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Re: Hydroforming of SHMS Heavy Gas Cherenkov windows

Procedure:

The thin aluminum window design and instructions on how to perform the hydroforming were examined in detail by Eric Sun, Mike Fowler and Steven Lassiter. The following instructions were received on Jan 31, 2012:

We don't recommend using the Cerenkov chamber to perform hydroforming because the Cerenkov's aluminum flange is not rigid enough to withstand either the 40-45 psi forming pressure or the 60 to 70 psig proof test. A steel forming flange matched to the Cerenkov's Al flange dimensions is recommended. There is no need to use 316 SS bolts during hydroforming since stainless steel bolts are weaker in terms of strength. Standard grade 5 steel bolts would be sufficient with an installation torque of 136 lbf-ft with an assumption of coefficient of friction of 0.15 if no anti-seize lubricant is used. Grade 8 or higher strength bolts are not required.

By using a separate forming flange, replacement windows (if ever needed) can be formed without the necessity of removing the Cerenkov from the detector hut. Spare windows can stored as flat sheet until needed.

The forming pressure for a 5065 mm diameter window made of 2024-T3 material will be about 40 psi (plus or minus a few psi). The window can be proof tested at Regina to 4 times the operating pressure or 60 psi. A puncture test of a 2nd window (formed to the correct radius) under vacuum, using the Cerenkov vessel and AL flanges can also be done at Regina. Our thoughts are that the window, if made from 2024 T3 material, will be equivalent to the HMS design and thus does not require this puncture test. All test should be witnessed by the person holding the design authority or their designated person and the records placed in JLAB's docushare database.

As a result of design changes later in 2012, the window diameter was decreased by 2.8% and the hydroforming curvature was decreased accordingly, from 5065 mm to 4921 mm. This corresponds to a hydroforming depth of 146.9 mm. The detailed construction drawings for every part of our Cerenkov vessel, including the steel forming flange and plate, were reviewed by Eric Sun, Mike Fowler and Steve Lassiter and permission was granted to proceed with procurement.

We purchased four sheets of 2024-T3 aluminum window material from a supplier recommended by JLab, ASM Aerospace Specification Materials. Lab tests by ASM of the sheet material indicated that they meet and exceed the properties of 2024-T3, but that they were mill stenciled by Alcoa as T4. Approval was given by Eric Sun to proceed with shipment. The sheets were subsequently cut to the flange dimensions by HAI Precision Waterjets Inc.

The hydroforming was performed at the University of Regina according to the above instructions.

Wednesday, June 19, 2013 – Window #1:

The first thin window was clamped in the hydroforming assembly and bolts torqued to 136 lb-ft. The assembly was then hoisted to a nearly vertical position. The procedure was performed by Derek Gervais, UofR Science Instrument Maker, assisted by Danny Kolybaba and Keith Wolbaum. The procedure was witnessed by Garth Huber, Wenliang Li and Thomas Fitz-Gerald, who also videotaped it.

Water was introduced into the gap between the thin window and steel plate from the bottom via a small pump. The bleed off valve at the top was left open until water started to exit. The top valve was then closed and the water pressure slowly started to increase. The water pressure and the bowing of the thin window being hydroformed were carefully monitored throughout. Because we wanted to be extra careful with the first window, we took up the water pressure quite slowly. In fact, the first driver for our pump could not generate more than 40psi and we had to replace it mid-procedure with a more powerful driver. After about 40 minutes, we finally achieved 45 psi and the window was hydroformed to a depth of 146.9 mm. This was determined by measuring the bulging past the hydroforming ring, using a measurement jig specially made for this purpose. We turned off the pump and let the pressure stabilize for 5 minutes before we drained the water from the assembly. The window depth relaxes by about 2 cm after the water is removed.

Monday, June 24, 2013 – Window #2:

We hydroformed the second thin window following the same procedure. The only difference was that we used a more powerful pump driver from the outset, so we were able to achieve 45 psi after about 20 minutes. In fact, the water pressure was just slightly over 45 psi (possibly 46 psi), and the hydroforming depth was 1-2 mm more than 146.9 mm. The procedure was witnessed by Keith Wolbaum, Garth Huber, Wenliang Li and Thomas Fitz-Gerald, who again videotaped everything.

Wednesday, June 26, 2013 – High Pressure Test:

We needed to purchase a more powerful pump for this test, as our previous pump maxed out at ~45 psi. We pumped water to a pressure of 45 psi, and then took it up quite slowly after that. After about 30 minutes we reached a pressure of 60 psi, with no evidence of water leakage from any part of the window or hydroforming assembly. We turned off the pump and the pressure dropped to 59 psi as the window relaxed. After about 20 minutes, we turned the pump back on and raised the pressure to 61 psi, still with no evidence of window failure. The test concluded, we then drained the water from the assembly. The total time that the water pressure was near or above 60 psi was at least 30 minutes. The procedure was witnessed by the same group as for window #2.

There is a fourth window which was left flat. It serves as a spare and can be hydroformed at JLab as required, as noted in Eric Sun's original message.

Garth Huber

Sincerely,
Garth Huber, Ph.D.
Professor of Physics