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MIR : AN IN-SERVICE INSPECTION DEVICE FOR SUPERPHENIX 1 VESSELS

ASTY, M.; CECCATO, S.; LERAT, B.; VIARD, J.
CEA CEN Saclay, 91-Gif-sur-Yvette (France). IRDI, DMECN

SAGLIO, R. Intercontrole, 94-Rungis (France)

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M. ASTY[x], S. CECCATO[x], B. LERAT[x], R. SAGLIO[xx], J. VIARD[x]

x CENTRE D'ETUDES NUCLEAIRES DE SACLAY
91191 GIF-sur-YVETTE, CEDEX France

xx INTERCONTROLE, Place VAUBAN, SILIC 433
94583 RUNGIS, CEDEX France

ABSTRACT

The main and safety vessels of SUPERPHENIX 1 were designed to allow in-service inspections. The remote controlled inspection device MIR was developed for this purpose. It allows both visual and ultrasonic examinations to be performed.

Basically, MIR consists of a tetrahedral structure provided with four steering and traction wheels, two for each vessel. A computer assisted control system enables it to be driven to any position on either the main or safety vessels.

Operating conditions are briefly reviewed and the main features of MIR presented.

INTRODUCTION

Although no in-service inspection contraints were imposed on the Phenix vessels, a Research and Development program has been initiated to monitor throughout the lifetime of the reactor, surface and internal defects on the main and safety vessels of Superphenix 1. The pool design of the reactor and the presence of heat baffles inside the main vessel make access from the inside of the vessel impossible. Thus, in-service inspection can only be performed from the outside of the main vessel : the distance between the walls of the main and safety vessels is such that an inspection device can be introduced into the corresponding space. Moreover, as the design of the reactor precludes radiographic inspection, the method which was selected for monitoring internal defects in the main vessel is ultrasonics. However, the anisotropic structure of austenitic stainless steel welds limits the performance of this technique.

OPERATING CONDITIONS

In-service inspections take place during fuel handling operations when the temperature of the main vessel is 180°C and that of the safety vessel 120°C. Both vessels are made of stainless steel plates, 25 to 60 mm thick for the main vessel and 25 to 30 mm thick for the safety vessel. They are both suspended from the slab (figure 1) which is provided with 12 oval shaped holes (440 x 770 mm).

A thermal barrier on the upper part of the vessels insures an adequate insulation from the water-cooled slab ; the thermal barrier on which the inspection device must not apply any force is equiped with corresponding holes. The distance between the walls of both vessels during fuel handling operations varies between 620 and 700 mm. The intervessel space is filled with nitrogen gas.

Thus, the in-service inspection device must first go across the slab and thermal barrier through a 440 x 700 mm oval shaped hole and then expand to the distance between the vessels which varies from place to place.

DESCRIPTION OF MIR

The in-service inspection device, MIR (Module d'Inspection pour réacteurs Rapides) consists of :

- a four-wheel drive vehicle provided with inspection equipment,
- a winch and penetration shaft extending from the thermal barrier up to a level several meters higher than the slab,
- a composite cable for the electrical and fluid supplies and a steel cable,
- a computer assisted control system.

Design criteria

Most of the design criteria adopted have resulted out of safety considerations, the most obvious of which being that it must be possible to extract the vehicle, even under emergency conditions. As it is not possible to permanently install a rail system even over the surface of the safety vessel, the inspection device must be able to move autonomously and to identify and track welds on the vessels. It is necessary that all the materials used to construct the inspection device or to operate in conjunction with it must be compatible with the reactor.

Description of the vehicle

The vehicle consists of a central structure about which four arms are articulated, two longitudinal arms and two side arms (figure 2). The motion of the side arms which is controlled via a connecting rod, is only used for spreading out the vehicle when it emerges from the penetration shaft. The movements of the longitudinal arms are interconnected via toothed segments. These arms enable the vehicle to go across the penetration shaft and to adapt to variations in the intervessel separation. A traction and rotation actuator is attached to the end of each arm together with the corresponding encoders.

The spreading-out and suspension functions are actuated by gas jacks which are connected is series through a distributor : thus the vehicle is spreaded out before a suspension pressure is exerted.

