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TRIGA International: A New TRIGA Fuel Fabrication Facility at CERCA

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1 - INTRODUCTION

Since the beginning of CERCA in the early 60's, the company has always be involved in the development and the manufacturing of nearly all kind of nuclear fuel, either for power reactors or for research reactors. Among these developments, we may note that CERCA has worked and been involved in the industrial development of graphite moderated fuel, PWR fuel, HTGR fuel, UAIX and U_3Si_2 fuels for research reactors.

Under the diversity of reactor worldwide, the TRIGA type, which was designed by GENERAL ATOMICS in San Diego (California, USA), has known a very special and important development, mainly among universities. At the time when GENERAL ATOMICS expressed its intention to cease fuel fabrication on its San Diego site, CERCA has been chosen to carry on the fabrication of TRIGA fuel. After negotiations in 1994 and 1995, a 50 % - 50 % partnership was decided, and, in July 1995, a new company was founded, with the name TRIGA INTERNATIONAL SAS, head office in Paris, sales office in San Diego and fuel fabrication facility at CERCA in Romans (France).

The intent of this presentation is, after a short reminder about TRIGA fuel design and fabrication to describe the new facility, with special emphasis on the safety features associated with the modification of existing fabrication buildings.

2 - BRIEF DESCRIPTION OF TRIGA FUEL TYPES

The nuclear fuel used in TRIGA reactors is based on an Uranium/Zirconium alloy with an enrichment in U-235 of 19,75 %, and a mass fraction of U in the alloy varying from 8.5 to 45 %. Additionally the U/Zr alloy is hydrided (a Zirconium hydride is formed) to be in a position to get internal moderation in the fuel, which gives to TRIGA reactors their special safe behavior. Also Erbium is eventually added in small quantities, as a burnable poison, intended to smooth the neutron flux all along the life of the fuel.

Three types of fuel elements, with a nominal 1.5" diameter, are used in the low power reactors: "Standard", "Instrumented", and "Fuel Follower Control Rods". Standard and Instrumented elements are composed of 3 fuel meats and a graphite reflector at each end of the fuel element. Instrumented Fuel Elements have three thermocouples measuring the temperature inside the central meat of the element, and running out of the element via two feedthroughs. The Fuel Follower Control Rods are composed of 3 fuel meats and B4C neutron absorbing rods. The Standard elements may be used individually, or combined in "Fuel Clusters" in case of a TRIGA converted MTR reactor. In the case of more powerful reactors (such as the Romanian reactor and the future Thai reactor), the fuel elements consist of fuel pins (1/2" in diameter) assembled in bundles. For nearly all elements the cladding as well as the end fitting is made of stainless steel.

3 - TRIGA FUEL FABRICATION PROCESS

TRIGA fuel fabrication requires special skills and know-how gained by GENERAL ATOMICS along the years, and which were part of the technology transfer, and special training of CERCA technicians before the closure of San Diego workshop and during the start-up of the fabrication at the CERCA workshop.

3.1. FUEL MEAT FABRICATION

The Uranium/Zirconium alloy is first cast in an induction furnace at high temperature under controlled atmosphere. Prior to casting, all components (Uranium, Zirconium, Erbium, recyclable material) have been carefully weighed and checked by the Quality department.

After fusion of components in a graphite crucible, the bath is poured in a graphite mold and allowed to cool down to room temperature. A second fusion is then performed directly in the mold, to improve the homogeneity and structural quality of the alloy. After cooling, the casting is removed from the mold, the ingots are brought to length and diameter on a lathe to produce the fuel meats, which are then individually identified. After machining, chips are washed and cleaned to be used as recyclable material, and samples are used for chemical analysis.

The meats are then hydrided, for which purpose they are placed in an electrically heated furnace at high temperature under a hydrogen atmosphere. After the completion of the hydriding run, the fuel meats are controlled for quality of hydriding.

A final grinding in a centerless grinder brings the fuel meats to final diameter. After cleaning, they are controlled for surface defects and dimensions, then approved by Quality and stored before being assembled.

