OPERATING ECONOMICS OF AIR CLEANING EQUIPMENT
UTILIZING THE REVERSE JET PRINCIPLE

William B. Harris
Health and Safety Laboratory
U. S. Atomic Energy Commission

and

Mont G. Mason
Health Physics Department
Mallinckrodt Chemical Works

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ABSTRACT

Plant experiences with the operations of 18 dust collectors is described. This equipment, supplied by two different manufacturers, is in continuous operation in one plant. The units are operated at housing pressures from 2" of water to 10" of mercury with capacities from 700 cubic feet per minute on pneumatic conveying to 12,000 cfm on dust control. The total designed capacity is 110,000 cfm.

Dust loading varies from 0.002 grains per cubic foot to 32 grains per cubic foot, with an average of 5 grains per cubic foot. Discharge air measures 0.0001 grains per thousand to 0.41 grains per thousand with an average of 0.16. Average cleaning efficiencies range from 99.946 to 99.9996 with an average under all conditions of 99.986. Overall annual cost, including five-year amortization, is 0.32 dollars per year per cfm for all equipment and 0.23 dollars per year per cfm for suitably designed equipment. This compares with three large wet collectors which have been described. They operate at 93.5% collection with an annual cost of 0.197 dollars per cfm. Maintenance costs of the wool felt collectors alone amount to 0.12 dollars per year per cfm for all units and 0.042 dollars per year per cfm for 14 adequately designed collectors.

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With the obsolescence of the war-built equipment for the refining and processing of uranium, it has been necessary to design replacement facilities. While the heavy stress of production was being carried by existing plants, it was possible to give adequate study to the many problems before settling on new plant designs.

Among the areas requiring special attention, the control of inplant and outplant pollution received intensive engineering consideration. This included:

1. The design of process controls and equipment to reduce exposures to potential toxic materials to within specified limits.

2. The design of adequate replacement air facilities to make up for that which would be removed by ventilation.

3. The design of air cleaning equipment to provide for minimum process losses and a clean external environment.

Experiences which had been gained in the many plants which cooperated in the production of uranium materials were carefully examined in every design area. On the basis of these experiences, it became obvious that the major problem in the choice of air cleaning equipment for operations of this type was to find equipment which would efficiently remove airborne dust from exhaust system effluents. The process and the material were such as to dictate dry collection as the preferable means of dust separation. Particle size and dust concentrations in all cases were comparable to usual industrial loadings.

CHOICE OF EQUIPMENT

On the basis of our experience with the collection of this type of dust, the following criteria were applied to the choice of equipment:

1. To attain the high efficiencies required both by health standards and process accountability, electrostatic precipitation was considered uneconomical.

2. Inertial and scrubber type air cleaners were found to be inherently of too low efficiency for most of the materials to be removed.

3. Deep-bed filters were discarded as not having sufficient holding capacity nor would they permit satisfactory recovery of the material for reprocessing.

4. Any kind of well designed and constructed cloth filter arrestor was believed to be adequate for this job.

After a careful investigation of commercially available cloth collectors, it appeared that conventional equipment had several basic disadvantages for our type of operation. Briefly, these were:

1. Under our conditions of use, this equipment required a degree of maintenance in man hours per year which resulted in unacceptably high radiation dosage to maintenance personnel. The only protection possible against exposures of this type is uneconomical shifting of personnel to reduce the duration of exposure.

2. The same thing is true of dust exposures to these toxic materials. Although in most cases, this type of exposure could be reasonably well controlled through the use of personal respiratory protection; this type of protection is, in our opinion, undesirable.

3. Our experience showed relatively high out-of-service time resulting either in process or sometimes plant shutdown with the alternative of large unnecessary loss of valuable product.

4. The fluctuating collector pressure drop of the conventional dust collector required either exhaust system overdesign, or the operation of the system at low efficiency during a portion of the cycle. In either case, this resulted in a diminished economy and generally in some loss of product either through increased carry-off or increased dispersion into the working environment.

5. A study of plant effluents revealed that large bursts of dust found their way outside of the plant immediately after filter cleaning.

In our attempt to reduce these deficiencies, we investigated the use of reverse jet air cleaning equipment. Installations were made on small extremely difficult units and considerable experience was gained. As a result of experiences with the operation of these few early dust collectors, the decision was made to standardize on the use of wool felt, reverse jet type, air cleaning equipment in all cases where high efficiency of collection was required and where the material being handled was dry dust. Other types of collectors have been used under other conditions. However, the purpose of this report is to describe the experience of one plant in the use of this type of air cleaning equipment.

