Summary and update on HGC Entrance Window Design and Testing

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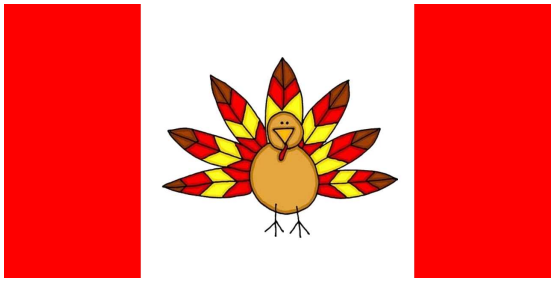


Canadian Thanksgiving

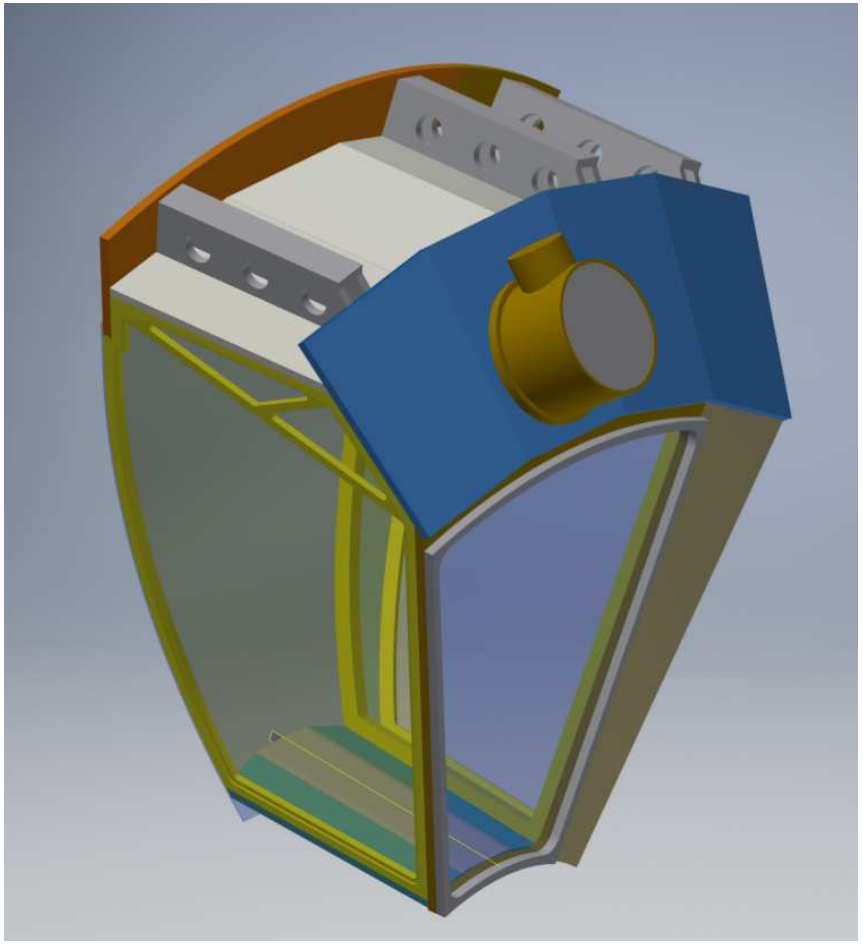
Informal SoLID HGC Review, Jefferson Lab, October 8, 2018.

HGC Prototyping Update

C$100k grants allow the U.Regina group to construct one SoLID HGC module for testing.

Questions to be addressed:

- Enclosure deformation at 1.5 atm operating pressure (investigate design and metal alloy options).
- Performance of the O–ring seals against adjacent units.
- Performance of thin entrance window in terms of light and gas tightness (test several options).



Conceptual design by Gary Swift, Duke U.

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HGC Thin Window Prototyping

- **Testing Requirements:**
  1. Safely hold 2x operating pressure for extended time periods
  2. Minimize bulge for clearance in SoLID
  3. Reproducible fabrication

- **Two prototype window frames:**
  - Full size window testing at +1 atm
  - Quarter-scale version testing at +4 atm

Above: Full size test window
Left: Quarter–scale test window frame

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All Mylar–Kevlar Windows Failed

¼–Scale Window Pressure Tests

- For same window tension as full size window, the maximum pressure needs to be increased 4x.
- i.e. Small window @ 60 psi roughly equivalent to full size window @ 15 psi.

