# FUEL HANDLING SYSTEM RENOVATION IN ASCÓ NPP

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## BACKGROUND

Every 18 months, and as a consequence of power operation, one of the units operated by ANAV carries out the replacement of part of the fuel inside the reactor core. This operation, among many other activities, is called "refuelling".

The fuel handling system is the set of equipment and tools that allows handling of fuel (new or spent) and other irradiated components safely and efficiently.

The fuel handling system consists of equipment, tools and structures to carry out a refuelling operation. In this article, we will focus on the following three equipment, which may be considered the main ones in a refuelling operation and which were recently refurbished at Ascó 1 and 2 NPP, and also at Vandellós 2 NPP, by means of an investment project:

### 1. Spent fuel pool bridge and fuel handling hoist:

This is a gantry crane located above the spent fuel pool that has the main function of extracting and inserting fuel elements (spent or new) in each of the positions of the rack of spent fuel pool. The gantry crane is equipped with an electric hoist to perform the movements. Fuel elements are stored temporarily and safely in the spent fuel pool in specially designed racks (Figures 1 & 2).

### 2. Fuel transfer system (FTS):

It is the set of equipment and structures that allows the transfer of a fuel element (new or spent) from the fuel building (spent fuel pool) to the containment building (reactor cavity) and vice versa. The movement of fuel between the two buildings is done through a steel nozzle (linking the two buildings) which is called a transfer tube (Figures 3 & 4).

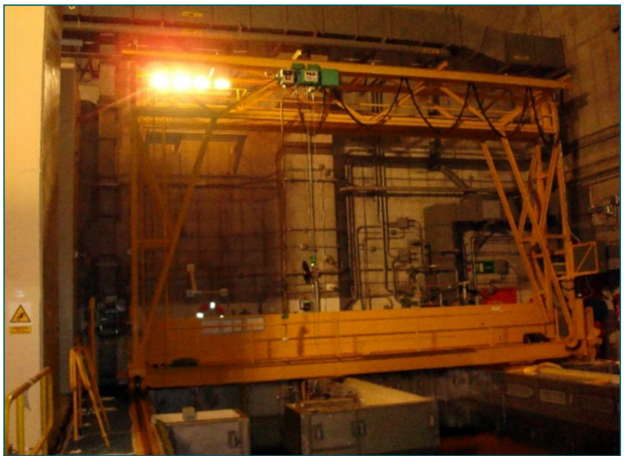


**Figure 1.** Overview of the spent fuel pool bridge.

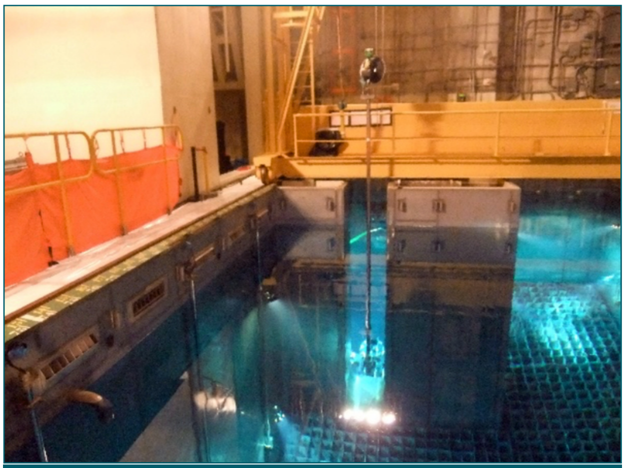


**Figure 2.** Fuel handling hoist over the spent fuel pool.

### 3. Containment fuel manipulator crane:

It is a gantry crane located in the reactor cavity, whose displacement covers the refuelling cavity and moves on rails placed on the edge of the cavity. It allows the removal and

