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CONTINUING CHALLENGES IN NUCLEAR AIR CLEANING

Dade W. Moeller
Harvard Air Cleaning Laboratory
Harvard School of Public Health
Boston, Massachusetts

Abstract

The safe operation of nuclear facilities is heavily dependent upon the adequate performance of air cleaning systems. Although many problems have been solved, new questions and new challenges continue to arise. These are well illustrated by weaknesses in air cleaning and ventilating systems revealed by the Browns Ferry fire, and the need to develop additional data on the reliability of such systems, particularly under emergency conditions, as revealed by the Reactor Safety Study. Assessments of the degree to which engineered safety features can compensate for deficiencies in nuclear power plant sites continue to challenge those involved in risk/benefit evaluations. Additional challenges are being generated by the air cleaning requirements associated with the commercial development of the liquid metal fast breeder reactor.

I. Introduction

Air cleaning systems play a major role in the safe operation of nuclear facilities, under both routine and postulated accident conditions. Many problems have been solved, but new questions and new challenges continue to have an impact in this field. Significant events which have occurred since the 13th Air Cleaning Conference two years ago include the Browns Ferry fire, publication of the Reactor Safety Study, and a variety of changes resulting from the formation of the Nuclear Regulatory Commission (NRC). Presented in this paper is a review of the implications of these and other events as seen primarily from my activities and personal observations as a member of the Advisory Committee on Reactor Safeguards. The comments are restricted to programs and activities within the United States and are primarily directed to problem areas, as contrasted to the many successes which could be cited. Although mention is made of fuel fabrication and chemical processing plants, the major focus is on selected air cleaning systems associated with nuclear power plants. Although various ACRS reports serve as a basis for much of the paper, the comments offered do not reflect official views of the Committee and should not be interpreted as such.

II. Recent Developments

For purposes of this presentation, recent developments which have had an impact on air cleaning operations are described below under three categories - Operating Experience, Theoretical and Experimental Evaluation, and NRC Regulatory Activities.

A. Operating Experience

1. The Browns Ferry Fire

The one single event which has had the greatest recent influence on the design, installation and operation of nuclear air cleaning systems is the fire which occurred in the Browns Ferry Nuclear Station near Decatur, Alabama, on March 22, 1975. Immediately following the fire, the U.S. Nuclear Regulatory Commission appointed a Special Review Group to institute a program to identify the lessons learned from this event and to make recommendations for the future in the light of these lessons. The report of the Special Review Group was published earlier this year[1] and the NRC subsequently issued a Branch Technical Position (APCSB 9.5-1) outlining "Guidelines for Fire Protection for Nuclear Power Plants."[2] Both of these reports contained recommendations relative to ventilation and exhaust systems.

a. Recommendations of the Special Review Group

Shortly after the Browns Ferry fire began, ventilation was lost due to failure of the electrical power supply to the ventilation system and to its control subsystem. As a result, even if venting the smoke through the installed ventilation system had been planned in the design, it would not have been possible due to inoperability of the system.

On the basis of its assessment, the Special Review Group recommended that ventilation systems in all operating plants be reviewed and upgraded as appropriate to assure their continued functioning if needed in a fire. Specific suggestions included:

(1) Control and power cables for a ventilation system important to fire control should not be routed through areas the system must ventilate in the event of a fire.

(2) Ventilation designs should be provided with the capability of isolating fires by use of cutout valves and dampers.

(3) Capability for the control of ventilation systems to deal with fire and smoke should be provided, but such provisions should be made compatible with requirements for the containment of radioactive materials. It must be recognized, however, that these provisions and requirements may not be mutually compatible and in some cases may be in direct conflict with each other. For example, operating ventilating blowers to remove smoke may fan the fire; the same action may also result in a release of radioactive materials, either directly by transport of radioactive particles with the smoke or by decreasing the effectiveness of the filters provided to contain the radioactivity. It is obvious that some compromise will be necessary and that flexibility of operation may be needed, depending on the nature of any event that may occur. The Special Review Group recommended that the pros and cons be considered in the development of detailed guidance.

