INTRODUCTION OF SPANISH IRRADIATED FUEL INSPECTION TECHNOLOGIES IN CHINA

As China quickly develops its nuclear sector with new types of reactors and fuel designs, it also opens opportunities for specialized companies to introduce their products and services in a fast growing market. ENUSA and Tecnatom, both members of the Spanish Nuclear Group for Cooperation (SNGC), are becoming part of this race and have already supplied two SICOM inspection equipment to SNPI, a subsidiary of the CGN group. In 2017 they also provided their first fuel inspection services at a nuclear power plant in China.

INTRODUCTION

ENUSA and Tecnatom jointly developed and hold industrial property rights over the SICOM family of irradiated fuel inspection equipment. The SICOM (Sistema Inspección COMbustible) family currently comprises 10 different equipment (see Figure 1). A singular characteristic of these equipment is their flexibility and modularity, easily adaptable to different types of nuclear power plants. That makes them especially suitable for R&D projects where plant operators intend to obtain information about the performance of the fuel assemblies that have operated in their reactors. On the other hand some of the SICOM equipment have an operational focus as they are capable of detecting leaking fuel rods or fuel assemblies.

The quick expansion of the Chinese nuclear program has offered opportunities for foreign companies to introduce their products and services in the giant Asian country. For ENUSA and Tecnatom, this has resulted in a potential market for advanced inspection equipment, both for fresh and irradiated nuclear fuel.

In this context the China General Nuclear Power Corporation (CGN) and in particular its subsidiary Suzhou Nuclear Power Research Institute (SNPI) identified the SICOM family as their preferred technology for SNPI development of irradiated fuel inspection capabilities. The need for this technology is twofold: on one side SNPI wants to become a fuel inspection service provider for the Chinese fleet of reactors and on the other side the CGN has instructed

Figure 1. SICOM inspection equipment family.

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SNPI to assist in the inspection of the new CGN-developed fuel assemblies, the so-called STEP design, and their associated new cladding alloys. Irradiation of the Lead Test Assemblies (LTA's) is taking place at Ling-Ao NPP in Guangdong province and the first inspection campaigns have been performed with a SICOM-COR equipment manufactured, delivered and operated by ENUSA-Tecnatom.

SUPPLY OF IRRADIATED NUCLEAR FUEL INSPECTION EQUIPMENT

So far two equipment supply projects have been carried out with SNPI, both of them related to the CGN new fuel introduction. In 2014 ENUSA and SNPI signed a contract for the supply of a SICOM-UT equipment for detection of leaking fuel rods within a PWR fuel assembly. The SICOM-UT, which has been already operated by ENUSA-Tecnatom in several nuclear plants, allows for the detection of leaking fuel rods by detecting the presence of water inside the rod by means of the different ultrasonic signal in the leaking fuel rods.

The equipment was successfully manufactured, tested and finally delivered to SNPI in 2015. Given the success of this first project, SNPI, ENUSA and Tecnatom entered into a cooperation agreement in January 2016 for which the Chinese company agreed to introduce in China the inspection technologies developed by the Spanish partners with preference over other existing alternatives in the market. The agreement reinforced the cooperation among the three companies and paved the way for the next important project, the supply of a SICOM-COR equipment.

The demanding requirements of the CGN new fuel introduction program caused that, in addition to the well proven peripheral rods corrosion layer inspection capability of the SICOM-COR, SNPI was in need of a new inspection feature: fuel rod diameter measurement.

Rod diameter is an important parameter when introducing new fuel designs. The behavior of the fuel pellet and fuel cladding under irradiation, their interaction and extent of deformation provide relevant information to the designers. It is also important from the safety point of view since an unexpected behavior could potentially lead to a fuel rod leak.