- Repeated mechanical failures of Kevlar window near maximum pressure, even after epoxy strengthening, lead us to explore alternatives.

Ripped epoxy-reinforced Kevlar window, which failed at 60 psi.

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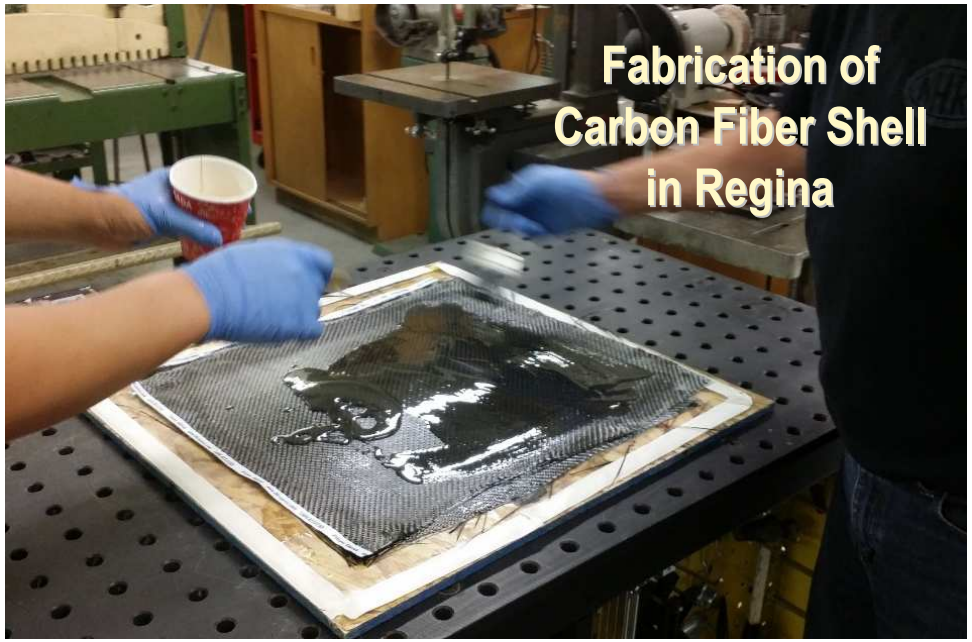
Carbon Fiber Shell + Mylar Inner Window

¼–Scale Window Pressure Tests

- Hard shell constructed with 3x FiberGlast carbon fiber and epoxy.
  - 13”x17” shell is molded with a 5cm bulge depth, approximately circular profile.
- 3mil Mylar inner window beneath shell is used to seal against O–ring.
- Kevlar from previous test placed on top as a safety measure, as protection against a catastrophic shell failure.



