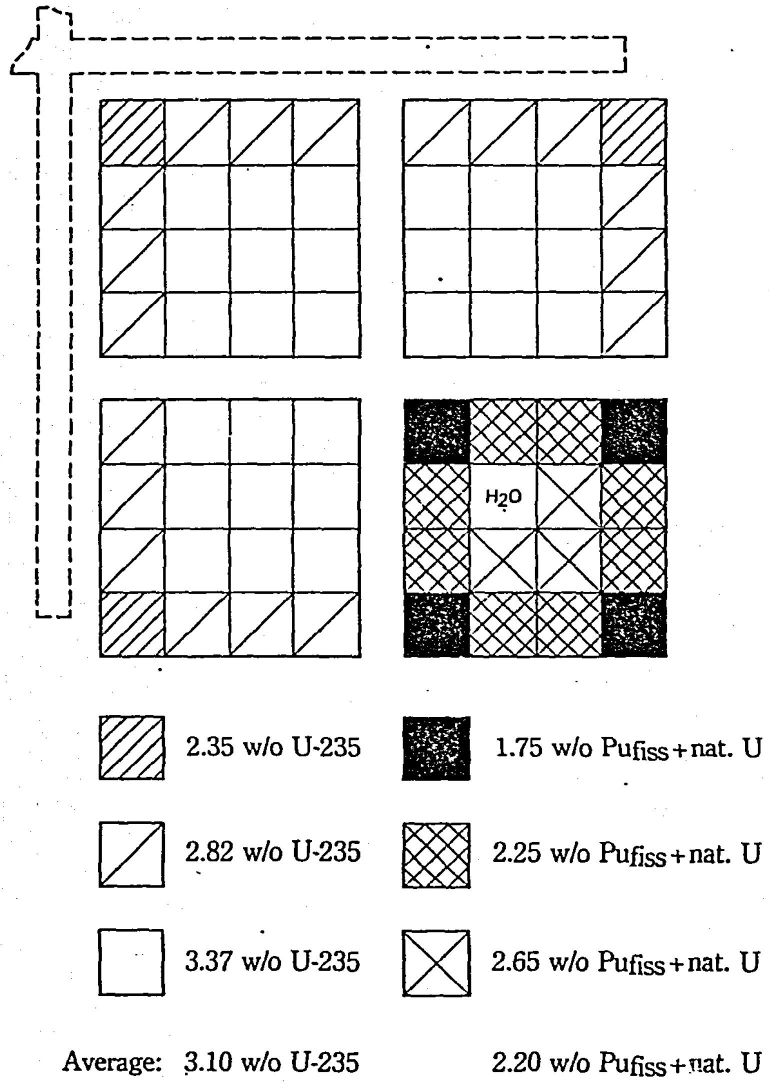
PLUTONIUM RECYCLING IN SVEA



ASEA-ATOM

FIG. 5.

THORIUM FUELS FOR HEAVY WATER REACTORS
Romanian Experience

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Abstract

The renewed interest in thorium fuel cycle due to the increased demand for fissile materials has resulted in speeding up the related research and development activities. For heavy water reactors the thorium cycles, especially SSET, are very promising and many efforts are made to demonstrate their feasibility.

In our country, at INPR, it has been initiated the research and development activity in the following areas:

- the conceptual design of thorium bearing fuel elements,
- fuel modelling,
- nuclear grade thorium dioxide powder technology,
- mixed oxide fuel technology.

In the design area, the key factors in performance limitation, especially at extended burnup have been accounted and different remedies proposed. An irradiation programme has been settled and will start this year.

The modelling activities are foccused on mixed oxide behaviour and material data measurements are in progress.

In the nuclear grade thorium powder technology area, a good piece of work has been done to develop an integrated technology for monasite processing (thorium being a by-product in lanthanides extraction).

As regards the mixed oxide fuel technology, efforts have been made to obtain $(ThU)O_2$ pellets with good homogeneity and high density at different compositions. Besides the mixing powders route, other non-conventional technologies for refabrication like: microspheres, pellet impregnation and clay extrusion are studied. Experimental fuel rods for irradiation testing have been manufactured.

