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From 1970 to 1985 worked from AUXIESA IIngeniería Española, S.A. (INITEC) in the design and construction of Nuclear and Thermal Power Stations.
From 1985 till the present working for Empresa Nacional de Electricidad, S.A. (ENDESA). While at ENDESA, he has worked in several areas:
- Maintenance and Operation of Thermal Power Stations.
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OVERALL PROBLEMS OF THE CRDM NOZZLES OF RPV HEADS IN SPANISH PWR UNITS: STRATEGIC REASONS FOR A GLOBAL SOLUTION

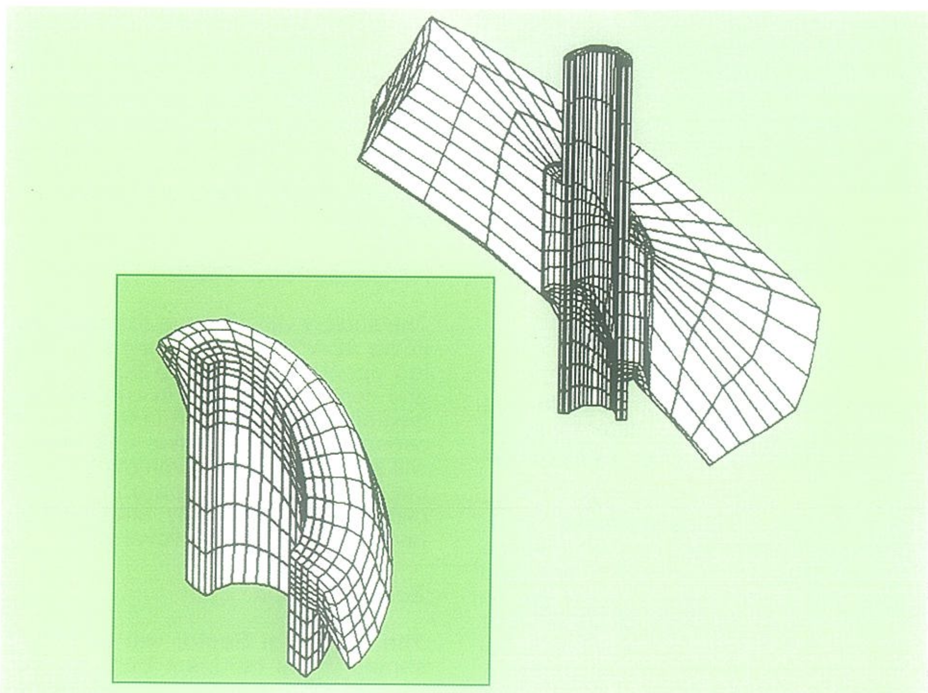
R. TRUJILLO

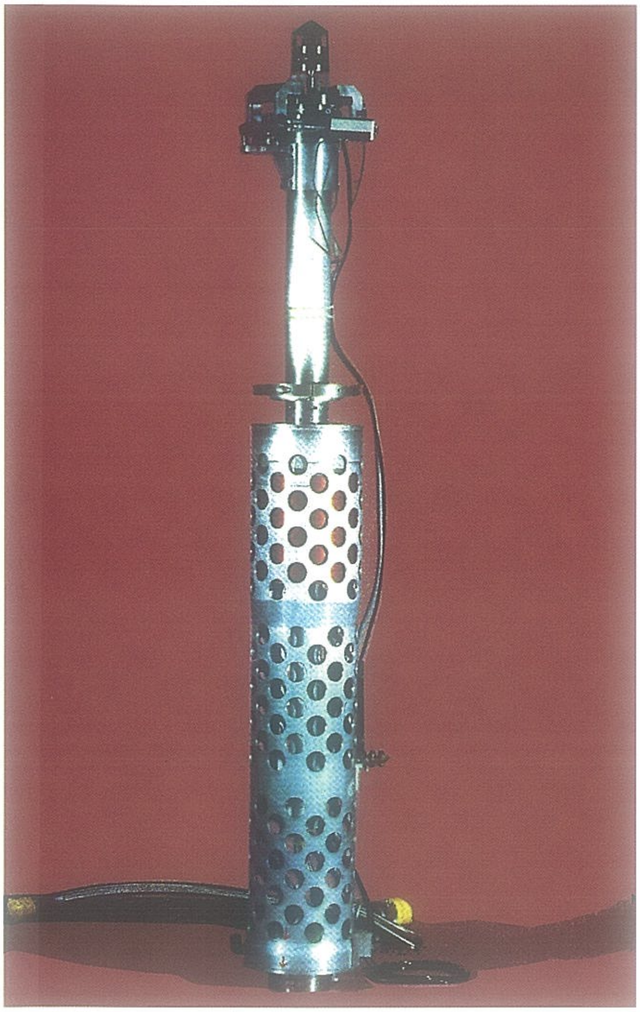
INTRODUCTION

The first indication of cracking of control rod penetrations in PWR reactor closure heads was discovered at the Bugey 3 plant (France) in September 1991. This was originally considered to be an isolated phenomenon until cracking was detected in the penetrations of the closure head at Ringhals 2 (Sweden) in May 1992. The problem was thereafter considered to be generic and to affect all penetrations manufactured using Inconel 600. This problem has been defined as one of primary water stress corrosion cracking (PWSCC).
In July 1992, the Spanish Nuclear Safety Council (CSN) requested the country's nuclear power plants to provide preliminary information on the situation and on their actions plans. Following submittal to the CSN of a study on the susceptibility of the Spanish plants, an inspection was required of the Ascó I and Almaraz I plants during their refuelling outage that same year.

The situation on the international market at that time for response to the problem was one of a single company qualified for the performance of inspections and another capable of carrying out certain types of repairs but without the possibility of acting beyond its national frontiers. No overall global capacity to respond, including inspections and, if necessary, repairs, existed on the market.

FI - *Threedimensional Modeling of a Penetration*





F II - *Tool for penetrations without thermal sleeve inspections*

THE PETAVA PROJECT

