Consequences and Causes of Criticality Accident at Conversion Test Facility at JCO Tokai Works on September 30, 1999

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Shunsuke Kondo

Department of Quantum Engineering and Systems Science The University of Tokyo

A nuclear criticality accident occurred on 10:35, Sept 30, 1999 at the Tokai Works of the JCO (former Japan Nuclear Fuel Conversion Company), a 100% daughter company of Sumitomo Metal & Mining. Three workers received high doses of neutron and gamma radiation and a local evacuation plan was implemented for more than two days, which was affected the daily life of more than three hundred thousand people.

The purpose of this note is to summarize the consequences and the causes of the accident as a quick report or letter to experts in nuclear business throughout the world. It should be noted that, as the official investigation is still on-going and no official report has been published yet, the description is based on personal observation and analysis.

1. Description of the Accident

In the Nuclear Fuel Conversion Test Facility at the Tokai Works of JCO, three workers were filling the Uranyl Nitrate solution (U.E. 18.8%, 360g/l) into a precipitation tank for homogeneous mixing of the solution under the contract with JNC. The solution was to be supplied for the fabrication of fuels for the experimental fast breeder reactor "Joyo". A criticality occurred when worker A poured the UN solution that he had prepared in a bucket of 10 l capacity into a precipitation tank with diameter of 45cm, height 70cm, and volume 137 l. The authorized limit of uranium for this tank is 2.4 kg. They had started the filling operation in the afternoon of the day before and the accident occurred when they started filling the seventh bucket.

Worker A received 17 Sv and worker B who supported worker A received 10 Sv. The two workers said later that they saw a flush of blue light. The third worker who was in the room next to the Facility room received a dose of 3 Sv. He helped workers A and B to escape the room and asked for help. They were transported to National Radiological Medical Institute in Chiba by a helicopter at around 15:25. Workers A and B are now being medically treated in the Institute of Medical Science at the University of Tokyo. It is reported that A is in serious critical condition and B's condition is also classified as serious, though better than A.

The action to terminate the nuclear criticality was determined at around 23:00 of the day and the criticality was terminated at 4:30am, Oct 1,1999 by discharging the water in the cooling jacket of the precipitation tank. This was by injecting Ar gas into the water-cooling circuit connected to the jacket. To assure the

attainment of sub-critical condition, water with boric acid was injected into the tank thereafter.

The Mayor of Tokai-mura village asked the people to stay in the house at 12:30 through the local broadcasting system and implemented the Recommendation of Evacuation within 350 meters from the site boundary at around 15:00 based on the request from the JCO Works and opinions of experts from JAERI and JNC. This was based on the interpretation of the sustained high level gamma ray dose of 0.7 m Sv/hr and a neutron dose of 4.5 mSv/hr, which was obtained by the neutron detector newly installed by JNC people, at the site boundary. About 160 persons were evacuated to the Village Center. This Recommendation of Evacuation was lifted in the evening of Oct 2, 1999.

A decision to recommend the people living within 10 km from the site to stay in the house was put into effect at around 22:30 by the Governor of Ibaraki prefecture by way of precaution to unexpected development of the situation. It was lifted at 16:30 of next day, i.e. Oct 1, 1999. The affected population by this recommendation was estimated as 310, 000 persons.

2. Energetics of the Accident and the Radiation Exposure of the People

It is reported that a funnel the workers used for pouring the UN solution into the precipitation tank remained at the observation hole of the tank when the emergency team tried to inject water containing boric acid through the hole. This suggests that the energetics of the initial fission spike were not so strong as to eject any amount of UN solution from the hole. The investigative entry to the facility confirmed this quiescent nature of the event. Based on this fact, the total fission of this initial spike is estimated to be about 10^{17}.

After this fission burst, the fission rate in the tank oscillatory converged to the level equivalent to the cooling rate through the cooling jacket, which is tentatively estimated as a few kW or so. Total fissions due to this sustained "critical operation" of the facility is estimated to be about five times 10^{18} fissions.

36 workers who were working around the facility at the occasion of the accident received a radiation dose in the range of 0.5 to 23mGy at maximum.
The exposures of three firefighters who transported the workers A, B and C were estimated to be in the range of 0.5 to 3.9 mGy. 7 residents of the village who were near the site received doses of 2.6 to 9.1 mGy at maximum. The maximum dose of 18 workers who engaged in the operation of water discharge from the water jacket around the precipitation tank was 98mSv.