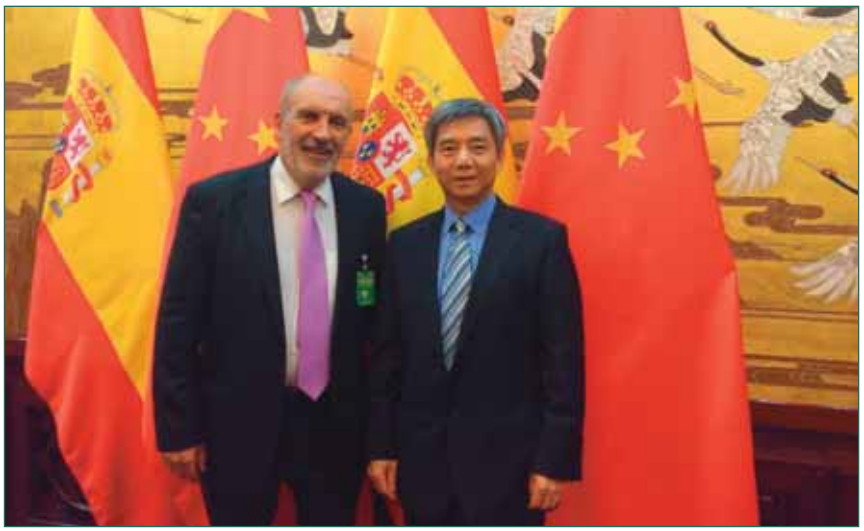

Figure 3. The ENUSA Chairman, José Luis Gonzalez and the CGN CEO He Yu during the signature ceremony of the SICOM-UT contract in Beijing in 2014.

Traditionally fuel rod diameter has been measured by Linear Variable Differential Transformer or LVDT. However taking into account the demanding accuracy requirements from SNPI, it was finally agreed to develop a new measurement technique based on artificial vision. The supply project was hence transformed in a more complex development and supply project and ENUSA and Tecnatom assumed the challenge in line with their declared strategy to keep a permanent technological evolution of the SICOM equipment family

THE UPGRADED SICOM-COR EQUIPMENT

The new SICOM-COR equipment delivered to SNPI is a multi-purpose multi-technique inspection system comprising the following subsystems (see Figure 3):

- µVIS module, for visual inspection of the fuel assembly.
- µDIM module, for peripheral fuel rod diameter measurement by artificial vision.
- Eddy current module, for corrosion layer thickness measurement on peripheral fuel rods.

µDIM and µVIS are the first commercial products resulting from the Tecnatom's DIRAC project for the research and development of metrology techniques applied to the nuclear sector. The purpose of the DIRAC project is to innovate with optical technologies applied in the improvement of critical processes related with nuclear safety.

The µDIM module is the most relevant improvement in the equipment. It consists of a number of lenses with automatic focus, measurement sensors and LED lighting. This module incorporates advanced signal processing systems to compensate for the effect of thermal turbulence around the fuel assembly that might otherwise affect the measurements.

The µVIS module makes use of high definition cameras, highly shielded to withstand the significant radiation fields that can be found in the proximity of the fuel assemblies.

Finally, the eddy current subsystem is the same as in the SICOM-COR equipment in operation in Spain. This features an eddy current probe that is put in contact with the surface of the fuel rod to measure

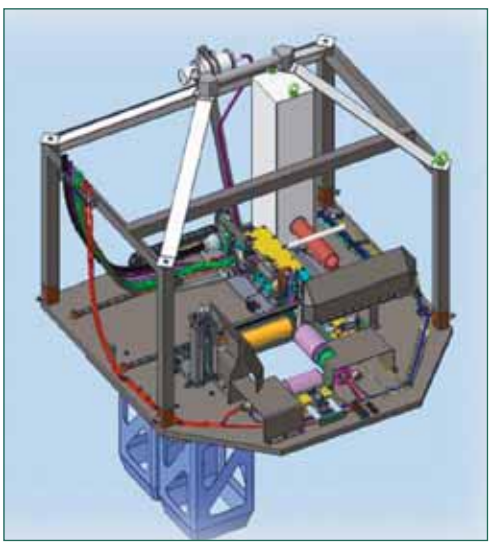

Figure 3. SICOM-COR equipment for SNPI.

the thickness of the corrosion layer.

