COMPARISON OF HIGH TEMPERATURE GAS PARTICULATE COLLECTORS FOR LOW LEVEL RADWASTE INCINERATOR VOLUME REDUCTION SYSTEMS

R. L. Moscardini
R. M. Waters
Combustion Engineering, Inc.
Nuclear Power Systems

J. R. Johnston
J. F. Zievers
Industrial Filter & Pump Mfg. Co.

ABSTRACT

Reduced burial site availability along with increasing costs for packaging, transporting, and burying low level radioactive wastes (LLRW) have resulted in the need for development of systems to reduce the volume of these wastes at the point of generation. Incineration offers the greatest degree of volume reduction (VR). In some systems, VR's of over 200:1 have been attained.[1]

Incinerator system off-gases must be treated to prevent the release of particulates, noxious gases, and radioactive elements to the environment. Fabric filters, venturi scrubbers, cyclone separators, and ceramic or metal filter candles have been used for particulate removal. Dry high temperature particulate collectors have the advantage of not creating additional liquid wastes. This paper presents a graphical comparison of different methods for filtering particles from high temperature incineration system off-gases. Eight methods of off-gas handling are compared. A much larger group may be present, but some judicious selection of different, but related systems was done for this paper based on experience with the Combustion Engineering Waste Incineration System (CE/WIS) Prototype[1]. The eight types are: Inertial Devices, Electrostatic Precipitators (ESP), Standard Fabric Bags, Woven Ceramic Bags, Granular Beds, Sintered Metal Tubes, Felted Ceramic Bags and Ceramic Filter Candles. For high temperature LLRW particulate collection in incinerator off-gas systems, ceramic filter candles are the best overall choice.

BACKGROUND

LLRW incinerator off-gas particulates are similar to, and can be correlated to, the off-gas particulates from coal pressurized fluidized bed combustors (PFBC). The federal government and the US power industry have spent a good deal of time and money reporting and studying the handling of coal combustion off-gases. Many of the references used herein are from those U. S. government & power industry studies. For comparison of typical LLRW high temperature incinerator system off-gas particulate removal, Combustion Engineering's CE/WIS prototype incinerator was used to generate ash typical of that found in power reactor LLRW. To demonstrate the validity of drawing from studies for PFBC's, Fig. 1 shows the close correlation between the particle distribution of the CE/WIS Prototype fly ash and PFBC test fly ash from the Department of Energy's pilot plant at Curtis Wright Corporation, Woodridge, New Jersey.[3]. In both cases, the fly ash is initially present in the off-gases at 900-950°C (1650-1750°F)[3, 4].

The figures that follow will graphically show the capability of the eight particulate collectors for temperature, flow, efficiency, size, and operational status.

Temperature Capability

Figure 2 shows the 8 selected candidate high temperature off-gas particulate collectors and their respective temperature capabilities. References to specific data reports are shown for each data point on the graph. This annotation method will be followed throughout the paper. Of the eight candidate devices, only ESP's and standard bag filters require significant cooling subsequent to incineration. However, in all cases, the off-gas temperature is well above the dewpoint, hence the gas remains in a dry state.

