Self Locking Insert for a PWR Upper Guide Tube

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ABSTRACT

It has been reported, in several plants, starting in 1979, in Japan, that failures had occured on flexures located on top of the upper guide tube in the reactor vessel upper internals. The failures are due to intergranular stress corrosion of Inconel X-750. The design purpose of the flexures is to hold in place a removable insert. With the flexures broken, an alternate solution should be found to hold the insert. ACEC has developed 2 self locking inserts that stay in place without the flexures. The first design has been made for DOEL I & II plants, an 8 feet core with a 14 x 14 guide tube. The second design has been done for Tihange I power plant, a 15 x 15 guide tube. The second design is generic and can be used in all Westinghouse type reactors having a removable insert.

1. PROBLEM

It has been reported, in several plants, starting in 1979, in Japan, that failures has occured on the flexures located on top of the upper guide tube located in the reactor vessel upper internals. The failures are due to the intergranular stress corrosion of Inconel X-750. In Belgium the first failures occured on the DOEL II Nuclear Power Plant, in January 1983, 8 years after reactor start-up. During core refueling 2 flexures were found with the head completely cracked off ; a third one was cracked but the head was not separated from the stem. Later on, after inspection using an eddy current technique, more guide tubes with cracked flexures were found.

The flexures are used to hold in place the removable insert during reactor operation and to allow removal of it during refueling. Removal of the insert is done remotely with a tool. The 4 flexures are pushed sideways and the insert is lifted out of the guide tube.

If the head of the flexures is broken, the insert is no more held in place. Replacement of the flexure is a long and difficult task.

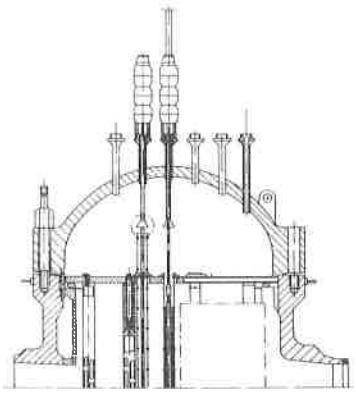


FIGURE 1

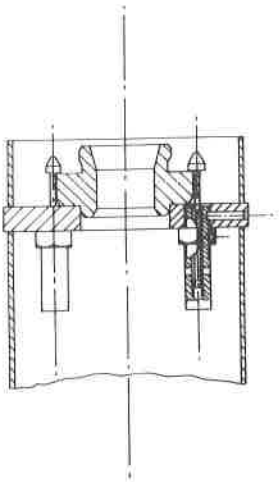


FIGURE 2

Figure 1 shows the location of the flexures in the upper part of the reactor internals.

Figure 2 gives some details on the geometry of the flexure.

2. SOLUTION

A more attractive solution is to design a new insert that remains in place without the flexures. ACEC has developed 2 different types of self locking removable inserts.
The first design has been made for DOEL I and II plants, an 8 feet core with a 14 x 14 guide tube.
The second design has been made for TIHANGE I power plant with a 15 x 15 guide tube.
It should be noted that no failures have been reported, to date, on the TIHANGE I flexures.
The second design is generic and can be used on all Westinghouse type reactors having a removable insert.

The ACEC self locking removable inserts have been designed to comply with the following functional requirements.

1. The self locking insert is adaptable to the existing 14 x 14 or 15 x 15 guide tube without any machining required prior to install it. The flexure may be in place or removed or without the head.
2. No stress is induced in the remaining flexures by the new self locking insert.
3. The flow area between the drive shaft and the insert is the same as before.
4. During core refueling the insert provides the required lateral guidance of the drive shaft.

5. Materials of construction comply with all codes and standards for reactor grade hardware.

6. Mechanical stresses are within the limit of ASME Boiler and Pressure Vessel code section III subsection NG.

7. The design is such to be easily installed and removed.

Figure 3 shows the DOEL type removable insert. It is a welded structure made of 304 stainless steel.

Figure 4 shows the TIHANGE type removable insert. It is much shorter because of the reduced space available in the upper guide tube.

