SESSION 1

OPENING OF THE CONFERENCE

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Co-Chairmen:	J. F. Leonard K. Duvall

OPENING COMMENTS OF SESSION CO-CHAIRMAN LEONARD

A BRIEF HISTORY OF THE AIR CLEANING CONFERENCES
M. W. First

THE INTEGRATED MELTER OFF-GAS TREATMENT SYSTEMS AT THE WEST VALLEY DEMONSTRATION PROJECT
R. F. Vance

OPENING COMMENTS OF SESSION CO-CHAIRMAN LEONARD

As has been mentioned earlier, we have a great challenge ahead of us in Environmental Protection and Waste Management. It is an area that has been growing by leaps and bounds. A great deal of the budget of the US Department of Energy is now going in that direction. The DOE organization that I am in, Defense Programs, used to be one of the largest organizations but its emphasis is now going down and emphasis on Environmental Protection and Waste Management is going up. A few years ago, the Department of Energy, in order to take on this challenge, which is enormous, not only for the Department of Energy, but for the entire United States, began doing the research needed to figure out how to handle these materials and how to accomplish it in a safe manner. They have received DOE's foremost emphasis.

A Brief History of the Air Cleaning Conferences

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Introduction

I have been asked to prepare a history of the air cleaning conferences. Undertaking such a task is, of course, a wonderful opportunity for reminiscences and a chance to retell old war stories. I must admit that it has taken much longer than I anticipated because I found myself so completely engrossed rereading the old records that time seemed to stop, although the hours passed. But a history of the nuclear air cleaning conferences means more than a stroll down memory lane. The 23 recorded air cleaning conference proceedings reflect an important aspect of the history of major nuclear developments, both military and civilian, because engineered safety features designed to prevent dispersion of radioactive products to the environment have always been a necessity for progress in this field. For this reason, I hope the history of the nuclear air cleaning conferences will not only be enjoyable, but also have meaning for young people entering this field.

The air cleaning conferences were an outgrowth of the operations of the U. S. Atomic Energy Commission's (AEC) Stack Gas Working Group established in 1948 to review air cleaning operations at AEC installations. AEC's Division of Engineering sponsored and funded air cleaning research and development at Harvard University's School of Public Health, beginning about the same time. In addition to research and development, the Harvard contract called for consulting and educational services. The latter provided the opportunity for meetings devoted to information on air cleaning that could be applied to ongoing and anticipated nuclear operations.

The Early Meetings

The first meeting was held in Boston at the Harvard School of Public Health in 1951 under the direction of Professors Philip Drinker and Leslie Silverman. The state of knowledge at that time was such that the first meeting was devoted to sharing information on air cleaning in a seminar and laboratory format. No formal report was published. The only record is a photograph of the participants. One session was devoted to a discussion of classified topics; specifically, current operations requiring improved air cleaning equipment. Those without clearance were excluded by a security force that guarded all doors and windows of the school's lecture hall.

After air cleaning research programs began at various AEC laboratories and production sites, the agenda of the meetings expanded to include the presentation of formal papers as well as the exchange of operational information. A mixture of basic research, product and process development, and practical operational experience has characterized all subsequent conferences.

The 2nd Air Cleaning Seminar, exclusively for AEC personnel, was held at the Institute for Atomic Research, Iowa State College, Ames, Iowa, September 15-17, 1952. Its purpose, once again, was to acquaint personnel at national laboratories and AEC contractors who did not have a background in this field with the fundamental aspects of air and gas cleaning. In addition, it was an opportunity to discuss with individuals responsible for selecting and applying the various air cleaning devices new problems, recent applications, and the performance of equipment in the field. The first half day was devoted, again, to a review of the properties of aerosols, descriptions of basic air cleaning principles, and the major types of air cleaning equipment. Those attending were presented a copy of the newly printed Handbook on Air Cleaning, the first of an extensive series of AEC-sponsored technical monographs covering many aspects of the developing technologies associated with environmental protection and occupational health and safety. The Handbook on Air Cleaning remained the principal reference source until the publication of the Nuclear Air Cleaning Handbook, authored by Burchsted and Fuller, 17 years later. An idea of the state of knowledge about air and gas cleaning technology in 1952 is conveyed by the information that the Handbook on Air Cleaning contained 89 pages. Of this number, less than one page was devoted to HEPA filters, then referred to as "absolute filters." In 1969, the first edition of the Nuclear Air Cleaning Handbook contained 202 pages. The second edition, a few years later, contained 290 pages and the third edition, currently in preparation, will no doubt contain more.

Among the topics covered during the second meeting, in addition to Harvard's air cleaning research studies, were reverse-jet filters for uranium refining operations at Mallinckrodt Chemical Co. and deep-bed sand filters at Hanford for treating dissolver offgases. It is interesting to learn from C. L. Lapple's account of the deep bed sand filter development at Hanford that it took but 3½ months from the start of experimental work to completion of the first full scale unit. Those were, indeed, heady times. Today, current projects of that magnitude will seldom take less than a year to clear the paper work to authorize and fund a study of project feasibility.

A part of the second meeting was concerned with removal of bacteria and bacteriophages from air by glass fiber filters; work conducted at Camp (later Fort) Detrick. Reports from Detrick of high efficiency air filtration for capture of biological agents continued for many conferences and ultimately contributed importantly to the development of biological safety cabinets. Other major topics of discussion were aerosol research at the University of Illinois and AEC-sponsored incinerator R&D programs at the U. S. Bureau of Mines, plus reports of incinerator operation (uniformly poor) at Los Alamos and Argonne National Laboratories. In fact, a review of later air cleaning proceedings shows a 40-year effort to design a safe, functional, and cost-effective unit for burning nuclear waste. Some never got built, some that were built never operated on nuclear waste, and the rest were soon abandoned. Nevertheless, interest in waste incineration persists as the search continues for a cradle-to-grave low-level rad-waste management system.

The reason I am spending so much time on the 2nd Seminar, when there are 21 more to go, is because I want to make the point that many of the problems that plague us today were recognized early on, in what we were then fond of calling "the nuclear age," and in spite of good intentions, we failed to solve them all before new ones caught up with us.

For the next few meetings, attention continued to center on aerosol sampling techniques and application of the chemical industry's wet gas cleaning methods to an atomic energy program that was mainly concerned with weapons-centered production activities. Two matters of concern were the release to populated areas of natural uranium compounds from ore processing and chemical purification steps, and the release of beryllium dust from ore refining and metal fabrication. In addition, there were needs for air cleaning research activities at the contract universities and national laboratories that involved the use of small quantities of radionuclides of an extremely diverse nature.

Starting with the third meeting, papers on the development and growth of the civilian nuclear power reactor program described methods for estimating fission product release rates and for collecting fission products, particularly radioiodine. For the latter, attention was directed toward the characterization and application of activated charcoal.

The third meeting took place at Los Alamos Scientific Laboratory, September 21-24, 1953, and was officially designated a "Conference" rather than a "Seminar." It included air cleaning status reports from nine AEC sites, four government agencies, (including the U. S. Weather Bureau and Bureau of Mines), six industrial companies, and five university research groups. Equipment manufacturers were invited to attend for the first time and Cambridge Filter Corp., Flanders Mill, Inc., and Mine Safety Appliances, Co., (all manufacturers of high efficiency (HEPA) filters), responded. Topics included the removal of radioiodine and particles from process gas streams at Hanford, the clean-up of stack gases from the Oak Ridge National Laboratory's (ORNL) gas cooled reactor with high efficiency filters, and the design of new ventilation and air filtration systems at Rocky Flats. The last topic was classified and not included in the unclassified proceedings of the Conference. As a sign of the euphoria then current regarding the nuclear industry, one contribution came from the aircraft nuclear propulsion program.

The 4th Conference, held at Argonne National Laboratory during November 1955, followed the same site reporting format of prior conferences. Prominent among the presentations were atmospheric diffusion studies of stack gas emissions that had been conducted at several AEC sites. Reports of blast effects on what were called AEC Type 1 Absolute Filters made their first appearance at this conference. Many more reports of filter resistance to shock followed and the subject remains a current interest, as may be seen from the Proceedings of the 23rd Conference. A method for changing contaminated AEC Type 1 filters without interrupting system airflow was described; it was a good try but it didn't make it. A functional system of this nature, from Harwell, was described at a later conference. Several of the presentations were classified, but all were later released. One described recent fires at four AEC installations and the effects on filter systems. A conclusion was that "heroic systems would be needed to protect large banks," and recommendations were made to make filter systems fire safe. Fire safety became a major topic at the 5th Conference and at all subsequent air cleaning conferences; it was on the agenda of the 23rd Conference.

