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人因失误定性描述

A QUALITATIVE DESCRIPTION OF HUMAN ERROR

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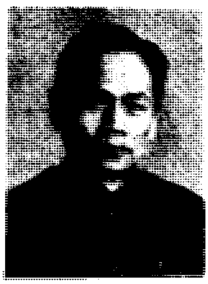

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人因失误定性描述

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摘　要

人因失误对核反应堆运行风险有重要意义。对人因失误的洞察和分析模型是人因可靠性分析的两个主要组成部分。对人因失误的洞察，包括人因失误概念，失误性质，发生机理，人误分类和行为影响因素等。在核反应堆运行过程中，人因失误定义为任务-人-机的失调。人因失误事件强调执行中的错误行为和由此引起不愉快的结果。在执行任务的时间限制上有时间-限制型和时间-开放型的操作两种。HCR模型仅适用于时间-限制型的。认识基本过程包括信息收集，认识/思考、决策和行动等四个基本阶段。人误可在任一阶段中发生并具有持续性。文中还描述较自然的人误分类方式和人的行为影响因素，包括个人、集体、组织管理和环境等方面的因素。

A QUALITATIVE DESCRIPTION OF HUMAN ERROR

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ABSTRACT

The human error has an important contribution to risk of reactor operation. The insight and analytical model are main parts in human reliability analysis. It consists of the concept of human error, the nature, the mechanism of generation, the classification and human performance influence factors. On the operating reactor the human error is defined as the task-human-machine mismatch. The human error event is focused on the erroneous action and the unfavored result. From the time limitation of performing a task, the operation is divided into time-limited and time-opened. The HCR (human cognitive reliability) model is suited for only time-limited. The basic cognitive process consists of the information gathering, cognition/thinking, decision making and action. The human erroneous action may be generated in any stage of this process. The more natural ways to classify human errors are presented. The human performance influence factors including personal, organizational and environmental factors are also listed.

INTRODUCTION

A potential hazard exits in the whole process of utilization of the nuclear reactor, both for the nuclear power plant and for the research reactor. A severe accident may release a large amount of radioactive fission products to the environment which harm the workers and inhabitants outside the site.

The risk is directly induced by defects or failures of equipment. An inadequate human-machine interaction may result in such defects or failures. Also an inadequate response or non-response post the failure of hardware may aggravate the situation. A common accepted view is that the human performance significantly influences the reactor operation safety. Such significance has been proved by experiences of the reactor operation and by the analysis of abnormal events occurred in the operation history of reactors.

In principle, activities and operations in the operation of reactor are guided by procedures and instructions. The human error data collection from the operation reactor demonstrates that the frequency of human error events occurred in every kind of operations and activities is rather high and has a periodical nature.

The human error analysis is a very complex problem. It involves the behavior and activity of persons, individually and collectively, in their specific society and on the reactor systems which the person interacts with. The person is not isolate, and in the hierarchical society is influenced by a great many of factors. The human performance may change from time to time.

Human errors which cause unacceptable result on an operating reactor, are made directly by the workers on the reactor, individually or collectively. They are operators, maintainers, repairmen and managers in the operation staff. The persons worked in the different levels of organization and in the engineering support systems can contribute to the human error. Some human errors occur in individual action randomly. Some are in the sequence of action. Usually when the error is just committed they can not be conscious. Only the effect becomes obvious, they can cognize it. The most of human errors have no significant effects on the operation safety. The minor are exception. It is difficult to identify/judge an error before its effect is resulted in.

All workers on the reactor are organized. Their activities are organized and controlled directly by the operation staff and indirectly by the different levels of organization. The performance of an individual and collective workers is influenced by such controls. However, the behavior of individual plays an important role, even influences the collective behavior in which he/she is organized and charged more or less responsibility.

For the operation of a research reactor the source of tasks mainly comes from the untilization of the reactor, such as the irradiation of samples, and from the requirement to maintain the reactor in safe operation conditions. The kind of utilization may be simultaneous multiplicity and may change from time to time. Both the characteristics of the utilization and change of the loading to satisfy the use purpose may change the reactor performance. Consequently, they may influence the chance of human error occurrence. Thus the experiences, both in operation and organization, significantly influence the occurrence frequency of human error.