1. Introduction

The development of nuclear power supply, especially during the last ten years has emphasized the need for greater efficiency in the utilization of natural resources. The presently operating commercial power reactors, based all on ^{235}U as fissile material (natural or low enriched) use only 1-2% of the uranium for energy production, the rest being discharged in spent fuel. Consequently, many countries are examining fuel recycling with a view to expand and ensure the nuclear resource base. In this respect, the introduction of the thorium fuel cycle has been recognized in the conversion of the fertile ^{232}Th into fissile ^{233}U.

For our country - which has an important programme for nuclear electricity supply based mainly on PHW reactors, the thoria based advanced fuel cycles constitute one of the main directions of research and development activity. The main target of this research programme is to develop and test a thorium based fuel for low and medium burn-up compatible with the standard CANDU-type reactors.

The Institute for Nuclear Power Reactors, the main nuclear center in Romania, started a research programme in this field both in reactor physics and fuel technology.

The paper deals with the most important results obtained in the development of thorium fuel at INPR, in the following areas:

- the conceptual design of thorium bearing fuel elements;
- fuel modelling;
- nuclear grade thorium dioxide powder technology;
- mixed oxide fuel technology.

2. Design Activities

Starting from the premise that the thorium fuel will be used in the standard heavy water reactors, the design activities followed two main points:

- to account the key factors affecting performances, especially at extended burn-up, and to find adequate remedies;
- to conceive a testing programme to validate the design solutions.

Among the factors affecting performances, the PCI has been identified to be very important. The thermo-mechanical analysis performed by using finite elements computer code ELFIN [1] has shown an increased probability of failure when the fuel is ramped at extended burn-up, as required by thorium fuel cycle. To diminish mechanical interaction between pellets and cladding, during transients, the pellets are chamfered on both ends in such a way to accomodate the pellet expansion. This shape for UO_2 pellets has been tested under irradiation by CARTER [2] and proved to diminish clad ridges. An experimental fuel rod with thoria-urania pellets of this design has been manufactured and will be tested under irradiation.

Another means to increase the fuel performances during transients is to increase the cladding tolerance to mechano-chemical restraints exerted by irradiated fuel. One of the possibilities considered is the use of claddings with pure zirconium inner coatings.

The fuel performances of collapsible sheet fuel elements can be improved by using unstable fuel pellets to in-pile densification. In order to minimize the PCI during transients, the accompanying thermal expansion has to be compensated by the shrinkage of the pellet due to in-pile densification. An optimized microstructure for this fuel will contain essentially pores with diameters smaller than one micron. To illustrate the favourable effect of in-pile densification on mechanical behaviour of the cladding, in Figures 3 and 4 there are shown the stress components of inner clad surface of a ramped fuel element.

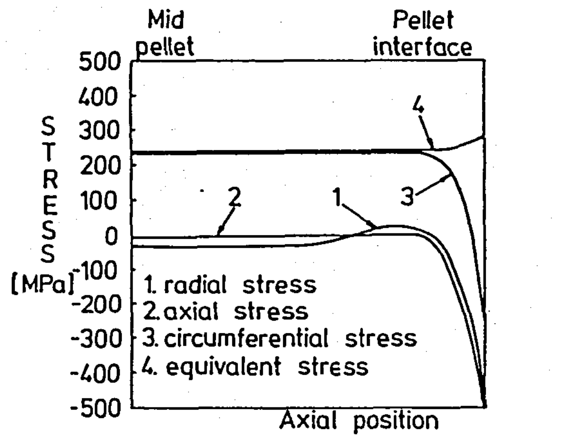

Fig.1- STRESSES VALUES ON THE INNER CLAD SURFACE VERSUS AXIAL POSITION (STABLE FUEL)

