IMPROVEMENTS TO PWR REACTOR VESSEL INSPECTION EQUIPMENT AND THEIR INFLUENCE ON REDUCTION OF THE DOSE ASSOCIATED WITH SUCH WORK

1 VESSEL INSPECTION STANDARS REQUIREMENTS

The in-service inspection of nuclear reactor vessels is required by the regulatory body in accordance with Section XI of the ASME code (programme B, article IWB-2000).

In accordance with this regulation, volumetric NDT techniques are to be used to inspect all the critical areas of the vessel, which in general are as follows (see following point):

- Vessel wall welds (longitudinal and circumferential)
- Vessel flange weld
- Threaded areas
- Inlet and outlet nozzles (nozzle-shell course, inner radius and connection to primary circuit)

Two inspections are to be performed during each operating interval (10 years): the first of which is a partial inspection performed at the end of the first period (3 years). This inspection is performed during the refuelling outage and covers areas accessible without removing the reactor internals. At the end of the operating interval and with the reactor internals removed, the second inspection is performed (also during the refuelling outage), this includes 100% of the areas to be inspected, which means a considerable volume of work directly impacting on the duration of the outage.

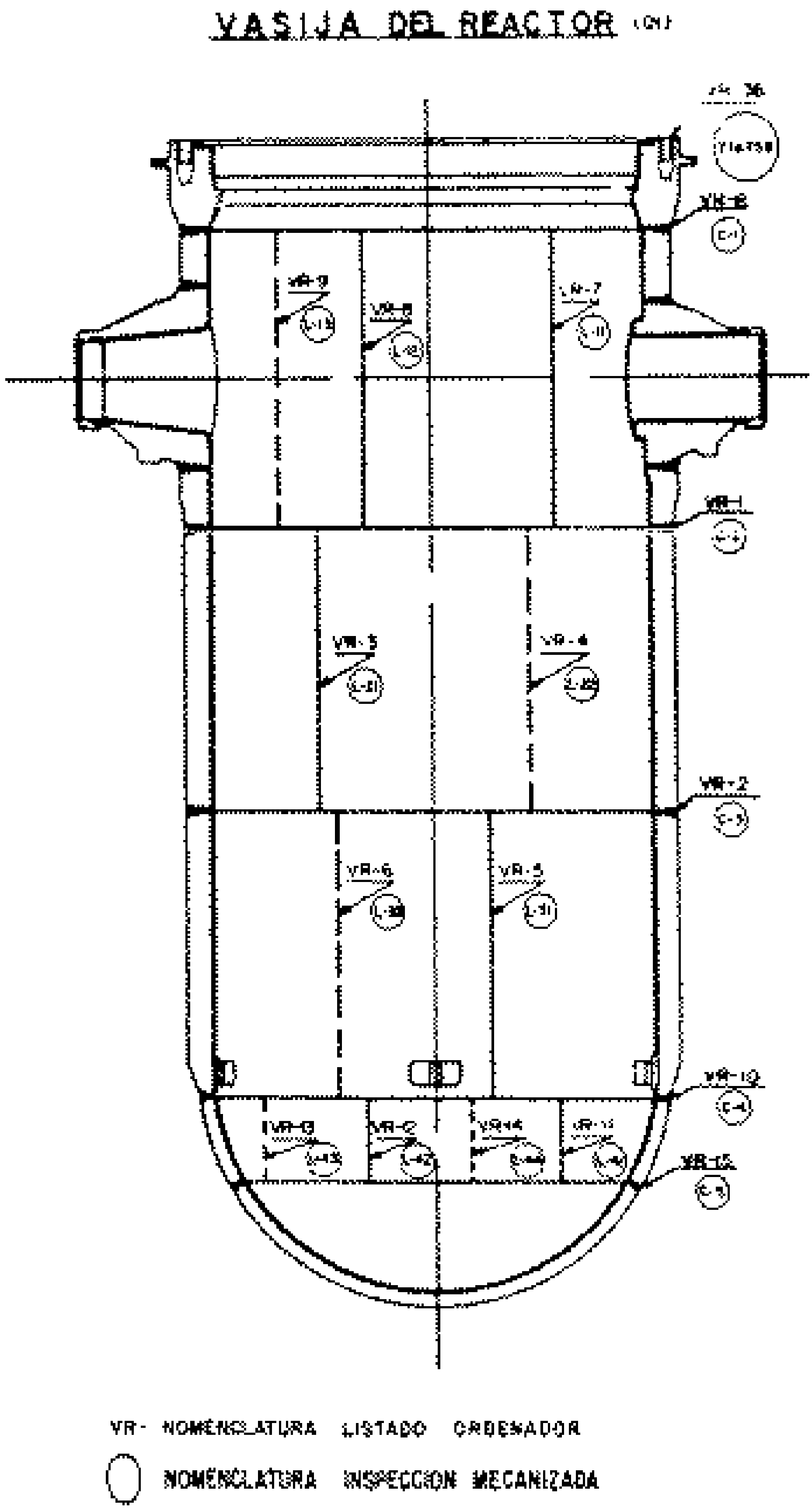
2 DESCRIPTION OF A TYPICAL PWR REACTOR VESSEL

The following figure shows the cross-section of a typical reactor vessel.

The main characteristics are as follows:

- Diameter: 3 ÷ 5 m.
- Height: 6 ÷ 10 m.
- Thickness: 150 ÷ 250 mm.
- Material: Carbon steel with inner cladding of stainless steel.

Figure 1: Cross-section of a reactor vessel



3 GENERAL DESCRIPTION OF INSPECTION SYSTEM

There are two types of equipment for the inspection of PWR type vessels: telescopic equipment with a fixed part resting on the vessel flange and mobile equipment displaced inside the vessel.

The company specializing in the performance of these inspections in Spain uses equipment of the first type, consisting of a tripod which is attached to the vessel flange and which supports a vertical telescopic mast at whose lower end there is a series of arms moving and positioning the ultrasonic probe-holding modules in charge of carrying out the volumetric inspection of the areas of interest, by means of the pulse-echo technique.

A more detailed description of the equipment currently used (known as TIME) is as follows:

TIME is made up of a square cross-section extendible central mast supported by three legs which rest on the vessel flange. The equipment is centred on the flange by means of the guide pins incorporated on two of the legs. The third leg rests on a special pneumatic system. The legs have an adjustable system for connection to the mast, making it possible for the equipment to be used on vessels of different diameters.

