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A Review on the Concept of "Practical Elimination"

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1. Introduction

One of the major shift in nuclear safety system since Fukushima Daiichi accident is adopting, in Vienna Declaration, "practical elimination of large/early releases from NPPs" as one of implementation principle. Since then, IAEA has published relevant Safety Standard(SSR-2/1) and technical document(TECDOC-1791) based on the discussion over how to achieve this principle. The concept of practical elimination of large/early releases was first introduced in IAEA INSAG back in 1999 by then coined as "Practical Elimination." As INSAG revised the "Basic Safety Principles(INSAG-3, 1988)" into INSAG-12 in 1999, INSAG-12 suggested to practically eliminate the causes of accident that can lead to large/early releases of radiological material. It was a technical safety target for future NPPs that had never been suggested before.

Since then, in the "Design of Reactor Containment Systems for Nuclear Power Plant (NS-G-1.10)" published in 2004, IAEA prescribes more concrete concept of "practical elimination" and defines it for new reactor. In Europe through WENRA statement in 2010, it was included as part of safety objectives for new reactors. However, actual international discussion of the concept began with the Fukushima accident and it now firmly stands as an international standard through new attention and reviews.

This paper deals with the meaning and applicability of the concept of "practical elimination."

2. The Concept of Practical Elimination

The concept of practical elimination suggested by IAEA NS-G-1.10(2004) intactly handed down to post-Fukushima accident publications including IAEA Safety Standard(SSR-2/1 r.1). technical document(TECDOC-1791), WENRA′s report[1] and OECD/NEA Green Booklet-17[2].

> "The accident condition that can lead to large/early releases of radiological material should entail both of: 1) severe damage on reactor core; and 2) loss of integrity in containment building (bypass)…
>
> …the possibility of certain conditions occurring is considered to have been **practically eliminated** if it is physically impossible for the conditions to occur or if the conditions can be considered with a high degree of confidence to be extremely unlikely to arise."

Thus, the goal of practical elimination is to demonstrate that the conditions assumed to threaten reactor core and containment building are physically impossible to take place or to prove that their probability is extremely low.

(i) *Demonstration of physical impossibility*: by reviewing safety characteristics specific to certain reactor type, it should demonstrate in a deterministic manner that the basic safety functions(control, cooling, confinement) are maintained by the law of nature and any progress of an accident is physically impossible.

(ii) *Demonstration of extremely low probability*: probabilistic figure can be provided but a satisfactory figure alone can not be interpreted as practical elimination. Rather, one also has to assumed, consider a high energy phenomena, and adequately takes into account independence, diversity, and redundancy of safety features, reinforced safety margin, and passive facilities.

What should be emphasized here is that physical impossibility or extremely low probability can not be simply achieved by design itself, but to be achieved through adequate test and inspection and maintenance that take place every stage from design, manufacturing, construction, to operation. For instance, there can be an action of removing welding in equipment or pipe line thereby excluding the possibility of pipe break and eliminating initial event. It requires design and selection of materials based on sufficient tests and theoretical interpretation and verification on time history after being manufactured. And also whether probability in causes of multiple failure including common cause failure remains extremely low just as assumed is confirmed through consistent check and complementation during the operation phase.

3. Response Strategy to the Risk with Extremely Low Probability

Physical impossibility better reflects the purpose of "practical elimination," considering the fact that the demonstration of extremely low probability entails various uncertainties. However, probability of occurrence is more likely to be met and better utilized in reality. TECDOC-1791 suggests frequency of large/early release caused by internal event is 10^{-6}/RY and below and Finland considers 10^{-7}/RY as the lowest limits for the standard falling to Design Extension Condition(DEC) among accident class.

Nonetheless, There is still a question about existence of standards for extremely low probability. To take up the right answer to the questions, not only scientific factors on probabilistic figures but also social factors have to be considered. That is, the decision to accept/refuse an expected risk with certain frequency is dependent on the nature of each society facing the issue and it requires a social decision.

Generally, under a uncertain situation where current information and knowledge are not enough to make assumptions, the attitudes toward decision making are divided into risk aversion, risk neutral, and risk prone. A rational decision maker is the one who is able to choose and apply one of the three in a consistent manner. However, in case of government- or society- wide decision making where all the different opinions exist and decision is being made in various areas, risk neutral seems like the only option. Because risk neutral is a policy decision based on social cost-benefit analysis that ensures consistency.

But it has been pointed that cost-benefit analysis has its limitation when making decisions against catastrophic risk whose main characteristics is low-probability and high impact.[3][4] With solely depending on risk neutral, one cannot find answers on, which is to be selected among risks with same size and how to prevent it. For instance, people raise their voice to guard against the risk with extremely low probability such as severe accident, but with risk neutral way of decision making, one cannot decide on how low a probability be considered.

