Inspection and Repair of Nuclear Components

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1. Introduction :

Experience shows that, despite a careful design, manufacturing and operation, some of the important safety-relevant components show deterioration with time. To allow continuation of the operation, these components have to be repaired or exchanged. Because of activation or contamination of these components, their inspection and repair has to be performed with manipulators. ABB Reaktor built, qualified and used a family of such manipulators together with the appropriate repair techniques and gained much experience and a broad range of knowledge during service jobs. In the following some of the more sophisticated manipulators are described.

2. Steam generator inspection, repair and maintenance:

Despite of large advances in material and chemistry, steam generators remain a vulnerable component in the primary circuit of a PWR. Since 1979 inspection and repair manipulators have been manufactured and used, which enable ABB Reaktor and our customers to provide remote inspection and repair work for the steam generator tubes (Fig.1). These manipulators can be installed or removed within 2-3 min without entering the steam generator channel head. It is controlled remotely from a distance of up to 150 m. It has a low generic weight combined with a sturdy construction to provide the necessary lifting force and a very short tube to tube positioning speed.

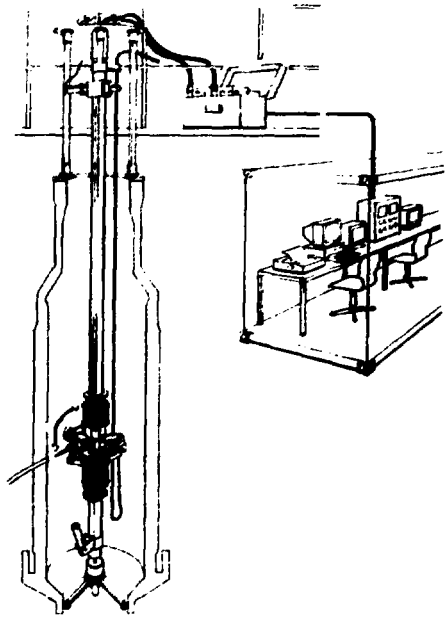

Fig. 1: Steam generator manipulator for a VVER steam generator

Fig. 2: Manual installation of an ABB removable plug in a test section of a VVER-440 steam generator

Inspection of such steam generator tubes is performed periodically. For such service ABB Reaktor employs eddy current inspection systems. Up to now, more than 250000 tubes have been inspected worldwide. In 1991, the steam generator tubes of 7 NPP have been inspected in Germany, corresponding to a market share of 50%. A wide variety of repair methodes have been developed and qualified for the repair of deteriorated tubes. A rolled plug has been qualified for horizontal steam generators as used in NPP of the VVER-440 design. The qualification was done using an original part of the steam generator (Fig.2). The complete set of repair methods developed by ABB Reaktor includes welding of plugs, rolling of the ABB removable plug and the tube in tube repair (sleeving). By means of special systems, axial tube sections can be extracted for metallurgical examinations. Up to now, more then 10000 tubes have been repaired world wide.

3. Fuel alignment pins inspection and repair:

The fuel alignment pins (FAP) are installed in the grid plates of the reactor pressure vessel (RPV) internals. They have to provide exact radial positioning of the fuel elements towards the control rod assemblies. In the late 80s cracking of some pins by intergranular stress corrosion has been detected. During the following years, all pins of a specific design and material were inspected and exchanged. ABB Reaktor together with ABB-TRC and Voest Alpine MCE developed and qualified the inspection and repair methods with specific manipulators (Fig.3). The manipulators are positioned on a supporting structure in the storage position of the reactor internals.

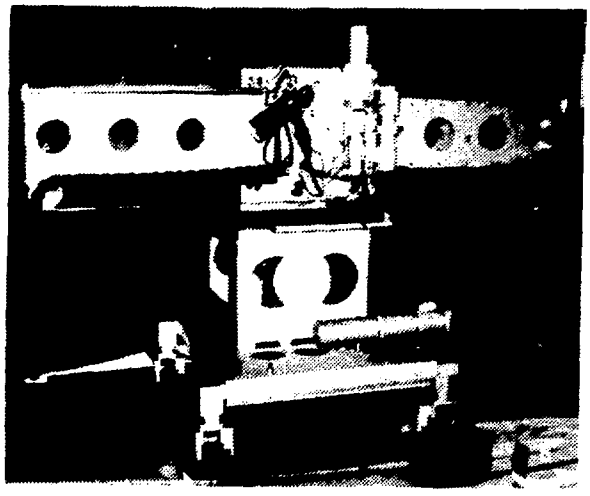

Fig. 3: Manipulator for fuel alignment pin inspection

The big advantage of this design is that the upper core structure does not have to be turned upside down. It can be handled by the normal reactor crane. The main components are the ultrasonic inspection (UT) equipment and the pin replacement equipment. The UT-equipment was qualified to detect failures with a depth of at least 1 mm. The repair equipment removes the old pin by cutting off the part below the grid, drilling out the core and removing the main residues. The new pin is of a special design with minimized stress concentration factors. It enables installation from beneath without any welding or machining procedure (Fig.4). ABB Reaktor received orders to inspect and repair the FAP from 6 German NPP. In 1991, a further developement was introduced by using a twin repair manipulator with two work stations thus increasing the exchange rate by a factor of 2. Up to the end of 1991 a total of 2770 FAP have been inspected and 1280 exchanged.

