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DELOPMENT OF NUCLEAR TECHNOLOGY IN JAPAN AND THE ROLE OF RESEARCH REACTORS

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ABSTRACT

DEVELOPMENT OF NUCLEAR TECHNOLOGY IN JAPAN AND THE ROLE OF RESEARCH REACTORS. The research and development activities made in Japan Atomic Energy Research Institute were reviewed with topics in the nuclear society of Japan and connected to the nuclear power development. JAERI has constructed six research reactors and three critical assemblies. They imported reactors first from USA, but from JRR-3, domestic nuclear group designed and constructed reactors, consulting with foreign companies. The research in JAERI has mainly connected to the national energy policy of using nuclear power as the main energy source to replace oil. Their efforts for nuclear safety has not yet been finished but still continued to contribute to the safe and steady supply of energy.

HISTORY OF RESEARCH REACTOR DEVELOPMENT IN JAPAN

In March, 1954, the parliament of Japan has first approved to finance the research to prepare for the constraction of nuclear reactors. Following the decision, Ministry of International Trade and Industry and the Prime Minister's Office have started to organize commitees to discuss how to develop nuclear reactor in Japan. The first overseas research mission was sent in December, 1954. In 1955, Japan-U.S. Atomic Energy Research Treaty was concluded, which implied that Japan could receive enriched uranium from USA. Having this new treaty to give ways to construct a reactor in Japan, Japan Atomic Energy Research Institute was established by the end of 1955 as non-profit affiliate foundation of government supported by all industrial sectors. This foundation had selected the site in Tokaimura and chosen a water boiler type reactor as a first reactor in Japan. In 1956, Atomic Energy Comission of Japan has announced that Japan will construct a water boiler type reactor first and oder CP-5 type reactor to USA for the second research reactor. JAERI became a government authorized institution in June, 1956. The construction of JRR-1 was started in August, 1956 and completed in August 1957. On 26 of August, 1957, the sulfuric uranyl solution (fuel) was started to fill the fuel vessel and at 5:23 am. on 27 Aug., the reactor reached to criticality. The operation and utilization of JRR-1 was controled by a steering committee organized by academic and industrial leaders.

At the same time, the bidding of JRR-2 was prepared for among USA companies. The main purpose of JRR-1 was for training operators and reactor experiments, while the JRR-2 was assumed to be the main research reactor in JAERI to be used for research activities. Therefore, the power level and the neutron flux density were discussed thoroughly, and the concluded that they would import CP-5 type reactor at relatively higher power level. JAERI decided to choose the CP-5 type reactor at the nominal power of 10 MW. The decision was rather risky, since the power of 10 MW was not yet achieved even in USA by CP-5 but only shown by calculation Moreover, Japan could not use more than 20% enriched uranium by that time. The negotiation with the contractor was made mainly in the view point of guarantee of the fuel supply and four U.S. contractors were competing each other for the bid. Finally, American Machine Foundry, Co.,Ltd, got the contract. However, the construction of JRR-2 faced several problems, ie; modification of auxiliary systems due to a change of aseismic design, delay of civil construction, and the leakage of the heat exchanger. Among them the leakage of the heat exchanger was found in Japan by helium leakage test and it took about one to repair it since the reparation was made in USA. Fuel fabrication was also troublesome. After the final check of the fuel cladding in the presence of JAERI researchers in USA, five fuel plates were found to be some cladding defects made in the fabrication processes. JAERI had to accept the fuel plates since they could not postpone the first operation of JRR-2 any further. JRR-2 reached to criticality in October 1960. In 1962, 90% enriched uranium fuel was allowed to load JRR-2 and getting the new fuel, JRR-2 has reached to 10 MW for sixteen hours continuous operation in October, 1962.