The Special Review Group also noted that, in the event of a serious fire in the cable spreading room, the control room might have become uninhabitable because of smoke and toxic fumes. In the situation at Browns Ferry, smoke and CO_2 entered the Control Room through openings in the floor at the point where the cables entered the Control Room.

b. Recommendations of the NRC Regulatory Staff

The Branch Technical Position included the recommendations of the Special Review Group, plus the following additional items related to the design and operation of ventilation systems.

(1) The products of combustion which need to be removed from a specific fire area should be evaluated to determine how they will be controlled. Smoke and corrosive gases should generally be automatically discharged directly outside to a safe location. Smoke and gases containing radioactive materials should be monitored in the fire area to determine if release to the environment is within permissible limits of the plant Technical Specifications.

(2) Any ventilation system designed to exhaust smoke or corrosive gases should be evaluated to assure that inadvertent operation or single failures will not violate the controlled areas of plant design. This requirement includes containment functions for protection of the public and maintaining habitability for operations personnel.

(3) Fixed automatic sprinkler systems, or alternative methods as described in Regulatory Guide 1.52[3], should be installed to protect charcoal filters.

(4) The fresh air supply intakes to areas containing safety related equipment or systems should be located remote from the exhaust air outlets and smoke vents of other fire areas. This is to minimize the possibility of contamination of the intake air with the products of combustion.

(5) Stairwells should be designed to minimize smoke infiltration during a fire.

(6) Smoke and heat vents may be useful in specific areas such as cable spreading rooms and diesel fuel oil storage areas and switchgear rooms. When used, they should be installed at a minimum ratio of 1 square foot of venting area per 200 square feet of floor area. The conversion factor for power venting is 300 cubic feet per minute equals 1 square foot of gravity venting area.

(7) Self-contained breathing apparatus, using full face positive pressure masks, should be provided for fire brigade, damage control and control room personnel. Control room personnel may be furnished breathing air by a manifold system piped from a storage reservoir if practical. Service or operating life should be a minimum of one half hour for the self-contained units. These recommendations were in direct response to the problems noted by the Special Review Group (and cited above).

(8) Where total flooding gas extinguishing systems are used, area intake and exhaust ventilation dampers should close upon initiation of gas flow to maintain necessary gas concentration.

2. Hydrogen Explosions (Selected Examples)

Although not comparable to the Browns Ferry fire in terms of the seriousness of their impact, hydrogen explosions have continued to be a problem in nuclear power plant facilities. A review of Licensee Events Reports, for example, shows that at least half a dozen such explosions, primarily within off-gas systems, have occurred in the last 18 months. The two events below were considered of special interest since both resulted from the impact of cold weather on an air cleaning system.

a. Cooper Nuclear Station

In January, 1976, a buildup of ice in the upper portion of an exhaust stack at the Cooper Nuclear Station resulted in back-pressure and the accumulation of hydrogen in the off-gas building. Later there was an explosion which completely demolished the off-gas building. Fortunately, there were no personnel injuries. Corrective action included heat tracing and insulation of the upper ten feet of the elevated release point pipe.[4]

b. Brunswick Steam Electric Plant, Unit No. 2

In January, 1976, there was an explosion in the stack filter house at the Brunswick Steam Electric Plant, Unit No. 2. The cause was later determined to be the improper positioning of a demister which permitted moisture to collect and freeze on a HEPA filter, causing an increase in resistance to flow. Pressure buildup resulted in blowing a number of off-gas loop seals which permitted both airborne radioactive materials and hydrogen gas to enter the stack filter house. Corrective action included proper positioning of the demister, plus a number of other measures.[5]

B. Experimental and Theoretical Evaluations

1. Routine and Accidental Releases

One of the primary needs in terms of defining performance requirements for air cleaning systems is an improved set of models for describing source terms for accidental releases of radioactive materials from nuclear power plants. Studies are also needed for improved definition of the fission product inventory within containment as a function of time. Guides currently used[6][7] require assumption of an instantaneous release. Hsia and Chester[8] have recently developed mathematical models for estimating the release rate for specific radionuclides into containment for light water reactors, assuming a LOCA coupled with a failure of the Emergency Core Cooling System. Their study shows that even for volatile radionuclides such as ^{133}Xe, ^{131}I, and ^{90}Sr several hours are required for a significant fraction of the curie inventory to gain access to the environment. (It is assumed that there is containment failure and that the core has not yet melted through the pressure vessel.)