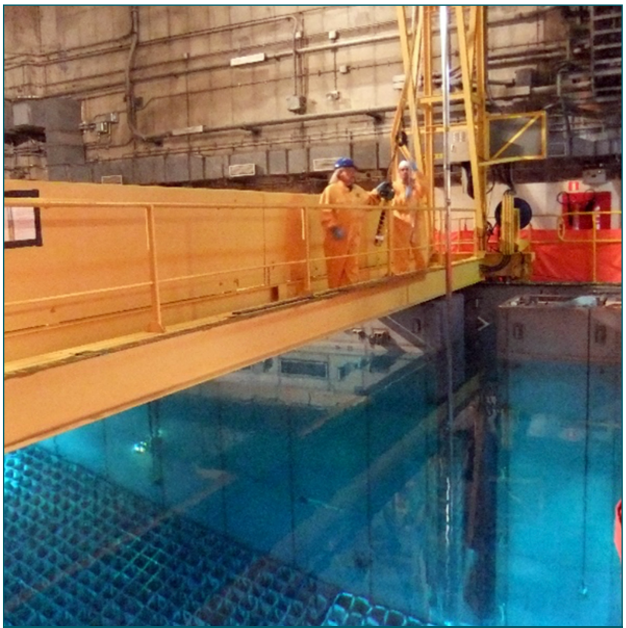


**Figure 3.** View of the access to the transfer tube from the pool.

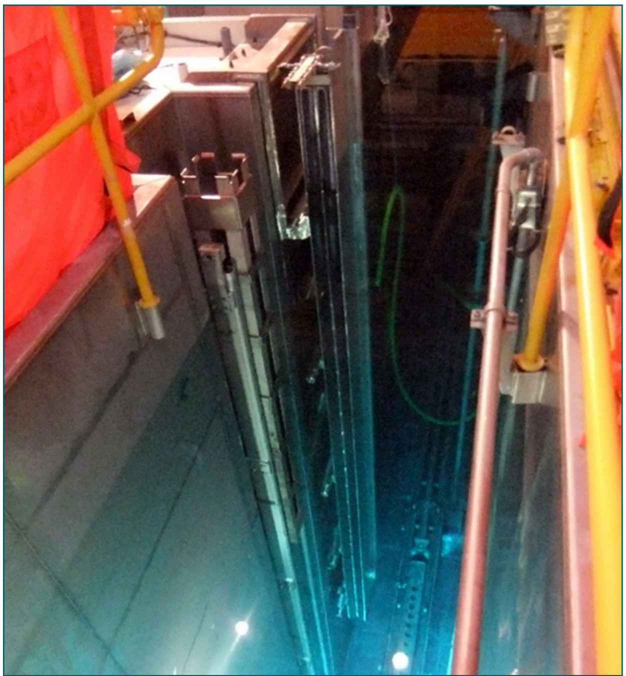


**Figure 4.** Partial view of the inside of the transfer tube.

insertion of the fuel elements (spent or new) into the reactor vessel (Figures 5 & 6).

The above equipment and structures work in a coordinated manner, strictly adhering to a set of restrictions and constraints to ensure that the transfer of fuel is carried out safely.

Fuel movement operations are carried out under borated water. Water provides effective, economical and transparent shielding, as well as a suitable cooling medium.

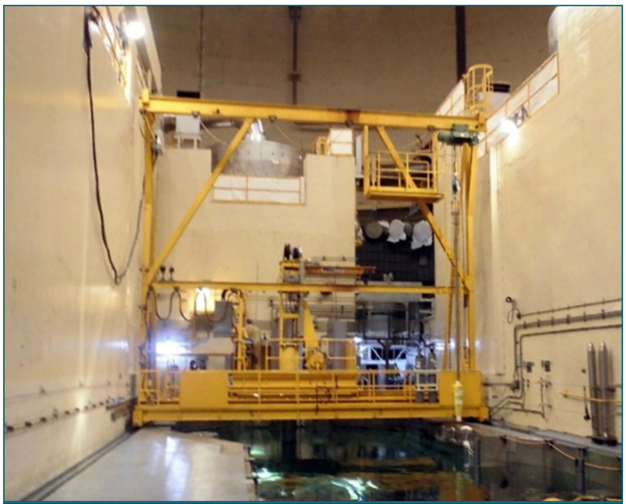


**Figure 5.** Containment fuel manipulator crane overview.

**Figure 6.** Containment manipulator trolley and equipment.

## PROJECT MOTIVATION

At Ascó 1 and 2 NPP, the fuel handling system is of Westinghouse design and was implemented in 1984 and 1986, respectively; it underwent a major upgrade, mainly at the control level, in 2003 and 2004 by means of a design modification.

