

PROCESS CONTROL FOR THE ISABELLE SYSTEM*

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Abstract

A low cost, highly reliable control system has been developed for use in the radiation environment of the ISABELLE ring. The Ultra-High Vacuum installation will consist of approximately 1500 stations - each having 8 readbacks, 4 on-off operations and 4 special functions - distributed over 2.5 miles. The paper will describe a multidrop party line system in which a μ p based controller located in a protected environment communicates with up to 25 vacuum stations. All the μ p controllers will be linked via the ISABELLE data highway. Mechanical, electronic and software aspects of the system are discussed and performance data from our First Cell model is presented.

Introduction

The Intersecting Proton Storage Accelerator - ISABELLE - under construction at Brookhaven National Laboratory will consist of two interlacing beam tube rings, each 3.8 km in circumference. To ensure high luminosity, the pressure in the beam tubes must be maintained below 3×10^{-11} Torr (hydrogen). This is necessary in order to avoid beam intensity loss from excessive beam-gas collisions. This is considered the high vacuum requirement of the accelerator and it is the purpose of this paper to outline the various components of the process control system which has been developed for the ISABELLE Vacuum System.

The ISABELLE High Vacuum System will consist of the following items:

1. 714 Diode Ion Pumps
2. 1428 Sublimator Pumps
3. 1428 Ion Gauge Controllers
4. 1428, 1000 W Pump Station Heaters and temperature readouts
840, 1000 W Beam Tube Heaters inside ovens and temperature readouts
336, 13 W Beam Tube Heaters inside magnets and temperature readouts
5. 84 Sector Valves
6. 42 Motor Autotransformers
7. 78 Clearing Electrodes
8. 78 Portable Pumping Stations

In this paper we will deal with items 1 through 4 only. Items 5 through 8 are considered Pseudo Stations and can be handled quite easily in the scheme devised for ISABELLE.

For purposes of high vacuum control, the smallest boundary of the High Vacuum System exists within the confines of two Sector Valves. This confined vacuum system is called a Sector. One Sector can have a minimum of 14 pumping stations and a maximum of 20. ISABELLE consists of a total of 78 such Sectors. Computer control is based on the Sector concept with a microprocessor devoted to each Sector.

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I. High Vacuum Components (Mechanical & Electrical)

Each High Vacuum pump station within a Sector has the following components:

1. Ion Pump
2. Sublimator Pump
3. Pump Station Heater and Temperature Readout
Beam Tube Heater and Temperature Readout
4. Ion Gauge Controller

Ion Pumps

Initially, we will equip every other pump station with a diode pump. To operate these pumps we will have two +5 kV, 150 MA ion pump power supplies which are constantly on. Each power supply will have ~ 5 ion pumps, in parallel, connected to it. We will control the high voltage to each pump by means of high voltage relays located at each pump station. These relays have a +12 V dc coil which will be activated by computer supplied ground. All the "ON/OFF" functions mentioned in this report are handled in this fashion. We will monitor pump operation with the computer by means of a voltage divider which outputs a +5 V signal that is scaled to +5000 V. Computer interface consists of reading voltage at each pump and being able to control the high voltage relay "ON/OFF" function at each station.

Sublimator Pumps

To supply the high current required for the sublimator pumps we will use 750 VA buck-boost transformers. They will be connected as twelve volt output-high current transformers, and are located at each pump station. Each transformer has a 12 V dc coil and DPDT relay located in it, controlling the primary power. Sublimator current will be measured by a current sensor which outputs a d.c. signal that is 1/10th the actual rms value.

The sublimation pumps have two modes of operation:

1. Bake-out mode: ~ 18 A for a 24 hour period, system at 300°C bake-out.
2. Sublimation mode: 48 A for 7 minutes, system at room temperature.

In the bake-out mode, all twenty pumps will be operated at a reduced input voltage. This voltage will be simultaneously applied to all buck-boost transformers. In the sublimating mode, one station at a time is activated. The input voltage will be increased so that the desired sublimator current is applied.

To control the buck-boost primary voltage we will use two 50 kV motor driven autotransformers. The low limit setting on the autotransformer defines the bake out mode voltage which is applied to each buck-boost transformer. The high limit setting prevents over driving the autotransformer. To sublimate a station, that particular buck-boost transformer relay is activated and the motor autotransformer is driven to a voltage that permits 48 A through that sublimator. It will be possible to control the motor autotransformer either manually or computer. The motor autotransformers are handled as Pseudo Stations within the scheme described later in the report.

