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TITLE: METHODS FOR AIR CLEANING SYSTEM DESIGN AND ACCIDENT ANALYSIS

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METHODS FOR AIR CLEANING SYSTEM DESIGN AND ACCIDENT ANALYSIS

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Abstract

This paper describes methods, in the form of a handbook and five computer codes, that can be used for air cleaning system design and accident analysis. Four of the codes were developed primarily at the Los Alamos National Laboratory, and one was developed in France. Tools such as these are used to design ventilation systems in the mining industry but do not seem to be commonly used in the nuclear industry. For example, the Nuclear Air Cleaning Handbook is an excellent design reference, but it fails to include information on computer codes that can be used to aid in the design process. These computer codes allow the analyst to use the handbook information to form all the elements of a complete system design.

Because these analysis methods are in the form of computer codes, they allow the analyst to investigate many alternative designs. In addition, the effects of many accident scenarios on the operation of the air cleaning system can be evaluated. These tools originally were intended for accident analysis, but they have been used mostly as design tools by several architect-engineering firms.

The Cray, VAX, and personal computer versions of the codes, an accident analysis handbook, and the codes' availability will be discussed. The application of these codes to several design operations of nuclear facilities will be illustrated, and their use to analyze the effect of several accident scenarios also will be described.

Introduction

Ventilation and air cleaning systems can be highly complicated and involve many interconnected flow pathways, rooms, flow controllers, filters, and blowers. The flow arrangement may use parallel and series systems, separate supply and exhaust systems, recirculation, and makeup air. Heating, ventilating, and air conditioning (HVAC) analysts and designers are capable of designing a highly complicated ventilation system. However, the ventilation and air cleaning systems for nuclear facilities require special design considerations and must be analyzed for the effects of hypothetical accident situations.

The "Nuclear Air Cleaning Handbook" provides information of special interest to designers of nuclear air cleaning systems.(1) The possibility of and concern for accidents such as earthquakes, tornados, fires, and explosions are discussed, but no methods are offered to analyze the entire ventilation system for these accident conditions. We believe that there are analytical tools in the form of handbooks and computer codes that will allow ventilation system designers and safety analysts to perform the necessary accident effect calculations. Further, there is no reason why the steady-state portions of the computer codes could not be used to aid the designer in determining the pressures, flows, and temperatures throughout the ventilation system. In addition, these codes would allow the designer to examine many alternative arrangements and subsystems. Perhaps the best part of these methods is that the analyst then can use the same codes to evaluate the potential effects of hypothetical accidents on the system design. In other words, both the system design and the safety analysis could be performed in parallel.

We will describe several computer codes that are available to perform both design and safety analyses. Several examples of applications of these codes will be illustrated.

Computer Code Descriptions

Computer codes that have been developed at the Los Alamos National Laboratory and at the Commissariate a l'Energie Atomique (CEA) in France will be described. All of these codes require a steady-state or normal operating condition calculation. This part of the analysis can be used by designers to verify designs or examine alternative ones. The transient calculations performed by the codes are optional and are especially developed to simulate large pressure surges, explosions, and fires. The codes are presented according to which accidents they are designed to model.

Tornado Modeling, the TORAC Code(2)

TORAC is an improved version of the TVENT computer code, which was developed at Los Alamos.(3) There are three basic differences between TVENT and TORAC:

- material transport capability,
- blowers can be turned on and off, and
- dampers can be controlled with an arbitrary time function.

The TORAC code can model large pressure surges or simulate the effects of a tornado depressurization at the inlet and exhaust points of a ventilation system. The capability to modify the effects of blowers and dampers within the system gives the designer a tool to examine alternative system designs, effects of equipment failure, and multiple damper control points.

The material transport aspects of the code are very basic. That is, only the convection, gravitational settling, entrainment, and filter depletion mechanisms are modeled. The complex interactions between material species and within material species are not modeled. TORAC and TVENT are available from the National Energy Software Center (NESC). CDC 7600 and CRAY versions are available.

Explosion Modeling, EVENT84(4) and EXPAC5

Two Los Alamos codes can be used to simulate explosions within air cleaning systems. EVENT84 simulates the gas dynamics of an explosion; EXPAC adds material transport to the calculation. The explosion codes are more complicated than the TORAC code because more detailed data are needed to complete the calculation. Like TORAC, these codes also obtain the flows, pressures, and temperatures in a normal operating condition before any transient calculations are performed. These codes can calculate the propagating effects of solid or gaseous explosions within an air cleaning system or through any air pathway. EVENT84 and EXPAC currently are being verified by selected experimental studies. EVENT84 is available from the NESC, but the EXPAC code is still under development. CDC 7600 and CRAY versions are available.