Completed shell showing formed 5 cm bulge

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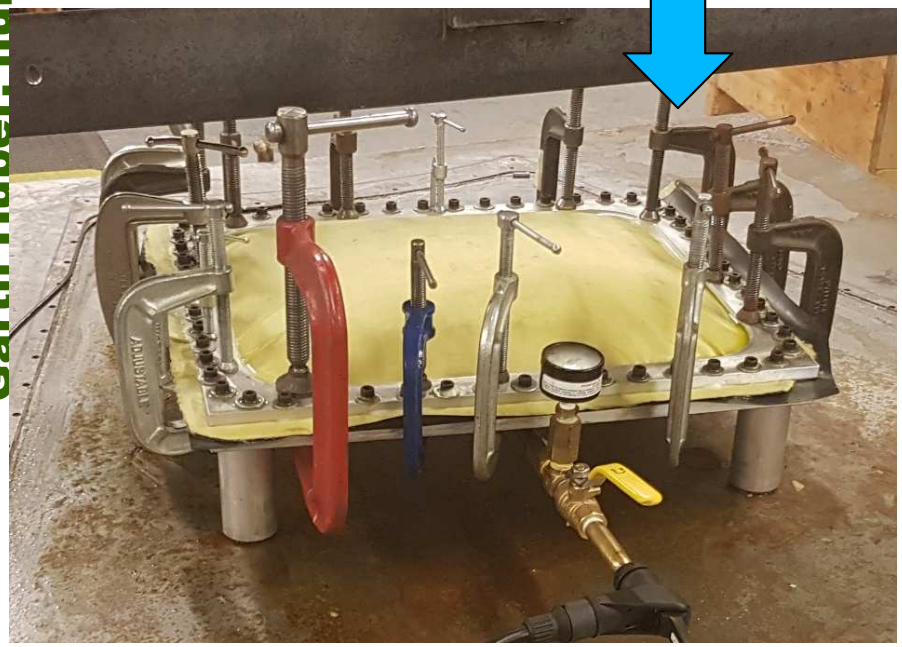
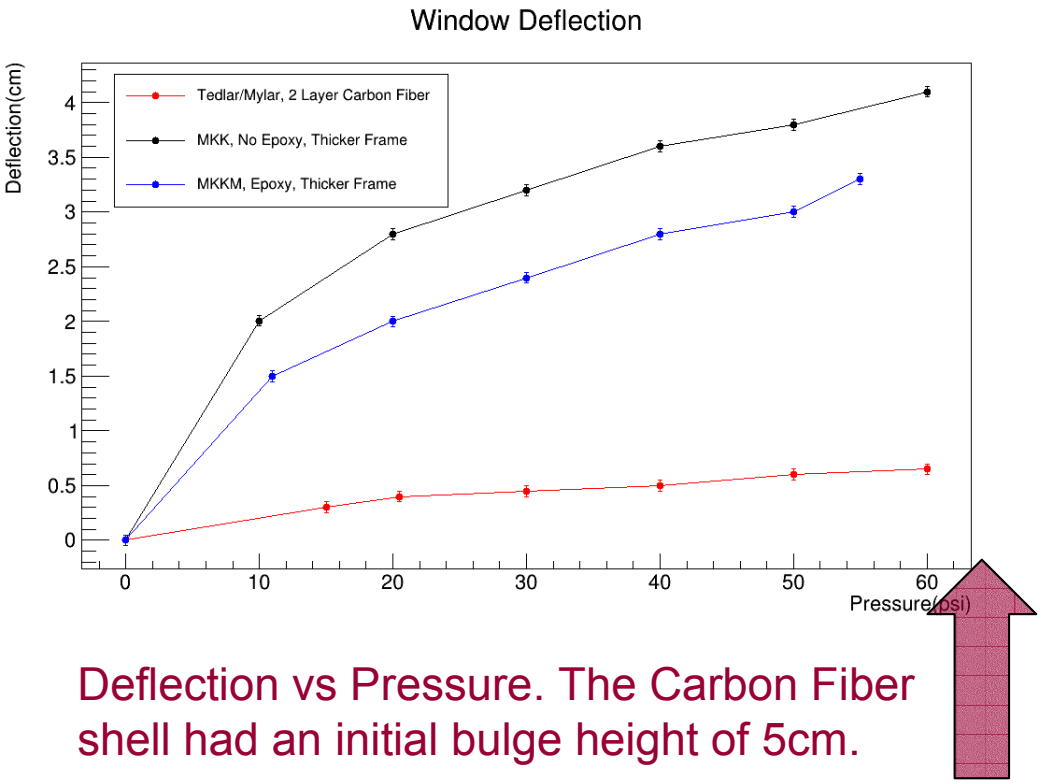
Small Carbon Fiber Shell + Mylar Results

- Substantially less deflection above initial height than reinforced Kevlar window.
- Carbon Fiber Shell is mechanically stable at 60 psi.
- Discover that window frame is too weak, leaking around bolts.
- Temporarily reduce leak using C–clamps around frame





Deflection vs Pressure. The Carbon Fiber shell had an initial bulge height of 5cm.

- Carbon Fiber Shell has the required strength.
  - Shell was reused in subsequent tests before failing.
- Results suggest clamping wire is interfering with the O–ring, and/or other sealing problems.