On the other hand, JRR-3 was designed to be the first Japanese originally designed reactor. The first working group was set in Japan society for the Promotion of Science (JSPS) in 1954 and the job was succeeded to JAERI. The conseptual design was completed in 1956 and the contract with five manufacturing group was completed in March, 1958. This reactor was using natural uranium for fuel and heavy water for moderator. The reactor attained the criticality in September, 1962 and reached to the designed power of 10 MW in March, 1964. JRR-3 is now under the process of upgrading to replace JRR-2 to give higher neutron flux for neutron beam experiment and better utilities.

In 1958, nuclear ship development program was started. The first mission to visit overseas research institutes concluded that the most important part of designing was the effective shielding without increasing too much weight and volume, though the technology for this evaluation was not open to any other countries. Following this report, the government of Japan has decided to develop a new reactor to study big scale mockup shields in JAERI. This, JRR-4 was designed following the requirements of shielding experiment and build by domestic contractors. JRR-4 adopted 90% enriched uranium for fuel and light water for moderator and coolant.

Japan Material Test Reactor (JMTR) was first proposed to meet with the growing demand of irradiation in the future in 1960. A lot of argument was arose about whether to install this reactor in JAERI or not, because this reactor was designed to do irradiation service to industries and other third parties. Since the argument took long time to get consensus, the specification of the reactor has just been finished in 1963. The construction was started in November, 1964. JMTR reached to criticality in March 1968 and in January 1970 it attained the nominal power of 50 Mw.

In order to follow the SPERT project of studying reactivity initiated accident in USA, the construction of Nuclear Safety Research Reactor (NSRR) was proposed in 1969. JAERI signed the contract with G.A. Technology in 1972 and the reactor reached to criticality in June 1975.

Japan Power Demonstrantion Reactor (JPDR) was the first nuclear power plant for generating electricity in Japan. JAERI had decided to construct light water reactor and the selection of whether to choose PWR or BWR was discussed. Finally, in March 1959, JAERI decided to import BWR from GE. The plant test of non- nuclear systems was started in 1962 and after the 100 hrs continuous operation at the designed power level of 50 Mwt, the reactor was handed over to Japan in Dec., 1963. The reactor gave a lot of information for the operation and maintenance of power reactor. Now the reactor is planned to be decomissioned to give useful information for the decomissioning of commercial power plant. JAERI has three critical assemblies. The first one was so called Semi Homogeneous Experiment facility (SHE). This critical assembly was designed to do experiment for homogeneous core, but it turned to be used for the study of graphite moderate core experiment for high temperatur reactor these days. Second one is Tank-type Critical Assembly (TCA). This critical assembly was designed to give data for JPDR. The third one is Fast Critical Assembly (FAC) and this is designed to do experiment for fast breeder reactor.

RESEARCH ACTIVITIES FOR NUCLEAR POWER DEVELOPMENT

Introduction of gas cooled reactor.

Japan Atomic Power Company was established in November 1957 and they decided to import Calder Hall gas cooled from UK. JAERI studied the neutronic cell calculation for it and gave safety assessment. Thermodynamic calculation was also made in JAERI and Co2 loop was installed to evaluate the heat transfer capacity of fuel element at a temperature of 400°C and a pressure of 10 atm. Irradiation of magnox alloys and fuel was made in JRR-2. The first commercial nuclear power plant reached to criticality in 1965.

Research on Light Water Reactor

JAERI has studied the criticality through the experiment. Nuclear data was accumulated in reactor physics group. The Tank-type Critical Assembly (TCA) was used to evaluate the cell constant for light water moderate reactors and the result was compared to those obtained in JPDR operation. The reactor kinetics and control were studied in JRR-1,2, and 3. The results were transfered for oxidefuel and plutonium fuel was done for the evaluation of fuel temperature and high burn-up. In pile loop was installed in JRR-2 and uranium capsule and other fuel materials such as zirconium alloys, stainless steel, aluminum alloys etc. were irradiated in JRR-2 and tested to evaluate their physical property chage through irradiation.