In the meats used for Instrumented elements, holes for thermocouples are drilled and the meats are machined to allow the routing of thermocouple leading up to the upper fitting of the element.

3.2. FUEL ELEMENT FABRICATION

Fuel elements are assembled by sliding the fuel meats in the cladding. The graphite reflectors or the thermocouples have to be installed prior to introducing the meats in the element. In the Fuel Follower Control Rods, the B_4C rods and the fuel meats are held at the right position by swaging the cladding in a spacer with magneforming equipment. The end fittings are welded and a Helium leak test is performed to check the tightness of the welds. Finally the elements are controlled for their dimension and a surface contamination measurement is performed.

4 -THE NEW TRIGA WORKSHOP AT CERCA ROMANS

4.1. THE WORKSHOP IN CERCA FACILITY

The new TRIGA workshop at CERCA has been installed in the same building as the MTR fuel workshop, in a section which was previously used by other fabrications no longer supported in Romans.

Prior to beginning of construction, this part of the facility has been freed of all remaining equipment, which had to be disposed of, according to the safety regulations. Walls and ground had to be scraped out and disposed of in containers. After clearance by the Safety Authorities, construction began in August 1995, Civil Work was completed by January 1996. On the US side, packing of all equipment began at San Diego in November 1995 and the containers were delivered at Romans in February 1996.

After completion of the building, all machines were installed between May and July 1996, first tests with depleted Uranium began in July. Finally, the last clearance to allow work with enriched Uranium was granted on October 31 1996, work began shortly after.

Eight cells have been built to be used as TRIGA workshop. They are separated in two areas respectively on the contaminated side (where the U is not cladded), and the non-contaminated side, where only structural materials or cladded fuel material are handled.

4.2 SAFETY FEATURES

Although it was considered as a modification to an existing installation, the new workshop has been built according to the latest safety rules applicable in France. Nuclear safety has been the main guide during the design of the facility. All cells have been constructed with concrete walls and calculated to withstand a maximum hypothetical earthquake in the Romans area.

A new ventilation building, used for the TRIGA and the MTR workshop has been built, and all cells have been equipped with a complete blowing and exhaust system. This system is fail safe by use of emergency blowers. Fire protection has been granted by the use of fire retarding doors, safety valves at each ventilation intake or out take. The general fire detection system has also been extended to TRIGA cells. The amount of burnable material in each cell has been determined and the ventilation and fire protection system has been designed accordingly.

Airborne contamination rejected in the environment during normal operation, and in case of fire or other nuclear accident, has been minimized by use of two stages of absolute filtration in the ventilation filter. These filters and the ventilation system are designed to withstand the maximum temperatures expected during a fire. Explosion risks in the induction furnace, hydriding furnace and grinder fines burning furnace have been evaluated and exhaust systems have been designed to withstand such hypothetical explosion.

The criticality risk has been evaluated, and a complete calculation of fissile material itself (U/Zr/H alloy), storage configuration and working conditions has been performed. One very important point for these criticality calculations is that water is present all along the process (cooling of the furnaces for instance), and on the machines (lathe and grinder). This is very new compared to the MTR (fuel plates) workshop, where almost no water is used in the process. Also the light material (hydrogen) present in the alloy has brought some serious troubles during criticality calculations, and has lead to very restrictive procedures for storage and for quantity of product allowable on the various working stations.

4.3. SAFETY REPORT

To start construction work, a letter of intent describing the main safety options, which were to be described with more detail in the Safety Report, was sent to authorities who in return listed all rules to be followed during the construction of the building. A preliminary Safety Report was necessary to get the operational license. This was written between October and December 1995, and was officially transmitted to the safety authorities at the beginning of January 1996. This report was completed during the first half of 1996 with the seismic and the criticality calculations. Additionally, to the said calculations, the report includes all assessments about contamination, fire hazard and prevention. All procedures have been inspected by French safety authorities. Four inspections have been performed during erection of the buildings and start-up of fabrication.

As of today, the final safety report is under completion; the results of remarks made by safety inspectors during all their visits, and CERCA experience from first fabrications.

