A STUDY ON RISK ANALYSIS FOR LOADING AND UN-LOADING ACCIDENT

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SUMMARY

Low Level Waste packages are transported from each Japanese nuclear power plants to Rokkasho-Mura by exclusive ship. These packages are contained in half-height 5 ton containers. The handling system for loading and unloading containers is composed of the 25 ton crane, the cell-guide system and transport trucks. These systems are mostly automated and under computer control. By design, the whole handling system should be highly protected from any accident. However unknown causes for accidents might be concealed in this handling system, because of complicated system interaction between computer control and human operation.

The representative 25 ton bridge type crane was analyzed in this assessment. As the first step, causes of drop accidents were analyzed using design drawing of the crane and its system operation flow chart as inputs to the analysis. After analysis the protection methods were reviewed, and where necessary, revised in each step of accident cause. Those results were rearranged by fault trees for each cause. To provide quantitative details of operational interactions, crane operators and safety supervisors were consulted. Based on their experience, a method to determine probabilities of basic events was tentatively adopted. According to this assessment, each protection method was clarified and some weak points of the loading and un-loading process were able to be identified. Figure 1 shows schematically the sequential steps in the method.

As a result of this assessment, the PSA method (including fault trees, etc.) was found to be adaptable for the loading and un-loading process (i.e. handling system) and to be effective in understanding the system characteristics. Further, using this PSA analysis method allows transport companies to review protection methods with "Cost & Benefit" analysis concepts.

INTRODUCTION

The authors have tried to apply Probabilistic Safety Assessment (PSA) methods to the safety evaluation of Radioactive Materials (RAM) transport. In the PATRAM'92 conference, a tunnel fire accident was selected as an exercise study of the PSA method, where results of accident development, accident cause analysis and probability of each accident scenario were reported. In PATRAM'95 conference, a tunnel fire accident was also selected, where the formation process of a risk curve for heat input to a package and the relation between the regulatory requirement of IAEA and the risk curve were reported.

In this study, the loading and un-loading of a package (one of major process of RAM transport) was selected from the viewpoint of demonstrating whether the PSA methodology is adaptable in the study of handling accidents.

There are two major purposes in executing a risk assessment in RAM transport. The first one is to execute "the external assessment" with the viewpoint of safety inspection, the second is to execute "the internal assessment" with a viewpoint of reducing risk of the current transport system to a reasonable level. This study looks at the handling risk from the viewpoint of the utility on transport company i.e. "the internal assessment".

SCENARIO ANALYSIS

As the result of reference to the LLW handling plan, the loading process from the exclusive ship and unloading onto a loading platform of a truck is the only process in which radioactive materials are handled. Therefore "the LLW package unloading from exclusive ship" was selected for this RAM transport study.

As described above, a 25 ton bridge type crane was selected and analyzed. Figure 2 shows the schematic situation of LLW handling, the hold with cell-guides, handling devices (called "spreaders") and transport truck with containers. The sequence of handling operations are highly automated by computers and plant state is monitored in both the control room on the crane girder and the steering room in the exclusive ship. The flow chart in Figure 3 shows the actual handling sequences at the harbor. The sequences consist of "Engage and lock", "Hoisting", "Connection of spreader", "Travelling", "Lowering", "Landing on a loading platform" and "Release and unlock".

Considering the crane handling manual and crane design diagram, the analysis of accident causes were investigated using the following basic principles;

a) to allow accident causes to be classified

b) to be systematic in classification

c) to identify quickly aspects requiring further analysis

d) to allow accident cause protection method statements to be prepared

From the analysis, the four main accident scenarios for "falling of package" are; "Unlocking of LLW container", "Cutting of wire", "Brake trouble" and "Destruction of crane supports", were extracted. At each stage further analysis was performed to check and review the protection method for the identified accident cause. The results of these analyses were fully reflected in drawing up the fault trees.

MAKING OF FAULT TREES

As described above, the fault trees, which start from "falling of package" as the initial event, consist of twenty three charts developed by "AND Gate" and "OR Gate" elements. The event "Falling of LLW package" can be initiated by four major sub-events i.e. hoisting, travelling , lowering and falling on landing platform. Each major sub-event can be further developed using AND/OR gate logic to device further events in a systematic manner. These fault trees are developed back to a basic events, or an inhibit gate, which cannot be further sub-divided. Figure 4 shows part of the outline of such a fault tree.

