Fire and Explosion at Bituminization Facility in Power Reactor and Nuclear Fuel Development Corp.

【March 11th, 1997　Tokai, Ibaraki, Japan 】

Haruhiko Itagaki (National Institute of Industrial Safety)
Mitsuo Kobayashi (Graduate School of New Frontier Sciences, University of Tokyo)
Masamitsu Tamura (Graduate School of New Frontier Sciences, University of Tokyo)

At around 10:06 on March 11th, 1997, at the Japan Nuclear Cycle Development Institute Tokai Nuclear Fuel Reprocessing Plant (formerly the Power Reactor and Nuclear Fuel Development Corp.), a fire occurred during the filling of a drum can at the bituminization facilities of the plant. At the facilities, a treated solution of radioactive waste from the reprocessing plant in which the radioactivity level was comparatively low was mixed with asphalt, heated and dehydrated by an extruder. The fire was extinguished by spraying water. However, at around 20:04 after about ten hours had passed, an explosion and fire occurred in the extruder room that was left as it was after the previous fire, where the filled drum can had been left. It seems that the cause of the fire is that the cooling after the fire extinguishing was insufficient. As a result of the explosion, the building and equipment were damaged, and there was a leakage of radioactive materials. However, no actual harm resulted because the maximum level of radiation to which the public and the workers were exposed was much lower than the annual dose equivalent determined by the government.

The operation that led to the accident was not a normal operation. It wad conducted for the purpose of developing the technology for improving the volume reduction rate in order to reduce the quantity of bituminized material.

Reprocessing means a process to manufacture the uranium and plutonium fuel by processing of the spent nuclear fuel from the nuclear power plant.

1. Event

Bituminization facilities perform solidification treatment of radioactive liquid waste that arises from a reprocessing plant in which the radioactivity level is comparatively low by mixing the radioactive liquid waste with asphalt.

The extruder room and the drum can filling room, which comprises the central part of the facilities, are shown in Fig.1 as the place where the fire occurred, and the outline of the treatment process is shown in Fig.2.

