Certification Test for Safety of New Fuel Transportation Package

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1. PROGRAM OUTLINE

According to the recent development of nuclear energy in Japan, the transportation of various radioactive materials will be ever increasing.
For the purpose of transportation safety, various laws and regulations were settled by the Prime Minister's Office and the Ministry of Transport based on the IAEA regulations. These laws and regulations are applied to confirm the safety of each package design and transportation operation.
Safety certification of various radioactive materials in case of supposed traffic accidents are carried out by experimental or analytical method according to the present regulations. And the special test conditions for drop, fire, immersion are applied to confirm the sealing, shielding and criticality of the transportation objects.
In addition to these safety certifications, a lot of experimental studies are conducted against supposed traffic accidents to confirm the safety margin of present transportation system.
The objective of this certification test is to prove the safety of new fuel transportation package against a fire of actual size caused by traffic accidents.
This project is sponsored by the Science and Technology Agency of Japan, and was started as a 4-year program. Basic plan of each fiscal year and the results obtained are as follows ;

FY1989 Preliminary survey and investigation of traffic accidents especially fire were carried out. Supposed accident scenario was examined and the plan of entire program was proposed.

FY1990 Preliminary pool-firing tests for about 10 minutes were conducted to study the basic characteristics of the fire of actual size. The amount of kerosene burnt is $2k\ell$. Temperature of 20 points in the flame and heat radiation of 3 points near the burn pit were measured. These data proved to be useful for planning the final tests.
Also the heating tests of mimic fuel rod elements and fuel assemblies of about 1m length in an electric furnace were carried out to examine the behavior (deformation, oxidization) of the specimen under high temperature environment.

FY1991 Mimic fuel assembly and real container of both the PWR and BWR type were manufactured for final tests. The tests were conducted by pool-firing of kerosene for 30 minutes with 11-ton type truck carring container and mimic fuel assembly on it.

FY1992 It is planned to summarize and evaluate the result of the above studies and experiments.

2. TEST FACILITIES AND MEASURING EQUIPMENTS

2.1 Burn pit

The burn pit was made of steel plate of 4.5mm thickness and steel channel bars for stiffener. The size of the burnpit is 5m in width, 11.5m in length, 0.5m in depth. The burn pit was settled in a hole of 0.5m depth dug in the ground and the outside of it was filled with sand.

2.2 Thermocouple

Alumel-chromel type thermocouple sheathed with Inconel tube was used. The specification of thermocouple is in conformity with JIS-C1602 and the outside diameter is 1.6mm.

2.3 Caloriemeter

HYCAL C-1301-A made by the Hycal Research Inc. was used for measuring heat flux near the burn pit. It was covered with ceramic wool (aluminium oxide) to prevent heat except for the sensor.

2.4 Wind direction and velocity detector

Wind velocity was measured by an equipement of electric generator principle. Wind direction was detected by its vane. As it is desired to carry out the experiment under calm weather, wind velocity and direction were measured for a week before the experiment to predict weather condition.

3. OPEN FIRE TEST OF BWR-TYPE SPECIMEN

3.1 BWR-type specimen

Figure 1 shows arrangement of BWR-type specimen. The container is real "RAJ" type containing one mimic fuel bundle and one dummy representing heat capacity of fuel bundle. Mimic fuel bundle is of 8 × 8 type and contains ferrite pellet instead of UO_2. The materials composing the mimic fuel bundle are the same as real one except pellet. Dummy for heat capacity is made of 64 iron pipes with similar size as real one.

3.2 Truck and other support materials

Figure 2 shows set up of truck and specimen in the burn pit. The truck is 11-ton type heavy duty truck and was supported by steel racks at its chassis frame.
Considering the loading arrangement in real transportation, a support deck was manufactured to raise the specimen at the level of top container on the loading platform that is supposed to be the most severe position in case of fire.