In addition to the above, the equipment is supplied with a number of corrosion standards specially manufactured and certified at the ENUSA Juzbado facility using cladding tubes provided by SNPI. It has been also necessary to manufacture a dummy fuel assembly for the acceptance tests in Spain and China.

INSPECTION CAMPAIGNS IN CHINA

Two inspection campaigns have been performed at Ling Ao NPP in this 2017 in support of the new fuel development program. In both cases SNPI has requested the cooperation of ENUSA and Tecnatom becoming the first opportunities in which the Spanish companies have provided fuel inspection services in the Chinese nuclear plants.

The first fuel inspection campaign with the new SICOM-COR equipment took place in February 2017. The purpose of this campaign was to test in real conditions – at the Ling Ao spent fuel pool and with a real fuel assembly – the capabilities of the new inspection equipment and to identify potential improvements during its operation. The joint ENUSA-Tecnatom inspection team comprised a crew of experts who gathered relevant experience and knowledge of the practices at Ling Ao NPP.

In April 2017, at the end of the operation cycle, the plant entered into a long outage. The inspection campaign with the SICOM-COR equipment was in the critical path of the reload outage and, in consequence, time limitations made this campaign even more challenging. Four fuel assemblies featuring new cladding materials developed by the CGN group and with a cooling time of only 21 days were to be inspected.

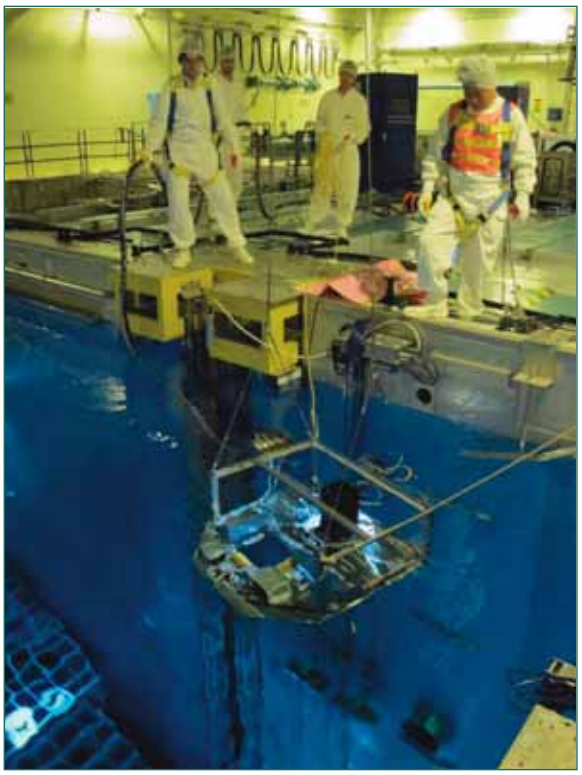

Figure 4. First introduction of the SICOM -COR into the spent fuel pool.

At the end of the inspection campaign, the plant operator has obtained a license from the NNSA, the Chinese regulatory body, to resume operation of the LTA's thanks to the data obtained with the SICOM-COR equipment. Preliminary results from inspection campaigns show good performance of the corrosion measurement system and, at the same time, several improvements were identified in order to increase the performance and efficiency of the system. Those improvements are foreseen for the upcoming months in order to have the equipment ready for the inspection campaign at Ling Ao in the Spring 2018.

FUTURE PLANS

ENUSA and Tecnatom expect that the Chinese market will continue offering opportunities in the field of irradiated fuel inspection as new fuel assembly designs and new reactor types are introduced in China. In this regard the cooperation with SNPI is of the highest importance. SNPI has made an strategic decision when it decided to put its confidence in the technology developed and supplied by the Spanish companies. With two projects successfully completed it is now time to expand this cooperation to the on-site services for supporting the inspection campaigns at the Chinese nuclear power plants and to identify new projects where the SICOM technology can be delivered to satisfy the growing needs of the Chinese reactor fleet. ENUSA and Tecnatom have demonstrated their commitment and ability to take on this challenge and have found on SNPI their best partner to make it a reality.■