OUTLINE OF THE ROKKASHO MOX FUEL FABRICATION PLANT

Ikeda K., Deguchi M., Mishima T.
Japan Nuclear Fuel Ltd., Rokkasho-mura, Aomori-ken 039-3212 Japan

ABSTRACT:
JNFL’s MOX fuel fabrication plant (JMOX) will be constructed in April, 2007 and start operation in April, 2012. It utilizes plutonium coming from RRP in powder co-converted with uranium and fabricates annually a maximum treatment quantity of 130 tons HM MOX fuel. The construction site is already reserved adjacent to RRP and an investment of so-called world standard, around one billion dollars, is expected. JMOX together with RRP will play an important role of achieve domestic plutonium recycling in Japan.

KEYWORDS: co-converted MOX powder, safe and secure operation, remote and automatic operation

1. Introduction

A new program of Japanese MOX fuel fabrication has been started by JNFL. It will be constructed adjacent to Rokkasho Reprocessing Plant (RRP) so as to utilize plutonium recovered by reprocessing and to fabricate annually a maximum treatment quantity of 130 tons HM MOX fuel. At RRP, plutonium is recovered together with uranium as mixed oxide powder in accordance with the Japanese nonproliferation policy. The MOX plant (hereafter JMOX) receives it as feed material, which is different from European MOX plants that are fed with 100% plutonium.

On April 20, 2005, JNFL submitted the license application on JMOX to the Japanese Government and the safety assessment by the regulatory authority is under way. The construction is expected to start in April, 2007 and the operation in April, 2012.

JMOX together with RRP would contribute to achieving domestic plutonium recycling in Japan.

2. Outline of JMOX

2.1 Fundamental Requirements

(1) Site
The area adjacent to RRP is already reserved for JMOX construction. The building of JMOX will be connected underground to RRP taking into account of security of MOX powder transportation.

(2) Throughput
The maximum throughput of JMOX is given as 130 tons HM/y that is based on a possible series of fabrication campaigns consuming the amount of fissile plutonium annually recovered at RRP.

(3) Time frame
RRP will start the commercial operation in August 2007. JMOX aims at starting the operation in not big delay after the commercial operation of RRP. Current schedule is that the construction will start in April, 2007 and the operation in April, 2012.

(4) Investment
It is necessary that the plant should provide MOX fuel at reasonable price to Japanese utilities. A so-called world standard level investment, around one billion dollars, is supposed to meet the requirement to the case of JMOX construction and operation.

(5) Safe and secure operation
Following the national policy of nuclear peaceful use, it is very important that JMOX should be incorporated in the international safeguards scheme. Also safe and secure operation based on matured safety
technology of plutonium confinement, radiation protection and other safety control including criticality control is required.

2.2 Policy on Achieving Process Equipment and Fabrication Technology

Followings are basic rules that JNFL applies in adopting technology and equipment for JMOX.

(1) Technology and equipment to be adopted for JMOX will be judged from whether it has been proven for large scale commercial MOX fuel fabrication.
(2) Basically a single production line, but may have redundancy or plural machines at each equipment level according to its capability.
(3) Proper buffer storage should be installed among sub-processes in order to keep flexibility as well as enough volume of final storage of fuel assembly.
(4) The main process should consist of dry sub-processes from the standpoint of criticality safety, and equipment should enable automated movement to be operated remotely from the standpoint of radiation control.

The fundamental MOX technology necessary for JMOX construction and operation is provided to the most extent by domestic sectors including uranium fuel fabricators and JAEA who has the only experience of MOX fuel fabrication in Japan. Based on this concept JNFL and JAEA concluded a collaboration agreement on JMOX construction and operation of in December 2000. Also, Nuclear Fuel Industries Limited, one of Japanese uranium fuel fabricators, and foreign sectors, AREVA NC and Belgonucleaire, supported JNFL in design stage.