4. Inequity Aversion

In the discussion process on what to choose among indifferent preference, a risk assuring standard based on explicit preference among catastrophe aversion, catastrophe neutral, and catastrophe acceptance has emerged as an alternative.[5] A society's attitude toward catastrophe is about its preference between an accident that causes N number of casualties and N number of accidents that cause one casualty. When a society prefers to the former, it is defined as catastrophe acceptance while it prefers to the latter, it is defined as catastrophe aversion.

For Instance, let us compare two situations where two individuals, Holmes and Moriarty, are exposed to a risk of death. In situation *A*, represented to the left of figure 1.1, either Holmes will die, or Moriarty will die, with equal probability. In situation *B*, either Holmes and Moriarty die together, or both stay alive, with equal probability. In this case, We can say that situation *B* is"more catastrophic" than situation *A* based on the notion mean-preserving spread.

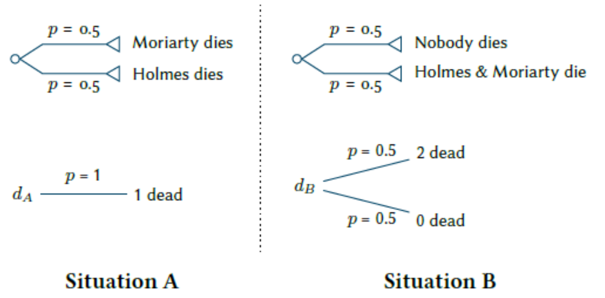

Fig.1 Probability trees (top) and the corresponding distribution of fatalities (bottom) for two risk situations.

Surprisingly, according to the empirical research on ordinary people, when the government(regulation) makes a decision on catastrophe causing lots of victims, people want it to be on the side of catastrophe acceptance.[5] That is, when expected values to the damage remain equal, people tend to prefer that all the people equally experience a catastrophe with low probability rather than a catastrophe where only certain amount of people are subject to the aggravating risk. It means that the government is required to make effort to remove high level of risk from being imposed on a certain people.

It is hard to tell which motives drive catastrophe-accepting attitudes. Such "catastrophe acceptance" attitude seems to be inclined from inequity aversion. That is, in a risk related decision making process, a situation where someone has to face higher risk tends to be avoided for the purpose of ex-ante equity or ex-post equity. The reason why people do not want "catastrophe aversion" attitude is because they prefer being a group sharing a common destiny, not because it is ex-post inequity.[5]

<Ex ante and ex post inequity>

Ex ante equity concerns the fairness of individuals' marginal probabilities of death, as they exist at the time of decision making. Ex post equity concerns the equality of individuals' fates in the outcome of an alternative. Usually, alternatives that are ex post equitable are also ex ante equitable; but the converse is not true.

To illustrate, if two people play Russian roulette with a single gun, this is ex ante equitable, but clearly not ex post equitable.

5. Conclusion

The concept of "practical elimination" first introduced in 1999 as safety target for new reactors has now become something necessary to demonstrate after international community experienced Fukushima accident. In Europe where it has already been adopted as a safety target for new reactors, practical elimination is expected to be a regular topic for heated debates. However, it should be reminded that the concept can only be achieved when there is consistent effort being made in each stage of design, manufacturing, construction, and operation.

In Europe, practical elimination has come as a realistic issue. The U.K has pursued a project to construct EPR from France on its Hinkley Point site and the Green party of Germany is going against the project arguing that according to the Aarhus Convention and Espoo Convention, the project violates procedural justification. The basic reason that made Germany intervene the project is that 1) the possibility of severe accident that might take place in an NPP site in the U.K is not zero; and 2) due to such reason, the UK-EPR project can have impact on German's domestic environment. Under such situation, interpretation on practical elimination has become crucially important.

One needs to deeply consider that how long we should ponder on risk with the frequency of 10^{-x}. Decision making based on risk neutral and cost-benefit analysis is considered as a rational judgement under uncertainty but it fails to guide us to decide what to eliminate when all the risks have same amount of expected values. The same can be applied on judgement about extremely low probability of "practical elimination." With vague standard and fear against uncertainty, judgement would only take us to the risk with a lower probability.

However, as we cannot respond to all the potential risks equally with such limited resource, decision should be made by additionally taking into account socio-ethical aspects. One of such aspects can be the equity over the damage experienced by members of society. As an extreme example, it is socially more desirable to prevent the risk whose frequency is $10^{-1}$and number of potential victim is 10, rather than to prevent a hypothetic catastrophe risk whose frequency is 10^{-10} and number of casualty is 10^{10}. Having said that, there exists other viewpoint including taking into account public preference among types of risks

What we have to admit is that when considering the equity of risk, extremely low probability in occurrence does not mean $10^{-\infty}$. Therefore, the probabilistic standard considered to be "practically eliminated" can be discussed between 10^{-6} and 10^{-9}.

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