SUPER PHENIX 1: IN-SERVICE INSPECTION OF MAIN AND SAFETY TANKS WELDMENTS

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Summary

In Service Inspection of the main tank of the Super Phenix 1 reactor is a new demand as compared to Phenix : the authorities have asked that surface and internal defects could be detected and their evolution monitored in the future.

The presence of thermal baffles inside the main tank precludes the access on that side : the distance between the main and safety tanks takes into account the room needed for an In Service Inspection module.

An inspection vehicle is presently under development, which includes ultrasonic examination (focussed probes) and visual examination (TV cameras) capabilities.

We briefly describe the techniques that have been selected for ultrasonic testing and also for the vehicle and its guidance between the tanks.

I - INTRODUCTION

In Service Inspection of the main tank of the Super Phenix 1 reactor is a new demand as compared to Phenix : the authorities have asked that surface and internal defects could be detected and their evolution monitored in the future.

Figure 1 shows a section view of Super Phenix 1 : access to the main tank weldments can only be achieved from the outside, i.e. from the space between main and safety tanks.

Special techniques of ultrasonic testing have been developed, to gether with a vehicle fitted to In Service Inspection conditions.

II- IN-SERVICE INSPECTION CONDITIONS

In-service Inspection will take place during the fuel handling operations. The temperature conditions will then be 180°C on the main tank and 130°C on the safety tank. The gas between tanks is nitrogen.

Both tanks are built with austenitic stainless steel plates, 25 to 60 mm in thickness for the main tank and 25 to 30 mm for the safety tank. The tanks (figure 1) hang from the slab which is fitted with 12 man-holes of oval shape (700 x 440 mm) through which the In-Service Inspection vehicle can be inserted. A thermal barrier at the upper part of the tanks provides adequate insulation of the slab which is water-cooled to room temperature : the In-Service Inspection vehicle will cross the thermal barrier in order to have access to the tanks weldments. In cold conditions (tanks at room temperature) the in-between-tanks interval is 700 mm. During the In-Service Inspections, due to thermal expansion, it will be reduced to ca.600 mm.

III-IN-SERVICE INSPECTION DEVICE

Because of the geometry of the reactor and also of the previously mentionned In-Service Inspection conditions, a special device was developed which includes :

- the vehicle carrying the ultrasonic and visual testing equipment.
- a winch and shoot assembly preventing any damage to the thermal barrier
- a computer-assisted control system.

- a composite cable supplying the vehicle with the necessary electrical power and fluids.

III.1 Vehicle

It was given the code name MIR (Machine d'Inspection pour réacteurs Rapides). Figure 2 shows schematic views of MIR, consisting of two steering traction-wheels resting on the tank to be examined and two lever-arms applying pressure on the opposite tank by means of spring mechanisms. The overall dimensions are 1800 mm in length and 560 mm in width. Its approximate weight is 250 kg.

Both wheels are independent. Each is activated by two electrical motors. The direction of each wheel is encoded by a potentiometer coupled to the steering motor. Two tachometers monitor the rotation of the wheels. A sphere rolling on the same tank as the wheels, encodes in two perpendicular directions the true path covered by the vehicle. A potentiometer is coupled to the lever-arms, so as to measure the interval between tanks.

When inserting, but above all, when extracting the vehicle, it is necessary to minimize the force acting on the thermal barrier : the pressure exerted by the lever-arms can be counterbalanced by hydraulic jacks.

The inspection devices on board the vehicle are :

- closed circuit TV cameras for weldments examination,guidance of the vehicle in the interval between tanks and general viewing of the environment.

- an ultrasonic testing device using focussed probes which is adapted to the material, plate thicknesses and weldment types to be examined.

All the visual examination is done with two TV cameras of standard characteristics. The first one which is devoted to environment surveillance, has a simultaneous backward and forward viewing capability. It will mainly be of use for inserting and extracting the vehicle and also when the vehicle comes in the vicinity of a weldment to be examined. The second TV camera, on one hand gives images of the weldments and on the other hand reads die stamped engravings on the only safety tank. Appropriate optical systems are fitted to the TV cameras.