Newly introduced topics of note at the 5th Conference were particulate airborne contamination at the startup of the experimental boiling water reactor (EBWR) at Argonne, and a Harvard Air Cleaning Laboratory progress report on filtration of freshly generated Nak (a sodium-potassium alloy) fume. Ultimately, Nak ruined a couple of nuclear submarines and burned down the Air Cleaning Lab. The Air Cleaning Lab made a recovery and later spent many years experimenting with molten elemental sodium coolant fires without incident. Air cleaning was being recognized as a significant cost factor in all aspects of nuclear operations, and cost accounting studies, then in progress, were reported. The 5th Conference was a totally open meeting.

The 6th Conference met at Idaho Falls during July 1959. It brought to the attention of the group a number of new topics of special importance, some of a decidedly disturbing nature, i.e., reports of radioactive particle fallout from tall discharge stacks and reports of serious defects in absolute filters delivered to AEC sites. Remedial measures for filter quality assurance included a mandatory retest of all filters at Hanford, WA, or at the Chemical Warfare Laboratory, before delivery to the user facilities, preparation of an Underwriters Laboratory standard for fire resistant filters, and a call for an industry standard for a fire-resistant filter. Euphoria continued, nonetheless, with reports of new air cleaning requirements for aircraft nuclear propulsion. Studies of adsorbents at several sites, principally activated charcoal, for retention of noble gases (in delay beds) and iodine (for permanent retention), were reported.

This was the first conference to which visitors from other countries were invited and a paper entitled, Air Cleaning Practice at ACE, Aldermaston, was presented. This became a tradition that has continued unbroken through the years. At the 23rd Conference there was a paper on the performance of HEPA filters from AEA-Harwell. The 6th Conference was the first at which discussions following each presentation were tape recorded and reported in the proceedings.

The practice of publishing in the Proceedings the names of those attending each conference did not begin until the 6th Conference, so we do not know all those who were present at earlier conferences except for the listed speakers and those we are still able to identify in the photo of the reception held during the 1st Seminar. In the attendee list published in the 6th Conference Proceedings there are two names that were present then and were also present at the 23rd Conference: Humphrey Gilbert, formerly with the AEC Office of Operational Safety, and Wendell Anderson, formerly with the Naval Research Laboratory. Both have taken a major role in the planning and conduct of the air cleaning conferences and continue to do so to the present.

After nuclear equipment suppliers were invited, and they began to attend the air cleaning conferences in substantial numbers, Humphrey Gilbert made a habit of inviting them, along with some concerned government regulators, to his room in the evening for a relaxing drink and some sober talk. Many serious problems were worked out in this way but it was recognized that a mechanism was needed for announcing and publishing the results of these informal, but important, information exchanges, so an election was held to choose a reporter. Wendell Anderson was elected to take notes, present the information to the entire conference, and write up his notes for the proceedings. In retrospect, my recollection is that Gilbert and I voted for Andy and he won the election two to one. In any event, the Government-Industry meetings were so successful and important that they were later conducted in an open forum and became a regular program event at each conference, from the 10th through the 19th. What happened then, will be taken up later.

The 7th Conference took place at Brookhaven National Laboratory during October 1961. Visitors from the UKAEA (United Kingdom Atomic Energy Agency) and the Center for Nuclear Energy (CEN), Mol, Belgium, attended and described new techniques for gaseous fission product containment. Methods for retention of radioactive gaseous and particulate releases occupied a major share of the conference agenda. It was also reported that the filter retest stations in operation at Hanford, WA and Edgewood, MD were responsible for a very satisfactory decrease in new HEPA filter rejections. This topic was revisited during the 23rd Conference. To eliminate damage from faulty filter installation procedures, an installation manual was prepared and a portable in-place filter testing procedure, developed at the Naval Research Laboratory for submarine service, was described. Other topics highlighted at the conference were stack testing and atmospheric dispersion, environmental air monitoring, radioactivity control following nuclear accidents, and a variety of cleaning techniques that could be applied to incinerator offgases. The 7th Conference was the first to be summarized in the Nuclear Safety journal (March 1962). The content of all subsequent conferences has been reported there.

At the 8th Conference, held at Oak Ridge National Laboratory during October 1963, increasing attention was focused on power reactor fission product releases from in-pile burning of reactor fuels; what we now refer to as the "source term." This is, of course, essential information for the rational design of accident control air cleaning systems. A review of the air cleaning conference proceedings shows many changes in the source term over time as new data became available and analytical procedures were improved. The somewhat different concepts of accident "containment" vs. "confinement" were subjects of vigorous discussion. It was noted at this conference that the first commercial chemical reprocessing plant was under construction in New York State (West Valley) and that future releases of radioactive noble gases from such sources could significantly increase atmospheric radioactivity world wide. At the conclusion of the 23rd Conference a site visit was conducted at West Valley to view the work being conducted there to decontaminate and decommission the facility and embed the residual high level waste in glass logs.

Four panel sessions were held on in-place filter testing and the development of fire resisting HEPA filter specifications. Panels proved to be an excellent way to explore emerging subjects and became a feature of all subsequent conferences. One of the unsettled questions brought out at this meeting, and that evoked many future research reports and panel discussions, was the chemical nature of the iodine released from fuel and its transformations between organic, inorganic, vapor, and particulate forms. In addition to the U. K., there were attendees from Canada, France, and the Netherlands.

The 8th Conference was the last one organized and attended by Leslie Silverman, "the originator and guiding spirit of the USAEC Air Cleaning Conferences." He died shortly before the 9th Conference, held in Boston during September, 1966.

Major topics on the agenda of the 9th Conference were source terms for water and gas cooled reactor accidents and for controlling sodium fires in liquid metal cooled fast breeder reactors (LMFBR); the chemical forms of iodine and their removal from air and steam; specifications for fire resistant HEPA filters; and studies of their resistance to heat, fire, and explosion. Definitive overpressure tests were reported on all sizes of HEPA filters constructed in accordance with military specifications.

In-place filter testing continued to be a subject of interest and technical development and, for the first time, there were reports of in-place test procedures for activated carbon adsorber beds. Other new topics were air cleaning systems for vented containment and floating roof containment vessels for holding fission product emissions pending treatment. For the first time, there was an Open-end Session for reporting short papers, research in progress, and puzzling phenomena needing discussion. Nationals from the U. K., France, and Canada were present. For the first time, representatives attended from Denmark, Switzerland, Germany, and Mexico. The names of J. L. Kovach and Dade Moeller appear on the attendance list for the first time at this conference. Both made outstanding contributions to this and all following conferences.

The 10th Air Cleaning Conference turned out to be two related but separate meetings. With great confidence and an excess of naiveté, the planning committee for the 10th Conference decided it was time for an international air and gas cleaning meeting in recognition of the increasing international interest in the AEC air cleaning conferences, plus the fact that important air cleaning research was now underway in many countries. AEC Headquarters readily accepted the plan and offered assistance, an offer that could not be refused because, unbeknownst to the Conference Program Committee, the AEC had already agreed that it was time for the International Atomic Energy Agency (IAEA) to hold an international air cleaning conference. What better time than the upcoming 10th AEC Air Cleaning Conference and what better place than the United Nations Headquarters in New York City! Learning that the Conference Program Committee no longer had control of the program and would not be permitted to publish the proceedings, they took advantage of a day set aside for foreign nationals to visit Brookhaven National Laboratory and held a one-day 10th Conference at the nearby Waldorf-Astoria Hotel. It was well attended by all the U. S. delegates plus many international visitors. This program, later published as the Proceedings of the 10th U. S. AEC Air Cleaning Conference, concentrated on a few topics of current importance: air cleaning system design, filter performance, and adsorbers for iodine. The International meeting at U. N. Headquarters was published by the IAEA and is entitled, "Environmental Aspects of Nuclear Power Stations", Vienna, 1971.

The Middle Period Conferences

The 11th AEC Air Cleaning Conference took place at Richland, Washington during August/September 1970. Major technical presentations included sodium aerosols from LMFBRs, water cooled reactor fission-product release estimations, removal of noble gases, iodine characterization and removal, filtration studies, instrument development and evaluation, effects of airborne radioactive materials, and standards development. Progress on engineered systems for the removal of the noble gases, krypton and xenon, from gaseous effluents was a major highlight. A computer model to simulate ignition of activated carbon adsorber banks by fission product decay heat was presented and, for the first time, the severe difficulties associated with extinguishing carbon fires were discussed. A number of presentations described the properties of inorganic adsorbents for iodine that would not be susceptible to ignition.

The 12th Conference was held during August 1972 at Oak Ridge National Laboratory. It was the last time the Air Cleaning Conference met at an AEC site. The large increase in the number of attendees from Europe, Asia, and South America made it expedient to meet at locations closer to an international airport.

