THE SPANISH EXPERIENCE ON-LINE FUEL INSPECTION AND REPAIR

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Reactor coolant activity in PWR plants is a limiting operating condition determined in each plant's technical specifications.

The value of this activity limit far exceeds normal operating conditions, even in the event of breaks or cracks in the fuel rods which release fission products to the coolant.

In other words, in order for the limit value to be reached, an extreme situation would have to occur in the fuel, e.g. baffle jetting, rod break, etc., which usually does not happen.

The most common causes of a fuel rod failure are as follows:

- Friction with a foreign particle (debris).
- Secondary hydridation.
- Fractures due to accidents during manipulation.

The first is responsible for approximately 80% of fuel failures or defects.

At any rate, the leak of fission products to the coolant considerably increases general plant activity, as they become trapped in the different plant components and circuits as part of the existing crud, and consequently the total dose received by the plant workers increases at the same rate.

These problems can be solved in many ways: carrying out component and system cleaning and/or decontamination processes; making improvements to reduce the presence of debris in the coolant; and above all eliminating the source of fission products, i.e. failed fuel elements.

Regulatory Agencies in different countries have had and continue to have varying criteria in this respect.

Certain countries such as Germany and Japan do not permit fuel elements with leaks to be reinserted into the core ("zero" leak criterion).

On the other hand, France's criterion is quantitative, as it permits the reinsertion of elements with leaks if the defect's "equivalent" size is lower than a certain value.

The United States and Spain do not impose any criterion, aside from, obviously, the maximum activity limit; therefore, each plant must decide to take the measures that it considers fitting as regards inspection, reinsertion, or possibly repair of the fuel elements.

The existing tendency in almost all plants around the world is to reduce activity increases, and consequently they undertake inspection programs during refueling (visual, sipping or ultrasonic) to determine which of the leaking fuel elements will be stored in the pool when the core is subsequently refueled.

The repair of these failed elements provides some benefits as follows:

- Reduction of coolant activity, as explained above.
- Recovery of the investment in the existing residual fuel in the damaged element.
- Increased storage space in the pool on recovering this element.
- Lastly, savings resulting from elimination of the following:

- The cost of redesigning the core (economic savings).
- Reduction of the new core's useful life (availability savings).

The latter benefit is obtained only if the fuel is repaired on line with the reloading. The Spanish Ascó I and II and Vandellós II power plants have opted for this solution. This article describes their experiences and the inspection and repair processes used.

PROCESS DESCRIPTIONS

ULTRASONIC FUEL INSPECTION

The ultrasonic fuel inspection method was chosen from among the different existing methods (sipping, visual, eddy current, UT, etc.), as it provides the following advantages:

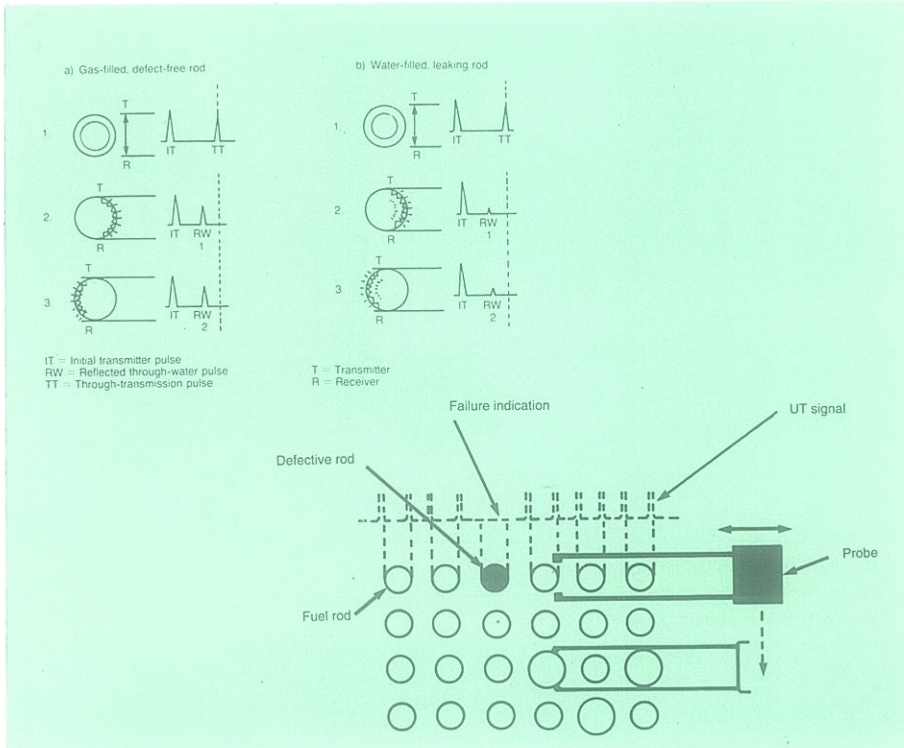
- Localization of the defective rod(s) in the fuel element.
- Very fast inspection (5 min. of inspection and 10 min. of manipulation) of each fuel element.
- The degree of burn-up or pool storage time is irrelevant.
- It is very accurate and reliable.