The die stamped engravings on the safety tank are representative of the weldment arrangement of both tanks. A first set of engravings is situated along the perpendicular projection of the main tank weldments on the safety tank. Great care was exercised to minimize errors in the projection process by taking into account the as-built dimensions of the tanks and their relative movements caused by temperature difference or mechanical loading (sodium and internal structures in the main tank). A second set of engravings follows the safety tank weldments at some constant distance : thus, should it be asked, the safety tank can be inspected too.

Each engraving consists of 4 characters, letter, numeral or sign. These characters are drawn by several hemispherical impresses. The characters are selected according to a code which avoids any ambiguity.

The focussed probes for ultrasonic testing are located inside a metal structure filled with a coupling liquid which is retained by a special gasket. The coupling liquid is Gilotherm RD whose compatibility with stainless steel was checked and which has the necessary physical properties : in particular, its vapor pressure allows complete evaporation of the liquid film left behind the vehicle.

The focussed probes inside the metal structure move in an alternative sweep perpendicular to the weld lines. A potentiometer encodes the sweep movement which is greater than the width of the weldments.

Along some generating lines of the tanks, are located instrumentation devices (thermocouples,...) which prevent access to the vehicle and

impedes the complete examination of some weldments. To minimize the length of these zones, the vehicle can move crabwise : the ultrasonic probe structure and the TV camera for weldments examination form a module which rotates around the vehicle axis.

No spare coupling liquid is stored on the vehicle : a feed line is included in the special cable which was previously mentioned.

The devices on board the vehicle, except the ultrasonic probes, cannot operate at the ambient temperature during In-Service Inspection (from 130°C to 180°C). These devices are located in insulating enclosures fitted with gas inlets : cooled nitrogen gas is fed through the cable to each insulating enclosure, according to the temperature needed and the heat to be dissipated.

III.2 Winch and shoot assembly

The winch continuously controls and minimizes the traction force and torque excerted on the vehicle by the cable. The winch is located (figure 3) about 6 m over the upper part of the slab. In case of emergency, it can extract the vehicle from the interval between tanks.

A shoot assembly allows easy insertion and extraction of the vehicle through the thermal barrier. The shoot assembly is fitted with closing devices which prevent an oxygen pollution of the nitrogen atmosphere in between tanks or a dangerous flow of hot nitrogen to the outside.

III.3 Control system of the MIR vehicle

It is achieved by a hierarchized computer system : a microprocessor carries out elementary orders and checks their performance by the motors on the vehicle. These elementary orders can be :

- a set point (for the steering wheels) ;
- a speed order (to the tachometers on the driving motors).

A mini computer determines and controls the logical sequence of elementary orders which is representative of the path that the vehicle must follow. Thus, the mini-computer signals to the microprocessor for an elementary order and receives in return an O.K. report or an alarm signal, depending upon the situation.

On site, the control system is divided in two parts : near the winch and shoot assembly, is the power equipment ; the control system itself is located in a mobile van, some 120 m. away from the power equipment. The ultrasonic and video-signals are conditioned in the power equipment.

III.4 Composite cable

Its duty is fourfold :

- supply the necessary electrical power to the motors on the MIR vehicle.
- transmit to the control system the signals from ultrasonic probes, TV cameras and encoders.
- supply the necessary fluids :
  - . cooled nitrogen for temperature regulation.
  - . ultrasonic coupling liquid.
  - . supply of liquid to the hydraulic jacks that counterbalance the pressure of the lever-arms when extracting the vehicle.

The composite cable has a diameter of ca. 40 mm and an extraction force capability of 12 kN at 180°C.

IV -ULTRASONIC EXAMINATION

Special high temperature focussed probes have been developed by adapting the solutions which were adopted for the In-Service Inspection of PWR reactors. Depending upon the type of weldments, different probes are fitted on the MIR vehicle.

IV.1 High temperature ultrasonic focussed probes

Figure 4 is a section view of a typical probe : a piezo-electric ceramic, of the PZT type, is coupled by high temperature adhesive compounds, on one side, to a focussing lens and on the other, to a damping block.