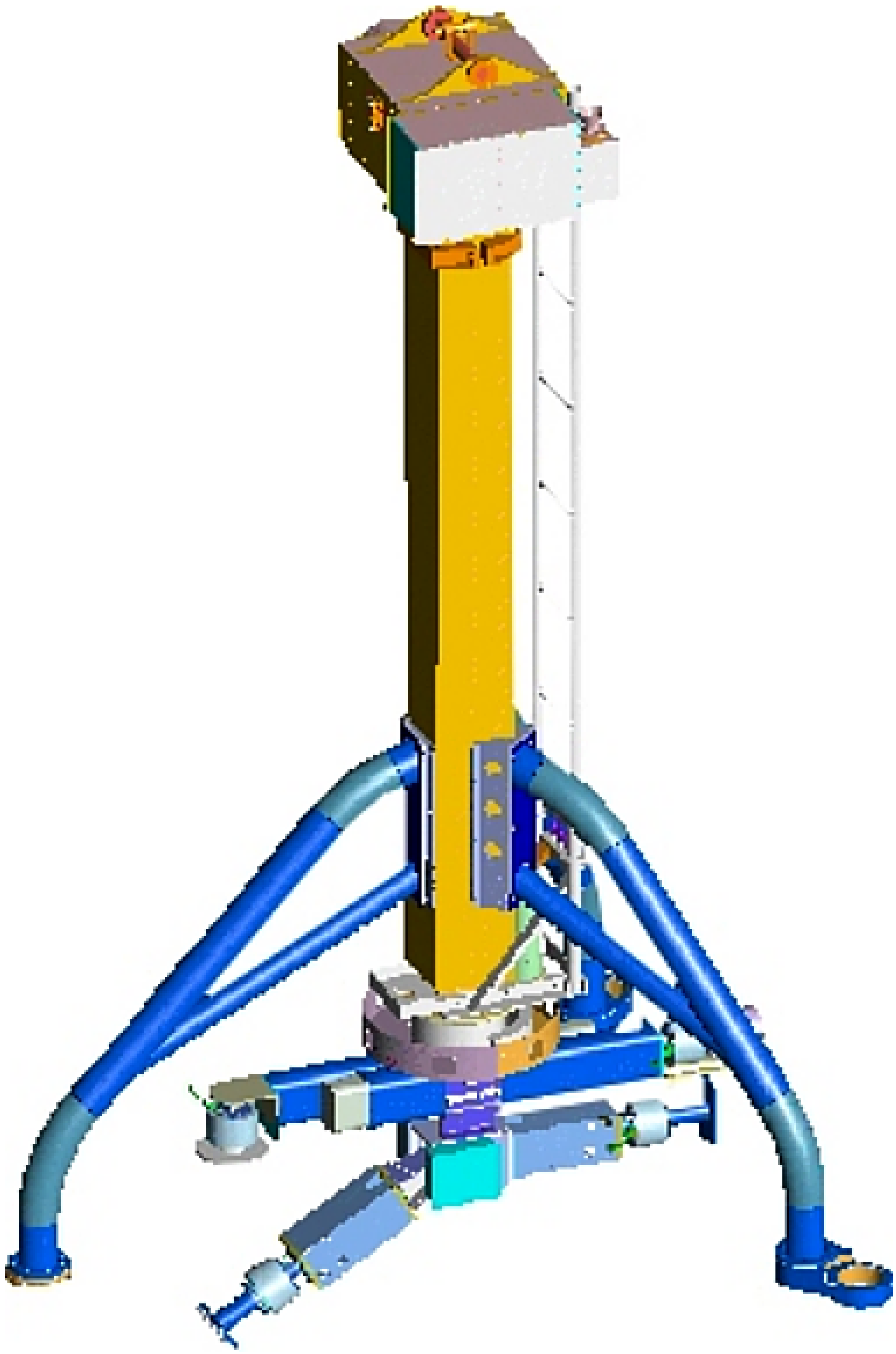
The mast is made up of five tubes, the outermost of which is fixed and the other four extending by means of a system of guides to a maximum distance of 11200 mm., allowing for the inspection of all types of PWR vessels.

The innermost tube of the mast is fitted with a flange on which is mounted the system of inspection arms, made up in turn of the rotating device, the cable guide system and the four inspection arms.

The two uppermost inspection arms support the modules for inspection of the inner radius and the primary to vessel nozzle weld, as well as the threaded areas of the flange. The two arms are interchangeable and may be extended radially to adapt to vessels of different diameters. The arms are constructed of square tubes providing sufficient rigidity to ensure bending of less than 5 mm. with an extension of 2 m.

Beneath these arms there are two others supporting the modules for inspection of the circumferential and longitudinal vessel welds and the

Figure 2: General view of mchanical equipment (TIME)



meridional welds on the lower hemispherical head of the vessel. As in the case of the upper arms, these are constructed with square tubes, with a telescopic device allowing the length required by the zone to be inspected, to be achieved. One of these two arms can pivot on a horizontal axis, this making it possible to inspect the spherical welds at the vessel bottom.

The modules housing the ultrasonic probes are mounted at the end of the arms. These probes move in contact with the surface of the areas to be inspected.