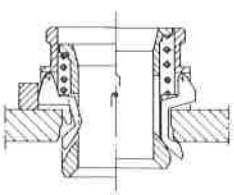


FIGURE 4

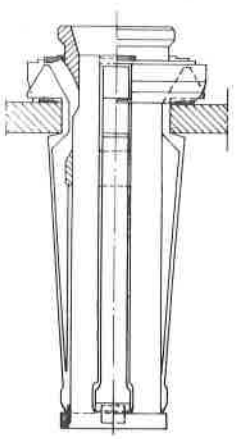


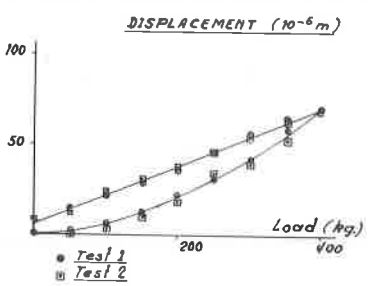
FIGURE 3

3. QUALIFICATION PROGRAMME

The ACEC self locking insert has gone through an extensive qualification programme to assess the design adequacy. The 3 major parts of the programme are a static test, a dynamic test and a in plant demonstration installation.

The static test shows the efficiency of the insert to remain in place by itself. The insert is installed on a mock up simulating the upper guide tube plate. A vertical upward load pulls the insert out of the plate. The load is increased step by step up to 400 kg. The vertical displacement of the insert with respect to the plate is recorded. The load versus the vertical displacement is reported on Figure 5. At 400 kg, a load much higher than the one existing during reactor operation, there is no significant displacement : only 70 10^{-8} m. The self locking insert remains perfectly in place.

FIGURE 5



The dynamic test investigates the flow induced vibration of the insert during reactor operation. The self locking insert is installed on a mock up simulating the upper guide tube region. The mock up is placed in a test loop with instrumentation to record the flow rate, pressures, accelerations and displacements. Figure 6 shows the spectrum of the vertical displacement of the insert with respect to its support. The displacement due to flow induced vibration is around 2.10^{-9} m RMS. It is a very small amplitude that introduces no significant stresses in the insert. The test indicates that the new self locking insert will not produce any flow induced vibration after installation in the reactor.

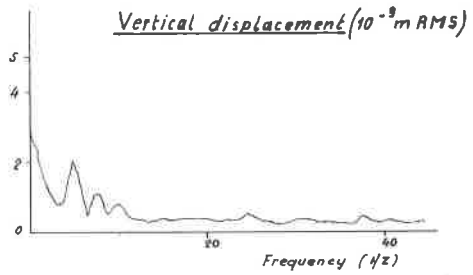


FIGURE 6

We have also investigated what will happen in case of failure of the spring of the TIHANGE I type insert. It must be noted that it has a very low probability of occurence because of the carefull design of the spring.

One spring has been cut in 2 pieces and assembled in the insert. The geometry of the insert is such that even with the spring in 2 parts, a reduced preload remains in the system. This preload is enough to keep the removable insert in place.

The insert with the spring in 2 pieces has been tested with the same procedure

Figure 7 shows the results of the static test : the vertical displacement versus the applied load. With 400 kg upward load the insert remains correctly seated on its plate. The deflexion increases slightly from 70.10^{-6} m to 84.10^{-6} m.

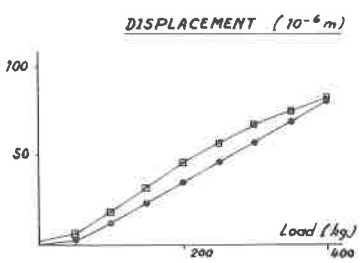


FIGURE 7

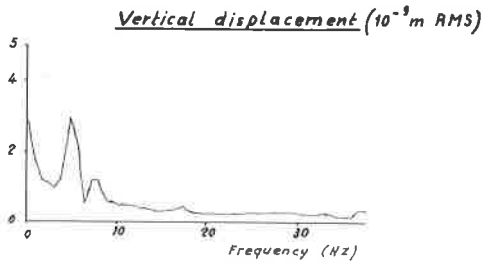


FIGURE 8

Figure 8 shows the results of the dynamic test : the spectrum of the vertical displacement. The flow rate is the same as the one of Figure 6. The displacement is around 3.10^{-6} m RMS. It is an increase of 50 % with respect to the insert with a correct spring. However the vibration level remains low and induces no significant stresses in the insert.

The tests have indicated that in case of failure of the spring the flexibility to the insert on its support increases but enough preload remains to maintain the self locking insert in place and to prevent any flow induced vibration.

All the tests have indicated that the design of the ACEC removable insert is adequate. Moreover for the generic type insert there is enough conservatism in the design that the insert remains correctly in place even with a broken spring.

A self locking insert has been installed in DOEL 2 power plant in April 1983. In September 1963, it has been successfully inspected and reinstalled in the reactor.

In March 1984, a self locking insert of the generic type has been installed in TIHANGE I power plant.