# VACUUM SYSTEM CONTROL FOR THE HEAVY ION TRANSPORT LINE*

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## Introduction

The Brookhaven AGS, 807 m in circumference, and the Tandem Van de Graaff are now joined together by a transport line, 600 m in length. This now allows heavy ions from the Tandem, up to fully stripped sulfur (M = 32) to be transported into the AGS and accelerated to 15 GeV/A. With the addition of a booster between the Tandem and the AGS in the near future, heavy ions such as gold (M = 200) can be accelerated to 30 Z/A GeV/A. This paper describes the HITL (Heavy Ion Transport Line) vacuum control system design and implementation.

## Description of Vacuum System

The HITL vacuum system is divided into 22 vacuum sectors isolated by sector valves. The bulk of these sectors are pumped by non-evaporable getter (NEG) strips[2] with a 20 ℓ/s diode pump every 80 m. A 20 ℓ/s diode ion pump is located at each diagnostic box. Diagnostic boxes are located at various spots along the HITL beam line. At these boxes are located sector valves at either end and two ion gauges. One ion gauge is located inside the diagnostic box, the other ion gauge is located to the downstream side of the downstream gate valve (see Fig. 1). Located along side of each ion gauge are convectron gauges.[1,4]

At either end of the tunnel are the transition areas, Tandem to HITL and HITL to AGS. At these points the NEG strips are discontinued and larger ion pumps are used (220 ℓ/s) along with 20 ℓ/s ion pumps. These pumps are spaced much closer together than throughout the main HITL tunnel. The NEG strips are powered by SCR controllers and high power transformers located in the HITL tunnel. Granville-Phillips 303 vacuum controllers (two ion gauges and two convection gauges) are located in half relay racks positioned along side of the diagnostic boxes. In the same half relay racks are located "local valve control" chassis for sector valve control and remote control of the ion pump power supplies. The ion pump power supplies are all placed in three external areas with RG213A/V cable connecting the power supplies to the pumps. At these three locations are placed vacuum device controllers which interface the Granville-Phillips 303's and the sector valve.

## The Ion Pump Power Supply

The ion pump power supply chassis is a dual supply, consisting of a designed-for-BNL current limiting transformer with a short-circuit current of 200 mA. This transformer is utilized in a voltage doubler circuit with associated bridge rectifiers and filter capacitors. The power supply is operated through relays located on the underside of the control chassis. Three 24V relays are activated by a

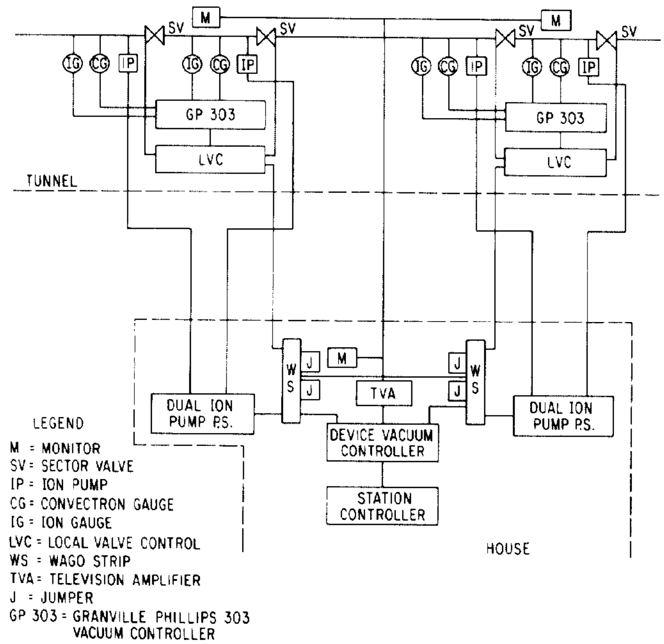


Fig. 1. System Layout.

d.c. supply located on the underside of the control chassis. A 0.85 mA coil relay is utilized in the return leg of the H.V. output and serves to turn the P.S. "off" when excess current is drawn. A 0.85 mA current is equal to $2 \times 10^{-6}$ Torr for a 20 ℓ/s pump and $3 \times 10^{-7}$ Torr for a 220 ℓ/s pump. This relay can be bypassed through a switch mounted on the rear of the power supply. The "on" relay is latched in by means of "on" and "enable" pushbutton switches mounted on the front panel. Both must be activated simultaneously. The power supply is turned off by utilizing the "off" and "enable" pushbutton switches on the front panel or by the overcurrent relay or the external 303 vacuum controller. On the rear panel are located control connectors and 10 Amp circuit breakers for each power supply. Also located here are two override switches for each power supply (current override and 303 override).

Monitoring of high voltage and current is done through tip jacks mounted on the front panel. A portable DVM is used for monitoring purposes. A 1000-1 voltage divider is utilized for the voltage readout. It is a thick metal film divider manufactured by TRW, Inc. Current is read across a 10 Ω, 2% metal film resistor. For low currents to 1 μA, a front panel momentary pushbutton switch accesses a 10 K Ω, 2% metal film resistor protected by a 10 V zener diode.