In response to the announcement of plans for constructing a full scale LMFBR to be operated by TVA, plus knowledge that construction was underway on the Fast Flux Test Facility (FFTF) in Hanford, WA, an entire session was held on LMFBR accident analysis. In addition to numerous presentations on iodine, noble gases, and high efficiency filtration of fission product aerosols, entire sessions were devoted to underground uranium mine air cleaning, the function of air cleaning technology in helping to achieve "As Low As Reasonably Achievable" (ALARA) conditions, and air cleaning design for plutonium processing facilities (this was a panel session). There was a separate Government-Industry Conference on adsorbers and adsorbents, reported by Clifford Burchsted, in addition to a Government-Industry Committee on Filters, reported by Wendell Anderson.

A special ceremony was held at the beginning of this conference in recognition of the retirement of Humphrey Gilbert from the AEC. He was cited for having "sparked these conferences" as well as "a substantial portion of the research and quality control efforts that have transformed the air cleaning field in the past years."

The 13th Conference was held in San Francisco during August 1974. Dade Moeller presented the first of several analyses of air cleaning and airborne waste management system failures in U. S. nuclear facilities. This one covered 1966 to 1974. It was based on reports to the AEC of abnormal events. Over 75% of the abnormal events were directly attributable to errors in the design or operation of the systems. Intended as a remedial response by the AEC, the newly-published Regulatory Guide 1.52, entitled "The Design, Testing, And Maintenance Of Air Cleaning Systems In Water Cooled Nuclear Power Plants", received extensive discussion at several sessions during the conference. The first paper on nuclear power plant control room system design was presented at this conference. Many additional reports on this subject were given during later conferences.

Plutonium continued to be a major topic, along with filters, iodine, and fire protection.

Deterioration of filters and adsorbents during storage and in normal service was the subject of several papers and more was heard about their deterioration at the 23rd Conference. At the Government-Industry Meeting on Filters, Qualified Product Listings (QPLs), under revised standards for nuclear grade filters, were discussed. At the Government-Industry Meeting on Adsorbers, weathering of charcoal was shown to be a source of serious deterioration.

The 14th Conference took place in 1976 after the AEC was abolished and replaced by the U. S. Nuclear Regulatory Commission (NRC) and the U. S. Energy Research and Development Administration (ERDA); the latter agency was the sponsor of the 14th Conference. Under the stimulus of a continuing oil crisis, the design of the Clinch River Fast Breeder Reactor was accelerated. But at the same time, anti-nuclear groups were becoming a major deterrent to the continued expansion of civilian nuclear power. Among concepts first introduced at this conference was a plan for floating nuclear power plants that would be sited offshore to help reduce population exposure should a major accident occur. It would also be far from land-based voters. Although viewed as an innovated approach, this idea was never applied. However, a September 1994 item in the Wall Street Journal reported that "Russia's nuclear industry hopes to build four floating reactors to supply electricity to Siberia."

Gaseous waste treatment was always a principal focus at these conferences, and, at this one, volume reduction of solid waste products and their preparation for long and safe storage, including vitrification, constituted a major part of the proceedings. System protection from fire, explosion, and natural disasters received renewed attention, at least partially as a result of the Browns Ferry Nuclear Plant fire in 1975 and the publication that same year of the Reactor Safety Study, WASH-1400, that contained analyses related to generic types of failure mechanisms that could lead to failures of air cleaning systems. Of outstanding importance for nuclear engineered safety systems was the announcement that nuclear standards N509 (Nuclear Power Plant Air-Cleaning Units and Components) and N510 (Testing of Nuclear Air Treatment Systems) had been approved by the American Society of Mechanical Engineers' (ASME) Committee on Nuclear Codes and Standards and were awaiting approval by the American National Standards Institute (ANSI). An explanation of proposed modifications to R.G. 1.52, designed to respond to criticisms and to resolve possible conflicts with N509 and N510, was presented. Important changes included substitution of air cooling for water sprays to prevent decay heat ignition of carbon beds. It was announced that the custody of N509 and N510 would henceforth be the responsibility of the ASME Committee on Air and Gas Treatment Equipment (CONAGT), a group that has since that time played a prominent role at the air cleaning conferences.

The 15th Conference was held in Boston, MA during August 1978. It was renamed the DOE Nuclear Air Cleaning Conference. Not only was the new U. S. Department of Energy the successor agency of ERDA, but the word "nuclear" was added when the DOE designation in the call for papers brought in offerings on pulverized coal flyash, shale processing effluents, etc. The principal technical subjects considered at this conference were reactor safety R&D, regulatory activities to avoid accidents, and waste disposal, a topic that has grown in importance, year-by-year, at these conferences. Of special interest were explanations of the structure of the new DOE, at that time less than a year old, and planned activities within the newly organized management program for airborne radioactive waste.

A new report on failures of nuclear air cleaning systems listed over 1,200 that had occurred during 1975-1978. Inasmuch as a large fraction of the failures occurred in equipment installed to sample and monitor air systems, the paper's author (Dade Moeller) cautioned that "inaccurate data on the performance of ... systems can lead to as many problems as inadequacies in the systems themselves." This was a wise and prophetic statement, as the Three Mile Island (TMI) event demonstrated less than one year later wherein inaccurate instrument readings played a major role in the disaster.

In a surprising announcement, NRC stated that their evaluation of recent test results from DOE's three filter test stations led them to conclude that it was no longer necessary for nuclear power plants to have their HEPA filters pretested prior to acceptance and installation; from this time on, in-place tests alone would provide confirmatory evidence of filter integrity. For the first time, minipleat filters of European design, having higher airflow capacity than the standard U. S. filter, were described, and representative performance data were presented.

The introduction of a new continuous automatic particle sampling, counting, and sizing instrument, the single particle intercavity laser spectrophotometer, developed at LASL (Los Alamos Scientific Laboratory, currently Los Alamos National Laboratory), made it possible to check more accurately the size of the monodisperse 0.3μm DOP aerosol used for bench-testing HEPA filters. Particle size was found not only to be off the mark but to vary from machine to machine. This discovery shook the foundation of HEPA filter technology and stimulated many re-studies of filter performance. Aerosol computer codes, designed to simulate the dynamic behavior of products released during core descriptive accidents, made a first appearance at this conference.

The 16th DOE Nuclear Air Cleaning Conference took place during October 1980. The full impact of the TMI-II accident figured prominently in the presentations at this meeting. Of special importance to the delegates were the sessions on air cleaning system performance at TMI-II. It was explained that noble gas leaks were the principal sources of radiation release to the environment but that HEPA filters prevented release of all particles, and that adsorbers reduced iodine release to a small value. Nevertheless, the TMI-II event initiated reports of a number of new U. S. studies of passive air cleaning devices, including deep sand filters that might be used to filter vented containment atmospheres. Many papers from Europe on vented containment were given at subsequent conferences.

A 1980 finding by the national toxicology program that DOP was a potential human carcinogen sent another shock wave through the nuclear air cleaning community and stimulated studies to find suitable substitutes for test stand and in-place filter testing. The search lasted 14 years. At the 23rd Conference there was a report from the Edgewood laboratory that they had, at last, discovered a perfect substitute, Emery 3004, a poly-alpha olefin synthetic lubricant. Simultaneously, the U. S. Environmental Protection Agency announced that they were considering the removal of DOP from the toxic products list.

Many of the presentations on reprocessing of spent fuels were now coming from Europe as this activity came to a halt in the U. S. during the Carter administration (1976-1980). In addition, the Clinch River LMFBR was cancelled, although the FFTF program at Hanford continued for a while. As a result, funding for most of the air cleaning research studies in the U. S. decreased or terminated, and a major share of the activities in this field shifted overseas. This was the first conference since the 10th to feature critical reviews. Three were given: on radioiodine control, aerosol filtration, and noble gas treatment systems. This was the first conference that was immediately preceded by a regularly scheduled CONAGT meeting, and CONAGT organized an entire session at the conference on the topic of nuclear air cleaning standards. ORNL provided an author, title, and permutated word index to the proceedings of all the nuclear air cleaning conferences up through the 16th. It was included as a part of the Proceedings of the 16th Conference and was designed to make the vast archive of information readily available for consultation, reference, and review.

The 17th DOE Nuclear Air Cleaning Conference was held in Denver, CO during August 1982. A new DOE program in the field of HEPA filters was announced. It involved the development of a set of DOE standards for filter testing that would use the previously cited single particle intercavity laser spectrophotometer in place of a total light scattering photometer and would focus exclusively on the least filterable particle size, approximately 0.09 μm. NRC announced an initiative to prepare Revision 3 to R.G. 1.52 within 1½ to 2 years.

The conference agenda included sessions on the redefinition of nuclear power plant source terms based on studies of the TMI-II accident; the behavior and transport of specific radionuclides under accident conditions; performance standards, procedures, and instruments for evaluating the efficiency of air cleaning systems; air cleaning requirements for spent fuel reprocessing; special approaches for the control of ^{14}C, radioiodine, and the noble gases; development of computer models for evaluating component failures in air cleaning systems and the performance of specific systems under normal and accident conditions; contamination control and personnel protection; repair requirements and failure rates in air cleaning systems; and problems relating to quality assurance.

