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PROCEEDINGS

of the

TENTH AEC AIR CLEANING CONFERENCE

held in

New York, New York

28 August 1968

Sponsors

The Harvard Air Cleaning Laboratory
Harvard University

and

Division of Reactor Development and Technology
U. S. Atomic Energy Commission

Editors

Melvin W. First
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FOREWORD

During the past two years since the Ninth Air Cleaning Conference was held in Boston, Massachusetts, in September 1966, the commercial nuclear power industry has continued to grow and mature. This growth is reflected in recent electrical energy estimates which indicate that approximately 100 nuclear power stations with a total generating capacity exceeding 70,000 megawatts will be in operation by 1975. The continued expansion since 1963 of this phase of the atomic energy program i.e., the design and construction of large power reactors (up to 1125 electrical megawatts), has resulted in an increasing need for assuring the reliability and effectiveness of high-efficiency air-cleaning systems under both normal operating and accident conditions. This then provided the theme for the one-day Tenth Air Cleaning Conference, which was held at the Waldorf-Astoria Hotel in New York City on Wednesday, August 28, 1968 -- the testing of full-scale air-cleaning systems or individual components under a variety of operating conditions and the validity of extrapolating small-scale test results to design conditions.

In this regard, about one-half of the day's session was devoted to a state-of-the-art discussion on all components of air-cleaning systems under reactor accident conditions, such as demisters, pre-filters, high-efficiency filters, filter media, moisture testing, gaskets, and the various types of activated charcoals, with their attendant problems of heat degradation, aging, service life, and effects of gamma radiation on their efficiency for removal of various species of iodine. A highlight of the meeting was the lively discussion which evolved from the presentation of approximately ten brief technical notes on recent air cleaning developments.

The Conference was unique in that it was held during the middle day of the week of August 26-30, 1968, in concert with the first international IAEA Symposium on "Operating and Developmental Experience in the Treatment of Airborne Radioactive Wastes" held at the UN Building in New York. This provided an opportunity for over 200 Symposium representatives from the United States and 13 foreign countries to participate in the tenth of a series of U.S. air cleaning conferences dating back to 1951.

The meeting was sponsored through the radioactive effluent control research and development program of the Environmental and Sanitary Engineering Branch, Division of Reactor Development and Technology, U. S. Atomic Energy Commission. We are indebted to Dr. Dade Moeller and his colleagues at Harvard University for assisting in the development of the technical program and making the administrative arrangements for the Conference.

Walter G. Belter

Walter G. Belter, Chief
Environmental & Sanitary Engineering Branch
Division of Reactor Development & Technology
U. S. Atomic Energy Commission

The 10th USAEC Air Cleaning Conference sponsored by the U. S. Atomic Energy Commission and the Harvard Air Cleaning Laboratory convened at the Waldorf-Astoria Hotel, New York City, at 8:30 A. M., 28 August 1968, at the mid-point of an International Symposium on Air Cleaning held at the United Nations during the week of 26-30 August 1968. The meeting was divided into four sessions, two in the morning. The morning sessions were devoted to Air Cleaning Systems and Air Cleaning System Components. Adsorbents for Iodine Removal and Open Discussion sessions completed the afternoon program.

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Harvard Air Cleaning Laboratory

WELCOME

Dr. Dade W. Moeller
Harvard Air Cleaning Laboratory

On behalf of the U. S. Atomic Energy Commission and the Harvard Air Cleaning Laboratory, it is my pleasure to welcome you to this, the 10th USAEC Air Cleaning Conference. I would particularly like to welcome our friends from overseas and to the North and South of our borders.

The Air Cleaning Conferences were an outgrowth of the operations of the AEC Stack Gas Working Group established in 1948 to review air cleaning operations at AEC installations. The first such meeting was held in Boston in 1951 under the direction of Dr. Leslie Silverman. The status of the subject as well as the work at that time is reflected in the fact that this first meeting was simply a training session and no formal report was published.

As air cleaning research programs developed at the various AEC laboratories, the Conferences were expanded to include the presentation of formal papers and the exchange of information on all aspects of the subject. At the Fifth Conference, held in 1957, the scope of the meetings was broadened to include, for the first time, non-government personnel. Still later, papers by air cleaning experts from foreign countries were included on the program. The increasing importance of such overseas participation is exemplified by the International Symposium being held at the United Nations this week. This Air Cleaning Conference was scheduled so as to permit those attending the International Symposium to join with us and we are delighted that so many of you have chosen to come today.