The spreading-out jack, which is of the double action type, is normally used to fold up the device. For obvious safety reasons, its failure cannot impede or render impossible the withdrawal of the vehicle from the intervessel space. An emergency extraction equipment is actuated by a steel cable which is also used for introducing the folded up vehicle down to the thermal barrier. This cable is maintained taut during the normal operation of the vehicle.

Each actuator is provided with a fuse device which decouples the wheel from the traction shaft : should a motor fail, it is possible to raise the vehicle up to the penetration shaft, using the three remaining motors.

Position identification and directional control of the vehicle

The general design of the vehicle enables it to move anywhere in the intervessel space. Several devices either on the reactor vessels or on the vehicle itself have been developed in order to identify its position and to control its direction in the intervessel space.

The safety vessel is provided with a large number of reference marks which are engraved on its walls and coded. These marks are aligned with the projections of the welded seams of the main vessel and with the welded seams of the safety vessel itself. The distance between two marks engraved consecutively along a weld is about 500 mm. A total of about 12 000 characters (letters and numbers) were punched (with a ball punch) onto the wall. These reference marks are visualized by the inspection television camera along with the corresponding area of the welded seam of the main vessel.

The vehicle itself is provided with several sensing elements enabling its position and orientation in the intervessel space to be determined. An accurate and complete determination of its orientation is obtained by means of three inclinometers.

An encoding device measures the length of welded seam which has been examined. Together with the inclinometers, it gives the position of the vehicle (altitude and longitude) in the intervessel space. The servo-control of the vehicle along a welded seam makes use of the difference in magnetic properties between the weld metal and the parent plate.

Non Destructive Examination equipment

It is located at the front of the vehicle (figure 2) and enables visual and ultrasonic examination to be performed.

A television camera housed in an insulated enclosure is used for visual examination purposes. It is cooled by a nitrogen gas flux which is evacuated into the intervessel space. A prism enables the camera to visualize both vessels at the same time : reference points engraved on the safety vessel are associated with the image of the weld on the main vessel. In this way a reference is obtained for the position of the device in the intervessel space.

A second camera designated "navigation camera" is fixed to the longitudinal forearm of the vehicle. This camera assures the safety of the vehicle's movements in the intervessel space. Both cameras are of a standard type (2/3" vidicon tube, 625 line definition), their originality being their compactness.

Focussed ultrasonic probes are located in a special enclosure fitted with a gasket allowing immersion technique examination. A scanning motion parallel to the longitudinal axis of the vehicle enables the entire examination of the welded joints. 45° and 70° longitudinal waves are used for butt welds examination, while the core support structure weld of the main vessel is examined using 0° and 35° longitudinal waves. The acoustic coupling is assured by Gilotherm RD liquid. Temperature tests have confirmed the compatibility of this liquid with the reactor. Its vapor pressure is such that it can be eliminated after control.

Winch and penetration shaft

Because of the high density of components on the reactor slab, it was necessary to locate the cable winding winch at about 6 m above slab level. This winch simultaneously ensures the winding and unwinding of both the drive cable and the umbilical cord. The umbilical cord part is constructed in such a way that no rotating electrical contact is used.

The winch is supported by the penetration shaft which is seated on the slab. This shaft is divided into two parts : a lower oval shaped part extending from the upper face of the slab down to the thermal barrier in the intervessel space and an upper rectangular shaped part extending from the slab up to the winch. The lower part assures an efficient guiding of the vehicle when it is folded up and prevents straining the thermal barrier.

Computer assisted control

A large number of functions need to be simultaneously assured and monitored. Only a computer assisted servosystem is capable of safely piloting the MIR (vehicle and peripherals). The main characteristics of the system adopted after a detailed analysis of the operating conditions (normal, incidental, accidental) are as follows :

- the power control is located next to the winch, while the measurement and control part is situated in a shelter outside the reactor building,

- under normal operating conditions, the transmission of the measurements and control signals is assured by a double digital line (for redundancy purposes) which is permanently monitored by the computer. Only absolutely necessary measurements are displayed. However, all measurements are monitored by the computer which provides a complete diagnostic once a threshold is exceeded. This monitoring is extented to the data transmission line as well as to the computer itself ("guard dog"),

- a scale model of the system representing the vehicle and its orientation in the intervessel space is available to the operator,

- in the case of a simple failure to the most critical components, the computer makes the proper connections with the components still available,

- in the case of failure of computerized elements or a complex breakdown of the device, an emergency (analog) transmission system enables the vehicle to be extracted from the intervessel space.