It was noted, once again, that the U. S. commitment to research on nuclear air and gas cleaning had been greatly reduced and that most research studies were now being conducted in Europe and Asia.

The 18th Conference, held in Baltimore, MD during August 1984, sported a new title, the DOE Nuclear Airborne Waste Management and Air Cleaning Conference. It signified a waning interest in the further development of U. S. government-supported research for engineered safety system air cleaning technology for commercial nuclear power plants and an increasing concern for nuclear waste management, an area where nuclear air cleaning technology was, and still is, desperately needed. Inasmuch as nuclear airborne waste management incorporates a very large component of air and gas cleaning technology, the combination is a natural one and it is logical to conclude that combining the two will enrich knowledge of both. The NRC, retaining a primary interest in commercial nuclear power, reported, at this and later conferences, continued refinements and improvements in the techniques for estimating accident source terms.

Performance and testing of adsorbers and filters installed in full-scale operating systems was the subject of several presentations at this conference, reflecting a determined effort by the Program Committee to respond more fully to the needs of operating personnel. Included were reports of a roundrobin test program for laboratory rating of nuclear carbon that demonstrated that the test protocol accepted by NRC was defective and required serious attention; this it received. The field of waste collection, processing, and storage was covered by numerous research papers, pilot plant operating reports, and theoretical studies. Of interest, was the first conference presentation by a representative from the People's Republic of China.

Recent Air Cleaning Conferences

The 19th Conference called for another title change when the NRC joined with the DOE to sponsor the first DOE/NRC Nuclear Air Cleaning Conference. It was held in Seattle, Washington during August 1986. Chernobyl was on the minds of all as they reflected on the consequences of a failure to employ containment structures and engineered safety systems as primary mechanisms for controlling airborne radionuclide releases following major accidents in nuclear power plants. The outcome at Chernobyl was contrasted with the outcome of the TMI-II accident where air cleaning systems proved to be effective barriers to emissions, even under unusual circumstances. The heightened interest in vented containment resulting from Chernobyl emphasized the need for new types of ultra-high efficiency air and gas cleaning systems. Accident analysis and loss control were prominent topics on the agenda. The latest developments in adsorption for removal of iodine and other gases, and aerosol filtration for particle retention, were covered during several half day sessions. The many papers and panel sessions on standards and regulations reflected a vigorous effort to prepare and apply nuclear codes and standards, plus a drive to eliminate conflicts between like-minded documents. Nuclear gas processing systems intended for decontamination, demolition, and treatment of nuclear wastes were recognized to be seriously in need of the kinds of standards that were already being vigorously developed for air cleaning systems used in engineered safeguard systems of nuclear power plants.

Fire detection and suppression in activated carbon beds came to the fore once again as a result of a series of false triggerings of water sprinklers, required by American nuclear insurers. After a thorough exchange of views between regulators, insurers, and plant operators during a panel session, a satisfactory resolution was reached to provide positive protections against accidental carbon flooding by providing a pipeline discontinuity that must be closed manually to activate the system. New nuclear carbon laboratory test protocols were proposed; they were ultimately accepted by all stakeholders and incorporated into a revised ASTM Standard, D3803-89. A feature of this conference was a luncheon address by Dixy Lee Ray, an ardent and fiery spokesperson for nuclear energy.

The 20th DOE/NRC Nuclear Air Cleaning Conference was held in Boston, Massachusetts during August 1988 amid great excitement over the (unsuccessful) bid for the presidency by the state's governor. Papers on severe accident mitigation were a continuing legacy from the Chernobyl disaster. Reactor operations were a prominent part of the agenda. Papers on decommissioning made their first appearance at this conference. The effects of age, fire, and physical stress on HEPA filter performance were discussed by representatives from five different nations, evidence of a continuing universal concern. Waste treatment was discussed, but was not a major contributor to the agenda.

At this time, the Nuclear Regulatory Commission and the United States Department of Energy requested the industrial beneficiaries of these conferences to demonstrate that the conferences were useful, needed, and as productive for them as for the agencies involved, by becoming identified as co-sponsors and by helping to provide financial support. A number of industry leaders responded by organizing themselves as an *ad hoc* committee to explore the formation of a group that would help support future air cleaning conferences. This tentative organization developed into the International Society for Nuclear Air Treatment Technologies (ISNATT). It became a co-sponsor of the conferences and assumed responsibility for arranging the Government-Industry meetings. Today, ISNATT is solely responsible for organizing and conducting exhibits that are held jointly with the conference. ORNL prepared a cumulative index from the beginning through the 20th Conference (as they had for the 16th) and it was distributed with the Proceedings of the 20th as Volume 3 of 3.

The 21st Conference, held during August 1990, returned to San Diego. A feature of this meeting was an introduction to the development of advanced reactor designs. Management and disposal of spent fuel and high level chemical wastes received considerable attention in formal papers and discussion groups. Codes and standards continued to be an important topic with the appearance of the first sections of an ASME/ANSI "Code on Nuclear Air and Gas Treatment, AG-1." There were continuing concerns expressed regarding compatibility of U. S. codes and standards with those being produced and adopted by the European Community. An entire session was devoted to the troublesome questions that arise when ASME N510 is invoked for testing systems that were not constructed in strict conformance with ASME N509. Incineration and vitrification of nuclear wastes were additional topics of interest. Vented containment studies from France, Germany, Sweden and Japan were presented. A panel session entitled, Nuclear Air Cleaning Programs Around the World, described current activities in 10 countries that ranged from reactor regulation to reprocessing and waste management.

The 22nd Conference was held in Denver during August 1992. In recognition of the greater interest and concern with the processing of gaseous effluents from nuclear waste treatment operations, a new title was chosen for the conferences, the DOE/NRC Nuclear Air Cleaning and Treatment Conference. The 23rd Conference retained the same designation. The opening session of the 22nd was devoted to a discussion of the current status of nuclear power in the U. S. and the importance of the advanced nuclear power reactors under construction in Asia. The impact of source term revisions on air and gas treatment requirements was the subject of a panel session. Another panel session reviewed new nuclear testing protocols. ORNL kindly provided an index for the 21st and 22nd Conferences that was included in volume 2 of the Proceedings of the 22nd Conference.

The most recent conference, the 23rd, was held in Buffalo, New York during July 1994. It was sponsored by ISNATT, in addition to DOE, NRC, and the Harvard Air Cleaning Laboratory. One hundred and ninety-two air cleaning specialists attended from the U. S. and 11 other countries. Proximity to West Valley, site of a major DOE program of decontamination, decommissioning, and waste encapsulation for permanent storage, made these topics a prominent part of the technical program. At the conclusion of the technical program, approximately 50 conference attendees visited the West Valley Demonstration Project and received a guided tour of a pilot plant used for operator training and a partially completed full-scale vitrification facility.

The development and application of nuclear codes and standards received a great deal of attention at this conference and, once again, re-emphasized the need to reconcile conflicts between codes and standards that are in good standing. Presentations about the ongoing West Valley Demonstration Project, a panel session on air cleaning for gas processing operations, and a description of the progress of cleanup efforts at the Fernald site brought to the fore the urgent need to develop, and have in place, nuclear gas processing standards that would apply uniquely to nuclear waste processing activities before major efforts are undertaken at numerous DOE sites. This need was communicated to representatives of CONAGT for action.

Deterioration of air cleaning systems after many years in service, and on standby, continues to be a major safety concern. Methods that might be used to downrate the "as-installed protection factors" provided by old systems were proposed, and continuation of work on this troublesome matter was promised by DOE representatives and their contractors. Changing materials and manufacturing methods for HEPA filters make predictions of future service life, based on analyses of old filters, somewhat precarious.

Refinements of the source term for nuclear power plant accidents were reported, and it was predicted that this activity will soon reach closure, at least for the present. During one of the panel sessions, efforts to define source terms applicable to the control of radioactive and chemical contaminants during decontamination and dismantling operations were reported to be underway.

Commissioner Kenneth C. Rogers, U. S. Nuclear Regulatory Commission, gave a featured address entitled, "Clean Air and Clear Responsibility" that focused on a discussion of optimizing the principles of ALARA plus procedures for amicably reconciling conflicts between regulations of the NRC and the U. S. Environmental Protection Agency.

During the final session of the 23rd Conference, recommendations were received for selecting a site and a set of objectives for a 24th Conference that will be held during 1996.

Conclusion and Afterthoughts

I have recounted only a few of the highlights from the past. Each conference has recorded advancements in nuclear safety and revealed the arrival of new challenges. The conferences have been a force for advancement as well as a forum for refinement of current technology, and the conference proceedings serve as a history of achievements in this field.