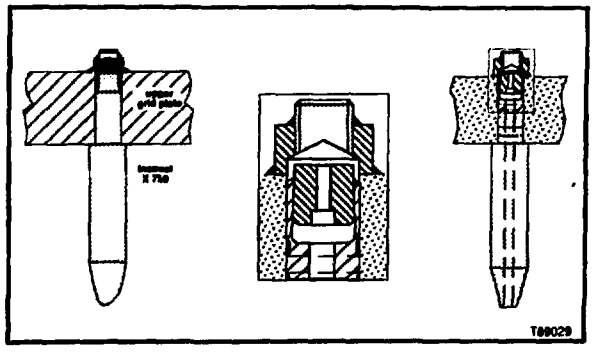

Fig. 4: Existing and new design of the fuel alignment pin

4. Core baffle former bolts inspection and repair:

In a PWR core the fuel elements are surrounded by core baffle plates to provide an outer boundary for the coolant during its flow upward through the core. In some designs, these plates consist of vertical stainless steel sheets fastened from the inside by baffle former bolts. These core baffle former bolts (CBFB) may crack or break. This could lead to vibration of the plates and damage the fuel elements. It is, therefore, of importance to inspect these CBFB by a non-destructive inspection method and to exchange them in case of failure. Because of the high radiation of the material in this area, all work has to be done remotely controlled by manipulators under water. The inspection and repair manipulator is shown in fig.5 schematicly. Fig.6 shows a detail of the head of this manipulator during the qualification at the ABB Reaktor Service-Center.

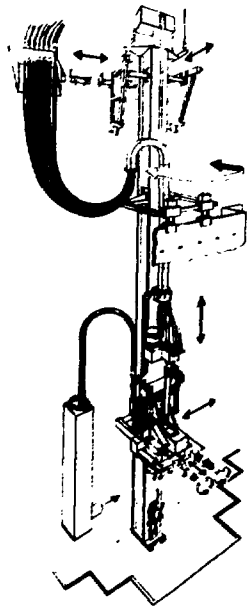

Fig. 5: Manipulator for inspection and repair of core baffle former bolts

The most difficult requirements to be fulfilled were: precise alignment of the UT-probes to bolts of various length and head-design, very small dimensions within the corners of the core-baffle, long distances under water requiring variable beam lengths. A high inspection rate of 20 to 30 bolts per hour was achieved. The main features of the inspection unit are: spring supported self aligning probe head ensuring a perfect probe to bolt alignment, resolution of flaws with a minimum size of 1 mm and low signal to noise ratios. In case of identification of a defective bolt, this bolt is changed using the repair system. The related repair method is based on proven and successful repair techniques.The main repair steps are: mechanical milling of the locking pin and subsequent unwinding of the pin by an integrated bolt unwinding tool, drilling out of any broken parts of the bolts by especially designed milling and "easy-out" tools, preparing the baffle hole surface for the installation of a new bolt and installing and locking the new bolt by an integrated locking cup.

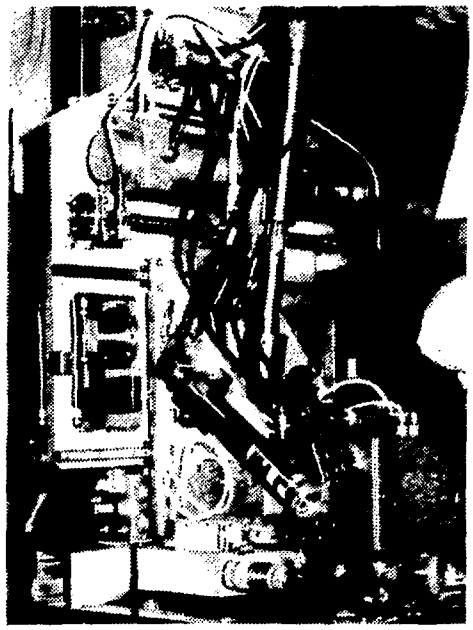

Fig. 6: Head of the CBFB repair manipulator

Up to May 1992, 3 complete inspection units and 2 complete repair units including the repair tools have been delivered. They have been used successfully in field.

5. Reactor pressure vessel head penetrations inspection:

In fall 1991, stress corrosion cracking has been detected in reactor pressure vessel (RPV) head penetrations made from Inconel 600. The inspection of such cracks is restricted by very narrow gaps between the thermal sleeves and the housing and by high radiation under the head. Based on standard elements of the ABB Reaktor manipulators a specific inspection manipulator (Fig.7) has been developed, qualified and put into service in very short time. For penetrations with and without thermal sleeves two

types of eddy current probes have been developed. Calibration standards are used to determine the optimum frequencies and the resolution of crack opening and depth. Cracks of 0.2 mm depth and 1 mm length are clearly identified. An additional visual inspection equipment is used in connection with the manipulator to reveal potential anomalies of the RPV penetrations. The manipulator can also be equipped with an ultrasonic inspection system. Up to May 1992, this manipulator has been used successfully for the inspection of the RPV head penetrations of several NPP.

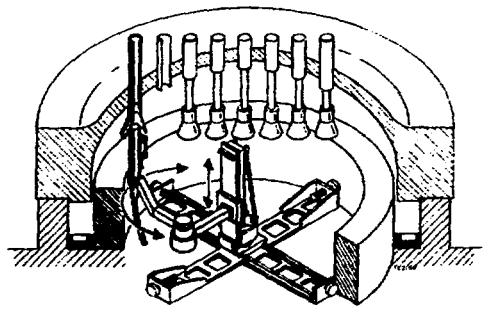

Fig 7: Manipulator for the RPV head penetration inspection

6. Other manipulators:

A series of other manipulators have been developed for various special applications. These include failed fuel rod detectior manipulators, visual inspection manipulators which are applicable above and under water and pipe inspection manipulators (crawlers). All of these can be equipped with a large variety of inspection and repair devices.
In all the above cases, the combination of utilization of proven manipulator modules and accumulation of years of field experience resulted in fast response to customer requests, fast delivery of reliable systems and, therefore, in customer satisfaction.