XA0201387

SICOM: On-site inspection systems

J.J. Serna*, M. Quecedo* J.R. Fernández**

* ENUSA, Madrid, Spain

** TECNATOM, Madrid, Spain

Abstract

As the irradiation conditions become more demanding for the fuel than in the past, there is a need for surveillance programs to gather in-reactor operating experience. The data obtained in these programs can be used to assess the performance of current fuel designs and the improvements incorporated to the fuel assembly design, the performance of the advanced cladding alloys, etc. In these regards, valuable data is obtained from on-site fuel inspections. These on-site data comprise fuel assembly dimensional data such as length and distortion (tilt, twist and bow) and fuel rod data such as length and oxide thickness.

These data have to be reliable and accurate to be useful thus, demanding a high precision inspection equipment. However, the inspection equipment has to be also robust and flexible enough to operate in the plant spent fuel pool and, sometimes, without interfering in the works carried out during a plant outage.

To meet these requirements, during the past years ENUSA and TECNATOM have developed two on-site inspection systems. While the first system can perform most of the typical measurements in a stand-alone manner thus, without interfering with the critical path of the reload, the second one reduces the inspection time but requires using the plant capabilities.

The paper describes both equipment for fuel on-site inspection, their characteristics and main features.

1. INTRODUCTION

As the irradiation conditions become more demanding for the fuel than in the past, there is a need for surveillance programs to gather in-reactor operating experience. The data obtained in these programs can be used to assess the performance of current fuel designs and the improvements incorporated to the fuel assembly design, the performance of the advanced cladding alloys, etc.

In these regards, valuable data is obtained from on-site fuel inspections. These on-site data typically comprise fuel assembly dimensional data such as length and distortion (tilt, twist and bow) and fuel rod data such as length and oxide thickness.

These data have to be reliable and accurate to be useful thus, demanding a high precision inspection equipment. However, the inspection equipment has to be also robust and flexible enough to operate in the plant spent fuel pool and, sometimes, without interfering in the works carried out during a plant outage.

To meet these requirements, during the past years ENUSA and TECNATOM have developed two on-site inspection systems. While the first system, SICOM, can perform most of the typical measurements in a stand-alone manner thus, without interfering with the critical path of the reload, the second one, SICOM-DIM & SICOM-COR, reduces the inspection time but requires using the plant capabilities.

The paper describes both equipment for fuel on-site inspection, their characteristics and main features.

2. SICOM EQUIPMENT CONFIGURATION

Figure 1 is a general representation of the SICOM equipment. The main parts of the equipment are described in the following sections.