The human error occurrence frequency is influenced by many factors. These are personal individual internal factors, team collective factors, organizational factors and environmental factors. The human performance influence factors are the important aspect in the human analysis. To treat these factors is different and depending on the model of human reliability analysis.

The essential aspects of human reliability study on the operating reactor are: the qualitative insight into the human error, modelling for estimation and finding the way or measure to prevent or to reduce the chance of human error occurrence. Although there are many studies on human errors (Refs. 1~4), the continuous insight of human error is still important for the further understanding of the nature (Refs. 4~8 and 10) and for the establishing of the improved model in its probability estimation. The qualitative understanding of human error mainly includes:

- the concept of human error,
- what man who has the chance to commit the error,
- the mechanism of human error generation, i. e. how human error occurs,
- the way to classify the human error,
- what factors influence the occurrence of human error.

The estimation of human error occurrence frequency is using the existing human reliability model (Refs. 1~4) or to establish an improved model for such estimation.

There are three ways to reduce the human error occurrence frequency: adapting workers to their workstation, adapting the workstation to the workers (Ref.

10) and adapting of the management and regulation environment of the reactor plant.

The purpose of this paper is to make a qualitative insight of human error. The first section of this paper describes the nature of human error and its relative topics including the essential elements of human error, the base to judge it and its characteristics. The second section describes the mechanism of human error generation on the operating reactor. The 3-rd section is the classification of human errors. The 4th section is human performance influence factors.

1 THE NATURE OF HUMAN ERROR AND ITS RELATIVE TOPICS

The human error is the defect of cognition which is inevitable in human activities. The notion of human error consists at least of two mutual related elements, i. e. the nature of human error and the base to recognize/judge it . Without such base the error can not be recognized. In a broad sense the human error is not, more or less, a very clear notion. It may vary from the view of philosophy, morality and traditional convention of society. The concept of human error in the human analysis should have the definitive and clear sense. The activities on the reactor operaiton, utilization and safety are originated from the tasks and interaction with systems. The concept of the human error is the task-human-machine mismatch (Ref. 5). In this sense two elements, i. e. the intention of action and human system interaction, are naturally emphasized. Besides, the unfavored result of erroneous action should also be added due to the possible judgement of an error. This concept provides a possible way to trace back the individual activities in the interaction with specific machine in an error, and it captures the inherent feature of an error in a dynamic process. But it does not define the cause and generation process of the error. It also does not provide the picture of the relationship in which the error is embedded.

In order to interpret the concept of the human error as the task-human -machine mismatch further, three aspects, at least, should be considered. First, what is a mismatch and is it identified as a human error? A mismatch is an event of bias or conflict in human machine interactions. There are two kinds of mismatches wich may be considered as human errors and may be defined them with specific terminology, respectively. All inadequately planned tasks, inadequate orders, instructions or erroneously arranged schedules carried out on the reactor operation that result in unfavored situations are defined as planning human error. All inadequate actions which interact with reactor systems and result in unfavored consequence are defined as executing human error. In a human error event the erroneous action is focused in performing the task and the trigger of conflict of the human-machine system is the human action by which the unfavored result is caused. The following are examples of such mismatches. A task is designed and executed beyond the limitation of system specifications, that results in a critical situation is the human error. At same time an inadequate action which results the failure to perform requirements of the task is also a human error. A part of operations including testing, maintenance, repairing, handling, calibration and etc. are guided by the relative procedure or instruction. A breach of such procedures or technical specifications is judged as the human error, because it usually causes and unacceptable result.

Second what man is involved in the human error event. There are three groups of persons who have the chance to commit or contribute to the human error. All workers who work on the reactor plant and carry out the task practically have the chance to interact with reactor equipment. The man-machine-mismatch events are directly caused by them. They are direct human error makers. All managers who work on the different levels of organization or administration are usually as the contributor to the human error, called indirect human error makers. Sometime they can commit or initiate the human error directly by erroneous interference of the operation action. A reactor can not operate without support of the engineering service sytems. A part of workers who work in these technical systems also have the chance to contribute the human error. In the most cases they are indirectly human error makers. In a word, the man who involves in the reactor operation activities may be the direct human error maker or be the indirect human error maker.

