memorandum

SNS-3, Mechanical Systems

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Subject: ***SNS D-Plate Diagnostic Beam Stop Design Review***

Executive Summary

A design review of the SNS D-plate diagnostic beam stop was held on Wednesday, February 6, 2002 in the Aviary conference room at TA-53. Reviewers attending the meeting were Will Fox (WF) (SNS-DO), Steve Black (SB) (ESA-TSE), and Jim Sims (JS) (ESA-DE). Kirk Christensen chaired the review committee. Presenters were Mike Plum (overview and physics requirements), and Steve Ellis (design, analysis, and fabrication.) Other attendees were Ross Meyer Sr. (SNS-3), Nathan Bultman (SNS-3, CCL Team Leader), and Gary Johnson (GJ) (ORNL-ASD).

Uniformly the review committee was very impressed with the effort of the design team and did not see any “show stoppers” that would require significant redesigns.

The committee’s comments basically fell in four areas, 1) General considerations and comments, 2) Design questions and suggestions, 3) Analysis questions and suggestions, and 4) Fabrication questions and suggestions. The comments are copied verbatim below, (with the author’s initials) for your consideration.

Suggestions and/or concerns

General Comments and Questions

1. The basic design is sound and straight forward. If successfully fabricated, it appears to have large thermal and structural design margins.—JS
2. I did not see any shop stoppers in the D-plate beam stop. I believe that the basic design is sound as is the analysis methodology. The design team has done a good job.—WF
3. Overall, I was impressed with the SNS beamstop thermal design. The analysis was quite detailed and the results seem quite reasonable. The beamstop design/analysis team has done a thorough, technically competent job—SB
4. As you already know,this is quite a "hot" beamstop....it has the nearly the same order of magnitude of average power as the LANSCE tungsten beamstop (12kW vs 64kW)!! In addition, rather than being deposited throughout an extremely thick tungsten target (800MeV), the beam is deposited on the surface due to the low energy (7.5MeV). Checking some of the average power densities, it appears that between 100 and 200 W/sq cm will be seen near the tip. With a film coefficient of 2 w/sq cm K, the film temperature rise alone should be 50 - 100K. The nickel liner must be doing a good job of carrying the heat from the heated zone down to the unheated zone since the maximum film delta T is indicated to be somewhat less than that. In fact, the fluxes may be high enough to

warrant looking at whether local boiling will occur (even though the coolant is subcooled). Have you calculated the critical heat flux for this condition?—SB

5. I liked the fact that the cooling channel design provided consistent film coefficients over the entire beamstop (rather than just at the tip). This will allow for any misalignment of the beam without degrading beamstop performance.—SB
6. I was a little surprised that the beam is impinging on such a small portion of the beamstop (~5%). Is this typical for conical beamstops?—SB
7. It was stated that the 10 gpm cooling flow will be provided by the DTL-2 cooling skid. It seems unlikely that this skid will be operational on the required time frame. This should be checked and confirmed with Jim Schubert who must make it happen, if required. Since the flow requirement is so low, using the FE cooling water system may be possible. This may be a simpler option.—GJ

Design

1. It is possible for this interlock to fail or to be overridden I suggest that a worst case analysis be conducted based on the small spot tune to determine if the water jacket of the beam stop is breached. I suspect that while the beam stop may be damaged, a breach may not occur or will occur on a time scale such that the beam may be shutoff *if you have another diagnostic such as a thermocouple to detect the temperature rise in the inner shell*.—WF
2. I would chose something besides Macor for the insulators, Vespel, G-10, or Torlon would be less susceptible to chipping and cracking.—WF
3. The velocities are quite high (as they need to be to handle this level of average beam power) and would need to be lowered if this beamstop was to be used for any extensive length of time, due to flow erosion concerns.—SB
4. Since the nickel inner sleeve acts as a fin, conducting heat away from the center of the beamstop, perhaps it should be thicker than 2mm. What would the performance be if the insert were 1 cm thick? Would having it thicker make it easier or harder to fabricate? If it for any reason makes it easier, I would recommend it due to the improved thermal performance.—SB
5. Putting the flow channel defining wire on the inside of the outer 304 stainless steel housing should be considered. A round 304 wire could be wound on an undersized carbon steel or aluminum cone shaped mandrel (undersized to address spring back) then the wound spiral could be inserted inside the outer cone and welded into place. A final machining cut would then be made to achieve geometry matching the nickel inner cone.—JS
6. Flow induced vibrations: the cooling water velocity and rapid change in flow direction may induce unstable flow conditions which could excite the system and produce excessive vibrations. Consider reorienting the outlet nozzles to match tangential exit flow from the spiraling flow channel. Also consider making two flow channels. The inlet flow velocity at the point of the cones is high and may be the source of flow problems; I recommend having a "easily" implemented way to change the geometry in this section.—JS
7. I recommend safety wiring the nylon ferrule friction type hose fittings to the water nozzles; I am uncomfortable with just the friction type connection. If safety wiring is not done, then at least check the effect of over-pressure on the fittings.—JS
8. Change the halo scraper petal screw insulator (155Y521823) material from Macor to some type of vacuum rated plastic (KelF or some type of polyimide).—JS

