RERTR-RELATED PROGRAM IN INDONESIA

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ABSTRACT

The RERTR-related program has been underway since 1989. It was commenced with the experiment to synthesize and characterize own-produced U_3Si_2 ingot. The work was conducted with the assistance of the IAEA through a technical assistance program starting in 1989 and ceased in 1995. Under the Agency's technical assistance program came a German and several US experts providing direct assistance and supervision. The program had successfully brought Indonesia to such a capability to produce U_3Si_2 fuel elements and ultimately insert some U_3Si_2 fuel elements in 1991 which then were subjected to a successful post-irradiation examinations (PIE) three years later. Another achievement was the conversion of the whole 30 MW RSG-GAS reactor core from using U_3O_8 fuel elements into using completely U_3Si_2 fuel elements domestically produced (Aug. 1999).

Since November 1994, BATAN and the University of Chicago (Operator of ANL) had come to an agreement to cooperate in the development of LEU target for Mo-99 production using uranium metal foil. The cooperation, until 2001 had proved that the metal foil target could be used successfully to substitute HEU oxide target now being used utilizing very similar geometrical external design. Having such design, the radioisotope producer would be expected not to suffer penalty with the necessity to change the rest of the processing hardware. The cooperation had also resulted in the improvements of the separation chemistry of the foil, the metallurgy of the foil as well as the cladding materials. However, the activities of the cooperation was unfortunately suspended until now pending the improvement of the world situation in the aftermath of the September 11 atrocity.

The post-tragedy activities on the subject are still going on, including experiments on the synthesis of U-Mo advanced fuel. This paper reports briefly the progress of the RERTR-related activities in Indonesia.

1. Introduction

The RERTR-related program was commenced in 1989. It was started with the experiment to synthesize and characterize own-produced U_3Si_2 ingot. The work was conducted with the assistance of the IAEA through a technical assistance program starting in 1989 and ceased in 1995. Under the Agency's technical assistance program came a German and several US experts providing direct assistance and supervision.

Domestic fuel production for RSG-GAS refueling

With respect to the operation of RSG-GAS (30 MW Multipurpose Reactor G.A. Siwabessy), the RERTR-related program had successfully brought Indonesia to such a capability to produce

U_3Si_2 fuel elements and ultimately insert some U_3Si_2 fuel elements in 1991 which then were subjected to a successful post-irradiation examinations (PIE) three years later. Another achievement in 1999 was the conversion of the whole core of the 30 MW RSG-GAS reactor from using U_3O_8 fuel elements into using U_3Si_2 fuel elements domestically produced. In terms of dimensional geometry, fuel loading as well as structural material, the U_3Si_2 fuel elements are the same with the U_3O_8 fuel elements. The decision to change the core from using U-oxide to U-silicide was to benefit better safety margin offered by U_3Si_2 fuel. However, until now the use of U_3Si_2 fuel is still under continuous investigation in order to obtain the permanent license from the Nuclear Energy Control Board of Indonesia. The investigation comprises monitoring of thermal and radiation impact from the use of U_3Si_2.

Spent fuel storage

With respect to spent fuel management, BATAN had provided RSG-GAS with an external interim storage which is called ISSF (Interim Storage for Spent Fuel), located adjacent to the reactor and connected via an underwater transfer channel. The underwater storage is to receive and store spent fuels temporarily with a capacity of 1436 positions whose design provides k_{eff} = 0.95. The spent fuels must have been cooled for a minimum duration ot 100 days prior to being sent to the ISSF. The transfer of spent fuel from the reactor fuel pool to ISSF is done through an underwater transfer channel connecting the two adjacent buildings.

Spent fuel re-export

As the US Government offered a window of chance to receive US origin spent fuel through the ROD (Record of Decision) for the Final Environmental Impact Statement (FEIS) on a Proposed Nuclear Weapon Nonproliferation Policy, Indonesia was among several countries that was entitled to re-export its US origin spent fuels. The chance was made realized in April 1999 where 48 spent MTR type fuel elements and control elements were shipped to USA following the ROD above. It was expected that within next few years several other batches of US origin spent fuels (both MTR and TRIGA types) would be re-exported to USA. However, as global political and security changes recently, this plan has not been implemented yet.