The chosen system, which was developed by ABB, identifies defects in the fuel rods and detects water inside them. The operating principle is simple:

A flexible probe with two ultrasonic sensors (transmitter and receiver) is moved along each row of fuel rods.
Two ultrasonic signals are recorded for each rod as the probe advances along the rows.
The presence of water inside a rod will cause the received signal to diminish or disappear, which will indicate a failure or defect in the rod (Figure I).
To perform this function, a mounting frame is placed in a certain position over the fuel storage racks.
The watertight manipulator that moves the probe along the rows and columns of the fuel element to be inspected is located on this support, as well as an underwater TV camera that displays the correct location of the fuel element and its inspection by the probe (Figure II).
Electronic cabinets located on the operating deck next to the fuel pool contain the ultrasonic generation and analysis equipment, the probe manipulator control, and the necessary visual recorders (monitors) and graphic recorder (plotter).

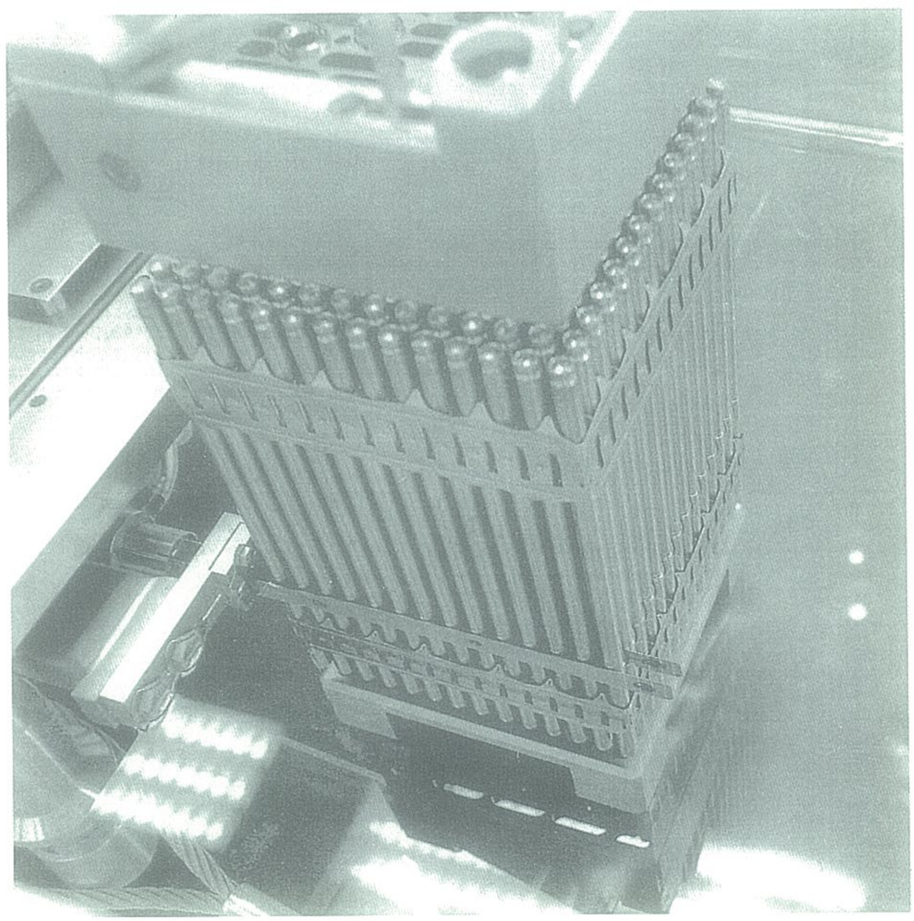
The inspection process is fast and easy:

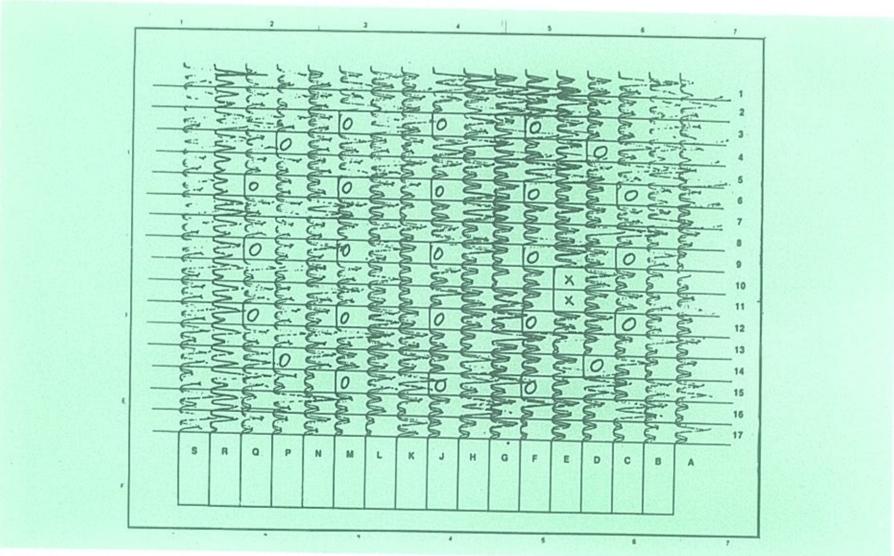
- The fuel element is taken from its pool location, which in the case of refueling is the fuel transfer system upender, and it is correctly positioned on the inspection rack.
- The probe is manually reset and aligned.