IV.2 Weldment examination

Longitudinal waves at an incident angle of 45° are used. The ultrasonic energy is focussed in a cylinder, ca. 5 mm in diameter : well oriented reflectors under 1 mm in size can thus be detected. As the length of the focussing area depends among other parameters upon its diameter, the complete examination of the thickest plates necessitates several probes. Such a grouping of probes is shown in figure 5.

A Y shaped weldment connects the core support structure to the main tank. Its ultrasonic examination is done using a special arrangement of two focussed probes (figure 6).

V - CONCLUSION

The structure of the Super Phenix 1 reactor and the conditions which are met during In-Service Inspections have led to new developments.

A special In-Service Inspection vehicle, named MIR, can move in all parts of the interval between the main and safety tanks. It is fitted with appropriate high temperature ultrasonic focussed probes.

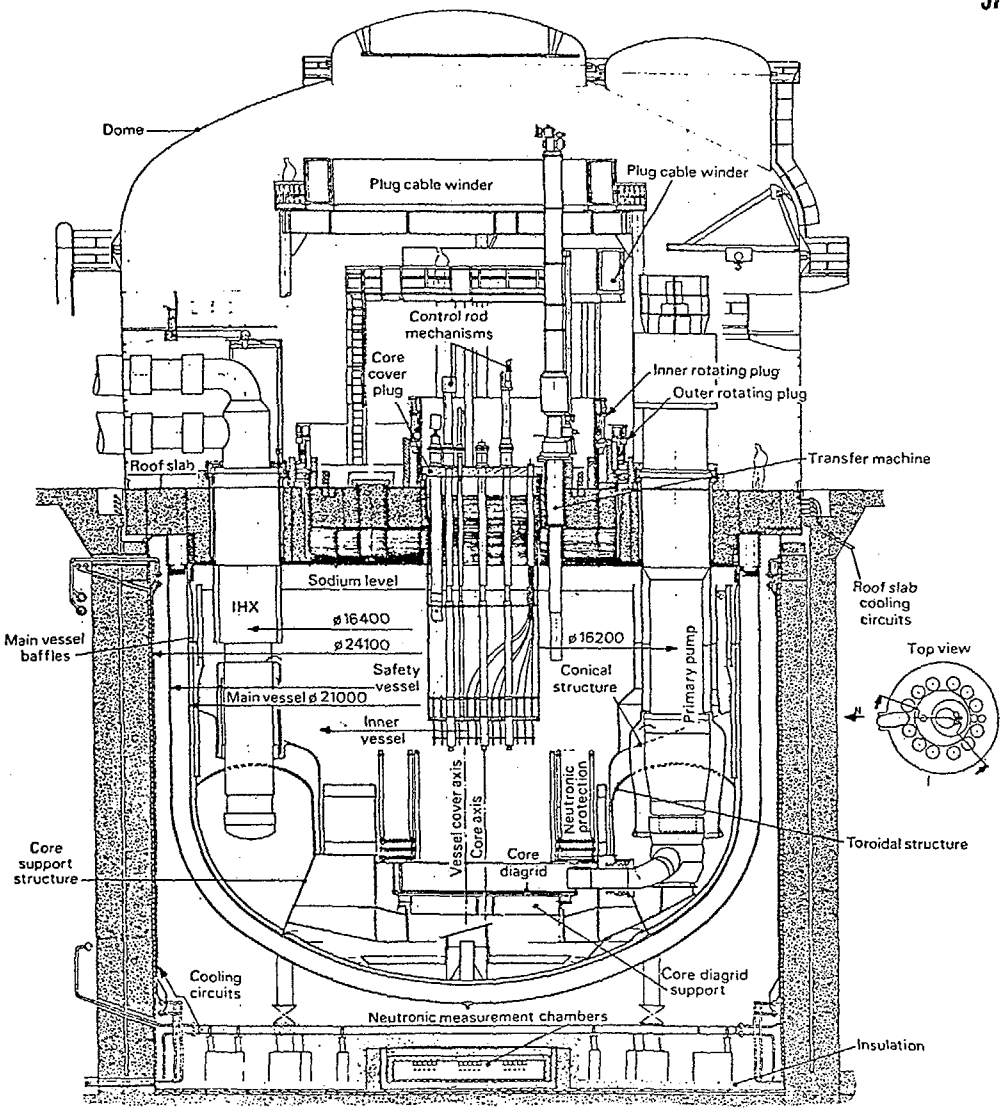

figure 1 : schematic view of Super Phenix 1

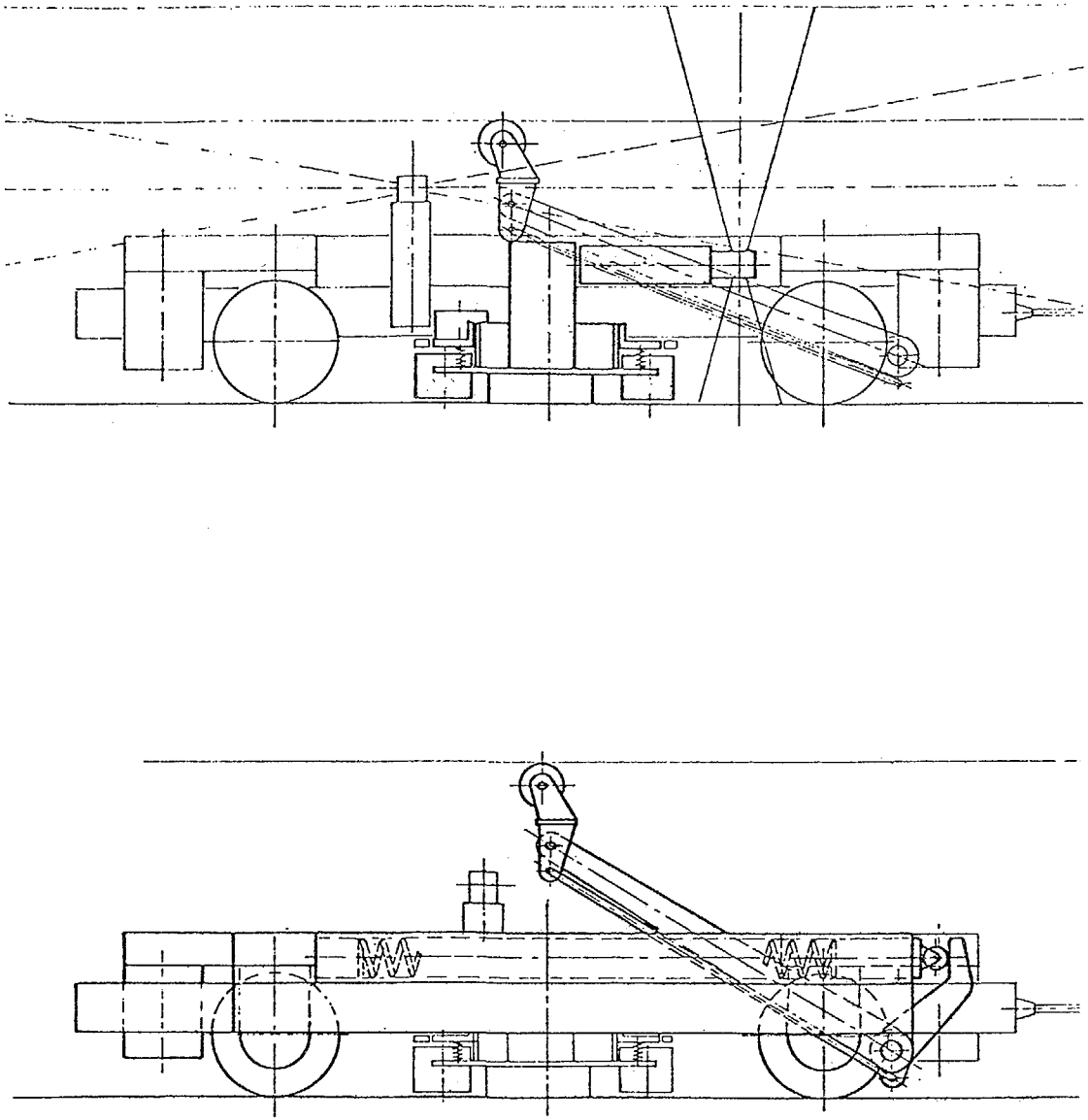