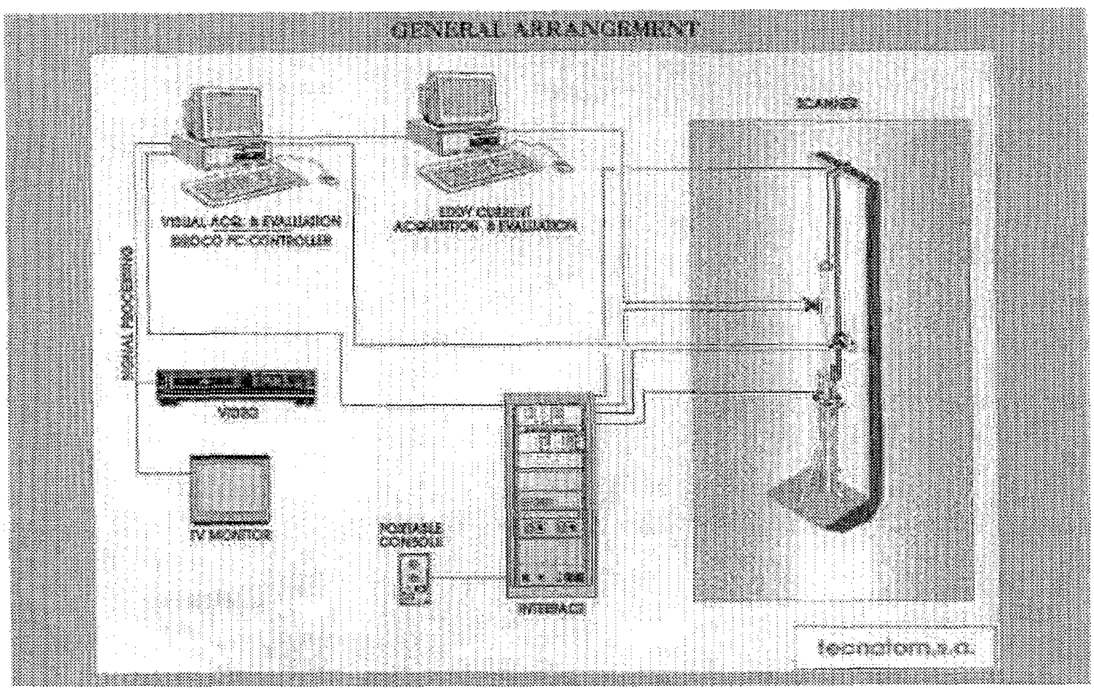

FIGURE 1. Representation of SICOM equipment

2.1. *Mechanical equipment*

Since this equipment must be installed in the spent fuel pool of different nuclear plants, it is necessary to adapt the equipment to fit in the different existing configuration.

Apart from the elements required to fit the equipment to each particular site, the mechanical equipment is designed to safely hold the fuel assembly, make it turn so each face can be inspected, and provide precise axial movement of the inspection modules.

The main sub-assemblies of the mechanical equipment are as follows:

- *Upper anti-seismic assembly:* This assembly, hanging from the rest of the mechanical equipment, is anchored outside the pool and allows the overall assembly to be leveled. It is designed such that SICOM is capable of withstand an earthquake, even in the case a fuel assembly is being inspected at the same time.

- *Mast*: Is hanging from the upper support and rests on the floor of the spent fuel pool. The inspection modules are displaced along its faces via linear guides, rack and pinions.

- *Mast support*: Provides the base to support the equipment on the floor of the pool.

- *Fuel assembly support*: Support and rotates the fuel assemblies in order to line up each face with the inspection modules.

- *Clamp*: Prevents the fuel assembly from falling, ensuring the safety of the assembly during the inspection. The clamp has no contact with the fuel assembly.

- *Displaceable modules*: The function is to transport the eddy current modules, television cameras, lights, etc. to any position along the length of the fuel assembly.

The mechanical equipment is designed and manufactured taking into account the high levels of radiation to which it will be exposed and the fact that it will operate under water.

An overview of the SICOM equipment handling a dummy assembly during the qualification test at TECNATOM is shown in figure 2.

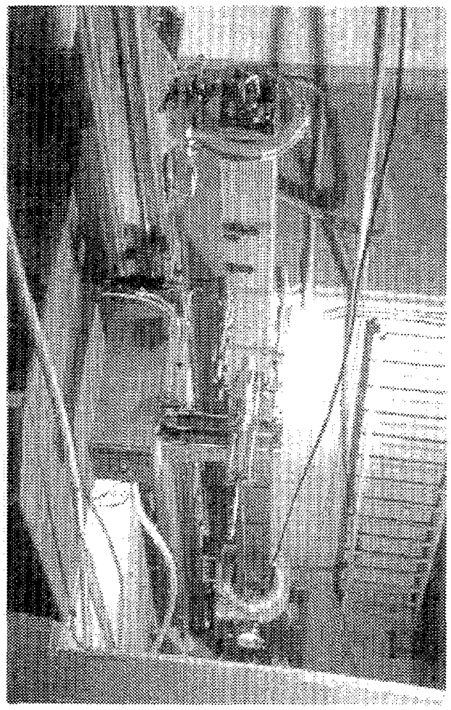

FIGURE 2. General overview of SICOM

2.2. Visual and dimensional inspection system

Dimensional measurement aims to measure variation in overall fuel assemblies geometry, namely that caused by the irradiation induced growth of the components, and the general distortion of the assembly.

The system is made up of an inspection module and the data acquisition, processing and storage equipment. The inspection module, located on the mechanical equipment, includes a radiation-resistant television camera and four spotlights. The acquisition system is made up of a personal computer including a digitizer card and software for image processing and for automatic calculation of the corresponding measurements by means of artificial vision algorithms.

The movements of the mechanical equipment for data acquisition are also automatically programmed from the visual inspection computer, along with those for the corresponding illumination. The SIROCO-PC controller executes the movements and actions generated. All the information from the visual system may be stored in the computer as well as in the video recorder.

A summary of the main characteristics SICOM measures is presented below:

a) Distance between top and bottom nozzles measured in the centre of each face.
b) Length of peripheral rods.
c) The rod-to-nozzle gap of peripheral rods on each nozzle.
d) The gap between rods at the centre of each span.

e) Assembly distortion, that is bow, tilt and twist.
f) Height of the top nozzle springs.
g) Grids width.