F I *UT Inspection Method.*

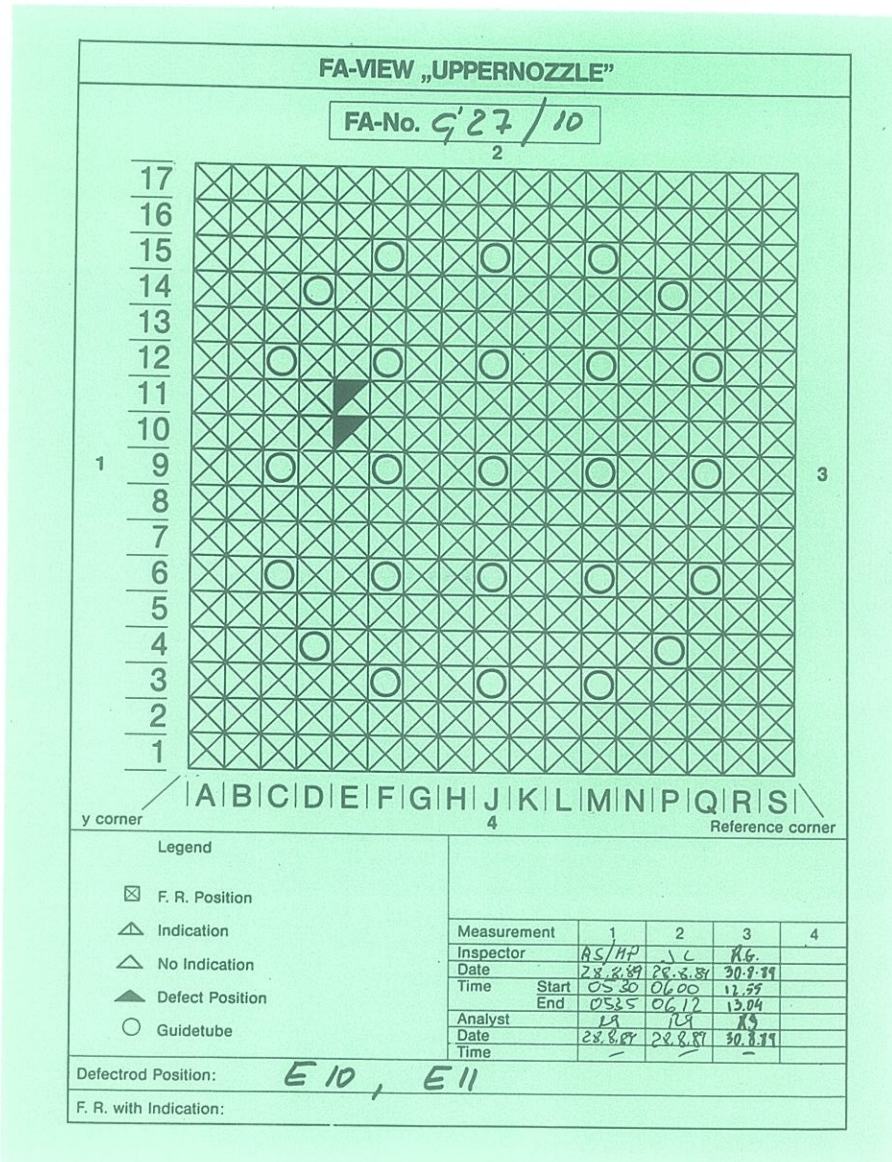
F II *Manipulator and UT Probe*





F III *Fuel Inspection Graphic Example*

F IV *Inspection Summary Sheet*



- All rods are automatically inspected and the data obtained are recorded.
- The graphic results are analyzed.
- The element is reinspected on another face or at another height if there are doubts or suspicions that a defect may exist.
- The element is removed and deposited in the assigned position.

The graphs obtained are subsequently delivered to the customer as part of the service report (Figures III and IV).

FUEL REPAIR

Once a feasibility study was performed for each plant (Ascó and Vandellós) and type of fuel (OFA, standard, etc.), it was determined that the repair process would be carried out using the Multi-Purpose Fuel Repair System (MFRS) and accessing the element through the bottom nozzle.

This MFRS system was designed and built by W to provide fuel repair services. It can access the fuel element either through the top or bottom nozzle depending on the type of fuel or the repair to be made.

American terminology defines two general repair types:

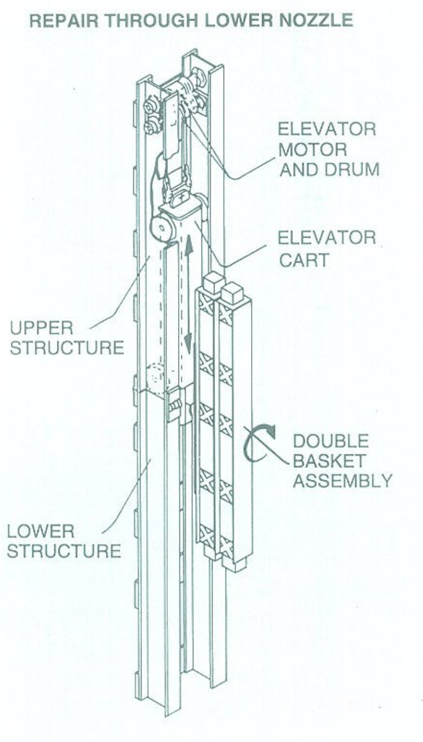
- Reconstitution consists of replacing one or more defective rods with others (low enrichment, stainless steel, etc.), provided that the skeleton is in good condition.
- Reassembly consists of transferring all an element's rods except the defective ones from the damaged skeleton to a new frame.