The information presented in this report covers the operation of 18 dust collectors built by two different manufacturers, all under the Hersey patent. These dust collectors are in continuous operation at the Mallinckrodt Chemical Works, Atomic Energy Commission plants.

SUMMARY

The following data summarize the conditions of operation:

1. They are operated at housing pressures varying from 2" c · cer to 10" of mercury, vacuum.

2. The individual capacity range is from 700 cubic feet per minute on a pneumatic conveying system to 12,000 cubic feet per minute on a simple dust control application.

3. The total design capacity of all of these machines is about 110,000 cubic feet per minute.

4. The average operating dust load for the individual collectors covers the range of from a minimum of 0.002 grains per cubic foot to a maximum of 32.0 grains per cubic foot. A peak dust load in excess of 100 grains per cubic foot occurs in the one pneumatic conveying system. The overall operating average dust load is about 5 grains per cubic foot.

5. The discharge air from the individual collectors under full dust load conditions contains dust concentrations ranging from a minimum of 0.0001 grains per 1000 cubic feet to a maximum of 0.41 grains per 1000 cubic feet. The overall average being about 0.16 grains per 1000 cubic feet. The data include the filter for the pneumatic conveying system as well as all process dust control filters. It should be noted, however, that they represent normal operating conditions (including cleaning cycles) but do not take into account unusual losses through the collector from abnormal operations such as excessive seepage or bag failure.

6. The average cleaning efficiency found during the two-year study period on individual collectors in the group has ranged from a minimum of 99.946% to a maximum of 99.9996% with an average efficiency for all machines under all conditions of test of 99.986% for the same period.

7. The overall costs for operating this equipment including a five-year write-off on initial installed cost and all labor and material maintenance comes to 0.32 dollars per year per cubic foot per minute. This, however, is not an accurate presentation of the facts as this number includes a cost of over $3 per year per cubic foot per minute for a single grossly undersized dust collector to an average of $0.23 per cubic foot per minute per year for equipment of adequate design.

8. Maintenance costs alone amount to $0.12 per year per cubic foot per minute when all units are included, and 0.042 dollars per year per cubic foot per minute for equipment of adequate design.

PILOT INSTALLATIONS

The first Hersey type filter installed at the plant was designed for an air/bag ratio of 20 cfm per square foot of filter surface. A number of small mechanical problems required correction before this machine gave satisfactory service, but once these corrections were made, it did do a very good job of air cleaning. Measurements made under operating conditions showed an average grain loading of 2.02 grains per cubic foot with an average cleaning efficiency of 99.977%. Within twelve months after the beginning of successful operations with this machine, two more machines were installed.

The second installation was also designed for 20 cfm per square foot, but before it could be completed, the process equipment was revised so that it became necessary to operate this machine at about 28 cfm per square foot in order to obtain satisfactory dust control. After start-up this machine was found to have dust loadings as high as 32 grains per cubic foot.

The third machine was installed as a final filter on a pneumatic conveying operation; it operates at an air/bag ratio of 17 cfm per square foot and an average grain loading of 14 grains per cubic foot with peaks exceeding 100 grains per cubic foot. This machine has given good cleaning efficiency, but maintenance problems have been excessive, indicating some deficiency in design. Certainly, for a collector of this design the dust and pressure loads are too high for the available filter.

In both of these latter filters the differential pressure across the filter was found to range from four to ten inches water gauge, even with continual operation of the reverse jet blow ring. Under the conditions as stated, bag life on both of these machines averaged about three weeks of operating time. There was found to be excessive stretching of the bags from the high differential pressure. This, combined with continuous blow ring operation, caused both the bags and the blow rings to wear excessively.

The experience gained with these three machines indicated that satisfactory cleaning could be done at an air/bag ratio of 20 cfm per square foot; however, it was apparent that when dust loadings were high enough to cause excessive pressure drops across the bag; the life of the filter would be shortened and maintenance would be high.

FIRST PRODUCTION GROUP

The next seven machines installed were designed to operate at a dust loading of approximately 1 grain per cubic foot of air, with air/bag ratios not to exceed 20 to 1. Many additional features were incorporated in this group of seven machines to eliminate some of the shortcomings which had developed with the first three installations.

