A CLEAN PUMPING AND VENTING SYSTEM FOR SRF CAVITIES AND CRYOMODULES

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Abstract

A system based on a pair of mass flow controllers has been used to evacuate and vent a clean cavity rf space. The mass-flow system is used in both single cavity testing and with the ATLAS upgrade cryomodule at Argonne. It is similar schematically to that already in use at DESY, however, it is very compact and maintains the capability to precisely control both the pump out and venting rates. Initial tests of the system with both the ATLAS single cavity test cryostat and the ATLAS upgrade cryomodule show that pump down and venting cycles may be performed without introducing substantial particulates into the cavity rf space. The system, together with the ANL top loading cryomodule design with easy access to individual cavities, will allow an individual cavity to be removed and replaced in a cryomodule string without the need to re-clean the entire string. This capability would also remove the need to test every cavity individually before installation into the string, constituting a major savings for large projects.

INTRODUCTION

A major focus of the assembly of a superconducting high gradient cavity string is on clean assembly. This is done in order to minimize the introduction of particulates into the rf space which can degrade the performance of the cavities. Special attention is paid to prepare the cavities and associated parts by ultrasonic cleaning, high pressure rinsing with ultra pure water, and cleanroom assembly of the entire cavity string. However, new techniques need to be implemented if a cavity string is to be repaired after testing. Therefore, a critical requirement for the maintenance of a clean cavity string is the ability to vent the evacuated string up to atmosphere without introducing any particulate contamination or disturbing any particulates already present in the rf space.

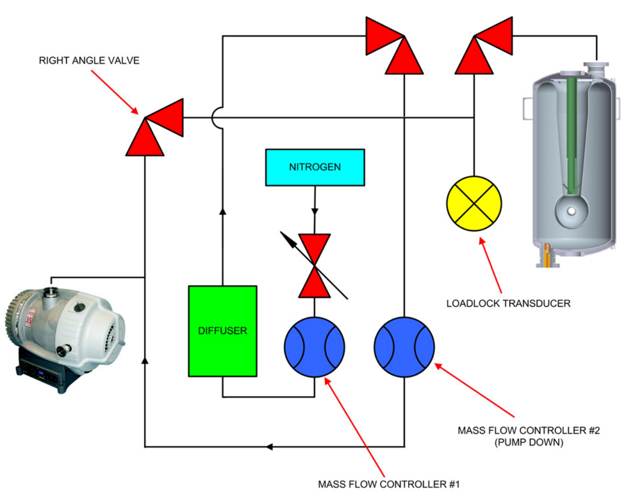

Figure 1: "Up-to-air" system schematic.

UP-TO-AIR SYSTEM

The ANL up-to-air system is schematically similar to a mass-flow system currently in use at DESY, however, with emphasis placed on the compactness and portability of the unit while still allowing the precise control of both the pump out and venting rates of the clean cavity rf space. The first unit was initially tested on the single cavity test cryostat and is currently installed on the ATLAS upgrade cryomodule. A second unit is being assembled for future single cavity tests.

Figure 2: Pall ChamberKleen 1100 Series diffuser welded into a 2.75" double-sided Conflat flange.

Design

The layout of the up-to-air system follows the schematic presented by DESY (see Figure 1), with the heart of the system being the mass flow controllers and diffuser. The system contains two separate mass flow controllers (one for venting and one for pump out), a loadlock transducer for measuring p and Δp, and a diffuser that both filters out any particulates that may otherwise be introduced into the clean rf space during venting along with reducing turbulent gas flow to limit the disturbance of any particulates that may already be present in the system [1]. The ANL system maintains all of the functionality of the DESY system yet still retains a very compact footprint.

Diffuser

The diffuser used at ANL is a ChamberKleen 1100 Series manufactured by Pall Microelectronics. This diffuser consists of a 316L stainless steel diffuser membrane which allows 360° gas flow in a uniform manner which limits the disturbance of particulates in the cavity rf space and a 316L filter medium that has a removal rating of ≥ 0.003 μm. The diffuser has a designed flow rate of 15 SLPM @ 15 psig and normally comes with a NW25 ISO flange for mounting. The Viton o-ring was removed for our application and the diffuser was welded into a 2.75" double-sided Conflat flange (see Figure 2).