The basic method utilised by SICOM system to perform dimensional measurement is as follows:

The camera is positioned at the edge of the characteristics to be measured. The edge co-ordinates are obtained by a digital image processing system that has been previously calibrated using a standard length gage. Then, the camera is moved to the other edge and the co-ordinates will be obtained as above. Finally, the characteristic to be measured is calculated subtracting both co-ordinates. (This method is applied to the b), c), f) and g) measurements from above).

For type a) measurement, the length is calculated as the distance between the upper edge of the bottom nozzle and the lower edge of the upper nozzle adding the nominal bottom nozzle height.

The rod-to-rod gaps, measurement d), are obtained directly with the digital image processing system. Figure 3 is an example of the system while gathering this characteristic.

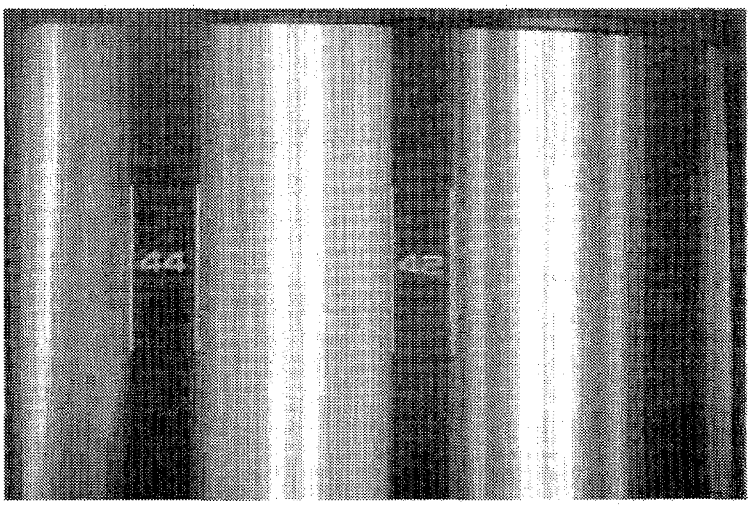

FIGURE 3. Gap between rods

For fuel assembly bow measurement two reference straight lines are drawn along the corresponding corners of the bottom and top nozzles. The horizontal distance between each grid corner edge and the reference line are measured at both corners of the grid. The bow value is determined as the average of the two measurements at each grid.

For tilt evaluation, a vertical reference straight line starting from the bottom nozzle corner edge is established. Then, the tilt would be the distance between the top nozzle edge and the reference line.

For fuel assembly twist the reference is a vertical straight line containing the bottom nozzle edge. The distance between each grid and top nozzle edges and the reference line are measured. Then, the difference between the measurements at both corners of the grid or top nozzle and the reference line gives the twist value.

In addition, the visual inspection system is used to check the general conditions of the fuel assembly (physical integrity, fuel rods, grids, nozzles and springs) and provides detailed visual examination to support, for example, oxide thickness data analysis.

2.3. *Oxide layer measuring system*

Measurement of the oxide layer on the peripheral fuel rods is performed using eddy current techniques based on measuring the separation between the probe in contact with the zirconia (not conductive) and the cladding material (conductive).

The system consists of an inspection module and a data acquisition system for data processing and storage. The inspection module includes the sensor (coil) which moves in constant contact with the fuel rod, and a television camera for observation of sensor coupling. The acquisition system is made up of a personal computer including the eddy current equipment and corresponding specific software. The results of the measurements performed may be displayed on the screen and printed out. Figure 5 shows an example of oxide layer thickness data display.

In order to ensure accurate alignment of the probe tip to the circular surface of the rod, the system counts with three degrees of freedom. Besides, grid collisions are avoided during the inspection thanks to this mechanical design.

The qualification of the equipment includes, apart from laboratory tests, hot cell metallography of irradiated rods with oxide thickness up to 100 μm. The accuracy of the measurement is estimated to be $\pm$ 6 microns.

3. SIMPLIFIED EQUIPMENT

In order to satisfy the utility generic needs such as reduced equipment size, short inspection time, adaptable to different fuel designs, low cost, etc., TECNATOM and ENUSA are developing new on-site inspection equipment.

With this objective two simplified equipment, with capabilities and accuracy comparable to SICOM, have been designed. One equipment is dedicated to the dimensional characterization of the fuel assemblies and a separate one is devoted to the measurement of the oxide thickness in peripheral rods.

