CONTROL SYSTEM FOR THE BCP PROCESSING FACILITY AT FNAL*

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Abstract

The surface processing is one of the key elements of superconducting RF cavity fabrication. Safety and reliability are the main requirements for the chemical surface treatment facility being developed at FNAL. Accepting the Buffered Chemical Polishing (BCP) as the baseline process, a "gravity feed and open etching tank" approach has been chosen at this stage. This choice resulted in the introduction of a control system with a strong automation since the number of elements to be controlled at different steps of the process is rather big. In order to allow for maximum flexibility, two operational modes were defined within the control system: semi-automatic, which requires an operator's decision to move from one stage to another, and manual. This paper describes the main features of the control system for the BCP facility that is under development at FNAL.

INTRODUCTION

FNAL BCP Facility

The significant improvement in the performance of superconducting RF cavities makes it possible to consider this technology for several new projects. At FNAL, the CKM experiment is going to use 3.9 GHz deflecting mode cavities, while a possible upgrade of the FNAL-NICAAD photoinjector requires the production of 3.9 GHz and 1.3 GHz accelerating mode cavities [1,2]. As an important step towards completing the infrastructure necessary for the cavity fabrication, a surface treatment facility is being developed at FNAL. Buffered chemical polishing was chosen as a well known and reliable surface treatment process to be implemented at the first stage of the development [3].

General Layout

Two different layouts can be chosen for the design of a BCP setup: in one case the acid is pumped through the cavity, while in the second case a gravity feed system is used to fill with acid the cavity sitting in a tank. At FNAL it was decided to use the gravity feed setup. In addition, a acid circulation system is going to be used during the chemical process to keep the acid cold, to facilitate the expulsion of gas generated during the chemical process, and to mix the Nb dissolved in the acid.

The large number of components present in this system [4] doesn't permit safe manual operation during the process. Several steps of the surface treatment procedure include a number of simultaneous or sequential operations that cannot be easily followed by an operator. This forced the introduction of a semi-automated control system. According to this scenario, the operator, standing outside the chemical room, interacts with the setup through a human machine interface (HMI), Fig. 1, installed on a PC. The PC is connected to a programmable logic controller (PLC) that controls all the system components, reads the feedback from the sensors, and generates the required outputs and interlocks.

DESIGN CRITERIA

In order to implement the semi-automated operating mode, the steps of the etching procedure have been condensed in stages. At the end of each stage the operator is asked to give the permission to proceed with the process. To overcome any PC related failure, instead of using directly the HMI, it was chosen to use a physical button on the control panel. The stages themselves are grouped in 6 sections, which represent the main divisions of the process:

- Test,
- Cool and fill,
- Etch,
- Rough rinse,
- Fine rinse,
- Clean-up.

Among them, the first one, "Test", is performed only manually since there is no acid involved and the goal is a full test of the equipment to make sure that everything works correctly and there are no leaks or sensor failures. At this stage the operators have access into the room to check the components, the barrels with acid are still outside the room, and there is no need for air quality monitoring.

For all the other sections, at any time, it is possible to switch from semi-automatic to manual mode. During manual mode the operator can directly control all components from the HMI by clicking on the icons representing them.

An interlock system prevents accidental or unauthorized access to the manual mode. Two different security levels have been implemented and both of them have to be satisfied to switch between the modes of operation: on the PLC it is necessary to turn a key, while on the HMI it necessary to provide a password in order to obtain an higher operator security level and then toggle a switch.