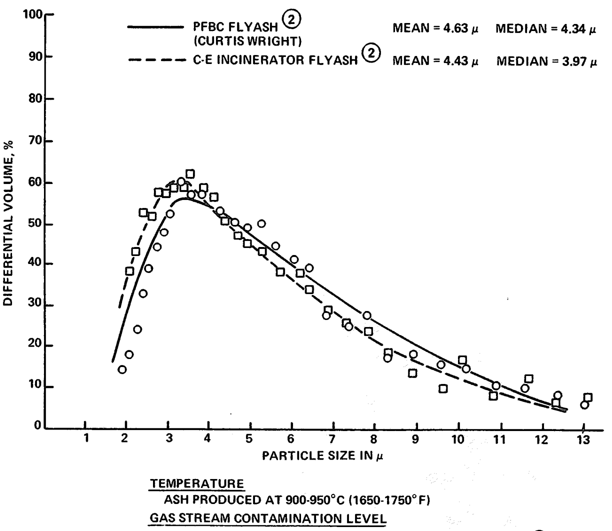


Fig. 1 Ash Comparison

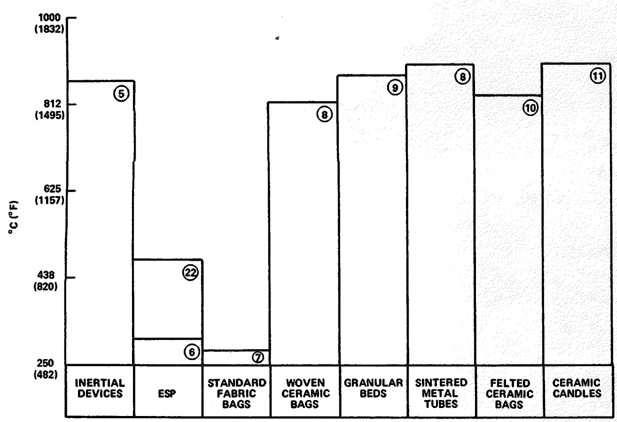


Fig. 2 Temperature Capability

General Characteristics

Some of the pertinent general characteristics of the candidates studied are set forth in Fig. 3. These characteristics include:

A. Description of the collection media itself.
B. Basic Advantages and Disadvantages.
C. Potential Functional Problems.

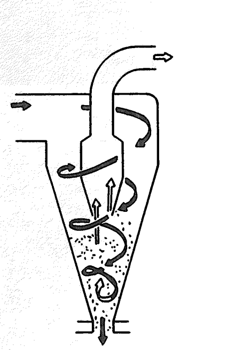
	MEDIA	ADVANTAGES	DISADVANTAGES	POTENTIAL FUNCTIONAL PROBLEMS
INERTIAL DEVICES	metal vessel centrifugal force	continuous on-line duty low cost	low efficiency	high temperature linings may be subject to errosion
ESP	electrode	low operating cost	limited high temperature operating experience	electrode system effected by high temperatures
BAG HOUSE Std.	parallel fibers on a course mesh fabric envelope felt (12)	low initial cost	temperature limitations	media failure due to low strength
BAG HOUSE ceramic	woven ceramic fibers (8)	low initial cost	unknown bag life	media failure due to low strength
GRANULAR BED	fine to coarse (13) granular particles	simple design low operating cost	low efficiency hard to clean	difficult to effectively clean without dislodging media (9)
SINTERED METAL	sintered Hastelloy "X" or other metals (8)	high collection efficiency	potential for metal corrosion, high initial cost	failure of media structure and welds
CERAMIC BAG	felted ceramic fibers (14)	low initial cost	unknown bag life	media failure due to low strength
CERAMIC CANDLE	silicon carbide (15) matrix with mineral fiber	high collection efficiency	media requires care in handling, high initial cost	requires heavy duty support structure and good high temperature sealing system

Fig. 3 General Characteristics

Particulate Collector Designs

Figure 4 shows a schematic of each of the various gas particulate collectors and their corresponding flow patterns. In each case, the dark arrows indicate the contaminated gas flow and the light arrows the clean effluent. Since the sintered metal filter is similar in design to the ceramic candle filter, the same figure is used to represent both.

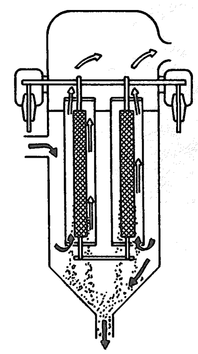
CYCLONE



Dirty gas enters cylindrical, conical chamber at high velocity. Dust particles are flung centrifugally to housing wall. Dust free gas exits via center outlet.

Limitation on efficiency and size.

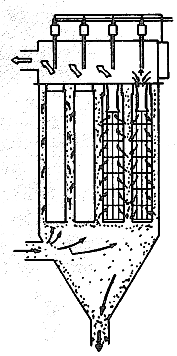
ELECTROSTATIC PRECIPITATOR



Dirty gas enters housing and escapes by passing in proximity to charged electrode. Dust is dislodged by periodically rapping the electrode.

Limitation on efficiency, temperature and face velocity.

