R & D ACTIVITIES ON CANDU-TYPE FUEL IN INDONESIA

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ABSTRACT

The status of R & D activities in Indonesia with respect of CANDU-type fuel development is presented. The activities have been started since the first feasibility study to introduce nuclear power plants was carried out in 1970s. The early research comprised the in-situ pilot production of yellow-cake in Kalimantan (Borneo) experimental mining site, uranium purification and pellet preparation. This program continued to gain a full support from the Government which culminated in the realisation of the construction by BATAN of a large fuel development laboratory in Serpong, starting from 1984 in co-operation with NIRA Ansaldo of Italy. The laboratory, which is called the Power Reactor Experimental Fuel Element Installation (EFEI) was originally designed as an experimental facility to integrate the acquired domestic R & D results gained so far on the CANDU-type fuel technology and the additional know-how received from NIRA Ansaldo which at that time was engaged in developing a CANDU-type fuel, called the CIRENE fuel design. In the present days the facility houses the power reactor fuel development activities carried out to build up the national capability on power reactor fuel fabrication technology in anticipation to embark upon the nuclear energy era in the near future.

INTRODUCTION

The prospect of nuclear energy in Indonesia

The demand for electricity in Indonesia increases year by year, whose rate reflects the economic development, the growth of the population and the rapid development in various sectors, especially in the industrial sector. The Government realises that to fulfil the ever increasing demand for electricity in the 21st century will become more and more difficult, especially when Indonesia is still merely relying upon the conventionally existing energy resources, such as petroleum and natural gas.. They continue diminishing and getting limited

and at the same time their extensive and increasing use will result in serious environmental impact. Therefore Indonesia is very determined in seeking other alternative energy resources by considering various aspects, such as the availability, safety, social aspect, and economic and environmental aspects. It is expected that the electricity demand fulfilment shall ultimately lead to the *Optimum Energy Mix*.

Despite the fact that Indonesia has considerable reserves of primary energy resources, each being not abundant, the current per capita energy consumption in Indonesia is relatively lower, even the lowest in the ASEAN community. During the 1st 25-year plan (1969 to 1994), however, the energy consumption had grown very rapidly, whose average growth of consumption being higher than the average world energy consumption. Yet in the 2nd 25-year plan (1994 to 2019), the annual energy demand is projected to remain increasing still more rapidly. There oil will remain an important part of the domestic energy mix, but its relative contribution is continuously declining. It is forecast that during that period Indonesia will be a net oil importer, a shift from decades of being an oil exporting country. Coal will be dominating the domestic energy mix in the 2nd 25-year plan but again its role is limited by unquestionable detrimental impact on environment.

The above situation becomes more complicated as the geography of Indonesia does not quite support the distribution of energy. Being an archipelago, Indonesia uniquely has the energy resources mostly situated outside of the Island of Java, and yet Java, with its large population and industry, constitutes the major sink for electrical energy supply. Such situation has led the Government to realise the need to study the prospect of utilising nuclear energy in Indonesia. The first feasibility study was carried out in 1970s which later was gaining less priority as the Government was heavily engaged in developing the economy of the country. Only recently the Government decided again to resume and renew the feasibility study to introduce nuclear power plants in Indonesia as part of the implementation of the national energy mix policy in anticipation of the scarcity of energy resources in the beginning of the 21st century. The study commenced in November 1991 and ended in May 1996.

The renewed, updated feasibility study on introducing nuclear power plants (NPP) in the national grid signalising an energy supply gap of around 7000 MW, for which nuclear being consider to fill the energy demand gap. The feasibility study also recognises the leading

NPP designs, namely the western-world PWR, BWR and PHWR as having been proven world-wide to be technically safe, reliable, clean and environmentally-friendly, offering economic advantages, thus feasible technically for Indonesia's future NPP. The study also reiterates the relevance of performing R & D on both natural and enriched fuel technologies.

FUEL DEVELOPMENT FACILITIES

Early fuel development activities

The R & D activities to acquire fuel technology had begun in 1970s: the Nuclear Mineral Centre in Jakarta performing exploration, experimental mining and ore milling to produce yellow cake, the Nuclear Research Centre in Yogyakarta performing yellow-cake purification and conversion to sinterable uranium oxide powder for pellet production and the Nuclear Research Centre in Bandung conducting UO_2 pelletisation. The choice of Candu-type fuel specification to be followed as guidelines in developing our fuel technology had been a natural choice since the CANDU fuel technology was considered to be the easiest fuel technology that we could acquire it without much hurdle and off-shore expert involvement.