Third, what task has to be considered. In general, the task is originated from the purpose of operation. For the nuclear power plant the operation purpose is unique to generate electricity. For the research reactor the purpose is usually multiple and often changes from time to time. Usually, tasks can be divided into active and passive ones. If the task is originated from the human intention, it can be identified as an active one. For example, to change the core of the research reactor in order to meet the requirement of specific irradiation purpose is the active task. The task is identified as a passive one, if it is caused by the degrade or abnormal function of systems. For example, the maintenance and repair for maintaining the reactor in normal operation conditions are the passive tasks. The response of operator on the initiating of accident event in order to mitigate its consequence is also the passive task. To perform any type of tasks involves both the direct and indirect man-machine interaction.

Among the task-human-machine interactions the man plays a central role since engineering systems are designed to server and function under the human control. The machine functions according to the specified performance. The intention of task is performed by workers. The most of system malfunctions (except some extreme low occurrence frequency or external catastrophic events, like very strong earthquake) can be recovered by the correct human actions.

Some tasks, like the response on the unexpected reactivity insertion or mitigation of an accident initiating event, require human response in a limited time, whthin limitation the operation could be effective. Beyond the time limitation the unacceptable consequence could be resulted. Some tasks, like to repair a failed pump or to calibrate a meter, may be relaxed. Thus the human activity from tasks on an operating reactor are divided into time-limited operation and time-opened operaton. The essential feature of each type is different. The model for estimation of its occurrence probability is also different. The most of active tasks, which have no strict time limitaition to carry out and are effective if they are finished, are time-opened tasks. The frequency of human error occurrence to perform these tasks is probably in a stochastic behavior. A part of passive tasks, especiallly, the operator response during the abnormal operation situation are time-limited tasks. The human cognitive reliability (HCR) model (Ref. 3) is applicable only to such cases.

The task which is characterized by the time-limited operation in its performing is in a dynamic process. The system conditions change and the reactor is transient during this period. The operator must take into account of the changed situation. The active task is, usually, less time dependent. But the system condition may also change during the execution of the task.

For a very simple, time-opened task and direct human-machine interaction the human error may be relatively easy to judge and recognize immediately. In general case, the base to judge the error is settled by the result of interaction rather than by procedures. The reason is in the following. Before performing a task one can not foresee the incorrect actions, even if the schedule is meticulously arranged. Once the error is committed, it is not possible to correct the effect of inappropriate variation in performance inversely, until it leads to unacceptable consequence. The situation may be complexed by the fact that the error or sequence of erroneous actions occurs in a dynamic process and is influenced by the internal and external conditions which are possibly varied from time to time. Even after incident/accident events one can judged its error by unfavored results, but one may not uniquely analyze erroneous actions.

The human error may occur in the whole process in performing tasks, from the very beginning of plan to the end of its executing. Not all of human errors result in the critical situation. Only a small part of erroneous events result in serious consequence. The chance of error occurrence in each case must be equal. For the safety related operations the chance or error occurrence may be less due to more attention or other reasons. Usually, the critical consequence is not created by a single error, but by a series of erroneous actions which result in an incident/accident sequence. Sometimes, a significant event or even a severe accident is , dramatically, originated from an unimportant human error and continuing a series of human erroneous actions. Consequently, from this point of view the human error data collections should not discard erroneous actions in insignificant events. Also the human data concerning the operating reactor should not be limited on the data of erroneous responses of operators, but in a more wide sense, it should be extended to erroneous events of all activities.

The reactor operator plays a crucial role to maintain the reactor in normal operation. During the abnormal situation the operator responses can have substantial impact on the possibility to return the systems to a safe operation condition. Operators may take recovery actions. Alternatively, erroneous responses can delay or hinder the chance of recovery.

2 THE MECHANISM OF HUMAN ERROR GENERATION

The basic stages of cognitive process consist of the information gathering, cognition/thinking, decision making and action. The information gathering is the beginning of the cognitive process. In this stage the situation is sensed by possible perceptive ways, for example, the read out meter, alarming, communication and etc. The gathered information induces the cognition. The cognition/thinking includes the diagnosis, the situation assess and the interpretation of phenomenon. Sometimes it also includes the recalling of procedure, manual or specifications, even making a simple estimation by mind for an astute worker. The decision making is the result of cognition. An intention is formed in this stage which decides what action is selected or to be taken. The action which symbolizes the end of cognitive process is putting the decision into practice. In case to perform a complex task required a series of actions the cognitive process may proceed in many times at a highly progressive form rather than in a form of simple repeat. The cognitive process may be performed by persons, individually or collectively, in the reactor operation staff, even extended to different levels of organization.