9. Consider the advantages to having the cooling come in the apex of the cone and flow directly up the cone verse turning and going around the cone. Routing flow directly up the nozzle will result in the velocity being greatest at the apex and decreasing as flow moves up the cone (basically what you want). If the reduction is larger than desired, the flow channel height can be reduced at the apex (or in all areas). This shouldn't be difficult since the part is likely machined on a lathe.—GJ

Analysis

1. When the magnet power supply fails the current will drop at a rate based on the inductance of the system. It will pass through the small spot tune during this decay and result in a highly focused beam on the beam stop. The detection of this failure is needs to occur on a time scale much shorter than the time scale associated with the decay of the current to be able to shut the beam off in time. These time scales need to be quantified and compared to see if a faster interlock is required.—WF

2. Water velocities appear to be 2 to 3 times the normal design velocity required for typical turbulent flow film coefficients. These high water velocities may result in cavitation around sharp corners at the entrance of exit of the beam stop shell as well as vibration associated with flow separation around corners. I suggest that design team evaluate the need for these high velocities and also determine if cavitation or flow separation is likely to occur.—WF

3. Run an additional case or two where the fluid velocities are reduced by as much as 75%. This will tell you the sensitivity to flow velocity (in case you can't achieve these flow rates).—SB

4. Perhaps you could run the analysis of the beam pulse transient with a 3-D thermal stress analysis for the elliptical beam. Your axisymmetric case resulted in a conservative prediction of peak temperature but would the radial variation caused by the elliptical beam enhance the stresses predicted by the axisymmetric case (perhaps this can be answered without doing a 3D model)?—SB

5. Since the thermal and structural models exist I encourage the extension of the analyses into the stagnant, no flow but with beam case and the unchopped, very high power beam case. These will likely require the consideration of two phase heat transfer and elastic-plastic structural analyses. In my opinion, it would be good to have some idea of performance in the "very worst case" situations if the project can do these analyses with a nominal effort and small cost. I suspect there is considerable design margin in the damaged, but no leak case.—JS

6. There seemed some uncertainty about the time for the control and interlock systems to react to an anomalous condition versus the time to damage or breach the inner cone. This should be checked to ensure the beam stop can withstand the anomalous conditions during the system shutdown time.—JS

Fabrication

1. My principal concerns are with the fabrication of the nickel beam stop cone assembly given the design shown on drawing 155Y521834. There may be schedule, cost and fabrication difficulties if the conical form and channel dimensions at noted must be maintained and a work hardened condition of the nickel is needed for the structural design margins.—JS

2. Machining the cone from a forged nickel billet will be expensive and the availability of such a billet (8.5" dia. x 15" long) within the required time frame should be checked. There is the possibility of leak paths due to material flaws in the billet core. This may require that the point of the cone be machined separately and welded on. I recommend some type of material QA beyond standard certs; consider UT and dye penetrant testing of the billet or rough machined part.—JS

3. Welding the spiraling .080" square (nickel?) wire to define the flow channels could result in distortion of the cone due to weld shrinkage stresses in this relatively thin material. What will be the source of .080" square nickel wire; is it available in the small quantity needed?. If the wire is hardened from drawing it will likely twist and spring back and therefore not lay flat when wound onto the cone. Also the wire may not stay in position (prior to welding) by friction if wound under tension from the small end of the cone. If the .080" channel standoff distance and .005 profile tolerance are actually needed then a post weld machining operation on the wire will likely be required. The 32 finish appears to be unnecessary. It may be useful to substitute slightly larger diameter (.090" dia.) round wire to overcome the twisting problem and provide a more substantial machining cut to reach the required dimensions.—JS
4. Also, putting the flow channel defining wire on the inside of the outer 304 stainless steel housing should be considered. A round 304 wire could be wound on an undersized carbon steel or aluminum cone shaped mandrel (undersized to address spring back) then the wound spiral could be inserted inside the outer cone and welded into place. A final machining cut would then be made to achieve geometry matching the nickel inner cone.—JS

KEC:kc

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