Heater Controls

The heater controls at each station consist of a bore tube heater and a pump station heater. These heaters will be enabled by a 12 V dc coil DPST relay. To limit the temperature we utilize adjustable thermostat controllers which are preset to 300°C. These switches are then connected in series with each set of heaters.

Three wire, 100 Ω platinum resistance elements will be used to measure temperature and interface with the computer. Microprocessor control of the heaters will enable us to control bake-out at various temperatures, with the computer acting as a temperature controller. We will have temperature readouts of the pump station and the beam tube.

Ion Gauge Controller

To measure the high vacuum that is necessary for ISABELLE, we will be using a modified Bayard Alpert gauge. With this design it is possible to measure pressure of 5×10^{-12} Torr.

The controller will be capable of reading these pressures and processing this information into decade and linear information within the decade. This information will then be fed into the computer interface. The decade information will be contained within 1 to 7 V dc, in 1.V increments. The linear information within the decade will be output by a separate 0 to +10 V dc signal. The pressure range covered by this controller, is from 10^{-6} Torr to 10^{-12} Torr.

Along with the features that are common on all commercially available controllers, we are requesting remote control of the following functions :

1. Filament ON/OFF
2. Filament #1, #2 select
3. Degas ON/OFF

These functions will be implemented by supplying a switched ground for each desired function to the controller.

Microprocessor Interface & Radiation

Around the ISABELLE ring, there will be 357 floor mounted equipment racks. These racks will contain electronics for the items previously discussed. One rack will control 4 pump stations and will be positioned up stream of the proton beam exiting the adjacent magnet.

Each rack will have a chassis which contains computer interface plug-in modules and vacuum interface plug-in modules. These modules will be interconnected within the chassis and will allow computer control of each high vacuum pump station. Also housed in this chassis will be all the necessary dc power supplies and control relays.

As noted above, there will be equipment placed in the accelerator environment, and thus exposed to radiation. We are requesting that all components placed in the ring be able to withstand 10^5 rads of cumulative radiation. This is a worst case figure and will occur in few places around the accelerator. It is estimated that with this radiation figure we can expect a 10 year lifetime.

II. Control Electronics

General requirements of the ISABELLE High Vacuum control are as follows:

1. To acquire data (re: pressure, temperature, current, etc.).
2. To provide ON/OFF control of gauges, pumps, heaters, sublimators.
3. To servo the heater temperature and/or sublimator current to set points determined by the operator.

Since the ISABELLE High Vacuum system will consist of 1400 stations distributed about a four kilometer ring, the somewhat appealing "Star" system configuration, where the controller communicates with each station via an individual cable, is cost prohibitive (550,000 ft of cable). Therefore, a form of a multi-drop/multiplexed system is mandated. A conventional binary control scheme would require five address lines (to handle our 20+ stations), plus two lines for function selection (readback, ON, OFF, spare). By utilizing tone multiplexing, we are able to perform the same functions with only two lines. High resistance to radiation damage in the electronics was achieved by carefully selecting I.C. families and by eliminating solid state memory devices from the design.

Signal Conditioner Board

The pump station package consists of two double tone decoders, two line driver/receiver I.C.'s, eight (max) V/F converters and four logic I.C.'s.

The analog signals are converted to proportional frequencies via the V/F's and are transmitted through a multiplexer to the line drivers.

The temperature sensor is a 100 Ω platinum resistor that provides a resistance proportional to temperature. It has excellent radiation resistance. In order to convert the variable resistance into variable voltage, and at the same time to deduct the 0°C voltage, a bridge circuit was used. The error due to the length of the leads is eliminated by using a three wire system. By utilizing a current source as one of the four bridge arms, the bridge linearity is better than 0.1%.

Tone Decoder Circuit

There are four tone decoders within a vacuum station, housed in two type XR 2567 I.C.'s. The device is utilized in a standard configuration except that a feedback circuit is added to prevent chatter in the output stage. Since the programmable counters that synthesize the tones generate square waves, there is no need to worry about second harmonics, and a tone frequency range of 9.88 kHz to 27 kHz may be used.

Microprocessor

The High Vacuum Controller performs the following functions:

1. Acquires data by scanning all controlled High Vacuum Stations
2. Receives, interprets and executes commands from the vacuum computer.
3. Communicates locally with a T.T.Y. for testing and maintenance purposes.