What of the future? Surely the conferences will continue to be highly involved in the important task of maintaining and improving engineered safeguards for existing power reactors and with meeting the air cleaning and treatment needs of advanced reactors. In addition, the scope must broaden to include whole new areas that we always knew were there, but tended to postpone coming to grips with. This means, of course, the tasks of reactor decommissioning and disassembly, the cleaning up of weapons sites, and the safe storage of nuclear wastes of many types. All of these tasks call for air cleaning and gas treatment applications that differ significantly from those applied to power reactors. There is hope and expectation that we will learn more about these requirements and their solution during future nuclear air cleaning conferences.

An appendix to this "Brief History" summarizes the date and location of each air cleaning conference and gives a reference for each volume of the proceedings.

Acknowledgement: The liberal use of Dr. Dade Moeller's several publications in the Proceedings on the history of the nuclear air cleaning conferences as well as his perceptive comments on the original draft are acknowledged with thanks.

APPENDIX

Chronological Listing of Air Cleaning Conferences

Conference Number	Date	Site	Document Number	Number of Volumes
1	June 12-15, 1951	Boston, MA	No Report	
2	Sept. 15-17, 1952	Ames, IA	WASH-149	1
3	Sept. 21-23, 1953	Los Alamos, NM	WASH-170	1
4	Nov. 2-4, 1955	Argonne, IL	TID-7513(Pt. 1)	1
5	June 24-27, 1957	Boston, MA	TID-7551	1
6	July 7-9, 1959	Idaho Falls, ID	TID-7593	1
7	Oct. 10-12, 1961	Upton, NY	TID-7627	1
8	Oct. 22-25, 1963	Oak Ridge, TN	TID-7677	1
9	Sept. 13-16, 1966	Boston, MA	AEC-660904	2
10	Aug. 28, 1968	New York, NY	CONF-680821	1
11	Aug. 31-Sept. 3, 1970	Richland, WA	CONF-700816	2
12	Aug. 28-31, 1972	Oak Ridge, TN	CONF-720823	2
13	Aug. 12-15, 1974	San Francisco, CA	CONF-740807	2
14	Aug. 2-4, 1976	Sun Valley, ID	CONF-760822	2
15	Aug. 7-10, 1978	Boston, MA	CONF-780819	2
16	Oct. 20-23, 1980	San Diego, CA	CONF-801038	2
17	Aug. 2-5, 1982	Denver, CO	CONF-820833	2
18	Aug. 12-16, 1984	Baltimore, MD	CONF-840806	2
19	Aug. 18-21, 1986	Seattle, WA	NUREG/CP-0086 CONF-860820*	2
20	Aug. 22-25, 1988	Boston, MA	NUREG/CP-0098 CONF-880822*	3
21	Aug. 13-16, 1990	San Diego, CA	NUREG/CP-0116 CONF-900809*	2
22	Aug. 24-27, 1992	Denver, CO	NUREG/CP-0130 CONF-9020823*	2
23	July 25-28, 1994	Buffalo, NY	NUREG/CP-0141 CONF-940738*	1

All documents available from:
National Technical Information Service
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* Also available from:
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U. S. Government Printing Office
Mail Stop SSOP
Washington, DC 20402-9328

THE INTEGRATED MELTER OFF-GAS TREATMENT SYSTEMS AT THE WEST VALLEY DEMONSTRATION PROJECT*

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Abstract

The West Valley Demonstration Project was established by Public Law 96-368, the "West Valley Demonstration Project Act," on October 1, 1980. Under this act, Congress directed the Department of Energy to carry out a high level radioactive waste management demonstration project at the Western New York Nuclear Service Center in Wast Valley, New York. The purpose of this project is to demonstrate solidification techniques which can be used for preparing high level radioactive waste for disposal. In addition to developing this technology, the West Valley Demonstration Project Act directs the Department of Energy to:

(1) develop containers suitable for permanent disposal of the high level waste;

(2) transport the solidified high level waste to a Federal repository;

(3) dispose of low level and transuranic waste produced under the project; and

(4) decontaminate and decommission the facilities and materials associated with project activities and the storage tanks originally used to store the liquid high level radioactive waste.

The process of vitrification will be used to solidify the high level radioactive liquid wastes into borosilicate glass. This report describes the functions, the controlling design criteria, and the resulting design of the melter off-gas treatment systems which are used in the vitrification process.

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* Work Performed Under Contract No. DE-AC07-81NE44139

I. Introduction

The primary objective of the West Valley Demonstration Project (WVDP), located at the former nuclear fuel reprocessing plant at West Valley, New York, is to solidify the high-level radioactive waste stored in underground tanks into a form suitable for transportation and disposal. Vitrification has been chosen as the method of solidification. The purpose of this report is to describe briefly the systems used to treat the vitrification system off-gases for the purpose of protecting the environment.

The gaseous effluent from the melter, mostly water vapor and oxides of nitrogen, are scrubbed in a submerged bed scrubber, processed through a high efficiency mist eliminator, and filtered before leaving the shielded vitrification cell. Before the off-gases are released to the environment, they are further filtered through High Efficiency Particulate Air (HEPA) filters, and the oxides of nitrogen (NO_x) are eliminated by selective catalytic destruction.

II. Functions and Design Criteria

The overall project approach was to incorporate the following principles:

(1) Make maximum use of existing technology, facilities and equipment.

(2) Minimize complexity.

(3) Produce a system that was safe, environmentally sound and cost effective.

Functions

The Vitrification Facility functional requirements that applied to the melter off-gas treatment systems are as follows:

(1) Remove radioactive particulate matter, toxic gases, and vapor from the process gases for release to the environment.

(2) Provide process solution re-use and recycle features to minimize derivative waste disposal demands.

(3) Provide process system redundancy and/or readily achievable remote removal and replacement capability for planned maintenance.

(4) Provide monitoring and control systems and maintain release levels below current state and federal regulatory limits.

(5) Use existing WVDP utility and support systems as far as practical.

(6) Provide design features to maintain internal and external radiation exposures to operating and maintenance personnel ALARA, and in no case exceed allowable design guidelines. Provide the capability to control contamination during routine and emergency operating conditions and during all hands-on and remote maintenance activities.

(7) Maximize the use of low maintenance process equipment in radioactive areas, and provide remotely operated decontamination capabilities for equipment to the extent necessary to support required maintenance.

(8) Provide alarm systems, and all other plant safety features essential to proper and safe plant operation.

(9) Evaluate remote equipment and components used in the vitrification for their service lives. Service lives may be enhanced, if required, by increased quality and reliability for the equipment, redundancy of equipment, and/or remote replaceability.

(10) Provide an alternate power supply and utilities as backup for essential equipment and systems.

Design Criteria

The primary design criteria applied to the melter off-gas treatment systems, excerpted from the design criteria document controlling the entire vitrification facility, are presented in the following paragraphs.

Operational Criteria The process off-gas system blowers will maintain a negative pressure on the major tankage and melter within the vitrification facility and throughout the upstream process train to assure any leaks are into the system. An installed back-up off-gas blower and an alternate power source shall be provided.

Maintenance Criteria Systems and components in contaminated areas shall be designed to be either remotely maintainable in place, or remotely removable and replaceable.

Spares shall be provided for critical components or components that have a high probability of failure during operation.

Connectors, bolts, flanges, wrenches, sockets shall be standardized to the maximum extent practical.

Equipment shall be movable, maintainable, and replaceable with minimum disturbance of adjacent equipment.

The vitrification facility systems and structures are to be designed to facilitate post solidification decontamination.

Structural Criteria Structures and components that are required to confine radioactive material shall be able to withstand the effects of natural hazards without loss of capability to perform safety function(s) or prevent the release of radioactivity and shall be designed to the "Operational Safety Design Criteria Manual," (ID-12044).

New confinement structures shall be designed to an acceleration of 0.1 g at ground level (horizontal loads).

The equipment shall be designed for a service life of seven years.

Safety Criteria The principle of "As Low As Reasonably Achievable" (ALARA) shall apply to all aspects of radiation exposure. On-site personnel exposure levels less than one-fifth of the DOE Order 5480.11 dose equivalent limits should be used as a design objective.

The maximum radiation dose rate for a full-time access area shall be 2.5/t mRem/hr in which "t" is the maximum average time in hours per day that the area is expected to be occupied by any one individual. A full-time access area is one in which no physical or administrative control of entry exists.

Environmental Criteria Gaseous releases shall be subject to applicable Environmental Protection Agency (EPA), New York State Department of Environmental Conservation (NYSDEC), and DOE regulations, Orders, and directives. These regulations shall include, but not be limited to, 40 CFR 61, 6 NYCRR Series 200, and DOE Order 5480.1A.

Where possible, radioactive liquid waste will be recycled within the vitrification facility.

Quality Assurance The Quality Assurance program will be based on ANSI/ASME NQA-1, and all supplements.

Decommissioning The vitrification facility design shall incorporate features that facilitate future decommissioning of the facility.