JMOX utilizes the co-converted MOX powder as feed material and because it is uniquely processed, it is recognized that the powder should be demonstrated to be compatible with MIMAS equipment before it is adopted. A comprehensive evaluation test was well planned whether the co-converted MOX powder suits with MIMAS process from powder preparation to sintering and is under execution utilizing both small size experimental equipment and actual scale equipment.

2.3 Fabrication Process

MOX fuel is to have the same reactivity as conventional uranium fuel, so that plutonium enrichment will be in the range of several % up to 16%. Fuel assemblies of PWR will consist of all MOX fuel rods and fuel assemblies of BWR will have a mixture of uranium and MOX fuel rods.

Figure 1 shows material flow of raw material and product to and from JMOX and Figure 2 shows fabrication process of JMOX. The process consists of several sub-processes. Those are powder process in which feed MOX powder is blended and milled with uranium powder to be adjusted to the given plutonium enrichment, pellet process in which powder is pressed into pellets and sintered, rod process in which pellets are inserted into zirconium alloy tubes which are then welded, assembling process in which fuel rods are assembled with other hardware and fuel shipment.

(1) Powder process
This process is unique to MOX fuel fabrication. Feed material, co-converted MOX powder by micro-wave heating technology, containing 50% plutonium and 50% recovered uranium, is weighed and blended to the given plutonium enrichment. Ball-milling in addition to blending is adopted to get fine powder in order to avoid so-called plutonium spot in sintered pellets. The MIMAS process developed by Belgonucleaire and adopted in MELOX plant is used in the process.

(2) Pellet process
Milled powder is pressed into cylindrical pellet having 10mm in diameter and 10mm in height before pellets are sintered at high temperature in reduction atmosphere. After sintering, all pellets go to dry centerless grinding before being checked with diameter measurement.

(3) Rod process
Pellets inspected by the regulatory body and the customers are inserted into zirconium alloy cladding tube already welded with lower end plug. After welding with upper end plug, rods are inspected for weld perfection and plutonium enrichment. Because of treating plutonium, all equipment up to the rod process is installed in gloveboxes with negative pressure.

(4) Assembling process
Prior to assembling fuel rods, a skeleton is assembled with grid-frames and other hardware, and then the skeleton is moved and fixed onto an assembling bed. Fuel rods are pushed into given positions of the skeleton, thus it becomes a fuel assembly. The assembly is inspected again by the regulatory body and the customers.

(5) Shipment
Fuel assemblies to be shipped are carried to the shipping yard from the storage room, and then packed into transport containers and shipped out by truck.

3. Philosophy and Plans for Safe and Secure Operation

3.1 Philosophy for Safe and Secure Operation
Operation of JMOX should be achieved safely and securely. Although it handles large amount of plutonium, it should not affect the public and operators by handling plutonium. To achieve the goal, it is important that the law, regulations and standards should be observed throughout design, construction and operation.

From technical standpoints, confinement of alpha material in glovebox with ventilation system, heavy shielding against neutron as well as gamma rays, and careful design and operation to prevent major accidents such as criticality accident will be applied to JMOX. The seismic design is based on the same condition as RRP.

3.2 Safety Design

(1) Confinement of alpha material
Since the feed MOX powder has plutonium fissile isotopes to total plutonium isotopes of about 60%, and specific alpha activity about 150 thousands times larger than uranium, it shall be handled in sealed glovebox system. The confinement system utilizes so-called defense in depth design with a stepwise negative pressure along the air stream going into room in which glovebox is installed. Redundancy or multiplicity supports the ventilation equipment to keep the system functioning at all times.

(2) Radiation shielding
Since feed MOX powder has neutron and gamma doses that are much larger than those from uranium, operators should be protected by proper shielding and/or kept apart from process equipment. To fulfill the requirements, shielding material is put on equipment itself, glovebox structure and building wall, and also process equipment is designed to operate automatically and/or remotely. Comprehensive radiation control will be managed by limiting operators’ working time at places classified with radiation dose rate.

