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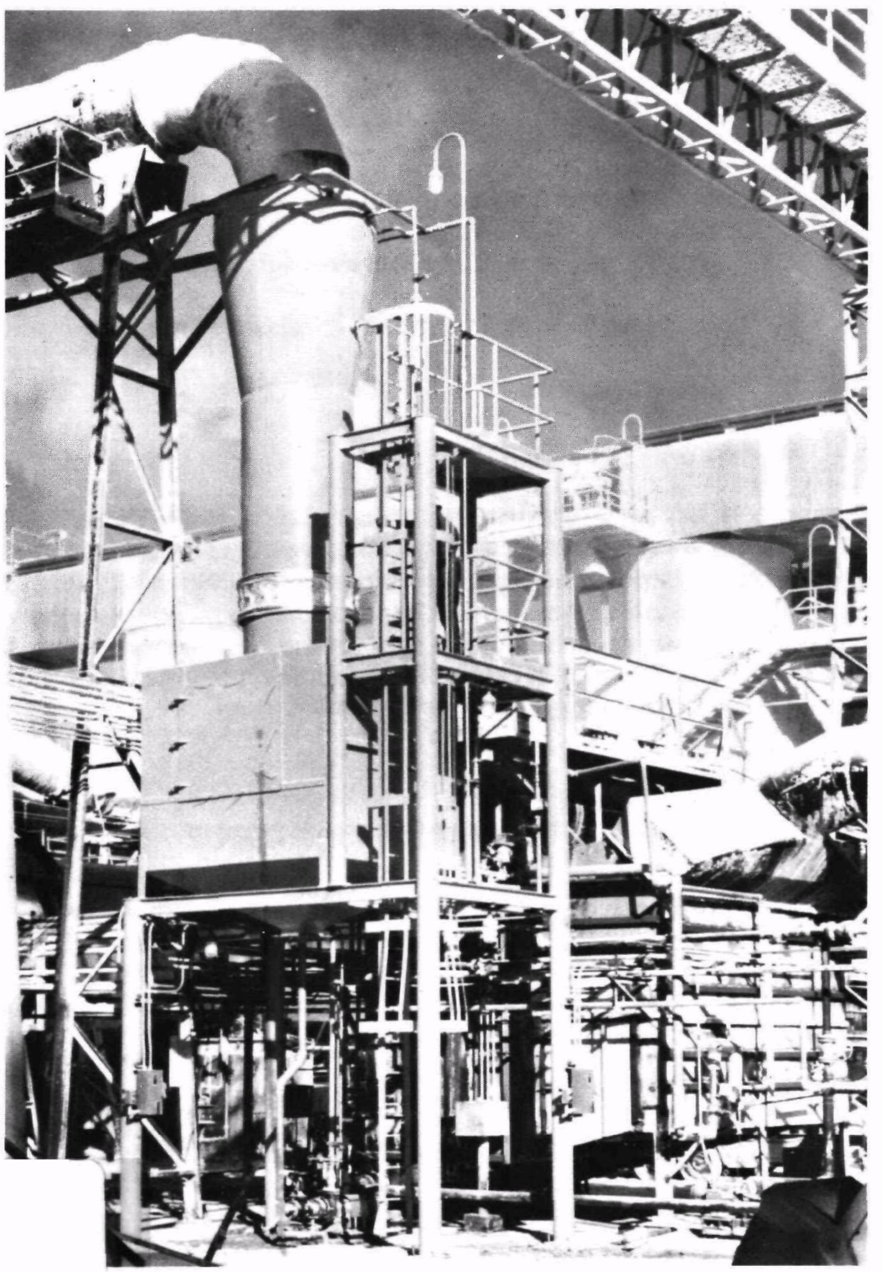
Particulate Control Highlights: Fine Particle Scrubber Research



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EPA REVIEW NOTICE

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Particulate Control Highlights: Fine Particle Scrubber Research

by

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ABSTRACT

Since 1970, the U.S. EPA has been actively involved in research and development work in the field of fine particle scrubbing. The overall objective has been to develop and demonstrate low pressure drop scrubbing systems capable of controlling fine particle emissions. Major accomplishments of the EPA scrubber program have included: publication of the Scrubber Handbook; development and demonstration of flux force/condensation scrubbing; generation of extensive scrubber performance data; development of design methods and criteria for entrainment separation; development and evaluation of novel devices for fine particle control; and presentation of two technical symposia on fine particle scrubbing.

