Vibration	Fracture of Heat Transfer Tube in Steam Generator	Plant
Self-Excitation		

Object Machine

U-shaped tube bundle of steam generator (square array, P/d = 1.46): Fig.1

Observed Phenomena

19 years after commencement of plant operation, one heat transfer tube suddenly broke, causing a fluid leakage and shutdown of the plant operation. Results of site investigation revealed that a member installed to shorten the support span of a heat transfer tube had a manufacturing defect (Fig.2). Thus, it is considered that the actual span became longer than the design, resulting to cause large vibrations. In particular, the U-bend tube bundle that is larger than the tube in question suffered a treatment to shut-down the flow during the initial plant operation. Although this was not a cause of this event, the disassembling inspection revealed a remarkable wall thinning.

Cause Estimation

A possible cause was estimated to be fluid-elastic vibrations of a tube bundle due to an orthogonal flow. This type of fluid-elastic vibrations is a sort of self-excited vibrations. There were two points in evaluation; why no trouble occurred for such a long period of time of 19 years, and why the U-shaped tube bundle in question broke.

Analysis and Data Processing

The U-shaped tube bundle of a steam generator is exposed to a water-vapor two-phase flow, and the generation limit of the occurrence of fluid-elastic vibrations under this condition can be evaluated by the value called “safety ratio SR” defined by the following equation (unstable for SR > 1).

SR=actual flow velocity/critical flow velocity

Evaluation of this critical flow velocity was made by using data obtained by large-scale experiments. From the results summarized in Fig.3. A conclusion was obtained that, since the tube has a high possibility for the occurrence of fluid-elastic vibrations, and this possibility becomes larger when the tube is supported as fixed by the attachment of sludge than when supported initially with a gap. It was also concluded that surrounding tubes might probably have suffered fluid-elastic vibrations from the beginning.

In addition, fluid-elastic vibrations under the condition of a water-vapor two-phase flow do not necessarily involve vibrations with an infinitely large amplitude. Instead, vibrations with a limited amplitude may also be generated, which can explain the reason why no trouble occurred for 19 years.

Countermeasures and Results

Summarizing the analysis of this event and the results of a large scale studies conducted subsequently, a standard of the Japan Society of Mechanical Engineers “Guideline for preventing fluid-elastic vibrations of U-shaped tube of a steam generator” was published in March, 2002. Since then, no trouble happened, which means that this standard is well observed, and at the same time, countermeasures have been taken to prevent defects during manufacture.

Lesson

This is an example to show how dangerous it is to manufacture products without properly understanding the intention of designers. It is very important to have common consciousness for all the persons concerned with products. That is the problem common to failure examples occurring frequently in recent years.

References

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Keywords

Fluid-elastic vibration, steam generator, heat transfer tube, water-vapor two-phase flow

