INSTRUMENTATION and CONTROL of the AGS BOOSTER VACUUM SYSTEM*

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ABSTRACT

The AGS Booster is a synchrotron for the acceleration of both protons and heavy ions. A pressure of low 10^{-11} Torr is rquired for the acceleration of the partially stripped, low β, very heavy ions. This paper describes the power supplies and controls for this ultra-high vacuum system with the emphasis on the operation of the ion gauge system over long cable length and on equipment interlock.

INTRODUCTION

The recently completed AGS Booster [1] at Brookhaven is a small synchrotron of 200 m in circumference for the acceleration of protons and heavy ions. It is located between the existing 200 MeV Linac, the Tandem Van de Graaff and the AGS. To minimize beam loss due to charge exchange [2] between the very heavy ions and the residual gas molecules, ultra-high vacuum of low 10^{-11} Torr is required. Various vacuum instrumentation is needed to produce, monitor and protect this ultra-high vacuum system. Due to the presence of high radiation levels in the Booster tunnel, all the power supplies and controls are located in the instrumentation building. The operation of these instruments over long cable length (up to 500 ft) and through computer interface are described in detail in this paper.

VACUUM SYSTEMS

The details of the Booster Vacuum System can be found in references 2 and 3. Major components relevant to the instrumentation are briefly described below.

Vacuum Chambers: The Booster ring has 48 half cells, isolatable with gate valves into seven vacuum sectors. A typical half cell chamber is about 4.2 m long and consists of chambers for dipole, quadrupole, PUEs, sextupole, bellows and the transition with ports connecting to gauges, valves and pumps.

Vacuum Pumps: The designed ring vacuum was achieved by a combination of titanium sublimation pumps and ion pumps. Fifty five titanium cartridges with three filaments each are mounted in the UHV bodies to pump active gases. The non-getterable gases such as methane and argon are removed by diode ion pumps. Ion pumps and non-evaporable getter pumps are used to pump the beam transport lines. Portable turbo-pump stations were used during pump down, bakeout and conditioning of the ring and lines.

Vacuum Gauges: Pirani gauges and Bayard-Alpert type nude ionization gauges are used in the Booster for measuring total pressures. Quadrupole type residual gas analyzers (RGA) are used in ring sectors for monitoring the partial pressures.

Bakeout: The vacuum chambers and the components within are designed to be insitu bakeable to 300°C. Custom heating blankets and E-type thermocouples (TCs) were installed around the chambers before assembling into magnets. The blankets were terminated to half-cell contactor boxes, which were then connected along with the TCs to the Programmable logical controller (PLC) carts before the bake. The PC based PLC initiates and maintains control over the programmed bake cycles, and alarms the operators when abnormal or failure conditions occur.

VACUUM INSTRUMENTATION and CONTROL

The vacuum instrumentation consists of the power supplies for ion pumps and titanium pumps, controllers for vacuum gauges and valves, and the computer systems. The instrumentation layout of a typical vacuum sector is depicted in Figure 1. The gauge controllers communicate with the device controllers (D/C) through RS232 links. The ion pump power supplies and valve controllers are linked to the D/Cs through IEEE-488 compatible Datacon interface cards. The D/Cs communicate with the Apollo system via a station drop.

Titanium Pump Power Supply: The titanium pump power supplies degas the titanium filaments during pumpdown and

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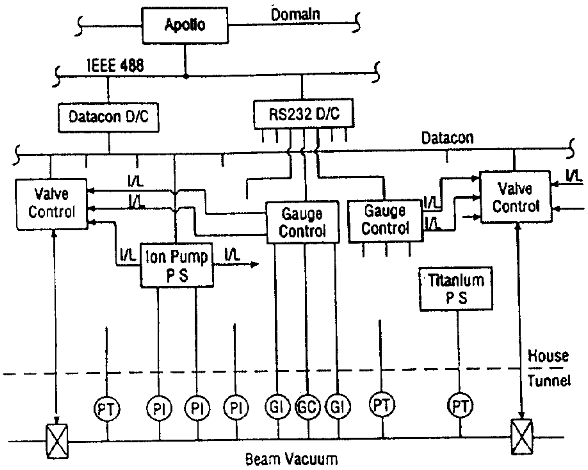

Figure 1
The Layout of Instrumentation of Typical Vacuum Sectors

bakeout, and sublime titanium to the UHV bodies when the needs arise. These supplies consist of SCR based controllers which power and regulate the sublimation rate through the constant current mode. The SCRs step up the filament current through transformers located near the cartridges. By calibrating the gain and offset pots of each SCR versus the transformer ratios, current stability of better than $\pm 2\%$ is achieved during sublimation at 48 A. The sublimation rate if approximately 1 mg/min. One gram of titanium per filament is available by using this constant current mode.

Ion Pump Power Supply: The power supplies, using ferroresonant transformers, develop potentials up to 5 KV and are current limited to 200 mA. Both voltage and current are measured for pressure monitoring and for diagnostics. Current down to 10 uA can be reliably measured through the linear and log amplifiers. The measured current and voltage are converted to frequencies and fed to Datacon interface cards for computer monitoring and display. Interlock and status signals, for controlling sector valves and other equipment, are opto-coupled for ground isolation.

Vacuum Monitoring: The vacuum is monitored by Pirani gauges, Bayard-Alpert type ion gauges, ion pump current and RGAs. The Pirani gauges cover from atmosphere to 1 x 10^{-4} Torr. The ion pump current can be used reliably for pressure measurement down to 10^{-9} Torr. the ion gauges, having a thin collector of 0.05 mm diameter and an X-ray limit of 5 x 10^{-12} Torr [4], can measure vacuum from 10^{-3} Torr to high 10^{-12} Torr.