Performance tests on these seven machines under operating conditions showed that six of them were doing a very satisfactory job of cleaning; the lowest efficiency found being 99.990%. The seventh machine, however, did not give completely satisfactory service, despite the fact that the air/bag ratio was only 17.5 to 1, with a dust loading of 4.2 grains per cubic foot. Extensive experimental work with this last machine established that the dust being handled is a "seeper" which migrates through the filter medium resulting in excessive losses. After several changes, a special resin treated felt which resulted in satisfactory operation was finally obtained from the supplier of the collector. However, this machine still gives as much trouble from a maintenance standpoint as any two other collectors of this group of seven.

SECOND PRODUCTION GROUP

Experience gained with this first group of machines resulted in the selection of a lower air/bag ratio for subsequent installations. Most of the collectors installed since that time have been designed to have an air/bag ratio not to exceed 15 cfm per square foot. The eight collectors installed since then have given very satisfactory long term operation.

MAINTENANCE PROGRAM

A preventive maintenance schedule provides for a daily inspection of all collectors and charts by production personnel. The Maintenance Department inspects each machine bi-weekly for mechanical conditions of bags, blow rings, suspension chains, drive sprockets, blow ring air supply tubes, etc., paying special attention to the following:

1. Blow rings must remain smooth and level to avoid excessive bag wear.

2. Bags must be maintained taut to avoid sagging or bulging.

3. Contact between blow ring and bag must be correct.

4. The blow ring air supply hose must be good to assure that bags are properly cleaned.

5. Canvas wear strips over sewed seams in the bags must remain in place to avoid splitting the bag from blow ring wear.

The Maintenance Department has assigned to one man the sole responsibility for all dust collectors; he has learned the problems of each individual machine and usually anticipates trouble before it happens. This policy has proved most advantageous.

Maintenance requirements for the eighteen collectors averaged 2 1/2 man days per week over a two-year period. If only 14 machines are included, this is a 1 man day/week. This covers both repairs and preventive maintenance.

With the exception of the three troublesome units previously discussed, maintenance problems have been minimal: however, none of these collectors can be expected to give continual good operation over long periods if allowed to go completely untended. It has been found desirable to provide safeguards in the form of instrumentation, a thorough inspection program and a preventive maintenance program in order to assure good continuous operations.

INSTRUMENTATION

All reverse jet collectors at the plant are now provided with pressure control instruments to provide intermittent blow ring operations; this instrumentation is of the recording type so that inspection of the charts immediately reveals abnormalities in operation. Optimum pressure setting maintains a pressure differential across the filters of between three and four inches water gauge. Electric eye dust detectors have been installed in the discharge stack of all collectors to detect bag failure. Thermocouples are installed in the housing of all collectors handling heated gases to provide an alarm and to safeguard againsts rises above permissible filter temperatures (175°F).

MAINTENANCE

The average downtime for sixteen of the collectors including preventive maintenance, has been less than two hours per month per machine. For the two remaining collectors downtime has averaged about two hours per week per machine; these machines are the pneumatic conveying system collector and the one other heavily loaded machine.

Average bag life for all machines included in these data was eight months per bag. However, this number does not correctly illustrate the true usage picture because it includes the high usage of the underdesigned pneumatic system and ore crushing system collectors, as well as the high usage on the seeper before the special resin treated felt was installed. The following breakdown shows actual usage by groups of machines.

Machine	# Machines	No. of Bags	# Bags Replaced/ 2 Years	Bag Life Months/Bag
Pneumatic System	1	1	70	0.33-1.5 wks
Ore	1	2	49	1
"Black"	1	4	16	6
"Orange"	1	4	16	6
Others	14	52	29	43
TOTAL	18	63	180	8

Since these data were collected, a new collector has been installed on the pneumatic conveying system. Although there are still some bugs in this system, bag life is now approximately two months. Further improvements to the system, now underway, are expected to extend this number to six months.

Plans to increase the size of the ore room collector were cancelled because recent process changes reduced both dust load and usage of this machine so that bag life now exceeds six months.

The special resin treated felt has produced satisfactory operations on the seeper and it is not planned to make further changes to this system.

ROUTINE MAINTENANCE PROBLEMS

1. Wear of supporting chains and drive sprockets results from excessive blow ring operation, from misallignment, and from faulty equipment design. Chain or sprocket slippage will cause cocking of the blow ring which in turn may tear up the filter medium and may cause breakage of the blow ring.