As there is an open hole at the tank, most of volatile fission products were released to the room. Several cases of slight beta contamination were reported at the survey of the workers evacuated in the JCO Works. However, the doses at the outside of the site were dominated by the direct radiation of neutrons and gamma ray from the facility.

3. Root Cause of the Accident

The measures to prevent criticality accidents implemented in the facility at the stage of operation permit

included the control of the amount of uranium in the process via the process control sheet, the geometrical shape of storage tower and the batch counter, which limits the amount of the UN solution in the precipitation vessel below the authorized value, - a factor of four smaller than the real criticality limit for the vessel.

In the original manual, the operation to prepare the UN solution should be done in a dissolution tank placed before the storage tower, where nitrogen bubbling method should be used for homogeneous mixing of UN solution. However, the workers used a modified operation manual that instructed them to use three buckets for the preparation of UN solution to be mixed in the storage tower, after separating the precipitation tank from the line.

It is reported that the workers discovered it was more convenient to use the precipitation tank, rather than the storing tower, for the homogeneous mixing operation, as it had a large volume and a mixer, though they should have known that the authorized amount of uranium in the vessel was only 2.4 kg. The primary reason for workers to implement an idea occurred to a chief worker to use the precipitation tank for producing a large amount of homogeneously mixed UN solution in far shorter time without any attention to criticality is apparently due to the complete lack of knowledge about the limit on the amount of U in the precipitation tank which was specified in the Technical Specification of the facility. The lack of this knowledge is obviously due to the lack of education to workers on the criticality safety in the facility and the Technical Specification. The process manuals used in the facility had no mention on the limiting conditions for processing in order to prevent criticality. The interview of the management revealed that they firmly believed that criticality accident was impossible as workers follow the procedures, though they themselves had not followed the Technical Specification for a long time.

It can also be pointed out that the fact that they were pouring the seventh bucket-ful UN solution when they saw a flush of blue light clearly might indicate that the control of the amount of uranium in the process was deteriorated. Workers in the facility could obtain significant amount of U_3O_8 powder to be dissolved in buckets, as it was stored in the facility as an intermediate product. According to the Technical Specification, the maximum storage amount in the processing zone of the facility was about 1 ton.

The top management of the Works acknowledged that the alternative manual was produced several years ago for accepting the then current practices, without receiving review by the safety department of the Works. This was clearly a violation of the Technical Specification and these indicate complete degradation of the sprits of observing the Technical Specification, to say nothing of the safety culture in the Works.

It is also important to point out that Science and Technology Agency, the competing organization for the regulation of facilities handling nuclear material in Japan introduced 7 years ago a new regulatory guide for production facilities which handle the uranium of which enrichment is more than 5 percent, which says that such facility should assume the occurrence of criticality accident and implement measures to inform the approach to criticality and mitigate the consequences. However, the management of the factory did not know the fact of the introduction. Apparently, the STA did not make any guidance on the voluntary back-fitting of the new guide to the facilities concerned.

It has been found that the STA has paid little attention to the safety management of nuclear fuel facilities in Japan after the issuance of operation permit and made no efforts to consider the employment of the progresses in the administrative measures taken by the Ministry of International Trade and Industry in the regulation of nuclear power plants (NPPs). For example, there have been no resident inspectors, no periodic safety review, no system for qualification of shift supervisor except the installation of qualified engineer for nuclear fuel material handling, no guidance for performing PRA studies and preparing severe accident management measures, no back-fitting issues with operators on the new guides etc. This deficiency might be brought about by the separation of nuclear regulation between STA and MITI, one for non-power producing reactors and non-reactor nuclear facilities and one for NPPS. It is also regrettable that the Nuclear Safety Commission has not taken any action to call the STA's attention to consider back-fitting of the new guide and such improvements.

4. Conclusion

A nuclear criticality accident occurred at Nuclear Fuel Conversion Test Facility at Tokai Works of JCO on 10:35, Sept 30, 1999. Three workers received high doses of neutron and gamma radiation and a local evacuation plan was implemented for more than two days. The primary cause of the accident is clearly lack of attention to criticality safety due to inadequate education and lack of spirits of observing the Technical Specification in the Works. At the same time, the inattention to the licensee's safety management at non-reactor nuclear facilities by regulatory body after the issuance of the permission of operation should be pointed out as a part of root cause.

It is quite regrettable to find that both regulators and operators of nuclear fuel cycle facilities in Japan have been ignorant to the measures taken globally by NPP regulators and operators to maintain and improve the safety of the facilities. It is hoped that this is not the case in other countries, though Japan is apparently not entitled to comment on the behavior of those in other countries.