Since this Conference represents a milestone in this series, as well as in the art and science of air cleaning, we are taking the liberty of placing in the published Proceedings a listing of all the meetings to date, the site at which they were held, and the document in which the Proceedings were published.

In closing, let me welcome you again. Through means of the program arranged by a Committee consisting of Walter Belter, Craig Roberts, Melvin First, and Fred Viles, you will have an opportunity to be brought up-to-date on major air cleaning research being conducted in the U. S. under sponsorship of the U. S. Atomic Energy Commission. Here to bring you the official greetings of the AEC and a review of the objectives of the meeting is Mr. Walter G. Belter, Chief, Environmental and Sanitary Engineering Branch, AEC Division of Reactor Development and Technology.

Chronological Listing of USAEC Air Cleaning Conferences

Meeting	Date	Site	Proceedings
First	June 12-15, 1951	Harvard Air Cleaning Laboratory, Boston, Massachusetts	No Report
Second	Sept. 15-17, 1952	Ames Laboratory, Iowa State College, Ames, Iowa	WASH-149
Third	Sept. 21-23, 1953	Los Alamos Scientific Laboratory, Los Alamos, New Mexico	WASH-170
Fourth	Nov. 2-4, 1955	Argonne National Laboratory Argonne, Illinois	TID-7513
Fifth	June 24-27, 1957	Harvard Air Cleaning Laboratory, Boston, Massachusetts	TID-7551
Sixth	July 7-9, 1959	Idaho Operations Office, U. S. Atomic Energy Commission, Idaho Falls, Idaho	TID-7593
Seventh	Oct. 10-12, 1961	Brookhaven National Laboratory, Upton, L. I., New York	TID-7627
Eighth	Oct. 22-25, 1963	Oak Ridge National Laboratory, Oak Ridge, Tennessee	TID-7677
Ninth	Sept. 13-16, 1966	Sheraton-Boston Hotel, Boston, Massachusetts	CONF-660904
Tenth	Aug. 28, 1968	Waldorf-Astoria Hotel, New York, New York	CONF-680821

OBJECTIVES OF THE TENTH USAEC AIR CLEANING CONFERENCE

Walter G. Belter
Division of Reactor Development and Technology

Thank you Dr. Moeller. On behalf of the U. S. Atomic Energy Commission and particularly the Division of Reactor Development and Technology, I would also like to welcome all of you to the Tenth AEC Air Cleaning Conference, with a special note of greeting to our foreign visitors. It is always a pleasure to see so many familiar faces present for these meetings, indicating, I believe, that many of you find these get togethers to be not only of some social interest, but also of some profitable use in the carrying out of your professional responsibilities in the field of air cleaning. While there are many familiar faces in the audience, there are also many newcomers, and as the late Dr. Silverman of Harvard used to say -- "You always see about fifty per cent new faces every two years when you come to the Air Cleaning Conference."

While the U. S. Air Cleaning Conferences started back at Harvard University in June 1951, this is the first time that we have had as extensive a participation from our foreign air cleaning specialists, principally because of our country having the opportunity to host this first International Air Cleaning Symposium. I can remember approximately 1½ years ago at a panel session in Vienna when the five-year program of the Health, Safety, and Waste Management Division of the Agency was being discussed and developed. It was stated at that time that the Agency in its ten years of existence had never had a large conference or symposium on the subject of air cleaning. It was then proposed that a symposium of this type be held in 1968. Having just completed our Ninth U. S. Air Cleaning Conference in Boston four months previously, it appeared that this international symposium would possibly conflict or coincide with the scheduling of the Tenth U. S. Air Cleaning Conference. Knowing of the large participation which we had at the meetings at Oak Ridge in 1963 and Boston in 1966 -- about 225 and 240, respectively -- some concern was expressed about the extent of U. S. participation in an international meeting of this type, during these days when international travel is becoming increasingly difficult. It appeared to us that a possible solution to this dilemma would be to invite the IAEA to hold their symposium in the United States to coincide with the time when the Tenth Air Cleaning Conference would normally be held. This would enable many of our air cleaning specialists from U. S. atomic energy installations, universities, and industry to meet and exchange views with our foreign counterparts for at least one week and thereby enable many more of us to obtain the benefits of their experience and expertise in this area. I am pleased that the Agency accepted our invitation to hold their symposium in the United States and that we have been able to obtain as excellent a meeting facility as this building and the UN building to hold both conferences. I hope that all of you are benefiting from the personal and technical exchanges which are taking place during this week.