5 - TRIGA INTERNATIONAL

The workshop is the property of TRIGA INTERNATIONAL, the JV created 50/50 by GENERAL ATOMICS and CERCA. The contacts with TRIGA customers are mastered by a TRIGA Int. commercial team including experts from GENERAL ATOMICS and CERCA. CERCA has been appointed by TRIGA INTERNATIONAL to operate the workshop. Several teams of CERCA engineers were trained on the GENERAL ATOMICS San Diego site before shut down, to learn about the process, the control and quality procedures, and to prepare packing and reassembly of all fabrication equipment in France. TRIGA fabrications take advantage of CERCA long experience in dealing with all safety and quality procedures.

The Romans site nuclear safety department performs all kind of routine and random inspection in the workshop, and assists the fabrication department in maintaining the highest standard in safety related actions. CERCA is ISO 9002 qualified. Quality assurance department is present at all steps of fabrication, from customer order to delivery. Internal and external audits are performed to regularly check every aspect of the fabrication process. Also, the Quality department is the place where all inspection records are controlled and brought together to make the final Inspection File delivered to the customer with the fuel elements.

After the first runs, performed with depleted Uranium, the first real Uranium casting was made in November 1996. First deliveries have been made to the McClellan reactor and to the JAERI / NSRR reactor in Japan. In the near future, further deliveries should be made to the McClellan reactor and to the Indonesian Bandung reactor.

General Atomics has been Chosen by Thai authorities to be the leader of the new Thai research center, the fabrication of 1/2" fuel pins will be the main goal of the new workshop in the next years.

Mixed Oxide Fuel Testing in the Advanced Test Reactor

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Abstract

In 1997 the Idaho National Engineering and Environmental Laboratory (INEEL) received funding from the Department of Energy to begin a materials testing program in the Advanced Test Reactor (ATR). In this multi-year program, sealed capsules of mixed oxide (MOX) fuel made from weapons-grade plutonium and depleted uranium will be placed in the ATR for irradiation. These tests will determine material interactions of gallium with zircalloy cladding, the impact of using dry-processed plutonium,

and the effect of weapons-grade plutonium isotopics on fuel performance.

Oak Ridge National Laboratory (ORNL) is leading the design of the capsules. Each capsule will contain 3.7 grams of plutonium and 1.26g of U-235. About 26 capsules are expected to be tested over the next 3 years, for a total amount of 96g Pu (3.4 ounces) and 33g U-235 (1.2 ounces). Half of this amount is expected to arrive at the INEEL in October 1997 after shipment from Los Alamos National Laboratory (LANL), where the capsules are being fabricated.

The MOX will be encapsulated in zircalloy at LANL before shipment to Idaho, so at no time is the plutonium expected to migrate outside the capsule. As an additional safety feature, the INEEL will place each capsule into a stainless steel capsule and weld it shut. The capsules will then be placed in the ATR reflector for irradiation of up to 3 years. After irradiation, the sealed capsules will be shipped to ORNL for post-irradiation examination.

These scientific experiments on small quantities of Pu will provide useful materials data for the ultimate disposition of excess weapons-grade plutonium. Thus, the INEEL will provide a useful service in support of the dismantlement of our nations excess nuclear weapons.

RERTR Irradiations of Advanced Fuels in the ATR

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Abstract

The Reduced Enrichment for Research and Test Reactors (RERTR) program has begun to develop very-high-density fuels for use with low-enriched uranium. Our goal is to achieve a uranium density of 8 to 9 g U/cm^3 in the fuel meat of a dispersion fuel plate. This goal appears achievable from a fabrication point of view using as dispersants alloys of uranium and small amounts of other metals. Although pure uranium is a notoriously poor performer under irradiation, several alloys containing molybdenum or zirconium and niobium which maintain uranium in the metastable phase and have uranium densities >15.5 g/cm^3 have shown good irradiation performance in bulk form under fast reactor conditions.

The key issues which must be addressed are the reaction of the fuel alloys with the matrix, both during fabrication and irradiation, and the irradiation behavior of the fuel alloys and of any reaction products.