For example, a typical large PWR with a hole in the containment building approximately the size of one of the equipment doors and an inoperative recirculating filter-adsorber is modeled. In this case upwards of 6 hours are required for a release to the environment of 10% of the core inventory of ^{131}I. Their models also show that in a case similar to the above, but with an operating filter-adsorber, the release to the environment can be reduced an order of magnitude. If the containment and filter-adsorber integrity are maintained, the release to environment can be reduced more than five orders of magnitude.

Other efforts with respect to the development of models for assessing accident situations include those for predicting the effectiveness of containment spray systems over a wide range of temperatures, pressures, and chemical compositions.[9] Similar models are needed for calculating the effectiveness of charcoal adsorption systems over a range of temperature and moisture conditions, for determining removal efficiencies for various potential leak paths through containment, for estimating the effectiveness of pool scrubbing (for Boiling Water Reactors) as a removal mechanism, and for predicting the role of plateout as a radionuclide removal process within containment.

In the case of the analysis of routine releases, the development of models appears to have progressed much further. The NRC Staff has recently published two reports[10][11] which, together with Regulatory Guide 1.112[12], provide methodologies for calculating source terms for nuclear power plants under normal operating conditions. The Commission has also published a detailed review of the wide range of models available for estimating fission gas release from reactor fuels under both routine and accident conditions.[13] Specific efforts by reactor vendors to provide better definition of radionuclide source terms under normal operations include models developed to take into account observed increases in the amount of radioactive material (particularly radioiodine) in reactor coolant systems following a power or system pressure transient.[14]

Models, such as these, can provide a very useful tool to air cleaning specialists. Thorough evaluation and application of modeling techniques, for example, can lead to better understanding of the basic mechanisms involved in specific removal processes and this, in turn, can lead to significant feedback in the form of refinements in the theory and design of improved air cleaning systems. This type of approach, combined with experience gained through operating systems, can also help to clarify the degree of removal effectiveness required for each of the variety of sources to be considered.

2. Failure Probabilities for Air Cleaning Systems

In October, 1975, the U.S. Nuclear Regulatory Commission published the final version of its Reactor Safety Study.[15] One of the innovative contributions of this report was that it contained a series of analyses related to generic types of failure mechanisms which could conceivably lead to failure of air cleaning systems.

The results of two such analyses are cited below. The first relates to an analysis of a Containment Spray Injection System for a Pressurized Water Reactor and is based on data for the Surry Power Station, Unit 1, in Virginia. The second relates to an analysis of a Secondary Containment System for a Boiling Water Reactor and is based on data for the Peach Bottom Atomic Power Station, Unit II, in Pennsylvania. Essentially all of the information presented is quoted directly from Appendix II of the published report.

a. Containment Spray Injection System

The Containment Spray Injection System (CSIS) is part of the engineered safety features installed to compensate for the effects of a loss of coolant accident (LOCA) within a Pressurized Water Reactor. The CSIS delivers cold water containing boron through spray heads to the containment volume from the refueling water storage tank during the first half hour after the postulated large LOCA incident. The principal function of the system is to reduce the pressure within containment and to provide the preferred path for delivery of additives such as NaOH to the containment atmosphere for initial airborne fission product removal.