For some years now, the fuel management system has had some obsolescence and reliability issues with some of its components.

In 2016, an analysis of the fuel management system was carried out in which the main aspects of obsolescence were identified. That same year, based on this report, an investment project was created to provide a solution to the problems identified and, finally, after a bidding process, the project was awarded to the supplier Manserva S.L. This started the project for the partial renewal of the fuel handling system, with the main objective of eliminating the obsolescence of the main components and, where possible, improving their reliability.

The renewal of the fuel management system is not intended to increase performance, nor is it intended to incorporate speed improvements in the transfer system.

## PROJECT SCOPE

The partial renovation of the fuel handling system carried out at Ascó NPP consisted mainly of:

- Replacement of the control system for the spent fuel pool bridge and the fuel handling hoist.

  A new control system has been implemented that centralises all the movements of the gantry crane and the fuel handling hoist in a single electrical cabinet. The fuel handling hoist has been replaced by a fully motorised hoist for both lifting and horizontal movements. Until now, the hoist's horizontal movement was manual using a chain. A new control system has been implemented based on a PLC and frequency drives, which are responsible for managing and controlling the motors, brakes and interlocks of the new system. All the original functionalities, logics and design restrictions have been maintained.

- Replacement of the fuel transfer system control system.

  At Vandellós 2 NPP, a new control system has been implemented that manages all the events of the fuel transfer tube control panels on both sides, the hydraulic control units, which provide pressure to the tumblers, and the control of the trolley transfer cart motor. At Ascó 1 and 2 NPP, this replacement will be carried out during the next refuelling outages (October 2021 and April 2022). The new control is based on an architecture where all events are managed by a PLC. The new system allows for control that is more precise and has a monitoring system that provides real-time process information. Once again, all the original functionalities, logics and design constraints have been maintained.

- Replacement of the control and monitoring system for the containment manipulator crane.

  This is perhaps the most significant modification of the project. The obsolete PLC platform has been replaced with an updated and better performing one. The new system has been designed to integrate with existing field equipment. The electrical cabinets and operator console have been replaced with a new, more compact design and current standard components. The trolley and bridge positioning system has been replaced with an absolute system based on laser telemetry. The reliability and robustness of the weighing system has been improved and the calculation algorithm to determine the optimal trajectory for the transfer of each fuel element has been improved. In addition, improvements have been added to the crane control user interface to facilitate crane operation. As indicated above, all original functionalities, logics and design constraints have been maintained as a minimum.

In addition to these modifications, the project envisages, in parallel, the punctual and progressive replacement of all those components not initially renewed, according to the needs of the system.

**Figure 7.** Overview of spent fuel pool bridge renewed.


**Figure 8.** New control of the fuel transfer system implemented at Vandellós 2 NPP.

## PROJECT DIFFICULTIES

During the project, a number of challenges have been faced that have required specific management and treatment. Some of the main ones, for example, are listed below as our own experience:

- In a project of these characteristics, where partial modifications are made and where original and new components have to coexist, all of them managed by the same control system, it is very important to have an updated collection of drawings and diagrams, as well as all the associated functional documentation. In some cases, detailed drawings of the original fuel handling system have not been available. In other cases, a large collection of general plans has been available, with some reference details from another plant. This fact has made the development of the project difficult in the initial phase, and has implied the performance of additional tasks to compensate for the lack of detail in the initial documentation.

