Application of Probabilistic Safety Assessment Method to Evaluate the Effects of Tests and Inspections for Nuclear Power Plant

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ABSTRACT

For nuclear power plants, various tests and inspections are performed, which include confirmed tests of new design, preservice inspection(PSI), in-service inspection(ISI), etc. In this study, the effects of various tests and inspections with respect to improved reliability of nuclear power plants have been evaluated by a probabilistic assessment method. From this viewpoint the reliability of the piping as a passive component was discussed.

1 INTRODUCTION

As one of many approaches to improve the reliability of nuclear power plants with cost minimization, system reliability analysis, which applies the Fault Tree Analysis Method, may be performed, mainly in the design step. This analysis evaluates the reliability and identifies system design weaknesses. However the Fault Tree Analysis Method can only evaluate the reliability of components used in the system, and the effects of tests and maintenance which are performed on these components during operation, as the frequency of tests and maintenance, and the time of tests and repair. Therefore this analysis does not evaluate the effect of various tests and inspections, which include confirmed tests of new design, preservice inspection(PSI), in-service inspection(ISI) etc. with respect to improved reliability of nuclear power plants.

On the other hand, from the viewpoint of safety, ensuring quality control is a very significant item at each step in design, construction, operation and maintenance. Therefore, quality control of each step is needed to evaluate their contribution to safety, in addition to the system reliability analysis. In this study, through evaluation of the reliability for piping as a passive component, the effects of various tests and inspections which are performed at each step have been identified for evaluation by a probabilistic assessment method.

In this study four approaches have been adopted in order to investigate the effects of various tests and inspections which are performed at each step. The first approach was application of new evaluation method:Hisecurity -E(Hitachi Information Security System - Evaluation). Hisecurity-E was used to evaluate the security of information systems. This method could illustrate the relations between various tests and inspections which are performed on nuclear power plants. In the second approach, the relations between various tests and inspection was evaluated by the probabilistic network model. Parametric analysis clarified the relations between them quantitatively. In the third approach the effects of human actions were evaluated in the context of various tests and inspections. In the fourth approach the failure of two passive components at the same period was evaluated. This evaluation found the effects of various tests and inspections for common cause failure with passive components. These approaches are described in more detail below.

2 APPLICATION OF HISECURITY-E

In probabilistic safety assessment, the Fault Tree Analysis Method and the Event Tree Analysis Method are usually used. However the former cannot evaluate failure with time progression. And the latter only treats system failure, though it can evaluate failure with time progression. Therefore the event tree cannot illustrate the processes of status transitions and failure propagation. The drawing of an event sequence, which is like the event tree, can illustrate the processes of status transitions and failure propagation. However it is apt to have a big scale in the horizontal direction, so it is difficult to realize the event sequence.

Therefore Hisecurity-E was applied in order to illustrate the relations between various tests and inspections. In it, a sequence tree, which is like a fault tree, is made instead of an event tree. The sequence tree for this study is shown in figure1. Tables 1 and 2 list gate and event symbols which are used in the sequence tree. The sequence tree can illustrate the processes of status transitions and failure propagation and helps to realize the relations between various tests and inspections.

3 EVALUATION BY A PROBABILISTIC NETWORK MODEL

In this study four tests and inspections(e.g. material tests at the time of purchase, preservice inspections after fabrication, monitorings in the operation and regular in-service inspections) were especially considered for prevention of piping ruptures. In order to model the relations between these inspections figure1 was utilized. The relations were evaluated by parametric analyses for the probability of overlooking defects at each inspection.

The relations between the monitoring during operation and regular in-service inspection are quantitatively shown in figure2 as one example of parametric analyses. Almost all defects are found by monitoring if fields and contents of inspections in the monitoring are the same in the regular in-service inspection. After all the regular in-service inspection has been very siginificant beyond fields and contents of inspections in the monitoring.

4 CONTRIBUTION OF HUMAN ACTIONS TO VARIOUS TESTS AND INSPECTIONS

Usually component failures and human errors are considered in probabilistic assessments. However the uncertainties of human judgment are not taken into account. So from the viewpoint of these uncertainties, the effects of human actions were especially evaluated.