A special note of thanks is also due to Dr. Moeller and his colleagues at Harvard University and to Mr. Craig Roberts of my office and Mr. Humphrey Gilbert of our Division of Operational Safety for their untiring efforts in planning and making the necessary arrangements to hold this meeting in New York City.

As already mentioned, this is the tenth in a series of U. S. air cleaning conferences. These conferences have provided a valuable opportunity to review R&D progress and to direct attention to the highest priority problems. The early conferences emphasized the problems and practices of individual AEC installations and it was at the 1963 meeting that the air cleaning needs of the nuclear power industry began to become a principal item of discussion. As an introduction to our session today, it may be of interest to briefly review the status of air cleaning requirements of an expanding nuclear power industry. Since our meeting in Boston two years ago, the trend toward nuclear power has increased at a rate that has exceeded the expectations and even the dreams of its most ardent supporters.

As of July 1, 1968, the status of the U. S. civilian nuclear power program was as follows:

	Kilowatts
15 reactors in operation	2,798,700
31 reactors under construction	22,501,000
42 reactors ordered	34,980,000
14 reactors planned but not yet ordered	12,660,000
	72,939,700

These approximately 100 nuclear power stations ranging in size from 400-1125 MW_e will be going into operation during the 1969-75 time period.

The development of air cleaning procedures and equipment at these nuclear power plants has been strongly influenced by a statement on the subject by the AEC's Advisory Committee on Reactor Safeguards. We are pleased that the ACRS is represented here for the meetings this week. I believe this statement very aptly summarizes the Commission's interest in air cleaning systems and also some key objectives of our present Reactor Development research and development program in this area. For that reason, I would like to present this statement as the theme for today's presentations and discussions. "The function of an air cleaning system as an engineered safeguard (for reactor systems) is to remove and to retain fission products from an unlikely partial or total fuel melt-down. Fission products that are thus retained should be fixed in a form that prevents redispersion. Components of the air cleaning system should be so located that decontamination and essential handling can be accomplished readily and without hazard to the health and safety of the public. For cleaning or decontamination purposes, the released fission products from a reactor fuel melt-down may be divided into four groups. These are: the noble gases (krypton and xenon); the halogens (bromine and iodine); volatile solids (such as tellurium, selenium, cesium and ruthenium); and other solids (primarily strontium, yttrium and barium).

Because of their chemical nature and short half-life, radioactive noble gases can usually be treated only by containment or controlled release from elevated locations such as tall stacks. Therefore, with noble gases, consideration must be given to meteorological dispersion and dilution as influenced by characteristics of the surrounding environment.

It is convenient to divide the remaining fission products into two physical groups -- gases and particulates. Gases (essentially iodine and bromine in elemental form) are removed by adsorbents such as activated charcoal, by chemi-sorption on silver, or by absorption in a reactant solution. Particulates which range in size from several microns down to less than 0.1 micron can be removed by impingement scrubbers, electrostatic precipitators, or filters. The final device in a particulate cleaning train is usually one based on mechanical filtration principles. Containment spray or "dousing" systems for condensing steam may also serve as decontamination systems because of the gas contacting and impingement action of the spray droplets. The multiple contacting which is possible within a contained gas volume makes a containment vessel with sprays equivalent to a scrubbing chamber.

Halogen gases may be adsorbed upon the surfaces of released particulates and may react with them. Hence, it is necessary to use a combination of adsorption, absorption, and filtration devices to remove halogens. Because iodine may occur in both inorganic and organic states, the gas cleaning system must be capable of removing both. Since the halogens adsorbed on particulates are not irreversibly bound, it is necessary to follow the filter with an adsorber. A liquid scrubber should be followed by both when maximum decontamination is necessary.