**Figure 9.** TRenovation work on the containment manipulator crane.

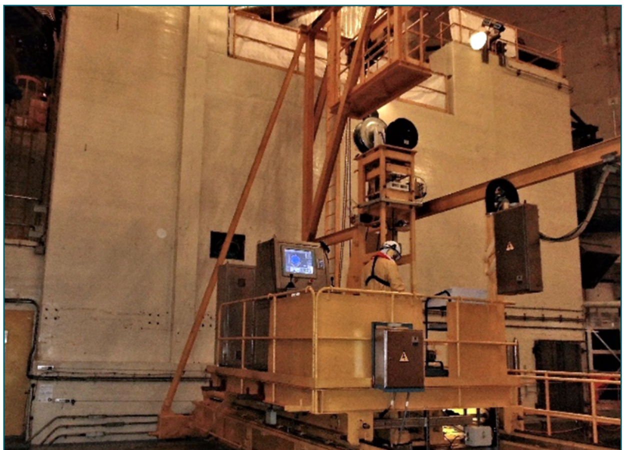


**Figure 10.** Refurbished equipment of the containment manipulator crane.

- Due to the characteristics of the project, only part of the fuel handling equipment has been renewed, mainly the control, which has meant that the new control system has had to be integrated with the current set of actuators, sensors, brakes, etc. Therefore, a coexistence of original components with new components had to be managed, where the compatibility between them had to be checked and guaranteed.
- Decisions had to be made to change the technology in some of the obsolete components or subsystems. For example, the replacement of technology in the positioning system of the containment manipulator crane, where a new system based on laser telemetry technology has been chosen. The incorporation of this new technology has implied a greater effort in validating the components, as it may entail the appearance of new risks, on some occasions difficult to quantify and minimise.
- A new control system has been designed with a new architecture, based on SIEMENS S7, very different from the original architecture, based on MODICON 800 Series. The change of architecture has involved the programming of more than 75 000 lines of code to implement the functionalities and maintain all the original restrictions.
- It was necessary to manage with the *key user* the functionalities to be maintained and those improvements that could be included in a reasonable way, seeking a balance between machine functionality, end-user requirements and development effort.
- A test plan had to be designed to validate the functionality of the new system and the strict compliance with all the original design constraints. The recovery and use of a full-scale model of the containment manipulator crane was very important for this purpose.
- It was necessary to plan and coordinate the best window for the implementation of the new system within a standard outage, without impacting the previously established critical refuelling path. For the implementation of the system in the plant, all possible scenarios had to be analysed, taking into account, among other interferences, the ALARA impact for the workers, this factor added more complexity in the search for the optimal window for carrying out the work.
- During all the development phases of the project, from the beginning of the design to the implementation and start-up, a constant risk management activity has been required, which has evolved throughout the various stages of the project, with the aim of identifying and minimising all the potential difficulties that could generate deviations and impact on the execution of the project.

Each of these difficulties, in addition to those intrinsic to the development of the project itself, compliance and commitments to supplier deadlines, purchase and delivery of equipment, etc., have hindered progress and have posed a challenge for the fulfilment of the project's objectives.

## PROJECT INNOVATION

Given the new features available in current technology equipment, during the design and development of the new fuel management system control system, while maintaining the original functionalities and design constraints, a number of improvements that could be considered innovative have been considered and implemented. Some examples are shown below:

- Positioning system for the trolley and bridge of the redundant containment manipulator, based on laser telemetry. It is an absolute, very accurate and robust system. In case of loss of a telemeter, the system is able to continue the fuel handling movement without interference.
- Reliability and robustness of the control system that can recover and continue where it was in the event of total loss of power.
- The new system has the ability to configure the core and cavity geometry as well as the guide pins, and is able to avoid impacts even when operating in manual mode.
- Real-time calculation of trajectories and approaches to the core based on the actual core configuration. The way of executing the unloading/loading steps of an element is not predefined. The new control system is able to evaluate in real time, for each element and depending on the core situation, the best trajectory and approach to be made to the final position of the fuel element.
- The fuel handling hoist of the spent fuel pool bridge has a speed span management implemented during the lifting/lowering of an element above its position in the spent fuel pool, which ensures that the lowest speed is always maintained depending on the span where the element is located.

## PROJECT IMPLEMENTATION

One of the important points in any project of this type is to determine when and how the work is to be carried out in the plant. Two possible scenarios were available for the implementation of the indicated modifications.

In both scenarios modifications to the spent fuel pool bridge and elements of the transfer system, fuel building side, were planned before the start of the target refuelling.

