QUALITY ASSURANCE AND ACCEPTANCE PLANS FOR THE GlueX BARREL CALORIMETER PROJECT

Version 2

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Introduction

The quality assurance (QA) plan overview for all aspects of the BCAL Project at the University of Regina is presented herein. The quality of every BCAL module depends on the quality of the fibres and the uniformity of the constructed matrix Details on the construction and fibre QA are provided as separate documents[1].

1 Fibre Acceptance

The response of randomly selected Kuraray SCSF-78MJ (blue-green) scintillating fibres from every production shipment for the GlueX Barrel Calorimeter (BCAL) is measured. The uniformity in diameter, spectral response, effective attenuation length and number of photoelectrons are extracted and reported to JLab and Kuraray, as per the Statement of Work (SOW).

Specifically, the objective is to evaluate whether the principal characteristics of Kuraray SCSF-78MJ scintillating optical fibres, namely the uniformity in diameter, the produced spectral shape, the effective attenuation length, and the light output in terms of the number of photoelectrons measured, meet GlueX specifications so that the fibres can be used in the construction of BCAL modules[*]. The contract specifications are summarized below.

1. *Diameter*: Dimensional uniformity of the diameter is specified at 1mm with a RMS<2%.
2. *Spectral shape*: The spectral shape is required to fall in the wavelength range of 430-550nm.
3. *Effective attenuation length*: The bulk attenuation length must be greater

[*] Other parameters were cladding thickness, time structure of the scintillation light and base material components, but these were not evaluated and thus not reported herein.

than 300cm when measured with a bi-alkali photomultiplier tube and with RMS<10%.

4. *Light output*: The GlueX Collaboration quantifies this as the number of photoelectrons (pe) collected at the fibre's end and must be greater than 3.5 pe and with RMS<15%, using a bi-alkali PMT at 200cm from the source.

The quality assurance for fibre testing and acceptance is comprised of several steps.

1. *Shipment receipt and inspection*. Each shipment received is inspected for damage to the exterior of the wooden crate. If any significant marks, gashes or breaks are noted, photographs are taken. Otherwise the crate is opened and the interior is inspected and photographed if anything appears out of the ordinary. Next, the cardboard boxes are counted and their labels checked and compared to the shipment information provided by the vendor. All this information is recorded in a logbook and in our electronic Log (Elog), and communicated to JLab and the vendor.
2. *Fibre testing for attenuation length*. Fibres a randomly selected for testing in the attenuation length station, where they are coupled to a photodiode, readout by a picoammeter, as described in a separate document[2]. If their condition does not meet expectations, this is recorded and reported as in Step 1. During data acquisition the operator notes deviations from the expected intensity and exponential behaviour and, if observed data is re-measured then or the next day following the, more detailed, offline analysis. Data and observations are recorded in Excel sheets, in the 'attenuation' logbook, the Elog and a password-protected web site, and reported to JLab as per the SOW.
3. *Fibre testing for number of pe*. The same fibres tested in Step 2 are moved over to the photoelectron station (in the same lab) and coupled to a PMT readout by a data acquisition system, as described in a separate document[3]. The operator runs an online script that provides graphical feedback on the quality of coupling to the PMT. If the requirements are not met, the fibre is recoupled up to 4-5 times. If all is ok, data is recorded, analyzed overnight, and inspected the next day. Data and observations are recorded in ascii files on a computer and backed up on another, in the 'phototelectron' logbook, the Elog and a password-protected web site, and reported to JLab as per the SOW.
4. *Fibre diameter measurements*. At the photoelectron station, the diameter of a few fibres (typically 30) is measured using a micrometer caliper. Data and observations are recorded in an Excel sheet, in the 'phototelectron' logbook, the Elog and a password-protected web site, and reported to JLab as per the SOW.
5. *Fibre usage in the builds*. Based on the evaluation of the first five shipments, the fibres meet contract specifications, but clear variation from batch to batch and shipment to shipment exist. The Regina

measurements track with those from Kuraray, lending legitimacy to the findings. As a result, the fibres can be grouped into two coarse categories, termed A and B, based on their attenuation length. Specifically, Caterogy A is composed of Shipments 1-3, totaling about 100,000 fibres, exhibit lower attenuation length as a group in comparison to Shipments 4-5 that also total 100,000 fibres and form Category B. The plan is to use fibre bundles from a single category in the build of each module. It should be noted that the number of pe does not exhibit any strong dependency, although patterns are observable as well. Feedback will be sent to Kuraray and we will ask them for details on their procedures, the critical step(s), and what they can do to tighten the spread in attenuation length.

The fibres are stored in their crate in the Detector Lab until acceptance of that shipment takes place, and then they are moved to the Construction Lab for use in the matrix building.

2 Lead Swaging

Lead swaging is one of the two critical operations in ensuring a uniform build of the matrix. Errors resulting from not following established procedures lead to severe problems in the build of the Construction Prototype that necessitated the construction of a stand-alone patch to rectify the straightness of the unit. We have identified two types of mistakes: a) lead sheets were used in the build that did not have an integral number of grooves all parallel to the long edge of the sheet, meaning that grooves vanish from one edge and appear on the other side, and b) one lead sheet had a kink or similar deformity lead to a change in direction from that parallel to the long axis of the module.