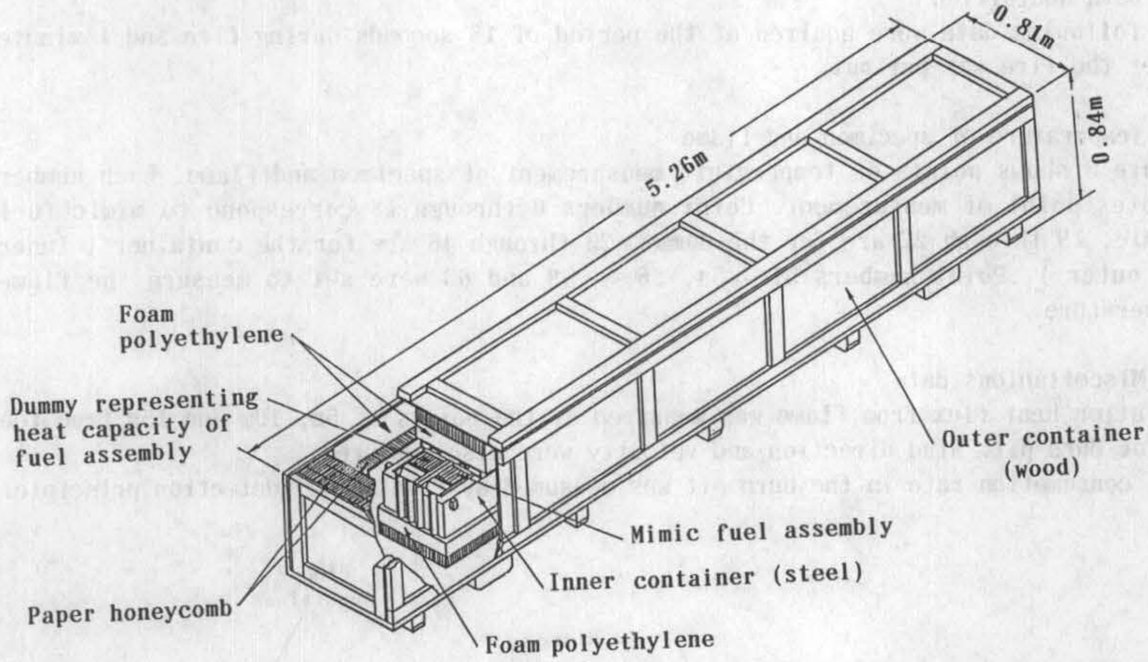

Figure 1 Arrangement of BWR-type specimen

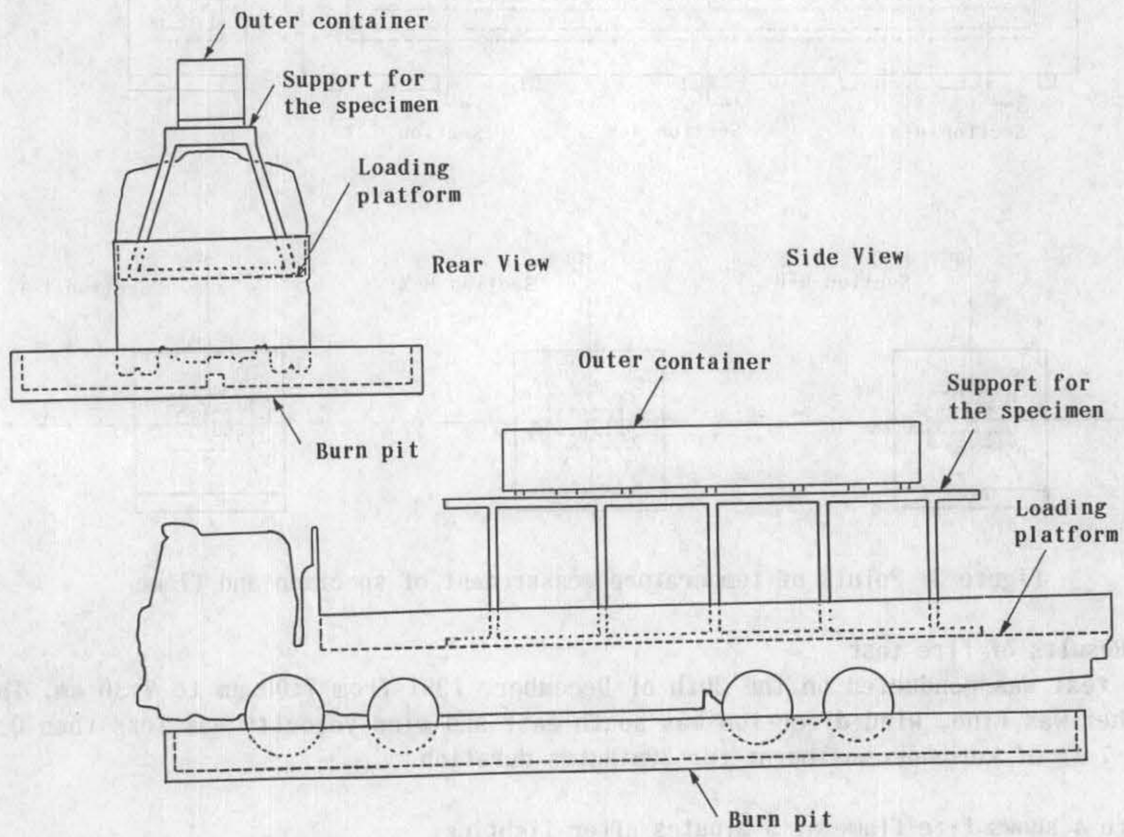

Figure 2 Set up of truck and specimen in the burn pit (BWR-type)

3.3 Data aquisition

The following data were aquired at the period of 15 seconds during fire and 1 minute after the fire was put out.

(1) Temperature of specimen and flame

Figure 3 shows points of temperature measurement of specimen and flame. Each number denotes point of measurement. Point numbers 0 through 18 correspond to mimic fuel bundle, 19 through 22 are for the dummy, 23 through 46 are for the container (inner and outer). Point numbers 51$\sim$ 54, 56 $\sim$ 59 and 63 were set to measure the flame temperature.

(2) Miscellanious data

Radiation heat flux from flame was measured at the points of 5m, 10m and 15m from the end of burn pit. Wind direction and velocity were also measured.
Fuel consumption rate in the burn pit was measured by float level detection principle.