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INTRODUCTION

Fine Particles

In recent years fine particles have come to be recognized as a significant type of air pollutant. Fine particles may be defined as solid or liquid aerosol particles smaller than three microns ($<3\ \mu m$) in diameter. These particles present the major health hazard because they are not filtered out by the human upper respiratory tract. They deposit deep within the lungs where they can cause significant respiratory damage. Fine particles also contribute to haze and smog formation. Unfortunately, fine particle emissions are very difficult to control.

Wet Scrubbers

Wet scrubbers are one of the major types of air pollution control equipment which have the capability of controlling fine particle emissions. A wet scrubber is any device which uses a liquid in the separation of particulate or gaseous pollutants from a gas stream. This broad definition includes a wide variety of scrubber designs.

There are many reasons why scrubbers are prominent in the field of fine particle control. They are ideally suited for situations where both particulate and gaseous pollutants must be controlled. They can be used to control explosive gases and dust without fire hazard. They can handle very hot gases, reducing the gas temperature by evaporation. Also scrubbers are generally more compact than their principal competitors: baghouses and electrostatic precipitators.

Of course there are also problems associated with the use of wet scrubbers. They often have a relatively large power requirement in order to obtain sufficient collection efficiency for fine particles. Liquid drops can be entrained in the gas flow leaving the scrubber, thus lowering the overall collection efficiency. Particles smaller than about one-half micron are extremely difficult to collect with conventional scrubbers. The availability of a water supply may be a problem in some areas. Scrubbers may be subject to severe corrosion problems, and also, scrubbers can present liquid waste disposal problems.

Therefore, there has been a need for further development and demonstration of lower pressure drop scrubbers capable of controlling fine particle emissions. The EPA has taken a leading role in this area.

WET SCRUBBER SYSTEMS STUDY

When EPA initiated the Wet Scrubber Systems Study in 1970 the state-of-the-art was largely empirical. Each application was considered to be a special case which could only be dealt with on the basis of long and specific experience. Engineering design was based on a primitive, cut-and-try approach and often resulted in an expensive overdesign to cover the wide range of uncertainty. There was also very little scrubber performance information available.

In the Wet Scrubber Systems Study all available information concerning wet scrubber theory and practice was reviewed and evaluated. The best available engineering design methods were evaluated and where necessary new or revised methods were developed to provide as sound a basis as possible for predicting performance. The result of this study was the publication in 1972 of the "Scrubber Handbook," which was widely recognized as the most extensive and authoritative engineering text on the subject.

Several paths which might lead to improved scrubber technology were pointed out in the Wet Scrubber Systems Study recommendations. Among those were the following topics:

1. To study phenomena which can exert forces other than inertial forces on particles and, where warranted to develop equipment to use these forces for particle collection.

2. To compare the new and generally untested design methods with reliable scrubber performance data.

3. To study entrainment separators (or "mist eliminators") and develop improved design methods and equipment.

FLUX FORCE/CONDENSATION SCRUBBING

In line with the first topic, a major thrust was aimed at developing and demonstrating Flux Force/Condensation (F/C) scrubbers. In an F/C scrubber water vapor is condensed from the gas. A representative F/C scrubbing system is illustrated in Figure 1. Some of the water condenses on the particles causing their mass to increase and thereby making them easier to collect. The rest of the water vapor sweeps particles with it as it moves toward the cold surface and condenses.

A series of F/C scrubbing studies progressing from theory through experiment and into industrial demonstration have produced a useful body of engineering knowledge. It is now possible to make reliable process designs and cost estimates for F/C scrubbing from the starting point of small scale sampling studies of the emission under consideration. Depending on the specific set of circumstances, F/C scrubbing can be economically superior to conventional scrubbing and in some cases may be technically feasible where conventional scrubbing is not. Figure 2 shows the effect of condensation on particle size distribution for a realistic set of conditions based on field measurements. If a venturi scrubber were used to obtain 85% collection efficiency on the initial particle size distribution, a pressure drop of 190 cm W.C. would be required. Were condensation and particle growth to occur, only 75 cm W.C. pressure drop would be required for 85% efficiency.