The point estimates reported for various types of failures which would lead to the unavailability of the CSIS in the event of a large LOCA were:

Type of Failure	Probability of Occurrence
Single	3.2×10^{-4}
Double	4.4×10^{-7}
Test & Maintenance	1.5×10^{-4}
Common Mode	1.9×10^{-3}

The median estimate of CSIS unavailability for the postulated large LOCA was:

Median Failure Probability = 2.4×10^{-3}

It may be noted that the greatest or highest probability of failure resulted from common mode failure. According to the analysis, the largest contributors to this situation would arise from two faults, both of which result from human errors. The first is common mode failure of the Consequence Limiting Control System due to miscalibrations of several sensors which prevent the proper signal reaching the CSIS in the event of a large LOCA. The second was the possibility that both CSIS pump flow recirculation valves were left open after the monthly pump test due to operator error. As has been pointed out in the past, this stresses the extreme importance for air cleaning specialists to design systems which are less subject to human error.

b. Secondary Containment System

In the event of a LOCA in a Boiling Water Reactor, there is a probability that radioactive materials may be released beyond the confines of the primary containment. A Secondary Containment System is provided to protect against such an event. This System consists of the reactor building, portions of the reactor building heating and ventilation system, and the Standby Gas Treatment System (SBGTS). In addition to these system elements, appropriate instrumentation is provided for monitoring radiation exposures and depicting system status. The purpose of the Secondary Containment System is to limit the ground level release of radioactive materials and to provide a means for controlled elevated release of the reactor building atmosphere.

In the course of the Reactor Safety Study[15], the probability of the unavailability of the Secondary Containment was assessed for two undesirable events. For an unfiltered ground level release, the overall probability of unavailability was estimated as:

Probability
(unfiltered ground level release) = 3.5×10^{-5}

For an unfiltered elevated release, the probability of unavailability was estimated as:

Probability
(unfiltered elevated release) = 5.6×10^{-5}.

For the unfiltered ground level release, the chief contributors to the assessed unavailability were four sets of hardware double faults involving the blockage of redundant sets of filters and intake ducting of the SBGT system. For the unfiltered elevated release, the single faults were the major contributors and consisted primarily of the unavailability of A.C. power for the heaters in the SBGT system. Loss of function of the heaters was assumed to result in loss of function of the filter bank due to excessive moisture reaching the filter. The amount of release was assumed to be dependent upon the amount of reduction in charcoal filter efficiency caused by excessive moisture and upon the volume of air which could pass through the wet filter elements. Double failures such as heater failure and a circuit breaker failing open could result in the same effect.

For unfiltered releases both at ground and elevated levels, test and maintenance were not considered to contribute to unavailability of the system in an emergency since no in-service testing or maintenance which would result in system unavailability is permitted. Another assumption made in the estimation of system unavailability was that activation of the fire protection deluge system would result in loss of the affected filter bank but would not cause a release of contaminants to the atmosphere.

As with the evaluation of the Containment Spray Injection System, these analyses were instrumental in highlighting potential weaknesses in the Secondary Containment System and in describing interplay among subsystems which could be improved. Such analyses could also be used to determine the cost effectiveness of proposed improvements, as well as to demonstrate instances in which current practice may not be warranted. It would also appear that application of similar techniques to reliability estimates for routine nuclear air cleaning systems might be a very worthy field of investigation. Such application could very well lead to the design and installation of systems and subsystems of increased reliability and performance.

C. NRC Activities

From the standpoint of the U.S. Nuclear Regulatory Commission, there are two types of activities which provide some indication as to which aspects of air cleaning are considered of primary importance by its staff at the present time. One is the nature or degree to which improved air cleaning systems are being backfitted into existing plants; the other is the degree to which air cleaning problems are listed in its status reports on safety problems. Summarized below are lists of topics currently occupying the interests of the NRC staff in both of these areas.

1. Air Cleaning Backfitting Requirements

A review of NRC actions over the past 3 years shows the following air cleaning system modifications being required within operating nuclear power plants.[16] Although not every item has been required for every plant, these items were selected as representing generic types of requirements for nuclear facilities.

a. Improved surveillance and performance requirements for filter systems;

b. Development of technical specifications for limiting conditions for operation and surveillance for filter systems including adsorbers and high efficiency particulate air filters;

c. Installation of augmented or modified off-gas systems to assure radioactive emissions as low as reasonably achievable;

d. Modification of off-gas recombiner systems to improve system reliability, performance, and safety;

e. Grounded off-gas system high efficiency filters to increase system safety by reducing the probability of an explosion;

f. Modification of penetration room ventilation systems to increase reliability in the event of an accident;

g. Required evaluation of facilities in conformance to Appendix J, 10 CFR 50, regarding Containment Leak Testing;

h. Increase in capacity of the auxiliary building special ventilation system to assure negative pressure within the Category I ventilation zone;

i. Increased requirements on systems used for preventing a hydrogen explosion in containment following a LOCA.