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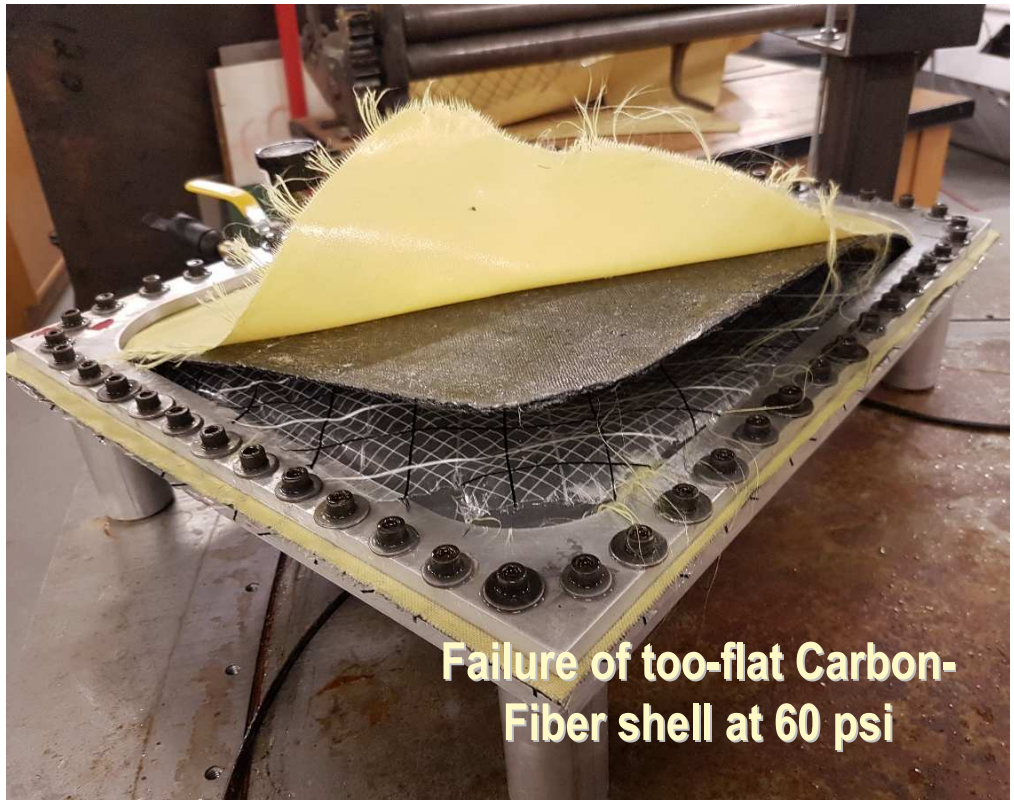
Further Small Carbon Fiber Shell Testing

With promising results for 5cm bulge Carbon Fiber Shell, further modifications were made:

- Decreasing the depth of the shell resulted in catastrophic failure!
- Still experienced issues with leaking, but ready to move to full–size window tests.
- **Several questions to be addressed:**
  - What is the optimal bolt/wire/O–ring arrangement on frame?
  - How thick does the frame need to be to ensure adequate clamping?
  - How many layers of carbon fiber are needed?
  - Can fractures in the shell be repaired and operate normally?



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Full Size Carbon Fiber Shell + Mylar Liner

- Hard shell constructed with 3x FiberGlast carbon fiber and epoxy.
- 3mil Mylar inner window beneath shell is used to seal against O–ring.
- Kevlar on top as a safety measure in case of catastrophic failure.