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Provisions have been made for future computer interface by installing a four-card multibus card cage in a separate compartment, located in the front section of the power supply chassis. Three multibus cards will reside in the card cage.

## The Local Valve Control Chassis (LVC)

This chassis is located in the tunnel at the valve locations and serves the following three functions:

1. Local valve control, open, close information transmission to remote house locations.
2. Local control (on, off) of remote ion pump P.S.'s.
3. Granville-Phillips 303 process control input, multiplication and distribution to remote house location.

The chassis consists of a printed circuit board with 24 V d.c. relays and a +24 V power supply. 24V LED's are provided on the front panel to indicate the following:

1. Valve open.
2. Valve closed.
3. Valve enable.
4. Ion pump on.
5. Ion pump disabled.

Relays are utilized on the board to provide isolation from local system to remote system. The relays used for the Granville-Phillips 303 process control also supply multiplication by giving two process control outputs for one process control input. 24 V d.c. and GND from the remote ion pump P.S. is supplied to this chassis and powers the "ion pump on" LED. A DPDT front panel switch utilizes the ion pump ground to turn "off" the remote ion pump P.S. and prevents it from being turned "on" from the remote location or from the local valve chassis itself. When this switch is disengaged, the ion pump P.S. can be turned "on" by the ion pump momentary "on" switch located on the front panel.

This chassis serves as the focal point for all control and sense information going to and coming from the valves, Granville-Phillips 303 vacuum controller, and ion pumps in a spcific vacuum area. This area is defined by a diagnostic box vacuum vessel with valves at either end. On the rear of the local valve control chassis are two nine-pin D connectors, one for each valve. The VAT valves have +24 V d.c. coils and receive their power from a +24 V, 5A supply located in the chassis. Valve position information is transmitted through this connector as well. Four process control channels from the G.P. 303 access the rear of this chassis through a 15-pin D connector. All information to and from this chassis to remote locations, inputs this chassis through a 37-pin D type connector which is attached to the P.C. board and mounted to the rear wall of the chassis.

The local valve control chassis is a dual unit supplying two sets of identical equipment. On the front panel are located two key switches. These key switches are utilized for valve operation. The key switch is a three-position wafer-type switch manufactured by Illinois Lock Company. This lock allows the valve to be open or closed, independent of interlock logic. In the center position, the key can be removed and the ion gauge logic will determine valve state.

## Granville-Phillips Model 303 Vacuum Controller (GP303)

The model 303 vacuum controller was chosen for vacuum readout and control because of its versatility and cost effectiveness versus other controllers available. For HITL, we chose to have the 303 equipped for two convectron gauges (1000 Torr to 1 Millitorr) and two ion gauges ($1 \times 10^{-1}$ Torr to $5 \times 10^{-11}$ Torr). The controller has a process control board which outputs four process control channels via relay contacts and an accompanying external enable board with a jumper connector. These channels can be assigned to any gauge convectron or ion gauge. For HITL we have assigned two P.C. channels to each ion gauge. One P.C. channel for each gauge is for valve control and the other two P.C. channels are for ion pump control. The 303 is equipped with RS232 for computer interface. No device control commands are issued from the computer to the 303.

The 303 is housed in the same open relay rack as the local valve control chassis and is located in the tunnel. The RS232 cable is a twisted pair cable which runs to the device vacuum controller located in one of three external locations. The gauge cables were supplied with each controller and installed to length.

## Nonevaporable Getter Strip Control (NEG)

NEG strips line the length of the vacuum pipes in the main HITL tunnel. NEG strips are not present in the Tandem, AGS transition areas. The NEG strips are utilized to pump active gasses without the sublimation; all that is necessary is activation of the strip. The NEG strips used in HITL are manufactured by SAES Getters, Inc. A strip consists of Zr-V-Fe alloy deposited on a constantan support strip 0.2 mm thick and 3 cm wide. Figure 2(a) shows the cross sectional view and Figure 2(b) the uncaptured version of NEG strip with support and insulators inside the pipe. The thermal expansion of the NEG strips during bakeout and activation is absorbed by two copper braids at each end of the pipe as shown in Figure 2(c).

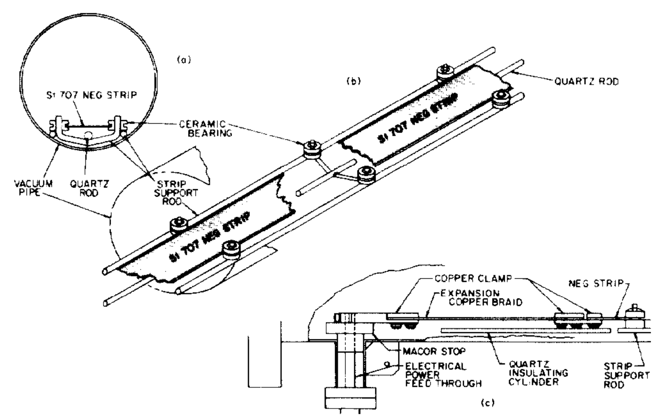


Fig. 2. NEG strip.