From the viewpoint of human errors there are two patterns in abnormal conditions like piping rupture(e.g. penetration crack). The first is overlooking the condition. As causes of overlooking during monitoring, overlooking the alarm (indicator) and operation mistake are considered. Usually these are dealt with as probabilistic parameters in probabilistic assessments.

The second is abnormal acknowledgment. When defects are found during monitoring, the operators must judge whether plant trip is made or not. This was modeled as probabilistic parameter for which judgment depends on the defect size. One example is shown in figure3.

In the probabilistic assessment of piping rupture (e.g. penetration crack) the above mentioned judgment model was adopted. The model was applied to judgments at preservice and regular in-service inspections. Results are shown in figure4. Judgment influences the probability of piping rupture, however the probability change is one order of magnitude at most.

5 EVALUATION OF TWO PASSIVE COMPONENT FAILURES AT THE SAME PERIOD

Components can be categorized as to passive components and active ones. The active components need to be supported by power support systems like an electric power supply. Common cause failures of active components have been reported from some countries.

The frequencies of common cause failures with passive components, which are pipings, tanks and so on, are estimated as very small except for hypothetical events like large level earthquakes. Then in this study frequencies of two piping ruptures in the same one year period were evaluated. In this evaluation preservice inspection (PSI) failures, in-service inspection (ISI) failures and stress under conditions of plant operation are taken into account as parameters.

The frequency of two piping ruptures is estimated as quite small under the PSI and ISI (figure5). The example frequencies for conditions of double failures are estimated as two times larger stress than the design one at two loops, ISI failure at two loops, two times larger stress than the design one at one loop and ISI failure at one loop. These are low because the ratio of crack propagation is small and the crack propagation under larger stress than the design stress is detected by ISI. In the case of passive components, inspection in reactor plants has various effects for frequencies of component failures, like piping ruptures, which are failure modes of crack propagation.

6 CONCLUSION

Through evaluation of reliability for piping, as a passive component, the effects of various tests and inspections which are performed at each step have been quantitatively clarified by a probabilistic assessment method. Moreover it was confirmed that the probabilistic assessment methods are useful for evaluation of the effect of tests and inspectionson nuclear power plants.

7 REFERENCES

H.H.Woo, The Impact of In-service Inspection on the Reliability of Nuclear Piping, ASME PVP Vol.92, 1984

K.Takaragi et al., The Method of Evaluation for the Security of Information

System: Hisecurity-E, The Symposium of Code and Information Security,1987

S.Lu, R.D.Streit and C.K.Chou, Probability of Pipe Fracture in the Primary Coolant Loop of a PWR Plant, NUREG/CR-2189, 1987

Table1 Gate Symbols

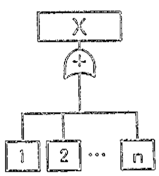
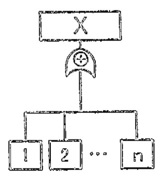
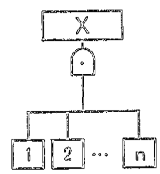
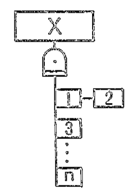
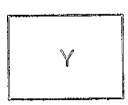
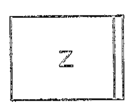
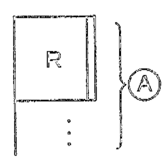
	A	B	C	D
Symbol and Name	 OR Gate	 Exclusive OR Gate	 AND Gate	 Sequential AND Gate
Definition	One or more of the events 1,2,···,n will occur after the occurrence of event X.	Only one of the events 1, 2,···,n will occur after the occurrence of event X.	All the events 1,2,···,n will occur after the occurrence of event X. The occurrence order is not specified.	All the events 1,2,···,n will occur after the occurrence of event X. The occurrence order is as depicted in the figure.