The air cleaning components of a reactor safety system include: a ventilation system, a heat removal device, air cleaners, and an air mover with motor. The system must be capable of working continuously in hot, saturated steam environments for a period of time long enough to remove the required portion of the released fission products from the containment or confinement system. To handle the anticipated release, the air cleaning system must have sufficient capacity in flow, in adsorbent and chemically reactive materials, and in filtration surface. Adsorption and filtration systems must be designed and installed so that the decay heat of collected fission products will not cause combustion or destruction of their media or overheating to the point where collected fission products will be redispersed. The media must also be protected against shock waves, missiles, moisture entrainment, liquid slugging, and radiation damage, as well as corrosion and chemical attack. The duct work and filter housing should be protected against mechanical injury or missile damage to avoid bypassing or leakage of untreated air. The system should be leak tested at the same pressure differential as it would have to endure under accident conditions.

Because electrical power is necessary for circulating and recirculating both air and water, it is essential that backup power be available for maintaining minimal flow rates.

The decontamination efficiency required of an air cleaning system will depend on whether the system is once-through or recirculating. The decontamination factors needed will be based on the dose to the environment and the dilution to be assumed for stack dispersion. In recirculating systems, the decontamination factor is related to the number of containment volumes passed through the cleanup system. Decontamination factors of 10 to 1000 or more may be required in most applications.

Gas leaks which bypass filters or adsorbers in effect decrease air cleaning efficiency. When an iodine removal efficiency of 99% is projected, a bypass or leak around the beds of 1% leads to double the iodine release. Appropriate design and testing of associated gas handling equipment is required.

The reliable performance of an air cleaning system must be assured by frequent "in-place" testing which includes monitoring with gases and particulates that simulate the expected fission products. Ease of testing for leaks, and access for inspection of seals, gaskets and clamps are necessary. A continuous monitor of resistance or pressure drop through the cleaning system is desirable where the decontamination unit is always in use. In the case of emergency or standby cleaning systems, at least quarterly operation and checking of both air mover and cleaner is desirable.

The nature of fission product releases to be expected in the unlikely event of a major accident is not yet well enough known to permit more than conservative lower bounds on the efficiency to be determined for air cleaning. Reliable lower bounds may, however, be assumed when individual cases are reviewed."

As I indicated previously, there are about 100 nuclear power stations in the U.S. in various stages of planning, design, construction and operation, with a fairly even split between BWR's and PWR's. In the design of the Humboldt Bay plant, in the late 1950's General Electric introduced the pressure suppression concept which continues through current BWR designs. This concept does not include the use of recirculating primary containment filter systems. For the General Electric BWR systems, the secondary containment (reactor building) is equipped with a once-through standby gas treatment filter which is scheduled for operation only under accident conditions. A typical design consists of a demister, heater, roughing and high efficiency prefilter, charcoal bed and high-efficiency after filter. Such a system is based on the following equipment and operating parameters:

Temperature	130-150°F
Rel. Hum.	70%
Impregnated Charcoal Residence Time	0.25 sec.
Charcoal Bed Depth	2 inches
Inlet Air Iodine Concentration	$\sim$10 mg/M^3

The 70% relative humidity condition is achieved by pre-heating the inlet saturated air steam to 150°F.

Several important milestones in the design of air cleaning systems at PWR plants can be briefly noted at this time. The Rochester, New York or Ginna #1 plant is the first to use chemical sprays to remove iodine. The design of this plant incorporates both sprays and solid adsorbers.

A recent approval by the Advisory Committee on Reactor Safeguards of a proposal to reduce the exclusion zone around Turkey Point, Florida, Units #3 and #4 provides the first instance in which credit is given for iodine removal by an air cleaning system. The iodine removal system consists of three filter units, each containing a demister filter bank, a high efficiency particulate air filter bank, and a charcoal filter bank installed with an electric-motor-driver blower and air diffuser in a common enclosure. The units are designed to operate under the adverse conditions expected in the containment in the event of a loss-of-coolant accident.

The containment and cleanup concept incorporated into the design of the Prairie Island, Minnesota, and Kewaunee, Wisconsin, plants provide another somewhat different design feature. At these plants, a free-standing steel shell is contained within a cylindrical concrete structure. An annular space of about five feet exists between these two structures. In this design, leakage from the primary shell containment would be collected within the concrete shell, circulated through charcoal filters and then discharged to the atmosphere.

