Analysis of Human Errors in Japanese Nuclear Power Plants using J-HPES/JAESS

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abstract

CRIEPI(Central Research Institute for Electric Power Industries)/HFC(Human Factors research Center) developed J-HPES(Japanese version of Human Performance Enhancement System) based on the HPES which was originally developed by INPO to analyze events resulted from human errors. J-HPES was systematized into a computer program named JAESS(J-HPES Analysis and Evaluation Support System) and both systems were distributed to all Japanese electric power companies to analyze events by themselves. CRIEPI/HFC also analyzed the incidents in Japanese nuclear power plants(NPPs) which were officially reported and identified as human error related with J-HPES/JAESS. These incidents have numbered up to 188 cases over the last 30 years. An outline of this analysis is given, and some preliminary findings are shown.

1 Incidents in Japanese Nuclear Power Plants

Tokai Power Station, owned by the Japan Atomic Power Co., started commercial operation in 1966 as the first commercial nuclear power plant in Japan. Starting that year, the Japanese government requires that all severe incidents at NPPs be reported to Ministry of International Trade and Industry(MITI).

At the end of the 1995 Fiscal year, there were 49 NPPs and a collection of 863 incident reports. These incident reports are investigated with their causes and 188 incidents were found to have resulted from human errors.

Fig-1 shows the number of Japanese NPPS, total incidents per each reactor year and human error related incidents per each reactor year.[1]

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[1]In 1981, report standards were changed to include less serious incidents, so this figure begins from 1981.

In Fig-1, total incidents decreased gradually, and in the 1990's, total incidents fell below one per each reactor year. On the other hand, incidents which were related to human errors were not so decreased in the late 1980's. Therefore the rate of incidents that were related to human errors has somewhat increased in the past several years.

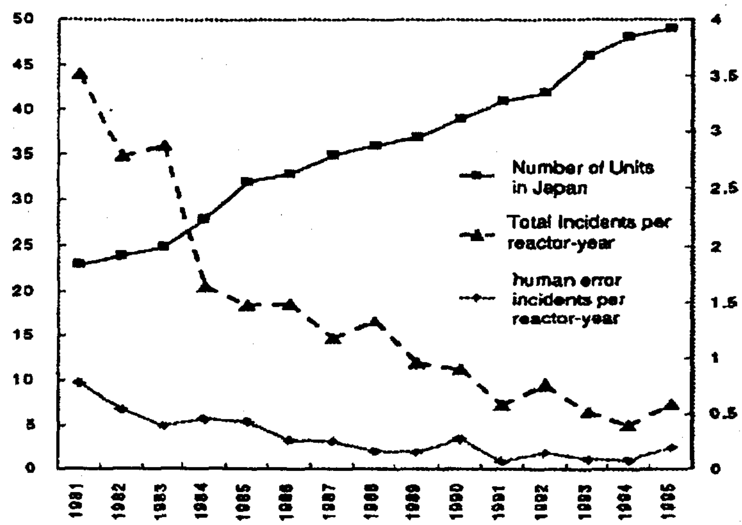

Figure 1: Number of Japanese NPP's, Incidents rates, Human Error rates

2 Definition of Human Errors

CRIEPI/HFC and NUPEC(NUclear Power Engineering Center)/IHF(Institute of Human Factors) have a joint committee to evaluate the causes of the incidents and decide whether or not they are considered as human errors. This committee uses the following definitions of human errors as guidelines in its evaluations.

- troubles caused directly by human actions,
- there were deviations from the standards in design, manufacturing, building, operation, maintenance and management,
- incidents caused by human actions which were deviated from standards

Since, these definitions of human error are very strict, only about 20% of the total incidents were identified as human errors. This result is very low compared to aviation or transportation industries, where nearly 50% to 70% of incidents were reported as human errors.

CRIEPI/HFC and NUPEC/IHF selected these definitions for the following reasons. First, to see characteristicsof human errors in NPPS, we want to use typical human error related incidents. Second, as NPPs are huge and complex system, there are too many factors relating to human errors to analyze completely. Therefore, we focused our analysis on the most common factors.