Fire Modeling, PIAF[6] and FIRAC[7]

Two computer codes have been developed to simulate the effects of fires within nuclear facility air cleaning systems. One was developed at CEA and is named PIAF. It was developed to study the responses of ventilation networks to mechanical or thermal perturbations.

Using the PIAF code to model mechanical systems in facilities has proven useful because it can identify events that are of safety concern and quantify the possible damage within the facility. A steady-state analysis of a large ventilation network is described in Ref. 6. A separate paper describing the PIAF modeling of the ventilation network operation is to be presented at this conference. This code's availability is unknown.

A second code to simulate fire conditions was developed by Los Alamos. This code is named FIRAC and soon will be available from NESC. It has been modified to run on a personal computer. CRAY, VAX, and CDC 7600 versions are available. FIRAC includes material transport and uses a burn room model developed by Battelle Pacific Northwest Laboratories. The code uses the basic gas dynamics available in EVENT84 but adds heat transfer from the system ductwork.

Handbook

An accident analysis handbook has been developed to assist safety analysts in modeling and analyzing nuclear facilities.[8] The emphasis has been placed on fuel cycle facilities, but other facilities also can be modeled. The handbook contains information on fuel cycle operations and processes as well as methods to develop radioactive source terms for fire and explosion events. Modeling techniques, many sample problems, and information on how to use particular computer codes are also included. This handbook is available in draft form from the Nuclear Regulatory Commission and currently is being revised for final form. (A completion date of October 1986 is planned.)

Applications

Design Simulation

An example of a design simulation using one of the TVENT codes involves determining the effect of a recirculation blower shutting off and the effect on room key pressures when the main supply blower slows down.[9] A study of these situations and their effects on part of the Los Alamos Plutonium Processing Facility are reported in Ref. 9. The results of this study showed that loss of the recirculation blower did not have a significant effect on the overall system pressures. (A 10% slowdown in the main supply blower caused a sharp reduction in corridor and compartment pressures.) This information allowed the analyst to identify certain control dampers to control large pressure fluctuations. These calculations could aid in the design of the system and the placement of system controllers.

A second design simulation involves using the FIRAC code to simulate the operation of a proposed radioactive waste incinerator. In this case, the FIRAC results were not the same as the design (because of a lack of extensive design data) but were within a reasonable range. Using FIRAC in parallel with the incinerator design can prevent design flaws that could appear when a safety analysis is performed after the incinerator is constructed.

Accident Analysis

The design simulation of the incinerator discussed above can be used to illustrate how an accident analysis can be performed in parallel with the design phase. In this case, we examined the possibility of an inadvertent injection of an explosive mixture into the pyrolysis chamber of the incinerator. In this accident scenario, we have assumed that a container of 100 cm^3 of toluene is inserted into the process line. After performing the analysis to determine the effects of this scenario, we found that a positive pressure is created in the pyrolysis and combustion chambers. This accident analysis scenario shows that a positive pressure in the pyrolysis and combustion chambers causes a flow reversal through the pyrolysis and combustion inlet air paths. Therefore, protective devices would have to be designed into the system to prevent a radioactive release to the atmosphere when the incinerator chambers overpressurize. A second accident scenario also was examined. This involved failure of the exhaust blower for the system. Again, this caused a pressure increase in the incinerator chambers.

In Ref. 6, an accident analysis using the PIAF computer code is described. The report discusses evaluations of the effects of a 9-kg and a 26-kg fire in gloveboxes. The effects of cell temperature, pressure, exhaust flow rate, and filter pressure drop are determined in these calculations. Future modifications to the code will include aerosol release calculations.

Summary

We have described analysis methods that can be used in the design and accident evaluation of nuclear ventilation and air cleaning systems. Applications of these analytical methods, in the form of computer codes, are given for both design and accident analysis. Four of these computer codes have been developed by Los Alamos, but one code developed in France also is discussed. We feel that future editions of the Nuclear Air Cleaning Handbook could benefit greatly if a chapter is devoted to use of analytical methods that bring the entire nuclear air cleaning system together for analysis. Evaluation of the systen as a whole for both design effectiveness and accident analysis could lead to more efficient and safer designs.

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