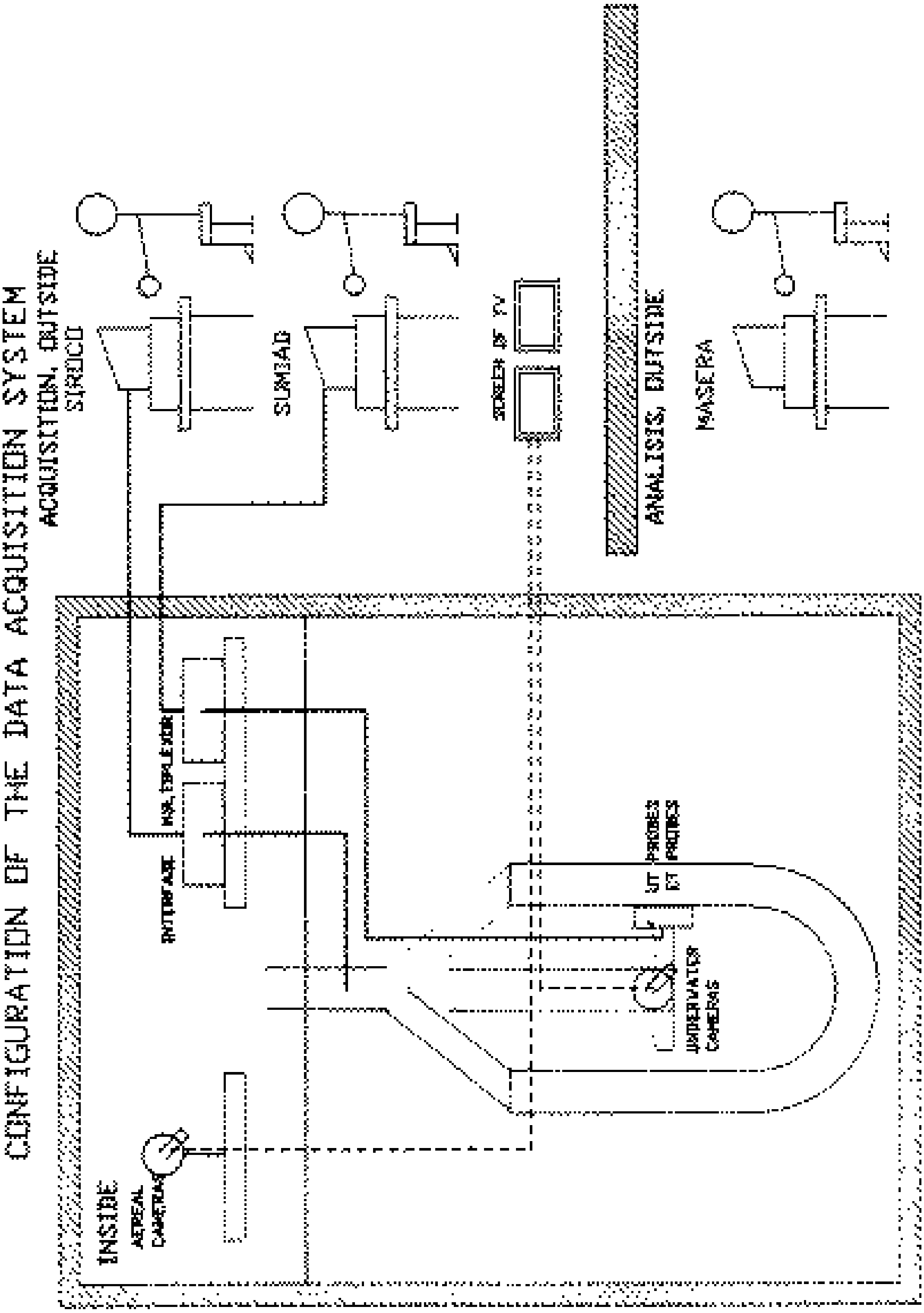
The entire mechanical system is automatically controlled by means of a PC with a graphic interface for operation of the equipment and for surveillance of its operating conditions.