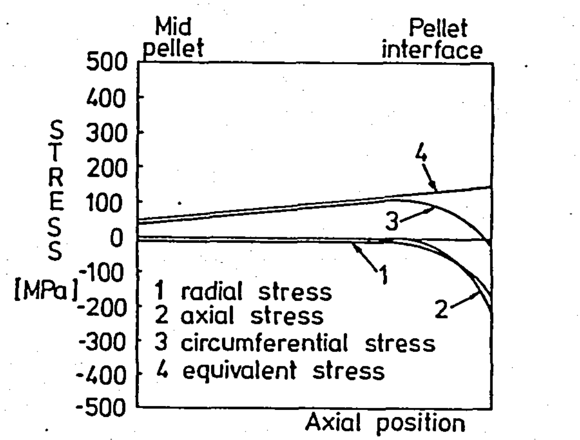

Fig. 2- STRESSES VALUES ON THE INNER CLAD SURFACE VERSUS AXIAL POSITION (UNSTABLE FUEL)

The testing programme, intended to be implemented for thorium fuel development, consists of two main parts:

a) irradiation of experimental fuel rods in our MTR-Triga reactor, to verify the design solution and to investigate the performance limits of this fuel;

b) out-of-pile fuel testing, in our high pressure-high temperature loop, in order to estimate the incidence of apendage wearing, vibrations, water corrosion on fuel performances, especially for extended burn-up type fuel.

3. Material Data and Modelling Activities

The design and performance analysis of thoria based fuel elements need adequate computer codes. Generally, the codes used for UO_2 fuels can be adapted for thoria fuels using appropriate material data and models.

We started by measuring the thermal diffusivity and the elastic properties of pure thoria and thoria-urania mixed oxide of various compositions (Fig.3). The thermal diffusivity measurement using a laser pulse technique gives us results in good agreement with literature data [3].

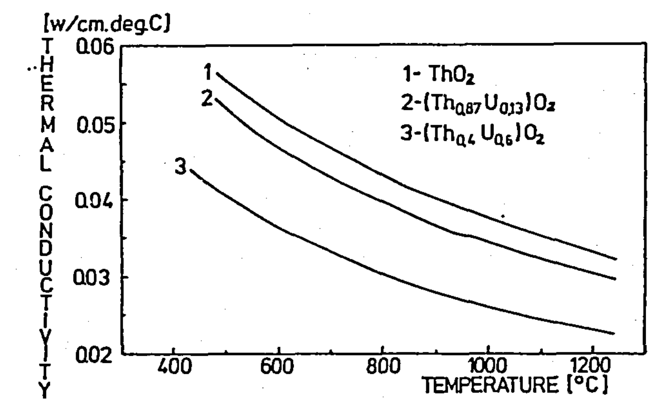

Fig. 3-THERMAL CONDUCTIVITY OF THORIA BASED FUELS

The mechanical properties of thorium fuel have been measured according to a procedure similar to that given by Awaji and Sato [4]. The results of shear stress for diametral compression tests on fuel pellets with different composition are given in Fig. 4.

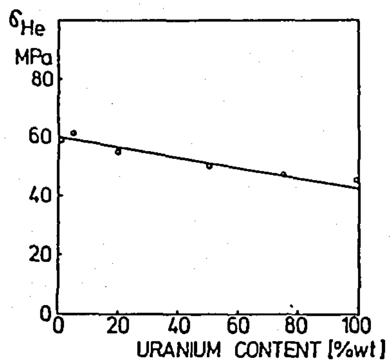

Fig. 4-SHEAR STRESS VERSUS COMPOSITION [DIAMETRAL COMPRESIVE TEST]

As regards modelling, we started with the study of MOX fuel densification, by using out-of-pile tests. The main results are a procedure to characterize the fuel microporosity in quantitative terms before and after the resintering tests, as well as data regarding density increase for pellets with different composition and microstructure. Based on these preliminary results we are testing the suitability of different densification models from literature to thorium fuels.