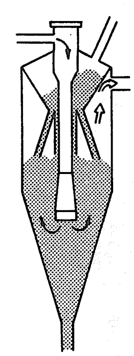
BAG TYPE



Dirty gas enters housing and escapes via woven bags of various textiles. Dust is captured on textile and removed periodicaly by a reverse jet of gas or by shaking or a combination of both.

Limitation on efficiency, temperature and face velocity.

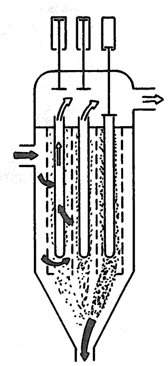
GRANULAR BED (MOVING TYPE)



Dirty gas enters housing (and granular bed) via inlet distribution. Dust is captured in and removed by countercurrently moving granular bed.

Some limitation on efficiency and face velocity.

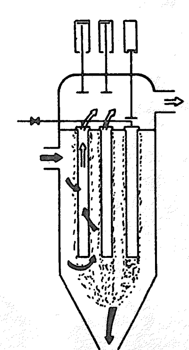
CERAMIC BAG



Metal candles covered with bags made of combination felt and ceramic mesh.

Some limitation on face velocity and temperature.

CERAMIC CANDLE (SINTERED METAL FILTER IS SIMILAR)



Dirty gas enters housing and exits via ceramic candles of controlled porosity. Individual banks of candles cleaned on HiΔp by jet pulse of controlled volume and pressure. Dislodged dust exits through bottom of vessel. Very high surface velocity feasible.

Fig. 4 Particulate Collector Designs

Face Velocity

The capacity of the various collectors to handle flow is dependent upon the gas face velocity, (Gas Flow in ACFM/Collector Area in Ft^2) and is shown in Fig. 5. Where the current literature reveals more than one face velocity, each is referenced in its relative position on the graph. Inertial devices are not properly compared in this manner since inlet velocity can be over 2300 feet per minute [22] compared to from 5 to 50 feet per minute for the other devices.

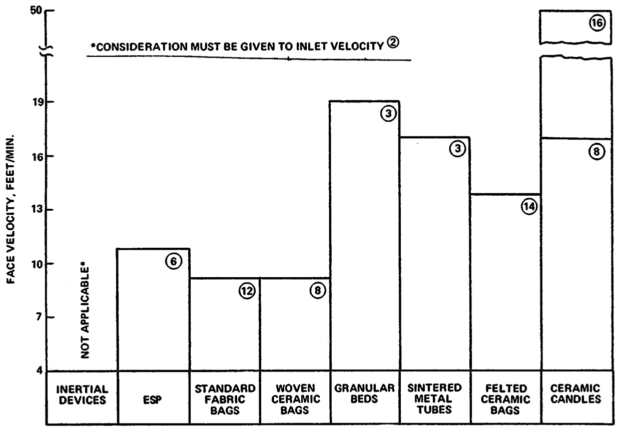


Fig. 5 Face Velocity

Efficiency Comparison

Figure 6 shows the relative efficiency of the various collectors based on the weight of particulate removed from the gas stream. Inertial devices are again a special case when considering efficiency. Since it is common to use two or more cyclones in series, cumulative relative efficiencies are indicated for one, two and three cyclones. In the case of the other candidates, the highest reported efficiency is referenced.

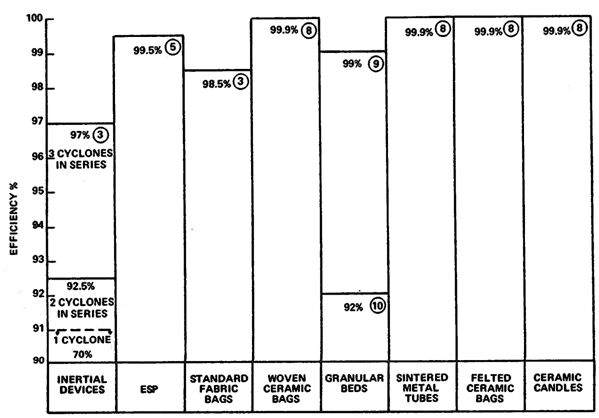


Fig. 6 Efficiency Comparison

Collector Size Comparison

The physical size of each design, Fig. 7, was calculated by taking the reciprocal of the flow per unit of collector system size expressed in ($ACFM/FT^3$) and multiplying by 1000. The result is the relative collector system size (FT^3) needed to accomodate the equipment for a unit of flow (ACFM). The smaller the value, the less space is needed for a given gas stream. Again, inertial devices require a special comment. If three cyclones in series are contemplated, the size factor would be increased by 2.65.

