3.9 GHz Cryomodule Design - Fresh Look Summary
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May 30, 2019

Abstract

Key aspects of the 3.9 GHz cryomodule design have been internally reviewed in detail with a "fresh look," first to ensure that lessons learned have been incorporated from the substantial 1.3 GHz cryomodule experience gained since the 3.9 GHz cryomodule final design review was held in January 2017, and second to glean the benefit of new design team members' experience. This final design was reviewed.

Based on our "fresh look" review, minimal necessary modifications will be incorporated into the design. However, optional or "would be nice" modifications will not be incorporated, since the design is reviewed and approved, components are procured and delivered, and the schedule is constrained. (Such optional improvements could be considered for future projects.)

Four areas of concern were identified for review: 1) Cavity supports and gate valves supports, 2) Thermal intercepts and cryogenic pipe supports, 3) Warm coupler and cold coupler, and 4) Cavity HOMs and HOM feedthroughs. This document summarizes the findings and recommendations from the four reviews.

Topic 1: Cavity supports and gate valves supports
Wednesday, March 13, 2019
Participants: Arkan, Cheban, Ginsburg, Grimm, Holzbauer, Kaluzny, Nicol, Orlov, Pischalnikov, Stanek

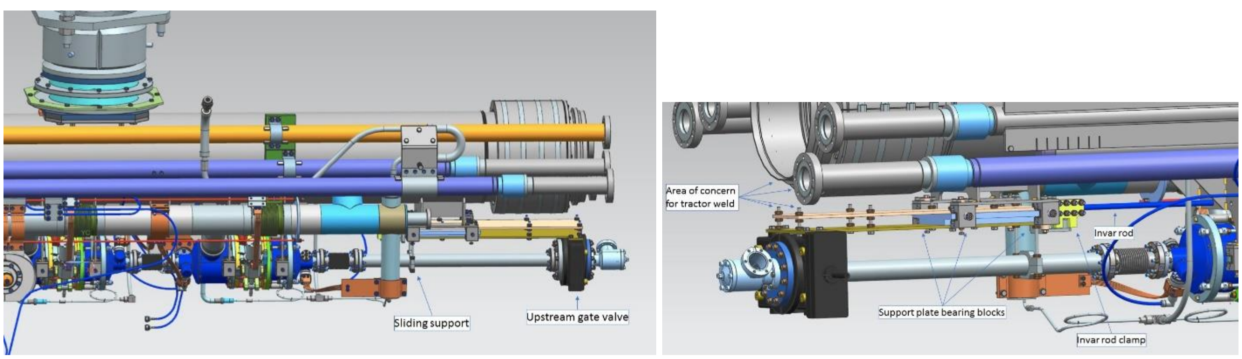

Figure 1: Upstream gate valve region: tunnel wall side (left), and tunnel aisle side (right).

Findings:

The upstream gate valve (US GV) support (Fig. 1) was investigated. This end doesn't move much through thermal contraction, only about 4.5 mm, because this is the fixed support post end. A sliding support was added to the beam tube that was cantilevered off of the US GV. The beam tube and the support are the same material, so they have the same thermal shrinkage, but the support needs to be sliding because the relative dynamic cooling is not known and would be difficult to predict accurately enough. A set of plates attaches the US GV to the HGRP, through bearing blocks which provide adequate travel for thermal contraction (4.5 mm). An anti-roll plate (not shown) has been added on the invar rod clamp to restrict the invar rod from rotating. The possibility of removing the sliding support and hard connecting the gate valve to the 300mm pipe was discussed and rejected as not necessary. Space between the HGRP and the two bolts at the top of the plates supporting the US GV were checked and confirmed for adequate tractor weld clearance.

