Several Concerns on Nuclear Safety
−From Experiences of TEPCO Fukushima Daiichi Accident−

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The focus of this commentary is to present the lessons learned from the on-site events caused by the nuclear accident that occurred on March 11, 2011.

I. Loss and Subsequent Restoration of Expert Credibility

To gain public support, the following three steps are required: (i) experts should, in principle, reach a shared understanding that is essentially correct; (ii) information related to this understanding should be communicated effectively to non-experts; and (iii) this information should help non-experts develop a deeper understanding. However, the lessons learned from the accident that occurred at the Fukushima Daiichi Nuclear Power Plant suggest that the first step has a number of inadequacies, such as the following.

(1) The reactor accidents resulted from both an underestimation of the forces of nature (tsunami height) and inadequate preparedness for unanticipated events. Preparations for accidents were also inadequate because the routine observance of defined procedures led to complacency based on the mistaken assumption that reactor accidents would be extremely unlikely to occur in Japan.

(2) Experts failed to anticipate M9 earthquakes in the vicinity of Japan (although seismic ground motions are not expected to cause reactor accidents) and tsunamis of the scale that occurred. They were unable to form a collective opinion that could be reflected in the disaster management measures adopted by the national government.

(3) Experts failed to anticipate that a hydrogen explosion could occur after a core meltdown.

(Experts were aware that hydrogen had burned inside a primary containment vessel during the Three Mile Island (TMI) Accident that occurred in the United States in 1979. Furthermore, the possibility of hydrogen combustion occurring outside the primary containment vessels for boiling water reactors during a severe accident had already been mentioned in two studies conducted in Finland and the United States. However, there is no evidence that these studies were taken seriously. It seems that nuclear engineers did not have a shared awareness of the possible occurrence of a violent explosion of the type experienced in

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Fukushima. This is probably because research on reactor safety had been focused on the prevention of severe accidents without addressing their progression of actual severe accidents. Experts must reflect deeply on their failure to predict such accident progression properly at the critical moment where they should live up to the public trust conferred on them in light of their expertise.)

(4) Many conflicting opinions have been voiced about the health impact of low-dose radiation exposure.

(Experts with extensive research experience tend to share an almost identical opinion on this matter, which seems quite different from items (1) through (3) above. However, people from apparently different backgrounds have many dramatically different opinions. Such confusion is probably causing serious problems for those who were compelled to evacuate and other concerned individuals.)

It will not be easy for experts to restore public confidence, but a society that lacks confidence in its experts will remain in disarray. An important task for experts is to tenaciously continue to investigate the Fukushima Accident, establish safety measures, determine the latest findings, and communicate their opinions.

Many questions remain to be answered, including the extent of damage caused to reactor pressure vessels and primary containment vessels as well as the current locations of the nuclear fuel materials. In addition, some experts have claimed that the reactor building for Unit 2 avoided a hydrogen explosion because its blowout panel opened when Unit 1 exploded, but this panel is installed at a much lower level than the ceiling of the building, thus leaving a considerably large space above it. It remains unclear whether the opening of the blowout panel was enough to prevent the explosion and whether there were any other openings in the ceiling. The composition of the accumulated gas should also be assessed. Moreover, before the Fukushima Accident occurred, studies on the structural behavior of primary containment vessels had focused on the fulfillment of functions within their design conditions. Too few studies have been conducted to determine at which point their functions are lost beyond their design conditions (leakage of radioactive materials in the case of primary containment vessels). Their behavior should be urgently examined while taking into consideration the temperatures and pressures.

II. Infrequent Unplanned Shutdowns and Robust Reactor Safety

A high level of technological competence in Japan has been assumed to explain why unplanned shutdowns are extremely infrequent compared to the rest of the world. However, a clear distinction must be drawn between infrequent unplanned shutdowns and a high degree of safety at nuclear power plants. The fact that unplanned shutdowns are infrequent under moderate external forces of nature does not mean that nuclear power plants can be shut down safely under rare but extremely strong external forces of the nature.