figure 2 : schematic view of the MIR vehicle

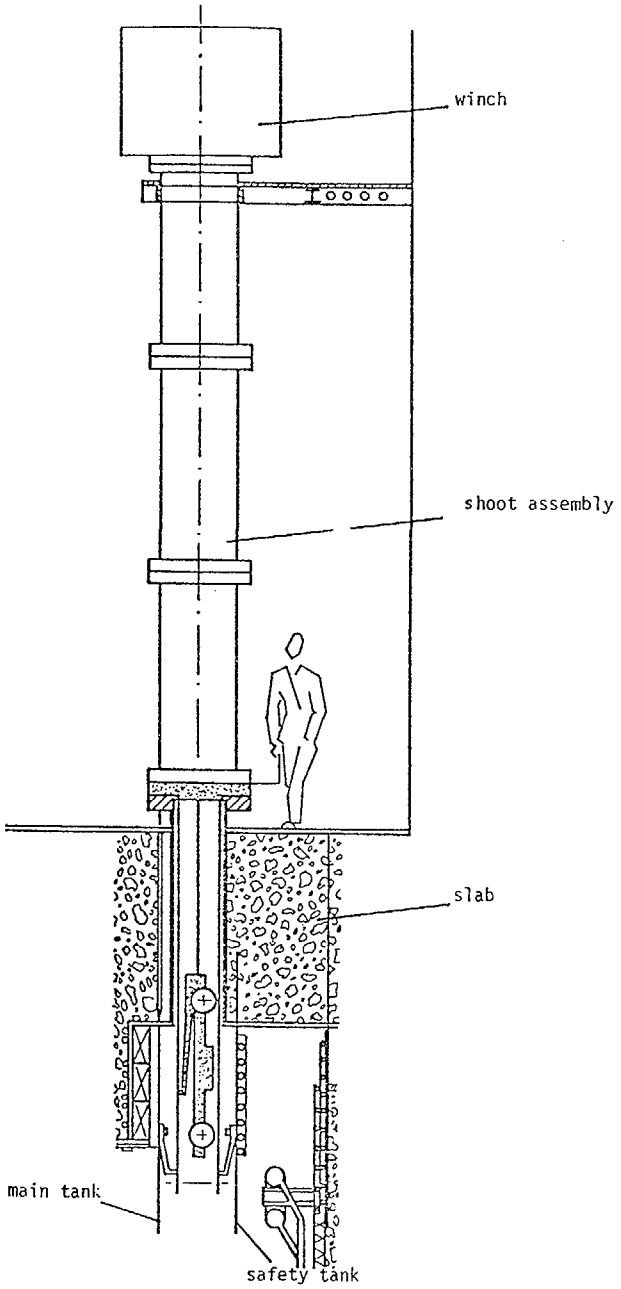

figure 3 : winch and shoot assembly

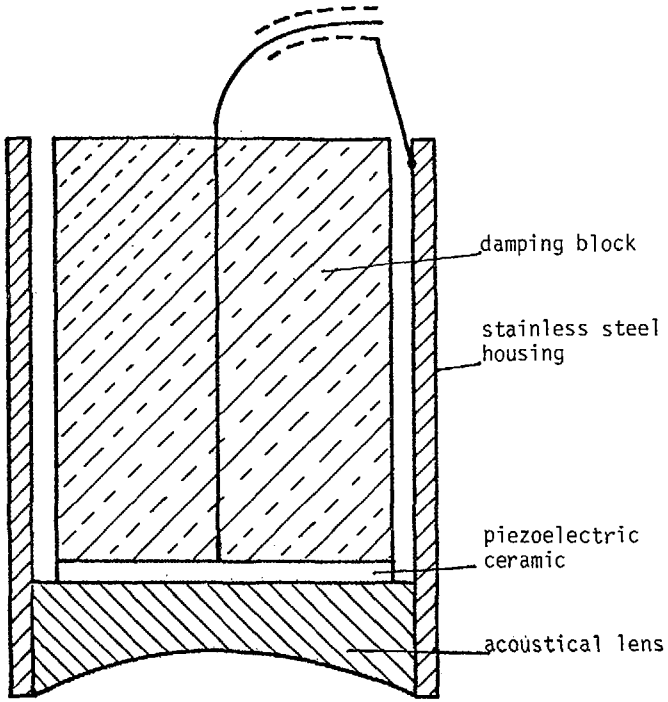

figure 4 : section view of an ultrasonic focussed probe

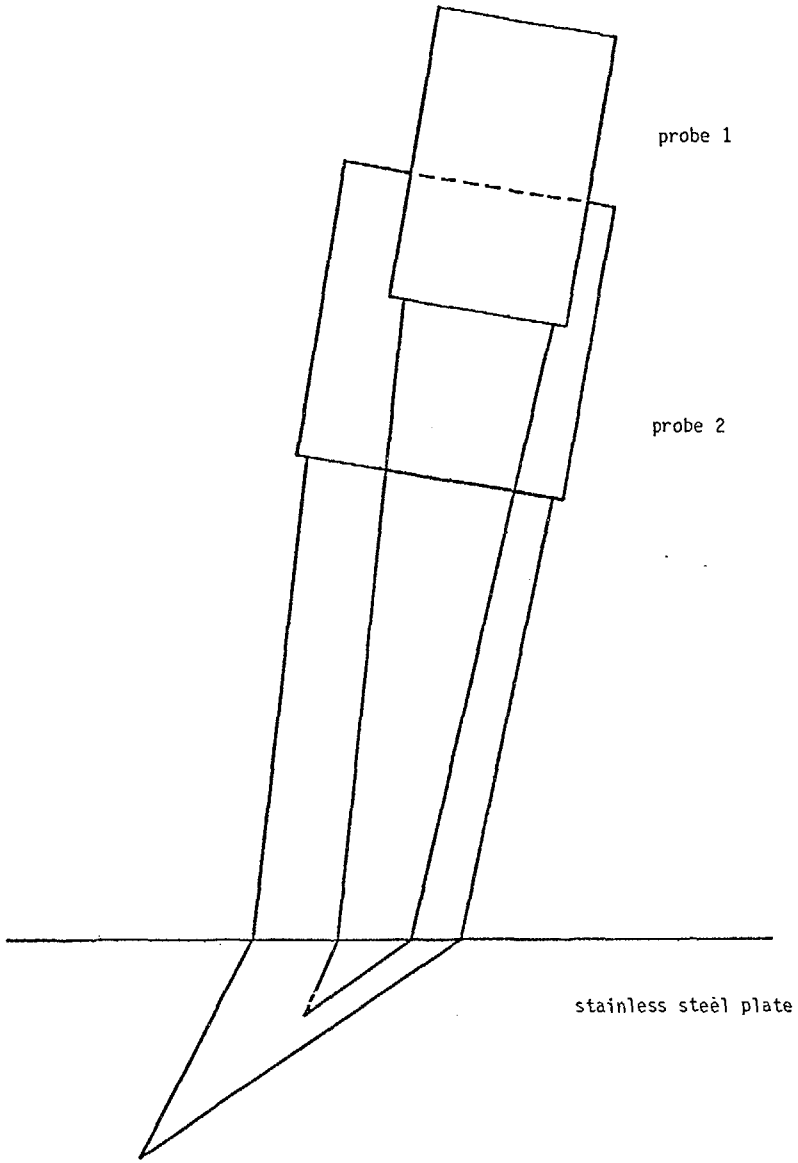

figure 5 : grouping of ultrasonic focussed probes for the examination of thick plates

