Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Predicting the Room Air Temperature of the Containment Spray Pump Room for the Loss of HVAC Accidents

Churl Yoon, Jinhee Park, Ho-Gon Lim and Sang Hoon Han
Korea Atomic Energy Research Institute
150 Dukjin-Dong, Yusong-Gu, Daejeon 305-353, Korea
Phone: +82-42-868-2128, Fax: +82-42-868-8590, E-mail: cyoon@kaeri.re.kr

1. Introduction

In PSA Models, the HVAC system is essential for the various vital mitigation safety systems operating during a mission time. So far, the unavailability of the safety system when the HVAC system is unavailable, has been applied conservatively or optimistically based on operating experience and expert judgment, so the total core damage frequency could be unrealistic. In this paper, we performed a heat up calculation for the Containment Spray Pump Room at Kori 3&4 Units using a CFD code to estimate the operability[1] of the CS pump and its support systems in the pump room under the situation of a loss of the HVAC. The result of this calculation could be applied the PSA Model for Risk Informed Regulation for Kori Units 3&4.

2. Methodology

2.1 Methodology

In this study, Computational Fluid Dynamics (CFD) is applied to estimate the room air temperature, instead of conventional lumped methods. Because CFD simulates all the air circulation, convection and heat transfer between the air and walls, it does not require any empirical correlations for heat transfer coefficients. Thus, it is believed to give a more accurate volume averaged air temperature but it costs more.

A commercial CFD code, ANSYS CFX release 10, is used for the simulation. The working fluid is air initially at room temperature and the computational domain includes room air, pump, and concrete walls. Buoyancy force induced by a surface heating and cooling was modeled by the Boussinesq's Approximation. The applied numerical scheme is the high resolution scheme.[2] A structured mesh of 367,788 cells (401,972 nodes) was generated and used for a transient analysis.
Initially, the room air was assumed to be stationary. Following the transient time, the flow is slow and laminar at the early stage and transits to turbulence after a few minutes.[3]

The containment spray (CS) pump rooms of Kori Units 3&4 are hexahedral concrete rooms of 16.0 x 18.0 ft^2 with a 20.0 ft height. The thickness of the side and top concrete walls is 1.5 ~ 2.3 ft, and the bottom wall is 12 ft-thick because the room is located at the lowest level. The motor is located in the center of the side wall, and a pump, pipes and electric equipments are connected to the motor. The room also has some ducts of the building AC system and a cubical cooler, which one assumed to have malfunctioned in this analysis.

2.2 Assumptions

The assumptions used in this analysis are as follows:

1. The stairway section divided by a 2 ft-thick concrete wall was omitted and the actual computational domain of an air cavity was reduced to 13.0 x 18.0 x 20.0 ft^3 as shown in Fig. 1.
2. The sump at the bottom is not modeled. Because the motor (heat source) is located about 2 meters from the floor and a natural circulation would occur mainly in the upper part of the room, the effect of the sump to the room air temperature will be insignificant.
3. The obstacles inside the pump room including a cubicle cooler, pipes, electric devices and lines, and compressor are omitted. These obstacles could disturb the air circulation, but, on the other hand, a structure mostly made of metal could work as a heat sink. Therefore, the omission is considered to be conservative. The total volume of these obstacles is less than 10% of the total volume of the CS pump room.
4. Real motor is installed in the middle of the side wall, at a height of 2.0 meters from the floor. The gap between the side wall and the motor is 0.2 meter. For a fast convergence, the motor is modeled to be attached the side wall without any gap. And the contact surface is assumed to be adiabatic.
5. Small holes around the penetrations of the pipes and electric lines, and the small windows above the door to balance the air intake and outflow are ignored.
6. The door is assumed to be closed during the whole transient period.

2.3 Heat Sources and Boundary conditions

The heat is assumed to be only generated in the motor. From the calculation sheets [4,5], the heat released to the room at a maximum operating load including the motor driver is 61,800 Btu/hr. The dimension of the motor is 1.3m X 1.45 m X 1.2 m(height), so that the volumetric heat generation rate becomes 8001.6 W/m^3. From the aspect of the room temperature, the excessive heat transfer from the motor to the room air associated with the lower heat transfer from the room air to the concrete walls are conservative. To over-estimate heat dissipation from the motor to the room air, the motor is assumed to be a porous media with a porosity of 0.5. If one sets a motor as a solid block, its heat transfer to air is less than the real one and the solid motor surface temperature will increase unrealistically. The reason is because the heat removal equipment such as a fin was not modeled appropriately in this solid block model.