Above: Test jig for full size window shell

Left: Foam mold for full size window shell

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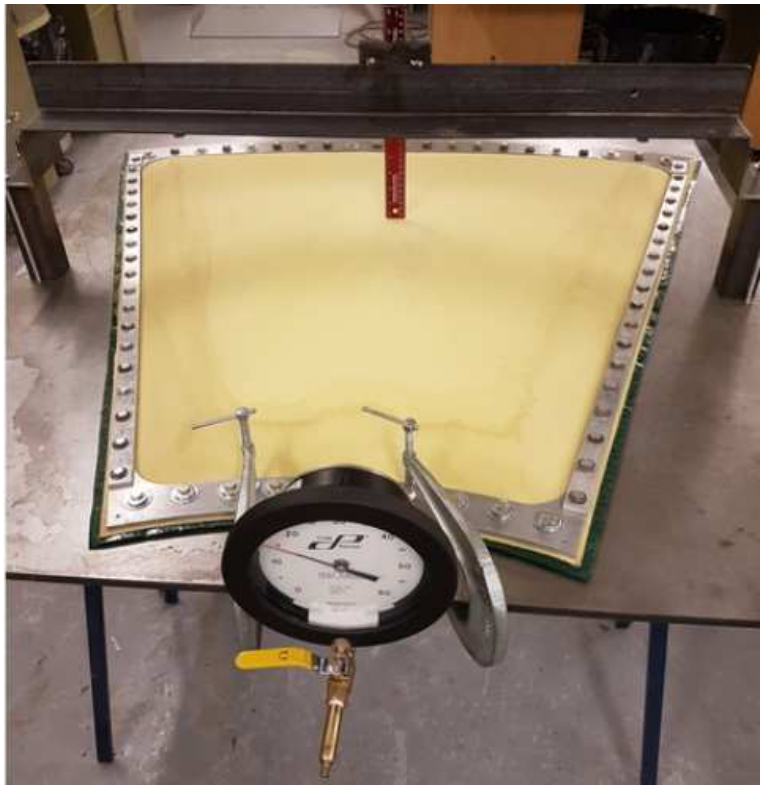
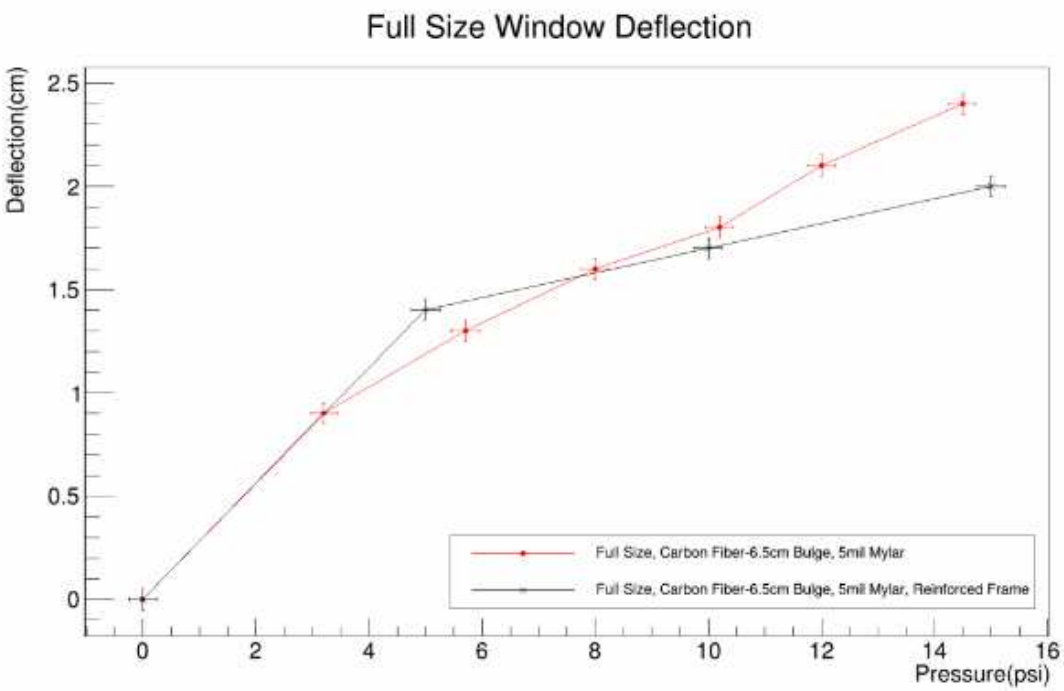
Full Size Carbon Fiber Shell + Mylar Results

- Moderate success with full size 3xCF shell:
  - Structurally stable at +1 atm
  - Failure in pressure seal due to previously identified frame issues
  - Alarming creaking noises from shell under stress while inflating
  - Deflection only 2cm beyond constructed bulge at maximum pressure





- New test frame following recent modifications forthcoming
- Replacement of O–ring with gasket being considered