Activation of the strip is done by resistive heating of the constantan support strip. A current of 70 A and 700 W/m power is required to maintain the NEG at 400°C. The NEG strip also serves as the heat source during in-situ bakeout. Power is supplied by means of an Athena 1200 SCR controller connected in each leg of 3ϕ 208 V transformer. Three NEG strips are connected in parallel off of each leg. Power is gradually increased in each leg while portable turbo molecular pumps evacuate the volume under bake.[3] Pressure is monitored by means of an ion gauge mounted on the pumping station. The SCR controller is interlocked off process control contacts from the pump station Granville-Phillips 303 vacuum controller. This control of the NEG strip provides protection against vacuum failure.

## Computer Interface

There are four HITL vacuum device controllers installed in three locations. Two are located in the Tandem Alcove, and one each in the Mid-point House (Power Supply House #1) and the AGS House (Power Supply House #2). The vacuum device controllers are capable of communicating with Granville-Phillips series 303 vacuum process controllers and the valve status information located in Wago strips installed in vacuum equipment racks in each house. A future upgrade of this system will allow readout of ion pump current, voltage, and various status conditions.

The vacuum device controller is connected via an IEEE-488 interface to a station controller in the same house. Each vacuum controller handles a section of the HITL tunnel. These controllers interface a monitor in the house and a series of monitors in the HITL tunnel through a video amplifier. The monitors in the tunnel are located under the second cable tray at each LVC, 303 equipment rack location. All the monitors display the following information:

1. Ion gauge status (on/off)
2. Convectron gauge status (on/off)
3. Ion gauge pressure
4. Convectron gauge pressure
5. Valve open
6. Valve closed

A total of 23 monitors are dispersed throughout HITL and support houses.

The vacuum device controller communicates with the Granville-Phillips Series 303 through an RS-232C interface. The interface contains a multiplexer which allows the controller to communicate with up to 8 Granville-Phillips 303's. The baud rate is 1,200, with cable lengths less than 1,000 feet. The vacuum device controllers are installed in vacuum equipment racks which also house the ion pump power supplies. Readout of the above information is available in both AGS and Tandem control rooms on Apollo systems.

## Vacuum System Control Logic

The control logic for HITL consists of the process control relay contacts from the Granville-Phillips 303. This information is transported to the appropriate remote location via an 18-twisted pair 20 AWG cable and terminates in Wago strips (terminal strip) installed in the vacuum equipment racks. The Wago strip has provision for 50 terminations, thus one Wago strip is assigned to one cable from the tunnel. Two contact closures are provided per ion gauge for sector valve control. Contacts from adjacent gauges are jumped together at the Wago strip (contacts in series) and this information is sent back to the LVC chassis via the 18-pair cable. Direct control of the sector valve is achieved in this fashion. Valves will open when gauges on either side of the sector valve read vacuum better than the process control setpoints. This requires that the LVC sector valve key switch be in the remote position (key removed).

The other process control contact from the Granville-Phillips 303 is used for ion pump power supply control. This contact can be utilized one of two ways by the power supply:

1. To turn "on" and turn "off" the supply based on the process control setpoint.
2. To turn "on" the supply and allow it to protect via the internal overcurrent relay. This allows the power supply to stay "on" if the Granville-Phillips 303 develops a problem.

## System Bakeout

In the main tunnel, the bakeout is accomplished by NEG strips in the vacuum pipe and heater tapes around the diagnostic boxes. Temperature is kept at ≈ 150°C and is monitored by means of portable thermocouple probes. At the Tandem penetration, the beam pipe and diagnostic boxes are wrapped with heater ribbon tape covered by aluminum foil. Temperature control is by means of convection losses which limit the temperature to ≈ 150°C. At the AGS penetration, beam pipes and diagnostic boxes are wrapped with heater tapes and covered with fiberglass insulating blankets. Each heater tape is controlled directly by a Fenwal temperature controller mounted directly to the surface by means of metal hose clamps. Temperature is readout by means of Chromel Alumel thermocouples placed throughout the system. A total of 22 thermocouples are readout through a thermocouple switch by means of a portable meter. Bakeout lasts for approximately two days. After bakeout, pressures ranges from mid $10^{-10}$ Torr in the main tunnel to mid $10^{-7}$ Torr in the AGS, Tandem transition areas.

## Conclusion

The vacuum control system has performed well to date. The valve interlock logic has provided reliable vacuum system protection with minimum downtime. The ion pump power supplies have proven to be quite reliable with no equipment failures to date. A few Granville-Phillips 303's failed early in the start-up phase with failures randomly scattered throughout the controllers circuitry. Since these initial failures, the 303's have been quite reliable. Some changes were made in software to better display system readouts in a fashion consistent with device location in the tunnel (i.e., convectron gauge, ion gauge, and sector valve at the same relative position in the tunnel). This control approach was chosen as an inexpensive means of monitoring the vacuum system while providing the necessary controls to effectively run the system. This approach also provides easy upgrade capability.

## References


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