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Experimental Study on NPP MCR Operators' Performance Measure using Functional Performance Measure

In Seok Jang [a], Poong Hyun Seong [a*], Jin Kyun Park [b]
[a] *Department of Nuclear and Quantum Engineering, KAIST*
[b] *Integrated Safety Assessment Division, KAERI*
373-1, Guseong-dong, Yuseong-gu, Daejeon, Republic of Korea, 305-701
[a] *nuclear82@kaist.ac.kr*
[*] *Corresponding author: phseong@kaist.ac.kr*

1. Introduction

Research and development for enhancing reliability and safety in nuclear power plants (NPPs) have been mainly focused on areas such as automation of facilities, securing safety margin of safety systems, and improvement of main process systems. However the studies of Three Mile Island (TMI), Chernobyl, and other NPP events have revealed that deficiencies in human factors such as poor control room design, procedure, and training, are significant contributing factors to NPPs incidents and accidents [1].

Above of all, human performance measures, therefore, are important to enhance human performance and to reduce the probability of incidents and accidents in NPP.

There are several methods to evaluate the human performance such as Operator Performance Assessment System (OPAS) developed by Halden, Human Performance Evaluation Support System (HUPESS), Functional Performance Measure proposed by NRC project and several questionnaire methods. [1,2,3]

In this paper, Functional Performance Measure is used to evaluate the human operators' performances with Full-scope simulators.

2. Functional Performance Measure

Functional performance measure indicates how well the operators controlled selected critical parameters. The parameters selected are usually derived from the fore Critical Safety Functions (CSFs) identified in the emergency operating procedures: Achievement of Subcriticality, Maintenance of Core Cooling, Maintenance of Heat Sink and Maintenance of Containment Integrity. [3]

Because the scenario provided to operators is the kind of LOCA, the subcooling margin is selected as the parameter most closely related to maintenance of core cooling.

2.1. subcooling margin

As shown in Fig.1, coolant exists as water over the limitation line of the subcooling operation, while coolant exists as steam under the limitation line. Consequently, each team must maintain and recover the subcooling margin whenever the operation line is under the limitation line of the subcooling margin.

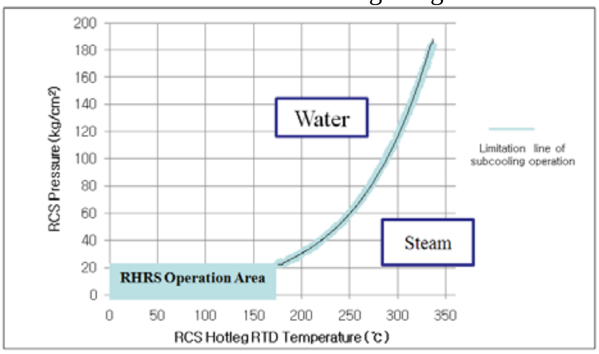

Fig 1. Subcooling Margin

Given this concept, to measure the performance of each team, the time to recover the subcooling margin and the temperature difference from limitation line are measured as the performance values.

3. Field Simulation

3.1. Participants

Ten teams working in NPPs participated in the field simulation. Each team consisted of five operators: a Senior Reactor Operator (SRO), a Reactor Operator (RO), a Turbine Operator (TO), an Electrical Operator (EO) and a Shift Supervisor (SS).

3.2. Scenario

The scenario provided to human operators is the Interfacing System Loss Of Coolant Accident Scenario (ISLOCA) from the high pressure Reactor Coolant System to the low pressure Residual Heat Removal (RHR) System. [4].

3.3. Procedure

The specific procedure in the field simulation is based on the scenario. A full-scope simulator provides an accident that requires cognitive action to solve. Subsequently, each team seeks the cause of the accident and attempts to stabilize the plant. During the accident, human operators respond to alarm signals, plant parameters, and other stimuli. Moreover, to find the source of the accident, an Alarm Response Procedure (ARP), an Abnormal Operation Procedure (AOP), an Emergency Operation Procedure (EOP) and a decision are normally enacted.

During this procedure, the plant parameters controlled by the operators are recorded to evaluate the operators' performance.

4. Results

Only two teams solved the problem provided by the scenario. As shown in Table I, the times to recover the subcooling margin for the successful teams were shorter than most of those of the failing teams and also the temperature difference from limitation line of subcooling margin is closer than almost of the other team.

Moreover, the operation lines in solving the problem for the two representative teams, consisting of one failing teams and one successful teams, were very different from each other. As shown in Fig.2, successful teams have more stable operation lines and never operate under the limitation line after recovering the subcooling margin. However, failing teams have less stable operation lines and operate under the limitation line after recovering the subcooling margin, as shown in Fig.3.

However, there were several exceptions that performance values were better although Team 3 failed problem solving. Therefore, further research will be needed.

Table I : Human performance values of each team

	Time to recover the subcooling margin (sec)	Temperature difference from limitation line (℃)	Problem-Solving
Team 1	401	-14.28768163	Failure
Team 2	331	-13.60091873	Failure
Team 3	291	-13.47640516	Failure
Team 4	303	-13.41031887	success
Team 5	379	-14.42952471	Failure
Team 6	260	-13.55717121	success
Team 7	376	-13.57511636	Failure
Team 8	520	-13.19810371	Failure
Team 9	656	-14.44366377	Failure
Team 10	536	-14.61764995	Failure

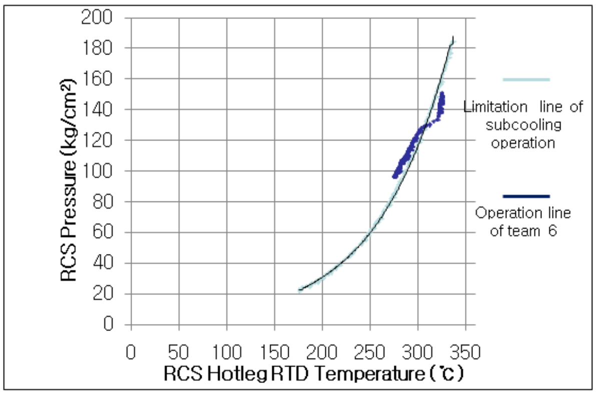

Fig 2. Operation line of Team 6

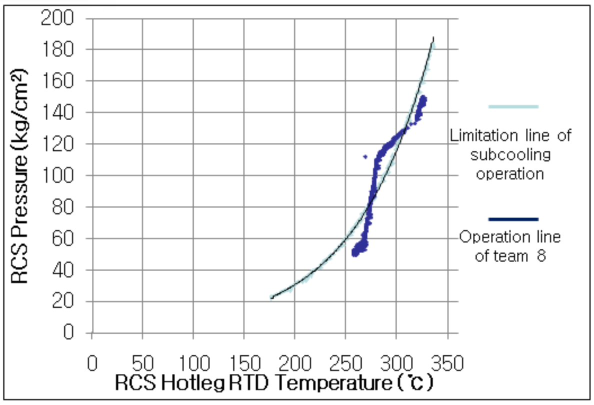

Fig 3. Operation line of Team 8

5. Conclusion

Human performance measures are important to enhance human performance and to reduce the probability of incidents and accidents in NPP. In this paper, Functional performance measure, especially subcooling margin is used to evaluate the MCR operators' performance.

As a result, operators' performance values are well matched with failure or success of problem solving. These results imply that performance values extracted from functional performance measure are useful.

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