III. Process Descriptions

The integrated melter off-gas treatment systems are depicted in Figure 1. The ALARA portion is located inside the vitrification cell and is identified as the In-Cell Off-Gas System. The atmospheric protection portion is located in the trench and in the 01-14 building and is identified as the Out-of-Cell Off-Gas system.

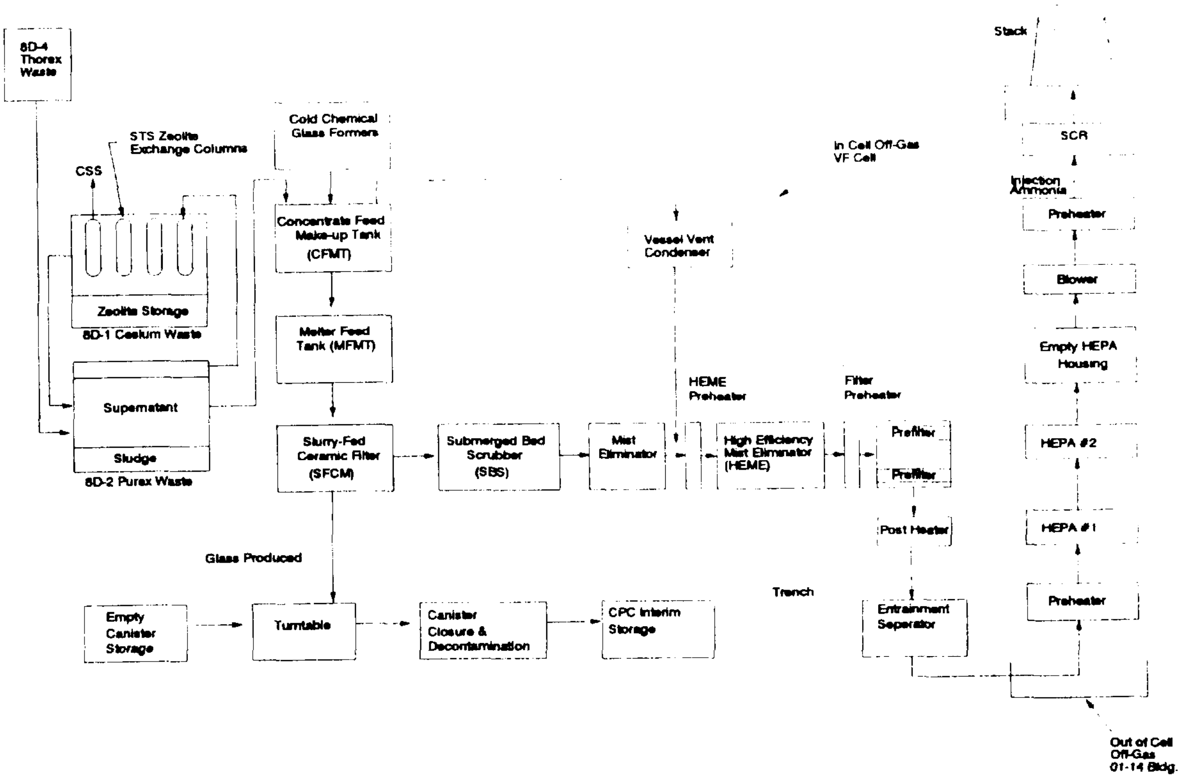

Figure 1: Integrated melter off-gas treatment systems.

ALARA Process

The ALARA melter off-gas treatment system, and associated vessel ventilation system, are depicted in Figures 2 and 3, and include all equipment required to treat, and transfer process gases and vapors from the melter and other in-cell equipment to the atmospheric protection off-gas treatment system.

Vessel Ventilation Ventilation gases and vapors from the concentrator, the feed hold tank, the canister turntable, canister decontamination station, and the vitrification cell waste header, are continuously collected into the vessel ventilation header. In the event that vacuum is lost in the melter, melter gases and vapors are also directed into the vessel vent header to re-establish the vacuum. The gases and vapors from the vessel vent header are directed into the shell side of the condenser. Closed loop cooling water is directed into the tubes, counterflow with the gases and vapors in the shell. The condensate from the condenser flows by gravity through a calibrated weir, and a liquid seal, to a header which directs the liquid to the tank farm for subsequent processing. Gases and uncondensed vapors are directed into the in-cell melter off-gas treatment system.

Quenching/Scrubbing The submerged bed scrubber is designed for the first stage scrubbing of melter off-gases, cooling and condensation of melter vapor emissions, and interim storage of condensed fluids. The scrubber is a passive device that uses water to remove particulate and to quench the off-gases. It functions by bubbling the off-gases through water in a bed packed with ceramic spheres. The rising bubbles of off-gas cause the liquid to circulate up through the packing. This simultaneously causes downward flow in the annular space outside the packed bed as liquid from the annular space replaces the liquid which is rising through the bed. The packing breaks larger bubbles into smaller ones to increase the gas-to-water contacting surface, thereby increasing the particulate removal and heat transfer efficiencies. The liquid circulation helps to prevent a buildup of captured material in the bed by constantly washing the material away. As the off-gases cool, water vapor condenses and increases the liquid water inventory. The excess water spills into the receiver, thereby maintaining a constant liquid depth in the scrubber. Heat absorbed by the water from the off-gases is removed by the cooling coils as the water flows downward in the annular space.

The mist eliminator consists of a mesh pad in a housing mounted directly on the submerged bed scrubber off-gas exit nozzle flange, plus a jumper that provides demineralized spray water to flush the pad, and pressure differential measurement across the pad during operation.

Off-gases enter from below the pad and exit from above. The mist eliminator pad collects entrained droplets by impaction against the pad fibers where they adhere and coalesce. The coalesced liquid flows by gravity back into the submerged bed scrubber.

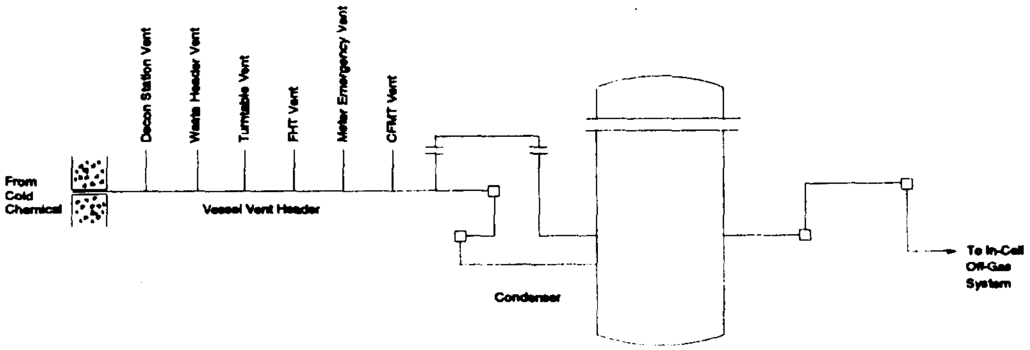

Figure 2: Vessel ventilation system.

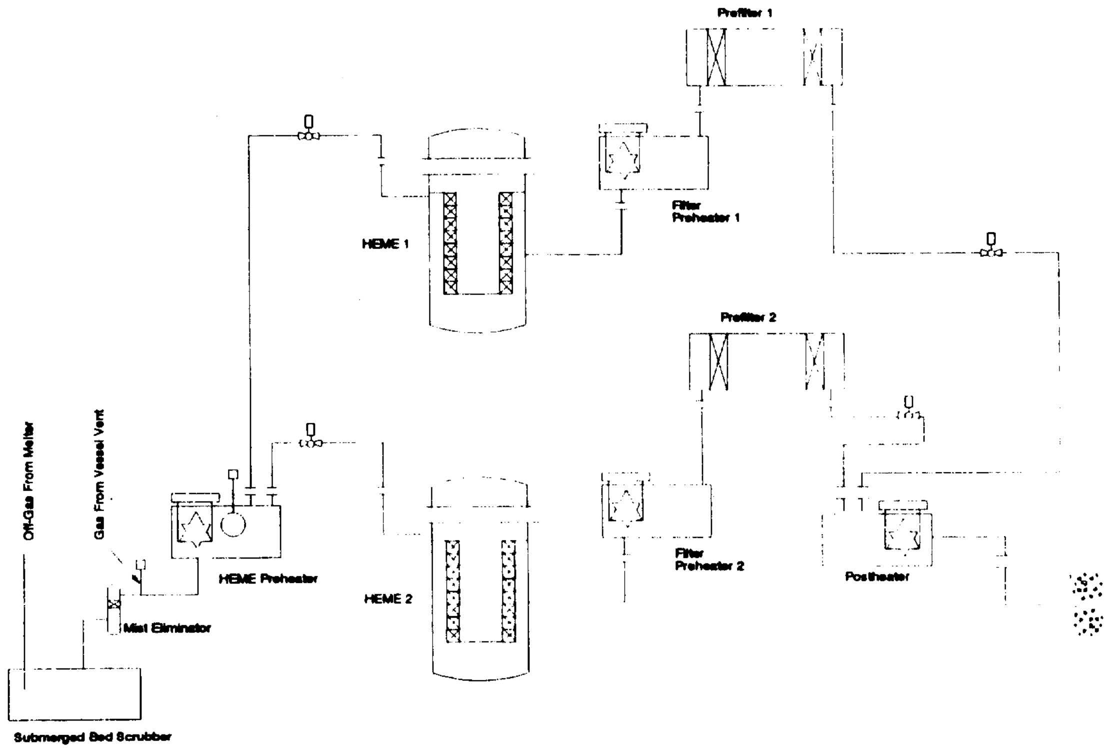

Figure 3: ALARA off-gas treatment system.

