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LCLS-II CRYOMODULES PRODUCTION EXPERIENCE AND LESSONS LEARNED AT FERMILAB*

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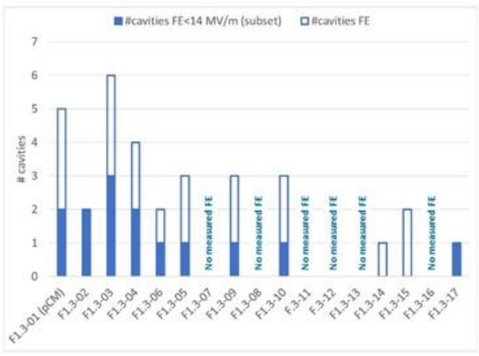
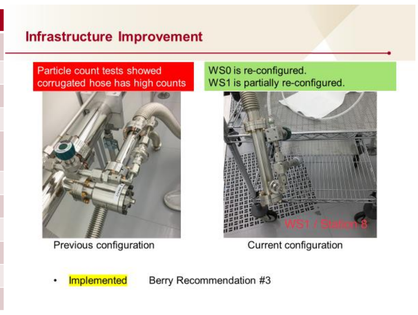
CHALLENGES & MITIGATIONS

Field Emission

During testing of the F1.3-1 through F1.3-3, we have experienced excessive field emission (FE). The field emission specification requires the onset of measurable field to be above a gradient (Eacc) of 14 MV/m for all cavities. During the F1.3-7 cavity string assembly, the cavity beamline vent procedures were optimized. During F1.3-9 cavity string assembly, an external expert audit was conducted Audit recommendations (infrastructure and assembly processes improvements) are mostly implemented to achieve consistent FE performance.

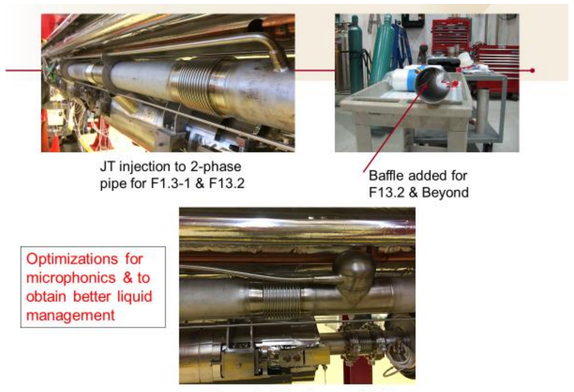


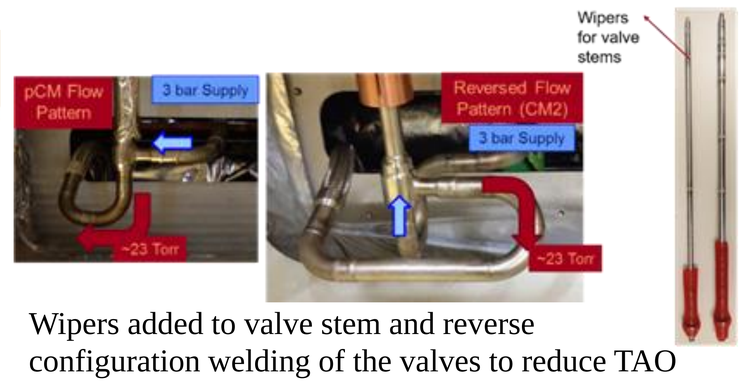
Recommendations	Description
1 Implemented	Guarantee the inside cleanliness for inter-cavity bellow, spool piece, coupler…
2 Not implemented	Increase the purging rate to 3L/min instead of 1L/min
3 Implemented	Install the purge line closer to the cavity
4 Not implemented	Revise the Bellows Assembly Procedure
5 Partially Implemented	Pump slowly 3 L/min (50 mbarL/s) and vent slowly
6 Not implemented	Move WS0 to WS1 location
7 Not Implemented	Reduce valve opening
8 Implemented	WS5 Improvement
9 Implemented	CMTF Improvement
10 Implemented	Gowning Area Improvement
11 Implemented	Miscellaneous Improvement