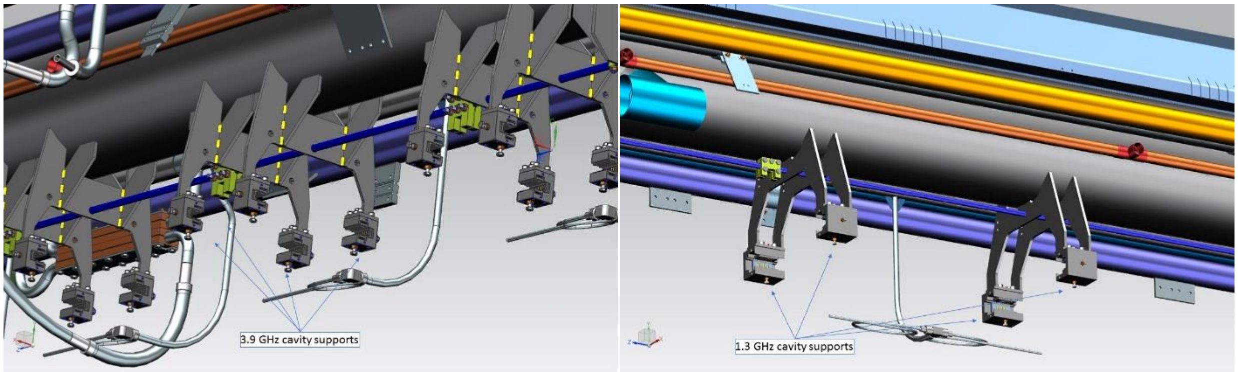

Figure 2: Cavity supports for 3.9 GHz cavities (left), and for 1.3 GHz cavities (right), for comparison.

The 3.9 GHz cavity supports (Fig. 2) consist of only one plate coming down from the GHRP, per cavity side, whereas for the 1.3 GHz cavities, the supports have two plates. The roller bearings blocks, one per cavity lug, are similar but not the same as for the 1.3 GHz cavities.

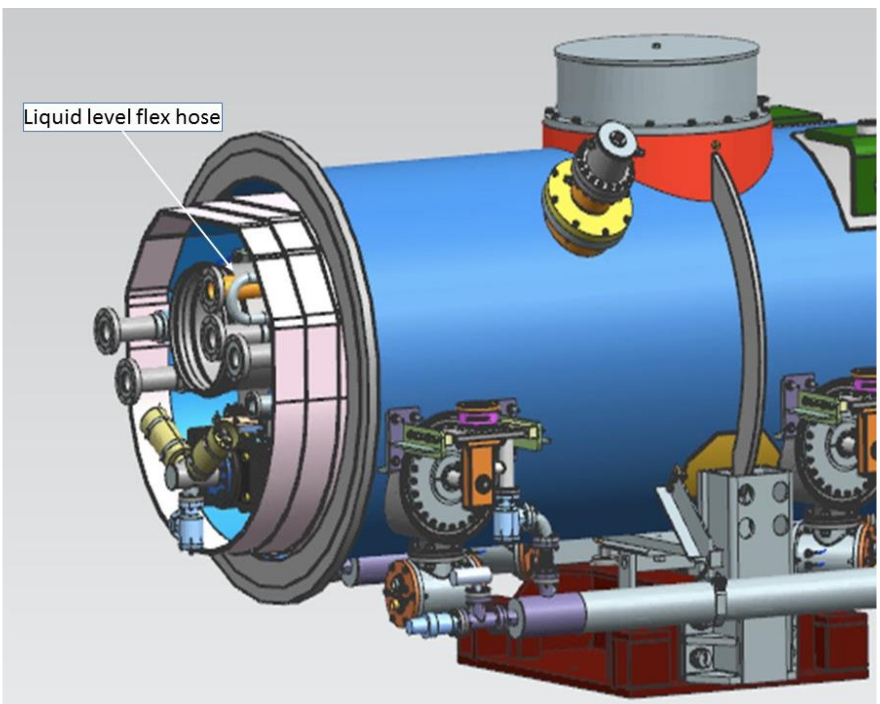

Figure 3: Model of the cryomodule downstream end showing the liquid-level flex hose.

For the downstream end (Fig. 3), the liquid-level flex hose may interfere with cryogenic pipe welding, maybe more so than for 1.3 GHz.

Recommendations:

1) Check whether the liquid level can flex hoses interfere with welding the interconnect.

2) Check that the seismic analysis (approved) is still correct based on lessons learned, and whether anything needs to be updated.
3) Check that capillary line supports are included in the 3.9 GHz model, as in 1.3 GHz, to reduce microphonics. The long liquid-level capillary pipe also needs support.
4) Check if the cryogenic pipes are the correct length, because they look short on the downstream end.
5) Do additional hammer tests to check if any components vibrate, and if so, add support.

Topic 2: Thermal intercepts and cryogenic pipe supports
Wednesday, March 20, 2019
Participants: Cheban, Hartsell, Kaluzny, Nicol, Orlov, Premo

Findings:

The coupler thermal intercepts were examined, and no recommendations were found.