Thus, the scenarios were as follows:

1. Implement and commission in a single refuel (R1), as follows,
    - In *R1 refuelling*, after fuel discharge is completed, with no fuel in the core: modifications to the containment manipulator crane and elements of the fuel transfer system, containment building side.
    - Before the start of refuelling: functional testing, validation and commissioning of the new system.

With this scenario, the unloading of fuel takes place with half of the system refurbished, and the refuelling takes place with the system fully refurbished.

2. Implementation in two refuelling, as follows,
    - *R1 Refuelling - Implementation phase:*
        - On completion of R1 refuelling, after closure of the vessel lid: modifications to the containment manipulator crane and elements of the fuel transfer system, containment building side.
    - *R2 Refuelling - Functional testing and commissioning phase:*
        - Prior to the start of fuel unloading: functional testing, validation and commissioning of the new system.
        - Fuel unloading is already carried out with the system fully refurbished.


**Figure 11.** Transfer of the Mock-up of the containment manipulator.

**Figure 12.** Mock-up updated and ready for testing.

Figure 13. Manipulator console (mock-up).

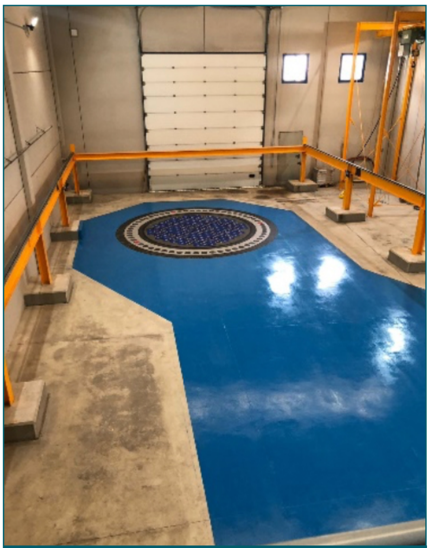
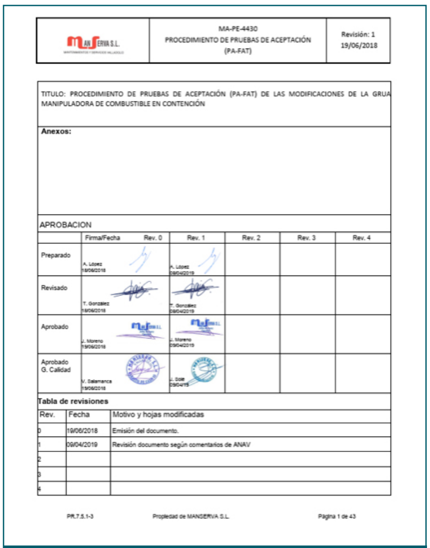


Figure 14. Reactor cavity simulation.



| MANSERVA S.L. | MA-PE-4430 PROCEDIMIENTO DE PRUEBAS DE ACEPTACIÓN (PA-FAT) | Revisión: 1 19/06/2018 |
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TITULO: PROCEDIMIENTO DE PRUEBAS DE ACEPTACIÓN (PA-FAT) DE LAS MODIFICACIONES DE LA GRUA MANIPULADORA DE COMBUSTIBLE EN CONTENCIÓN

**Anexos:**

APROBACION

| | Firma/Fecha Rev. 0 | Rev. 1 | Rev. 2 | Rev. 3 | Rev. 4 |
|---|---|---|---|---|---|
| Preparado | A. López 18/06/2018 | A. López 08/04/2019 | | | |
| Revisado | T. González 18/06/2018 | T. González 08/04/2019 | | | |
| Aprobado | J. Moreno 19/06/2018 | J. Moreno 09/04/2019 | | | |
| Aprobado G. Calidad | V. Salamanca 19/06/2018 | J. Sole 09/04/19 | | | |

**Tabla de revisiones**

| Rev. | Fecha | Motivo y hojas modificadas |
|---|---|---|
| 0 | 19/06/2018 | Emisión del documento. |
| 1 | 09/04/2019 | Revisión documento según comentarios de ANAV |
| 2 | | |
| 3 | | |
| 4 | | |

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Figure 15. Example of FAT test procedure.

