SRF CAVITY PROCESSING AND CLEANROOM FACILITY UPGRADES AT MICHIGAN STATE UNIVERSITY*

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Abstract

The Michigan State University (MSU) SRF cavity processing and coldmass assembly infrastructure is being upgraded to meet the production needs of multiple SRF projects, including the driver linac for the Facility for Rare Isotope Beams and the MSU Reaccelerator. The objective is to modify the current infrastructure to increase throughput and optimize the process workflow, while minimizing impact to the overall preproduction schedule. Facility upgrades include a cleanroom addition, chemistry room with part etching hood, cleanroom preparation area, and a new ultra pure water system. New handling fixtures and specialized tools are being implemented. Methods are being developed to streamline the workflow, increase repeatability, enhance process safety and reduce cross contamination and waste. The proposed cleanroom layout, process requirements, optimized workflow strategies, and plans for continuous improvement are presented.

INTRODUCTION

The FRIB baseline design requires a total of 341 certified cavities for cryomodule installation [1]. Thirty additional cavities will be fabricated for spare modules. It is assumed 20% of the cavities will be reprocessed resulting in 480 cavity processes. The estimated number of processes is summarized in Table 1.

Table 1: Cavity Quantities for FRIB

Description	Proposed Baseline
Certified cavities required	341
Certified cavities for spare modules	26
Non-performing cavities	10%
Total fabricated cavities for production	400
Reprocess fraction	20%
Number of processes	480
Total number of cold masses	55

The FRIB baseline cavity processing and coldmass schedule encompasses six months start-up and 30 months production. The average process rate is 16 cavities per month over 30 months. An estimate of 20% scheduled downtime and process delay results in 24 months of available process time. To complete 480 cavity processes, the infrastructure will be optimized to achieve a peak throughput of about 21 processes per month. A certification efficiency of 80% yields up to 17 cavities per month installed to a coldmass string. The takt time (eq. 1) for the cavity process workflow is the work time available divided by the number of cavities.

$$Takt\ Time = \frac{132.8\,\frac{hrs}{month} \times 30\ months}{480\ Processes} \cong 1\ \frac{day}{process} \quad (1)$$

PRODUCTION PROCESSING

The upgrade to the processing facility assumes the baseline SRF cavity processing plan (Table 2).

Table 2: Baseline SRF Cavity Processing Plan

Process Step	
Degrease cavity	*Vendor*
Bulk buffered chemical polish (BCP)	*Vendor*
Pure water rinse	*Vendor*
Hydrogen degas	*MSU & JLab*
Degrease cavity & components	MSU
Light BCP (10-30 microns)	MSU
High pressure rinse (HPR) with UPW	MSU
Assemble to test insert (*RF certification*)	MSU
Purge & remove from insert	MSU
Install to cold mass string	MSU

Baseline processing procedures may be modified from results of preproduction cavity testing research (i.e. post certification HPR and low temperature bake-out). The SRF cavity process and test facility will be designed to certify up to one cavity per day. Preproduction cavity processing is planned to begin in middle of 2012, with full production beginning late 2013.

PROCESSING FACILITY UPGRADES

Cleanroom Facilities

The current SRF clean room facility will not accommodate production processing and assembly due to the size of the FRIB coldmasses (up to 20 feet long) and the amount and the volume of work that requires a

* This material is based upon work supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661

controlled environment. Figure 1 shows the proposed 2,700 ft^2 (approximately 251 m^2) cleanroom facility which contains a new addition for coldmass assembly, a second high pressure rinse and a second crane hatch. The upgrade encompasses an ISO 5 [2] and ISO 6 cleanroom. Lean manufacturing principles are implemented to streamline work flow, minimize cross-contamination risks and ultimately enhance SRF processing capabilities. Table 3 and Table 4 describe the process steps for the key cleanroom tasks. Critical procedures such as high pressure rinsing and cavity/coldmass assembly are performed in an ISO 5 cleanroom environment. Less critical processes such as ultrasonic cleaning, low pressure rinsing, pump down and leak check take place in an ISO 6 cleanroom environment.