As a safety measure, the mechanical equipment is fitted with references to limit the movement of the mast and of the arms when these movements are not compatible with each other or with the dimensions of the vessel. Both the mast and the arms may be manually withdrawn in emergency situations, such as loss of plant electricity supply, etc.

The equipment is also fitted with auxiliary systems such as an ultrasonic calibration block for checking of the ultrasonic probes, as required by the code, without the need to remove the equipment from the vessel. It also has two colour television cameras making it possible to monitor the movements performed inside the vessel.

For its part, the data acquisition system is made up fundamentally of a multi-channel digital ultrasonic system based on the contact pulse-echo technique. The equipment directly involved in signal generation and data acquisition is positioned close to the mechanical equipment (refuelling cavity), in order to minimize the length of the cables and, consequently, the production of noise. The computers in charge of control and data storage and a analysis are located in the conventional area. The equipment inside the controlled zone communicates with those located outside for the dispatch of data, voice and video.

Figure 3: Placing of inspection system components



4 IMPROVEMENTS MADE TO THE BASIC INSPECTION SYSTEM

In 1976 the Spanish company supplying this service acquired inspection equipment from a specialist US company. After having performed several pre-service and in-service inspections, it acquired sufficient experience to undertake a series of improvements aimed at shortening the time spent at the vessel and reducing the infrastructure required from the plant and the doses received by the participating personnel.

The first modification to the equipment was made in 1986. A third arm was added to the two that the equipment initially had and an eight channel ultrasonic system was provided, as a result of which it was no longer necessary to extract the equipment to change its configuration when changing the area to be inspected.

In 1991 the mechanical equipment was redesigned (motors, arms, interfaces) and all the data acquisition system was moved outside the controlled zone, with television cameras being used for the first time for remote monitoring of system operation. These modifications meant a reduction in dose, since it was no longer necessary for the operators to be permanently present at the refuelling cavity. The time required to inspect 100% of the vessel was also reduced from 13 to 10 days.

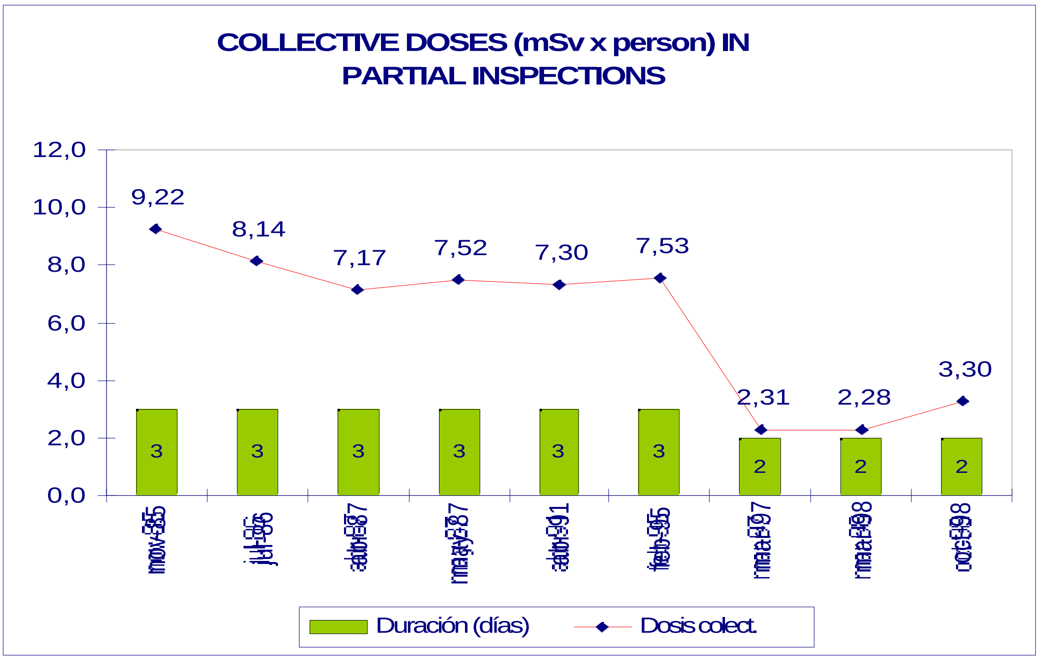
In 1993 a new faster data acquisition system was developed in order to take advantage of the increased speed of the mechanical system achieved through the modification made in 1991. The time required to inspect 100% of the vessel was reduced to 7.5 days.