CONCLUSION

In order that non destructive examination could be performed on the main and safety vessels welds of SUPERPHENIX 1, a specific in-service inspection equipment, MIR, was developed. Successful tests were performed on various mock-ups, including tests at the operating temperature in a full scale mock-up of a portion of the intervessel space. During its first operation on the reactor site (march 1985) MIR has proved its ability to move in the intervessel space. At the time of its first on-site operation, vibrations had appeared on the inner vessel structure of Super Phenix 1. Using its ultrasonic transducers, MIR was able to give an absolute measurements of the amplitude of vibration with an accuracy of 0.5 mm. A slight modification of the hydraulic conditions on some fuel elements was sufficient to master this phenomenon which no longer exists.

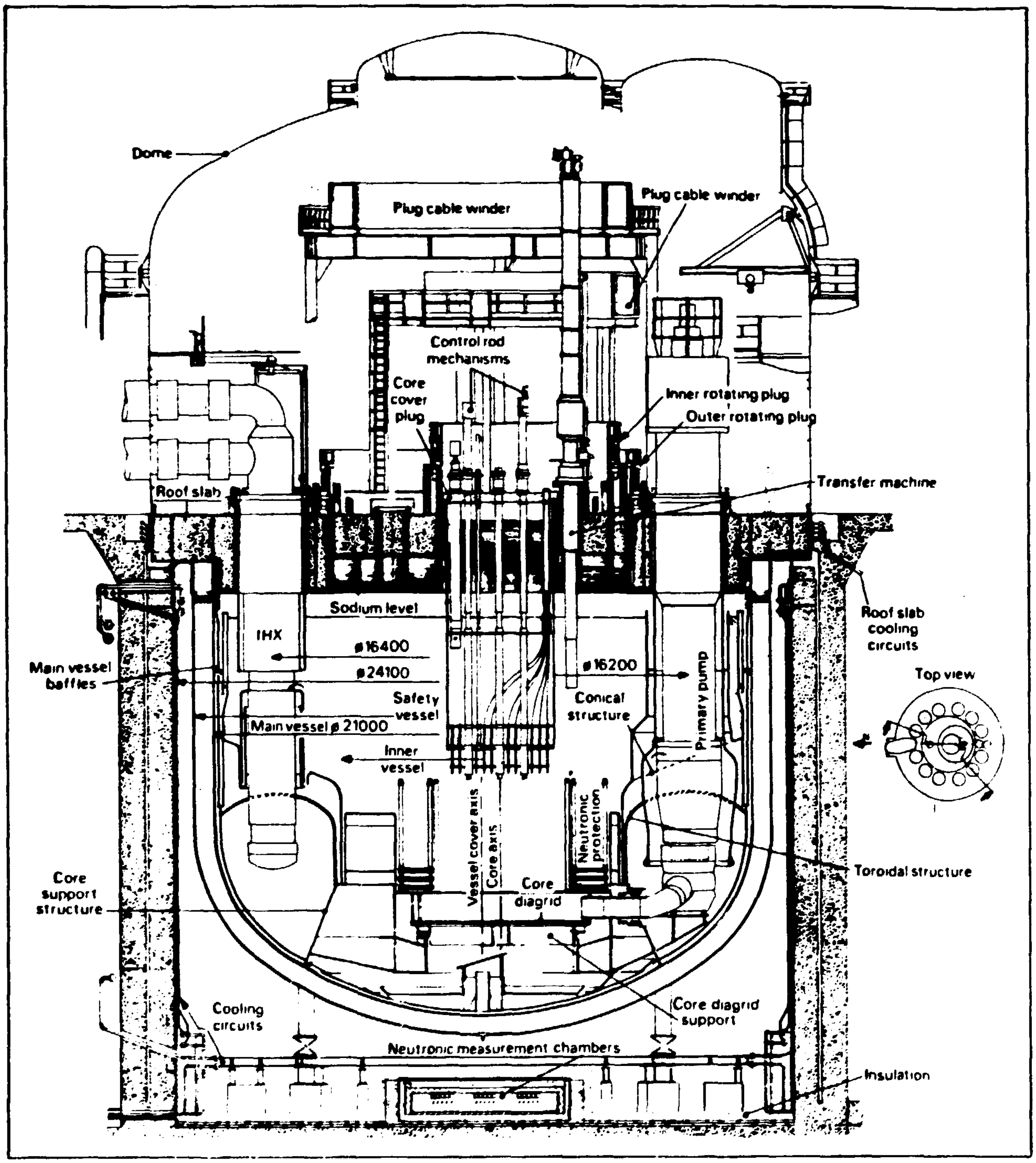

FIGURE 1 : ARRANGEMENT OF SUPERPHENIX 1 VESSELS

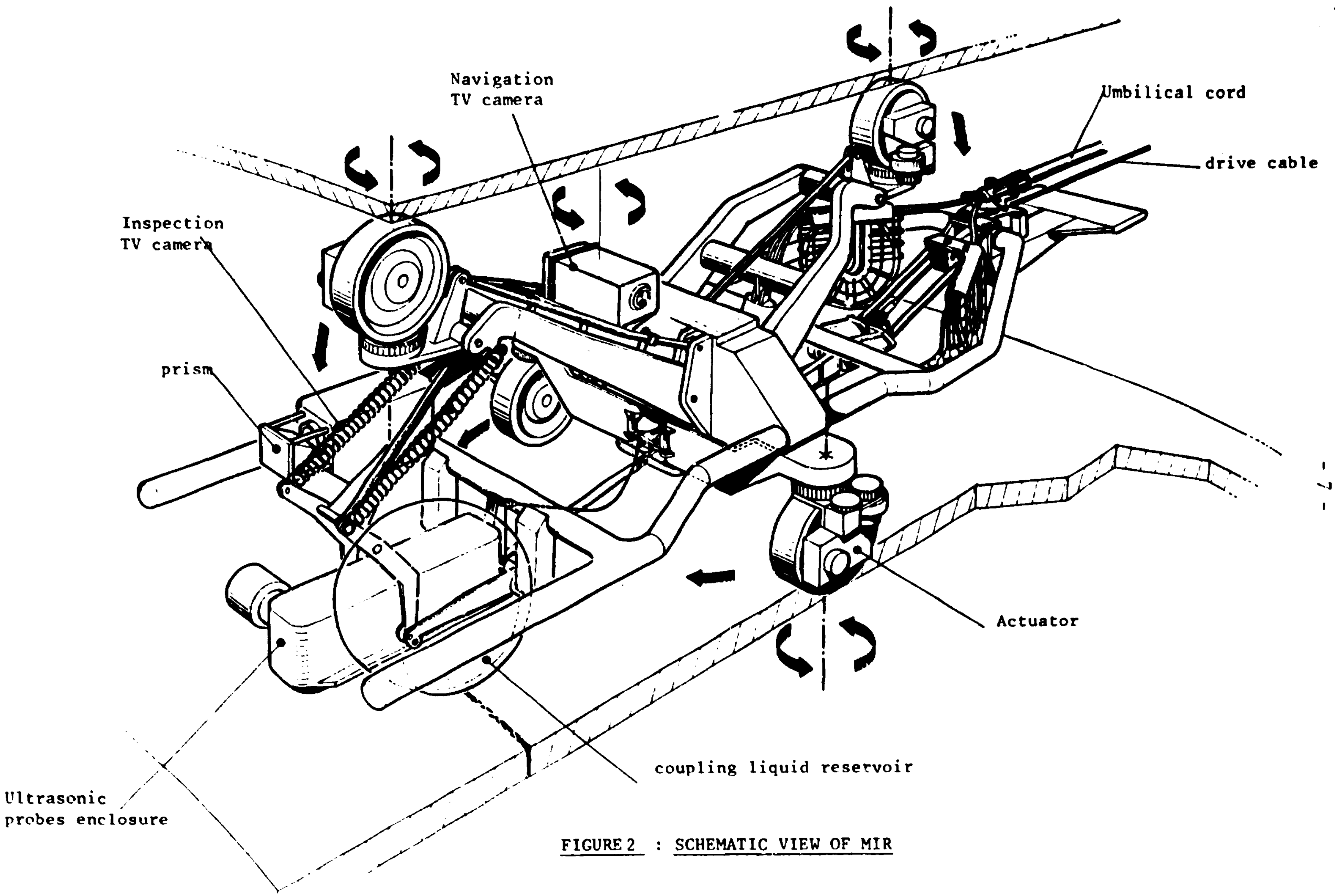

FIGURE 2 : SCHEMATIC VIEW OF MIR