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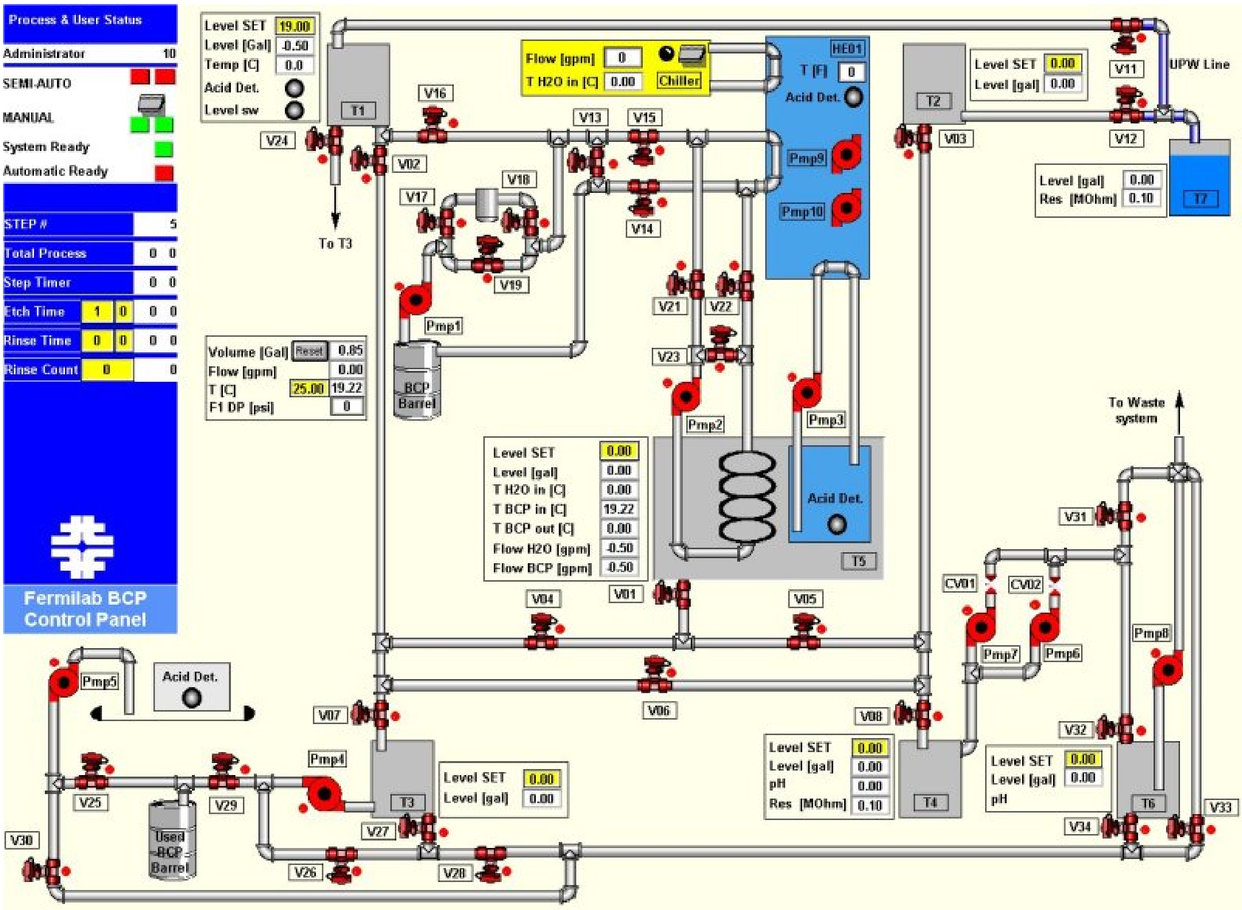

Process & User Status
Administrator 10
SEMI-AUTO
MANUAL
System Ready
Automatic Ready
STEP # 5
Total Process 0 0
Step Timer 0 0
Etch Time 1 0 0 0
Rinse Time 0 0 0 0
Rinse Count 0 0

Level SET 19.00
Level [Gal] -0.50
Temp [C] 0.0
Acid Det.
Level sw

Flow [gpm] 0
T H2O in [C] 0.00

T [F] 0
Acid Det.

Level SET 0.00
Level [gal] 0.00

Level [gal] 0.00
Res [MOhm] 0.10

Volume [Gal] Reset 0.85
Flow [gpm] 0.00
T [C] 25.00 19.22
F1 DP [psi] 0

Level SET 0.00
Level [gal] 0.00
T H2O in [C] 0.00
T BCP in [C] 19.22
T BCP out [C] 0.00
Flow H2O [gpm] -0.50
Flow BCP [gpm] -0.50

Level SET 0.00
Level [gal] 0.00

Level SET 0.00
Level [gal] 0.00
pH 0.00
Res [MOhm] 0.10

Level SET 0.00
Level [gal] 0.00
pH

Figure 1: HMI "Control area"

Changing from manual to semi-automatic mode introduces the problem of matching the actual status of the valves and pumps (feedback from the limit switches) and the position of the switches on the HMI. As soon as the manual mode becomes operative, all valves and pumps move to the default status of the HMI switches. This situation can clearly generate severe consequences on the process. This issue was solved by introducing LEDs that define the status of the HMI switches. This feature allows the operator to manually match the interface with the real status of the hardware before toggling to the manual mode. All the information shown in the HMI comes directly from the PLC, there is no logical or numerical manipulation made by the HMI, which makes the system more stable.

SAFETY CRITERIA

In general, during the chemical process, it is not possible to define a unique safe position for all system components. In case of failure, at different stages, the safe action to be performed can be different. In some cases it is necessary to dump the acid from the cavity and fill it with water while in other cases the cavity is already filled with water. The sequence of closing and opening the valves can be different in several scenarios if the environmental or human risk involved is low enough not to overcome the priority of keeping the cavity safe from air exposure. In case of major acid spill, or failure, a unique safe position for all valves is defined so that all the acid is dumped to waste tanks regardless of the status of the cavity. Taking into account all the features, like guttering or screening introduced in the setup, it is considered a major acid spill if the amount of acid lost doesn't permit a safe completion of the process. For all the other scenarios, a number of specific sequences have been developed to set the system in a safe state based on the type of failure and the step of the process.