The human error may occur at any stage of cognitive process. There are two types of human errors which can be distinguished, i.e. the intention error or mistake and the action error or slip. The definition of mistake is an error of intention formation that is generated in some stage of cognitive process before the action. The erroneous sequence is occurred in such mechanism. The slip is generated during the process of execution, either by omitting of an action or by disregarding the new information. For example, a worker fails to perform a task only due to the slip, like to select a wrong switch, to turn a manual value in a wrong direction. The most of such errors have instantaneous and stochastic behavior.

The human intention error belonged to the mistake has the behavior of continuity. If an error occurred at the previous stage of cognitive process, it remains and influences the present and the next stages. It is less possible to correct the previous error, especially for the time-limited operation. The misperception of situation, i.e. an inadequate information gathering results in inadequate interpretation and decision making which makes a person to take a wrong action (commission error). The most cases of misperception are due to the irratonal gathering information. A typical example is described in the following. A flow rate meter indicated a full scale flow rate in the in-pile irradiation loop due to the failure of that meter. The local operator closed fully the manual adjust valve while he wanted to reduce the flow rate. It resulted in a significantly critical event. In fact there were several informations to indicate the failure of that flow meter. Of even more concern, a person may take actions that would exacerbate the problem, while it is seemingly appropriate to the person's perception on the situation, A misinterpretation may occur while the gathering information is adequate. That results in inappropriate decision making and action. The right interpretation provides the base for the appropriate decision making, but does not guarantee the correct of its decision. The erroneous intention results in inadequate action.

Even in some case for time-opened interactions, like to repair a failed pump by a crew, they may be aware their previous incorrect action at present step, but the success of the repair can only be checked during the test or after the next start-up of that pump.

Thus the mechanism of an human error describes that the error may begin from any stage of basic cognitive process, and continues to remain to the action. After the practice the worker can be conscious his/her error.

The cognitive processes both for the individual and collective are influenced by the human performance influence factors which make the larger difference of the occurrence frequency of human error between individuals or crews from one to another. The cognitive environment simulator which is a typical try of the plant operator performance experiment is based on the cognitive process (Ref. 9).

3 CLASSIFICATION OF HUMAN ERRORS

To classify human errors may be in different way. The more natural ways are to be introduced. The first way is to clssify them into indirect and direct human error. Because all tasks performed on the operation reactor are in organized form. All person involved in it may have the chance to commit the error. The persons who occupy the position in one of levels in this organization do not take part in direct interaction with machine. Their error is classified into indirect one. The indirect human error is often committed in collective form and connects with operation workers. All workers who take part in direct interaction with machine have the chance to commit the direct human error. Often the indirect human error is identified as the human performance influence factor of human and the direct human error is considered and estimated in human reliability analysis (Refs. 1 and 2).

Next, an erroneous action can be committed by the individual or by the crew who take part in human-machine interaction. Thus human error can be clssified into individual/personal human error and collective human error. In a simple case when a task is performed by the individual worker, for example, to turn-off a switch or to calibrate a meter, its error is easily identified as an individual error. The probability of occurrence of erroneous action depends on the performance of that worker. If the action is monitored by the another worker, then the erroneous action is contributed by the second person. Such human error should be identified as a collective one.

The most of man-machine interactions on an operation reactor are performed by the specific crew of workers. For example, the reactor are operated by the crew in the control room, the systems are maintained by the different teams of maintainers. Consequently, the most of human errors are identified to the collective class. As well known that the probability of collective error can not be reduced by simply increasing the number of workers in that team. It depends on the behavior of the task-team. Each individual in a task team may play a substantially different role in performing the task. In general case, the performance of the team is mainly determined by the team leader and the central persons in the team. It is also depending on the distribution of responsibility, the relationship among members of the team, the relationship between the team and the operation staff. Sometimes, organization of different levels may influence the team behavior. The classification of human error into collective and individual should be helpful in the human reliability analysis.