Efforts to reduce unplanned shutdowns have most likely been reinforced in light of the need to sustain power generation, as well as based on the recognition that these shutdowns may cause concerns for nearby residents even though there is no direct effect on their safety. Arguably, an assessment should be conducted to also consider infrequent unplanned shutdowns as a possible cause for the lack of experience in operating emergency equipment.

A vital aspect of safety measures for nuclear power plants is to prevent an abnormality from escalating into an accident with an external release of radioactive materials. The utilities and regulatory authorities should both do their utmost to ensure this.

III. Aging Management

As part of the aging management measures adopted in Japan, extensive studies have been conducted to investigate changes associated with the aging of structures and power lines. Japan has been leading the world in terms of measures to address phenomena such as stress corrosion cracking, pipe thinning caused by internal flow, and fatigue damage caused by temperature fluctuations. Japan has a wealth of experience in performing preventive maintenance through the application of research findings at existing plants.

However, aging management needs to be bolstered from a broader perspective that goes beyond measures that deal with aging in materials over time. Among other things, the conditions need to be constantly revised to account for external forces of nature and a practical sense of the operating safety systems employed only in older plants should be cultivated.

For reference, the US approach to the service life of nuclear power plants is described here.

Initially, a service life of 40 years was specified in the United States. This period was determined by simply adopting the amortization period of 40 years that was used for fossil fuel plants in 1954. In fact, the Nuclear Regulatory Commission (NRC) of the United States admits in its report entitled “A Short History of Nuclear Regulation, 1946–2009” that the period was not specified with any consideration given to aging in structures over time, other technical factors, or safety. In the 1980s, the NRC carefully considered the possibility of extending the service life of nuclear power plants. It concluded that the service life could be extended by up to 20 years provided the latest safety verifications were performed. In the NRC report published in February 2013, a service life of 60 years was authorized for 73 out of the 104 reactors in the United States. Of these reactors, 17 had already been in service for more than 40 years. The report explains that the NRC is discussing this extension for 15 units and that applications are expected to be submitted for an additional 13 units.

IV. Importance of Continuous Improvements

Unlike the TMI Accident (USA) and the Chernobyl Accident (USSR), the Fukushima Accident was not caused by factors such as the neglecting of device failure, faulty reading of instruments, or inadequate safety considerations being given to plant performance surveys. It is important to clearly recognize that the accident could not have been prevented by simply observing the regulations that had been authorized internally or by regulatory authorities or by just repeating the same tasks as those conducted the previous day. False assumptions must be dispelled and a critical review must be conducted to enhance safety. Continuous improvements are vital.

Plant personnel did their utmost to respond to the Fukushima Accident. For instance, the fact that injection lines to the reactors were quickly installed immediately after the loss of power probably prevented a further escalation of the accident. Moreover, a monitoring vehicle was deployed at 5 p.m. on March 11 to routinely cover those monitoring posts that were no longer able to conduct measurements after the station blackout. Data on the radiation doses registered by this vehicle proved vital in examining the development of later events.

The failure to prevent this accident despite such efforts has given rise to some fundamental soul-searching. This experience highlights the importance of preparing equipment and conducting emergency response drills before exceptional events can occur.

V. Building the Technical Capacity of Regulatory Authority Personnel

One of the most important tasks carried out by regulatory authorities is to build up the technical capacity of its individual employees in charge of regulatory matters. Continual capacity building must be pursued so that the employees gain a better understanding of what reactor safety entails and what activities enhance reactor safety.

The NRC is a notable foreign organization that serves as an important reference. It gained the top rank under the evaluation system called "Best Places to Work" among U.S. government agencies for two consecutive years in 2009 and 2010. This evaluation is conducted based on various criteria, including capacity building for personnel, the manager's capacity to run the organization, and teamwork. The majority of the staff at the NRC work there for a long time. Many experts with years of service in performing regulatory work are also trained through the provision of on-site experience to build up their technical competence. They conduct their own research and draft standards for regulation. In addition, they monitor efforts to enhance safety measures at the respective nuclear power plants. (The NRC systematically incorporates opinions of external academic experts into their regulatory standards as necessary.)