Based on these strict definitions of human errors and discussions in the joint committee, personal differences are not taken into account in the judgment of whether incidents are human errors or not.

3 J-HPES/JAESS - Human Error Analysis system

J-HPES means "Japanese version of Human Performance Enhancement System". The original HPES was a kind of root cause analysis system designed by Institute of Nuclear Power Operations(INPO). HFC adopted the outlines of the HPES and re-designed it to suit Japanese situations.

The original HPES is check sheets methods but HFC arranged the method into combination of check sheets and free format fields. Check sheets are used to summarize the situations and free formats fields are used to write down the causes and measures in detail. The procedures of the J-HPES have four stages and divided into fifteen steps and these procedures were defined in J-HPES procedure manuals. Coordinators (people who analyze the incidents with J-HPES) can follow the manuals and check all items thoroughly.

The four stages are follows:

1. understand the incidents

2. analyze the circumstances of the incidents

3. analyze the causes of the incidents

4. propose countermeasures against each cause

In J-HPES, actions which directly caused the incidents were named "inappropriate actions". Causes which directly brought upon the "inappropriateactions" were named "direct causes". Similarly, causes which brought "direct causes" were named "indirect causes" and causes which brought indirect causes were named "latent causes". "Latent causes" are conceptually similar to "root causes".

The above terms and methods were also defined in J-HPES procedure manuals. The methods of J-HPES were programmed into a computer application running on MS-Windows, which was named JAESS(J-HPES Assistance and Evaluation Support System). HFC distributed J-HPES procedure manuals and JAESS program to all Japanese Electric Power Companies and held one day course of training for the past five years. Attendants of this course to date total over 200 persons.

4 Some features of Human Errors in Japanese NPPs

In this section, we will show the some features already known from our research.

4.1 Where the Inappropriate actions occurred

Using 188 cases of HE related incidents, fig. 2 shows the proportion of "Where the inappropriate actions were occurred ?" From this figure, almost 90% of the inappropriate actions occurred in five locations, namely "Turbine building","Reactor building/Annulus","Central control room", "Containment/Drywell"and "others(such as factories/offices/unknown)".

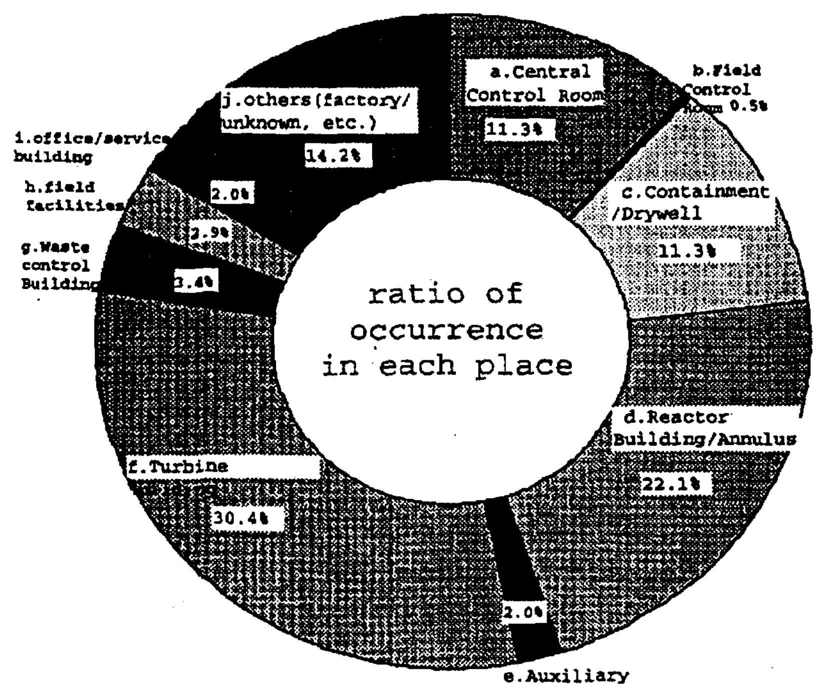

Figure 2: Where the inappropriate action occurred ?