2. Current Air Cleaning Studies and/or Investigations

Through its Technical Safety Activities Reports[17], the NRC Division of Systems Safety provides an ongoing account of the status of various studies underway to resolve problems related to reactor safety. The most recent report lists the following air cleaning items which are receiving attention.

a. Review of current data to update models for estimating fission product releases during accident conditions;

b. Development of safety guides for the design, evaluation and testing of containment spray systems for fission product removal;

c. Development of a mathematical model for methyl iodide removal by containment sprays;

d. Determination of the hazardous effects of airborne gases which may be accidentally released on or in the vicinity of a nuclear reactor site; development of a diffusion model for calculating concentrations at short distances in order to determine the hazards from toxic chemicals or radioactive gases that could potentially reach control room intake locations;

e. Measurement of air infiltration into control rooms to determine the effectiveness of isolation for protection of control room operators against external airborne contamination; development of a staff position with respect to isolation requirements for control room ventilation systems;

f. Evaluation of dose consequence problems of PWR and BWR (Mark III) containments with continuous purging;

g. Development of a Regulatory Guide specifying acceptable methods for design, testing, and maintenance of HEPA filters and iodine removal systems used in plant ventilation systems under normal operating conditions;

III. Air Cleaning as an Engineered Safety Feature

For many years, it has been the policy of the U.S. Atomic Energy Commission, and now the U.S. Nuclear Regulatory Commission, to recognize the use of engineered safety features as an effective means for limiting radiation doses to the population residing near a nuclear power plant. This policy is of special importance to air cleaning specialists since air cleaning systems are considered one of the primary forms of such safety features. The basis for this policy is exemplified by the wording in 10 CFR Part 100[18] which states:

> "Where unfavorable physical characteristics of the site exist, the proposed site may nevertheless be found to be acceptable if the design of the facility includes appropriate and adequate compensating engineering safeguards."

A. Reports of the ACRS on Engineered Safety Features

In a report issued in 1964[19], the ACRS affirmed its concurrence with the principle stated above and made the following additional statements relative to this matter. Although these statements were made over a decade ago, they are well worth repeating today:

> "It is important to recognize that engineered safeguards are designed to allow the siting of reactors at locations where, without such safeguards, protection of the public would not be adequate. The advantages of a remote site cannot be exactly balanced by engineered safeguards. On the other hand, the advantages of a remote site may be temporary, if appreciable increases in population density occur near the reactor. Few sites presently in use are such that some engineered safeguards are not desirable. Thus, the protection of the public ultimately depends on a combination of engineered safeguards and adequate distances. Engineered safeguards which can justify decrease of the distances must be extraordinarily reliable and consistent with the best engineering practices as used for applications where failures can be catastrophic. To be worthy of consideration, engineered safeguards must be carefully designed, constructed and installed, equipped with adequate auxiliary power, and continuously maintained. Certain designs are based on sound engineering principles supported by materials acceptance tests; others require developmental and proof testing. In any case, provisions for regular and careful testing are required where deterioration may be expected. The acceptance of engineered safeguards to mitigate unfavorable aspects of reactor sites should continue to be based on positive evidence that these design objectives can be attained. In addition, there will probably be a continuing need to develop new devices and design concepts as reactors are proposed for less and less remote sites."

> "In each case, the engineered safeguard must be considered with respect to the specific nuclear plant for which it is intended. It is equally important to assess the degree of confidence that the safeguard will function properly in an emergency. An engineered safeguard that must remain operable for the life of the plant but cannot be tested without ruinous effects would not usually be accorded the same importance as one that can be tested periodically."