Fission radioisotope production

Since 1987 BATAN has acquired Cintichem Process license from the Transfer of Technology Agreement with General Atomic Inc, USA. Along with that, an installation to produce ^{99}Mo from HEU fission was built in 1986 and operated commercially and in routine basis from 1989 on. As a result, since 1989 $^{99}Mo/^{99m}Tc$ generator from BATAN have been widely used in routine basis in many hospitals in Indonesia.

By having a good production facility, a quite big reactor, and sufficient workers who are familiar and experienced with the Cintichem Process, BATAN accepted the cooperation work offer by ANL which included the development of ^{99}Mo production process from irradiated LEU target. It was realized that the substitution of HEU with LEU target would imply that there would be challenges with regard to the target design and the separation process as well as ^{99}Mo product purity and quality. There were three major challenges, namely: (1) modification of target and the separation process as minimal as possible; (2) assurance or maintaining of high yield and good product purity and quality of ^{99}Mo and (3) control of additional cost likely to be incured. The effect of irradiation on LEU target was expected to be minimal by keeping similar geometry of

the target. To reach the same production yield of ^{99}Mo would imply that the ^{235}U content in the LEU target should be as much as the case of using HEU. In turn it means that the U content in LEU target must be around 5 times as much as that in HEU target. (see Table 1). This has been the basic consideration to choose highly dense uranium material target, for which uranium metal suits the requirement and the metal was chosen in the form of foil in order to resemble the original target using HEU. Changing the amount and geometry of uranium in the target at least would give two impacts on the process. First, the dissolution of the irradiated foil, and second the preliminary separation process of ^{99}Mo. Most parts of the developmental work on this line have dedicated to master in these two mentioned process.

Table 1. Comparison of HEU-UO_2 target and LEU Foil target

	HEU UO_{2+} target	**LEU Foil target**
Chemical form	UO_2	U metal
Total content of U	~ 16 g	~ 94 g
Enrichment of ^{235}U	~ 93%	~ 19,8%
^{235}U content	15 g	18,5 g
Yield ^{99}Mo	532 Ci	545 Ci
^{239}Pu Impurity	30 μCi	720 μCi
$^{234, 235, 238}$U	1280 μCi	840 μCi
Total α	1310 μCi	1560 μCi

Result of ^{99}Mo process development using LEU metal foil targets gives a good prospect for the commercial and routine production of ^{99}Mo. The following shows some of the advantages of using LEU foil targets:

1. ^{99}Mo product contains γ emitting impurities that matches the specifications .
2. Yield of ^{99}Mo is higher due to shorter processing time around 1.5 to 2 hours.
3. Lower cost of waste processing due to the fact that the liquid waste volume is smaller and the use of sulfuric acid is avoided.
4. Dependency on overseas supply of foil can be minimized or annihilated by domestic production of foil. In this case, BATAN and PT BATAN Teknologi has been cooperating in developing foil production capability.

Cooperation between BATAN and ANL: LEU target development

Since November 1994, BATAN and the University of Chicago (Operator of ANL) had come to an agreement to cooperate in the development of LEU target for Mo-99 production using uranium metal foil. The cooperation, until 2001 had proved that the metal foil target could be used successfully to substitute HEU oxide target now being used utilizing very similar geometrical external design. Having such design, the radioisotope producer would be expected not to suffer penalty with the necessity to change the rest of the processing hardware. The cooperation had also resulted in the improvements of the separation chemistry of the foil, the metallurgy of the foil as well as the cladding materials. However, the activities of the cooperation was unfortunately suspended until now pending the improvement of the world situation in the aftermath of the September 11 atrocity. The year 2001 experiment, scheduled to occur at the end of 2001, which was intended to re-confirm the technical feasibility of using uranium foil target, could not be realized.

We still have hope as situation is bettering, the experiments could continue in order to confirm the conclusion that the LEU metal foil target could really replace the use of HEU target now still being used.