In the beginning of 1980s we were already able to process our indigenous yellow cake from ores taken from West Kalimantan (Borneo) mining site, into pure, sinterable UO_2 powder, and produce sintered pellets of UO_2 based on CANDU specifications. Such achievement had convinced us that we could ultimately acquire the natural uranium fuel technology which we believed would as well be a good basis for developing much more complicated fuel technology, such as PWR or BWR fuel technology. The historical background above indicates that Indonesia obviously has long been engaged in the R&D activities on CANDU-type fuel technology.

Having success in conducting the early stages of R&D activities on fuel, yet timely in coincidence with the encouraging results of various seminars on future Indonesian nuclear energy programme during 1970s, BATAN had succeeded in gaining more support from the Government to further advance in nuclear fuel programme. The nuclear research complex in Serpong was the result of such Government full support. One of the nuclear laboratories

constructed in Serpong is the Power Reactor Experimental Fuel Element Installation (EFEI). The facility was built based on the contract between BATAN and NIRA of Italy, which was signed on May 3, 1982. The scope of the contract covered the supply by NIRA of a heavy water type fuel development facility comprising mainly two major laboratories, i.e. the yellow-cake conversion laboratory and the fuel fabrication laboratory, both being supported by a quality control laboratory. The physical construction commenced in 1985 and completed only in 1989.

The deliberate introduction of a large scale heavy water-type fuel development laboratory, which originally was designed to be a pilot plant for producing Italian CIRENE fuel elements, again clearly indicates our original intention to acquire the natural uranium fuel technology, firstly in order to provide a good basis for more complex fuel technology and secondly as an anticipation of possible operation of CANDU reactors in Indonesia.

Since 1986, i.e. during its construction till now the EFEI has been under the management of the Nuclear Fuel Element Centre and constitutes a division in the Centre. The Centre has main tasks to develop fuel technology, both for research and power reactors.

Apart from the fuel R&D activities taking place at EFEI in Serpong, various R&D activities also are taking place currently in Nuclear Research Centre in Yogyakarta pertaining to concentrate purification and fuel synthesis and in Nuclear Research Centre in Bandung pertaining to fuel pellet and pin assembling for enriched uranium. Duplication in R&D topics is minimised by conducting a periodical fuel cycle co-ordination meeting programme.

As the CANDU reactor is one of the candidate reactors for Indonesian NPPs to fulfil the future national energy program, the R&D activities on CANDU-type fuel still receives adequate priority as do the other R&D activities on LWR-type fuel.

Description of EFEI

The EFEI was originally designed as an experimental facility to integrate and utilise the domestic R & D results gained so far on the CANDU type fuel technology and an additional know-how received from NIRA Ansaldo which at that time was still engaged in developing a CANDU-type fuel called CIRENE design (18-element bundles developed in Italy for use in a boiling water vertical prototype reactor).

The EFEI building has a sufficient size to house a pilot plant as originally intended. The design provided a complete facility for the production of fuel assemblies, starting from natural uranium yellow-cake. As a consequence, the facility comprises mainly two laboratories, i.e. the yellow-cake conversion laboratory and the fuel fabrication laboratory, both being supported by a quality control laboratory.

Yellow-cake purification and conversion laboratory

This laboratory is basically a chemical plant in a pilot scale. The designed capacity of the pilot plant is to produce 100 kg UO_2/day from yellow cake. The flow-sheet comprises a series of unit processes and operations.

a. crushing operation performed to yellow-cake incoming feed to get finer powder for digestion,
b. digestion of yellow cake using nitric acid,
c. solvent-extraction using tri-n-butyl-phosphate solvent diluted with odourless kerosene which is performed in a series of multistage mixer-settler banks, the stripping part of the system producing pure but dilute aqueous solution of uranyl nitrate
d. concentration process to reach a 140 g U/l concentration level
e. precipitation of concentrated uranyl nitrate solution by introducing a reaction with ammonia yielding a precipitate of parent material which is well known as the yellow ammonium di-uranate (ADU).
f. separation by filtration of the precipitate from the liquor in a high-speed centrifuge
g. drying of wet cake of ADU in a spray drier
h. calcination of ADU to convert it into UO_2 powder.

The current situation in this part of EFEI is not quite encouraging as a result of its capacity being very large that it is not suitable and flexible as an R&D tool to improve and develop its process technology. Besides, as the activities on enriched uranium fuel fabrication increase, the need of using the chemical plant decreases. The feed for enriched fuel development, i.e. enriched UO_2, can be readily made available from a direct purchase.

