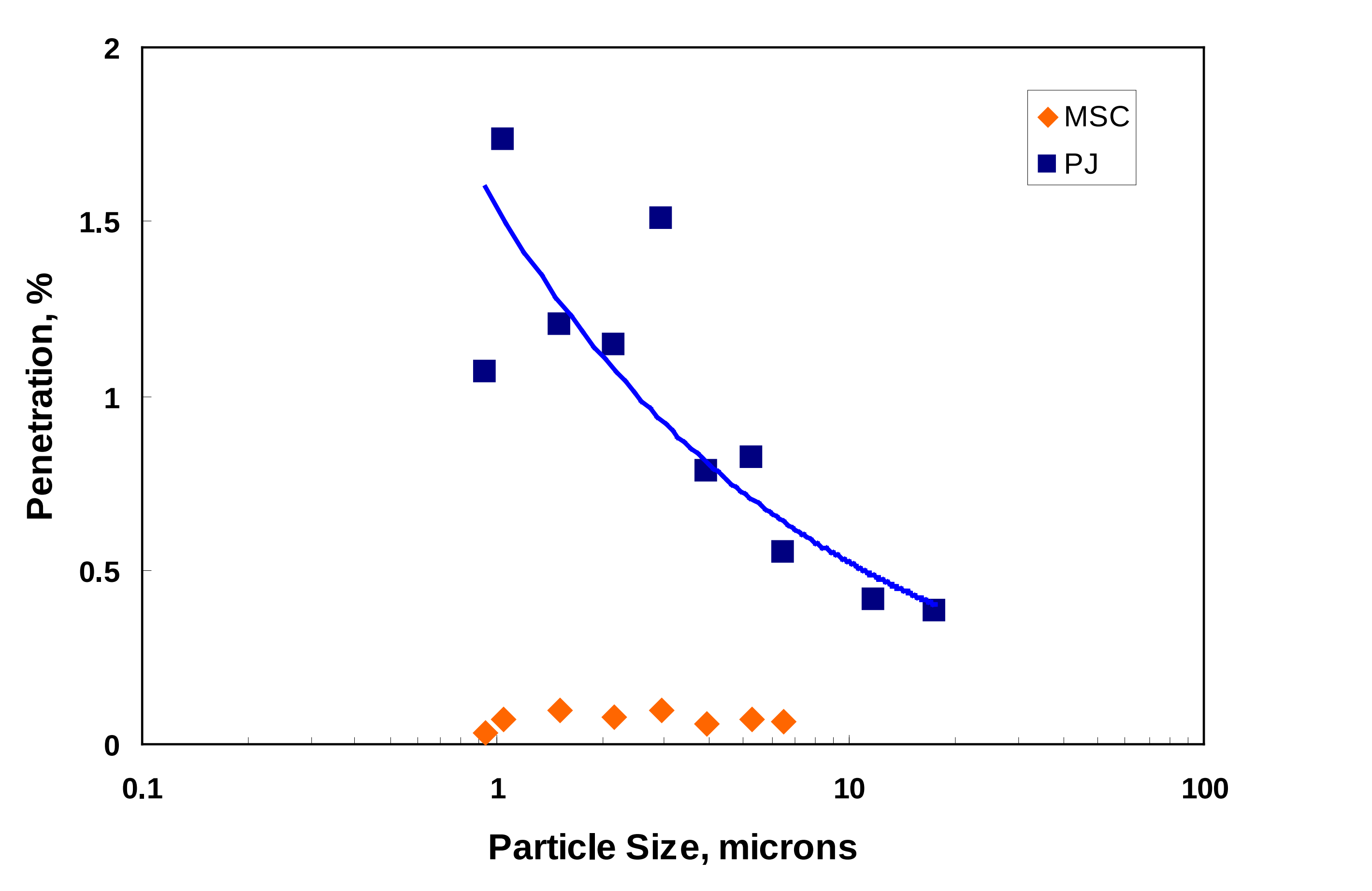


MSC™ Pilot Tests: Penetration vs. Particle Size



MSC™ Proof of Concept Pilot

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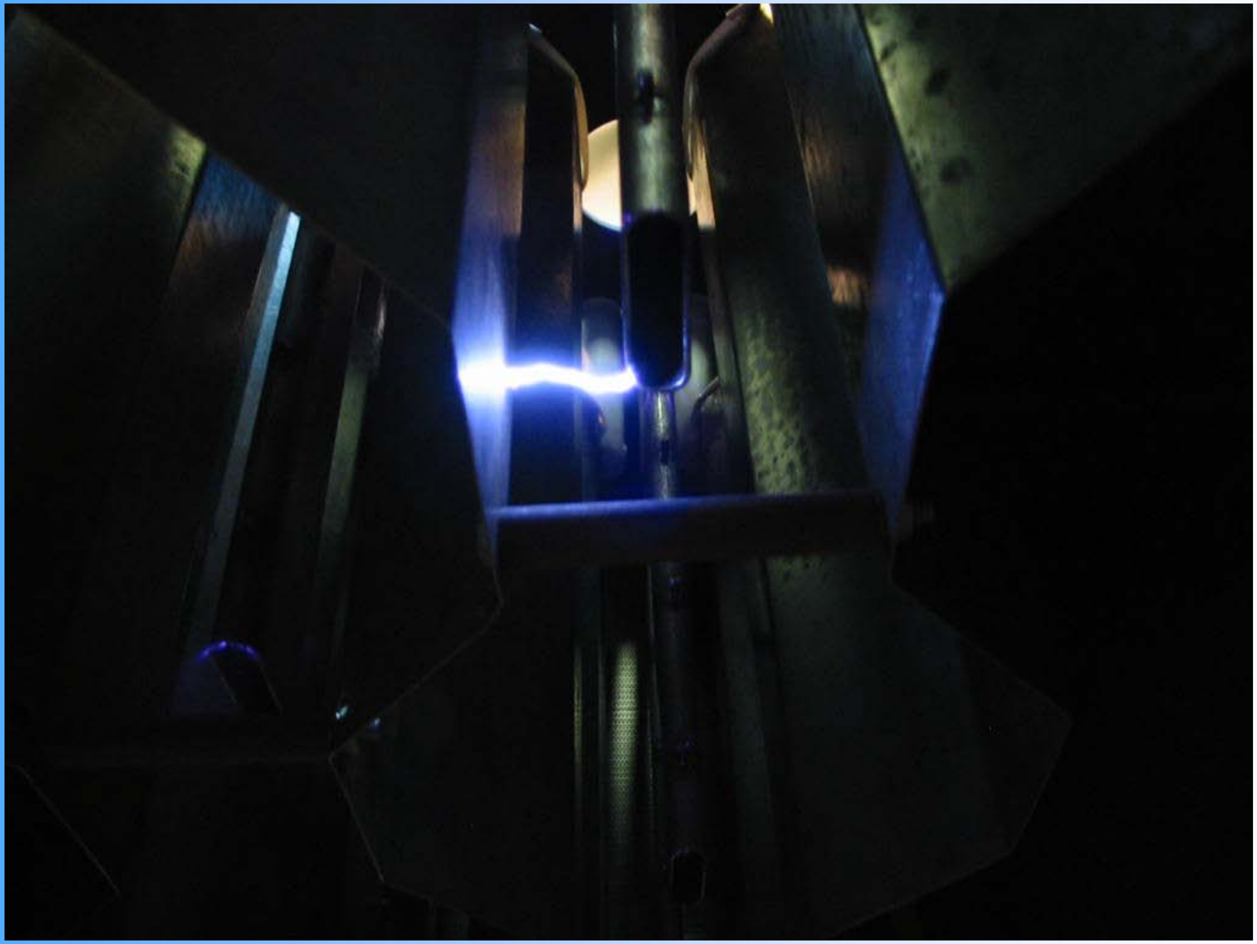
Sparking Between the Discharge and Collecting Electrodes.



MSC™ Proof of Concept Pilot

Corona Discharge

MSC™ Proof of Concept Pilot

Sparking Between the Discharge and Collecting Electrodes.

Fundamental Differences

MSC™ & Hybrid Technologies – Fundamental Differences

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- 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 filed 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

MSC^{TM} & Hybrid Technologies – Fundamental Differences

- 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

MSC^{TM} & Hybrid Technologies – Fundamental Differences

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- 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

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- 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

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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

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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

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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^{TM} & Hybrid Technologies – Fundamental Differences

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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.