To see the differences between these locations, fig.3 shows the contents of the inappropriate actions which occurred in each location. From this figure, we can see what kind of actions are apt to occur in each location. For example, "omission of necessary operations" occurred in all locations nearly same ratio except in "Others". But the ratio for other actions varies between location to location.

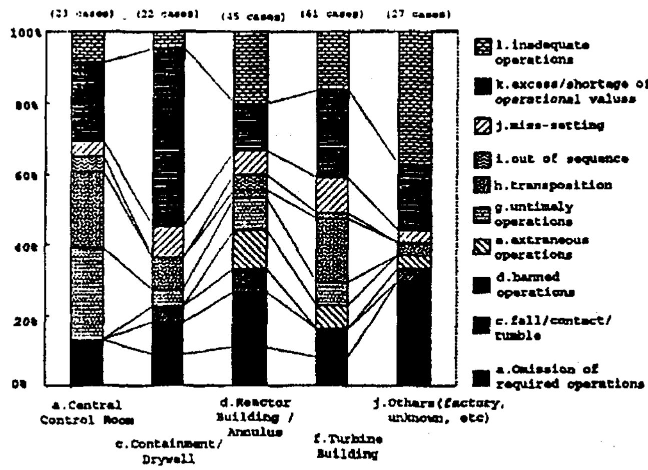

Figure 3: contents of the inappropriate actions occurred in each location

In the location of "Central control room", "untimely operations", "transposition" and "excess/shortage of operational values" are the most common kind of inappropriate actions. On the other hand, "excess/shortage of operational values" are the most common kind of inappropriate actions occurred in "Containment/Drywell". In "Reactor building/Annulus", many kinds of incidents were reported but "fall/contact/tumble" of the workers and "inadequate operations 277 were two major inappropriate actions and the rate of "excess/shortage of operational values" was somewhat fewer than other locations. In "Others" (most common location was cc manufacturers' factories"), "inadequate operations[2]" was most common inappropriate actions and "omission of required operations" was in second place.

These results could be used to propose methods to prevent such inappropriate actions suited to each work place.

[2]we use "inadequate operations" to describe errors related to carelessness and clumsiness, e.g. too much or too little force was used.

4.2 Detailed results in BWR plants

In the total 188 incident reports, 117 incidents were reported from BWR plants, 50 incidents from PWR plants, 21 incidents from GCR plant. So authors want to show the details in BWR plants.

In Japanese BWR plants, there are four kinds of design types according to General Electric's design scheme and one Japanese original design(ABWR). There were one BWR-2 plant, two BWR-3 plants, seven BWR-4 plants, 16 BWR-5 plants and 1 ABWR plant at the end of 1995 fiscal year.

On the other hand, after the late 1970s, plant designs were somewhat modified to fit Japanese situations from the accumulated operational experiences over the past decades. These modifications were standardized by MITI as "new standards of reformed plant designs". BWR plants that started commercial operation after 1984 were designed according to the revised design standards.

Categorized according to this criterion, there are 12 plants which was constructed from original GE designs(BWR-o group) and 14 plants constructed from the revised design standards(BWR-r group).

By analyzing the differences between these two groups using J-HPES data, we can identify what kind of improvements were achieved as a result of the revisions in design standards.