4. Thorium Dioxide Powder Technology

The ceramic grade thorium powder is obtained via oxalate route starting from pure nitrate solution. This process widely used everywhere has the advantage of producing high sinterable powders with a close control of ceramic quality. The nuclear purification as well as the ThO_2 powder preparation have been integrated with the lanthanides separation in a complex for monasite ore processing. In this way the technological aspects are solved more consistently and efficiently. Due to the increased demand for lanthanides, the thorium oxide resulted as by product in this process has a more convenient price.

5. Mixed Oxide Fuel Technology

The fabrication experience of high density thoria-urania fuel is based mainly on the conventional route of powders mixing, pressing and sintering. To obtain a good mixing of UO_2 (ADU route) and ThO_2 (oxalate route) powders having different bulk densities and morphological characteristics, a dry ball mill equipment has been used. Starting from readily sinterable powders with a good mixing, sound high density pellets (> 96% TD) are obtained. Due to the higher hardness of thoria in comparison with urania, the pressing and grinding of MOX pellets have been performed with other parameters than the uranium ones.

Some technological problems arise when MOX fuels for denaturated thorium fuel cycle are fabricated. At large uranium contents, a careful control of powder grinding and pressing is necessary in order to obtain high density, sound pellets. As shown in Fig. 5, we obtained densities exceeding 96% TD, over the whole composition range [5].

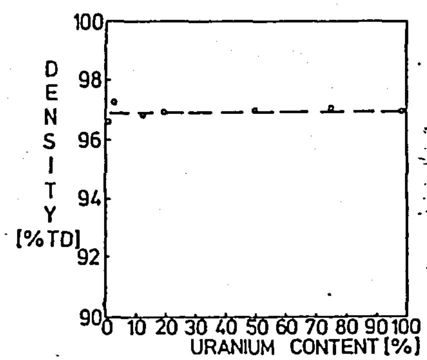

Fig. 5 - SINTERED DENSITY VERSUS URANIUM CONTENT

The quality control procedures used for thorium fuels are generally those used for uranium fuels with small adjustment

The thorium fuel rod manufacturing used only standard procedures for natural uranium fuel (brazing, graphite coatings, resistance end cap welding).

Besides the powders mixing, the other non-conventional technologies: microspheres pressing, impregnation and clay extrusion have been studied at laboratory scale. The preliminary results obtained until now are not sufficiently conclusive to make a selection especially when high density fuels (>96% TD) are to be manufactured.

The future development works in the technological area will be directed towards the preparation of homogeneous mixed oxide powders by coprecipitation or denitration, in order to eliminate as much as possible the dust generating process.

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IRRADIATED FUEL BY-PRODUCT SEPARATION RESEARCH IN CANADA

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Abstract

Although no decision has been made to reprocess irradiated CANDU fuel, by-product separation research has recently been initiated in Canada because of its potential importance to Canadian research programs in advanced fuel cycles (especially U/Pu cycle development in the near term) and nuclear waste management. In addition, separated by-products could have a significant commercial potential. Demonstrated applications include: heat sources, gamma radiation sources, light sources, new materials for production of other useful isotopes, etc.

For illustrative purposes the calculated market value of by-products currently stored in irradiated CANDU fuel is approximately \$210/kgU. Ontario Hydro has initiated a program to study the application of new separation technologies, such as laser-based techniques and the plasma ion cyclotron resonance separation technique, to either augment and/or supplant the chemical extraction methods. The main goal is to develop new, more economical extraction methods in order to increase the magnitude of the advantages resulting from this approach to reprocessing.

1.0 INTRODUCTION

Although no decision has been made in Canada to reprocess irradiated fuel, by-product separation research has recently been initiated because of its potential economic impact on advanced fuel cycles (especially U/Pu cycle development in the near term) and nuclear waste management systems. Ontario Hydro has recently completed a preliminary evaluation of by-product separation in conjunction with fuel reprocessing research. Findings indicate that[1]:

(a) The by-product separation fits well with the current Canadian objective to develop lower cost reprocessing, since any credits obtained via by-product net value would in turn mean lower reprocessing and U/Pu fuel cycle cost.

(b) The by-product separation could have a major favourable impact on the whole waste management system from an economic environmental/safety and technical point of view.