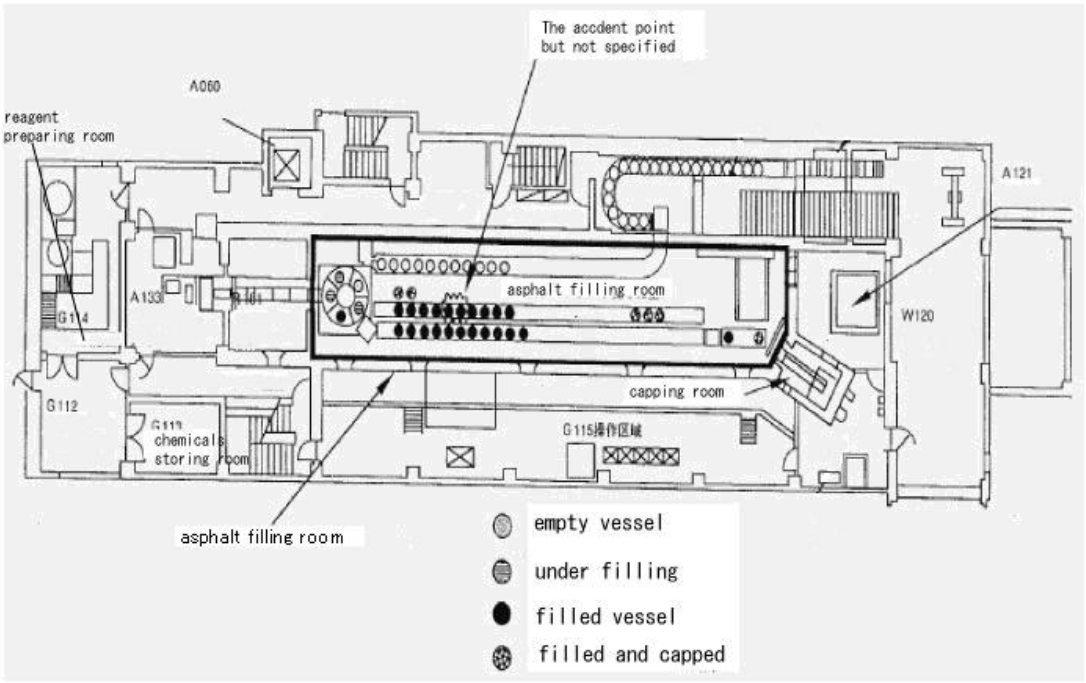

Fig. 1 sketch of the fired place

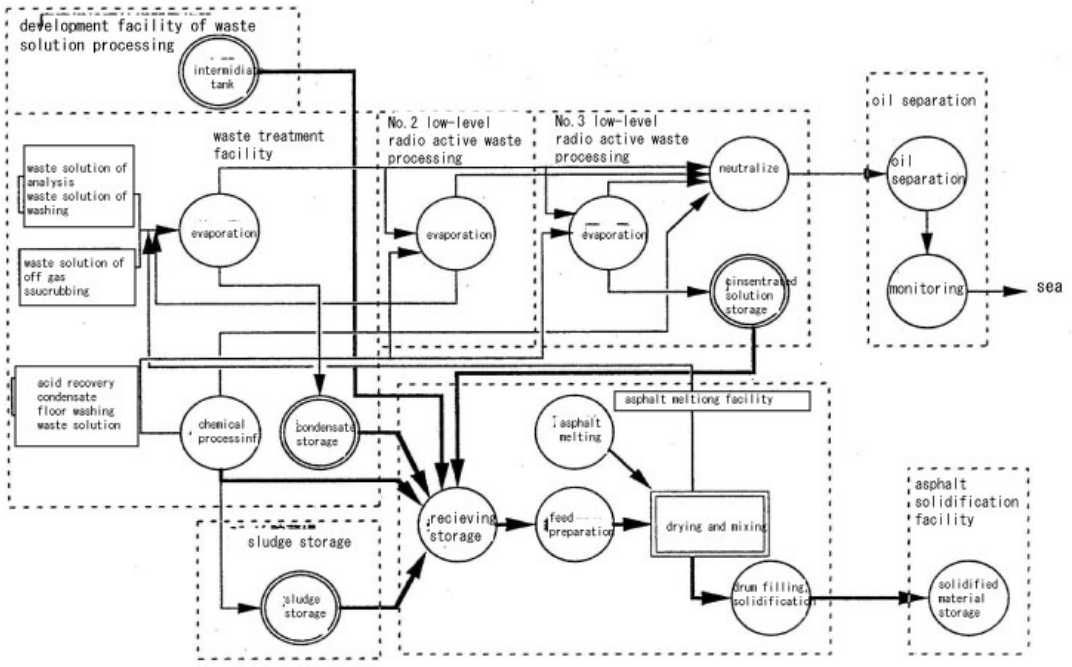

Fig. 2 outline og the process of bituminized solidification facilities

The facilities receive various kinds of radioactive waste. The waste liquids received by the facilities at the time of the accident were a phosphoric acid waste liquid from the

waste solvent processi ng te chnology develop ment facilitie s, and a low radioactivity concentrated waste liquid from th e waste disposal site. T he concentrated waste liquid was stored in a waste li quid receiving tank since the begin ning of the op eration th at led to the a ccident, and a small qu antity of ph osphoric aci d waste liquid was pou red into the storage tank during the operation.

The received waste liqu id was trans ferred to the reactor, and its pH wa s adjusted and the ins oluble tr eatment of cesium, st rontium and iodi ne in the w aste liquid was executed. The treated waste liquid was fed to the extruder via the supply drum. In the extruder, th e waste liquid p assed through tw o treatment p rocesses: d ehydration and mixing with asphalt. The outline of the extruder is shown in Fig.3.