As regards the dimensional equipment, SICOM-DIM, the measurements are based on LVDT technology rather than in image analysis as is the case of SICOM. The corrosion equipment, SICOM-COR, uses essentially the same corrosion inspection module than SICOM.

The principal characteristics of these simplified equipment compared to SICOM are:

- Smaller size, lighter.
- Portable. Installation over the spent fuel rack.
- Faster assembling.
- The handling crane supports the fuel assembly during the inspection.
- Reduced inspection time (on line with the reload in the case of the dimensional equipment).

Figure 4 shows a general view of SICOM-COR equipment.

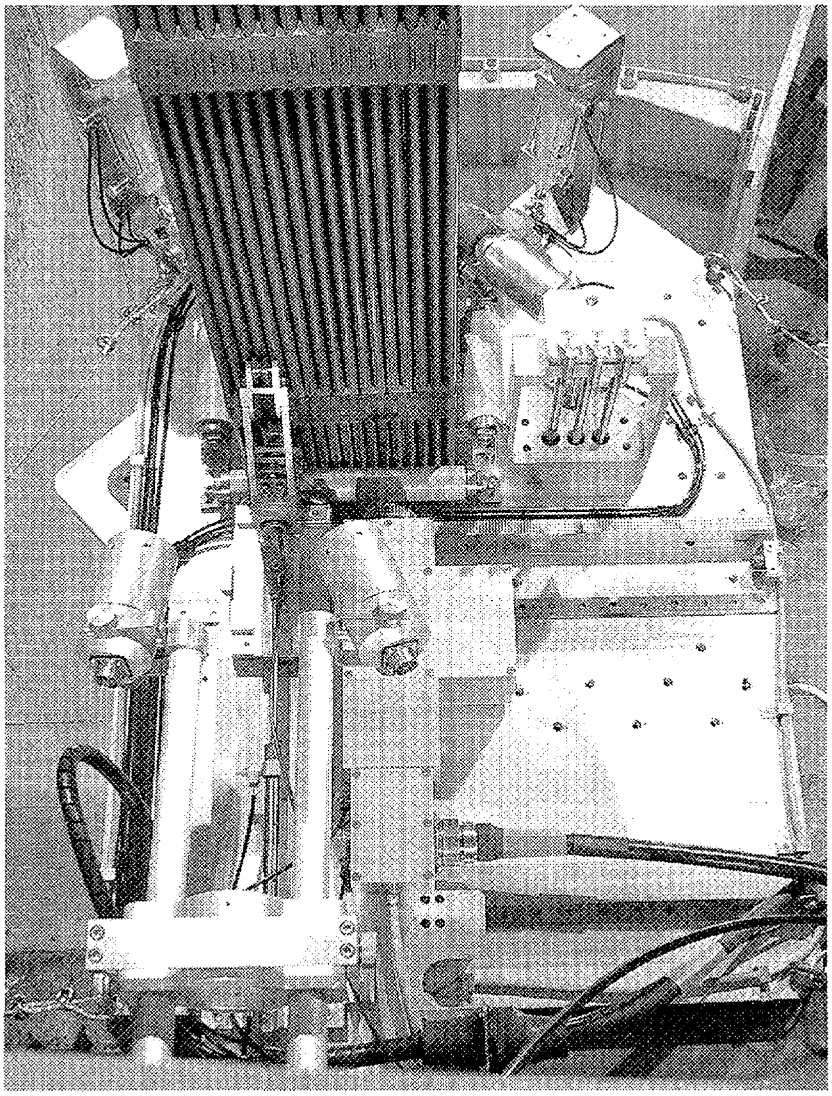

FIGURE 4. SICOM-COR equipment.

4. CONCLUSIONS

SICOM is a state of the art fuel assembly inspection system providing high resolution visual inspection, fuel assembly dimensional characterization and accurate fuel rod oxide thickness measurements.

The development of on-site inspection equipment carried out consists of two types of equipment:

- Stand-alone system, SICOM, whose capabilities includes fuel rod corrosion and fuel assembly dimensional characterization handling safely the fuel assembly.
- Two simplified equipment, SICOM-COR & SICOM-DIM, with the same capabilities show a considerable reduction of the inspection time but requires the use of the handling crane.

Field experience of these equipment includes the exam of more than 300 fuel assemblies and the measurement of the oxide thickness of more than 1500 fuel rods.