MSC™ & Hybrid Technologies – Fundamental Differences

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ESFF/MSX9

- **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**

MSC™ & Hybrid Technologies – Fundamental Differences

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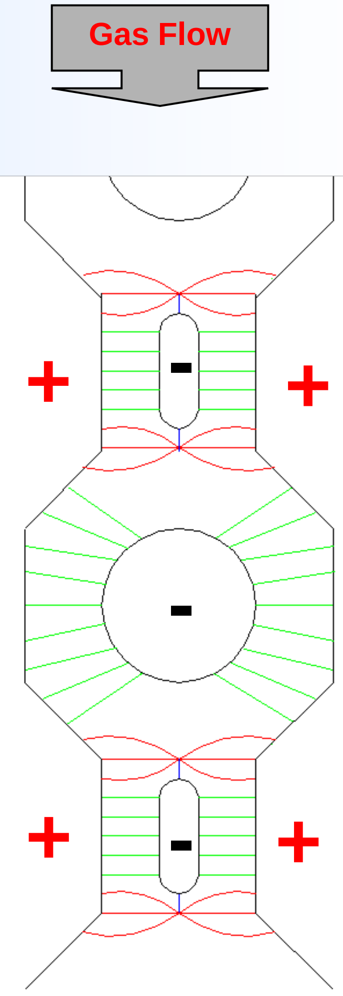
What Differentiate the MSC™ from Other "Hybrid" Technologies?

- 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.



MSC™ & Hybrid Technologies – Fundamental Differences

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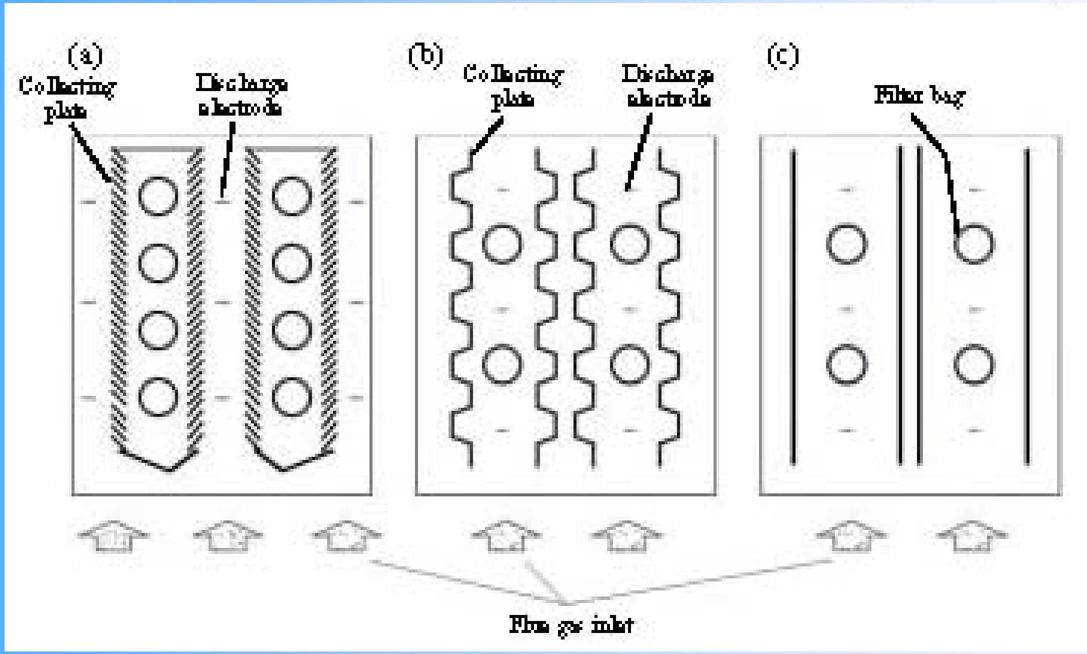
Multi Stage Collector (MSC™) Technology