High Efficiency Mist Elimination Should the operations organization decide to employ the high efficiency mist eliminator as a dry filter, the 480 V electric preheater would be used to elevate the temperature of the off-gases above their dew point. The reference use for the high efficiency mist eliminator is mist elimination, and this preheating option is not expected to be employed.

Impact wrench operated isolation valves in the jumpers to the high efficiency mist eliminators are used to select which of the two installed parallel off-gas trains (high efficiency mist eliminator, filter preheater and prefilter) are used.

The high efficiency mist eliminator receives off-gases from the preheater. It collects and coalesces entrained liquid droplets, and is 99.8 weight percent efficient for droplets 3 microns in diameter and larger. Simultaneously it removes submicron particulate from the gases.

Off-gases enter the center of the cylindrical pad from the top and pass through the pad to the outside. Because the pad is so large, the velocity of the gas through the pad is slow. Due to Brownian movement, droplets and particles contact the fibers of the pad where they collect and coalesce. Collected particulate is carried to the high efficiency mist eliminator drain lines either by the gravity flow of the coalesced liquids, or by demineralized water spray.

The high efficiency mist eliminator vessel has a drain line which directs coalesced liquids, and spray water, to the submerged bed scrubber.

Prefiltration The filter preheaters operate by the same principles described for the high efficiency mist eliminator preheater.

The filter preheaters are used to elevate the temperature of the off-gases above the dew point to assure that no condensation occurs on the prefilter elements downstream.

The prefilter assemblies capture dry particulate to retain radioactive contamination inside the vitrification cell. This prevents significant contamination from reaching off-gas treatment equipment located downstream, outside the vitrification cell, thereby allowing hands-on maintenance there.

Heating The off-gases from the parallel off-gas trains are directed to a common "postheater."

NOTE

> The original purpose of the postheater was to elevate the temperature of the off-gases above the dew point sufficiently to assure that no condensation occurred in the duct from the vitrification cell to the 01-14

Building. Insulation, an entrainment separator, and reheaters installed to protect the HEPA filters rendered the "postheater" redundant.

Atmospheric Protection Process

The Atmospheric Protection Off-Gas Treatment System is depicted in Figure 4, and includes all equipment required to treat and transfer process gases from the vitrification cell to the base of the plant stack.

HEPA Filtration The off-gases from the vitrification cell are directed through an insulated duct to the atmospheric protection off-gas treatment equipment. The insulation is intended to protect the HEPA filter elements by mitigating condensate formation between the vitrification cell and the final HEPA filters. Immediately upstream from the HEPA filters the off-gases are processed through an entrainment separator, and one of two redundant electric reheaters connected in parallel, which restore the off-gas temperature to above the dew point.

The off-gases then pass through the HEPA filters. In each of two parallel filter trains are two HEPA filter elements arranged in series. The gases pass through one filter train while the other remains available as an installed back-up. The purpose of the HEPA filters is to provide final atmospheric protection against dispersion of radioactive particulate. The integrity of the filter elements, and the seals between the elements and the housing, is verified by in-place DOP testing.

Following HEPA filtration, the off-gases pass through another, empty, filter housing, One housing is located immediately downstream from each HEPA filter. These previously existing housings were retained for possible future use.

Motivation Following filtration, the off-gases pass through one of three redundant, positive displacement, off-gas blowers installed in parallel. One blower operates while the others provide reliable, full capacity, backup service. The blower provides the motive force to maintain all of the vitrification equipment upstream under a slight vacuum for the purpose of contamination control. It also provides the motive force to discharge the treated off-gas into the base of the previously existing plant stack.

NO_x Destruction From the blower, the off-gas passes through a NO_x abatement system to destroy the noxious oxides of nitrogen (NO_x). The oxides of nitrogen are reacted with ammonia at an elevated temperature, and in the presence of a catalyst, to produce harmless water vapor and nitrogen.

The NO_x destruction equipment includes redundant off-gas preheaters, an ammonia supply system, and redundant catalytic reactors. The preheaters elevate the off-gas temperature to

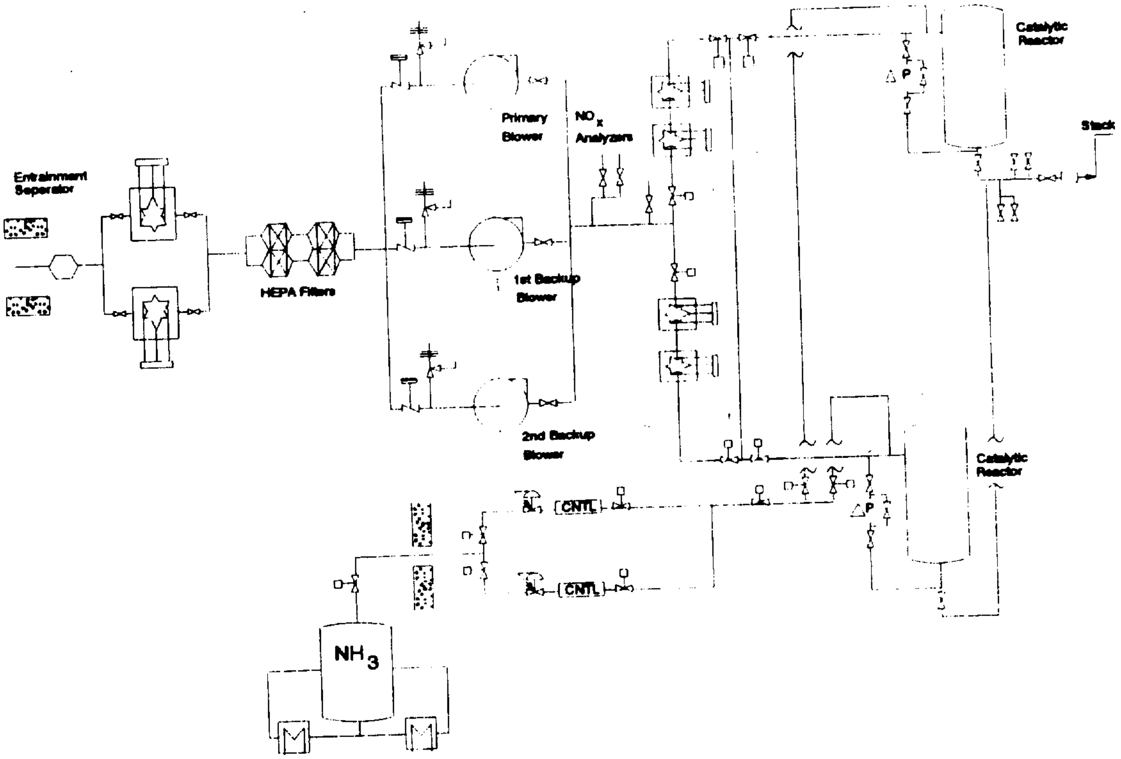

Figure 4: Atmospheric protection off-gas treatment system.

promote the desired reaction, the ammonia supply provides the necessary reactant, and the catalytic reactor accelerates the desired reaction.

The NO_x gases are destroyed by several competing chemical reactions involving NO_2, NO, N_2O, NH_3 and O_2. Test results indicate that, at WVDP operating conditions, the following reactions dominate.

$$2\ NO + O_2 \rightarrow 2\ NO_2$$

$$8\ NO_2 + 6\ NH_3 \rightarrow 7\ N_2O + 9\ H_2O$$

$$2\ N_2O \rightarrow 2\ N_2 + O_2$$

Following NO_x destruction, the treated off-gas is directed to the previously existing plant stack.

IV. Equipment Descriptions

ALARA Equipment

The vitrification cell environment which the melter off-gas treatment equipment must endure is tabulated below.

Temperature	16 to 35 °C	(60 to 95 °F)
Pressure	0 to -1 kPa	(0 to -4 InWC)
Relative Humidity	30 to 80 %	
Nitric Acid Fumes	100 ppm	
Radiation (SBS)	50 Gy/h	(5 x 10^3 Rad/hr)
(other)	1 Gy/h	(100 Rad/hr)

For corrosion resistance against nitric acid fumes and solutions, the fabrication materials used for surfaces of equipment exposed to the vitrification cell environment, and to process fluids, is generally Type 304L stainless steel. The structual supports are made from carbon steel, and are painted for corrosion resistance.