Finally, the Cook plant units to be located on Lake Michigan near the Michigan-Indiana border represents another design variation in that sprays only will be incorporated into the design -- there will be no solid iodine adsorbers.

These comments provide a brief summary of the rapid rate of growth of the nuclear power industry and the evolution of air cleaning systems. In looking at todays program, you will see that we will be discussing each component of these systems, and what we know of their performance under varying operation conditions. We are asking each of you to give us your comments and opinions on the need for performance and reliability testing of these systems. Some of the questions we are seeking guidance on are: Is it necessary to test entire and complete systems or is it sufficient to test components individually? Should full-size systems be tested or can the results of testing small-scale systems be scaled up? Should the tests be performed under conditions which approximate design conditions or is it possible to extrapolate to design conditions?

These are particularly timely questions for the AEC because we must decide whether to take advantage of the unique testing capabilities offered by the Containment Systems Experiment (commonly referred to as CSE) facilities at Hanford. These facilities will be described in detail later this morning by Jerry McCormack and Cliff Linderoth of the Battelle NW Laboratory. They will describe the effort that has already gone into planning and designing an air cleaning system test bed at the CSE. That effort has been delayed purposely to allow other testing, principally spray tests to be completed. For the benefit of our foreign friends, this may be a good time to briefly describe the AEC facilities that can and are being used to test air cleaning systems. In order of size these are the Containment-Decontamination Experiment at NRTS (86 ft^3), the Continment Research Installation (163 ft^3) and the Nuclear Safety Pilot Plant (1350 ft^3) both located at ORNL, the Containment Systems Experiment (30,000 ft^3) at Hanford, and the LOFT facility (300,000 ft^3) under construction at NRTS. Test programs are being proposed which are designed to determine the performance of filter systems under the containment conditions anticipated following the meltdown of a water cooled power reactor.

Consideration is being given to the testing of full size filters (1000 CFM) in the CSE. The large size of the vessel limits the concentrations of radioactive simulants that can be used. Thus the effect of radioactivity on filter systems cannot be tested in this facility. The simulants developed for the CSE consist of iodine (to represent radioiodines), UO_2 and zirconium (to represent fuel cladding), K_2O (to represent water-soluble oxides), and xenon (to represent rare gases). Radiotracers are added to the simulants to determine their behavior in the test system.

Work is underway at Savannah River and at ORNL to determine the effect of radiation on the adsorption and retention of iodine by charcoal as well as the ignition of charcoal by trapped fission products. Much of this work involves the use of small quantities of charcoal and the question of whether the results can be extrapolated to full size charcoal components has not been completely resolved.

Returning to the CSE, we must this fiscal year decide the extent of the air cleaning system test work which should take place at CSE. Our decision must take into account the importance of such test work in terms of funding, man years, and use of the CSE facilities relative to other development efforts. We are seeking your comments and opinions on this subject and have organized the program to yield maximum, direct discussion. You will note that attention will be directed to each component of a total air cleaning system. The discussion leaders have been asked to summarize the development status of his component and then individuals who have made significant development progress since the Ninth Air Cleaning Conference will have a chance to briefly summarize that progress. Persons whose work is not recognized on the program should not fail to take advantage of the discussion period to inform the conferees. This points up the need during this period of budget austerity to make maximum use of available R&D money. Duplicate efforts are becoming much more difficult and the particular experience and expertise of each installation has to be used to the maximum extent possible by other installations rather than duplicating that experience and expertise. If we are to continue to solve the real air cleaning problems of the nuclear industry, we must work as efficiently as possible within our budget limitations. Before turning the meeting over to our 1st session moderator, Fred Viles, I would like to emphasize that the main value of our previous air cleaning conferences has been the uninhibited, completely frank discussions we have had.

We need your reactions, the comments and suggestions of our operational people, reactor designers, architect-engineers, and the regulatory or nuclear safety groups, if the R&D program is to meet the needs of the industry.

So with a full schedule ahead, it is a pleasure to introduce Mr. Fred Viles of Harvard University, who will be our moderator for the first session.