Removal of Particulate Matter from Air by Various Pollution Abatement Systems[1]

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ABSTRACT

To design proper pollution abatement systems, we must understand the causes of air pollution problems. The particle size from some industrial air contaminants, the proper selection and use of devices for contaminant removal, and several pollution control case histories are described in this paper. Also, design criteria for air vent systems are discussed. The application of the systems engineering approach to handle pollution abatement problems and the recommendations for this approach are described in this paper.

INTRODUCTION

Ecology and air pollution abatement are of prime concern to all of us. To stay in business, industry must comply with Environmental Protection Agency and other governing body regulations. It is becoming increasingly difficult to obtain variances from governing bodies. As this decade continues, additional pollution control legislation will be passed and more stringent measures will become effective. How shall we meet this challenge?

We must understand the causes of air pollution problems before we can consider potential remedies. To do this, this article will discuss particle size of some industrial air contaminants, proper selection and use of devices for contaminant removal, and several pollution control case histories.

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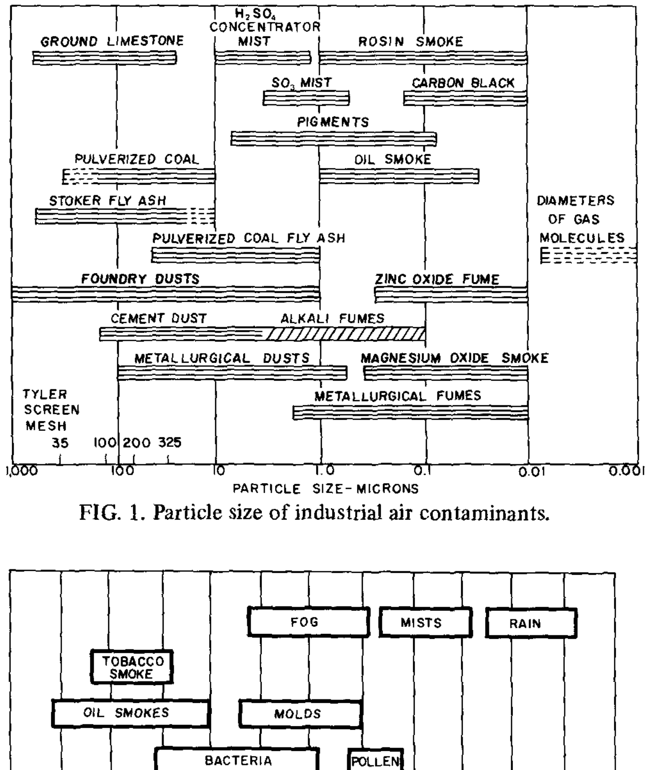

FIG. 1. Particle size of industrial air contaminants.

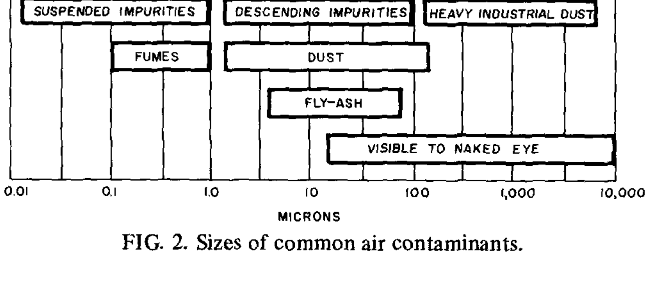

FIG. 2. Sizes of common air contaminants.

PARTICLE SIZE AS RELATED TO CONTAMINATE REMOVAL DEVICES

Figure 1 (1) shows the particle size range in μ of typical industrial air contaminants. For large size particles, the comparative Tyler screen size also is shown. The particle sizes of several industrial contaminants are worthy of special mention (Table I).

Figure 2 (2) shows additional comparative sizes of common air contaminants–industrial, natural, and household. Particulate matter of ca. 10 μ and larger is visible to the naked eye. Organic (aerosol) smokes from 3-sub μ particle size also can be seen by the human eye, not as discreet particles, but as a blue (or smoky) haze.

