

Systematic Quality Approach Program for Zr Alloy Tube Manufacturing Technology and Performance Evaluation Technology

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1. Introduction

The objective of the systematic quality approach program described in this paper is to verify that the tubes manufactured by Techno Special Alloy (TSA) of Korea Nuclear Fuel Company Limited (KNF), Daejeon, Korea meet the specification and drawing requirements, and to show the quality of tubes are considered equivalent to the tubes manufactured by Westinghouse Electric Co. (WEC), Blairsville, PA, USA. This systematic quality approach program consists of a three-phase program which is designed to assure the equipment feasibility, tube quality and further the adaptability in fuel assembly.

2. Methods and Results

In order to demonstrate the tube equivalency quality between WEC products and KNF products, KNF strategically performed a three-phase qualification program, divided into three major categories: equipment qualification, tube product qualification and fuel assembly qualification through integrity of cladding tube to end plug welding.

2.1 The 1st Phase: Equipment Qualification

The first phase for equipment qualification is further divided into four categories as per step by step process. The final objective of this phase is to qualify equipment and set up manufacturing parameters for each unit process.

2.1.1 Vendor Site Acceptance Test (VSAT)

VSATs were performed to see if the equipment manufacturer designed and fabricated machines per the requirements such as the technical specification and drawing and their performances reach the specification requirements. WEC, the counterpart of joint development program, and KNF developed proper checklists, measured and recorded the results of the VSATs on equipment. WEC provided competent personnel and vendor provided devices for such performance tests in accordance with requirements of each test as defined by WEC in order to address functionality of the equipment. Most of test results were

satisfactory to the requirements, and some of needed improvements issued during VSATs were made to the machines prior to Daejeon Acceptance Test (DAT).

2.1.2 Daejeon Acceptance Test (DAT)

DATs were performed to demonstrate the proper functions as manufacturing equipment and verify whether each equipment conform to the requirements requested by the technical specification. In addition, the tests confirmed the successful completion of the installation as well as the readiness for conducting the Zirconium Demonstration Test (ZDT) for each piece of the equipment. The DATs of the equipment were performed by vendors, WEC and KNF. All the DAT results were found to be acceptable to proceed with ZDT.

2.1.3 Zirconium Demonstration Test (ZDT)

After the successful completion of the DATs, ZDTs were cooperatively carried out by KNF and WEC for the equipment associated with manufacturing process to check each machine function and inspect tube dimensions and surface condition meet their requirements for manufacturing zirconium alloy tubes. WEC and KNF prepared ZDT plans and reports describing test criteria and results regarding each individual item of the equipment qualification test (EQT) for each item of the equipment. All ZDT results were found to be acceptable enough to proceed with EQT.

2.1.4 Equipment Qualification Test (EQT)

After the completion of DATs and ZDTs, EQTs were performed by KNF's authorized personnel with the technical assistance of WEC. KNF developed and customized the EQT plans to KNF own QA requirements referring to the WEC's current practice and equipment operating parameters. Manufacturing process parameters for the machines were set up through EQTs. Basically, parameters currently in use for production in WEC were used for the qualifications of KNF equipments. In some cases, minor adjustments were made to parameters used in the tube manufacturing processes at KNF. All the test plans

and reports for the qualifications were verified by WEC. Sample tubes were manufactured during the qualification tests. The qualification tests demonstrated that WEC supplied equipment and the localized equipment associated with process package are able to produce the intermediate and final products, as agreed by KNF and WEC. All test results were found to be acceptable to meet acceptance criteria based on the drawing and specification requirement and successfully set up parameters for each piece of equipment in its unit process.

2.2 The 2nd Phase: Tube Product qualification

The second phase for tube product qualification is divided into two major tests, namely, product qualification test (PQT) and characterization test (CT).

2.2.1 Product Qualification Test (PQT)

KNF performed PQTs to qualify each type of tube product to be manufactured in KNF plant. PQT consisted of continuous processing from forming process to finishing and final inspection steps which are required to manufacture the finish tube product. PQTs were performed to confirm by the inspection and test that tubes conform to the specification and the drawing requirements. PQTs were conducted on 21 different types of tubes and all were successfully qualified for manufacture by KNF. All 21 tubes met the specification, and drawing requirements.

2.2.2 Performance Evaluation by the Specification and Characterization Test

As part of joint development program, a joint characterization test program including specification test was developed by KNF and WEC to demonstrate to customers of KNF the tube equivalency of products manufactured by KNF and WEC plants respectively. KNF and WEC manufactured at KNF plant and WEC plant, respectively seven strategically different tube sizes, two ZIRLO™ alloy cladding tubes, one Optimized ZIRLO™ cladding tube and four different ZIRLO™ alloy guide thimble tubes respectively and exchanged products of sufficient quantity between two plants for the purpose of performing characterization tests mutually developed and agreed in order to demonstrate the equivalency of KNF manufactured tubes to WEC manufactured tubes. In the specification test, tubes were tested such as 6 test items for fuel tube and 3 test items for thimble tubes. In the characterization test, tubes were tested such as 19 test items for fuel tubes and 15 test items for thimble tubes. All the test results from the specification test were shown to meet specification requirements. Besides, the results of each characterization test for both KNF and WEC manufactured tube lots of a given design were

found to be comparable. Therefore, the tubes manufactured by KNF are considered equivalent to the tubes manufactured by WEC.

2.3 The 3rd Phase: Fuel Assembly Qualification through Integrity of Cladding Tube to End-plug Welding

Finally, in the third phase, qualification test for fuel assembly of end-plug welding process was performed in KNF to demonstrate the integrity of the quality of fuel rod assembly loaded with tubes manufactured by KNF. As part of qualification, the following tests were performed with welding samples in the final phase : weld bead visual & dimensional inspection, burst test, metallographic test for bursted area, and corrosion test. All test results were found to be acceptable in accordance with the specification requirements.

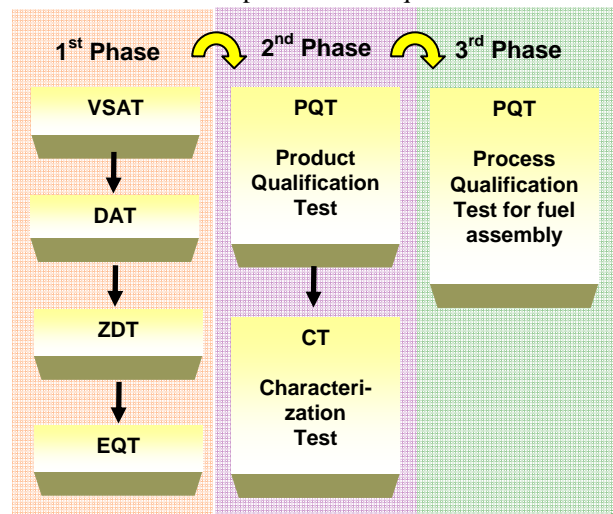


Fig.1. Schematic Diagram of a Three-phase Qualification Program

3. Conclusions

Throughout the three-phase qualification program finally aimed at overall integrity of fuel assembly loaded with tubes manufactured by the localized tube manufacturing technology, it was demonstrated that all tube manufacturing technologies and processes were successfully established and tubes made in KNF are equivalent to tubes manufactured by WEC.

As part of additional verifications, in-pile test shall be performed to monitor the integrity of KNF tubes in the near future so that it will confirm the stability on the nuclear fuel loaded with localized tubes.