Vessel Ventilation The vessel ventilation header is located near the top of the vitrification cell walls. It rests on supports at a slope of 10 mm/m (1/8 in/ft) so liquids will drain to the condenser. The header is made from seamless 150 mm (6 in) pipe. Stresses in the header due to thermal expansion and contraction are accommodated by six, permanently installed, expansion joints. They are physically protected by external covers, and from accumulations of particulate by internal sleeves.

The vessel ventilation condenser is a vertical, 3.2 GJ/h (3.0 x 10^6 Btu/hr) shell and U-tube heat exchanger. The shell is 760 mm (30 in) in diameter, is 3400 mm (11 ft) high.

Quenching/Scrubbing Quenching and initial scrubbing is accomplished by the Submerged Bed Scrubber (SBS). It is comprised of a scrubber vessel, and a receiver vessel which completely envelopes the scrubber vessel.

The scrubber consists of two concentric right cylindrical vessels.

The inner vessel contains the bed, is 1220 mm (4 ft) tall, 910 mm (3 ft) in diameter, and is constantly flooded with the water contained by the outer vessel. An Inconel 690 bed support/gas distributor plate forms the bottom. It houses a 0.5 m^3 (18 ft^3) bed of 10 mm (3/8 in) diameter ceramic sphere packing. Off-gases are introduced through a 250 mm (10 in) diameter Inconel 690 downcomer entering from the top and discharging at the bottom of the bed.

The outer vessel is 1750 mm (69 in) tall and 1830 mm (6 ft) in diameter. It is open at the top, and is kept filled with water.

The scrubber contains cooling coils in the annular space outside the bed. Instrumentation to measure temperature, vapor space pressure, liquid specific gravity and liquid depth are provided.

The maximum operating volume of the receiver is 5.5 m^3 (1450 gal). The SBS receiver vessel is a right cylindrical vessel, 2440 mm (8 ft) in diameter and 3350 mm (11 ft) tall. Steam jets (not shown) are provided to evacuate the contents. Instrumentation is provided to measure temperature, vapor space pressure, liquid specific gravity, and liquid depth.

The mist eliminator housing is made from 460 mm (18 in) pipe, and the inlet and outlet ducting is from 150 mm (6 in) pipe. The pad is a 150 mm (6 in) thick, knitted mesh with a 360 mm (14 in) diameter exposed face. The pad is designed to minimize fouling, and consists of four pads in series with each successive pad having a greater packing density.

High Efficiency Mist Elimination The high efficiency mist eliminator (HEME) preheater 50 kW, electrical resistance heating element is operated with 480 V, electrical energy.

The HEME vessels are cylindrical, 1070 mm (42 in) diameter, 4060 mm (160 in) tall. The HEME elements are 760 mm (30 in) in diameter, 3050 mm (10 ft) tall, with a wound glass fiber element.

Prefiltration Each filter preheater consists of a housing and an element, with temperature instrumentation.

Each prefilter assembly consists of a housing, a perforated flow straightening baffle, and two HEPA filter elements in series. Provision is made to measure the differential pressure across the filter elements.

Atmospheric Protection Equipment

Equipment located inside the 01-Cell of the 01-14 Building was designed for remote manual switchover. These items include the off-gas reheater, HEPA filters, filter housings, reactor preheaters, and catalytic reactors.

HEPA Filtration The duct from the vitrification cell to the 01-14 Building is an insulated, 250 mm (10 in) stainless steel pipe. The trench through which the duct runs is heated to help maintain the temperature of the off-gas above its dew point. An entrainment separator is located at the low point between the vitrification cell and the 01-14 Building to collect any condensation that might occur in the duct.

Dual, redundant, electrical resistance reheaters are provided. Each reheater consists of a 1570 mm (62 in) tall, 250 mm (10 in) diameter housing with a 60 kW, 480 V, heating bundle. Thermocouples located in the outlets of the housings serve as process control sensors.

Parallel HEPA filter trains, consisting of two HEPA filter elements in series, are contained in a common housing. The housing accommodates filter elements 610 mm by 610 mm by 290 mm deep (2 ft X 2 ft X 11-1/2 in). Each filter element position is provided with a bag-out port.

Motivation The off-gas blower is a positive displacement rotary blower slightly oversized for 42 m^3/min (1500 ACFM). It is driven by an electric motor typically at a speed to motivate only 37 m^3/min (1300 ACFM). The blower suction is equipped with a vacuum relief valve.

NO_x Destruction The NO_x destruction system is designed to limit NO_x emissions during any 1-hour period to no more than 1.9 kg (4.2 lb_m).

The ammonia supply system was designed for anhydrous ammonia to minimize the equipment complexity and aqueous waste streams associated with use of aqueous ammonia. The ammonia storage tank is a carbon steel cylinder, 5180 mm (17 ft) tall, 1070 mm (42 in) in diameter, with elliptical dished heads. It is designed for a maximum inventory of 3.8 m^3 (1000 gal). The tank is equipped with two, redundant, 18 kW, 480 V, electric vaporizers. The vaporized ammonia is drawn from the top of the tank, and is routed to the mass flow control train. The ammonia is delivered to the off-gases downstream from the preheaters at the reactor inlets.

Dual, redundant, preheaters are provided. Each consists of two electric heater elements in series. Each heater element is rated at 480 V and 100 kW. Each preheater assembly includes a 3100 mm (122 in) tall, 300 mm (12 in) diameter housing. A thermocouple located in the housing outlet serves as the process control sensor.

Two identical reactors are installed in parallel. The reactor vessels are right cylinders made from Type 321 stainless steel, with the inlet at the top and the outlet at the bottom. The overall height of each reactor is 3480 mm (11 ft - 5 in). The cylindrical sections have inside diameters of 1000 mm (39-1/2 in).

The 1120 mm (44 in) deep catalyst bed is zeolite based. The primary catalyst bed consists of 890 mm (35 in) of 6 mm (1/4 in) Raschig rings. The polishing bed is located beneath the primary bed and consists of 230 mm (9 in) of 1.6 mm (1/16 in) catalyst extrudate.

The duct leading toward the stack is an insulated 200 mm (8 in) pipe. The insulation is specified to maintain the off-gas above its dew point.

V. Systems Control

ALARA Control

The motive forces for establishing a vacuum are provided by the blowers located downstream in the out-of-cell melter off-gas treatment system. The control valve located in the jumper that directs vessel ventilation gases and vapors to the melter off-gas treatment system is automatically modulated to maintain the vessel ventilation header at a predesignated vacuum. This is done to maintain a slight negative pressure on the primary process systems, relative to the vitrification cell atmosphere, for purposes of contamination control.

The amount of water that is discharged from the system, in the form of water vapor directed to the stack, is established by controlling the operating temperatures of the condenser and submerged bed scrubber. Temperature increases result in increased water vapor expulsion rates. The temperature in the submerged bed scrubber must be kept low enough, however, to prevent loss of solution from the scrubber. Temperature control is provided by modulation of the amount of closed loop cooling water sent to the cooling coils in the condenser and the scrubber vessel.

The temperature of the off-gases approaching the prefilter is maintained above the dew point by modulation of the power supplied to the filter preheater elements, based upon off-gas temperature readings immediately downstream from the preheater.

Atmospheric Protection Control

NO_x analyzers at the inlet of the NO_x abatement equipment, and at the outlet, are used to control the addition of the ammonia reactant and to monitor the NO_x destruction efficiency.

VI. Equipment Maintenance

ALARA Equipment

To allow for equipment maintenance without having to suspend melter feed operation, a redundant train of off-gas treatment equipment was installed. Normally, one of the installed redundant off-gas trains is operated while the other train is valved out-of-service. While out-of-service, maintenance operations can be performed.

Atmospheric Protection Equipment

The system is designed for hands-on maintenance. Installed redundant equipment was required for all equipment which would require removal from service for periodic maintenance, and whose removal from service would require suspension of melter feed operation.

The design for maintenance was based upon the philosophy that opening of a boundary, when pressurized NO_x is isolated by valving alone, would be an undue risk to personnel. Therefore, double isolation valves with bleed lines between the isolation valves leading to the blower suction, were provided to positively isolate process gases from equipment requiring maintenance.

The design for maintenance is also based upon the philosophy that routine access to a room or space in which pressurized NO_x exists in equipment would also be an unacceptable risk to personnel. Therefore, items of equipment on the discharge side of the blowers were located inside the 01-Cell of the 01-14 Building, and an off-gas by-pass line was provided for use when any of those items of equipment requires maintenance.

To allow for purging of NO_x, purge ports are provided for all major components exposed to off-gases.