**Technical Review of SBND APA Frame Design**

**23 February 2016**

Committee Members:

Lee Greenler (PSL,University of Wisconsin)

Jo Pater (University of Manchester)

 Peter Sutcliffe (University of Liverpool)

**Executive Summary**

**Specific Comments and Recommendations**

**Findings:**

***Lee Greenler***

The plans for the fabrication of the APA frames appear to be well advanced and reasonably complete. The areas that weren’t complete were identified and a path to finishing them was identified. The fabrication drawings appear finished.

Plans for board and wire assembly, APA handling during installation and for mounting the APAs were not discussed significantly. The focus in this review was mostly the fabrication of the APA steel frame.

***Jo Pater***

The design of and drawings for the APA frame seem to be complete and adequate, except for the final definition of post-weld holes; I agree that in principle there is enough time during the early stages of manufacture of the first frame to finalise these so I see no reason not to commence the manufacture.

***Peter Sutcliffe***

The APA Frame drawings and analysis are in an advanced state and were submitted for manufacture. I visited the company making the frames, Portobello, and from my experience are an excellent company who are experts in welding high quality fabrications. I have no doubt they will meet the geometric specifications shown in the drawings.

**Comments and Recommendations:**

***Lee Greenler***

1. There are slots in some of the tubes for cleaning access. Some thought should be given to how these will work and whether they will provide adequate access.
2. Some concern was expressed about the mesh inserts. The side members (steel angle) holding the mesh are fairly heavy so they might be rigid enough but, on the other hand, they are pretty long. The main question is whether they can provide adequate tension to the mesh without bowing in too far. As was suggested, the sides may need an intermediate screw anchor to achieve this.
3. The loose holes for holding the photon detectors in place look well thought out. It appears they will fit on the screws over the whole frame size tolerance range. Although it’s conceivable that the frames might shift during cooldown it was stated that this would not be detrimental if it happened.
4. Use of 304L stainless instead of 304, if possible, appears to be a good idea. The welded areas will be slightly less susceptible to corrosion (though this is not a corrosion prone application). The mechanical properties, such as yield strength, are decreased but the stresses in the APA are probably far from yield.
5. The ends of the frame tubes that butt into the side of a tube will be profiled to match the rounded corners of the tube they join. PSL did this and found it led to shrinkage and deformation problems. It was made more difficult by the variability in corner radii from one tube to another - preventing a good fit without custom machining of each one. If the fabricating company has experience with this technique it may not give them any trouble.
6. 10 mm pins are being proposed to locate the geometry boards. These will be advanced as successive boards are put in place by pulling them out of a close fitting hole. It could be difficult in steel to get the exact right fit that would keep the pins from falling out but that would still allow them to be slid up with a reasonable effort. These would be high precision holes. The pins should probably not be left during cool down. A slight unevenness in cool down rates could cause the pins to become loose.

***Jo Pater***

I apologise that I was not able to stay to the end of the review.

As I expressed in the review, I was concerned that the deformational FEA of the frame in its vertical position was done without the additional weight of everything that will eventually be attached to it, in particular the PDS units. The largest deflection is near the bottom of the frame where some of the shortest wires will be attached; significant stress could be put on those wires if the frame were to sag significantly under load. Peter Sutcliffe has since done an FEA with added solid blocks, leveling bars and an extra 110 kg of load, distributed evenly over the frame, to simulate other components including the PDS units; with this load in place the expected deflection is still only a fraction of a mm; I’m satisfied that this will not cause a problem.

No mention was made of a definitive plan to check the inside of the hollow sections for metallic debris (especially post-weld-drilling swarf) once the frames are delivered (unless this was discussed after I left). I strongly recommend that such a procedure be developed, as drifting metallic debris in the TPC volume would be disastrous.

I also recommend that the holes for the PDS frame mounts be drilled post-weld if at all possible; I do appreciate however that this could result in debris inside the RHS that may be difficult to remove after welding, but as I’ve already said I believe we need to become confident that we can identify and remove any such debris. The reported plan to use oversized mating holes and correspondingly large washers could allow the PDS units to slip, potentially causing damage to the fixing screws, particularly if the PDS units are at all heavy.

If these holes really must be drilled pre-weld, a better option would be to survey their positions once the APA frame is complete, and drill mating holes of the same size in each PDS mounting frame (although this is unattractive from the point of view of modular construction as the PDS units would then likely not be interchangeable.)

I support the suggestion to drill extra holes on the inboard faces of the frame to allow more attachment points for the mesh frames; this will provide additional electrical contact and keep the mesh well tensioned without allowing the mesh frames to bow. As with the PDS-frame holes, these would ideally be drilled post-weld, or the mating holes in each mesh frame would be drilled to measure.

***Peter Sutcliffe***

All the specifications are well defined and any questions I had were answered. One particular question was to the tolerance on the M5 tapped holes, which are to be pre drilled in individual parts. These holes can vary by as much as +- 3mm (1133+-2 on the rectangular opening and +-0.5 x 2 on the hole) and this was accepted due to the mating components having a large clearance hole and washers to take up any slack. This information will then be provided to the designers of the PMT frame and Mesh frame so it can be incorporated into their design.