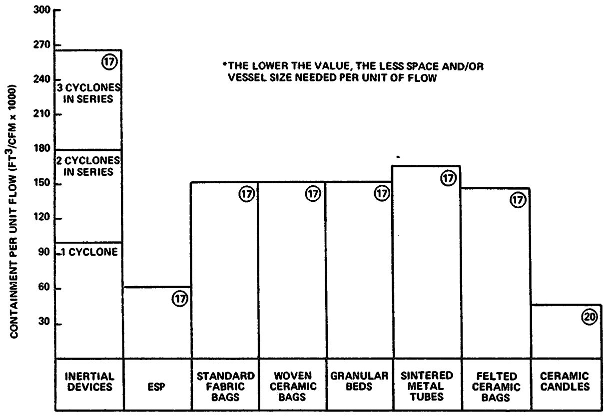


Fig. 7 Collector Size Comparison

Development Status

The development status of the various collectors is depicted in Fig. 8, based on the referenced reports.

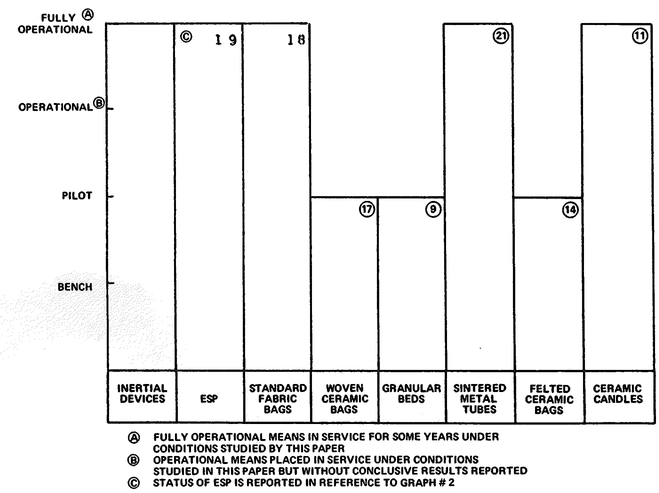


Fig. 8 Development Status

Rank Comparison of Collector Designs

Figure 9 is a summary of the collector designs ranked against each other. Those with the best features are ranked 1. Those with significantly poorer features and characteristics are ranked 3. A rank of 2 was assigned to those filter systems of average characteristics.

	INERTIAL DEVICES	ESP	STANDARD FABRIC BAGS	WOVEN CERAMIC BAGS	GRANULAR BEDS	SINTERED METAL TUBES	FELTED CERAMIC BAGS	CERAMIC CANDLES
FIGURE 2 TEMPERATURE CAPABILITY	1	2	3	1	1	1	1	1
FIGURE 5 FACE VELOCITY	N/A	3	3	3	2	2	2	1
FIGURE 6 EFFICIENCY COMPARISON	3	2	2	1	2	1	1	1
FIGURE 7 SIZE COMPARISON	3	1	2	2	2	2	2	1
FIGURE 8 DEVELOPMENT STATUS	1	1	1	2	2	1	2	1

Fig. 9 Rank Comparison

Application of a particulate collector to each incinerator system design is based on the merits of the collector design for that specific system. For example, high collection efficiency may not be of utmost importance in a system with little fly ash carryover. This is the case for off-gas systems developed for starved air incinerator designs that utilize wet scrubbers for particulate collection. For fluid bed incinerators, inertial devices are acceptable due to the typically large size of the fly ash. An excess air suspension burning incinerator system,[23] is best served with high temperature ceramic filter candles because of high temperature particulate carryover.

In all cases, the use of dry high temperature particulate collectors is preferred over wet particulate scrubbers since secondary liquid LLRW streams are not created.

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