Sergey's simulations show a low natural frequency of the warm-up/cool-down capillary tubes. The helium return chimney on the cavity is narrower than for the 1.3 GHz case. One mode of vibration has been identified in which the two-phase pipe moves with respect to the chimney. The vibrations shall be checked after installation and associated damping with a hammer test (see above).

The downstream end aluminum-to-stainless-steel transitions on the cryogenic pipes are close to end of the cryomodule, closer than for the 1.3 GHz cryomodule. Since the transitions are larger diameter than the nominal pipe, they can cause interference for the spider weld fixture. The gate valve supports may also interfere with the spider.

In the 1.3 GHz cryomodule, the cryogenic pipe supports are tack welded to the cryogenic pipes to keep them from moving. For the 3.9 GHz cryomodule, the pipes are aluminum, and the supports are stainless steel. It is critical to keep the cryogenic pipes from rotating, so we would either need aluminum clamps to be able to tack weld, or else to put a notch in the clamp so that the block would restrict rotation.

The downstream and upstream liquid-level capillary tubes for instrumentation were found to be missing supports to the 50K shield.

Recommendations:

1) More so than for the 1.3 GHz cryomodule, ensure the cryogenic pipes are correctly aligned during assembly, and that they are stably fixed.
2) Investigate interferences for installing the spider on the 3.9 GHz cryomodules. If the spider cannot be used, and pipes are not sufficiently well aligned, we might want to substitute adjustable pipe supports.
3) Add clamps for the liquid-level instrumentation capillary lines to the 50 K shield.

Topic 3: Warm coupler and Cold coupler
Friday, April 12, 2019

Participants: Arkan, Cheban, Hartsell, Kaluzny, Nicol, Premo, Solyak

Findings:

Sergey's simulations show that the cavity/cold coupler has a natural bending frequency of ~40Hz. Given a realistic (to account for shrinkage) initial offset transverse to the flange (cold coupler/cavity), and initial stress, the first mode is 40.6 Hz.

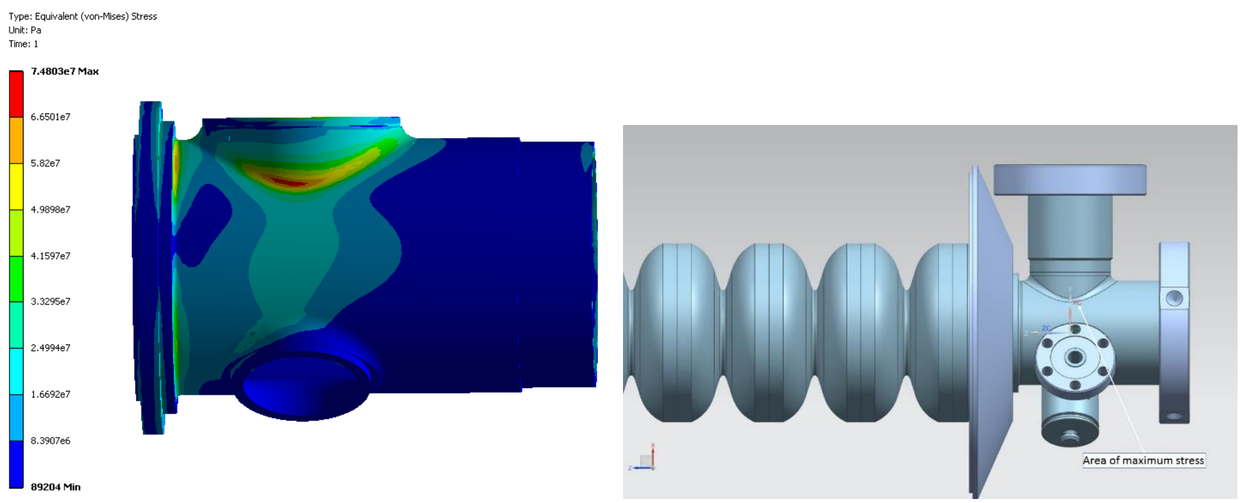

Figure 4: Cavity simulation showing area of maximum stress (left), and model showing the same location (right).

The simulation (Fig.4) shows a high stress concentration in the niobium at the coupler tube with 1.5 G loads. From the stress standpoint, the levels are acceptable, but fatigue could be an issue, e.g., during shipment. This motivates a shaker-table test. If the cavity/coupler passes the shaker table test with a safety factor on acceleration and cycles we do not need additional support (which would be from the warm-to-cold coupler flange to the two-phase chimney (50K).