Fuel fabrication laboratory

This laboratory is the most important part of EFEI in respect to its function to develop fuel fabrication technology. The originally designed capacity of the laboratory is 3 fuel assemblies of CIRENE design. The laboratory consists basically of four sections, namely:

1. **pelletisation section**: The pelletisation sub-laboratory prepares UO_2 pellets through premixing UO_2 powder and Zn-stearate powder, pre-pressing, granulation and sieving, final pressing, pellet sintering, surface grinding, ultrasonic cleaning, and pellet drying. From this end the UO_2 pellets are put into fuel tubes. The design of this sub-laboratory provides a potential capacity of producing 80 kg UO_2/day. This particular part of the EFEI is the most utilised for R & D activities since it has been functional since its qualification for CIRENE type fuel element production.
2. **fuel component section:** The fuel component section is a workshop to prepare fuel components such as end-caps, bearing pads, end plates, and spacers. Besides, the workshop also provides maintenance services to other parts of the EFEI. Almost all equipment is in function except the beryllium coating device which has problem associated with its electronic parts.
3. **fuel rod manufacturing section:** This workshop assembles fuel rods by performing end-cap welding and pellet filling. There are two magnetic force welding machines, a pellet filling machine and two-face turning lathe used in this laboratory. This laboratory runs quite well except one of the magnetic force welding machine which suffers from a defect in its rectifier.

4. **fuel assembly section:** This end workshop assembles several rods into fuel assemblies. A resistance welding machine is employed here to weld the rods and the end-plates. An autoclave is also available should passivation of the surface of fuel assembly is required upon completion of fuel assembling. This laboratory is functional.

The quality control laboratory

The quality control laboratory is capable to perform quality control for intermediate and final products from the first two sections. This laboratory is equipped with chemical analytical and physicochemical instruments, non-destructive test devices, mechanical test devices, etc. required for qualifying the products.

CURRENT R&D ACTIVITIES

As EFEI becomes central in fuel technology development in Indonesia, it has to house several different R&D activities pertaining thereto, some related to PHWR fuel and the other related to LWR, specifically PWR fuel technology. To integrate capabilities in different research centres, research co-operations are instituted, e.g. with the fuel researchers in Yogyakarta and Bandung, and to some extent with an off-shore institute.

In an effort to qualify the EFEI capability to produce CANDU fuel in the future an agreement between BATAN dan AECL was signed in November 1995, immediately executed by AECL sending an expert to visit EFEI to study the feasibility of EFEI to processing and fabricating CANDU nuclear fuel. That was meant as a prelude to BATAN acquiring capability to demonstrate production of commercial CANDU fuel. The most important result of the study indicates that an upgrading of the present status of EFEI will have to be done to help it transform to CANDU fuel manufacturing capability, including its certification as a reactor fuel supplier. The transform to CANDU technology is partly much simplified due to the fact that there is much similarity between CIRENE and CANDU fuel designs.

Lack of hardware and software as well as infrastructure to support LWR fuel development has urged us to study the possible modification of EFEI to be able to prepare

LWR fuel specimens (pins or mini-bundles). The study has been carried out and completed in the end of 1996 in a co-operation with an Italian company. Based on the study we start now procuring the most essential parts required to enable EFEI to conduct LWR fuel development.

Researches on power reactor fuel fabrication and performance are carried out. Regardless the types of reactor fuels, the R&D on fuel fabrication covers quite a wide area. A group is engaged more in the fuel design through fuel modelling, some other group in pellet production. The current topics on this line are, among others, the use of a minute amount of TiO_2 to improve the density and strength of the pellet, the use of excess oxygen in the sintering process, improvement of weld quality. Another group is more absorbed in synthesising different alloys of U and Si.

As far as irradiation and post-irradiation tests are concerned, there is not even a single pin or bundle of fuel prepared by EFEI ever inserted in the reactor core. In fact the 30 MW multipurpose reactor is equipped with various irradiation positions for fuel irradiation tests, such as rigs, chauca, rabbits and PRTF (power ramp test facility). Lack of experience in the irradiation and post-irradiation experiments requires us invite other institutes to co-operate.

CONCLUSIONS

The power reactor fuel development activities in Indonesia are still continuously performed in anticipation of the future operation of power reactors, whose types may well include the CANDU PHWR. The advantage of acquiring CIRENE fuel technology is very obvious that we easily can adopt the CANDU fuel technology. A study on this fact even suggests that EFEI has a potential to be improved towards commercial production operation of CANDU fuel in the future.

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