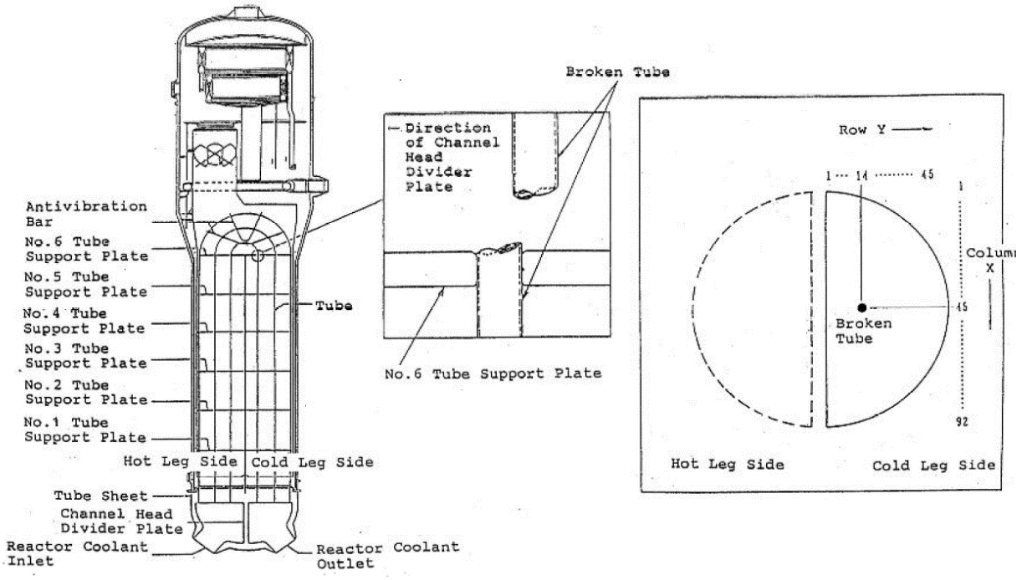


Fig.1 Cross-section shape of a steam generator and position of broken heat transfer tube

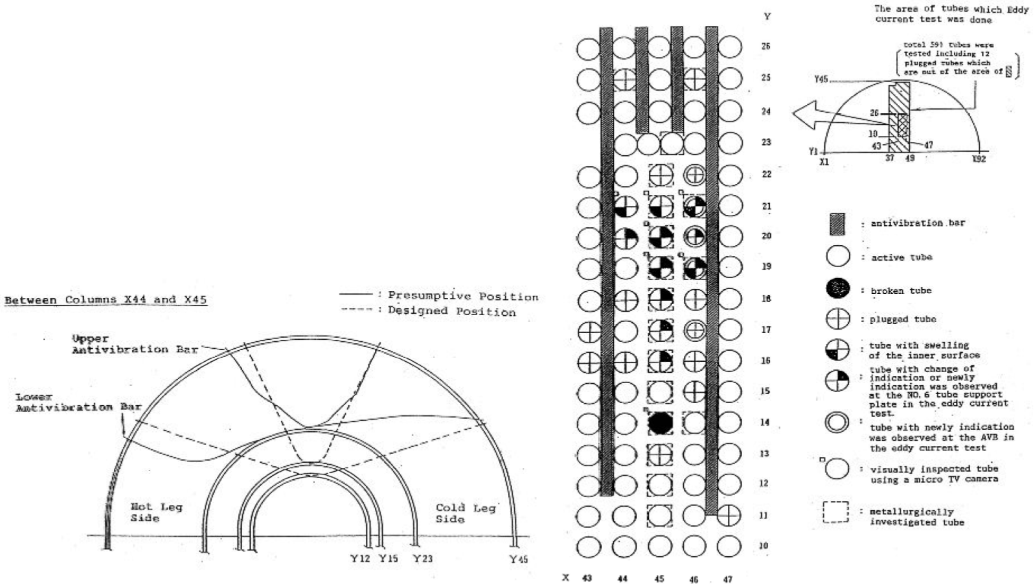
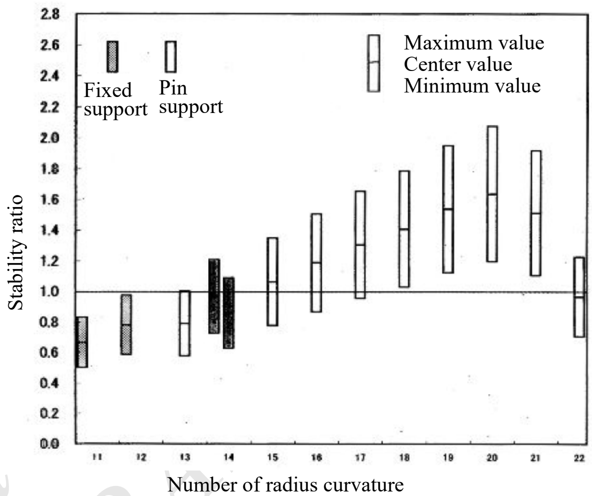


Fig.2 Difference in the designed position (dotted line) and actually installed position of an anti-vibration bar, and cross-section view of inserted condition



Stability ratio of broken tube and surrounding tube

Fig.3 Result of stability ratio analysis