In subsequent deliberations over the past decade, the ACRS through its Siting Evaluation Subcommittee has given further consideration to engineered safety features. In drafts of reports never formally issued, but subsequently made public[20], the Committee made the following additional recommendations pertaining to such safeguards:

1. Because of the small likelihood that proof of the efficacy of engineered safety systems under accident conditions will be obtained as a consequence of actual accident experience, extra margin

should be provided in the design of these systems wherever such provision is practical and will clearly improve safety.[21]

2. Improved testing provisions for and reliability of engineered safeguards should be endorsed for all reactors.[22]

The reason that this matter was assigned to the ACRS Siting Evaluation Subcommittee was due to the fact that applicants were proposing to locate power reactors at sites in areas of increased population density. The series of meetings of the Subcommittee contributed to the development of an ACRS position that large power reactors might be acceptable at sites having population densities somewhat greater than had been previously approved, but only if certain kinds of improvements were made in their design and construction and if additional safeguards were provided. The history of these deliberations was most recently summarized in an ACRS report in 1974.[20] This history has shown that, whenever a choice is available, regulatory authorities would generally prefer the use of distance to engineered safety features as a protective approach.

The history of these and other deliberations also shows that there is a limit to which engineered safety features can compensate for population densities. In other words, there are sites, particularly near major metropolitan areas, where the population density is considered too large for a nuclear power plant to be located, regardless of the extent to which it would be equipped with engineered safeguards. Notable examples are the cases of the proposed site for the Burlington Nuclear Generating Station in New Jersey and the proposed site for the Newbold Island Reactor near Trenton, New Jersey. In the former case, the ACRS unanimously stated that it did "not see how the site could be approved"[23] and the application was subsequently withdrawn. In the latter case, the Atomic Energy Commission staff persuaded the applicant to shift the plant to a more acceptable, less populated, site.

The challenges of decisions in this problem area continue to exist today and are exemplified by a report issued by the ACRS in December, 1975[24], wherein the Committee suggested that:

> "Studies be conducted on the degree to which engineered safety features or alterations in plant design should be used to compensate for specific site deficiencies. In particular, it would be useful to determine whether there are characteristics for which compensating engineering changes should not be applied."

B. Reports of the ACRS on Specific Safety Features

1. Reactor Containment Systems

In its 1964 report[19] the ACRS also stressed the importance of containment as a specific engineered safety feature and cited double containment as appearing to have particular promise as a means for minimizing the release of airborne fission products following a postulated accident in a nuclear power plant.

Later, in its review of the proposed Newbold Island Reactor[25], previously mentioned, the Committee commented favorably on the double containment approach proposed for this facility. At the same time, however, because of the high population density of the site proposed for this plant, the Committee was careful to reserve judgment as to the adequacy of even this type of containment, which included air recirculation and filtration, for this plant at this site.

Continual prodding by the Committee and the AEC and NRC staffs down through the years has led to the design and construction of improved reactor containments and the specification of reduced maximum leakage rates for such facilities. Today, double containment systems consisting of an inner steel shell and an outer concrete vessel, with an intermediate annulus, are becoming increasingly common for both Pressurized and Boiling Water Reactors.

Some of the problems and considerations involved in such containments are illustrated by the recent NRC Staff and ACRS review of the GESSAR-238 standardized plant design which had been submitted for preliminary design approval by the General Electric Company. In its report on this design, the ACRS enumerated questions on two air cleaning items.[26]

One pertained to the proposal that the plant be operated with continuous venting of the containment. A second pertained to the seismic capability of the off-gas system and conformance with the dose limitations of Regulatory Guide 1.29.[27] Final resolution of the first item was that the containment could be continuously purged so long as the exhaust was passed through a cleanup system and discharge lines were limited in size. Following this practice, the containment would be sealed on a high radiation alarm, and any later purging for hydrogen control would be through the Standby Gas Treatment System. This approach makes the effective operation of containment heavily dependent on rapid acting valves to seal the purge lines. Resolution of the second item involved designing the off-gas system to withstand an Operating Basis Earthquake. The fact that it was not required to withstand a Safe Shutdown Earthquake was based on theoretical and experimental evaluations which showed that, even if the charcoal adsorption beds were fractured, the evolution of the adsorbed radioactive gases would be relatively slow.