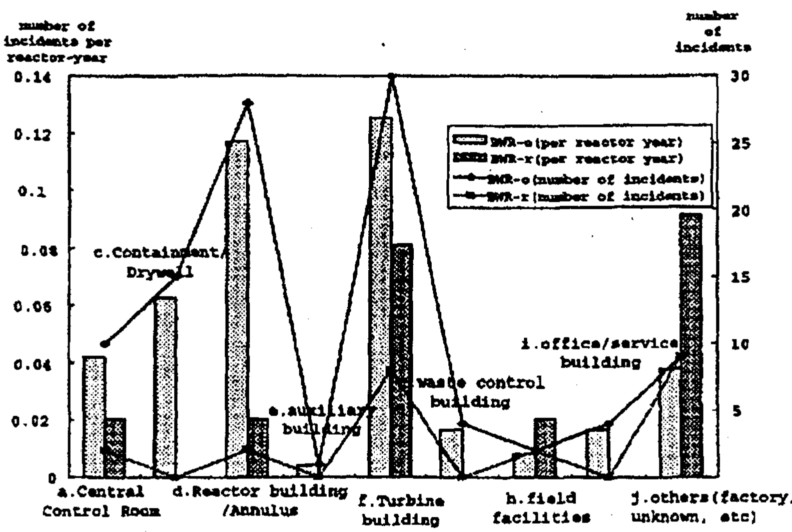

Figure 4: inappropriate actions occurred in each location between BWR-o and BWR-r

Fig-4 shows the differences between these two groups, regarding the locations where the inappropriate actions occurred. Lines show the numbers of actual incidents(scate on right axis) bars show the rates of incidents per one reactor-year(scale on left axis).

From this figure, you can see that a drastic decrease in inappropriate actions occurred at "Containment/Drywell" or "Reactor building/Annulus" in BWR-R group.

Design modification initialized by MITI was aimed at "improvement of availability and operability", "shortening of periodic maintenance outage times" and "reduction of workers' radioactive exposure". These design modifications were mostly applied to reactor containment to improve working environment there. The effects of these modifications were clearly shown from the occurrence of human error related incidents.

But BWR-O reactors(BWR plants which adopted GE's original plants' design) also improved year by year. To see the differences between periods, we divided BWR-O reactors operational periods into two decades at the year 1987. First half of the period is until 1987 and the other is after 1987 to the end of 1995. Fig. 5 shows the differences of the frequencies of inappropriate actions at each location between two decades.

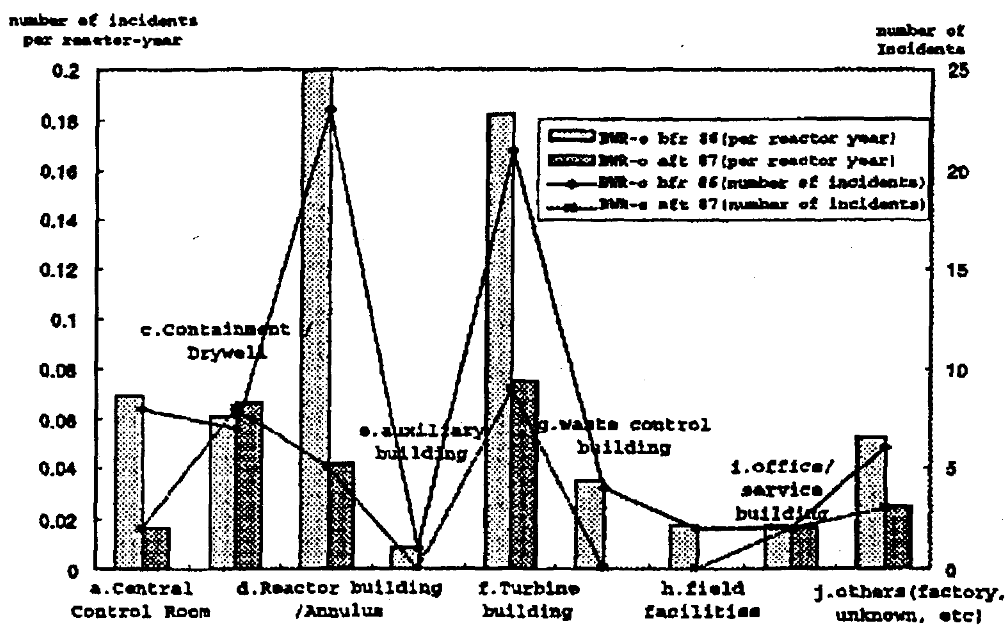

Figure 5: periodical differences in inappropriate actions occurred in each location between BWR-O group

From the Fig.5, we can also see the improvements that have been made in the BWR-O group. Especially, inappropriate actions occurred at "Central control room", "Reactor building/Annulus" and "Turbine building" are decreased radically between these two periods. On the other hand, inappropriate actions occurred at "Containment/Drywell" didn't decrease like other locations. In Japan, improvements were horizontally developed into electric power companies, so the principles of the above mentioned design modifications were also applied to these BWR plants if they were possible to adopt. But the modifications of working reactor's containment vessel was impossible, so authors suppose the occurrence of inappropriate actions in "Containment/Drywell" didn't decrease like other locations.