INQUIRIES TO EXPERTS

For the purpose of compileing a database for failure probabilities of the crane system, recourse was made to a 3 men inquiry team of crane handling and the safety supervisor experts. Such expert inquiry methods have been applied to the risk assessment of chemical plant (Suzuki 1991). The method requires experts to compare, and if necessary extrapolate, well known failure probabilities (i.e., start failure probability of A.C. motor) and a failure probability of aimed event probabilities into areas where statistical data is sparse and evaluate/classify "Demand failure" and "Miss-operation"probabilities (Watabe et.al. 1997).

A schematic chart of "the probability scale" is shown in Figure 5 for example. In this figure, an aimed or discussed event is put in the left side of probability scale, and each scale measure corresponds to each well known probability, i.e. "Demand failure" and "Miss-operation" probabilities which are listed in Table 1 and Table 2. Most of those listed probabilities are well known values in risk assessment for nuclear power plants and other plants. According to the results of inquiries, each probability of basic event or inhibit event was estimated with averaging of the answer values as shown in Figure 5.

The probabilities estimated by participants in this inquiry method will include some fluctuation, but are considered sufficient for comparing the relative probabilities of each accident scenario or each event in fault trees from the view point of a safety review.

PROBABILITY ESTIMATION

The results of these probability estimates were used in further probability estimates in fault trees, and the occurrence probability of "Falling of LLW package" accident was finally calculated. The probability was estimated $3.8x10^{-8}$ (/hour) within the limit of adopted probabilities in this analysis and was judged to be sufficiently small. Among four stages, i.e. "Falling in hoisting process", "Falling in Travelling process", "Falling in lowering process" and "Falling in landing on a platform". The largest contributing event value was $2.1x10^{-8}$(/hour) for "Falling in lowering process" which shared 56% of above probability.

In "Falling in lowering process", "Brake failure" shared over 99% of probability, and its main cause was that "Electromagnetic brake failure" and "To overlook brake failure in daily test" would occur simultaneously. The probability of "Brake failure" was consequently estimated to be $2.1x10^{-8}$ (/hour) ,because the probability of "Electromagnetic brake failure" was estimated to be $1.9x10^{-6}$ (/hour) and the probability of "To overlook brake failure in daily test" was estimated to be $1.2x10^{-2}$ (/hour).

Similarly, the causes of "Falling in landing on the platform", (31% of total falling probability, i.e. $1.2x10^{-8}$(/hour)) , were "Unlock of package" ,"Cutting of wire and falling of package", "Crane supports fall down" and "Brake failure". Among the four causes, "Unlock of package" represented 98% of the probability. Thus, the probability of "Landing failure" is almost totally due to "Unlock of package".

"Falling in hoisting failure" (13% of the total probability, i.e. 4.9x10-9 (/hour)), its causes were almost totally due to "Unlock of package" (99% of the above probability). Of this "Unlock of package" failure, the two main causes were "Lockpin movement failure" and "Lockpin break down" which share 97% of "Unlock of package" probability.

The probabilities of many of the basic events have used industry wide data and an expert inquiry team to evaluate failure data for this "Falling of package" study. More accurate probability analysis will require the compilation of a failure data base by industry.

CONCLUSION

As a result of this risk assessment of LLW package handling, using PSA methods, it was clear that the probability of "Falling of package" was estimated to be very small. This study has confirmed that the PSA method would be adaptable to the assessment for handling accidents of bridge type cranes. It was confirmed that expert team inquiry an statistically rare event would be an effective approach to estimate unknown probabilities and confirmed that the probability estimation using fault trees would be useful for safety reviews by industries.