The NRC that exists today was not built overnight. In particular, nuclear power attracted severe public criticism in the United States after the TMI Accident of 1979. The NRC and various utilities undertook a process of trial and error to ensure the safety of nuclear facilities. Meanwhile, the generation that had given rise to the era of nuclear power reached retirement age while the number of students of nuclear energy dropped sharply in the aftermath of the TMI Accident. Such developments led to serious concerns over inadequate knowledge and technology transfers.

In response, the United States adopted long-term measures (e.g., college education programs) to encourage a new generation to participate in the nuclear sector. At present, the number of students specializing in nuclear energy has grown considerably compared to the level that existed before the TMI Accident. In light of how highly it is rated as a workplace, the NRC attracts many outstanding talents year after year. (Some speculate that a considerable number of former navy staff who have worked on nuclear submarines or aircraft carriers join the nuclear power sector including NRC. They further point out that, in striking contrast with its U.S. counterpart, the Japanese nuclear sector does not enjoy a sufficient supply of human resources from the military sector. In response to this speculation, an NRC commissioner explained that "a certain proportion of new recruits do have a navy background, but the military cannot match universities in terms of their ability to provide a reliable source of new recruits to sustain our activities. The number of graduates who are directly recruited to the NRC after completing their nuclear studies is much higher.")

VI. Ongoing Discussions among Stakeholders

Efforts to ensure nuclear safety must be undertaken in various areas. In addition to regulatory authorities conducting a review of regulatory requirements, discussions should be held repeatedly by scientific communities, utilities, and industrial circles. These efforts should be conducted in tandem while also complementing one another.

A good example of a foreign standard that has been developed mainly by industrial circles is Section III of the "Boiler and Pressure Vessel Code" published by the American Society of Mechanical Engineers (ASME). Issued in 1963, this structural standard for the mechanical equipment employed in nuclear power plants has been honored and adopted in various forms by the regulatory authorities of not only the United States, but also many other countries around the world, including Japan.

In response to the Fukushima Accident, the ASME set up a taskforce headed by Dr. Diaz, who once served as the chair of the NRC. In June 2012, the taskforce proposed new nuclear safety measures in a presentation entitled "Forging a New Nuclear Safety Construct." Based on this proposal, a workshop was held in Washington D.C. in December 2012. Participants from industrial circles and regulatory bodies based in various countries around the world discussed how these measures should be implemented. Ms. Macfarlane, the incumbent NRC chair who was appointed last July, also attended the workshop and made a speech stressing the importance of the efforts made among industrial circles to enhance nuclear safety.

At the quarterly ASME meetings held to review the "Boiler and Pressure Vessel Code," many participants from the NRC voice their opinions as representatives of their respective regulatory authorities. At these meeting, reports of 10 pages or more are distributed to brief on the activities conducted by the NRC.

The following remarks made by Dr. Diaz in his presentation during the ANS 2012 Winter Meeting offer suggestions concerning the desirable relationship between regulatory authorities and utilities as well as public acceptance of reactor safety.

- On the "acceptability" of safety, the U.S. Appeals Court ruled as follows in 1987: "The level of adequate protection need not, and almost certainly will not, be the level of zero risk."
- The reality is that there is no such thing as zero risk, and for all technologies, including nuclear, a certain level of risk is/should be acceptable to society.
- There has to be a defined, fair, visible CONTRACT between regulators and operators, with accountability by and for all, that considers internal and external events and extends the protection to severe rare events.

VII. Conclusions

Our hearts go out to the many people who even now are forced to continue their lives as evacuees following their displacement due to the accident that occurred at TEPCO's Fukushima Daiichi Nuclear Power Plant. However, nuclear technologies remain vital for Japan in terms of not only supplying energy, but also providing medical diagnoses, conducting cancer treatments, carrying out industrial inspections, and so forth. Therefore, it remains essential that we continue to conduct nuclear-related research and foster the necessary human resource development.