2. Containment Spray Systems

Another engineered safety feature of interest to air cleaning specialists which has received attention from the ACRS over the years is the matter of containment spray systems.[28] The basic purpose of such sprays is to provide a mechanism for reducing the pressure within containment following a LOCA. In most plants, the system also has the capability for removing a portion of the airborne fission products from the containment atmosphere. Such systems are now common-place as a part of engineered safety features since they have proven to be a very effective economic trade-off as compared to the costs which would be involved in purchasing additional land to achieve greater isolation of a nuclear power plant.

In early plants, sodium hydroxide (NaOH) was used as an additive to the spray since it was a very effective radioiodine removal agent. In addition, the NaOH served as a pH adjustor. Since the spray also contained boric acid, adjustment of the pH to the alkaline range (pH 9-12) was necessary to keep certain metallic parts of the reactor vessel, and other safety related systems, from being damaged by stress corrosion.

Later, to increase the radioiodine removal efficiency, another material, sodium thiosulfate, was added to containment sprays. This enhanced their removal capability for organic iodine, but again, to keep the sodium thiosulfate stable, the pH of the boric acid solution had to be maintained in the alkaline range (using NaOH).

As contrasted to the above, there is another class of containment sprays which do not contain iodine removal additives at all. Their sole purpose is containment depressurization. When this type operates, initially only borated water is sprayed within containment. As the water collects in the containment sumps, it washes through baskets of trisodium phosphate (TSP) which raise its pH to a neutral range (pH = 7). Again, this adjustment in pH is necessary for protection against stress corrosion. Plants using sprays of this type depend upon the use of charcoal filters for radioiodine removal.

Another additive proposed for years for use in containment sprays, but only recently considered for actual use, is hydrazine. Tests have shown that addition of this chemical to boric acid sprays in trace quantities will provide effective radioiodine removal. As in the case of systems using boric acid alone, hydrazine systems would employ TSP powder baskets for pH adjustment.

As may be noted from the above, containment spray systems have been the subject of a number of evaluations in the past years and a range of systems are in use today. Concurrent with these developments, the ACRS has raised a variety of questions and has made a number of recommendations regarding such systems. These were most recently outlined in its report on the "Status of Generic Items Relating to Light-Water Reactors: Report No. 4,"(29) and included the following:

a. A review and evaluation should be made of the variety of experiments which have been conducted on the effectiveness of various containment sprays, specifically with respect to the removal and retention of airborne radioactive materials of the types anticipated to be present within containment following a LOCA. This review should include consideration of the adequacy of definition of the physical and chemical forms of the anticipated airborne radionuclides, and the applicability of the evaluative tests for estimating removal efficiencies of the various proposed sprays under the conditions of temperature, pressure, and radiation doses expected to exist under post-LOCA conditions.

b. The Committee also recommends that, if compounds, such as hydrazine, have distinct advantages, action be taken to encourage their use. At the same time, the Committee suggests that studies be conducted to determine if there are better additives which might be considered.

IV. Other Challenges in Air Cleaning

Nuclear safety is a dynamic field and present positions are constantly undergoing review and evaluations. Many examples of emerging problems and challenges have been cited by other speakers at this Conference. Several other new developments and/or problems which could have an impact on air cleaning systems are mentioned below. The list is by no means comprehensive. It is simply a sampling of a few of the emerging challenges.

A. Development of Liquid Metal Fast Breeder Reactors

Within the next few years, a decision will be made as to the extent to which the Liquid Metal Fast Breeder Reactor (LMFBR) will be used in meeting our future energy needs. If large scale development of the LMFBR is undertaken and plutonium recycling is approved, this will involve the construction and operation of commercial fuel fabrication facilities to prepare plutonium fuels for fast breeders, as well as mixed oxide fuels for light water reactors. Such facilities will require air cleaning systems of high efficiency and reliability, since release limits for plutonium to the environment will undoubtedly be extremely restrictive.[(30)] Also implied in plutonium recycling is the operation of a number of large scale fuel reprocessing plants. Such operation will involve air cleaning challenges for the commonly known radionuclides such as ^{85}Kr and ^{3}H as well as the "newer" problem nuclides such as ^{129}I and ^{14}C.