Through the operation of JPDR, unexpected crackings were found at reactor vessel liner and pipings. as they were observed later in other commercial light water reactors in Japan. First in 1966, so many cracks were found at the liner of the lid of the pressure vessel. The content of ferrite and the ratio of Cr/Ni were analysed at the cracking area and it was concluded that the both values were lower than nominal values and the cracks was observed along the hand welding line. JAERI has removed the old welded part and welded again in a newly developed way. Since then, no cracking was reported in the liner of the pressure vessel. In 1972, at the spray piping near the nozzle end, water leakage was found since the crack had pressed through the pipe. This kind of stress corrosion cracking (SCC) was later widly as a typical trouble found at the regular maintenance in BWR in Japan. JAERI removed and assembled the piping again by carefully welding the parts so that the least stress would be residued. These two unexpected phenomena contributed to the research and the development for the material and structural analysis of stress corrosion cracking in stainless steel piping systems.

As for the administration of lisensing and controling, the experience of JPDR operation was very useful for the development of regulation and lisensing system in Japan, since this is the first experience for the government of Japan to give lisense to generate electricity by nuclear energy.

JMTR has been designed for irradiation and inpile loop test for nuclear fuel and material development. In the inpile loop of JMTR, LWR fuel was irradiated to evaluate the effect of burnup and temperature in the pelet to release the fission products from degraded fuel. In the irradiation position, fuel capsule and other reactor materials were irradiated to evaluate the effect.

The simulation experiment of reactivity accident was made by Nuclear Safety Research Reactor (NSRR) to give pulse reactivity of up to 4.7 dollars. The experiment was analysed and give data base for the analysis of light water reactor.

The reactor safety was mainly studied by the development of simulation code first, but the poor results of "Semiscale Blowdown and ECCS Test Program" in Loss of Fluid Test (LOFT) project in USA, caused the need of larger scale experiments to show the safety performance in LWR. JAERI has built a mockup facilities to test the functioning of ECCS and simulation of LOCA accident, especially for the reflooding of core. The experimental data was applied to computer simulation to evaluate the safety analysis of LWRs.

Advanced Thermal Reactor (ATR)

Advanced Thermal Reactor (ATR) was designed and operated by Power Reactor and Nuclear Fuel Development Corporation (PNC). The core cell constants was evaluated through the experiment of critical assembly in JAERI and the fuel was also irradiated in JMTR to do the post irradiation test.

Fast Breeder Reactor

Fast Breeder Reactor (FBR) was developed by PNC. JAERI had constructed the Fast Critical Assembly (FCA) and evaluated the nuclear data to design the core configuration. JAERI also made a lot of basic research for sodium engineering to make up sodium loops to develop the sodium technology to handle the coolant for FBR safely.

High Temperature Reactor

High Temperature Reactor has long been investigated by JAERI for the purpose of multi-purpose development for industry, ie., not only for electricity generation, but also for getting high temperature (1000 C) as a source of chemical process heat. SHE critical assembly was used to give basic data for neutronic core design and several high temperature loops were installed to study the thermodynamic analysis of this reactor.

Others

Nuclear physics, using neutron beam from the reactor was very unique field connected to research reactors. JAERI started the research with JRR-2 and studied mainly in inelastic neutron scattering and magnetic spin. JAERI also measured cross sections for various kind of elements to complete nuclear data.

Radioisotope production was first projected in 1962. By the anti pollution movement in early 1970s, labelled organic chemicals were developed and delivered to many institutions. In 1980s, the demand for nuclear medicine has been increasing and newly developed chemical species for diagnosis and therapy are requested from nuclear medical institutions.

Outline of research reactors in JAERI.