  There are many causes of damage to a skeleton, but it almost always stems from irreparable damage to the fuel support grids.

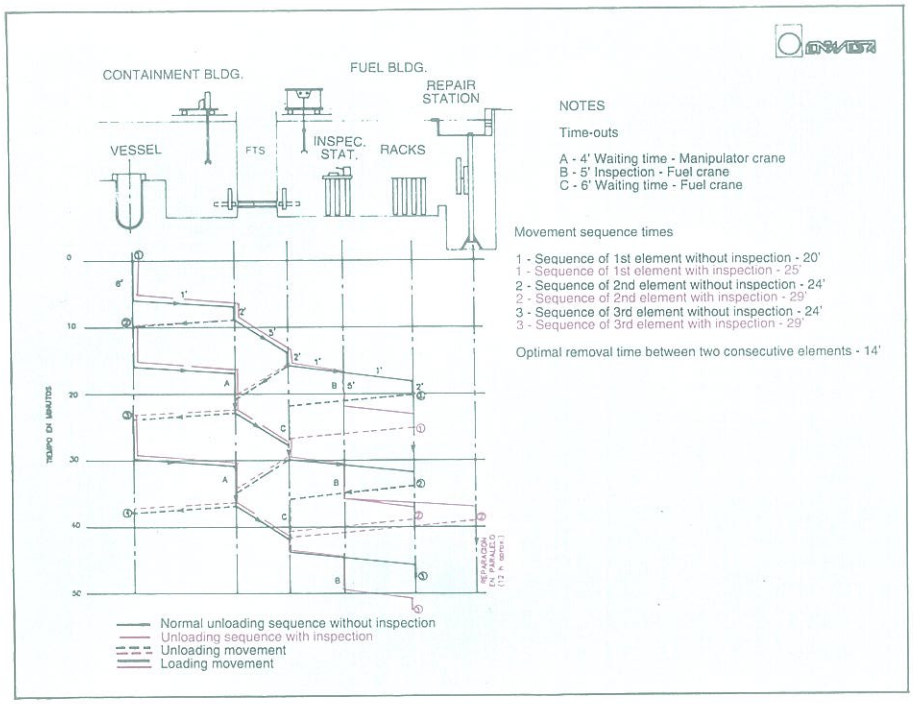
The MFRS system is basically composed of the following components (Figure V):

- A support structure that is hung on the edge or rests on the bottom of the fuel pool.
- A motorized elevator assembly that lifts and lowers a 2-basket assembly, arranged vertically, which serves to properly position the element to be repaired and the new skeleton (in the event of reassembly).
- A set of different tools to disassemble, manipulate and reassemble the element to be repaired.
- A tool to remove, handle and reposition individual fuel rods.
- A defective rod storage basket.
- An underwater display system with different working cameras, magnetoscopes, etc., used to observe, control and record the different process steps.

The fuel element reconstitution process can be summarized as follows:

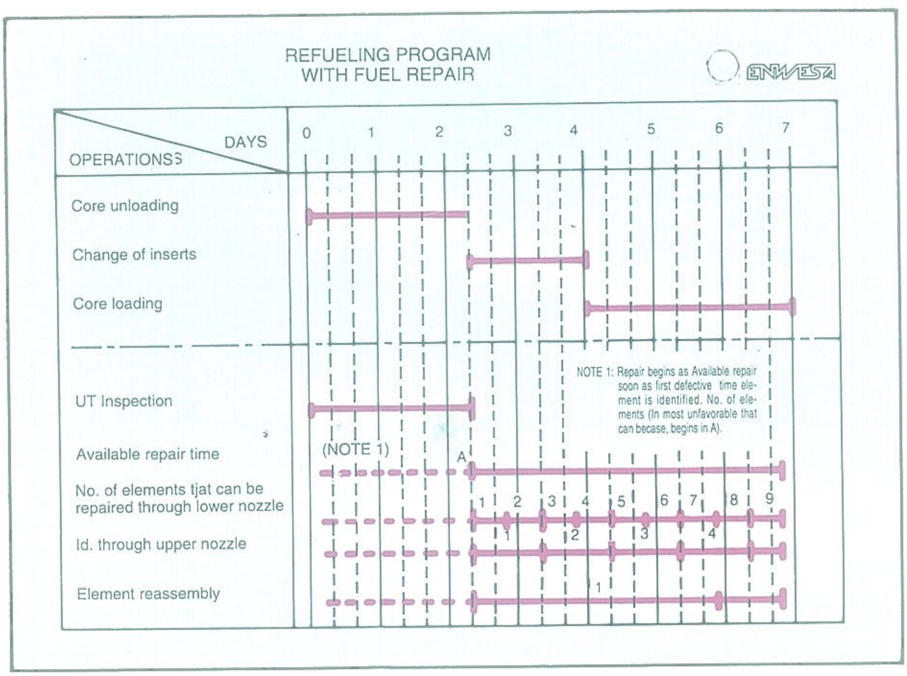


F V *Multi-Purpose Fuel Repair System, MFRS*



F VI *Operating Sequence - Fuel Unloading*

F VII *Fuel Repair Program*



- The leaking element is placed in the outside basket facing in a certain direction.
- The basket with the fuel assembly is lifted and turned, thus providing access to the bottom nozzle.
- The bottom nozzle is disassembled by loosening the screws that attach it to the framework and removed for subsequent reuse.
- The damaged rod(s), previously identified by the ultrasonic inspection, are removed and placed in the storage basket. For this operation, the elevator is lowered to the lowest position.
- If deemed advisable, magnified visual rod inspection is performed to identify the cause and quantify the damage.
- One or more stainless steel rods are inserted to replace the damaged ones.
- The lower nozzle is reassembled and the screws are tightened.
- The basket with fuel assembly is turned and lowered to the lower position.
- The element is removed from the basket and final inspection is performed.

For the reassembly process, the new skeleton is placed in the other basket and the process is performed in the same way, transferring all the damaged element's rods that are in good condition to the new frame.

Logically, all operations will be properly controlled, documented and recorded by underwater camera.

SCHEDULING

As indicated hereinabove, the big advantage of performing fuel inspection and repair is that it can done on line with refueling without causing delays and avoiding the above mentioned costs.

In the feasibility study, the different operations in the fuel unloading process were timed to verify the impact of fuel inspection on the total unloading time (Figure VI).

As shown in the diagram, since inspection takes only a short time to perform (5 minutes), no delays are caused in the total unloading time of each element (15-20 minutes); the critical path in the unloading process is the time spent by the fuel element in the transfer channel.

Once it was verified that inspection was

TOTALS

Year	Plant	Inspected Elements	No. Defects	Rods
89	Vandellós II	157	2	3
Total 89		**157**	**2**	**3**
90	Ascó II	293	4	5
90	Vandellós II	157	3	5
90	Ascó I	377	15	19
Total 90		**827**	**22**	**29**
91	Ascó II	157	2	5
91	Vandellós II	157	3	5
91	Ascó I	157	1	1
Total 91		**471**	**6**	**11**

TOTALS:
- Number of inspected elements: 1,455
- Number of defective elements: 30
- Number of defective rods: 43.