2. Failure of blow ring air supply hose due to excessive operation of the blow ring and/or poor allignment of air outlets on the side of the collector housing --- will result in failure to clean the filter medium which in turn causes excessive pressure drop across the bag with resultant bursting of the bag.

3. Excessive blow ring operation due to underdesign of equipment or to changes in ductwork - continuous blow ring operation causes unnecessary bag wear and low collection efficiency. This in turn causes frequent bag changes and high effluent dust loadings.

4. Faulty blow rings, i.e.: warping of the blow ring; improper manufacture, and poor selection of blow ring material; erosion of the blow ring surface, or buildup of residue on the face of the ring causing localized wear of the bag which eventually results in splitting. The material of choice for blow rings is stainless steel with overlapping staggered slots. It has been found that very few dusty materials will adhere to stanless steel and the hardness of stainless steel minimizes surface flaws.

5. High temperature will result in rapid degeneration of the wool fibers, which in turn cause frequent bag failure. Exhaust systems should be designed so that collector housing temperatures do not exceed 175°F.

6. Some chemical fumes may result in splitting of the bags at the seam due to acid or alkaline action on the material used to sew the seam. Wool felt is moderately resistant to both mild acids

and mild alkalines. However, the material used for stitching the seam should be selected to resist the particular chemical fume present. Nylon stitching has been found satisfactory for alkaline fumes and orlon stitching is satisfactory for acid fumes.

7. Poor clamping of the bag to the bag collar resulting in the bag tearing loose at high pressure differentials, with a resultant high loss of material in the effluent air stream.

8. Stretching of bags usually due to excessive temperature or excessive pressure drop across the bag --- the bag should be pulled tight at frequent intervals to avoid lapping of the filter media beneath the blow ring. This eventually results in creasing and splitting of the bag.

COSTS

Total maintenance cost for all machines during the two year period is summarized as follows:

Total bag cost for 180 bags	$16,500.00
Blow ring hose	1,800.00
Miscellaneous parts	2,000.00
Maintenance labor	6,300.00
	$26,600.00/2 years or $13,300.00/year

110,000 cfm @ $13,300/year = $0.12/year/cfm.

Operating costs may be computed on the basis of $13.90/1000 cfm or $1400 for 110,000 cfm. Assuming a five year write-off and using $1.00/cfm as installed collector cost, the total annual cost for all machines is:

22,000 + 1,400 + 13,300 = $36,700

or $0.335/year/cfm.

Cost for maintaining new design equipment is obtained as follows: Operating costs for 14 machines:

Total bag cost for 29 bags	$3,900.00
Miscellaneous parts	1,500.00
Maintenance labor	2,400.00
	$7,800.00/2 years or $3,900/year

93,000 cfm @ $3,900/year = $0.042/year/cfm.

A calculation similar to that made previously shows, for the 14 well designed machines:

Operating Costs	$ 1,300.00
Maintenance Costs	3,900.00
Amortization	18,600.00
	$23,800.00

or $0.256/year/cfm.

The following conclusions may be drawn from the above data:

	All Collectors	Well Designed Units
Man hour/week for maintenance	2 1/2	1
Downtime - hours/month/machine	3	2
Bag life - months/bag	8	43
Total cost - $/year/cfm	0.335	0.256
Maintenance cost - $/year/cfm	0.120	0.042
Total cost - $/ton material handled	6.50	5.00
Maintenance & operating costs - $/ton	2.50	1.00

An interesting comparison can be drawn between the operation of these dust collectors and that of three large wet collectors recently reported by Bloomfield*. These three units were high efficiency wet collectors with a cumulative capacity of approximately 52,000 cfm. Installed cost of these collectors is $38,600 or 0.74 dollars per cfm. On the basis of the data given, the annual cost of these collectors, neglecting maintenance is:

Operating Cost (assuming power at an average cost of 5 mils)	$ 2250.00
Maintenance	--
Amortization	8000.00
TOTAL	$10250.00 or 0.197 dollars per year per cfm.

The overall average efficiency of these collectors operating on an average dust load of 1.70 grains per cubic foot is 93.5%.

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* "Efficiency Studies on Three Wet Type Dust Collectors", Heating and Ventilating, Volume 51, No. 4, Page 89, Bernard D. Bloomfield.

It can be seen from the above data that any cost advantage is lost when the material being collected can be valued at $16.00 a ton or more.

It is also interesting to note that the installed cost of collector A operating at 89% was .64 dollars per cfm, while collector C which had an average efficiency of 97% cost 1.20 dollars per cfm.