Table 3. Cleanroom Process Steps for Cavity Vertical Dewar Testing

	Process Description
1	Ultrasonic cleaning of components (ISO 6)
2	Cavity high pressure rinse (ISO 5)
3	Cavity & component assembly (ISO 5)
4	Cavity assembly to vertical test insert (ISO 5)

Table 4. Cleanroom Process Steps for Coldmass Assembly

	Process Description
A1	Purge certified cavity after dewar test & disassemble (ISO 5)
A2	Disassemble fundamental power coupler (ISO 5)
A3	Assemble lifting fixtures to solenoid & ultrasonic clean (ISO 6)
B	Coldmass rails received / prepared (ISO 6)
C	Assemble certified cavity / FPC / solenoid to rail system (ISO 5)
D	Pump down & leak check coldmass (low temperature bake-out "under investigation") (ISO 6)

The cleanroom temperature and humidity will be controlled. The air flow will be periodically checked to ensure air velocity is between 85-110 ft/min (0.43-0.56 m/s). Airborne particle counters will constantly monitor certified areas and will be integrated into a facility monitoring network. Handheld particle counters will be used before critical process steps. The SRF group has recently acquired a surface particle counter [3] which is used for cleaning process development research and quality control prior to cavity assembly (see poster TUPO059).

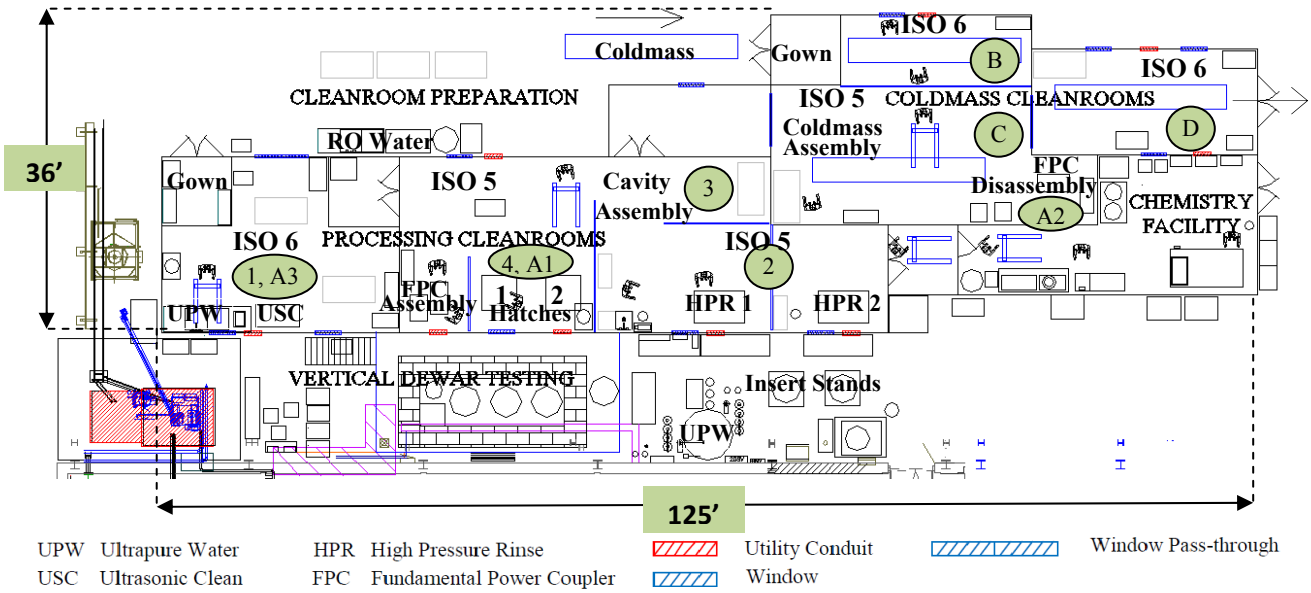

Figure 1. Proposed cleanroom layout for cavity processing and coldmass assembly.