(3) Fire protection
Nonflammable material will be used to the maximum extent to prevent facility fires, and gas fire extinguish system is to be adopted rather than a water sprinkling system because of criticality and safety considerations. Nitrogen atmosphere of glovebox system also helps prevent fires inside gloveboxes.

(4) Criticality safety
Criticality safety is one of the major safety concerns of JMOX since 1) there actually happened the criticality accident at JCO and 2) technically, criticality mass of MOX is much smaller than that of slightly enriched uranium. At JMOX, almost all processes, except analytical gloveboxes where a little amount of nitric acid is to be used, consist of dry processes and criticality mass under dry condition is basically bigger than wet condition. JMOX adopts physical control such as mass-control, geometry-control and neutron-
absorbing material and logic control for nuclear material handling and movement in order to avoid criticality anytime at any process.

(5) Heat removal  
Heat generation from MOX powder due to alpha decay of plutonium is not negligible, so that nitrogen flow inside gloveboxes is properly designed and the cooling system for both interim storage and final fuel assembly storage is incorporated to prevent overheating.

(6) Seismic design  
Design philosophy for earthquakes is that JMOX facility should have enough physical strength at the site not to trigger another big accidents. Any structures, including the building and gloveboxes, are to be designed to have enough strength to withstand earthquake.

(7) Waste treatment  
Any radioactive waste generated through operation of JMOX should be properly conditioned before being discharged. Both gaseous and liquid waste is to be discharged under regulation limits.

4. Physical Protection and Safeguards  
In the field of nuclear fuel facilities, the government of Japan and the facility operator are obliged to shoulder international responsibility to secure the safety of the facility and to demonstrate the peaceful use of nuclear materials to the international community.

To this end, JMOX facility must take necessary measures for physical protection and safeguarding nuclear materials. As for physical protection, as a Category I plutonium handling facility, measures like strong fence or barrier etc. are taken to cope with stealing or illegal transfer of nuclear materials and the sabotage against the facility, following the local regulations.

As for safeguards, the government of Japan and IAEA shall apply safeguards on this facility from the standpoint of non-proliferation of nuclear materials to make it recognized in the international community together with the operator’s appropriate materials accountancy system defined in the Japanese law.

5. Conclusion  
Recycling plutonium in domestic LWRs is one of the major nuclear programs defined in the national nuclear program. The experience on MOX irradiation includes 6 LWR fuel assemblies and a large number of ATR fuel assemblies in Japan. More than two thousands of MOX fuel assemblies have been irradiated for more than thirty years without any problem abroad, mainly in Europe. Japanese utilities announced a program of loading MOX fuel in some 16 to 18 reactors stepwise by 2010. The MOX fuel assemblies fabricated with Japan originated plutonium have already come to Japan from European MOX fuel fabricators. The JMOX project is aimed at the recycling of domestic plutonium coming from RRP and is expected to start operation in a proper timeframe after the RRP operation.
Figure 1: Material Flow to and from JMOX
Figure 2: Process Flow of JMOX

**Powder Process**
- **Powder dosing**: Milling and mixing feed powder and adjusting the Pu content given
- Press: Pressing the mixed powder into pellets
- Sintering: Sintering pellets at high temperature
- Grinding: Grinding pellets with centerless grinder

**Pellet Process**
- **Pellet inspection**: Having pellets inspected with diameter, density, etc.

**Rod process**
- **Assembling and inspection**: Assembling fuel rods with other hardware and having inspection
- **Welding and inspection**: Welding upper end plug and having inspection
- **Pellet loading**: Loading pellets into zirconium alloy tubes

**Reprocessing**
- MOX powder
- UO₂ powder

**Shipment**
- Packaging fuel assembly in containers and shipping on board/truck

*Figure 2: Process Flow of JMOX*