Commercial vacuum process controllers (VPCs) are used to power, monitor and interlock the gauges, the ion pumps and the titanium pumps. The VPCs have process control channels which can be assigned either to ion gauges or Pirani gauges. The Pirani gauges interlock the turning-on of the ion gauges, the ion pumps and the titanium pumps in the same sectors. The ion gauges are mainly used to interlock sector valves and other equipment.

To overcome losses over long cable runs (up to 500'), large gauge wires and modified transformers in the VPCs with 40% higher output voltage are used to heat the filaments, especially during electron bombardment (EB) degassing. Figure 2 gives the measured filament heating power during EB degassing for two cable length and two types of filaments. The standard transformers can only degass thoria-coated iridium filaments over long cable length. The modified transformers allow degassing of tungsten filament up to 35 watts over 500 feet #12 AWG cables.

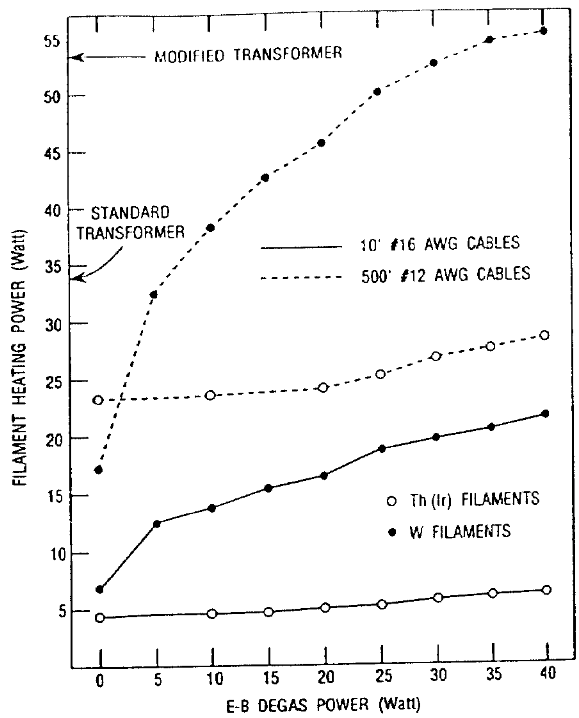

Figure 2
Filament Heating Power Versus the Electron Bombardment Degassing Power Over Different Cable Length for Two Types of Ion Gauge Filaments

At low 10^{-11} Torr vacuum, the collector current is only a few picoampere and is susceptible to noise pick-up such as the electrical-magnet interference (EMI) of power supplies and the radio-frequency interference (RFI) of accelerating cavities. The collector coaxial cable is a potential source of noise especially over long length, resulting in erratic pressure readings. Tests of noise pick-ups over long cable runs in the AGS ring during machine operation have been carried out in the last few years. The results are summarized in Table 1. Regular RG-59 coax, with effective shielding around 90%, has microphonics of over 100% at mid 10^{-11} Torr. To minimize

EMI/RFI, Beldon 9311 cable is used. This cable has microphonics of approximately 30% at mid 10^{-11} Torr and is acceptable for Booster vacuum operation. This coax features 100% shield coverage, a foil/braid outer shield, a polyethylene dielectric of 26 pf/ft, and good DC performance. The grid and filament wires (4 each., 12 AWG) are also placed in a single twisted shielded, low smoke and radiation retardant jacket.

Table 1 Noise Pick-Up of Long Coaxial Cables

Cable Type	Vacuum/Environment*	Microphonics
RG 59 A/U, 1000'	5×10^{-11} in Lab	+ 20% - 20%
RG 59 A/U, 650'	5×10^{-11} in AGS w/ RF	+200% -100%
RG 59 A/U, 650'	5×10^{-11} in AGS w/o RF	+ 25% - 25%
RG 59 A/U, 650'Triaxial	3×10^{-11} in AGS w/ RF	+ 30% - 30%
Beldon 9223,500'	4×10^{-11} in AGS w/ RF	+100% - 50%
Beldon 9311,500'	2×10^{-11} in AGS w/ RF	+ 50% - 50%
Beldon 9311,500'	2×10^{-11} in AGS w/o RF	+ 30% - 30%
Beldon 9311,500'	5×10^{-11} in AGS w/ RF	+ 30% - 20%

*Vacuum in Torr; "w/RF" = magnets and cavities ramping; "in AGS" = cabling from power supply house to UHV chamber in AGS tunnel.

One RGA head is installed at each ring vacuum sector and will be powered with portable RF box and controller to measure the residual gas composition and for trouble shooting. The RGAs have proven to be very powerful tools during the commissioning of vacuum sectors. It identified the presence of leaks or contaminants immediately even at vacuums as low as 10^{-11} Torr level.

Valve Control and Interlock: The beam vacuum is protected by sector valves. A fault detected by any two ion pumps or ion gauges in the same sector will cause the valves at both ends of the sector to close, thus minimizing the loss of vacuum in adjacent sectors. This voting scheme minimizes false triggering due to noise or malfunctioning of individual devices. A fast closing valve with a closing time of less than 15 msec is also used between the Linac and the Booster to protect the Booster ultra-high vacuum ring from catastrophic failure. To prevent beam damage to the valves, the valve closing signals will trigger the fast beam interrupt system located at the ion source within 350 μsec. Auxiliary interlock I/Os in the valve controllers also allow for interlocking other valves or equipment.

The entire vacuum instrumentation system, except for equipment in the Booster-to-AGS line, is in operation. A few false closings of the valves occurred during beam commissioning and were found to be caused by ion gauge shut downs. This problem is under investigation.

REFERENCES

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