In view of this situation, the Spanish Electric Sector represented by ENDESA, initiated the PETAVA Project in April 1993, in conjunction with three Spanish service companies (TECNATOM, S.A.,Equipos Nucleares, S.A., and ENWESA) and a research center (CIEMAT), with participation by the country's PWR nuclear power plants. The PETAVA Project was aimed at promoting performance of PWR reactor vessel closure head penetration inspections and repairs at national level, with the following objectives:

1. Studies of the causes and mechanisms of degradation

The scope of this study included determination by CIEMAT of the susceptibility of Inconel 600 to primary side stress corrosion cracking and the acquisition of data on crack growth rate.
In order to determine the susceptibility of Inconel 600, crack initiation tests were performed using ovalized test pieces in primary water at a temperature of 360° C and steam at 400° C.
The crack growth rate tests were performed using Inconel 600 and Inconel 182 weld material in primary water at a temperature of 325° C.
The stress intensity factor values obtained as a result of the above for crack growth rate in Inconel 600 were between 29 and 39 Mpa $\sqrt{m}$. The data obtained are somewhat smaller than those provided by the Scott curve. The crack growth rates obtained for Inconel 182 are similar to those obtained for Inconel 600.

2. Establishment of defect acceptance criteria.

In order to meet this objective TECNATOM has carried out various studies by means of three-dimensional penetration models (developed using the finite elements method), fig.I, with a view to gaining insight into the stress distributions that might give rise to axial and circumferential cracks, which was contrasted with experimental measurements, X-ray and blind holes. Subsequently, through the incorporation of growth rate data, acceptance criteria were determined.

3. Development of inspection techniques and procedures by means of non-destructive testing (NDT) techniques for the detection and dimensioning of defects in penetrations, with or without thermal sleeve.

Given that the penetrations are difficult to access, have various different configurations and a high level of radiation, it was necessary to use automatic, remotely controlled systems (or tools) for their inspection, these being specially developed.