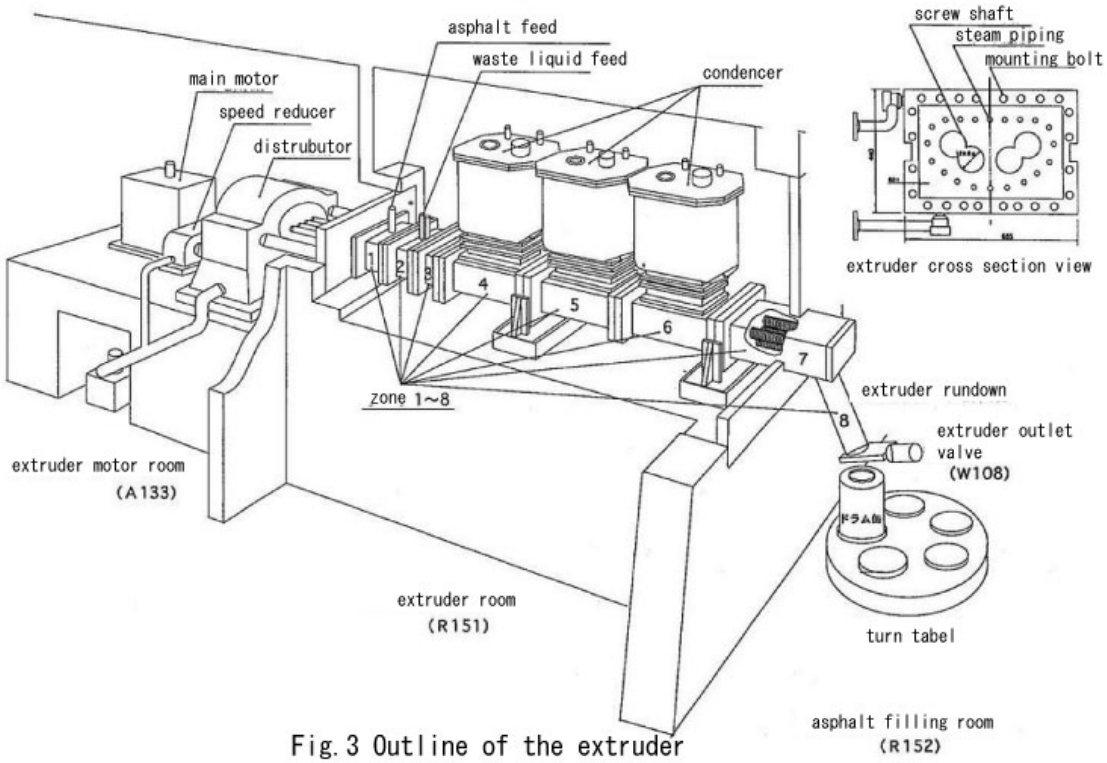

Fig. 3 Outline of the extruder

In the extruder, raw materials asphalt and the waste liquid were fed and extruded in the downstream direction by the rotation of the screw shaft, and at the same ti me the materials wer e h eated by shea ring str ess, causing the moisture in the feed to evaporate. The condensers, which were mounted at the top of the extruder, condensed and rem oved the st eam. In th e latt er p art of t he extruder, the mixing of th e asp halt with nitrate and other materials in the waste liquid was carried out, the asphalt and nitrate/nitrite mixture was discharged in a molten state fr om th e outlet at the final stage, and the mixture was filled i nto the dr um cans on t he turntable. After natural

cooling, the filled drum cans were capped in the filling room , and they were stored in the storage cell of the bituminized material storage facilities.

In the schedule from Fe bruary 7th to April 25th, s ome t est runs were planned. On March 11th, a t est of the improvement of the volume reduction rate was executed. In the test, the fe ed rate of th e wa ste liquid to the ext ruder was d ecreased and t he evaporation rate of the moisture in the extruder was increased. Thus the volume of the generated bituminized material was d ecreased for th e sa me fe ed rat e of th e wa ste liquid.

The test was performed by lowering the waste liquid feed ra te first from 200l/hr to 180l/hr, and then to 160l/hr . The supply rate of asphalt was lowered in proportion to the waste li quid feed ra te. This was the first t est in which the waste li quid feed ra te was lowered to 160l/hr for low radiation concentration waste liquid including phosphoric acid waste liquid.

At around 10:06 on March 1 1th, during the test run, a fire oc curred at the bituminization facilities. A pillar of fire about 2m in height rose from a drum can filled with the sol idified material in the f illing ro om, and immediately after t hat, pillars of flames rose from many nearby drum cans. Upon receiving the direction to extinguish the fire using water spray from a member of the staff of the Power Reactor and Nuclear Fuel De velopment Cor p., at around 10:12, the subcontra ctor workers at the si te sprayed water int o t he filling room for about one minute. Since the fire was extinguished at around 10:13, the water spray was stopped.

As a result of this fire, the radioactiv e material that h ad been sealed in the bituminized material spread inside this bu ilding and into t he adjoining buildings, a nd a rise in the radiation level was confirmed by the alarm. However, the abnormally high level of radiation was not observed outside the building by environmental monitori ng at that time.

The ventila tion system of the facilities stopped working after the fire, and the ventilation of the facilities became impossible.

At around 20:04, about ten hours after th e f ire, an explosion oc curred at the facilities. As a result of this explosion, th e radioactive material was discharged to the environment from openings such as windows of the building.

The order t o evacuate the facilities was issued about thi rty minutes after the explosion in order to av oid exposure of the wo rkers to radiation, and all field workers were evacuated. The confirmation of the l evel of radiation exposure was conducted on the 129 workers who were in the building wher e the accident occurred, near the fire, or at the explosion. A very low level of ^{134}Cs and ^{137}Cs were detected in 37 workers, but all

of the detected values were under the national safety standard.