PERFORMANCE DATA

Fine particle scrubber performance data for a number of industrial sources have been measured under several EPA contract programs. These have yielded the most detailed and precise body

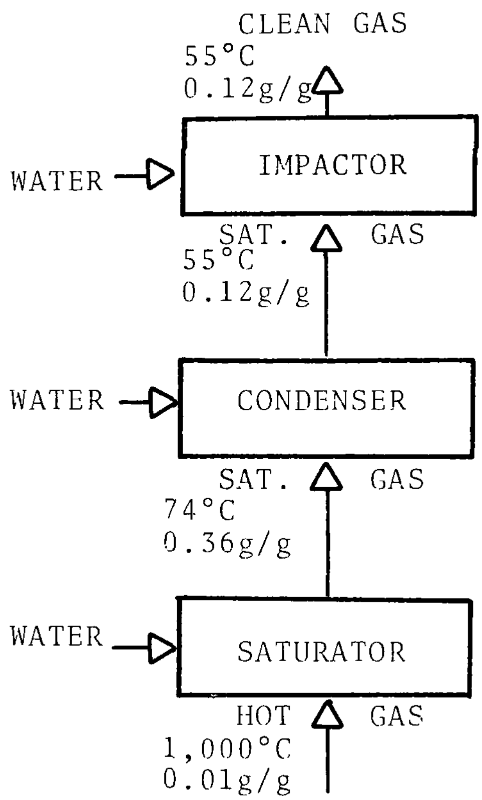

Figure 1. Generalized F/C scrubber system.