Water Systems

The estimated maximum clean water usage in the SRF processing facility is 2,000 gallons (7,570 litres) per day during production. The proposed water systems include one deionized water system for preparation of items entering the cleanroom and a two loop ultra pure water (UPW) system (Figure 2) for processing and cleanroom assembly.

The cleanroom preparation area is used to degrease parts with detergent in an ultra sonic cleaner. The cleanroom preparation water system has a 210 gallon (795 litres) storage tank fed by a reverse osmosis (RO) water system with a 0.5 gpm (1.9 lpm) make-up rate. The RO system has a carbon based chlorine filter, a five micron particulate filter, RO filtration membranes and a mixed resin deionizing bed. The preparation water system continuously circulates through a 0.1 submicron filter and UV bulb to maintain the optimum quality (5 megaohm resisitivity) for ultra sonic cleaning [4].

Cleanroom process steps require ultrapure water (resistivity > 18 MΩ·cm). The UPW system has one 1,500 gallon (5,678 litres) storage tank fed by a 5.2 gpm (19.7 lpm) makeup RO system. The 1,500 gallon tank feeds two recirculating polishing loops: one for cleanroom sinks, ultra sonic cleaners and HPR 1 and one for the chemistry facility and HPR 2. Each recirculating loop is designed to 3-5 ft/s (0.91-1.52 m/s) water velocity to meet turbulent flow and reduce biofilm buildup [5]. In the event of planned or unplanned downtime, plumbing can be designed such that all points of uses can receive UPW from a single recirculating loop. Diagnostics monitored will include total dissolved solids (TDS), resistivity, total organic carbon (TOC) and particle distribution. A liquid TOC monitor and liquid particle counter have been purchased to monitor the existing water system, and develop improved maintenance and process procedures (see poster TUPO059). Major component spares will be stocked in house and scheduled maintenance will be performed in parallel to reduce system downtime.

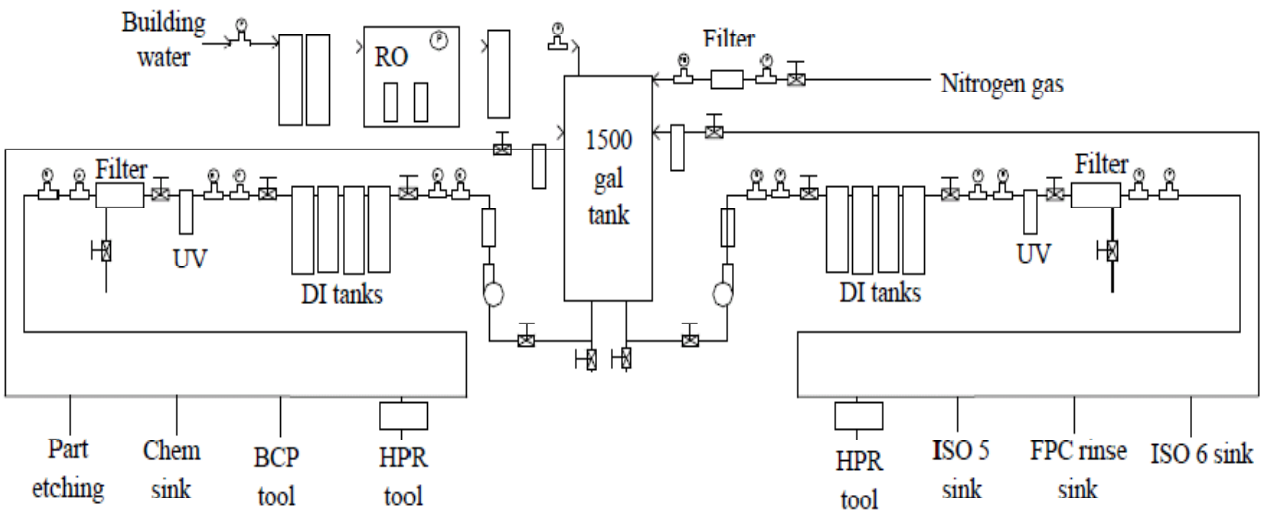

Figure 2. Sketch of a proposed ultra pure water system.