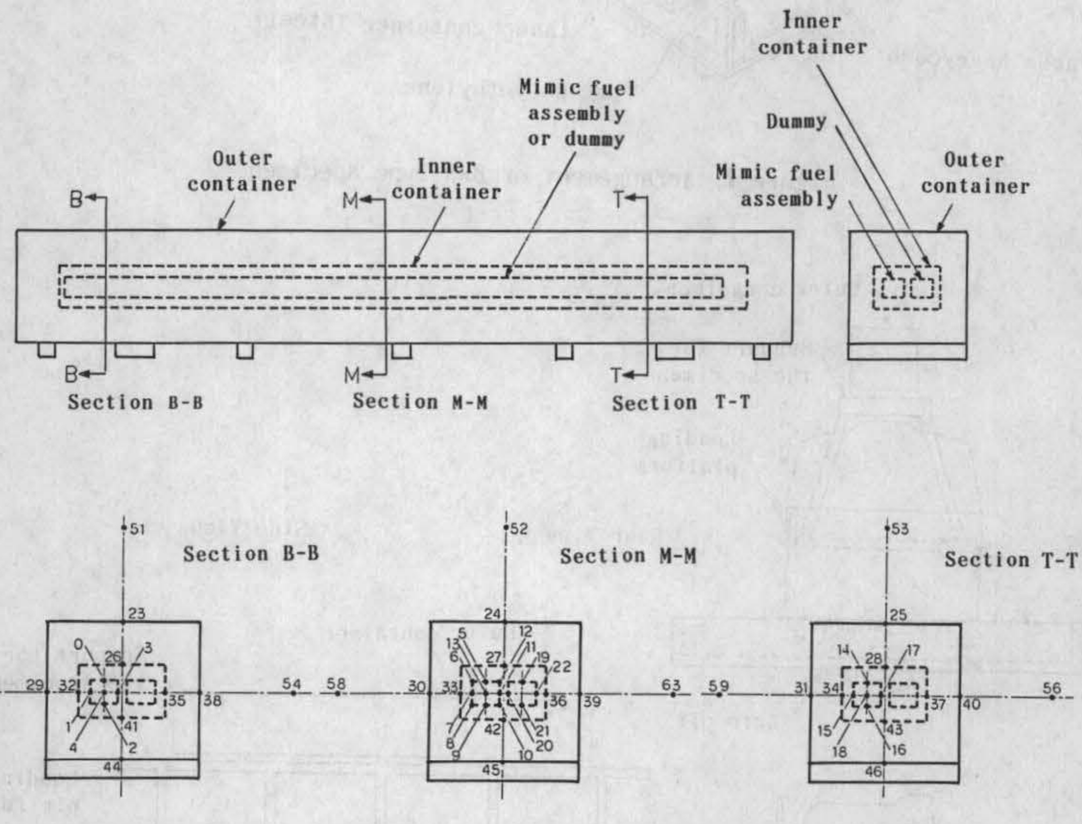

Figure 3 Points of temperature measurement of specimen and flame

3.4 Results of fire test

Fire test was conducted on the 20th of December, 1991 from 7:00 am to 7:30 am. The weather was fine, wind direction was south east and wind velocity was less than 0.2 m/s. 7 $k\ell$ of kerosene was burnt for 30minutes duration.

Figure 4 shows fire flame at 5 minutes after lighting.

Figure 4 Fire flame 5 minutes after lighting

(1) The wooden outer container was burnt out 15 to 30 minutes after lighting.

(2) The loading platform of truck made of wood was completely burnt out. The chassis frame of truck was bent due to heat and weight of the specimen.

(3) Inner container made of steel showed a little deformation. But the bolts connecting the container and the lid were not broken.

(4) The color of fuel rod surface was dark grey or black and was supposed to be the color of oxide of Zircaloy. Also coaltar-like material adhered to the rod surface.