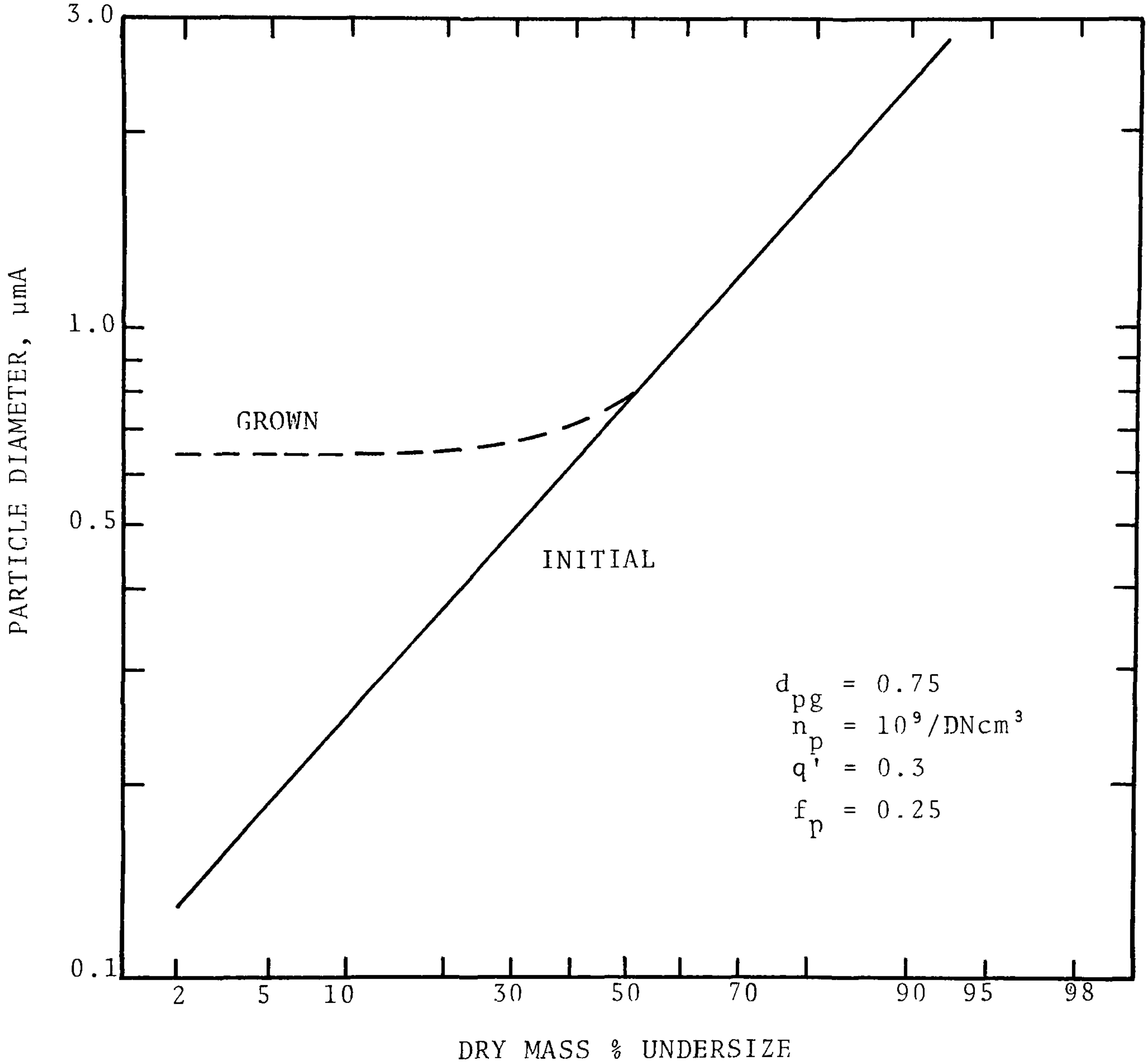

Figure 2. Particle size distribution before and after condensation.

of information available on the measurement of collection efficiency as a function of particle size in industrial systems. Many improvements of testing instruments and methodology have been made as the result of this work.

All of the scrubber performance studies include a comparison of the measured efficiency with that predicted by means of the available mathematical models. In cases where there was disagreement the model was re-examined and sometimes revised. One very useful and practical engineering design tool which was developed through the EPA program is the particle cut diameter versus scrubber power relationship created by A.P.T. This "cut/power" relationship in conjunction with a general design procedure which originated in the Wet Scrubber System Study enables one to make a rapid and usefully accurate estimate of the power required to achieve a given efficiency for a specific particle size distribution.

LIQUID ENTRAINMENT

Entrainment from scrubbers has proven to be the potential cause of very serious reduction in performance and even operability. Power plant scrubbers which utilize concentrated suspensions or solutions have been especially susceptible to entrainment problems. EPA contract and in-house efforts have been aimed at this problem for several years.

The results have been new knowledge of the efficiency, capacity, and pressure drop of entrainment separators, and of the size distribution of the entrained mist. Figure 3 is a cut/power plot which illustrates the efficiency characteristics of several types of entrainment separator. The effect of separating element orientation on capacity limitations is shown in Figure 4. Here again, the EPA program has expanded the rational basis for the engineering design of better, more reliable, more economical equipment.