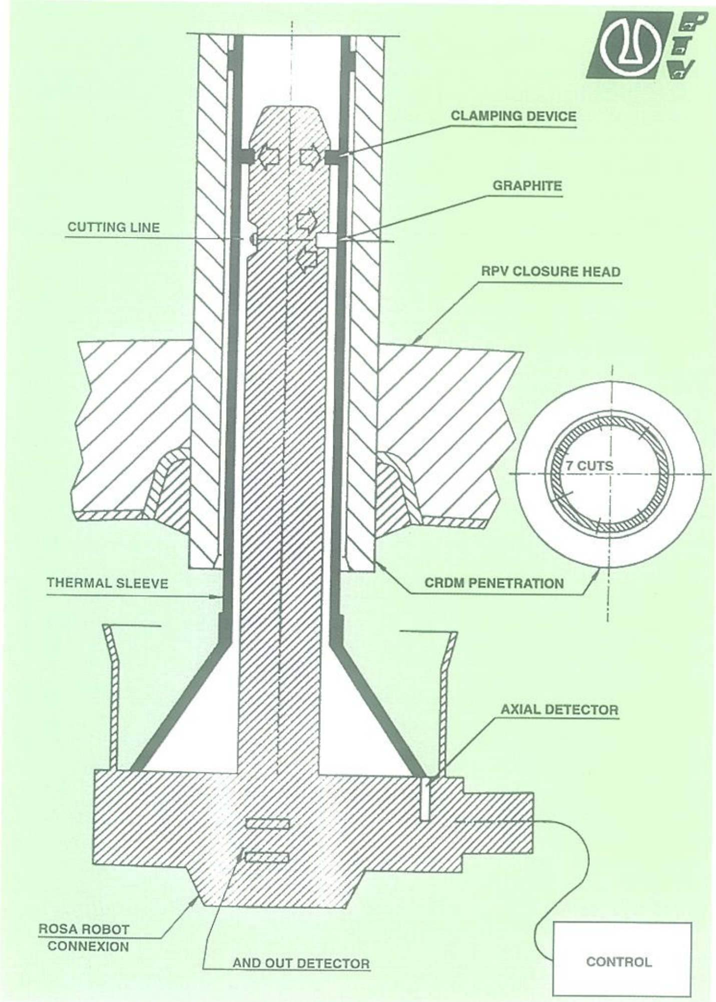
In order to obtain all the data required to determine the degree of deterioration experienced by these components, it was necessary to develop complementary techniques allowing the maximum possible information to be obtained and with the highest possible degree of accuracy. The techniques developed for this purpose were Eddy Currents (EC), used for defect location and length dimensioning: Ultrasonics (UT), used for dimensioning in depth: and Penetrant Liquids (PT) and Visual Inspection (VT) for characterization of defects and determination of their morphology.
With regard to inspection tools and techniques, TECNATOM has developed a motorized tool for penetrations without thermal sleeve, which is coupled to the robot-operated positioning system. In addition, to this tool it is possible to couple different probe holders to carry out the inspections with EC, UT and VT techniques, fig. II. For PT various simpler tools have also been developed.
As regards penetrations with thermal sleeve, another tool (which it is based on Sabre equipment of Framatome) has been developed allowing EC inspections to be performed without the need for this element to be cut. This is accomplished by using a small sensor (less than 2 mm in thickness) which is inserted via the gap existing between the thermal sleeve and the penetration (this gap measuring approximately 3 mm). A "comb" type scan is then performed to cover the entire area of interest.
A qualification process was performed for each of the inspection techniques, initially on a mock-up and subsequently validated under actual conditions at the operating Nuclear Power Plants.

4. Development of repair techniques and procedures.

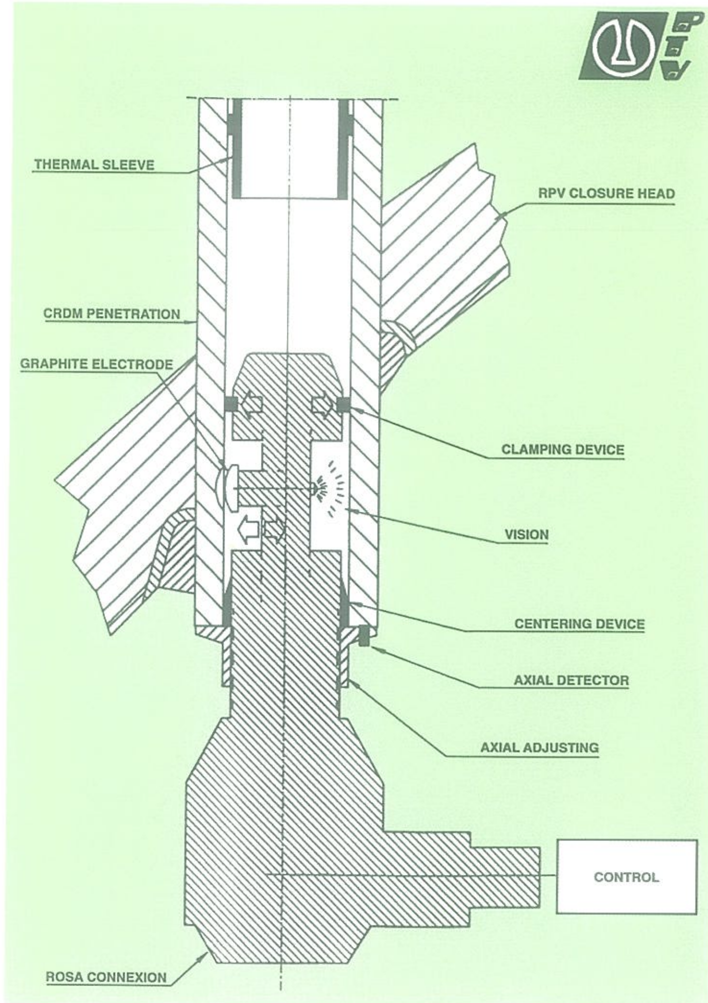
The following techniques were developed by Equipos Nucleares, S. A., in the framework of the PETAVA Project:

- Cutting of thermal sleeves (fig. III).
- Weld edge preparation of the upper part of the sleeves.
- Cleaning of the edges.
- Removal of the cracks by excavation (fig. IV).
- Weld overlay repair of the excavation.
- Thermal sleeve replacement weld.