(5) Any deformation of the fuel rod such as puncture, crack, bend or swell was not observed.

Figure 5 shows rods of mimic fuel bundle after test.

Figure 5 Rods of BWR-type mimic fuel bundle after test

3.5 Observed temperature

Figure 6 shows temperature change of mimic fuel bundle, inner container and flame during the fire test.

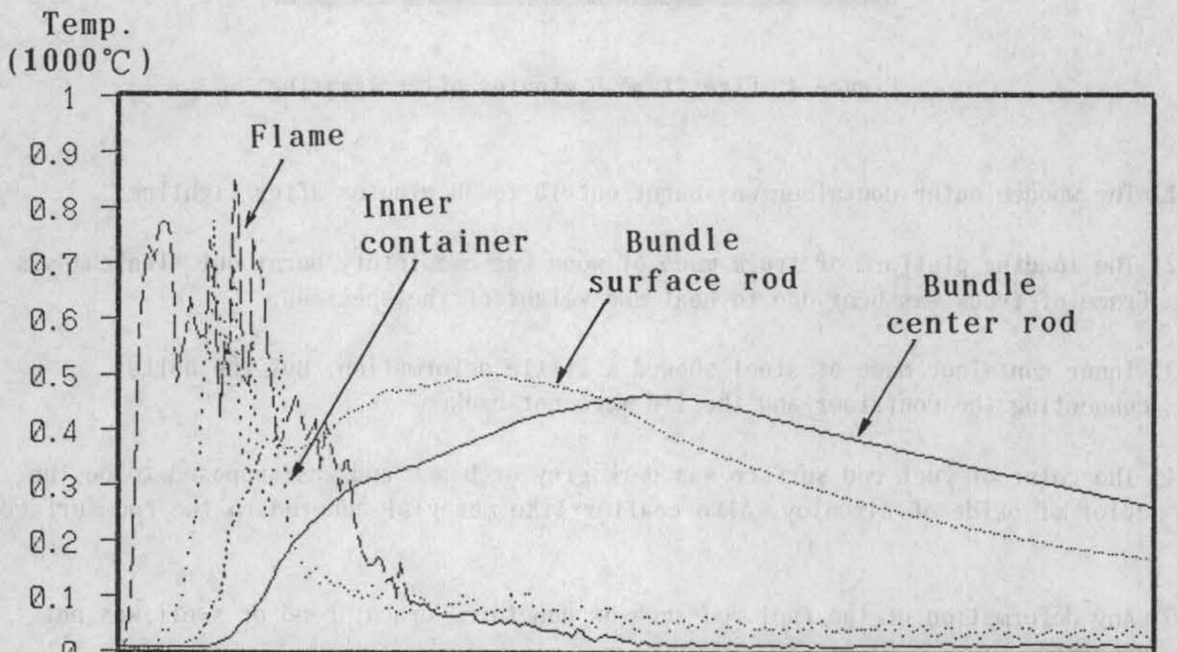

Figure 6 Temperature change of specimen and flame during fire test

The temperature at the inner container surface began to rise 15 minutes after lighting, because the wooden outer container was burnt out. The rise of rod temperature shows another time lag due to delay of heat transfer. The surface rod rises first, then the center rod of the bundle.
The maximum observed temperature of mimic fuel bundle was 499 ℃ at the time of 78 minutes after lighting. This condition proved to be less serious compared to the condition of heating test where the rod element was completely sound conducted in FY1990 using electric furnace.