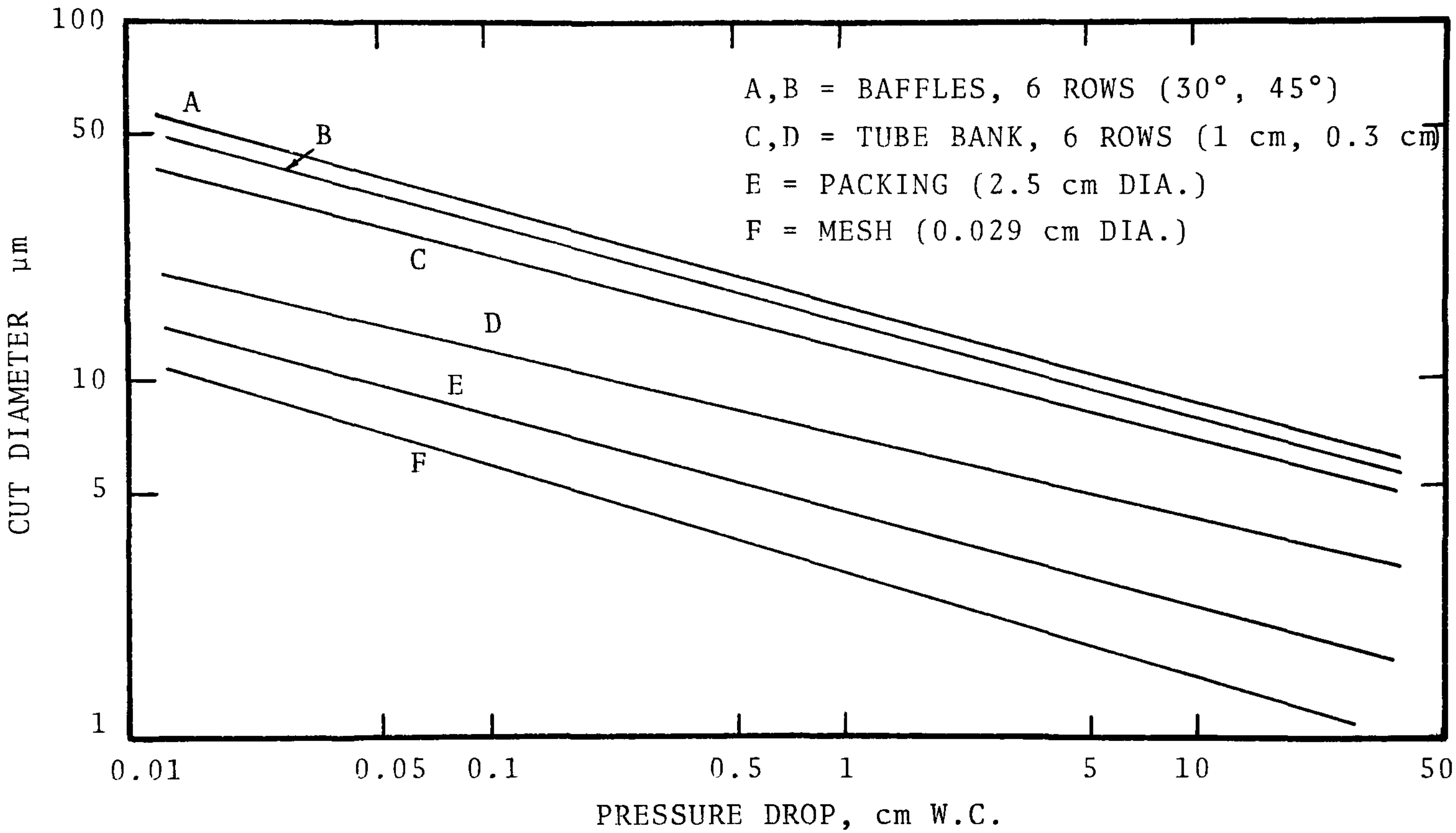

Figure 3. Entrainment separator performance cut diameters.