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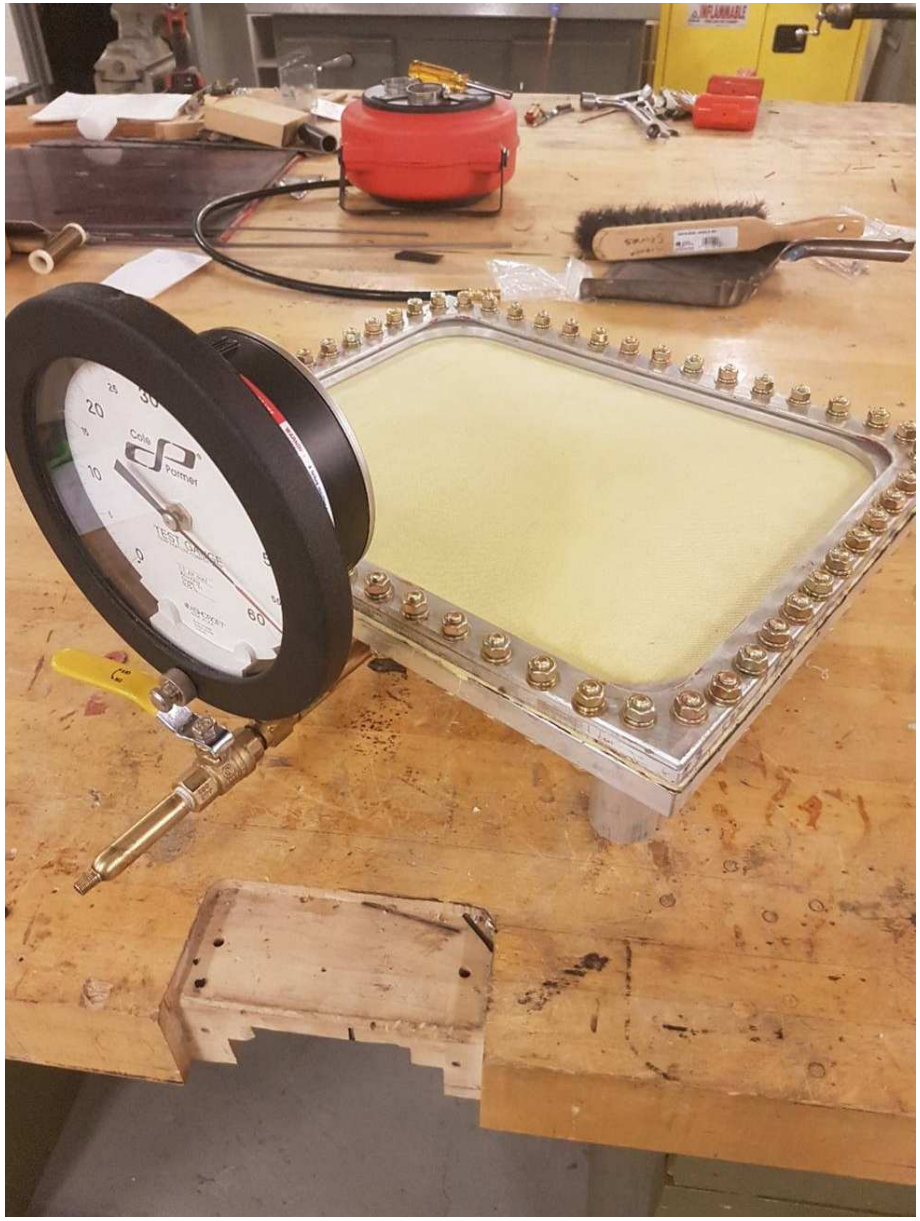
Heavy Stock Flat Carbon Fiber Shell

- Heavier stock carbon fiber fabric from FiberGlast.
- Try flat window (no preformed bulge) to improve clearance and simplify fabrication.
- Flat window structurally stable at +4 atm where previous flat window (with lighter CF) failed.
- Significantly reduced creaking noises over previous tests.
- Maintaining pressure for over 6 months with only small pressure drop (possibly due to atmospheric pressure variations).

- Very promising results from the thicker Carbon Fiber.
- Waiting for completion of full size version with this technique.



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Next Steps

- **If test of flat full–scale CF window is successful, we expect to have arrived at the final thin window design solution.**
- After your design review is completed and all changes are made by Gary Swift, we will shift effort to fabrication of the prototype vessel.
- The grants from CFI and Fedoruk required the HGC prototyping project to be completed by Dec 31, 2018.
  - Current Account Balance: C$59,654.81
  - As the project scope has expanded since the original proposal, both agencies recently approved a 1 year extension.
- **Planned Prototype Vessel Schedule:**
  - Bids on largest vessel parts by vendors completed by January, delivered to UofR campus by April. In parallel, UofR machine shop makes smaller parts not sent out to vendor.
  - Assembly, and testing during assembly, in Summer, 2019.
  - Testing likely to identify further changes that we could try to implement before end of 2019 (this is the point of prototyping).
- Once we are done our tests, we could ship the prototype to either Duke or JLab for additional studies (such as PMT mounting, mirror placement), if desired.

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