Part of the safety criteria in building the facility is that most of the components of the hydraulic circuit are cleaned before anyone is allowed in the room in order to limit the human exposure to acids. This issue is satisfied during the last section of the automated procedure. The control system also includes air pollution monitors for NO_x and HF.

CONTROL SYSTEM DESCRIPTION

Components

The schematic of the optimized FNAL BCP setup is rather complex and the total number of components to be controlled is relatively large.

Figure 2: Control panel

All valves (PVDF with viton o-rings) are air driven with spring back return in order to allow for a safe positioning in case of failure. They are equipped with limit switches and manual override. The pumps are air driven, piston or diaphragm type. Both valves and pumps are controlled by solenoidal 24VDC valves rack mounted outside the chemical room. This choice reduces the amount of acid-sensitive or electrically powered elements in the room.

The instrumentation used in the setup consists of several gauges to acquire a feedback on: level in the tanks, flow, temperature, pressure, pH, and resistivity. All the sensors are connected to reading/programming transmitters, which are rack mounted outside the room and 24VDC powered. The signal coming from these transmitters is used by the PLC to correctly control the operations of valves and pumps.

Programmable Logic Controller

The PLC is a Direct Logic 205 provided with 32 analog inputs, 96 digital inputs, 64 digital outputs and is 24VDC powered. By using a PLC the risk of system failure due to PC operating system instability is minimized. When the HMI is off due to a PC failure, or due to a power outage, the PLC, which is equipped with battery backup, can still be controlled and operated by crosschecking the components status through the room windows and through the instrumentation transmitters.

The PLC is mounted inside a cabinet together with a PC, Fig. 2. The cabinet, equipped with two monitors, is placed in front of the process compartment. The transmitter units of the sensors are mounted on the front panel of a second cabinet to easily allow double-checking the readings from the HMI. The solenoidal valves are mounted on the side of the same cabinet allowing checking the open/closed position through LEDs. There are only a few buttons on the panel of the control cabinet. According to the actual stage and the type of failure, the stop button locks the system in the safest position, while preserving the cavity from air exposure. In case of major failure, the emergency button is used to set the pumps and the valves in a unique status without taking into account the cavity preservation. To prevent any accidental use, the emergency button is protected by a safety screen.

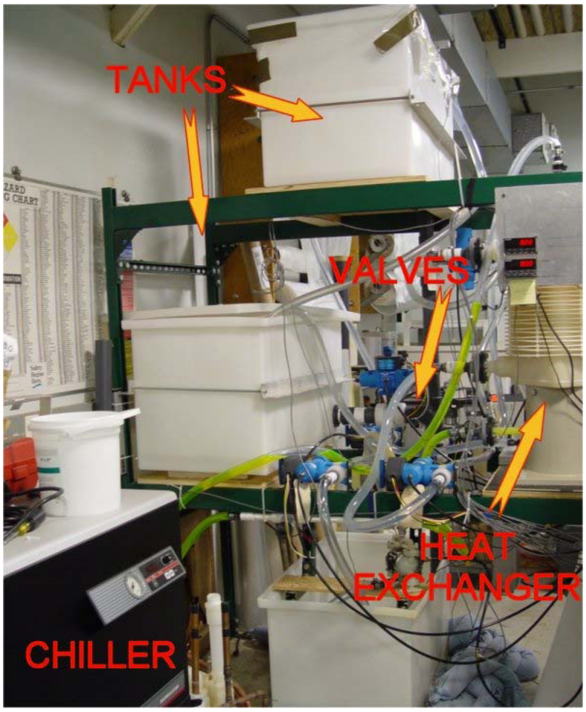

Figure 3: Test setup

A separate control panel contains the air scrubber controls.

Human Machine Interface

The HMI, divided into two different sections, is visualized in two monitors. The first one is the “control area” where all the monitored elements are visualized as shown in Fig. 1. The second section is the “data logging area” where the trends of: level, temperature, pH, and resistivity are plotted in real time for the tanks where these sensors are installed. A list of pumps and valves with check LEDs permit a redundant cross check between the positions of the limit switches with respect to the position requested by the HMI. In the second section an alarm area is also present. Warning lights inform about failures in the system. A log file is generated during the process. Every 20 seconds a line is added where: the elapsed time, the valves positions, the pumps status, and the sensors readings are recorded.

TEST SETUP

In order to test the control system and the hardware for the new facility, a mockup test stand was built in the FNAL TD Material Development Laboratory, Fig. 3.

During testing, only water is used as a fluid. The main feature of this setup is flexibility, since only the minimum number of components required to simulate a single stage of the procedure is used. This choice allowed building the test setup quickly, minimizing the number elements to be controlled and to facilitate the debugging process.

After the control system is tested at every stage of the process using this simple setup, a full-featured facility will be built. As before, no acid usage will be allowed, but a complete test of the hardware and control system will be possible. At this next stage all the failure modes will be implemented and tested.

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