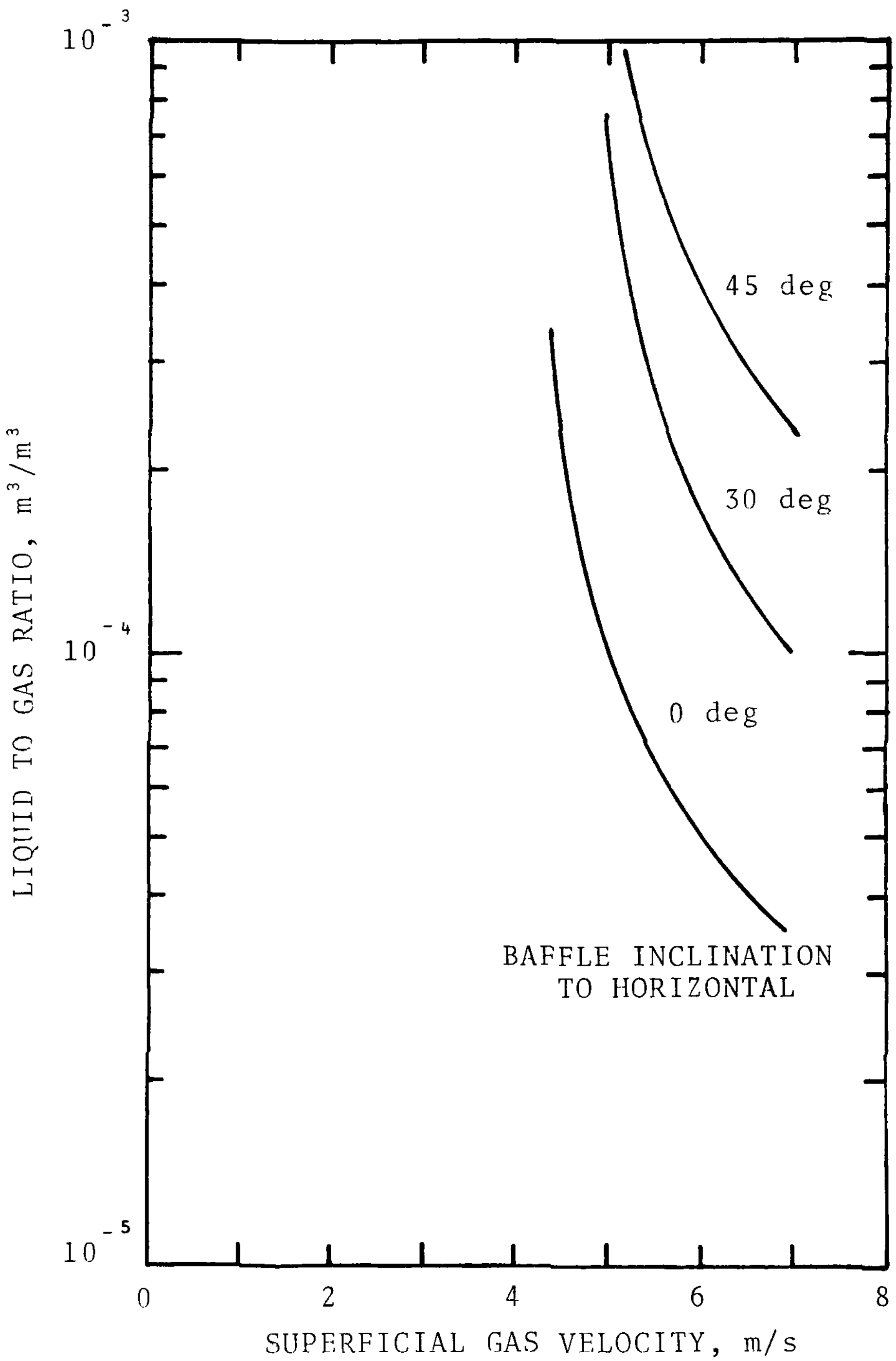

Figure 4. Throughput of horizontal and inclined baffle units, as restricted by reentrainment

NOVEL DEVICES

Other EPA contract programs have been directed toward the exploration, development and demonstration of unusual or new technology for fine particle collection. These include electrostatically augmented scrubbers, foam scrubbers, and other novel scrubbing devices. Mobile bed scrubbers, whose performance in practical installations has covered a puzzling range of effi ciencies, have been studied in detail with regard to particle collection and entrainment.

EPA PROGRAM GOALS

Table 1 lists the major fine particle scrubber research and development projects sponsored by the IERL-RTP. The broad objective of this program is to develop and demonstrate low pressure drop (30-50 cm water) scrubber systems capable of collecting at least 90% by mass of particles smaller than three microns in diameter. This objective is illustrated in Figure 5, which shows the performance of conventional scrubbers in terms of a cut/power plot. For situations where free steam is available, F/C scrubbing approaches this objective.

To resolve some of the problems associated with scrubbers, the EPA has sponsored studies in the areas of entrainment separation, liquid utilization, energy consumption, and particle wettability. The EPA also owns a truck-mounted mobile scrubber unit for testing the suitability of venturi and sieve plate scrubbers on different industrial sources.