Acknowledgment

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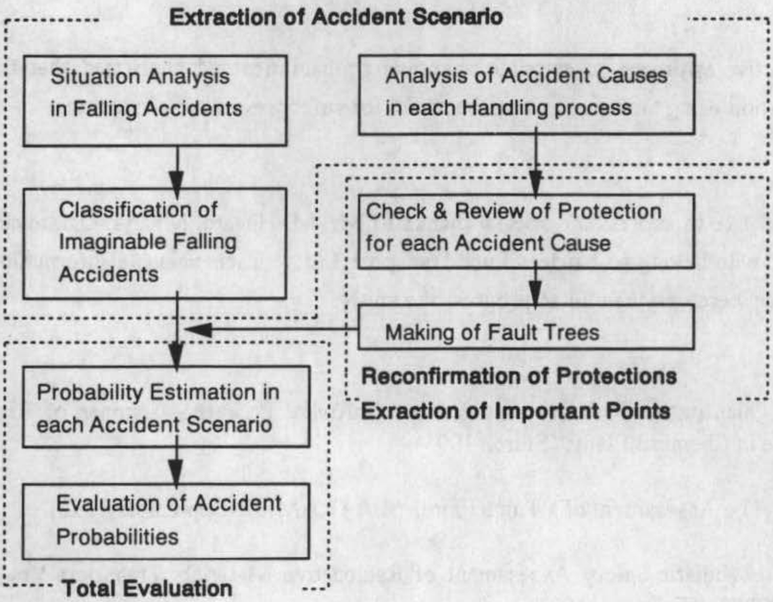
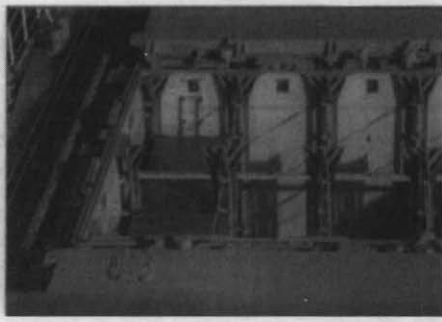
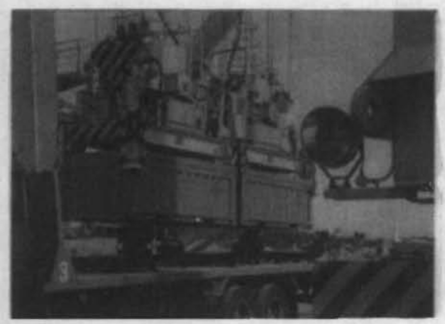


Figure 1 The Schematic Flow of This Study

25t crane and LLW exclusive ship



Cell-guide in a hold



Joint handling devices
and 5t containers

Transport truck

Figure 2 The photograph of LLW handling system

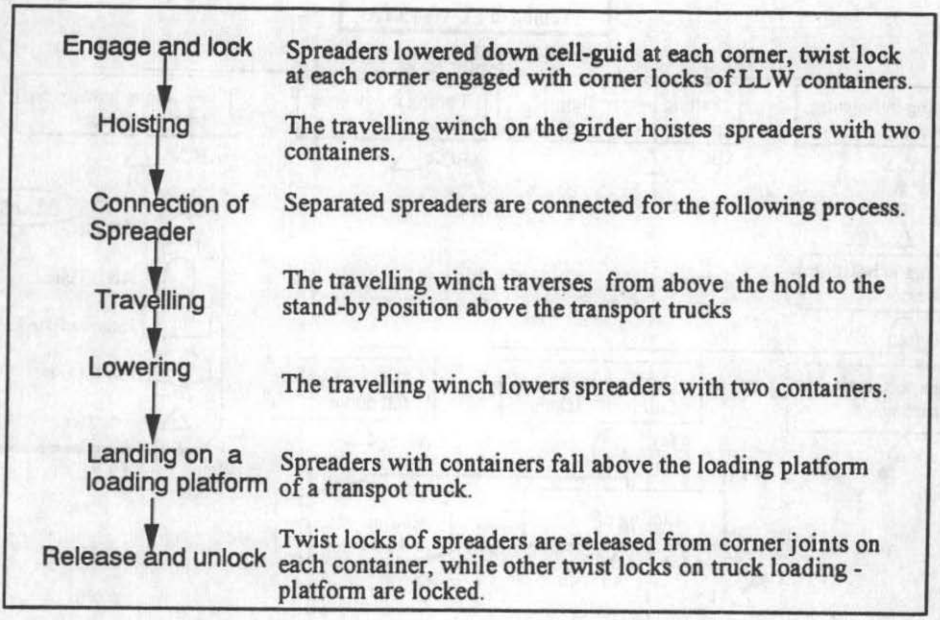


Figure 3 The handling process of LLW containers (See Figure 2)

Table 1 The demand probabilities of miss-operation referred in inquiries

Event number (Measure in scale)	Contents	Probability (1/demand)
1	Not probable	1.0x10-9
2	Start failure of AC motor	2.0x10-5
3	Miss-operation of Important switch	3.0x10-3
4	Start failure of fire pump	4.0x10-2
5	Certainly occurs	1.0

Table 2 The time probabilities of miss-operation referred in inquiries

Event number (Measure in scale)	Contents	Probability (1/Hour)
1	Occurrence of severe accident	1.1x10-10
2	Battery breakdown (NiCd)	2.5x10-7
3	AC motor trouble	1.5x10-5
4	Electric pump trouble	1.0x10-4
5	Changing time (3 times a day)*	1.3x10-1

*Laborers who work in shifts of 8 hours each.

