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ENERGY DOUBLER VACUUM DEVICES AND CONTROLS

L.Bartelson and H.Jöstlein
Fermi National Accelerator Laboratory*
P.O. Box 500
Batavia, Illinois 60510

Description of the Vacuum System

The vacuum system consists of three different systems, each with its own particular characteristics and requirements:

-The cryostat insulating vacuum which is completely separate from the two systems below.

-Cold beam tube, vacuum sections in which the beam tube is at cryogenic temperature (about 4.6K).

-Warm beam tube, vacuum sections in which the beam tube is at room temperature.

The beam tube is, of course, continuous around the ring, approximately 6 km in length. The beam tube vacuum around the ring is conveniently divided into 24 sections which coincide with 24 cryoloops (there are 24 satellite refrigerators). Each section terminates in a cryogenic turnaround box at either end. At each of these points there is a short (about 10 cm) warm section of the beam tube with an isolation valve (section valve).

Each section consists of two "magnet strings" with four quadrupole magnets, 16 dipole magnets and four "spool pieces" (which contain correction elements, cryogenic equipment and quench protection connections).

Each magnet string has one permanent pump station associated with the insulating vacuum. The insulating vacuum is further subdivided into "half-cells" (four dipoles, one quadrupole and one spool piece) by vacuum barriers inside of each spool piece. A "bypass manifold" connects the vacuum spaces on either side of the spool pieces. The bypass manifold contains an electropneumatic valve and gauging. These valves may be closed in order to facilitate leak checking, to allow work on any half-cell, and to protect the rest of the ring in case of catastrophic vacuum failure. (See. Fig. 1.)

The bore tube is pumped down initially by means of a mobile turbopump cart with liquid nitrogen cold trap and is then allowed to cryopump once it is cold. The pressure will be monitored with Bayard-Alpert gauges (BAG) and via the current readout of diode type ion pumps. Those gauges also interlock the section valves.

The warm bore sections will be monitored similarly and will be pumped by ion pumps.

Overview of Vacuum Instrumentation and Control

The task of the controls system is threefold:

- to provide adequate information on vacuum pressures and equipment status,
- to allow operator control of valves and pumps,
- to protect the magnets and the vacuum equipment in case of malfunction and operator error.

Figure 2 shows the communication channels for vacuum data and controls.

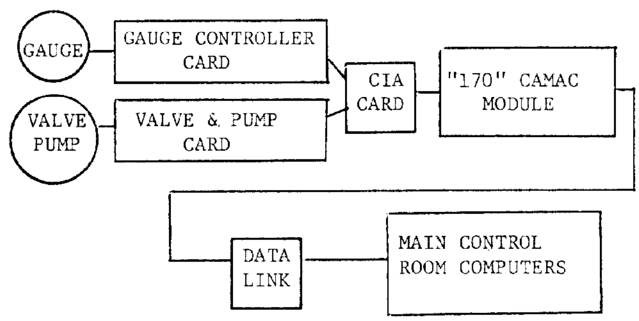
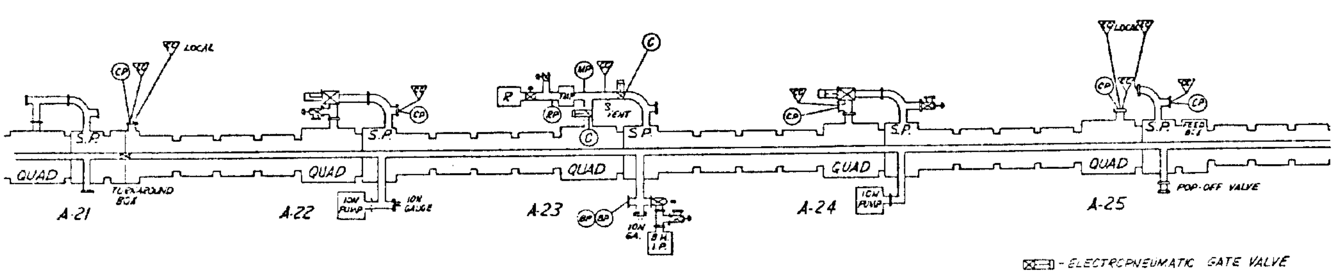


Figure 2. Controls configuration.

