NUCLEAR EMERGENCY RESPONSE PLANNING AND PREPAREDNESS FOR THE HTR-10

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ABSTRACT

The 10 MWth high-temperature gas-cooled test reactor (termed HTR-10) went into criticality at the Institute of Nuclear Energy Technology (INET) of Tsinghua University in December 2000. As required by China nuclear safety authorities, we had developed nuclear emergency response plan and relevant technical procedures for the implementation of protective actions should an accident occur. This paper presents the technical basis for the development of the HTR-10 nuclear emergency plan. Firstly, it describes briefly the requirements of the China nuclear safety authorities about the nuclear emergency planning and preparedness for research reactors. Then, the paper focuses on the technical development of initiating conditions (ICs) and emergency action levels (EALs) for HTR-10. The ICs and EALs developed are tabulated in this paper. Finally, a brief presentation about the on-site emergency response exercise carried out before the first fuel loading on HTR-10 and other emergency preparedness activities conducted or being planned are given in this paper.

1. Emergency Classification System

Similar to the emergency classification system for nuclear power plants, the emergency states that may happen on research reactors can be classified into four categories, i.e. emergency standby, plant emergency, site area emergency and general emergency based on the features and consequences of potential events or accidents, which are characterized by emergency action levels.

In the current China nuclear safety regulations, emergency action levels for research reactors are defined in terms of the air concentration of or radiation exposure from the effluents released at the site boundary (Table 1). However, it is often a big challenge to estimate the concentration or radiation dose in the event of an accident. In fact, it is in general required that proper mitigating measures should be carried out to avoid or decrease the release of radioactive material into the environment before the release actually occurs. The experience and lessons learnt from the emergency management of nuclear facilities have shown that the operability of the emergency action levels as given in Table 1 is relatively poor. Because of this, the National Nuclear Safety Administration (NNSA) requires that quantitative emergency action levels be established in the emergency response planning for research reactors. They should be developed based on the initiating conditions or events defined in the safety analysis. They should be straightforward and easy to use, such as instrument readings, equipment states or other directly observable information and phenomena etc. Clearly, this kind of action levels facilitates quick recognition and determination of emergency classes.

2. Quantification of Emergency Action Levels

Emergency action levels are used as the technical criteria or parameters for the classification of emergency states, such as instrument readings and alarm settings etc. The purpose is to facilitate recognition and determination of the emergency states and hence take prompt and effective protective actions to avoid or mitigate the potential consequences should an accident occur.

Table 1 Emergency Classification System for Research Reactors [1]

Emergency Classes	Action Levels
Emergency standby	• Actual or projected radiological effluents at the site boundary exceeding 10 DAC* when averaged over 24hrs, or 0.15mSv whole body dose accumulated in 24hrs. • Report or observation of severe natural phenomenon, such as earthquake and hurricane etc.
Plant emergency	• Actual or projected radiological effluents at the site boundary exceeding 50 DAC* when averaged over 24hrs, or 0.75mSv whole body dose accumulated in 24hrs. • Actual or projected radiation levels at the site boundary of 0.2mSv/h for 1 hour whole body or 1mSv thyroid dose.
Site area Emergency	• Actual or projected radiological effluents at the site boundary exceeding 250 DAC* when averaged over 24hrs, or 3.75mSv whole body dose accumulated in 24hrs. • Actual or projected radiation levels at the site boundary of 1.0mSv/h for 1 hour whole body or 5mSv thyroid dose.
General emergency	• Sustained actual or projected radiation levels at the site boundary exceeding 5mSv/h whole body. • Actual or projected dose at the site boundary in the radioactive plume exposure pathway exceeding 10mSv whole body or 50mSv thyroid.

DAC: Derived Air Concentration

In HTR-10 emergency response plan three emergency classes are identified. It includes emergency standby, plant emergency and site area emergency. The corresponding initiating events and emergency action levels are listed in Table 2. The methodology for development of emergency action levels for nuclear power plants was taken as a reference in this task [2]. It should be noted, however, that it is generally not possible to develop quantified indicators for all initiating events that may result in emergency states. Therefore, qualitative judgment about the safety status and eventual progression of reactor system is also needed in many cases.

3. Determination of Emergency Planning Zones

In China the emergency planning zones for research reactors are determined primarily using the criteria given in Table 3. The radionuclide inventory in a research reactor core is generally much less than that in commercial nuclear power plants. Consequently, the quantity of radioactive material that may be released into the environment in an accident and hence the potential impact on the population living in the vicinity would be significantly smaller compared with an accidental release from a large-scale nuclear power plant. The principal purpose of establishing emergency planning zones around a research reactor is to be able to take effective protective actions to avoid or mitigate the radiation exposure from the passing radioactive plume to the workers and the public members who are occasionally on-site or near the site boundary in the event of an accident.