F VIII *Fuel inspection*

TOTALS

Year	Plant	No. Repaired Elements		No. Rods
		Racon	Reassy	
90	Vandellós II	5		8
90	Ascó I	8	1	11 + 264
90	Ascó II	2		2
Total 90		**15**	**1**	**21 + 264**
91	Ascó II	2		6
91	Vandellós II	3		5
91	Ascó I	1		1
Total 91		**6**		**12**

TOTALS:
- Number of repaired elements: 21 + 1
- Number of rods transferred: 33 + 264

F IX *Fuel Repair*

compatible with unloading, the fuel repair program was studied.

The times required for repairing a fuel element vary depending on the element type and repair method, but they can be summarized as follows:

- Reconstitution through lower nozzle: 10 to 12 hours per element.
- Reconstitution through upper nozzle: 20 to 24 hours per element.
- Reassembly (ONLY through lower nozzle): 72 to 84 hours per element.

With these data and on the basis of an optimal refueling program, we would obtain the graph shown in Figure VII.

The results are obvious:

In the most unfavorable case, a total of 9 elements can be reconstituted without interfering with the refueling program. It is extremely rare for this number of defective elements to appear in a single operating cycle, unless caused by something atypical such as baffle jetting. It must be noted that in actual scheduling, some waiting times are scheduled between unloading and loading to core due to maintenance work; they are not reflected in this program because, as mentioned above, it is considered to be an optimal program.

We should also add that inspection equipment assembly and calibration take one day to perform, and three days are required to assemble the repair equipment.

The same times (one day for inspection equipment and three days for repair equipment) are required to dismantle, decontaminate and pack the different components.

We should also mention that the working day usually consists of three 9-hour shifts, with one overlapping hour for inspection as this is an ongoing activity, and one or two 10- or 12-hour shifts for repair, depending on the estimated number of defective elements to be repaired.

EXPERIENCE

The experiences of the Ascó I & II and Vandellós II power plants concerning fuel inspection and repair are shown in Figures VIII and IX.

As we can see, the number of inspected (1,455) and repaired (22) elements is significant enough to demonstrate that the experience has been even more satisfactory than expected, and it confirms that repairs at no time affected the duration of the critical outage path.

Following are the most significant facts of the events to date:

- In its first refueling (1989), the Vandellós II plant performed on-line inspection of the core elements, proving that the prediction that this inspection would not interfere with the critical path was right.
- In 1990, an extensive inspection and repair campaign was carried out in the two units of the Ascó power plant, during which all the elements stored in the pool, plus those from the respective cores, were inspected. This explains the large number of inspected elements: 293 in unit II and 377 in unit I, and a total of 11 repaired in the two units.
- In order to make repairs and on the basis of the feasibility study results, a different special platform had to be built for each plant to secure the MFRS structure at each site. In Ascó it is located at the cask pit, and in Vandellós at the new fuel pool.
- The discrepancy between the number of defective elements (30) and the number of repaired elements (22) is due to the Ascó plant decision not to repair those elements that, due to their nuclear characteristics, are not likely to be reused in future cores.
- All elements stored in the Ascó I and II and Vandellós II plant pools have been inspected, and their condition as regards physical integrity is known.

It should also be noted that these services have been performed jointly by different organizations and companies:

- ENUSA:
  - Component supplier (nozzles, rods, etc.).
  - Supervision and quality assurance services.
- ENWESA:
  - Component supplier (platforms, waste baskets, etc.).
  - Inspection, repair and coordination services for these components.
- W NSD:
  - Repair equipment designer.
  - Repair and consulting services.
- ABB:
  - Inspection equipment designer.
  - Inspection services.

and above all the different plant organizations: Radiological Protection, Quality Assurance, Operations, and especially Nuclear Technology, which was in charge of this work and coordinated and organized all the groups throughout.

CONCLUSIONS

The experience obtained during the course of past inspection and repair campaigns in the Ascó and Vandellós power plants has confirmed that this work can be safely and efficiently performed during refueling without affecting its duration, assuring on one hand that pre-established nuclear designs are not modified and on the other that fission product release to the coolant is reduced, thereby reducing the collective dose to the personnel.