An irradiation test to screen candidate fuel alloys began in the Advanced Test Reactor (ATR) in August of this year. Because of space limitations in irradiation holes near the core, the fuel plates are very small. They contain elliptical-shaped fuel zones with nominal dimensions of about 50 mm x 9.5 mm x 0.42 mm, which mechanical analyses have shown to be sufficiently large to behave like those in much larger fuel plates. Since the first tests will focus on obtaining basic information about fuel particle-matrix

interactions and fuel particle swelling, we chose to limit the fuel loading to 25 vol.%. Two test rigs are being irradiated--one to ~40% burn-up of ^{235}U and the other to ~80%. The first irradiation will be completed on November 30, 1997, and the second around June 1, 1998.

Fuel plates containing three classes of alloys are being irradiated. The alloys in the first class (U-10.3Mo, U-8.1Mo, U-7.6Nb-2.6Zr, where the alloying additions are in wt.%) are expected to remain in the γ phase (or a phase closely related to the γ phase) during plate fabrication. However, they also have the lowest uranium content. The alloys of the second class (U-6.1Mo, U-5.2 Nb-3.4Zr) have a higher uranium density, but are expected to partially transform during fabrication. Small ternary additions of platinum and ruthenium have been found to be powerful γ stabilizers of U-Mo alloys, so two candidates (U-6.5Mo-1.1Pt, U-6.4Mo-0.52Ru) are being tested. Finally, it has been found that the addition of small amounts of tin and silicon to form intermetallic precipitates has a beneficial effect on swelling, so one such alloy (U-9.5Mo-0.042Sn) is being tested. In addition, several samples containing U_3Si_2 fuel are being irradiated to provide normalization to previous results. Finally, the irradiation behavior of fuel particles produced by mechanical chipping will be compared to that of fuel particles produced by atomization for both U-10Mo and U_3Si_2.

Research Reactor Fuel Transportation: NAC International's Experience and Capabilities

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Abstract

NAC International has experience transporting a variety of research reactor fuel types, both internationally and domestically in legal weight truck casks. NAC owns and operates 16 truck casks of three designs, the NAC-1, the NLI-1/2, and the NAC-LWT. Fuel types transported include MTR, Mark 22, Mark 42, and TRR metallic fuel. NAC is currently developing the ability to transport TRIGA type fuel elements utilizing the NAC-LWT. The majority of the fuel transported has been transferred from its storage location to the shipping cask using Dry Transfer Systems (DTS's) designed, fabricated, and operated by the NAC. MTR type and TRIGA type fuel is of highest interest to most TRTR attendees.

NAC has shipped nearly 1500 MTR fuel assemblies to the Savannah River Site in the NAC-LWT cask. The current licensed capability of the NAC-LWT cask is 42 cut MTR assemblies, or 28 un-cut MTR assemblies. The maximum decay heat of each assembly is 30 watts, with a cask total decay heat load of 1.26 kilowatts. NAC has shipped MTR fuel with a minimum decay time of 90 days. NAC has applied for NRC authorization to ship MTR fuel in the NAC-LWT cask based on a preferential loading of assemblies with decay heats up to 120 watts. NAC received a letter amendment from the NRC to ship MTR fuel from Brookhaven National Laboratory with decay heats of approximately 100 watts.

NAC will apply for NRC authorization to ship TRIGA fuel in the NAC-LWT cask by mid October,

1997. The NAC-LWT will transport up to 140 TRIGA elements, including fuel follower control elements. The maximum decay heat per element is 7.5 watts, and the minimum decay time is 90 days. The NAC-LWT will be capable of transporting failed TRIGA fuel in specially designed failed fuel cans.

The inner cavity of the NAC truck casks is 13 3/8 inch in diameter and approximately 15 feet long. The cask was originally designed to transport LWR fuel. Segmented fuel baskets are used to transport MTR and TRIGA fuel. The baskets, generally 30" to 46" in length, can be transferred to the cask using the NAC MTR Dry Transfer System (MTR DTS). The MTR DTS allows access to facilities with limited crane capacity or limited access clearances. The MTR DTS weighs less than 8 tons loaded, however intermediate shield assemblies have been used to transport fuel from facilities with crane capacities of less than one ton.