- **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

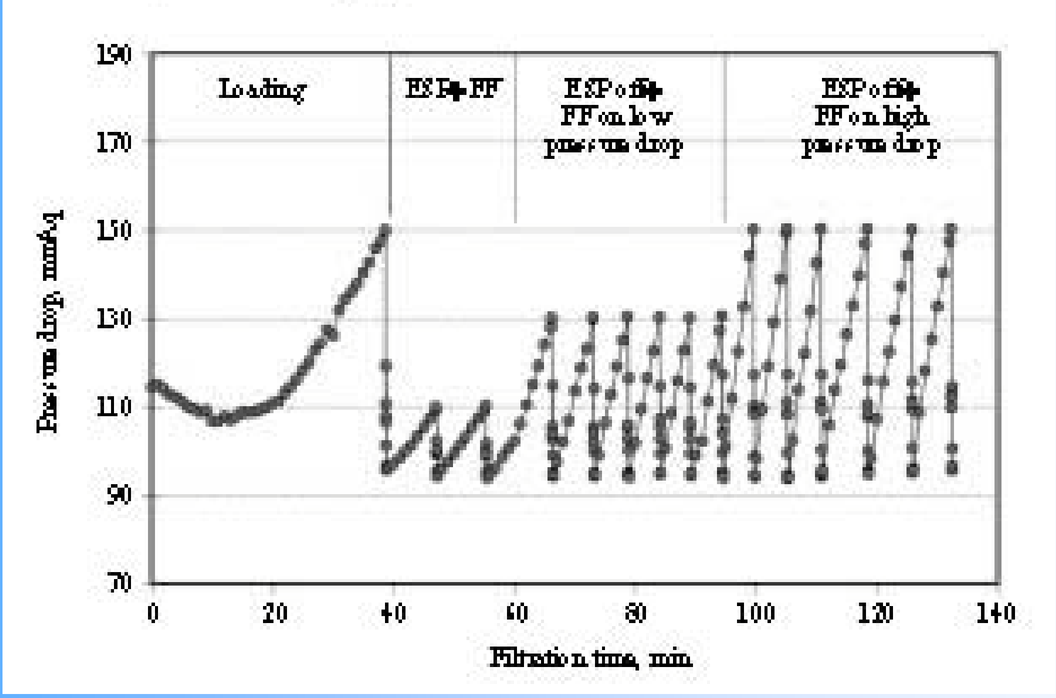
Multi-Stage Collector - MSC™

Korea Institute of Energy Research



Multi-Stage Collector - MSC™

Korea Institute of Energy Research



Multi-Stage Collector - MSC™

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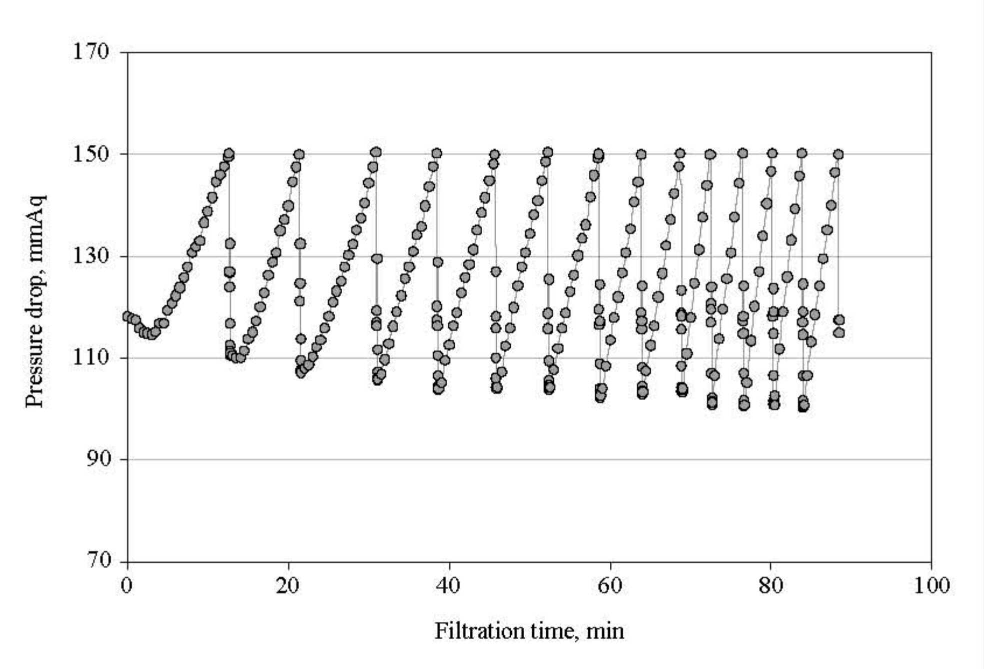