All equipment is controlled by printed circuit cards (PC) housed in the "interface adapter crate" (CIA crate). These PC cards include the following types:

- The Pirani card drives six pirani type vacuum gauges.
- The Cold Cathode card reads out 12 Penning-type gauges, whose high voltage supplies are housed in a separate enclosure.
- The Pump card controls one of the two pump stations at each house.
- The Valve card controls valves in two bypass assemblies per card.
- The Ion Pump card controls and reads six ion pumps.



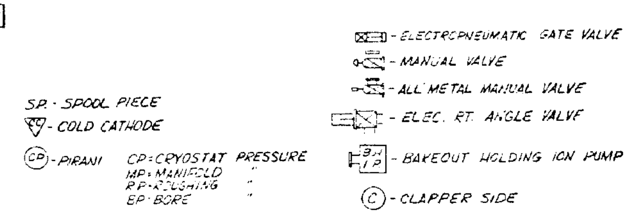


Figure 1. Vacuum equipment layout for one-half section of the Energy Doubler

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- The Ion Gauge card controls and reads six ion gauges (BAG).

- The Section Valve card interlocks two section valves.

The "CIA driver card," housed in the same crate, contains an ADC which can address any of the source cards and cause it to place a given analog signal on a common bus for conversion to digital data. The CIA card handles all traffic between source cards and the "170" module which is housed in a CAMAC crate nearby. This CAMAC module communicates via its bus lines with a special crate controller connected to the "link," which runs all around the ring and provides communication between the 24 section houses (plus six straight section houses) and the Main Control Room computers. The following section describes components of the system in more detail.

The Pirani Card

The Pirani card contains circuits to drive six gauges. The gauges are made by Granville-Phillips (Convectron") and contain a bridge network which takes about 70 ma of current to drive at atmospheric pressure and 10 ma at 1×10^{-4} Torr. The analog output of the operational amplifiers is 9 volts at atmosphere to 0.3 volts at 1×10^{-4} and is connected to the crate bus via an addressable analog multiplexer. Each circuit provides a fault status if a gauge cable has been unplugged. A permit signal is developed when the pressure drops to 3×10^{-3} Torr to energize an associated cold cathode. The main 12 volt supply is interrupted if the plus or minus 15 volt supply starts to drop in voltage.

The Cold Cathode Card

Each cold cathode (Penning-type) vacuum gauge is powered from an independent 3kV high voltage supply. Twelve of these supplies are housed in one crate. Each uses a separate transformer with rectifiers in the cascode configuration to minimize current leakage in the transformers. The gauge current is monitored by a log (current)-to-voltage circuit (Analog Devices 759P) in the return path. An operational amplifier on the output adjusts the gain such that the pressure range from 3×10^{-4} Torr to 1×10^{-7} Torr corresponds to an output voltage of 1.2V to 7.2V. A current source of 10 nA is fed into the log amplifier to allow testing it when the 3kV supply is switched off. All channels should then read 9V. The 12 separate channels are switched on and off by a solid state relay via a permit given by a Pirani channel. Analog data are multiplexed by one card in the CIA crate. (See Fig. 3.)

The Pump Card

The roughing station card controls a roughing pump, turbopump, and two roughing valves under the following stipulations. A roughing valve may be operated only when the roughing pump is on, proper air pressure applied and differential pressure across the valve within acceptable limits. When the roughing pressure is below 1 Torr, the turbopump must be running. If the turbopump does not run (i.e., draws no current) a fault status occurs and the valves will close and shut the roughing pump off. This action will in turn vent the pump station to atmosphere, provided the gate valves have indeed closed. The differential pressure is derived from an analog voltage from Pirani gauges mounted on each side of the valves. A valve may be opened against atmospheric pressure if the pressure on the other side is at least

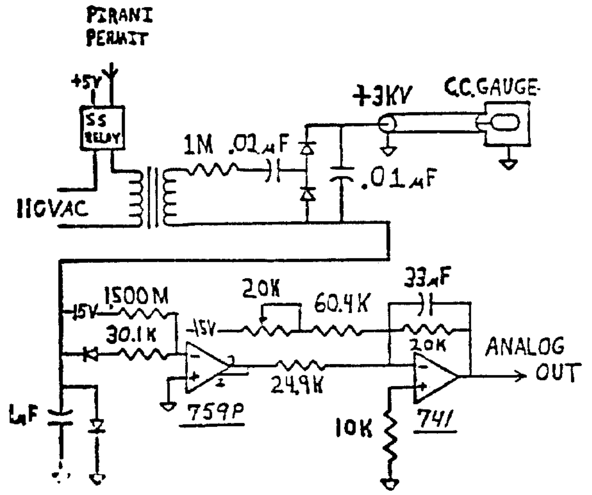

Figure 3. Cold cathode gauge power supply.