4. OPEN FIRE TEST OF PWR-TYPE SPECIMEN

4.1 PWR-type specimen

Figure 7 shows arrangement of PWR-type specimen. The container is real "MFC-1" type containing one mimic fuel assembly and one dummy representing heat capacity of fuel assembly.
Mimic fuel assembly is of 17×17 type and contains ferrite pellet instead of UO_2. The materials composing the mimic fuel assembly are the same as real one except pellet.
A dummy for heat capacity is made of 289 iron pipes with similar size as real one.

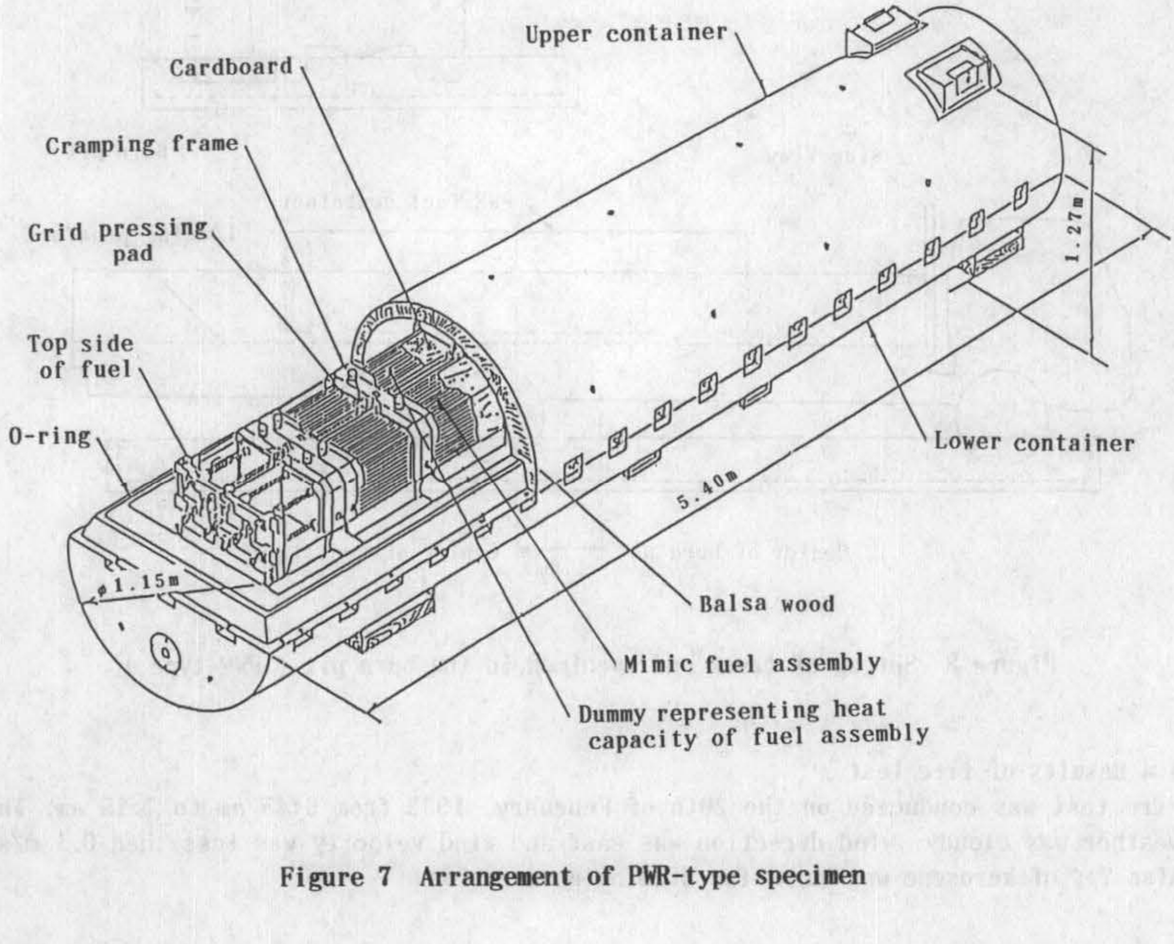

Figure 7 Arrangement of PWR-type specimen

4.2 Truck and other support materials

Figure 8 shows set up of truck and specimen in the burn pit. The truck is 11-ton type heavy duty truck and was supported by steel racks at its chassis frame similarly to the case of BWR.