All the outer surface temperatures of the concrete walls are assumed to increase slowly based on previous studies. [6]

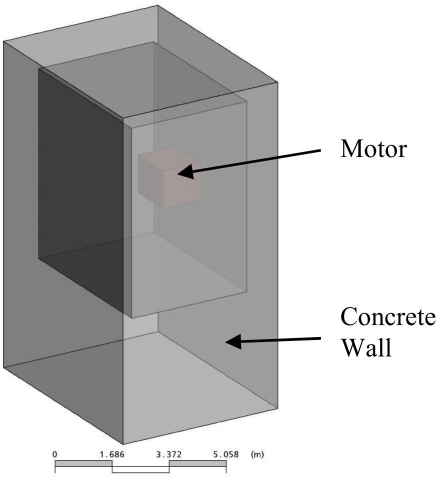

Figure 1. Geometry for predicting the room air temperature of a CS pump room by using a CFD code

3. Transient Temperature Prediction

Transient temperature of the CS pump room is predicted for 4,800 seconds after the Loss of HVAC transients. The initial air temperature is set as 30°C. The time step was set as 0.2 sec, and the energy balance was checked at every time step. Figure 2 shows the temperature distribution and the velocity field on the vertical center plane at 3,600 sec. Air fluid circulates mostly around the upper region of the room and the temperature in the upper region is higher than that of the lower region. And the temperature differences of the air and pump surfaces are less than 10°C due to the porous media assumption.

Figure 3 presents the volume-averaged temperature of the CS pump room air for Loss of HVAC accidents. The air temperature increases rapidly until 600 sec, then the increasing speed slows down. At 4,800 seconds after Loss of HVAC, the room air temperature reaches around 50°C. Further transient calculation will be performed continuously.

4. Conclusions

The CFD analysis has been performed to simulate the heat-up of air in a CS pump room of the KORI 3&4 NPP's for the Loss of HVAC accidents. A transient calculation until 4,800 seconds gave a volume-averaged air temperature of about 50°C, with an initial air temperature of 30°C.

Acknowledgement

This research was supported by "The Mid-&-Long Term Nuclear R&D Program" of MOST (Ministry of Science and Technology), Korea.

REFERENCES

[1] NUMARC 87-00, Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at LWRs
[2] *CFX-5: Solver Theory*, ANSYS Canada Ltd., Canada, 1996.
[3] Adrian Bejan, *Convection Heat Transfer*, 2nd Ed., Chap. 6, john Wiley and Sons, Inc., 1995.
[4] KORI 3&4 Calculation No. 3-M-GL-311-1: Auxiliary Building Heat Load Calculations HVAC (Normal), 1978.
[5] KORI 3&4 Calculation No. 3-M-GL-311-3: Auxiliary Building ESF Heat Load Calculations HVAC, 1978.
[6] P.M. Daling, J.E. Marler, T.V. Vo, H. Phan, J.R. Friley, *Value Impact Analysis of Generic Issue 143*, "Availability of Heating, Ventilation, Air Conditioning (HVAC) and Chilled Water System", App. F, NUREG/CR-6084, 1993.

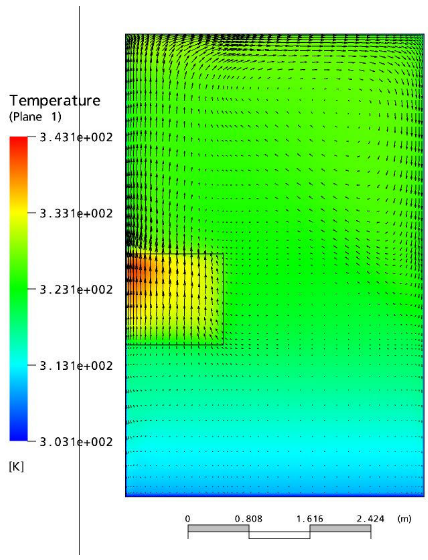

Figure 2. Computational results of velocity fields and temperature distributions at 3,600 sec

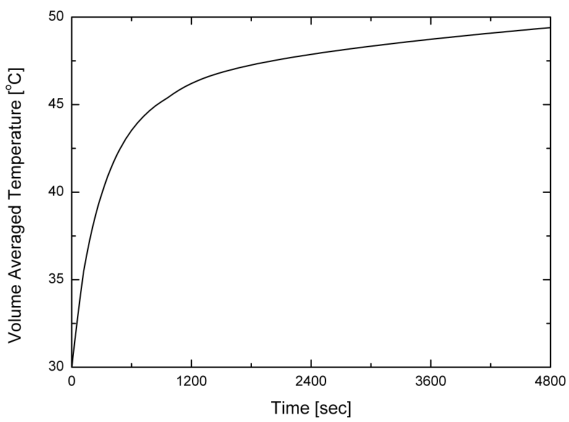

Figure 3. Predicted volume-averaged air temperature of the CS pump room for Loss of HVAC accidents