1. JRR-1

Reactor type	Water boiler
Fuel	Sulfate uranyl-20% enriched
Maker	N.A.A. (USA)
First criticality	in August, 1957
Nominal Power	50 MW
Facilities	RI production, irradiation

Note: JRR-1 was enclosed in September, 1968

2. JRR-2

Reactor type	Heavy water moderated and cooling
Fuel	MTR-type, 20% enriched, U-Al alloy (90% enriched since 1962).
Maker :	AMF (USA)
First criticality	in Oktober, 1960
Nominal power	10 MW
Facilities	15 horizontal exp. port 9 vertical exp. port

3. JRR-3

Reactor type	Heavy water moderate and cooling
Fuel	Natural uranium, metal (since 1972, 1.5%enriched oxide fuel)
Maker	Domestic Nuclear Group
First criticality	in September, 1962
Nominal power	10 MW
Facilities	8 horizontal exp. port 3 vertical exp. port (F.P. gas release loop, completed in 1965)

4. JRR-4

Reactor type	Light water moderate and cooling
Fuel	90% enriched, MTR Type
Maker	Domestic Nuclear Group
First criticality	January, 1965
Nominal power	3.5 MW
Facilities	Shielding Test Neutron radiography RI production

5- JPDR

Reactor type	BWR natural convection power reactor(modified to forced convection in 1972)
Fuel	Low enriched uranium,oxide
Maker	G.E. (USA)
First criticality	August, 1963
Nominal power	50 MWt (modified to 100 MW in 1972)
Facilities	Demonstration plant for LWR

Note: JPDR is planning to be decomissioned soon

6.JMTR

Reactor type	Light water moderate and cooling
Fuel	90% enriched MTR type
Maker	Domestic Nuclear Group
First criticality	March, 1973
Nominal power	50 MW
Facilities	8 irradiation port (3 light water inpile loop and one helium gas inpile loop)

7. NSRR

Reactor	TRIGA-ACPR type
Fuel	TRIGA fuel
Maker	GA Technology
First criticality	June, 1975
Nominal	300 kW (constant) 23,000 MW (pulse) 130 MW/ sec (differential)

DISCUSSION

Sulaiman:

It is amazing after 10-12 years first encounter with the atomic bomb in Nagasaki, Hiroshima, Japan was able to build her first nuclear reactor.

1. How could Japan overcome the public fear for nuclear and could go ahead with the atomic age by building so many nuclear power plants and reactors? Was there any program to educate the comman people so that they could accept the existance of nuclear plants in Japan?

2. Were there an accidents in nuclear power plants in Japan and what precautions were taken to safeguard the general public?

Fumoto:
1. In the first board meeting to establish Atomic Energy Commission of Japan. One professor from Hiroshima who has exposed, opposed to the R&D for nuclear energy but most of the members approved to start nuclear energy development in Japan. Especially in 1960's all the political parties agreed with nuclear energy development and government did not face any problem of assessment exept for the financial matters and economical aspect of NPP
2. The electric utility companies ahoose the best way of P.D. ie charge all the parts/ facts, which seems no to be necessary in a point of technical view.

Markham:
Japan has already explored nuclear science and technology and nuclear energy to tremendously, how could you persuade the general people to accept nuclear power programme of the country, since probably the majority of them are still having the trauma of the Atomic blast at Hiroshima and Nagasaki in 1945. How was their attitude when you want to start your nuclear power programme? How is their attitude now while you extend your nuclear facilities?

Fumoto:
My friends, one from Hiroshima the other from Nagasaki, once told me that they had never recognized that they were born in atomic bom herd cities. It suggested me that the anti-nuclear moment was not connected to Atomic bomb victims. Before the villagers where NPP would be located were against the instruction of NPP. Government payed a lot to persuade them and it was suceeded. But nowadays, the city residents moved against NPP. Government cannot persuade them by payroll. This is the present situation of nuclear power in Japan.

A. Razak:
On 1957 You had a Naguoe reactor and you mentioned that weaknesses are on earth quake is any weakness about Technological Basics
Your JPDR will decomissioning soon according to crack of SS and all SS will be changed by carbon steel, we know that nine more than 90% of reactor all over the world are SS, what plant of changing SS in nuclear pmen plant in Japan

Fumoto:
First, they did not realize the weakness but after they compared the specification to LWR, they realized the sraphite block moderator was against earthquake
I hear from BWR the pipings connected to reactor vessel was changed to steel pipe in newly built plant. In the old plant stainless steel is steel adapted