The specimen was set just on the loading platform as is set in real transportation. The protecter made of thin steel plate covering loading platform was not used, because it is desired to be able to observe the situation of the specimen during test. This is considered to give more severe condition.

4.3 Data aquisition

Aquired data and period of measurement are the same as the case of BWR test.

Measuring points of temperature of specimen and flame are just the same as the case of BWR test in topology.

Miscellanious data other than temperature were measured similarly to the case of BWR test.

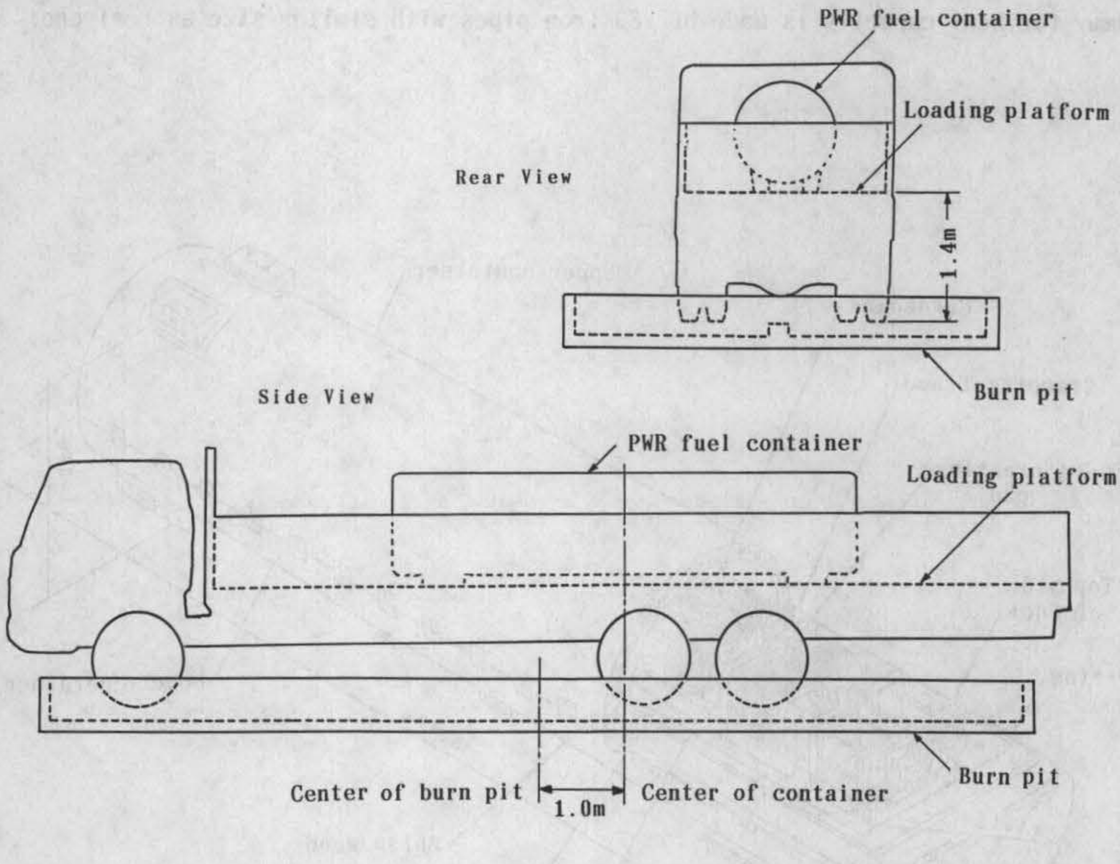

Figure 8 Set up of truck and specimen in the burn pit (PWR-type)

4.4 Results of fire test

Fire test was conducted on the 20th of February, 1992 from 6:45 am to 7:15 am. The weather was cloudy, wind direction was east and wind velocity was less than 0.1 m/s. Also 7$k\ell$ of kerosene was burnt for 30 minutes duration.