Finally, an off-limit zone and a restricted zone were established in the building in order to regulate the entrance to the radioactive contamination zone, and outside the building, the areas around the bituminization facilities were temporarily designated as controlled areas.

2. Course

On March 6th, the waste liquid feed rate to the extruder was lowered to 160l/hr.

At around 10:06 on March 11th, a worker found a light from the filling room, and he confirmed through the peep-hole that a pillar of fire rose from one filled drum can. After less than a minute, the worker observed that all of the drum cans began to burn. The automatic fire alarm rang at 10:10.

At around 10:12, the worker started to extinguish the fire by spraying water. He stopped spraying water at around 10:13, because he could not see any fire through the peep-hole.

At around 10:13, dust monitors started ringing. In addition, at around 10:23 the ventilator stopped as the outlet damper remained closed.

At around 20:04, the explosion occurred.

3. Cause

The main course of the fire is as follows. As a result of the difference of the properties of the waste liquid and the lowering of the feed rates of asphalt and waste liquid, the temperature of the mixture of the asphalt and the nitrate/nitrite at the outlet of the extruder rose. During the natural air-cooling stage of the process, a slow exothermic reaction was generated, which caused heat to accumulate in the drum can, and then a runaway reaction, in which the exothermic reaction between nitrate/nitrite and asphalt progressed rapidly, was induced. By the exothermic reaction, the local heat accumulation at the center of the drum was accelerated, and the temperature became high, causing the asphalt to decompose. Finally a combustion reaction between air and the asphalt decomposition material was generated, and the fire occurred.

The bituminization treatment was carried out through the following method. First, asphalt, which is a mixture of combustible organic substances including various hydrocarbons, and the radioactive waste liquid to be treated, which contains oxidizing materials such as nitrate and nitrite, were charged together to the extruder. In the extruder, the two charged materials were dehydrated and mixed at a high temperature. Then they were filled into drum cans and were solidified by natural cooling. However,

as the oxidizers and the combustible materials were left together at a high temperature, there was a high possibility of causing an exothermic reaction. In addition, as both the asphalt and the radioactive waste liquid are mixtures of many kinds of chemical substances, control of the thermo-chemical reactions is very difficult.

Therefore, while the bituminization processing system is generally considered an appropriate method from the viewpoint of preventing the leakage of radioactivity, the potential danger is large from the viewpoint of chemical safety, so that sufficient knowledge regarding chemical characteristics of the bituminization processing system is required for ensuring the safety of the treatment. A basic factor leading to the the accident might be the insufficient consideration of the chemical safety.

The cause of the explosion seemed to be the insufficiency of the extinguishment of the first fire. Although as a general rule, water spraying should be continued for over eight minutes, the spraying was stopped after only one minute because the fire could no longer be seen. Therefore, cooling of the inside of the drum was insufficient, and the flammable materials were formed from the bituminized material. The first fire caused the cell venting system to stop, so the flammable materials accumulated in the filling room and leaked to the adjoining room. A combustible gas-air mixture was formed by mixing with the air from the ventilation system of the facilities. The combustible gas-air mixture was ignited by the heat caused by an exothermic reaction of the bituminized material in the drum can on the turntable, and flames reached the extruder room via the duct causing the explosion there.

4. Process of cause elucidation

It appeared certain that the drum, in which the first inflammation occurred by heat generation was filled with bituminized material of a certain batch during the test operation period from the conditions of the combustion and the estimated combustion occurrence time. In addition, it was estimated that the waste liquid of the batch or the operating conditions related to the treatment of the batch affected to the accident. From the properties of the waste liquid, it was estimated that the reactivity with the asphalt was higher than that of the conventional waste liquid; this was also supposed to be one of the causes of the accident. However, the effect of the property was denied as a result of the supporting experiment. Beside the high temperature of the extruder outlet was regarded as another cause of the accident.

The temperature rise was estimated with a high probability from the observations of the worker, the indications of the thermometer, and so on. Moreover, an even larger heat generation was predicted to have occurred as a result of changing the feed rate

and the difference in the property of the waste liquid, and it was proven by the supporting experiment.

5. Immediate action

Spraying of water at the first fire was the only immediate action that was executed during the whole chain of events. Measures such as the medical examination of radiation exposure and evacuation of the workers from the building were taken, because it was an accident related to nuclear energy.