Mass Flow Controllers

The mass flow controllers measure and set the flow of a gas, providing a constant flow control for the chosen set point. The mass flow controllers used in the ANL system are Model #FMA-772A-V (see Figure 3) and are manufactured by Omega Engineering, Inc. Each mass flow controller has a flow range of 0 - 20 SLPM with a maximum pressure of 1000 psig. Connection to each controller is made with a ¼" Swagelok compression fitting. Both controllers were calibrated for use with nitrogen gas, however, the venting controller was calibrated for a 20 psi inlet pressure/0 psi outlet pressure while the pump out controller was calibrated for a 10 psi inlet pressure/0 psi outlet pressure. All of these parameters were calibrated accordingly by the manufacturer before shipment.

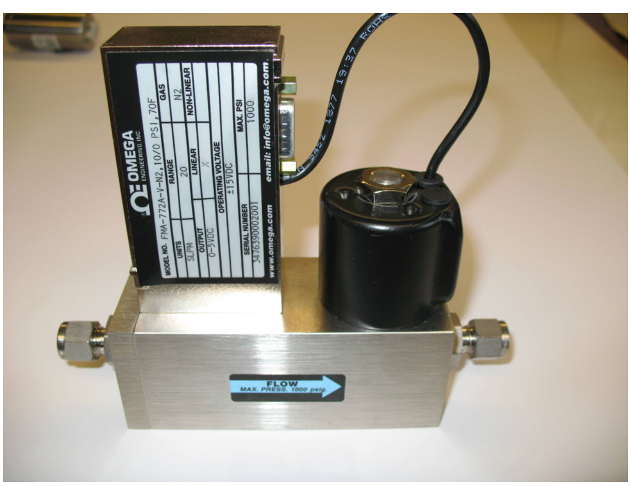

Figure 3: Omega Model #FMA-772A-V mass flow controller

Compact Footprint

In order to keep the up-to-air system as compact as possible, 1.33" "mini"-Conflat (CF) connections were used when possible (see Figure 4). The system consists of four manually actuated values; three of which are VAT Series 284, DN 16 (1.33" CF), UHV angle valves, while the fourth valve is a Circle Seal Series 9500 shutoff valve with a ¼" Swagelok compression fitting threaded into the outlet side and a ¼" Rad Lab style fitting threaded into the inlet side. The loadlock transducer attaches to the system via a ¼" VCR fitting. To mount the diffuser into the system, a 2 ¾" CF nipple was produced as well as fittings to adapt from both 1.33" CF to ¼" VCR and 1.33" CF to ¼" Swagelok. The remaining components were standard 1.33" CF tees, cross, elbow, a 2 ¾" CF to 1.33" CF conical reducer, and a 2 ¾" CF to 1.33" CF zero-length reducer.

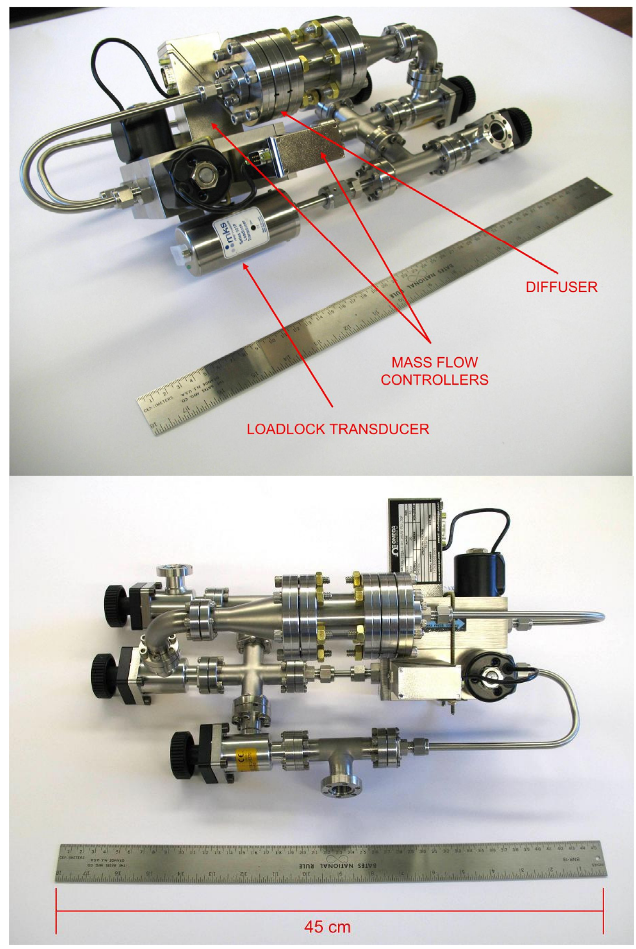

Figure 4: Assembled "up-to-air" system.