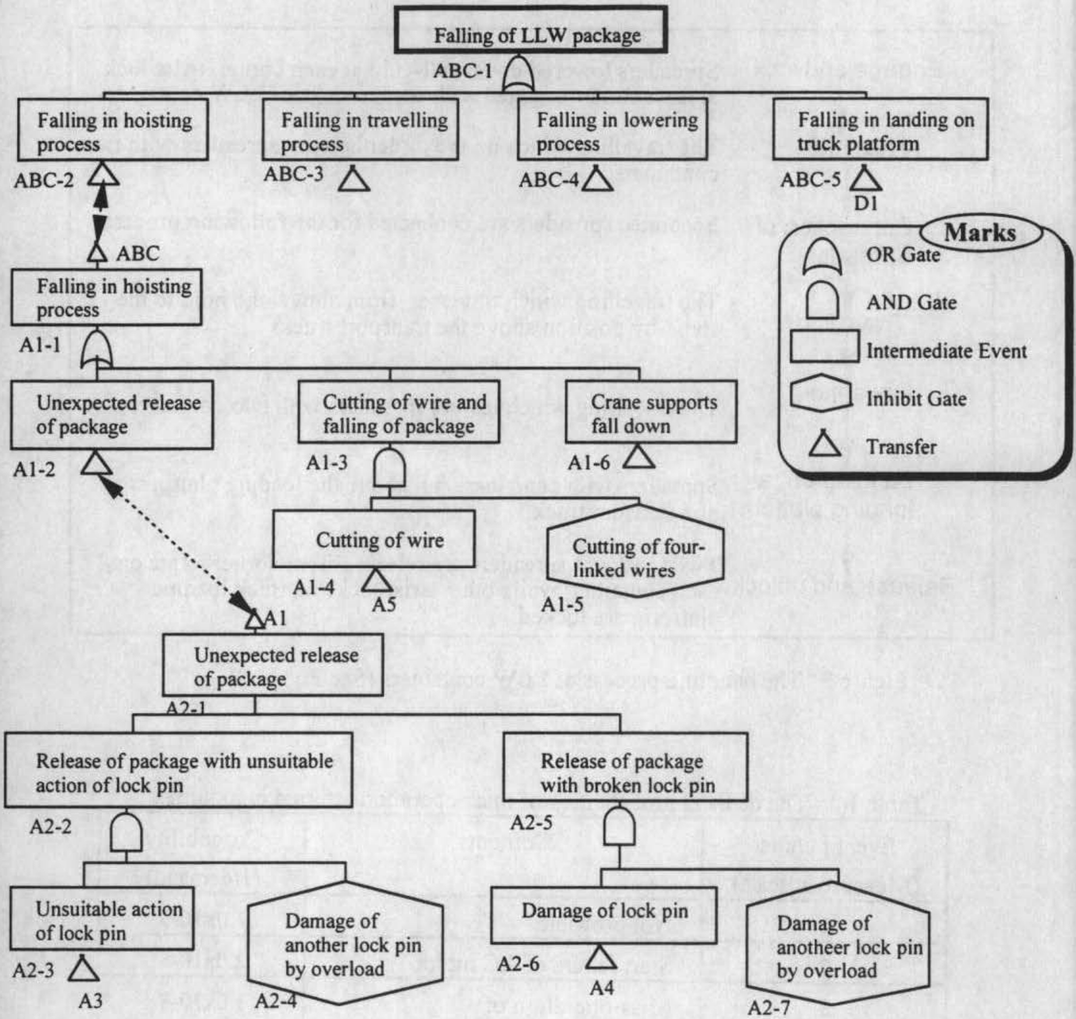
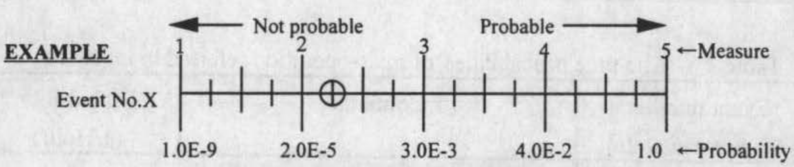


Figure 4 Fault Trees of package falling accident (partially extracted)



<< The Probability Scale used in inquiries >>

Calculation : log(p) = (3xlog(p2)+log(p3))/4
= (3xlog(2E-5)+log(3E-3))/4
p = 7.0x10-5

Figure 5 The Probability Scale (See Table 1 & 2)