6. Countermeasure

1) Innovations of the management system of the Power Reactor and Nuclear Fuel Development Corp: In addition to the technical problems of the bituminized material, there were some problems in the management system of the Power Reactor and Nuclear Fuel Development Corp. According to the research report by Ibaraki Prefecture, "About problems of the safety management system and direction of the improvements", there were many points concerning of the constitution of the Power Reactor and Nuclear Fuel Development Corp. itself from the viewpoints of the following: prevention of the occurrence of the accident, prevention of its escalation, and information transfer transmission at the time of the accident. Here, some points are quoted from the problems concerning the prevention of the accident:

a. There was insufficient sharing of the technical information because the organization of the Power Reactor and Nuclear Fuel Development Corp. had become too rigid.

b. In the operational control aspect, as the Environment Facility Department that was in charge of it was isolated from the site, the department paid little attention to the problems at the site. The operational control of the solidification disposing facilities was left to the subcontractor only, as mentioned above, and the Power Reactor and Nuclear Fuel Development Corp. did not make any attempt to grasp the operating state.

c. Regarding the security management system, concern for education and training of the subcontractor's employees was insufficient, the approval methods in making changes to the operation plan from the conventional procedure were indefinite, the evaluations of the safety at changes of the operation plan were not sufficient.

2) The bituminization method cannot be regarded as a chemically safety method as described in the "cause" section. It is necessary to take sufficient countermeasures for the facilities and operation acquiring accurate knowledge of chemical safety.

7. Knowledge

1) For ensuring the nuclear safety , it is necessary to consider safety from the viewpoint of not only the leakage of radioactivity, which is the main elemental technology, but also chemical safety of all other elemental technologies.

If an explosion and fire occurs as a result of problems related to chemical substances and so on, not only damage from the explosion and fire but also damage from the leakage of radioactivity is caused, and the accident could become a major disaster.

2) Various chemical substances are used in nuclear power facilities. The understanding of the potential risk of the chemical substances is a basis of chemical safety, and the appropriate handling must be done based on this understanding.

3) Considering the size of the drum can, only the surface will be cooled by about one minute of cooling from the surface, and the cooling of the inside is impossible. It takes time to cool to the inside. Also, heat accumulation cannot be avoided if there is some heat generation in a container with a size above the critical threshold. This fact can be understood if it is considered that heat generation is proportional to the volume of the container, which is proportional to the "cube of the length of a side", and the cooling is proportional to the surface area, which is proportional to the "square of the length of a side". This fact is also applied to the accident occurred in Mie Prefecture, where a fire and explosion occurred in a large gas tank of refuse-derived fuel (RDF) that was used for producing electric power by making solid fuel from the garbage.

8. Influence of failure

1) As for the physical damage, the bituminization facility buildings were severely damaged.
2) Although 37 persons where exposed to radioactive material, the level of exposure was low in all cases, and there was no actual harm.
3) The biggest damage must be the loss of social confidence in the safety of nuclear energy.
4) The bituminization facilities were stopped.

9. On the side

The extruder is a rotating machine that is generally used in the pelletizing process of synthetic resin such as polyolefin. However it is a rather special machine, so it must

be used with care. Due to its characteristics, a change of output is performed by changing the operation time not by changing the feed rate to the machine. When the feed rate is lowered, it is usual to decrease the rotation frequency of the screw after the tests are repeated, because flow conditions in the extruder change when the flow rate changes.

Moreover, it may have been a bad choice from the viewpoint of the chemical safety to have used the extruder for mixing nitrate/nitrate and asphalt because its control for safety is very difficult.

In the twenty-first century, large accidents appear to occur frequently. The issues raised in 1) of the countermeasure section should be generally true not only for the Power Reactor and Nuclear Fuel Development Corp. but also for the entire industrial world in our country.

References

- Nuclear Safety Countermeasure Section, Living Environment Division, Ibaraki Prefecture Government, “Survey result on fire and explosion accident at bituminization body disposing facility - Safety management system and direction of the improvement” (1998)
- Power Reactor and Nuclear Fuel Development Corp. "Examination of the cause of the fire and explosion" (1997)
- Fire and explosion accident investigation committee on bituminized material disposing facility at Tokai Nuclear Fuel Reprocessing Plant, “Fire and explosion accident in the bituminization facility at Tokai Nuclear Fuel Processing Plant in Power Reactor and Nuclear Fuel Development Corp” (1997)
- Power Reactor and Nuclear Fuel Development Corp. “The outline of fire and explosion accident in the bituminization facility” (1997)
- Power Reactor and Nuclear Fuel Development Corp., “Fire and explosion accident in the bituminization facility at Tokai Nuclear Fuel Reprocessing Plant” Kindai Shobo, extra ed. July 2000, 129-133. (2000)