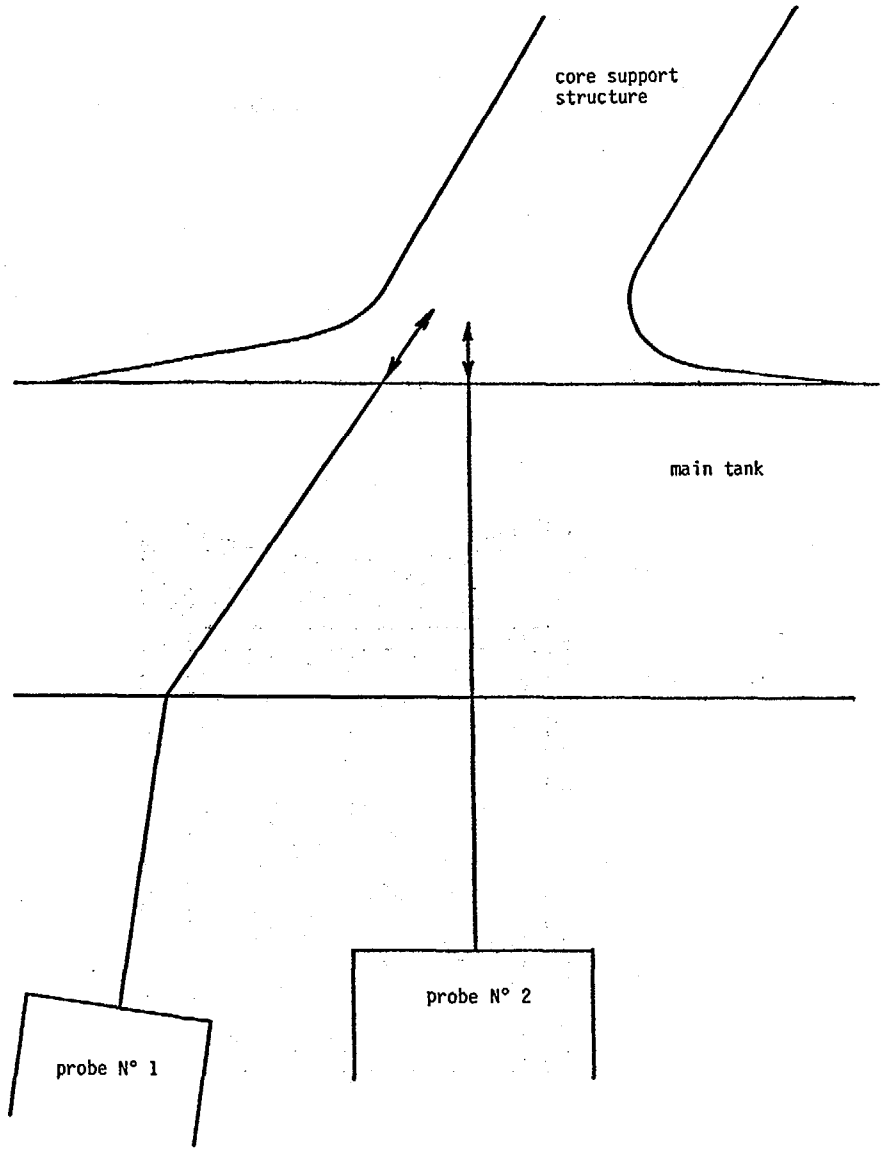

figure 6 : probe arrangement for a Y shaped weldment on the main tank

ACTIVITIES WITH REGARD TO RESEARCH AND DEVELOPMENT OF TECHNICS FOR SNR 300 REACTOR VESSEL IN-SERVICE INSPECTION PROCEDURES

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Introduction:

During the development of SNR 300 inservice-inspection equipment several branches were tested by experiment. In this report especially steps for testing of manipulation systems and additional engineering equipment for control systems, such as coupling fluid circuit or camera cooling system are considered more in detail.

1. Handling and Manipulators

As concept of accessibility for inspections of the reactor vessel outer surface a system of twelve vertical rail tracks was developed, on which a hollow chain with guide wheels and special examination vehicles on top is driven into the annular gap between reactor tank and guard vessel. Inspection methods to be used were visual examination of surfaces and volumetric testing of reactor vessel welds by ultrasonic method.

For operational tests of the essential mechanical parts of the inspection equipment a test rig was constructed and built up. In a detailed programme the whole sequence of motions for the examination vehicle with TV-camera dummy and the hollow chain with guide wheels were tested at ambient temperature and certain parts at operating temperature of 250° C in nitrogen atmosphere.