EPA has sponsored two symposia dealing with fine particle scrubbing. The first symposium was in May, 1974 in San Diego. The second was in May, 1977 in New Orleans. These symposia stimulated and generated new ideas for fine particulate control by bringing together experts in the development and use of wet scrubbers.

They also provided means for the transfer of technology between researchers and users of wet scrubber technology.

TABLE 1. LIST OF PROJECTS RELATED TO SCRUBBER RESEARCH AND DEVELOPMENT SPONSORED BY INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY RESEARCH TRIANGLE PARK (IERL-RTP)

Starting Date	Title	Contractor
1970	Wet Scrubber Systems Study	A.P.T., Inc.
	Flux Force/Condensation Scrubber Feasibility	A.P.T., Inc.
	Fine Particle Scrubber Performance Tests	A.P.T., Inc.
1971	Systems of Charged Droplets and Electric Fields for Removal of Submicron Particulates	M.I.T.
September 1972	Wet Scrubber Entrianment Separation	A.P.T., Inc.
December 1972	Pilot Scale Demonstration of Charged Droplet Scrubbing	TRW Corporation
June 1973	Wet Scrubber Development II (F/C Scrubbers)	A.P.T., Inc.
September 1973	Wet Scrubber Liquid Utilization	Stanford Research Institute
October 1973	Foam Scrubbing for Fine Particle Control	Monsanto Research Corporation
December 1973	Growth of Fine Particles by Condensation	Stanford Research Institute
June 1974	Fine Particle Collection with University of Washington Electrostatic Scrubber	University of Washington
1974	Evaluation of Novel Control Devices	A.P.T., Inc. Southern Research Inst. GCA, Meterology Research Inc.
June 1974	F/C Scrubber Demonstration Plant on Secondary Metal Recovery Furnace	A.P.T., Inc.
July 1974	Evaluation of Wet Scrubbers for Control of Particulate Emissions from Utility Boilers	Meterology Research Inc. A.P.T., Inc.
July 1974	Operation of EPA-Owned Mobile Units, Aerodynamic Test Chamber, and Pilot Scrubbers	Monsanto Research Corp.
August 1974	Rocket Motor Emissions Control	A.P.T., Inc.
September 1974	Entrainment Characteristics of Mobile Bed Scrubbers	A.P.T., Inc.
January 1975	Evaluation of Horizontal Scrubber	A.P.T., Inc.
February 1975	Evaluation of Systems for Control of Rocket Motor Test Pad Emissions	A.P.T., Inc.
April 1975	Evaluation of Electrostatic Scrubber	TRW Corporation
June 1975	Wet Scrubber Energy Utilization	Stanford Research Inst.
August 1975	Effects of Interfacial Properties on Fine Particle Scrubbing	Meterology Research Inc.
November 1975	Mobile Bed F/C Scrubbers for Collection of Fine Particles	A.P.T., Inc.
September 1976	Superior Entrainment Separator	A.P.T., Inc.
September 1976	F/C Scrubber Demonstration Plant on a Foundry Cupola	A.P.T., Inc.