Table 2 HTR-10 Initiating Events and Action Levels

Emergency Classes	Initiating Events and Action Levels
Emergency standby	• Loss of off-site or on-site AC power supply, and failure of the diesel generating unit supplying power to designated loads within 60 min; • Failure of engineered safety features or fire protection system, and the Technical Specifications requiring reactor shutdown. • Abnormal opening of certain safety valve or pressure relief valve, and failure of closing as system pressure decreasing to a preset value; • Failure of the indications and alarm signals for more than two reactor safe shutdown parameters in the control room, and loss of protection function for one of them; • The mean concentration of airborne radioactive effluents into the environment over 30 min exceeding 10 times of the routine discharge concentration; • The specific activity of the coolant inside the primary circuit during 5 min exceeding 10 times of the preset alarm threshold; • Loss of pressure accident caused by tube rupture in primary circuit; • The decreasing speed of the liquid level due to abnormal leakage of liquid nitrogen system exceeding 5 times of the normal speed.
Plant emergency	• The mean concentration of airborne radioactive effluents into the environment over 30 min exceeding 100 times of the mean discharge concentration; • Decrease in pressure by 20% in 5 min due to abnormal leakage of the waste gas processing and storage system; • Decrease in liquid level by 2 cm due to abnormal leakage of the storage tank in the tritiated water collection system; • Loss of feed water supply without trip; • Uncontrolled lifting-up of a control rod during power operation without trip; • Water ingress into reactor core due to SG tube rupture, and the safety valve in the pressure relief system of the primary circuit in open position; • Loss of off-site and on-site power without scram; • Failure of all indicators and alarm signals for reactor safe shutdown; • The specific activity of the coolant inside the primary circuit during 5 min exceeding 100 times of the preset alarm threshold.
Site area emergency	• The maximum dose expected on the site resulting from the effluents exceeding the lower intervention level for taking sheltering (5mSv whole body dose or 50mSv thyroid dose); • Double-ended break of the hot gas duct (air ingress accident) • The specific activity of the coolant inside the primary circuit during 5 min exceeding 500 times of the preset alarm threshold, and the safety valve in open position.

Table 3 Recommended Radius of Emergency Planning Zone for Research Reactors [1]

Thermal Power (P)	Radius of Emergency Planning Zone (m) (Centered at reactor)
P≤2MW	Operations boundary
2MW＜P≤10MW	100
10MW＜P≤20MW	400
20MW＜P≤50MW	800
P＞50MW	To be determined on a case-by-case basis

Besides the HTR-10, there are two other research reactors at INET. They are the twin-core shielding research reactor, each with a thermal power of 1MW, and the 5MW district heating experimental reactor. According to the recommendations given in Table 3, the outside wall of the building in which the shielding research reactor is located could be chosen as boundary of the emergency planning zone for this reactor. For HTR-10 and the 5MW district heating experimental reactor we could establish an emergency planning zone with a radius of 100m for each of them. For the sake of effective management, we have taken the site boundary of INET as the emergency planning zone for all the three reactors instead of setting up separate emergency planning zones for these reactors.

According to the criteria given in IAEA TECDOC-953 [3], an urgent protective action zone with a radius not less than 500m and a long-term protective action zone with a radius not less than 5km would be required for HTR-10. It means that off-site emergency response planning would be needed. Although the principles proposed for establishing adequate emergency response capabilities are sound and comprehensive and the corresponding technical steps reasonable and operable, we are of the opinion that in this document the safety features of a nuclear facility are not explicitly emphasized in the quantitative criteria suggested for defining the magnitude of emergency planning zones. Apparently, it is reasonable to establish different size of emergency planning zones for nuclear facilities with different safety features. The safety analysis done for HTR-10 has shown that this reactor is of advanced inherent safety features. Reactor states that could result in high radiation doses or significant radioactive releases are of extremely low probability of occurrence [4]. Based on those considerations, we find it would not be necessary to extend the emergency planning zone for HTR-10 beyond the site boundary of INET.

4. Emergency Preparedness Activities

To be able to respond promptly and effectively to emergency situations in case of an accident, a comprehensive and integrated emergency response plan has been developed [5]. On the basis of this, an on-site emergency response center has been established. In addition, information network connecting relevant emergency organizations will also be put in place in the near future, in particular the data network connection between the HTR-10 control room and the response center. Each of the emergency organizations has compiled their emergency response implementing procedures. The have also conducted relevant training and exercise activities.

A convincing demonstration of emergency response capability is a mandatory requirement for the issuance of fuel loading license in China [6]. Therefore, an on-site emergency exercise for HTR-10 was carried out shortly before the first fuel loading. The hypothetical accident scenario was water ingress into primary loop. The initiating event supposed was SG hot tube rupture.

The whole exercise progressed from emergency standby via plant emergency to site area emergency and lasted for 1.5 hours. All the emergency organizations of INET was involved in this event. They performed their tasks satisfactorily under the direction of the on-site emergency response center. Protective actions, including sheltering and evacuation of part of the site personnel and public members (students), were smoothly conducted.

The NNSA staff supervised the whole exercise on the site and convened a technical evaluation meeting thereafter. They concluded that the exercise was a great success. They also made some suggestions for further improvement of the INET emergency response capabilities.

5. Conclusions

The emergency response capability established for HTR-10 is an integral part of the whole safety management system aiming at the safe operation of the reactor. The development of quantified emergency action levels represents a key issue in this aspect. Because of the limitation in the knowledge of the safety performance of high temperature gas-cooled reactors, the initiating events and action levels presented in this paper are preliminary. They will be further elaborated in the future as more experience is accumulated in this field.

References

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