As a result of this experience, the Swager was inspected, its table adjusted, and, most importantly, the procedures were overhauled and improved. This included a re-training of all students in swaging, tagging, and recording, and swaged sheets are coiled and now tagged and separated into perfect ('P'), 1-groove off ('1-off'), and scrap (anything more than one grooves off or having any other structural deformity). Each sheet is unfurled and re-checked just before being used in a build. The step-by-step procedures are provided in a separate document[4]. The students now alert the Construction Manager to inspect every sheet that does not comes out perfect or 1-off. A new brass gauge will be constructed to facilitate the thickness measurements of swaged sheets.

Perfect sheets will be used for the bottom layers of each Mayan step, then 1-groove-off sheets off may be used near the top of each step, as long as they roll on correctly and host all fibres parallel to the module's axis.

The lead is stored at our other campus in a humidity and temperature-controlled environment until needed for swaging.

3 Matrix Construction

The matrix build (or lay-up) is the second critical operation towards a uniform build. This is a multi-step process and tolerances have to be strictly adhered to in each step in order to achieve the desired goal:

1. Both presses must be level. This has been accomplished for both to 0.004" (1/10 of a millimeter).
2. The 1.25" aluminum base (outer) plate must be flat and the guide groove must be 0.54mm deep to allow a firm sitting of the guide fibre. Each plate is machined at Ross Machine Shop (RMS) to ensure these and re-measured at the UofR before starting a build. This has been accomplished.
3. The guide fibre is glued into the guide groove using optical epoxy. This is straightforward and has not resulted in any issues in the past.
4. The first (perfect) lead sheet is bonded to the base plate by judiciously applying industrial epoxy. The sheet's centre groove is aligned and set over the guide fibre. This is also straightforward. The straightness of the lead sheet is checked the next day using a toothpick and a straightedge and wire with posts that are aligned with the base plate's centerline. If the sheet is not straight it will be removed and the procedure starts again with a new plate. The old plate will be machined to remove the epoxy and can be reused.
5. Epoxy is applied to the top grooves. Its amount is hard to control very precisely, but we will err on applying more rather the less. Care will be exercised to ensure that adequate epoxy is applied to the perimeter of the sheet. Topside illumination will be used to allow good visibility of the glistening fibres and catch any problems. Typically, 100g of resin and 28g of hardener suffice to build two layers. The epoxy is monitored for stiffness and the amount used and discarded is tracked. The module will be inspected each day to observe the epoxy runoff along its four vertical sides.
6. Fibres are laid in the grooves. We expect no problems during this step.
7. Perfect or 1-groove off lead sheets must be employed, as described in the previous section, laid alternatively to avoid stacking tolerances front to back (accounts for thickness difference between one edge and the other as extruded by the swager) and top to bottom (to account for differences in the swager's rollers/drums). When sheets are straight the roll nicely over the fibres and they are felt 'clicking' onto them. The straightness of

each is checked with a toothpick and posts plus wire and runner system. If not straight, the sheet is removed and discarded.

8. The foam rubber plus polyethylene sheet will be used under the top aluminum pressing plate. A Teflon sheet will be used between the rubber and pressing plate to avoid friction and movement when the plate is laid down. Fettuccini will be used at the two ends to block epoxy migration.
9. The height of the build will be measured each day after pressing, at several spots along both of its long edges.
10. Any misalignment in any step will face immediate corrective measures or if not possible stoppage of the build until the situation is correctly assessed and a suitable corrective action is chosen.
11. The top (inner) aluminum plate is affixed to the completed matrix using industrial epoxy and a set of custom jigs. This has only been done once, but worked perfectly, even under the adverse conditions resulting from the poor alignment of the Construction Prototype. No issues are expected here.
12. The finished module is craned off the press, crated and shipped to RMS. We will enact a contract between the UofR and RMS for the construction of all 48 modules.
13. RMS machines four modules in sequence to the dimensions and tolerances specified in the contract drawings and record the final dimensions into the traveler document. UofR personnel will inspect the module and check all measurements. In particular, a gauge will be custom build at UofR to check the alignment pin and bushing locations and sizes to ensure that the module can mate properly with its adjacent neighbour during BCAL assembly.
14. Optical testing of the module will take place using digital photographs to inspect the matrix and compare with the logged information during the build. A second test will measure the transmission uniformity across the face of the module. Issues are not expected with the latter, and the former depends on the success of the build.
15. All the information above is recorded in the traveler documents, logbooks, E-log, etc.

All conceivable improvements in our past procedures have been considered and implemented towards the quality assurance of the modules. The crew has been re-trained in procedures and the crucial aspects of the swaging and building have been impressed on them. They have also completed a refresher course in safety. In the initial stages of construction for the first two production modules, the Construction Manager will lay every lead sheet and supervise all aspects.

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[1] BCAL Readiness Review, GlueX-doc-1372.
[2] Fibre Handing at the Attenuation Length Station, GlueX-doc-1372, attachment.
[3] Fibre Handing at the Photoelectron Station, GlueX-doc-1372, attachment.
[4] Lead Handling Instructions, GlueX-doc-1372, attachment.