APA Acceptance Process

There are a substantial number of QC checks that are performed during APA fabrication. The detailed criteria used in assessing whether an APA passes each check are documented within the written procedures, which are stored in EDMS ([CERN-0000214924](https://edms.cern.ch/project/CERN-0000214924)) under formal change control. The results of the various QC tests are stored in a hardware database. In some cases, the information in the database is just an acknowledgement that specific checks have been done (for example, the frame bolts have been checked to confirm proper torques). In other cases, test data is collected and input into the database (for example, the measured tensions on each APA wire are recorded). Once an APA is completed, an Executive QC Summary is extracted from the information in the hardware database. This Executive Summary is used by the Technical Coordinator and DUNE Compliance Office to assess whether an APA can be accepted.

Some of the important acceptance criteria are the following:

1. Aside from a few very short segments, wires are required to have measured tensions of 7.0 +/- 2.0 N. In addition, no more than ten percent of wires on individual layers are permitted to have tensions lying within the outer portions of the allowed region (5.0-5.5N and 8.5-9.0N). To meet these requirements, individual wires are cut out, replaced, and re-measured as necessary. We expect, therefore, that the post-fabrication Executive QC Summaries will report tension data consistent with meeting these requirements.
2. Frames are surveyed prior to winding to ensure that they meet flatness requirements and fit within their defined envelope. The survey also measures the twist and bow in different regions of the frame to check that these are within acceptable limits. Survey results are stored in the database and output as part of the QC Executive Summary. It is expected that the survey results reported in the Executive Summary will lie within specifications since the frame would otherwise not be wound.
3. The thickness and geometrical features of the APA edge boards are checked to make sure that they are fabricated within defined tolerances. The results of these measurements are stored in the hardware database. Boards not meeting the requirements are not used in the construction of APAs.
4. Each spool of wire received from the supplier is tested to ensure that it meets minimal strength requirements. The results of breakage tests performed on several wire segments taken from each spool are stored in the hardware database. The results of the breakage test need to demonstrate that the wire on the spool satisfies minimal strength requirements. If not, the spool is discarded and not used for winding APAs.
5. A consequence of the APA design is that it is not possible to replace wires on completed layers (once the winding of the subsequent layer has been initiated). For this reason, if accidents occur during the fabrication process leading to wires being broken on already completed layers, the only action to be taken is to remove these wires (leading to missing channels). Electrical connectivity tests performed after the winding of each wire layer can also indicate problems within edge-board stacks that prevent the read out of individual channels. The edge-boards are tested for electrical connectivity prior to installation, but if problems develop after they are glued to the edge-boards of the previous layer, there is no way to remove them leading to the possibility non-functioning channels. DUNE has a high-level requirement for >99% working detector channels. In the case of APAs, this requirement encompasses both the APA wires and their associated readout electronics. For this reason, we will not accept an APA with greater than 0.5% non-functioning wires. Removed or non-functioning wires are detailed in the hardware database and this information is presented in the QC Executive Summary used by the Technical Coordinator and DUNE Compliance Office to determine whether an APA should be accepted.
6. Material certifications are received from the suppliers of the components needed to construct the APAs (frames, boards, mesh panels, wire, and conduits). For each component, a specific individual is charged with inspecting the certifications, making sure that the accompanying documentation is sufficient, and uploading this documentation to EDMS. Once these checks are complete, the individual responsible indicates in the hardware database that these checks have been completed. Information regarding who has signed-off for each component are included in the QC Executive Summary.

APAs will not be shipped to Fermilab until the QC Executive Summary has been produced and signed-off on by the Technical Coordinator and the DUNE Compliance Office. After an APA is received at Fermilab, an additional set of checks is performed to verify that no additional damage has occurred during its transport. In addition to visual inspections, tension measurements of each wire are repeated using a charge-injection system. Because of the relaxation of wires over time, we do not expect all wire tension measurements to lie within the original 7.0 +/- 2.0 N range. In the case of wire tension measurements lying substantially outside the prescribed range, the individual wires are removed. The charge-injection technique used to make the tension measurements is also effective for determining if any additional bad connections in the board stacks are present. After this testing, the total number of bad channels is re-assessed to ensure compliance with the >99.5% working channel requirement. At this point, DOE accepts of ownership of the APAs coming from the UK which meet all acceptance criteria.