The design drawings are sufficient to manufacture a ‘bare’ frame, which will then need more information to manufacture the ‘final’ frame for installation. Specifically, the levelling bar drawings and post machined holes.

There are no welding symbols on the drawing and it has been agreed that Portobello will use their own discretion and expertise when deciding what type of weld to use.

I think the hidden detail on the part drawings should go, as I think this is confusing and could lead to manufacturing errors. Showing the face with only the holes on that face is only required.

An FE analysis of the frame confirming the results is shown on an attached file.

**Recommendations**

***Lee Greenler***

1. Recheck the weld-stress calculations. The calculated stress was around 3e3 Pa (compared to a yield stress of 2.4e8 Pa or more). If this is accurate the stress in the area examined is approximately zero. Are there welds in the frame that have some significant stress?
2. Look at the bowing in the side members of the mesh frames when loaded with the desired mesh tension.
3. Checking flatness of the assembled frame is to be done with the frame in a vertical position. This sounds like the right way to do it. It would also be good to use the minimum number of supports required to hold it up so that the supports don’t affect the flatness.

***Peter Sutcliffe***

With regard to the M5 holes on the frame for the PMT structure and mesh, there is no information on the weld drawing to define where these are, and nothing to show the built up tolerance. The only way to do this is to go through a calculation using the different drawings, which could lead to error. This hole pattern will be needed for the PMT and mesh frame, designs so I would recommend that the 18 hole pattern is shown ‘typical’ for each opening on the weld assembly drawing with the built up tolerance.

However, with this in mind, I feel that the hole definition ie dimensioning on individual parts does not cover the main purpose, which is to define a pattern of 18 holes (4 for the mesh frame and 14 for the PMT structure). If the holes were drilled after welding, at Portobello, then the tolerance of +-0.5 can easily be achieved and the subsequent designs will follow on in a manner which will not need extra large clearance holes and large washers.

The holes can be marked out by either standard marking out techniques or by the use of a flat plate with 18 holes in, which can be ‘spotted’ through, then drilled and tapped. (see attached fig) I think this will not have any financial implications as all the holes will be drilled in one operation, rather than individual operations, as is the current case.



Holes in drill plate

(shown oversize for clarity)

Another recommendation I can give is that geometric tolerancing should be used on holes, especially when they are to be machined as a group. Where Portobello are concerned with regard to the holes and slots they need to add, then they have accepted the current method, but the levelling bar holes and dowels are machined at another company and they will need to understand the tolerances required The best way to do this is with basic (boxed) dimensions and geometric tolerances. I believe the US standard is ASME Y14.5 the international standard ISO8015 and the UK standard BS8888.

**Answers to Charge Questions**

***Jo Pater***

1. Are the technical specifications of the APA frame and its interfaces to wire-winding, TPC assembly, front end electronics and light detector installation adequately defined?  Do the key design parameters follow from them?

*Yes, with the caveats as mentioned above.*

1. Are engineering documentations sufficient enough to support the fabrication and installation of the frame?

*I believe so, except for the post-weld holes, the definition of which can come later in the manufacturing process.*

1. Can the designs be fabricated and assembled on schedule?

*Portobello seems an experienced and reputable company, and they have agreed to the timescales so it seems sensible to believe that they will deliver on schedule.*

1. Have key risks captured and is there a plan for managing and mitigating these risks?

*A final cleanliness-checking procedure should be developed, as the risk of trapped swarf from post-weld hole drilling seems quite high.*

***Peter Sutcliffe***

1. Are the technical specifications of the APA frame and its interfaces to wire-winding, TPC assembly, front end electronics and light detector installation adequately defined?  Do the key design parameters follow from them?

*Yes, see above*

1. Are engineering documentations sufficient enough to support the fabrication and installation of the frame?

*See above, but with notes about mating holes with other components.*

1. Can the designs be fabricated and assembled on schedule?

*I believe Portobello, being an experienced company, can do this*

1. Have key risks captured and is there a plan for managing and mitigating these risks?

*The main risks will be towards welding stability and manufacturing to tolerance. A company like Portobello will understand these risks and have various procedures to keep the tolerances and rectify if needed.*

**Appendix A: Charge to Reviewers**

##### Design Review of  SBND TPC APA Frame    February 23, 2016

##### Charge

The Committee is to conduct a technical review of the APA frame design to assess its readiness for fabrication.   In particular, the review team is asked to address the following questions:

* Are the technical specifications of the APA frame and its interfaces to wire-winding, TPC assembly, front end electronics and light detector installation adequately defined?  Do the key design parameters follow from them?
* Are engineering documentations sufficient enough to support the fabrication and installation of the frame?
* Can the designs be fabricated and assembled on schedule?
* Have key risks captured and is there a plan for managing and mitigating these risks?

The committee should present its findings, comments, and recommendations as well as answers to the above questions in a written report within 1 weeks of the actual review.

**Appendix B: Agenda**

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