Assembly

Before assembly of the up-to-air system, all of the components and necessary hardware were ultrasonically cleaned (minus the mass flow controllers and the loadlock transducer). After ultrasonic cleaning the components and hardware were high pressure rinsed in a Class 100 cleanroom, allowed to thoroughly dry, bagged, and then transported to a larger Class 100 cleanroom for assembly via a portable, battery powered cleanroom. Once in the larger cleanroom all of the components and hardware, including the mass flow controllers and loadlock transducer, were blown down with filtered nitrogen while taking measurements of the blow-off with a particle counter. Once the particle counts of the blow-off for each component was acceptable, the unit was assembled in the configuration seen in Figure 4.

EXPERIMENTAL TEST AND RESULTS

The up-to-air system was tested on a single cavity test of a quarter-wave resonators (QWR) that is now currently installed and operational in the ATLAS upgrade [2]. The QWR was first evacuated, cooled down, pulse conditioned, and quality tested following the normal cavity testing procedures at ANL. The test cryostat was then backfilled with neon gas in order to warm up the cavity quickly. Once warm, the up-to-air system was used to vent the cavity rf space to atmosphere with nitrogen gas following the venting procedure outlined in Ref. [1]. After being vented to atmosphere, the system was used to pump out the cavity following the pump down procedure again outlined in Ref. [1]. Following pump out, the cryostat and cavity were once again cooled down, pulse conditioned, and another quality test on the cavity was performed. The results can be seen in Figure 5.

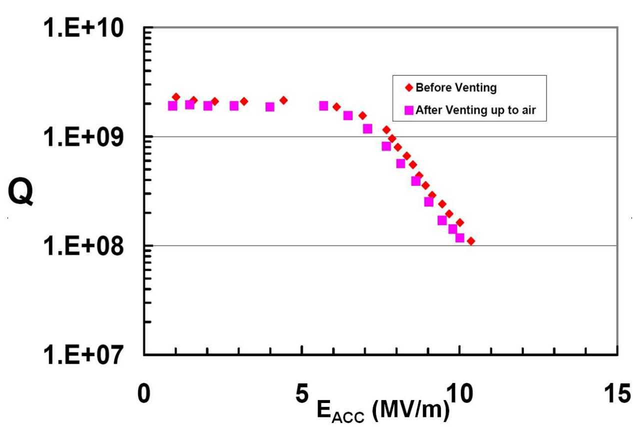

Figure 5: Plot showing Q-curve data from a single cavity test before and after the clean cavity space was vented and evacuated using the "up-to-air" system.

FUTURE APPLICATIONS

The up-to-air system, combined with the ANL top loading cryostat design which allows easy access to individual cavities, will allow an individual cavity to be removed and replaced in a cryomodule without the need to re-clean the entire cavity string. This will greatly reduce downtime of the cryomodule. However, before replacing a poor performing cavity in a cryomodule, a nitrogen gas purge system will need to be developed. This purge system will keep the cavity rf space and related components at a positive pressure of clean nitrogen gas, preventing any particulates present in the cleanroom from migrating into the rf space. Once developed, this capability would also remove the need to individually test every cavity before installation into the string, resulting in a major cost savings.

SUMMARY

The use of an up-to-air system based on the diffuser/mass flow controller schematic can prove to be a viable option when performing single cavity tests or constructing a new cryomodule. The use of this system has shown that pump down and venting cycles may be performed without introducing substantial particulates into the cavity rf space. An up-to-air system may also prove not only to reduce the downtime associated with replacing a poor performing cavity in an operational cryomodule, but can also cut down the time and costs associated with the construction and testing of a new cryomodule by removing the need to test every cavity individually.

ACKNOWLEDGEMENTS

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