20 Torr. At lower pressures the differential must be less than 1 Torr. This guards against accidental opening of a section under vacuum.

When pumping down from atmospheric pressure, the operator opens the valves and turns the roughing pump on. When the pressure falls below 1 Torr, the turbopump comes on. If the section was already under some vacuum, the operator may preset a "request to open valve." As soon as the pressure in the pump station reaches the pressure in the system, the valve will open and pumpdown proceeds.

In the case of great gas loads, the reverse of the pumpdown proceeds. This may happen when warming up a magnet string in which much gas had previously been frozen out. In this case the turbopump will continue to operate as long as the roughing pressure is below 1 Torr. When the pressure increases, it will shut off while the roughing pump continues to operate. In this way the lowest possible system pressure is maintained without endangering the vacuum equipment.

A circuit has been incorporated to sense a sudden increase in roughing pressure in case of disaster. The circuit closes the valves to protect half-cells adjacent to the one which has a largeleak.

The Valve Card

The valve card controls two bypass assemblies. Its actions are similar to those of the pump card, except that there are no pumps to control.

The Ion Pump Card

The Doubler will use diode-type ion pumps driven by a voltage doubler power supply capable of 5500V open circuit voltage and 70 mA short circuit current. The supply has front panel and computer control for on, off, and reset functions. On turn-on, the current must be below 3 mA within 15 minutes, and never again exceed 3 mA thereafter or it will go off with a fault status requiring a reset before it can be turned on again.

The current readout utilizes the same six decade log (current)-to-voltage hybrid as the cold cathode gauge supply. These circuits can, however, only handle 10 mA maximum current. Therefore, a hexfet is used as a bypass which shunts an increasing fraction of the pump current around the hybrid, while still giving a useful current estimate. Currents from 10 mA to 70 mA cause output voltages from 0.1V to 9V. Six such power supplies connect to one ion pump card (in the CIA crate) for readout and control. Figure 4 shows the circuit diagram.

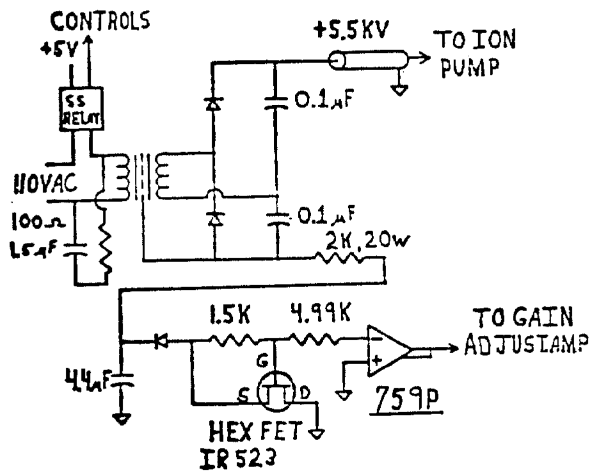

Figure 4. Ion pump power supply.

The Ion Gauges

Currently work is being done to use a commercial electrometer op amp (Analog Devices AD515) with a commercial precision logarithmic module (Analog Devices 751N) in the feedback loop. Data have been taken for a current span from 25 pa to 25 μa. A prototype is now being built for field testing. Control from the CIA crate could possibly use the same PC card as used for ion pumps.

The Section Valve Card

Section valves are at the boundary of sections, and are interlocked to shut whenever the pressure exceeds 10^{-6} Torr on either side. The pressure measurement requires three out of four gauges (ion pumps or ion gauges) to be operating and reading low pressure. These valves can be operated from either one of the adjacent houses, and through the computer system.