The purpose of this paper is to provide pertinent information relevant to the subject matter of Almaraz NPP Steam Generator Performance, regarding the scope of inspections performed, eddy current and ultrasonic applied techniques, tube cracking defectology, tube pulling and destructive exam as well as the Spanish GRUVAL qualification program involved.

Almaraz NPP Units 1 and 2 replaced the three existing Steam Generators (SG) model D3 of Westinghouse in 1996 and 1997 respectively with steam generators designed and fabricated by Siemens-Framatome model 61W/D3 with advanced material tubing Incoloy 800 Modified, with no pre-heater design and with flow distribution baffle. Each steam generator has 5,130 U-tubes ¾” x 0.043” in a triangular pitch pattern. The U-tubes were manufactured by Sandvik and are supported by stainless steel lattice grid supports along the straight portion of the tube and bars in the U-bend region as shows the following picture.

At the beginning of the operation with the new replaced SG, the inspection scope performed was according to the technical specifications, in general, 9% of the tubes, full length bobbin coil Eddy current Testing (ET) in one SG each outage. In the first years of operation, there were not tubing degradation and no loose parts present at the secondary side. As particular, situation was Almaraz 2, where no one tube was plugged in all 3 SG during 7 years operation neither pre-service examination and in-service inspections until 2004 (first tube removed from service by plugging).
In 2006, after Unit 1 11 years of operation and Unit 2 9 years, the inspection scope was increased up to 50% with bobbin coil probe in order to meet with the Generic Letter 2006-01. In addition to, it was performed an inspection with motorized rotating pancake coil +point probe (RPC) at the upper roll transition zone at the top tube sheet (TTS); at that time, denting phenomena was detected in the TTS in both legs, hot and cold and located at the sludge pile area where there is not flow distribution baffle (FDB). Denting was present since 2004 but it was reported as first time in the following ET examination, year 2006 (18 months operation cycles) and it was associated with deposits and hard sludge in the area below the hole of the FDB where there is less velocity flow.

Until the refueling outage in 2009, no indications related corrosion were detected in all SG, however, in 2009, circumferential crack like indications outside surface at the top tube sheet were detected when performing the rotating pancake coil sample examination. In order to confirm these unexpected results, an ultrasonic (UT) examination was performed in a set of tubes sample with and without ET indications; In a total, UT inspection was performed to 10 tubes reported as ODSCC with ET as well as in 2 tubes reported as NDD with ET. Both Non Destructive Examination (NDE) methods were fully consistent. This information will be used for the ulterior qualification of ET technique within the Spanish qualification process called GRUVAL. All tubes where circumferential crack-like indications were present were stabilized and then plugged.

The following plots show the ET and UT evaluation results:

Since the corrosion problem was detected, the ET inspection scope has been adapted to the defectology observed and both large bobbin coil and RPC inspections are being performed.

In addition to UT inspection and eddy current bobbin coil and rotating pancake +point coil probe, other ET probes such as 8x1 profilometry probes and array probes have been applied.

The following graphic shows the 8x1 pancake coil Profilometry ET predicted maximum depth measurement at dented position vs METallographic (MET) examination of the 3 tubes pulled tubes:
On the other hand, a sample of tubes were inspected with both 8x1 pancake coil profilometry probe and Bobbin coil probe and a good correlation between bobbin coil denting amplitude and 8x1 probe profilometry average diameter was observed as shows the following graphic:

In 2010, apart from the ET large inspection scheduled, 3 tubes were pulled out from the SG3 for determining the root cause of SCCOD degradation as well as for confirming the ET indications. Destructive examination in lab confirmed the presence of tube cracking in a form of intergranular crack morphology and stress corrosion crack process within corrosion environment slightly alkaline and containing high iron content, magnetite, silica, calcium, etc. the sludge analysis.

The selection criteria for the 3 tubes pulled were, tube with maximum amplitude of ODSCC ET.
signal, tube with maximum arc of ODSCC ET signal and tube reported as having maximum Denting amplitude by means ET.

The next picture shows the ET terrain plot as well as the MET results for the tube with the maximum amplitude of ODSCC ET signal and the following picture shows that in addition to the normal eddy current data analysis from the raw data of the +point probe and in order to determine the percent degraded area, “sizing” process was performed and the result for the tube with maximum arc of ODSCC ET indication is included in the mentioned graphic.

The presence of this corrosion damage mechanism on the SG dented tubes at Almaraz is a big concern and a qualified inspection is a key activity to guaranty safe and reliable operation and several actions are taken to reduce the initiation conditions such as reduction of sludge generation in plant startup and shutdowns, as well as in both transitory and operation conditions.