2. Current Activities

a. High load U_3Si_2 fuel

The success to develop U_3Si_2 fuel in the first half of nineties has been the basis to gradually, completely change the core of the RSG-GAS reactor from using oxide fuel into using U_3Si_2 fuel. As already mentioned before, the use of silicide is still based on oxide fuel design, that is with low uranium loading (only around 3 gU/cm^3). This is indeed a low loading that would only satisfy our RSG-GAS but does not fulfill most of world reactors demand for fuels.

It is therefore, BATAN and PT BATAN Teknologi jointly work to make experiments on high loading silicide fuel, i.e. 4.8 and 5.2 gU/cm^3, respectively. The preparatory work prior to insertion in reactor has been completed, fabrication of "mini-plates and assembly" has been completed. It is very much expected that the insertion can be made in 2004 and the PIE (post irradiation examinations) two years later.

b. LEU target development

Since the cooperation with ANL was established, the activity to develop domestic capability to prepare uranium foil had been carried out in a very slow pace due to an internal organizational change in BATAN and the emergence of PT BATAN Teknologi who operates machineries which were previously under BATAN. This disorganization lasted several year until finally BATAN and PT BATAN Teknologi could come to a joint work in the development of fuel and foil target.

It is worth reporting here that BATAN and PT BATAN Teknologi have been able to prepare uranium foil having thickness of 125µ that is suitable for target production. On the other side, sill to produce target structure finds no hurdle.

c. U-Mo fuel development

Since 1999 BATAN and PT BATAN Teknologi have been trying to synthesis U-Mo fuel at various Mo contents and performing characterization of the alloy. Much assistance from ANL experts was received in this respect. The alloy preparation is being carried out using the arc melting furnace, working under argon atmosphereU_3Si_2 alloy. The work encountered hurdle when attempting to prepare alloy powder.

In trying to solve the problem, a combination of milling and grinding techniques was employed to prepare U-Mo powder but the result was not satisfactory. Finally we considered the old technique, i.e. hydrogen adsorption-desorption process to solve the problem. Based on experiments done in Japan to make a hydrogen storage. (see Fig.1).