The human errors can also be classified into a cognitive error and action error according to their formation in the cognitive process. The cognitive error is defined as such errors that its cause is formed in cognitive process before the action is taken. The action error is defined as a chance error due to the omission or carelessness. The cognitive error results in not only one emotion, but in series of erroneous actions, if the task requires many of executing interactions with equipment. The action error is in isolation and random form. There is, probably, no relation with other action.

4 HUMAN PERFORMANCE INFLUENCE FACTORS

A human being is not a mechanical system and neither can nor should be studied in isolate form. Although persons act in a specific society, the human performance differs from one to another. The performance of individual depends on his/her nature which is progressively formed in his/her specific society. The human performance is influenced by a great many of factors which can be categorized into personal internal, organizational external and environmental external.

Almost all of human reliability studies consider the human performance influence factors. The different model may consider them in different way. Some may consider specific factors like onion model in Ref. 11. In more early publications (like

Ref. 1), these influence factors as the human performance shaping factors were considered by the correct factors to modify its estimated occurrence frequency. Recently, the human performance and these influence factors are integrally considered in the estimation (Ref. 6~8). The human performance influence factors are listed in the following table.

Table 1. Human Performance Influence Factors

Personal internal	Individual, productivity and reliability
Knowledge:	Training background
	Experience: Past practical experience
	Current experience
	Skill
Ability:	
	Efficiency
	Practice
	Aptitude
Motivation:	State of mind
	Attention
	Awareness of safety
	Alertness
	Charge of responsibility
	Participation of decision making
Culture:	Personal individual
	Relationship and cooperation with team or crew
Competence	
Compliance:	Relationship with the operation staff and managers
Attitude:	Spirit of discipline
	Invocation
	Moral
	Commitment
	Attention
	Memory
Stress	
Collective internal	
Structure of group, team or crew	
Delegating responsibility	
Clarity of charge in the collective-delegate responsibility	
Leadership of	
Relationship:	With operation staff
	With organizations
	Internal cooperation
Efficiency:	Ability of the head of crew
	Personal background
	Personal control
	Discipline
	Communication
	Feedback
	Response
	Learning from its past experience, adapting accordingly
Participation of decision making:	
	Within the crew
	In operation staff and organization
External organizational	
Structure of organizations:	
	Organization
	Task-structure
	Program
Leadership ability	
Technology level	
Policy consistency	
Responsibility	

Management:	Style
	Discipline
	Explicit rules, standard, procedures and instructions
	Personal control
	Corporate culture
Efficiency:	Communication
	Feedback
	Immediacy in addressing problem
Relationship:	Among the organization
	between organizations
Awareness of safety	
Reward/punishment	
External situational environmental	
Quality of workstation enviroment conditions:	
	Temperature
	Humidity
	Air quality
	Noise and vibration
	Degree of general cleanliness
Working condition:	Availability/adequacy of specific equipment, tools and supplies
	Radioactive level
Facility quality:	quality
	Facility age
Explicit procedures	
Work hours	
Explicit display in instrumentation and control system	

SUMMARY

Human reliability is a developing technology, currently at the threshold change. The insight of the human error is the basic problem for the analysis study and modeling of estimation.

The insight of human error has been done as above. The basic concept of the human error is the task-human-machine mismatch. The error is identified by the unfavored result of action. The human errors are divided into planing error and executing error. The persons involved in the operation of the reactor have the chance to commit or to contribute the human error. They may be direct human error maker or indirect human error maker. It may be done individually or collectively, directly or indirectly. The task may be active or passive from its origination. Also the task may be time-limited or time-opened from its requirement to perform. The task may have a dynamic behavior that the human error is embedded.

The basic stages of cognitive process are the information gathering, cognitive/thinking, decision making and action. The human error may be originated in any stage of this process. Two types of human errors should be distinguished. The intention error is originated from in the intention formation process. It has the behavior of continuity. The slip is generated during the execution and has the instantaneous and stochastic nature.

There are many ways to classify the human errors. The more natural ways are introduced. These are the direct and indirect, individual and collective, intention and action errors. The human performance influence factors are categorized into internal, organizational and situational external.

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