

## Steam Generator Management Program Members Inquiries

SGMP recently answered some of our members inquiries and capture them in this document.

Question: Have there been any incidents in US power plants where foreign objects caused SG tube leakage? Please include information on the material and size of the foreign objects, the location where the foreign objects were found, the number of foreign objects, and the primary side leakage volume.

Answer: Yes, this happens infrequently but foreign objects are the leading cause of primary-to-secondary leakage in the US. The most recent event was at a US plant in 2020. The object was identified atop the hot leg flow distribution baffle. The plant shutdown at 177.91 liters per day. The tube was identified by secondary side hydro and the foreign object was retrieved. It was a 50.8mm x 10MM metallic object resulting from maintenance activities. Wear was identified on the following tubes: Row 59/Column 55, Row 58/ Column 54, Row 58 Column Row 55, Row 57 Column 54, Row 57 Column 55. This information is on the NRC Website (E200917t015525, ML21056A435, and ML21078A000.

There is no experience of a foreign object directly causing a tube burst and the most recent events were indications that satisfied the performance criteria.

Plants that have experienced leakage have always been able to safely shut down the plant. Typically, the objects that cause wear are found in high flow regions of the bundle. This is why inspections include visual inspections of periphery tubes (the annulus between the SG shell and tube bundle) and the tube lane (the area between the hot and cold leg of Row 1 tubes).

Question: Have there been any cases in US power plants where foreign objects were missing and could not be found or fully recovered? How were they assessed?

Answer: Yes, this is a typical occurrence. Eddy current may identify potential loose parts (PLPs) and sometimes they are not located when visual inspections are being performed or they are located in areas that cannot be visually inspected. Sometimes foreign objects are identified by visual inspections, but the foreign object cannot be retrieved. In both cases, utilities use SGMP reports (1019039, 1020989) that provide a prioritization strategy for foreign object removal decisions. The technical basis for the guidance in these reports is primarily operating experience from many years where foreign objects have been evaluated. The guidance evaluates the risk of leaving foreign objects in the bundle based on flow conditions and specific foreign object parameters (size and material). These reports are publicly available. Some plants have their inspection vendor perform an evaluation of the foreign objects that are not retrievable and will remain in the bundle. Some plants have had their original equipment manufacturer develop site-specific strategies based on SG-specific thermal hydraulic conditions.

Question: Have there been any cases in US power plants where foreign objects were detected by eddy current testing but could not be visually inspected, and how were they dealt with?

Answer: This was answered above.

Question: Have there been any cases in US power plants where the location of the foreign object was so special that it could not be removed? What was the solution?

Answer: If foreign objects are detected but can't be removed and the risk is high for causing wear, the affected tube and surrounding tubes are plugged and stabilized. Flow is evaluated to determine other tubes that should be plugged and stabilized.

Question: What is the composition of information in EPRI's Steam Generator Degradation Database system, and how is the data maintained?

Our members enter data after each steam generator inspection and SGMP personnel maintain the database. EPRI's own informal assessment is that this database is categorized at Part 810.

Question: Have foreign object exclusion devices/systems been installed in the feedwater systems of steam generators upstream in US power plant? What are their specific structures?

Answer: We are not aware of any US plant installing supplemental foreign object exclusion devices in the feedwater systems; however, some feedwater control valve designs include a foreign object trapping screen at the outlet.

Question: Have foreign object exclusion devices/systems been installed inside the steam generators of US power plants? What are their structures respectively?

Answer: In several replacement steam generator designs, there are "spray nozzles" included in the feedring that trap foreign material (see ML23018A178, ML23087A063 on NRC website). They have been successful in keeping larger foreign objects from entering the bundle. Another plant discusses a disk stack positioned in the feedwater regulating valve that is an effective barrier against foreign objects (ML23086B917).

Question: Have US power plants installed foreign object exclusion devices on the feedwater ring headers of steam generators? Are there inspection ports/flanges on the feedwater ring headers? What is the inspection frequency?

Answer: See previous response. The spray nozzles can be opened, inspected, and cleaned out (ML23087A063). There is no requirement to do this. Utilities typically do this in conjunction with upper internals inspections.

Question: Have US operating units implemented secondary side modifications to add foreign object devices/systems inside the SGs? What are the implementation plans, and have any defects or foreign object risks been generated after operation?