Figure 3 (3) illustrates some fundamental principles employed in the selection of devices to remove stack gas contaminants. The type of contaminant, particle size and concentration, gas temperature, face velocity, and removal efficiency must all be considered to ensure that the right device can be selected. To remove 99% or better of small particulate matter from stack gases, it is usually necessary to employ absolute or industrial filters, Venturi scrubbers, or deep bed gas absorbers. With the exception of high pressure drop Venturi scrubbers, these devices normally operate at relatively low face velocities. Electrostatic precipitators, direct or catalytic incinerators, and various types of gas absorbers can be operated at medium face velocities to achieve up to 95% removal of particulate matters. The dry inertial cyclone, perhaps the most common removal device, can be operated at relatively high face velocities, but its efficiency is usually lower than that of other devices. However, high and ultra high efficiency dry inertial cyclones have been employed at efficiencies

Name of device		Removable contaminants	Optimum size particle microns	Optimum concentration grs./cu.ft.	Limits of gas temp °F	Usual face velocity FPM	Through	Usual efficiency % by wt
Absolute filters	Paper--asbestos	Special	<1	<0 001	0 – 1,800	4 – 6	Paper	>99.95
Industrial filters	Cloth bag		>0 3	>0 1	0 – 180	1 – 30	Fabric	>99
Electro. precip. high voltage	Single stage, plate		<2	>0.1	0 – 700	180 - 600	Plates	<95
Dry inertial collectors	Cyclone Multiple-cyclone	Dusts, fumes, smokes, mists	>10 >5	>1 >1	0 – 700 0 – 700	2,000 - 4,000 2,000 - 4,000	Inlet Inlet	<80 <90
Scrubbers	Cyclone Venturi Submerged nozzle		>10 <2 >2	> 1 >0.1 >0 1	40 – 700 40 – 700 40 700	2,000 – 4,000 12,000–24,000 2,000 – 4,000	Inlet Throat Nozzles	<80 <99 <90
Incinerators	Direct Catalytic	Gases, vapors, malodors	Any (molecular)	(Combustible) any	2,000 1,000	500 – 1,000 500 – 1,000	Chamber Chamber	<95 <95
Gas absorbers	Spray tower Packed column Fiber cell		(Molecular) (Molecular) (Molecular)	>0 001 >0.001 >0 001	40 – 100 40 – 100 40 – 100	300 – 800 500 – 1,000 200 – 300	Lower Bed Cells	<95 <95 <95
Gas adsorbers	Deep bed		(Molecular)	>0.001	0 – 100	20 – 120	Bed	<100

FIG. 3. Selection of devices to remove stack gas contaminants.

TABLE I

Particle Sizes of Several Industrial Contaminants

Rosin smoke	0.01-1μ
Pulverized coal fly ash	1-80μ
Cement dust	8-200μ

higher than 95%. How can engineers and plant supervisors in operating companies help select and maintain these removal devices?

Operating companies must obtain thorough data on every polluting air effluent and its source so that others can make effective pollution abatement recommendations. Likewise, operating companies should help anticipate future pollution problems and keep abreast of new developments and environmental legislation. Their pollution control manager should insist on periodic inspections and maintenance specifically directed toward pollution control. In the past, the equipment and instrumentation installed for pollution abatement frequently have not been maintained adequately. Hence, it is strongly recommended that operating companies remedy this situation promptly.

DESIGN CRITERIA FOR AIR VENT SYSTEMS

The attitude and pressure for low price, regardless of quality, must be abandoned for pollution abatement and other chemical process systems. Pollution control is a major factor in profits and is unrelenting with respect to quality and performance. The design and selection of pollution abatement systems should be by experts, not by amateurs. Often some pilot plant work may be extremely important. Some of the design criteria for air vent systems are: (a) take process vents from points where least concentrations of particulate matter occurs (provided that this point permits pick-up of sufficient dust from the area of concern to meet all OSHA requirements); (b) minimize particulate matter concentrations by using low velocity pick-up points; (c) keep air transfer lines under negative pressure whenever practical; (d) provide instruments and controls for alarming or correcting a system malfunction in the control room which could result in abnormally high pollution (some typical malfunctions are: (bag failure in a bag collector, low flow rate in an inertial separator, power failure in an electrostatic precipitator, saturation of an adsorption filter, and plugging or nonrotation of a cyclone lock); (e) minimize vent volumes by eliminating unnecessary openings and air leakage points; (f) consider the cumulative effect of small amounts of 10 μ and under particles when selecting a filter; (g) give particular attention to air effluent discharge design and location from health, safety, and operational standpoints (both for normal and abnormal operations); and (h) perform the most important task by making a "systems engineering analysis" to determine the cause, magnitude, and most practical solution to a pollution problem (such a systems engineering analysis also must evaluate potential secondary problems, such as water pollution and solids disposal).