(1) The fuse plugs on the outer shell of the container were fused to release gas pressure generated by carbonization of balsa wood, and luminous flames due to combustion of this gas were observed.

(2) Damage of loading platform and chassis frame of truck was similar to that of BWR fire test.

(3) Outer shell of the container showed a little bend and swell. But the bolts connecting the upper and lower container were not broken.

(4) Inner shell of the container swelled to inside due to gas pressure generated from balsa wood.

(5) The rubber of shock-mount (suspension mechanism) was damaged due to heat and the mimic fuel assembly and the dummy fell off in the container.

(6) Coaltar-like material adhered to inside of the container, but cardboard covering the assembly remained (not burnt).

(7) The fuel rod surface kept gloss of original material Zircaloy-4. Figure 9 shows rods of mimic fuel assembly after test.

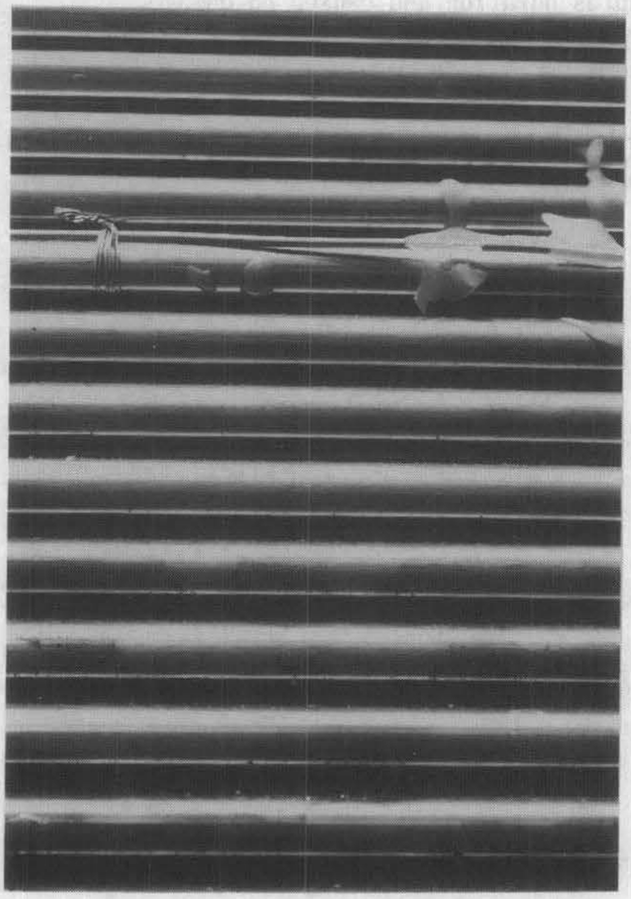

Figure 9 Rods of PWR-type mimic fuel assembly after test

(8) Any deformation of the fuel rod such as puncture, crack, bend or swell was not observed.

4.5 Observed temperature

The trend of temperature change in various part of the specimen was similar to that of BWR case.

The maximum observed temperature of mimic fuel assembly was 302 ℃ (surface rod) at the time of 61 minutes after lighting. This condition proved to be less severe compared to the condition of heating test where the rod element was completely sound conducted in FY1990 using electric furnace.

5. SUMMARY AND CONCLUSION

After the fire test, the fuel assemblies were covered with coal-tar like material vaporized from anti-shock material used in the container.

Surface color of BWR-type fuel assembly was dark grey that is supposed to be the color of oxide of Zircaloy. As for PWR-type fuel assembly, the condition encountered during fire test caused no change to the outlook of the rod element.

Both the BWR and PWR type fuel rod elements showed no deformation and were completely sound.

Therefore it may be concluded that the container protected the mimic fuel assemblies against fire of 30 minutes duration and caused no damage.

This report is the result of the above experiments and examinations, and we appreciate the cooperation of those who are concerned.