Finally, taking into account work interference criteria, the appearance of unexpected emerging correctives, potential critical path impacts and operational dose reduction considerations (ALARA), after analysing all the factors and risks, it was decided to carry out a two-refuelling implementation.

In all three ANAV groups, the implementation of the modifications to the fuel management system has been successfully carried out following the strategy of two refuelling per group.

## PROJECT KEYS

The following aspects can be considered key to the achievement of the project's objectives:

- Recovery of the full-scale mock-up of the containment manipulator crane, which was moved to a new location, refurbished and made ready for testing.
- Performance of a very comprehensive FAT (*factory acceptance test*) test suite using the full-scale mock-up installation.
- Use of design techniques based on system and element modelling, which has allowed more flexibility and precision in the development of the final solution. To this end, it was important to carry out several rounds of refuelling prior to the start of the design, in order to document, measure and analyse the elements and the operation of the fuel management system.
- Creation of a team that brought together experience in fuel handling systems and knowledge of current tools and technologies. We were able to count on the advice and support of one of the engineers who participated in the design and implementation of the original handling crane.
- Involvement in all phases of the project of the main user of the fuel management system to clarify doubts, ensure functionalities and guarantee restrictions.
- Planning and coordination of all implementation activities of the new system within a standard recharge taking into account all required support and departments involved.

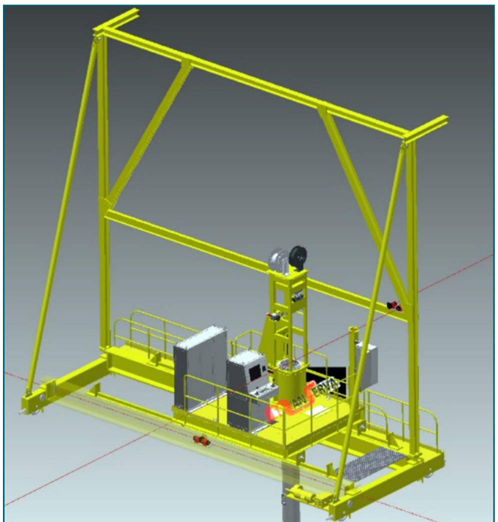

Figure 16. Containment manipulator crane 3D Model.

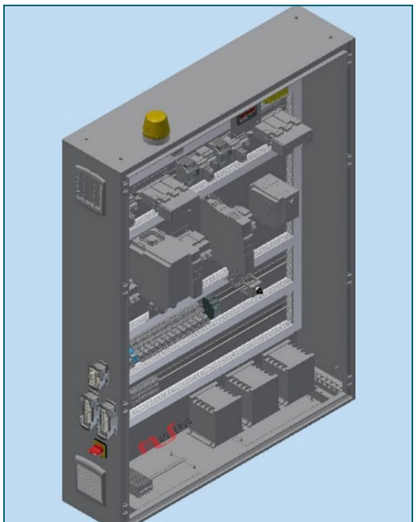

Figure 17. Spent fuel pool bridge electrical cabinet Model 3D.

## PROJECT CONCLUSIONS

At Ascó 1 NPP, the system was implemented satisfactorily during refuelling outage 1R26 (October 2018), although there were some difficulties with the transfer system during fuel unloading (not related to the project). In the following refuelling 1R27 (April 2020) the functional testing, validation and commissioning of the fully refurbished system was performed. The commissioning was also not without difficulties with the transfer system that impacted the critical refuelling path.

**Figure 18.** Carrying out work on the containment manipulator.

At Ascó 2 NPP, the system was successfully implemented during refuelling outage 2R25 (April 2019). During the following refuelling outage 2R26 (October 2020), the functional tests, validation and start-up of the completely renewed system were performed. The commissioning took place without relevant incidents, fully meeting the expectations of the new system.

At both Ascó NPP sites the implementation of the new fuel transfer system control system is pending, a system already implemented at Vandellós 2 NPP with satisfactory results.

With the investment project in place, it can be stated that

- the problems of obsolescence of the main components of the fuel handling system have been eliminated,
- the accuracy and reliability of the fuel management system has been improved,
- the positioning and weighing systems of the fuel handling system have improved, and improvements have been made to the control system and the user interface.