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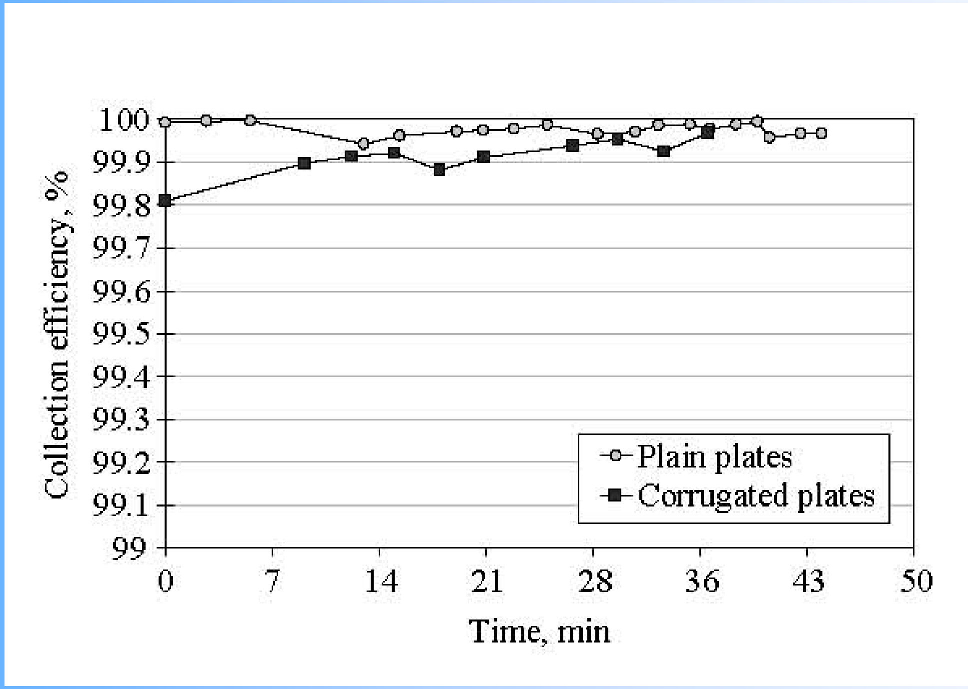

Multi-Stage Collector - MSC™

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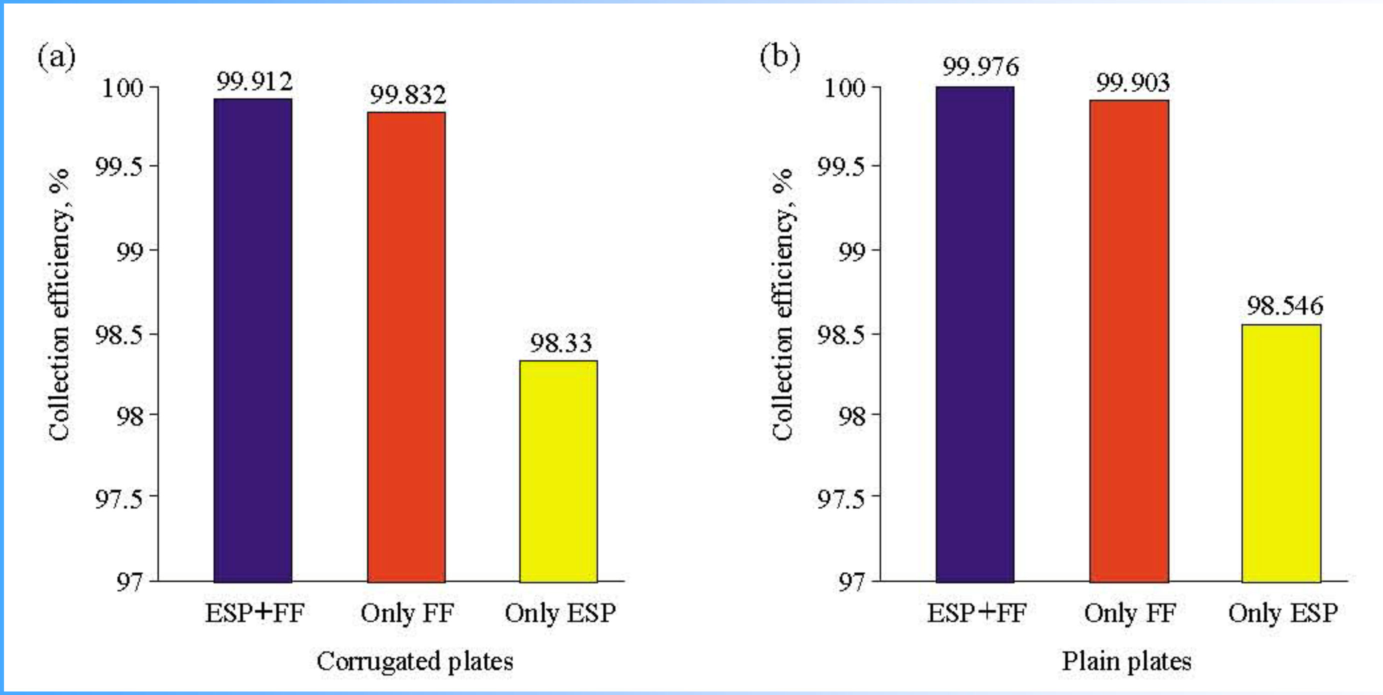

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