These results are comparable to BWR-R group. In fig.6, we compare the frequencies of inappropriate actions at each location between BWR-O group after 1987 and BWR-R group. In BWR-O group, total reactor years amount to 108(all 12 reactors were in operation in 1987) while for the BWR-R group, the total reactor years are 98.

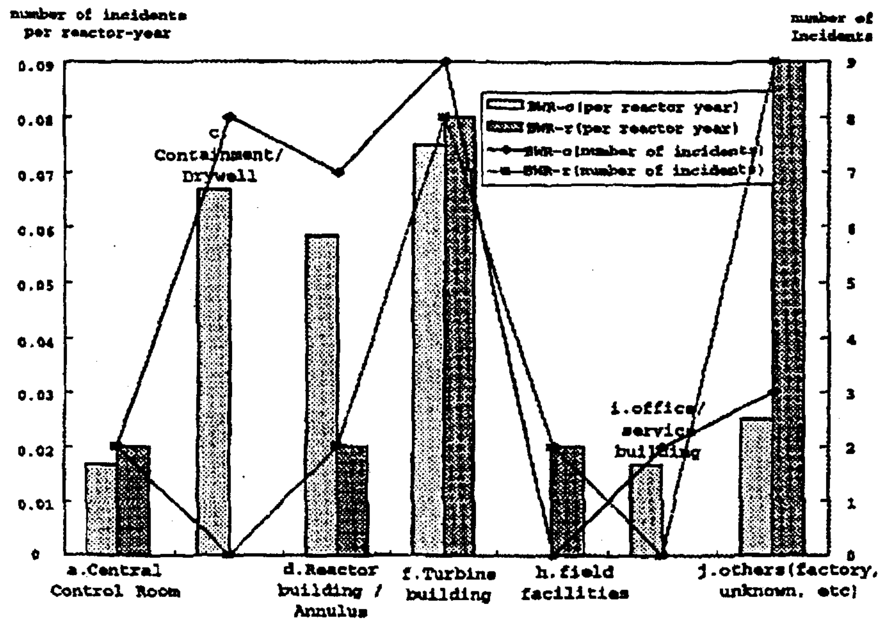

Figure 6: Comparison of recent BWR-O group and BWR-R group

From this figure, we can also see the improvement in BWR-O plants. Over the past 9 years(1987 to 1996) the number of incidents occurring at BWR-O plants were 25 cases and at BWR-R plants were 22 cases. There is no significance differences of the frequencies of incidents between these two types of BWRs.

On the other hand, differences axe found between the two groups regarding where the inappropriate actions were apt to occur. In some locations, such as "Central control room" or "turbine building", occurrence of inappropriate actions were nearly the same frequencies between two groups, but the frequencies of incidents occurred at "Containment/Drywell" or "Reactor building/Annulus" is somewhat higher in BWR-O group.

These results also show the difficulties in making improvements at the "containment vessel" or "reactor building" in working plants and hardware improvements are most powerful measures for preventing human errors.

5 Conclusion

From this study, we have learned that design modifications to improve working environments reduced human errors drastically, but improvements in original design plants were also effective to decrease the human errors in many locations. On the other hand, incidents occurred in specific locations, such as "Containment/Drywell" or "Reactor building/Annulus" were not reduced significantly in the last decade at the BWR-O group compared to BWR-R group. These results show the difficulties of making improvement in such locations. Of course, these incidents were very rare in absolute value(O.06 per each reactor-year), so we don't think any specific improvements were required in these locations.

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