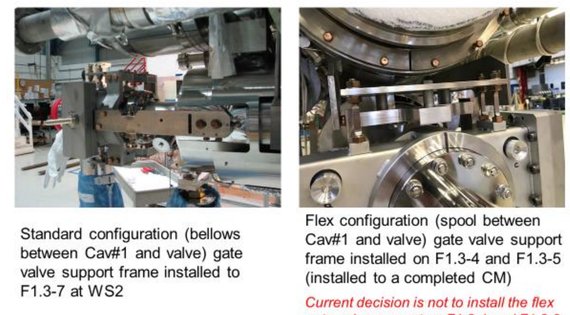
Microphonics

During F1.3-1 testing, microphonics detuning exceeded the specification. Thermal acoustic oscillations (TAO) in the cryogenic valves internal to the cryomodule were found to be the main culprit. During F1.3-2 testing, microphonics problems were reduced but cavity string position #1 still did not meet the requirements of the LCLS-II project. Additional design and assembly modifications were done for F1.3-3 through F1.3-7. F1.3-7 is the first module where all the cavities met the micro-phonics requirements.





Wipers added to valve stem and reverse configuration welding of the valves to reduce TAO



Standard configuration (bellows between Cav#1 and valve) gate valve support frame installed to F1.3-7 at WS2

Flex configuration (spool between Cav#1 and valve) gate valve support frame installed on F1.3-4 and F1.3-5 (installed to a completed CM)

Current decision is not to install the flex gate valve support on F1.3-1 and F1.3-2

Quality Issues

F1.3-3: Eng group heating due to not properly thermal intercepted HOM: repaired in situ at CMTS

F1.3-5: Broken HOM feedthrough center pin during cryomodule assembly: repaired outside of the cleanroom

Thermal intercept repair

Broken HOM feedthrough replacement

Cryomodule Shipping

-F1.3-6 is the first cryomodule shipped to SLAC. Beamline vacuum integrity was compromised during shipping. Initial investigation showed that the BPM electrical feedthrough flanges lost some fasteners. After investigations, the main root cause was identified: Improper design transfer - not suitable fasteners type and material use

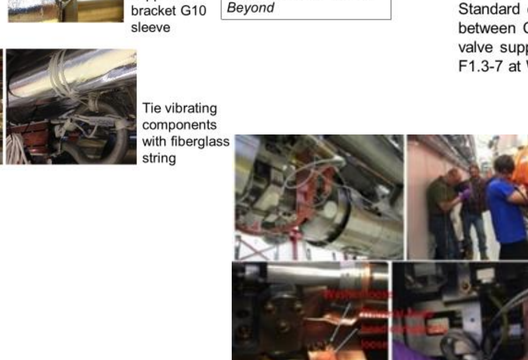
-F1.3-6 is then returned to Fermilab for disassembly and further investigation of the beamline failure. Detailed leak checks showed that BPM was not the main culprit for the beamline leak. Two fundamental power coupler cold end bellows were broken and caused catastrophic beamline leak.

-Vacuum vessel removed from F1.3-6 is inspected for damages. Unusual wear marks indicated that cold mass moved and shifted inside the vacuum vessel during cryomodule shipping.

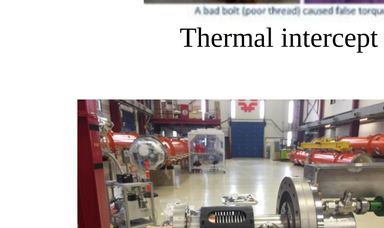
-An extensive investigation was also done by several multi laboratory teams to better understand the root cause of the coupler bellows failures. There were no indications that anything done by coupler vendor nor the cryomodule assembly group could have caused these bellows to fail during cryomodule shipping.

-Simulations, shaker table tests using actual coupler components, road tests using the concrete dummy cryomodule with sophisticated instrumentation indicated that the shipping caps did not provide reliable support. Shipping frame fixture isolation springs were not properly sized to dampen the unwanted shocks and to restrict the undesired motion: fundamental power couplers as assembled in the cryomodule experience motion which results failure of the cold end coupler bellows.

-JLab team developed a scheme to install temporary supports called M-mounts to the coupler. This scheme provides the needed support to minimize the motion of the coupler which causes cold end bellows failure.



G10 coupler supports friction dust and scoring points to excessive motion



M-mount installed in an LCLS-II coupler

Wear Marks inside F1.3-6 Vacuum Vessel

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