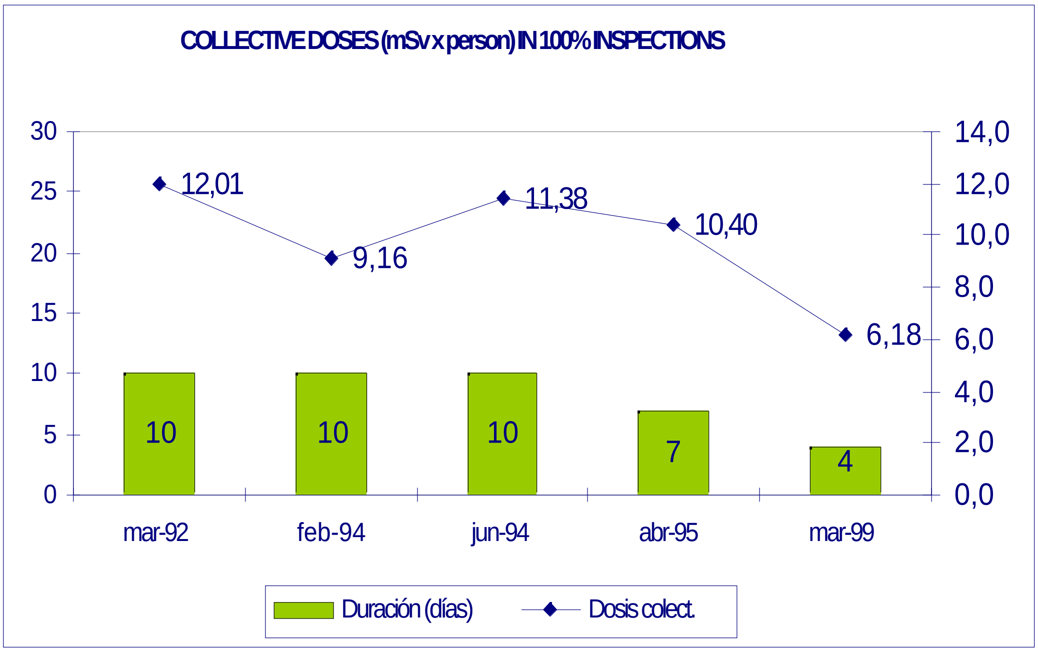
In 1995 the packaging and support of the equipment was modified to reduce the equipment assembly and disassembly time at the refuelling cavity and the time taken to arrange the crane. This improvement also led to a reduction in personnel dose.

Finally, in 1998, the TIME equipment referred to above was designed and manufactured. This equipment is based on the experience acquired throughout the years in use of the previous equipment. It was used for the first time in March 1999 to inspect 100% of the Vandellós-2 NPP vessel with fairly successful results since the work was performed in a record time of 4 days.

5 EVOLUTION OF ASSOCIATED DOSE

As a result of the improvements made to both the mechanical equipment and the data adquisition system, collective doses have decreased considerably, as may be seen from the following graphs:





6 CONCLUSIONS

The costs associated with improving the inspection system are more than compensated for by the following:

- Reduction of vessel occupation time on the critical path, thus increasing the plant load factor.
- Reduction of the dose in both partial and 100% inspections, which, as may be observed in the graphs, have decreased by factors of between 30% and 50%.