The controller is an intelligent system based on an 8085A Microprocessor (μ P). The μ P executes instructions from 6K bytes of program memory and uses 512 bytes of RAM for storage of results. Most of the time the μ P is busy collecting data from the high vacuum stations. The incoming data is a pulse train ranging from 10 to 10 kHz, which corresponds to a 0 to 100% reading of a particular gauge scale. Two independent channels (reply lines 1 & 2) are read simultaneously. Since the controller supervises 20 stations with 8

pieces of data each, there are 160 distinct pieces of data to be collected in 80 cycles. A complete set of data is acquired every 2.5 seconds.

Certain operations like "Bake out" or "Sublimator Flash" require time as a parameter. Likewise, servoing temperature or current requires periodic comparison of setpoint and readback. For these reasons the hardware provides a one second clock that interrupts the μP and activates a time keeping routine. The clock source, is the μP 's 6.144 MHz crystal clock.

Communication between the High Vacuum controller and the vacuum computer is done via IEEE 488 standard protocol. The hardware provides the proper interface utilizing a P8291 GPIB talker/listner in conjunction with two MC 3447 octal bidirectional bus transceivers. The talker/listner interrupts the μP whenever the vacuum computer tries to communicate with the controller.

Status Lines

The controller has the ability to read 48 binary status lines. The status line presents information on manual valves, sector valves, roughing pumps, etc. The 48 lines are buffered by 74LS244 chips and are multiplexed to an I/O port.

Pseudo Station

Devices such as motor autotransformers, sector valves, etc. are controlled via modified signal conditioner boards tailored to their unique requirements. The basic tone addressing scheme is unchanged.

Conclusion

The ISABELLE Full Cell Vacuum System consisting of a 40 m long, by 8.8 cm diameter stainless steel tube pumped by seven pumping stations was assembled and processed for 10^{-12} Torr operation. Evaluation and testing of the system and its subassemblies has been completed. Pressures below 2×10^{-11} Torr are now routinely achieved in normal operation of the Full Cell. The microprocessor controller was installed with six hundred feet of cable inserted to simulate a full ISABELLE sector. All required operations and monitoring were accomplished using the microprocessor controller. No serious defects were discovered. Radiation testing of the signal conditioner electronics is in progress. The system has remained operational to 10^5 rad.

Tone B # \ Tone A #	1	2	3	4	5	6	7	8	9	10
1	Lower		ENA 1	ENA 2	ENA 1	ENA 2	ENA 1	ENA 2	ENA 1	ENA 2
	Variac Sta.	Home	Sta. #1		Sta. #2		Sta. #3		Sta. #4	
2	Raise	Home		ENA 3		ENA 3		ENA 3		ENA 3
3	ENA 1				ENA 1	ENA 2	ENA 1	ENA 2	ENA 1	ENA 2
	Sta. #5		Reserved		Sta. #6		Sta. #7		Sta. #8	
4	ENA 2	ENA 3				ENA 3		ENA 3		ENA 3
5	ENA 1		ENA 1				ENA 1	ENA 2	ENA 1	ENA 2
	Sta. #9		Sta. #10		Reserved		Sta. #11		Sta. #12	
6	ENA 2	ENA 3	ENA 2	ENA 3				ENA 3		ENA 3
7	ENA 1		ENA 1		ENA 1				ENA 1	ENA 2
	Sta. #13		Sta. #14		Sta. #15		Reserved		Sta. #16	
8	ENA 2	ENA 3	ENA 2	ENA 3	ENA 2	ENA 3				ENA 3
9	ENA 1		ENA 1		ENA 1		ENA 1			
	Sta. #17		Sta. #18		Sta. #19		Sta. #20			Vacuum Barrier
10	ENA 2	ENA 3	ENA 2	ENA 3	ENA 2	ENA 3	ENA 2	ENA 3	ON	OFF

Tone #	Frequency	Tone #	Frequency
1	9980	7	17096
2	11170	6	19088
3	12443	8	21370
4	13846	9	23977
5	15360	10	26933

Select Lines	ENA 1 (Read back)		ENA 2 (Activate)	ENA 3 (Deactivate)
B1 B2	On Line #1	On Line #2		
0 0	Ion Gauge	Ion Gauge range	Ion Gauge "ON"	Ion Gauge "OFF"
0 1	Ion Pump Voltage	Ion Pump Current	Ion Pump "ON"	Ion Pump "OFF"
1 0	Temperature Sensor #1	Temperature Sensor #2	Heaters "ON"	Heaters "OFF"
1 1	Sublimator Current	(reserved for acknowledgement signal)	Sublimator "ON"	Sublimator "OFF"