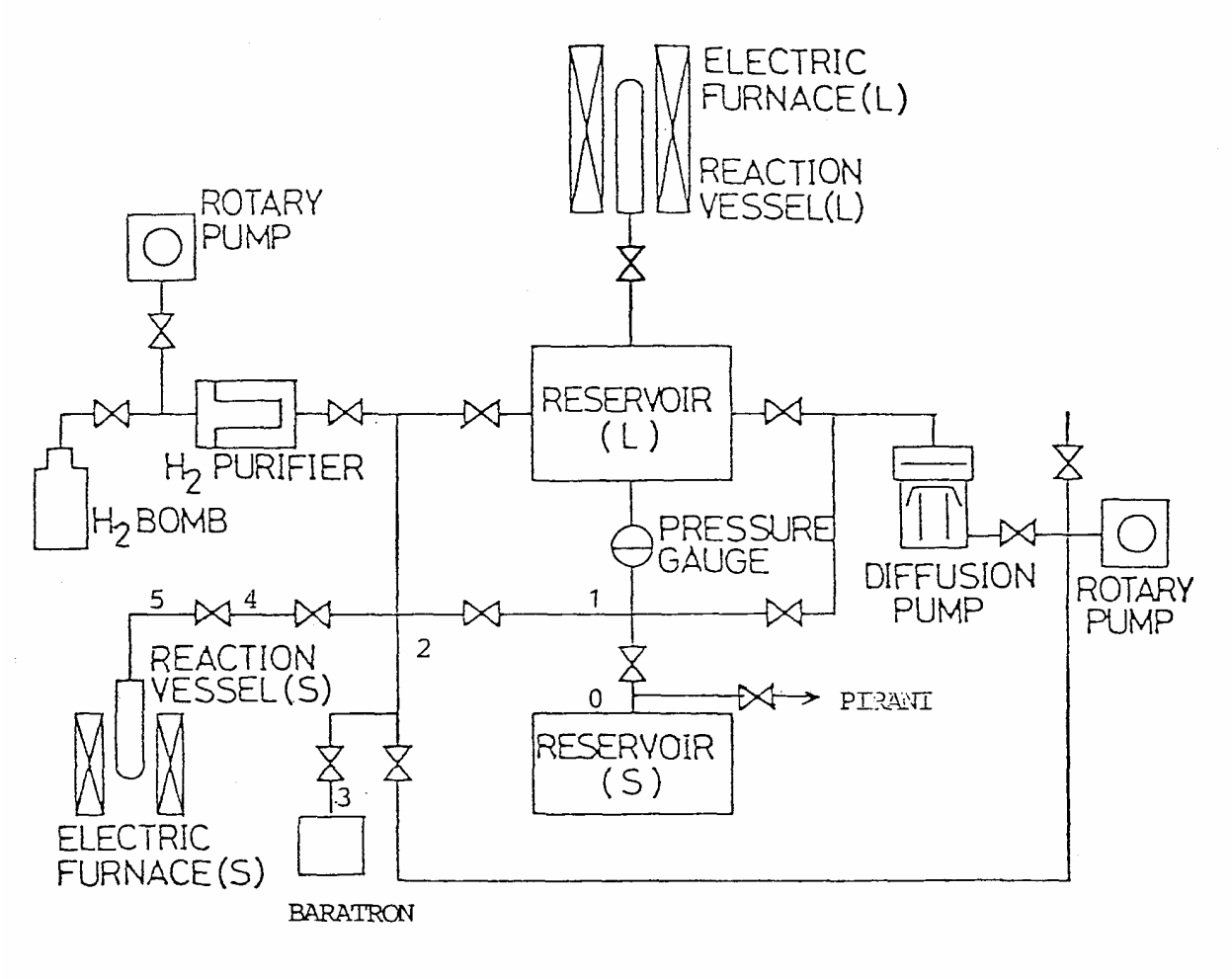

Figure 1. The basic diagram of hidridisation-dehidridisation process adopted

3. Future challenges

As Indonesia has the capability to produce ^{99}Mo and is equipped with good production facility, Indonesia can contribute to the world market with the supply of the radioisotope. The demand on that particular radioisotope, especially in Asia is growing. The demand is so strong, when Japan as the biggest importer of ^{99}Mo was suffering from supply problem from Nordion Co.(biggest supplier of ^{99}Mo) in the aftermath of the atrocity of the WTC in New York, 2001.

Indonesia expects to become one of the supplier of ^{99}Mo, especially for the Asian market. In this regard, BATAN and PT BATAN Teknologi shall anticipate the use of LEU target for commercial production of ^{99}Mo

Almost in the similar manner, BATAN and PT BATAN Teknologi look forward to having a good roll in providing high density fuel for neighboring countries. The capability already obtained and long experience in supplying fuel for RSG-GAS without any single bad record for years should be a good base to market the fuel product.

4. Conclusions

Summarizing all the above it can be concluded that the RERTR-related program in Indonesia has achieved the following.

- National capability to produce high density fuel U_3Si_2. This new fuel is now being produced by the PT BATAN Teknologi, a state-owned company, and has completely replaced the U_3O_8 fuel which was originally produced by Nukem and BATAN. Due to the reactor design constrain, the U_3Si_2 is used in rather low loading, about 3 gU/cm^3.
- Attempt to fabricate high load U_3Si_2 (4.8-5.2 gU/cm^3) for in-pile experiments and post irradiation programs has been pursued using mini-plates. The in-pile experiment is expected to commence next year.
- As a result of the Cooperation Agreement between BATAN and ANL which took place from 1994 until 2001, BATAN has acquired much additional capability relative to LEU target, namely: metallic U target foil preparation, target preparation, irradiated U foil processing.
- BATAN and PT BATAN Teknologi have already been able to prepare uranium metal foil with thickness suitable for use in target assembly, i.e. 125 μ, fabricate the target structure of aluminum.
- BATAN and PT BATAN Teknologi are engaged in a joint research on U-Mo fuel. Synthesis of the alloy fuel at different Mo contents has been made and alloy powder preparation has been attempted using milling and grinding technique. A new alloy powder production line based on hydrogen adsorption-desorption process is being setup.
- BATAN and PT BATAN Teknologi shall jointly work to enhance their roll in regional and world market of fission product radioisotope and high density fuel elements, both relying on RERTR related program.

5. References

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