Answer: No

Question: Have US operating units implemented modifications to add inspection ports on the secondary shell of the SG? Can all the support plate positions inside the SG secondary side be inspected, and what methods are used for inspection?

Answer: Replacement SGs will have more inspection ports than the original SGs but still not every support has an inspection port. It would be unusual for a plant to cut a hole in the shell of a SG in an operating plant for purposes of foreign object retrieval, but this has occurred.

Question: Does the United States have foreign object inspection tools that can reach the entire SG tube area?

Answer: The US plants use vendors to perform visual inspections. They have tools that can retrieve foreign objects, but there are objects where these tools are not used. There are risks associated with inserting a retrieval tool deep in the bundle. There are also areas of the bundle that are not accessible for visual or retrieval.

Question: What is the supplementary inspection strategy for foreign objects in US power plants, and which inspection methods are used respectively?

Answer: Some plants use an array coil on the periphery of the bundle, and some use a rotating coil probe on the periphery. Most plants perform visual inspections of periphery tubes each time they perform eddy current testing (see ML23018A17B).

Question: What is the strategy for dealing with foreign object wear on SG tubes or damage to SG tubes in US power plants?

Answer: As stated in White Paper 3002030563 (publicly available), when assessing the need to plug tubes due to foreign object wear, the same 40% through wall plugging criteria as used for other wear mechanisms is used. As seen in several steam generator inspection reports on the NRC website, plants perform eddy current and secondary side visual inspections to identify foreign objects, and some objects are determined to pose no threat to tube integrity and left in the bundle (ML23018A17B, ML23086B917, ML23087A063, ML23095A171, ML23114A341, ML23305A041).

Question: Do US power plants install stabilizers on all tubes that need to be plugged?

Answer: Not for all damage mechanisms. For all tubes plugged for foreign object wear when the object cannot be retrieved, the tube is plugged and stabilized (ML23291A081). If the tube is plugged for other reasons, an evaluation is performed to determine if the degradation will continue to grow. If it is assumed the degradation will continue to grow, the tube is stabilized (ML23305A041).

Question: Does EPRI use a porous medium model or real modeling in the calculation of secondary thermodynamic parameters during the calculation of foreign object wear on SG tubes?

Answer: As reported in SGMP White Paper 3002030563, SGMP has an ongoing project that completed the first phase in 2023 and provides a software for evaluating foreign objects in the SG tube bundle. This software calculates the SG tube wear from a given object at a specific bundle location. This project's deliverables are not publicly available. In this research, the foreign objects are located near the top of the tubesheet where the tube is not vibrating only the foreign object displays movement. Turbulence force spectrum in the tube bundle near the foreign object is measured and the spectrum is used to estimate the sliding motion of the foreign object on the tube outside diameter which leads to the wear. Steady and turbulent drag forces are parameters for estimating contact force between the foreign object and the tube. Turbulent lift force is a parameter creating the foreign object sliding motion on the tube surface. The fluid force data developed in this research is only applicable for the top of the tubesheet region and is based on results from a test rig

designed to simulate the top of the tubesheet region. Thus, the fluid force data should not be used for any other regions in the steam generator.

Question: What are the main prediction methods used by US power plants in the process of predicting foreign object wear, and in what situations are they used respectively? Please give an example for each and express the specific calculation and evaluation process in detail.

Answer: Plants use the prioritization strategies discussed above. The only time the wear would grow is if the object is left in place and in that case the plant would plug and stabilize (ML23305A041). SGMP has developed a software discussed above that could be used to estimate the wear time until a certain wear depth is reached. However, according to EPRI's own internal assessment, this software is categorized as Part 810.

Question: Please specifically introduce the strategy and requirements of US power plants for foreign object management in steam generators, as well as how they are specifically implemented.

Answer: US plants perform eddy current to identify foreign object wear and if identified with no object present, the tube is plugged if the wear is greater than 40% as stated above. If the foreign object remains, the tube is plugged and stabilized. Other tubes surrounding that tube may also require plugging and stabilizing. US plants also perform visual inspections to identify objects. They use the prioritization strategies referenced above to make decisions regarding retrieval attempts (see ML23018A178).