Table2 Event Symbols

	A	B	C	D	E
Symbol and Name	 Entry Symbol	 Error Symbol	 Movement Symbol	 Routine Symbol	 Connection Symbol
Definition	Starting and ending point of accidents sequence.	Symbol implying Y is an undesirable event such as error or failure.	Symbol implying Z is a prescribed motion or an event which occurs after error or failure. It is neither error nor failure.	Symbol implying the event sequence starting from the event R is the same as that defined at another place with the symbol A. It is used for the event sequence consisting of only prescribed motions (movement symbols).	Symbol indicating the connection position between sequence trees which are depicted in separate locations.

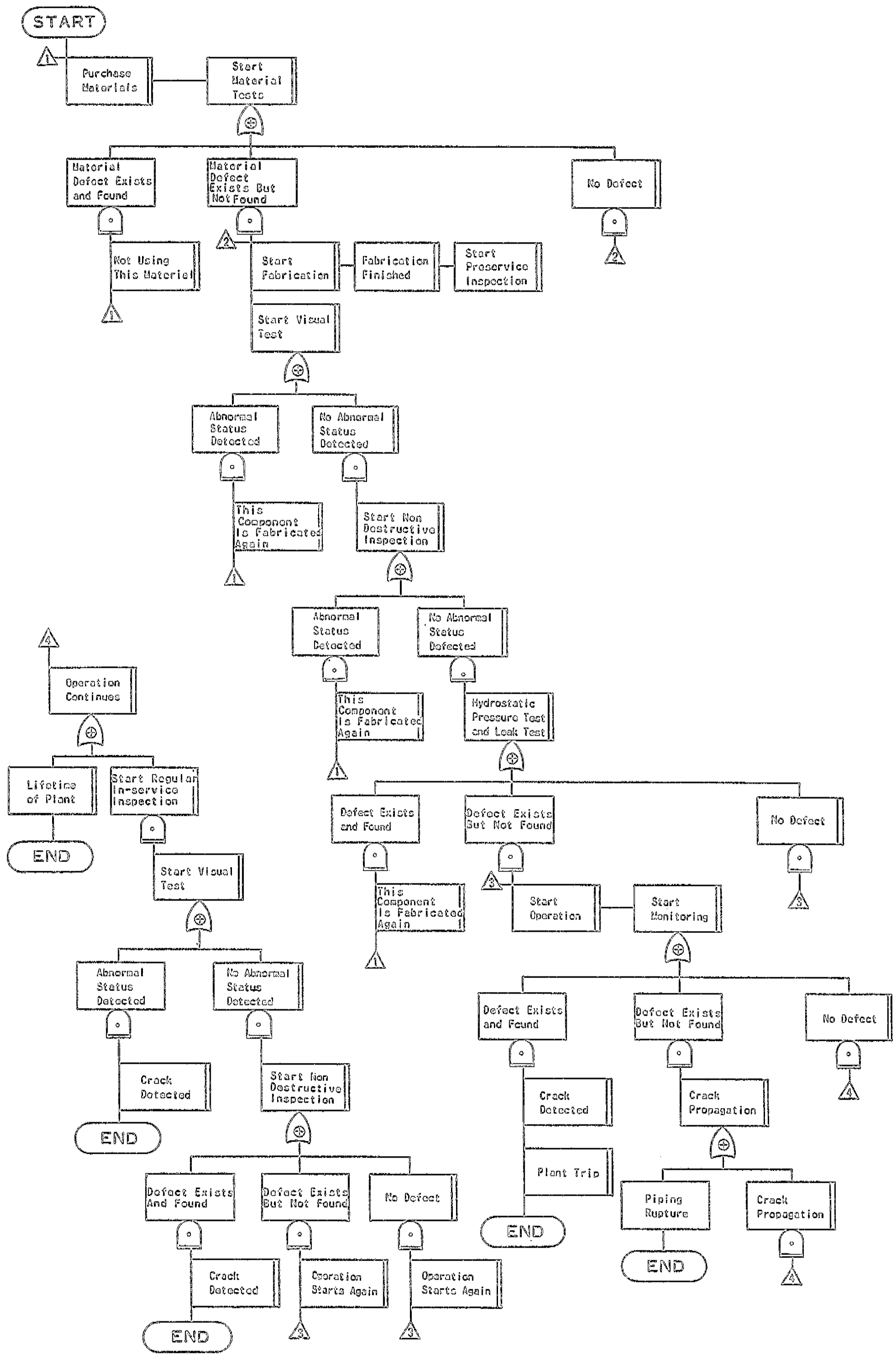


Figure1 The Sequence Tree of Piping Rupture

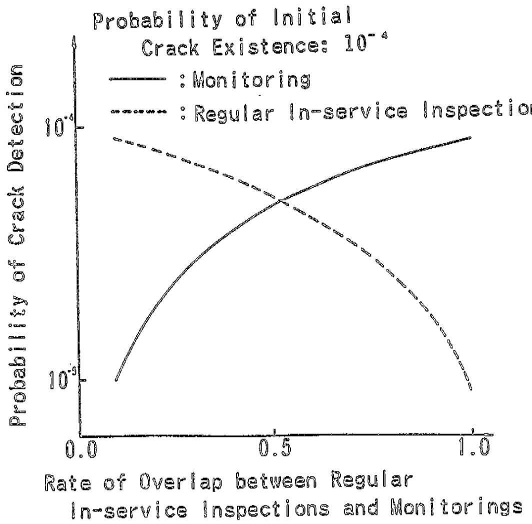


Figure2 Relations between Monitorings and Regular In-service Inspections

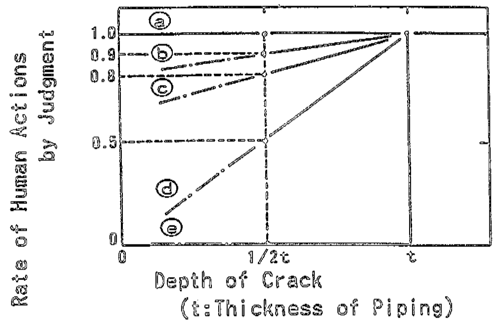


Figure3 Example of Judgment

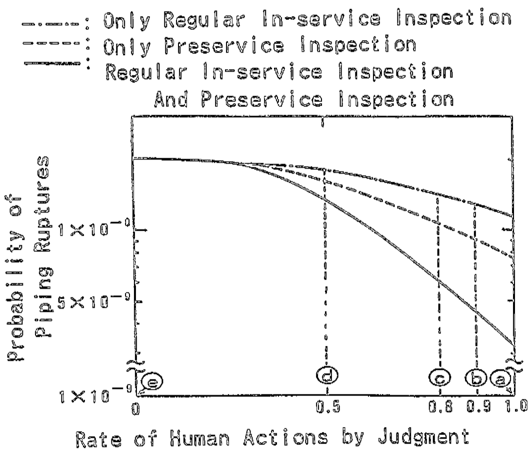


Figure4 Effects of Judgment on Probability of Piping Ruptures

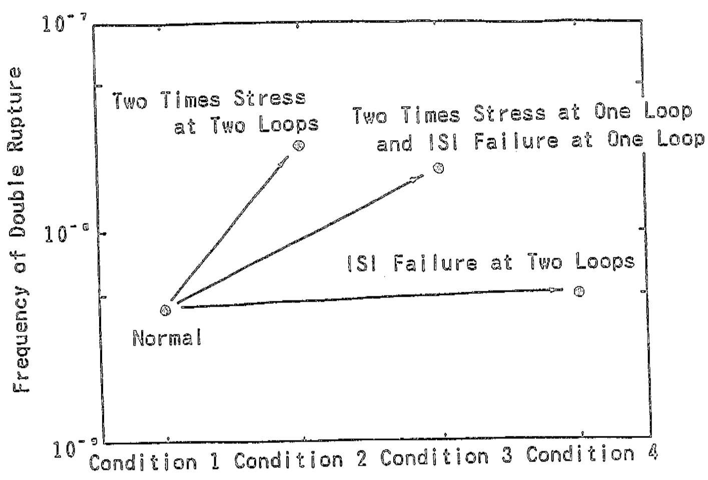


Figure5 Effects for Frequencies of Double Ruptures at Double Failures