Recommendations:

1) Perform bellows fatigue EJMA calculations for all four bellows: two coupler bellows (one inner, one outer), cavity string bellows, and 2-phase pipe bellows.
2) Perform a shaker table test of the actual cavity/coupler connection.
3) Find the minimum thickness of the pull-out at the coupler tube with an ultrasonic probe, to ensure the necking during fabrication leaves adequate material in this area.

Topic 4: Cavity HOMs and HOM feedthroughs
Monday, May 20, 2019
Participants: Arkan, Cheban, Ginsburg, Hartsell, Kaluzny, Nicol, Orlov

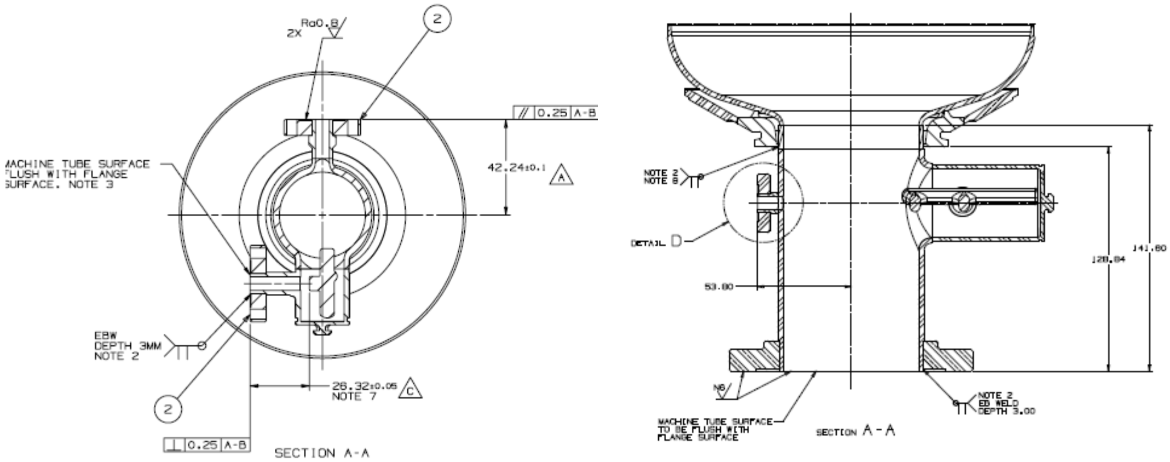

Figure 5: Cavity end-group detail showing HOM can for 3.9 GHz cavity (left), and 1.3 GHz cavity for reference (right).

Findings:

A comparison of the 3.9 GHz cavity HOM with that of the 1.3 GHz cavity (see Fig.5) demonstrated that the HOM's have many similarities (same ceramic portion of the feedthrough, same flange size), and some differences (antenna has a smaller diameter and is shorter, the F-part is different). The same RF cable will be used as for 1.3 GHz. The knob stability on the HOM can is expected to be better for the 3.9 GHz case, and specifically should be less sensitive to detuning by moving the RF cable connected at the flange. The shrinkage which moves the 3.9 GHz cable will be different (less) in this cryomodule. It will be more difficult to tune the HOM notch frequencies after the vacuum vessel is installed, because there are no tuner access ports. The HOM can magnetic shielding caps are finalized, ordered and received, but the received caps have yet to be checked on a real cavity to make sure they don't put undue pressure on the HOM tuning knob, and detune the notch frequency.

Microphonics checks with an impact hammer are planned prior to the completion of WS3.

The impact on coupler alignment from cavity roll could be larger than for the 1.3 GHz case, because of the relatively smaller cavity. Alignment of the helium vessel lugs is supposed to make the coupler level. The only place to check cavity roll and coupler alignment is in the cleanroom, during string assembly, because afterward any such effort would twist the cavity-to-cavity bellows, which is not acceptable. One possibility under consideration is to use the outer coupler flange vertical position for roll alignment.

Recommendations:

1) Monitor the notch frequency during assembly to confirm no assembly activities cause detuning.
2) Fit up the magnetic shielding caps for the HOM cans to ensure installation doesn't detune the HOM's.
3) Check that the HOM notch tuning device will fit properly to the full dressed cavity assembly, including cables.
4) Check/confirm strain relief of RF cables connected to HOM's.
5) Review cavity roll alignment procedure.