These techniques were developed by designing, constructing and testing one special tool for each technique, the associated procedures and procedure qualification tests.
The cutting of the thermal sleeve by electrodisintegration was developed to be used as a prior operation to allow access for the ultrasonic characterization of the defect when the dimensioning of the defect by eddy current requires such operation. The sleeve must also be cut if removal of the defect is required, to provide access to the excavating tool head.
The weld edge preparation and excavation tools are based on electroerosion techniques to reach a



F III *- Thermal sleeve - Cutting tool*



F IV *- Tool for defect grooving*

good surface finish, particularly in the case of the excavation where L.P. and U.T. inspection need to be performed. The thermal sleeve reconstruction and overlay repair welds are performed by TIG heads, qualified according to the ASME code.
The cutting technique has been validated in Zorita RPV head where 5 sleeves were cut. The other techniques have been validated on a real scale mock-up, where at the same time optimization tests have been carried out. Irradiated material has been used in the tests for a better simulation of the real conditions.
All the techniques are applied by the robotic arm and fixtures common to all tools of the PETAVA Project.

5. Robotization of all applications.

The robot-operated system used for positioning of the inspection and repair tools was the so-called ROSA III, this consisting of an articulated arm having six degrees of freedom, a work station from which the operator remotely controls all the operations, and the controllers required to supply hydraulic, pneumatic and electrical power to the arm and communicate with the work station. An independent audiovisual system displays the images captured by four TV cameras to the operator.
The developments made within the PETAVA Project by ENWESA, to adapt the robot to the specific problems of the penetrations consisted of designing a software package providing the following functions:

- Definition of the geometry of the surrounding area and the position of the penetrations (different at each plant).
- Calibration of the position of the robot with respect to each of the heads.
- Allowing tools to be loaded and unloaded by extending the arm to the external part of the biological shield.

6. Validation at the plants.

The techniques and equipment developed within the framework of PETAVA were validated at the beginning of the year at the operating Nuclear Power Plants, in order to check and demonstrate their efficiency. Previously qualification process was carried out on a scale 1:1 mock-up of a reactor vessel head. Detection techniques were validated at the Almaraz and Ascó NPP's. Subsequently on the Jose Cabrera plant, UT dimensioning and PT characterization techniques were validated, along with thermal sleeve cutting tools.

7. Experience.

Given the reliability of the techniques and tools developed, as demonstrated during validation, inspections were performed at various other plants: Almaraz II, Jose Cabrera, Ascó II and Vandellós II, with optimum results being achieved. A total 54 penetrations with thermal sleeve and 45 without were inspected using EC techniques, 21 were inspected by means of UT techniques and four thermal sleeves were cut. (See Table I).
In view of the defects which have appeared at the José Cabrera NPP, and as required by the CSN the inspections had to cover 100%

length to the bimetallic weld of all the penetrations without thermal sleeve, since defects were detected above the penetration-closure head weld.

On average, the levels of performance achieved during EC inspections allowed penetrations fitted with thermal sleeve to be inspected in about 2 hours, those not having thermal sleeve being completed in 0.5 hours.

The collective dose received at those Nuclear Power Plants at which interventions were performed were completely acceptable and lower than the optimum values estimated by the most optimistic forecasts.

T I

PWR SPANISH POWER PLANTS INSPECTED BY PETAVA

REACTOR VESSEL HEAD PENETRATIONS INSPECTION RESULTS ON PWSCC

Insp. Date	Plant	Hours of Operation	Head Temp (°C)	Total N° of Penetrations		Inspected Penetrations	
				with sleeve	without sleeve	with sleeve	without sleeve
2/94	ALMARAZ II	81.355	319	57*	8	14	8**
3/94	ASCÓ II	61.464	321	52	13	7	13**
5/94	VANDELLÓS II	47.730	313/292	52	13	16	4**

REACTOR VESSEL HEAD PENETRATIONS INSPECTION RESULTS ON IGASCC

Insp. Date	Plant	Hours of Operation	Head Temp (°C)	Total N° of Penetrations		Inspected Penetrations	
				with sleeve	without sleeve	with sleeve	without sleeve
2/94	JOSÉCABRERA	173.000	294	17	20	17	20**

5 Penetrations with part length.* * Full length inspected by E.C.*

CONCLUSIONS

In summary, the interventions performed have demonstrated the reliability of the equipment developed and the technical and coordination capacity of the participating companies. The developments have also allowed the following to be achieved:

- Availability of domestic technology.
- More solid bases for decision taking.
- Greater reliability in planning of inspections.
- Positioning of the participating companies on the national and international markets.

The PETAVA Project has been the quickest response by the Spanish Electricity Sector to difficult problems posed by PWR nuclear power plants for which no global solution existed.