In connection with the operation of LMFBRs, it might be noted that the NRC staff has stated[(31)] that the Clinch River Breeder Reactor will be required to have engineered safety systems adequate to cope with identified design basis accidents to ensure that off-site doses are less than 10 CFR 100 guidelines. For design purposes at the construction permit review, the operative guideline of the NRC staff has been to limit off-site doses for emergency releases to 20 rems whole body and 150 rems thyroid, as contrasted to the values of 25 and 300 rems, respectively, specified in 10 CFR Part 100.[(18)] Since postulated airborne releases from an LMFBR under accident conditions could include plutonium as well as perhaps activated sodium, the NRC staff has specified additional design guideline dose limits of 7.5 rems for the lung and 15 rems for the bone. Again the challenges to air cleaning specialists to design systems to meet these requirements will be extremely demanding.

B. Role of Ventilation in Assuring the Performance of Electronic Equipment Under Emergency Conditions

As noted earlier, the NRC review of the Browns Ferry fire pointed out a number of problem areas with respect to the performance of ventilation and/or air cleaning systems under emergency conditions. One additional potential problem is the functioning of ventilation systems in order to assure the continued satisfactory performance of electronic equipment under such conditions.

Most of the electronic equipment in nuclear facilities is now solid state. If normal power to ventilation systems is lost in an emergency situation, the D.C. input to electrical panels will cause rapid temperature increases. Since solid state equipment in logic panels can yield unpredictable operation at temperatures as low as 125°F, maintenance of adequate ventilation becomes an extremely important matter. In the case of control rooms, continuous ventilation is also necessary to maintain temperatures low enough for human habitation.

Although "service" systems of this type are generally designed to be redundant, it is reasonable to assume that sooner or later one of the two systems (usually the "active" system) is going to fail. When it does, the failure constitutes an emergency and nuclear facility operators must then call upon the single remaining alternative service system. As a consequence, the emergency, as postulated, leads to a situation in which redundancy in the backup system is no longer available.

This is an area to which air cleaning and ventilation specialists need to direct more attention. The expensive approach would be to provide "post-emergency" redundancy through the installation of three ventilation trains, the third one being a simple and less efficient, but nonetheless adequate, system. Another approach might be to provide only two trains with the second one being a passive system, or to provide a two train system supported by a guaranteed limited time for repair of any defects and restoration of service. This last approach, however, is not a very sure course of action.

C. Increasing Emphasis on Waste Management

During the past several years, there has been an increasing emphasis on the development of techniques for the long term management of radioactive wastes. This has included attention not only to the problems of high level liquid wastes but also to the problems of the large volumes of low level solid wastes being generated in all facets of the nuclear industry. Major consideration is being given in the latter case to the use of incineration as a method for reducing the volumes involved. This will require extensive air cleaning for the particulates and gases generated in the combustion process, particularly in the case of wastes containing the transuranics. Also needing greater attention is the development of air cleaning filters and adsorbers which can, themselves, be readily reduced in size and volume for final disposal.(32) Studies show that air cleaning operations are a significant source of solid wastes. For example, the annual volume of waste filters from a typical 1,000 MWe nuclear power station totals some ten cubic meters.(33) For a mixed oxide fuel fabrication plant, it is estimated that, of the total radioactive material content being sent to waste disposal, 18% will be that contained in the HEPA filters.(33) As would be expected, most of this activity will consist of alpha emitters.

D. Feedback of Information from Operating Reactors

The recent establishment within NRC of a new Division of Operating Reactors offers a chance for increased benefits to air cleaning system design, maintenance, and operation via the feedback of information from operating nuclear power stations. Although much useful information results from the feedback of "Licensee Event Reports" and "Abnormal Occurrence Reports," there remain defects in these systems from the standpoint of the provision of information in a form most useful to air cleaning specialists. For example, such events are not always categorized in a way so as to be readily recognized as being important in air cleaning, nor are they always recorded in the computer storage bank under terminology commonly used within the air cleaning industry. This is an area which needs attention. Consideration might be given to the formation of a small committee of air cleaning specialists to advise the NRC on this matter.

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