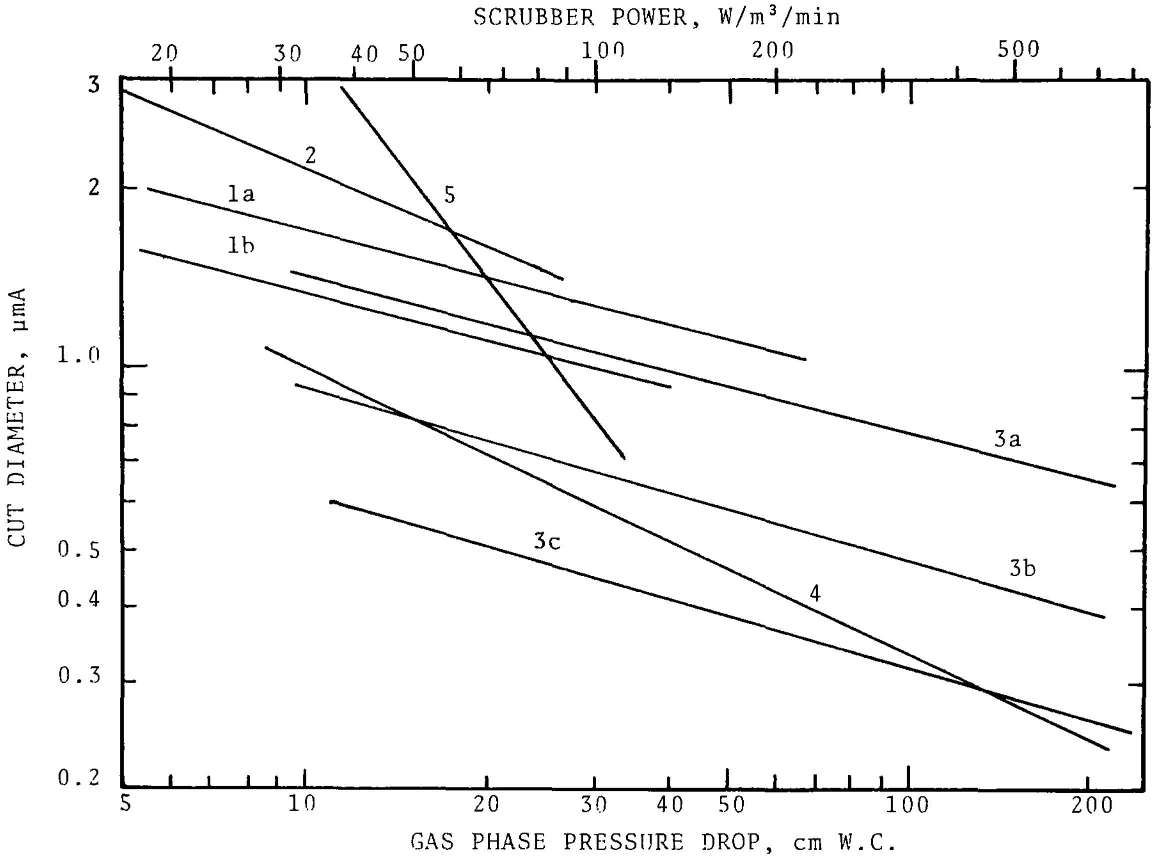

Figure 5. A.P.T. cut/power plot.

1a. Sieve-plate column with foam density of 0.4 g/cm^3 and 0.5 cm hole diameter. The number of plates does not affect the relationship much (experimental data and mathematical model).

1b. Same as 1a except 3.2 mm hole diameter.

2. Packed column with 2.5 cm rings or saddles. Packing depth does not affect the relationship much (experimental data and mathematical model).

3a. Fibrous packed bed with 0.3 mm dia. fiber, any depth (experimental data and mathematical model).

3b. Same as 3a except 0.1 mm dia. fibers.

3c. Same as 3a except 0.05 mm dia. fibers.

4. Gas atomized spray (experimental data from large venturis, orifices, and rod type units, plus mathematical model).

5. Mobile bed with 1 to 3 stages of fluidized hollow plastic spheres (experimental data from pilot plant and large-scale power plant scrubbers).

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16. ABSTRACT The report gives highlights of fine particle scrubber research performed by, or under the direction of, EPA's Industrial Environmental Research Laboratory (IERL-RTP) at Research Triangle Park, North Carolina. The U.S. EPA has been actively involved in research and development in the field of fine particle scrubbing since 1970. Its overall objective has been to develop and demonstrate low pressure drop scrubbing systems capable of controlling fine particle emissions. Major accomplishments of EPA's scrubber program have included: publication of the Scrubber Handbook; development and demonstration of flux force/condensation scrubbing; generation of extensive scrubber performance data; development of design methods and criteria for entrainment separation; development and evaluation of novel devices for fine particle control; and presentation of two technical symposia on fine particle scrubbing (in 1975 and 1977).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Polluation Control	13B
Dust	Stationary Sources	11G
Scrubbers	Particulate	07A
Gas Scrubbing	Flux Force/Condensation	13H
Entrainment		07D
Separators	Entrainment Separation	

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