Chemical Facilities

The BCP chemical processing includes the light etch of all cavities and niobium components for the FRIB project and MSU reaccelerator cavity production. The light etch requires an approximate surface removal of 10µm-30µm from the superconducting surface.

The proposed chemical etching facility will require a minimum of 400 ft^2 internally as well as 80 ft^2 externally for chillers, scrubbers and utilities. The facility will be at ground level for easy transportation of heavy and/or hazardous items. Overhead lifting equipment will be required to maneuver cavities for etching.

The air flow rate and packed stack of the scrubber will be sized to keep NO_2 concentration levels below the 5 ppm short-term exposure limit mandated by OSHA [6] and ensure safe exhaust of acid vapours.

The chemical facility will house a batch etching hood for components and a waste water neutralization system. The neutralization system will require 1 litre per week of sodium hydroxide base (NaOH). All spent BCP will be disposed of by the Office of Radiological Chemical and Biological Safety (ORCBS) at MSU.

The chemical tool used to etch the cavities must remove about 4 kW of heat generated during the etching process. This will require two chiller units; one for the cavity heat exchanger and one for the BCP tank heat exchanger.

To estimate production consumables, we assume the BCP will be replaced when the concentration of niobium

in solution reaches 20 g/L. Vertical test performance versus niobium in solution data is analyzed to optimize this value however research to date is inconclusive [7]. Each etch of a cavity will consume about 3-5 L of BCP. The BCP acid solution will be purchased premixed from industry in 35 gallon (133 L) drums. The drums will need to be changed every 5 weeks during FRIB production.

High pressure rinse capability

After the final chemical treatment the internal surfaces of the cavity will be cleaned with a high pressure rinse tool. The HPR tools will be located in an ISO 5 cleanroom, with mechanical pumps, filters, etc. located outside the cleanroom.

The HPR tools must be robust and easy to operate. The HPR tool will use 1.5-2 gpm (5.7-7.6 lpm) of UPW at 1200-1500 psi (83-103 bar) with variable wand speed. We propose to purchase a new HPR tool and upgrade our existing HPR as a spare and for redundancy and flexibility.

LEAN STRATEGY

Lean Manufacturing Workouts are being conducted across all cleanroom processes to reduce waste, identify critical product paths and bottleneck operations, improve visual controls and enhance safety. Takt time-based, standard (one-piece) operations and workflow are being created to minimize cavity processing time, keep inventories low, and optimize consumption rates and storage capacities of chemistry consumables.

FACILITY RISKS AND MITIGATION METHODS

Risks associated with the process infrastructure have been identified and methods to reduce the risks will be implemented. Process tool unavailability because of maintenance or repair will impact the production schedule. Risk can be reduced by replacing old infrastructure, following a scheduled parallel maintenance program and stocking all consumables. Component failure downtime can be reduced by keeping spares on hand, performing root cause analysis on failures, and replacing components before the end of their estimated lifespan. The availability of redundant process tools alleviates both risks.

Cavity certification rate in the vertical test can be improved by continuous research and development of processing and assembly procedures. Employing repeatable methods will reduce contamination and vacuum leaks. Diagnostic tools will be used to monitor and control the quality of the processes and to discover problems quickly so they can be corrected.

AKNOWLEDGEMENTS

The authors would like to thank all the members of the NSCL & FRIB staff whose dedicated effort has made a significant contribution to the progress. In particular, Steve Bricker, Chris Compton, Alberto Facco, Gerald Gentz, Lee Harle, Matt Hodek, Tim Kole, Doug Miller, Sam Miller, Dave Norton, Katie Pomaville, Nicholas Putman, Greg Velianoff, Ken Witgen and Jon Wlodarczak. We also would like to acknowledge the impact of our weekly SRF teleconference on the overall success of our program, with special thanks to Curtis Crawford, Walter Hartung, Bob Laxdal, and Peter Kneisel for their continued contributions.

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