ADVANCES IN PASSIVE COOLING DESIGN AND PERFORMANCE ANALYSIS

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ABSTRACT

The Third International Conference on Containment Design and Operation continues the trend of rapidly extending the state of the art in containment methodology, joining other conferences, OECD-sponsored International Standard Problem exercises, and vendor licensing submittals. Methodology developed for use on plants with passive features is under increasing scrutiny for advanced designs, since the passive features are often the only deviation from existing operating base of the past 30 years of commercial nuclear power. This session, "Containment Passive Safety Systems - Design and Operation," offers papers on a wide range of topics, with authors from six organizations from around the world, dealing with general passive containments, Westinghouse AP600, large (>1400 MWe) passive plants, and the AECL advanced CANDU reactor. This level and variety of participation underscores the high interest and accelerated methods development associated with advanced passive containment heat removal. The papers presented in this session demonstrate that significant contributions are being made to the advancement of technology necessary for building a new generation of safer, more economical nuclear plants.

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INTRODUCTION

Objectives for advanced new generation of nuclear power plants include enhanced safety, reliability, and economy. Designs have been proposed by vendors that meet these objectives through approaches based on simplified safety systems that are passive, making use of natural forces of buoyancy in gravity-driven flows. Passive containment cooling features generally rely on internal natural convection driven flows to transfer heat to large structures and may also passively transfer heat to the ultimate heat sink. Such designs make limited use of active components, reducing or eliminating pumps, fans, diesel electric generators, or operator actions to accomplish their safety functions. This leads to a reduction in the number of safety grade components, systems, and structures as compared to currently operating nuclear plant designs. The application of such systems satisfies the goals of system simplification, reduced operator actions, high reliability, minimum maintenance, and reduced plant size and cost, and in most cases is within the bounds of proven technology.

ANALYTICAL REQUIREMENTS

Reliance on natural convection stretches the limits of available test databases and calculational tools. Without the relatively huge driving forces developed through active systems, closely coupled interactions between flow fields and heat and mass transfer rates in a natural convection system add significant complexity to analytical models. Thorough validation of models is necessary to demonstrate with confidence that performance goals are met.

Because natural processes are governed by non-dimensional parameters such as the Grashof number which contains a length-cubed term, the effects of scale are more pronounced for such systems. Thus there is a need to carefully examine the test database used for code and model development to assure that all important phenomena are correctly captured. In many cases new tests need to be run to address the effects of test scale.

Performance quantification tools, such as computer codes for design and safety analysis, must be able to account for all relevant effects over the entire range of interest. For example, inside a large containment volume, phenomena include buoyant plumes and jets from postulated breaks, stratified atmospheres, entrainment into wall boundary layers, and resulting condensation. Since there is a high degree of non-linearity in the systems of equations, computations which consider a high level of detail can be expensive. It is therefore necessary to understand the details involved well enough to develop simplified tools that can be effectively used for design and parametric safety studies.

Some phenomena, such as detailed hydrogen distributions in stratified fluids, may limit the amount of simplification possible, so that a clear understanding of the underlying physical processes is necessary to assure that safety issues are adequately addressed without large numbers of calculations. For designs which rely on passive heat rejection to the ultimate heat sink, such as natural convection over the external containment surface, the effects of environmental influences on boundary conditions must be determined.

Finally, for presentation to regulatory authorities, it is necessary to develop and qualify Safety Evaluation Models. This qualification requires assessment of uncertainties and demonstration that margins in design are sufficient to offset those uncertainties.

ADVANCED PLANT REGULATORY PROCESS

To reduce economic risks for utilities, regulatory authorities are developing new licensing processes for advanced plants. For example, the US Nuclear Regulatory Agency provides for a one-step licensing via Design Certification. This process gives a single construction and operating license at one time with sufficient opportunity for public hearings early in the process, greatly reducing the uncertainty associated with purchasing, building, and starting a new nuclear power plant. This process is very demanding for analysts since it requires resolution of all significant technical issues prior to receiving Design Certification. Thus, as result of economic concerns, the time is greatly reduced over which significant advances in methods must be made.

ADVANCES IN METHODS DEVELOPMENT

Presentations in this session demonstrate advances in methods development. They include a scaling approach which demonstrates the usefulness of a zonal estimation concept in reducing the total number of parameters to be considered. Wind tunnel tests provide external boundary conditions caused by high wind speeds and turbulence from nearby buildings. Both the GASFLOW and WGOTHIC computer codes, enhanced with more accurate models for passive containment cooling, are compared to tests. Design alternatives for a large passive nuclear steam supply system are quantified and discussed. Comparisons are also made between the GOTHIC code and the PHOENICS code as part of a validation program.

CONCLUSIONS

The Third International Conference on Containment Design and Operation continues the trend of rapidly extending the state of the art in containment methodology, joining other conferences, OECD-sponsored International Standard Problem exercises, and vendor licensing submittals. Methodology developed for use on plants with passive features is under increasing scrutiny for advanced designs, since the passive features are often the only deviation from existing operating base of the past 30 years of commercial nuclear power. This session, "Containment Passive Safety Systems - Design and Operation," offers papers on a wide range of topics, with authors from six organizations from around the world, dealing with general passive containments, Westinghouse AP600, large (>1400 MWe) passive plants, and the AECL advanced CANDU reactor. This level and variety of participation underscores the high interest

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