Systems engineering (4) is the cooperative application of all branches of engineering to all aspects of the whole problem. The objective is to obtain the most efficient system at the least overall capital investment and operating costs, consistent with governmental regulations, environmental legislation, community responsibility, and operating practice.

POLLUTION CONTROL CASE HISTORIES

Case One–Fly Ash Particulates

Low heat capacity coal-fired furnaces sometimes have a fly ash particulate problem. For example, a unit for heat treating rolls which burned about one ton/hr coal discharged too much fly ash. To meet pollution regulations, it was essential to remove 98% of the particulate matter. The particle size of the fly ash is shown in Table II.

TABLE II

Particle Size of Fly Ash in Case One

98.6 wt. % smaller than	38 μ
81.6 wt. % smaller than	25 μ
50 wt. % smaller than	12 μ
19.4 wt. % smaller than	4.7 μ
13.7 wt. % smaller than	2.4 μ
5 wt. % smaller than	0.5 μ

After an engineering systems analysis was made of the problem, wet venturi scrubbers with spray presaturators were selected. More than 98% of the fly ash particulate matter recovered, and the following objectives were accomplished: low capital cost installation; easy operation, control, and maintainence; fly ash tolerance by scrubbing water; adaptation without using tandem scrubbers for later SO_2 control; and fly ash recovery as wet (nondusting) solid suitable for land fill.

Case Two–SO_2 and SO_3 in Stack Gases

A smelter had a problem of removing SO_2 from its stack gases. It installed a pilot limestone scrubbing process to remove the SO_2. The system removed SO_2, but some SO_3 was produced which was really sulfuric acid mist. The acid mist passed through the scrubber and exited as a visible plume. Since particulate material now had to be removed, the pollution problem was compounded.

The problem was solved by adding electrostatic precipitators to the limestone scrubbing system. This illustrates that a problem must be analyzed fully before it can be solved. In this instance, the SO_2 removal was only part of the problem. Since the SO_3 was even a more serious problem, proper pollution abatement was not obtained until the total problem was solved.

Case Three–Cottonseed Dust in Cooler Stack Gas

Solvent extracted cottonseed meal was air cooled in a parallel flow horizontal rotary cooler. At the specified throughput rate, the supplier of the cooler system guaranteed cooling to within 10 F of ambient temperature and 99% or higher recovery of particulate matter. However, to achieve some flash cooling, this supplier insisted that all meal exiting from the rotary cooler be air conveyed through a large diameter cyclone. Although it did not seem logical that significant flash cooling could be achieved during air transport, the supplier would not make guarantees without that type of installation. Consequently, provisions were made, in case of emergency, to by-pass the air transport system by discharging the cooler contents into a screw conveyor.

When the cooler system was placed in operation, a huge yellow cloud of cottonseed dust covered the area. The air transport system was quickly by-passed and cooling efficiency was not decreased. However, there still was some yellow plume in the air.

Then a systems engineering approach was used to solve the problem. Data were obtained on the μ size distribution and quantities of particulate matter. Different pollution abatement devices were evaluated. Finally, a high efficiency small diameter cyclone was selected that would recover better than 95% of 10 μ particulate matter. This cyclone also had a pressure drop low enough so that it could be adapted easily to the remaining portion of the existing system. When it was placed in operation, the yellow plume entirely disappeared.

To utilize all expertise fully, better communications must be established among engineering firms, operating companies, and governing bodies. Engineering firms should study the causes of pollution and recommend corrective measures before new projects are funded. The best utilization of these firms' vast expertise in solving related problems can be had when sufficient lead time and data on every polluting effluent and its source are available to them. As illustrated by the case histories, effective pollution abatement frequently can be obtained with existing technology. Under favorable circumstances, it may be possible to anticipate future pollution problems and develop new expertise and thereby avoid more difficult pollution abatement problems later.

Even though we constantly read and hear newscasts about pollution, travel in the U.S. and foreign lands clearly illustrates the contrasts of polluted and nonpolluted areas. On an airplane trip over eastern U.S., northern Europe, or Japan, it is common to observe an extensive haze of pollution at lower altitudes; but, in parts of western U.S. and in much of Canada, the haze does not exist. To survive and enjoy life on this planet, we must apply our vast technological resources to clear the air.

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