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Argon and Argon-Oxygen Glow Discharge Cleaning of the Main Ring Beam Pipe

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Technical Memo

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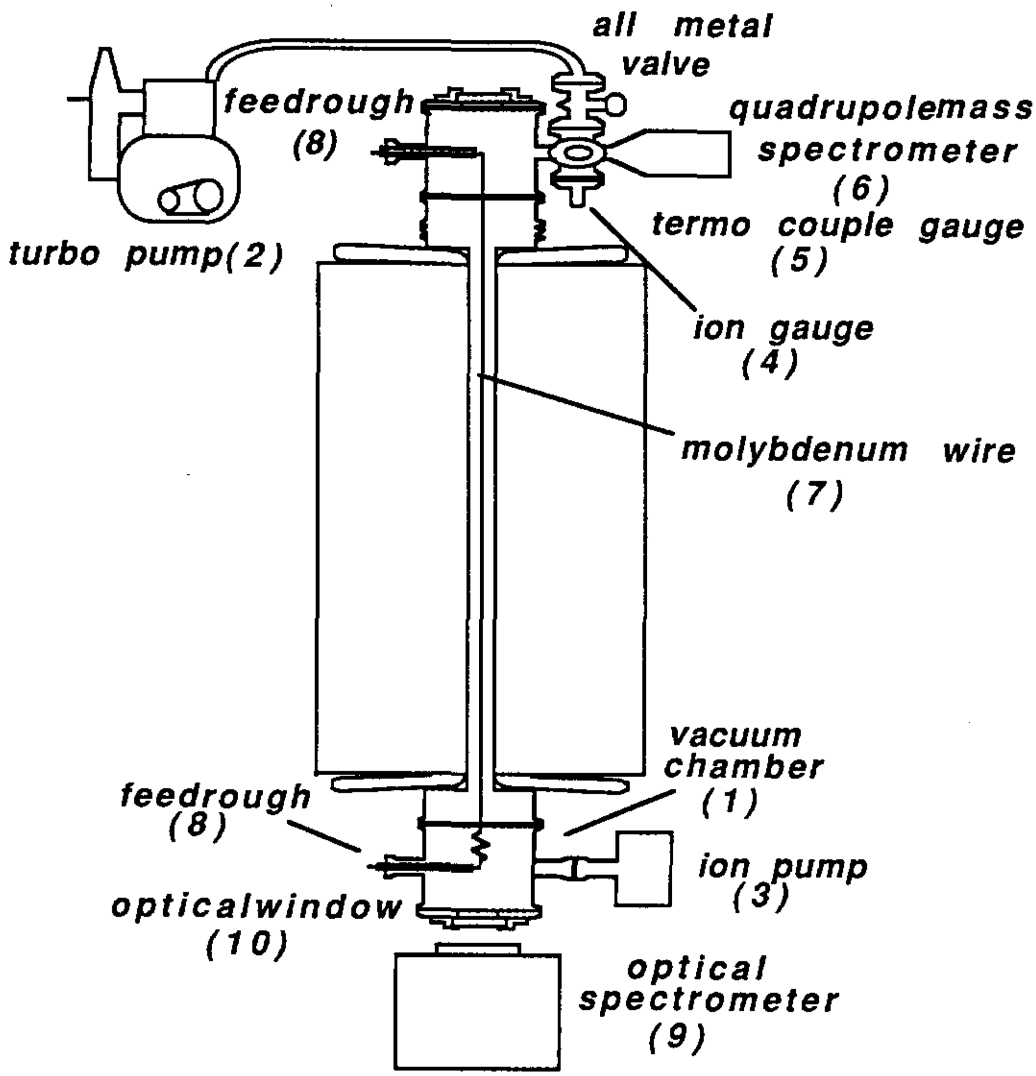
ARGON AND ARGON-OXYGEN GLOW DISCHARGE CLEANING OF THE MAIN RING BEAM PIPE

This report presents the experimental results from the argon and argon-oxygen gas mixture glow discharge in the Main Ring beam pipe and is a follow-up to the proposal for vacuum improvements of the Main Ring magnets and straight sections and the warm Tevatron straight sections(1). Glow discharge was used in the experiment in order to clean the vacuum system instead of bakeout which could only be performed with great difficulty or not at all. It is a relatively simple and very effective method.

The glow discharge occurs under specific gas pressures (10-120 mTorr) and current flows (10^{-5} - 10^{-1} A) through gas excitation and formation of plasma conditions. Deexcitation of the gas molecules produces visible light. Several mechanisms have been proposed to explain the glow discharge cleaning process. Ions can sputter adsorbed molecules or atoms at the cathode surface and even produce lattice damage extending several monolayers below the surface(8). The glow discharge has already been extensively used for vacuum improvements in accelerators (2-7).

Experimental Procedure:

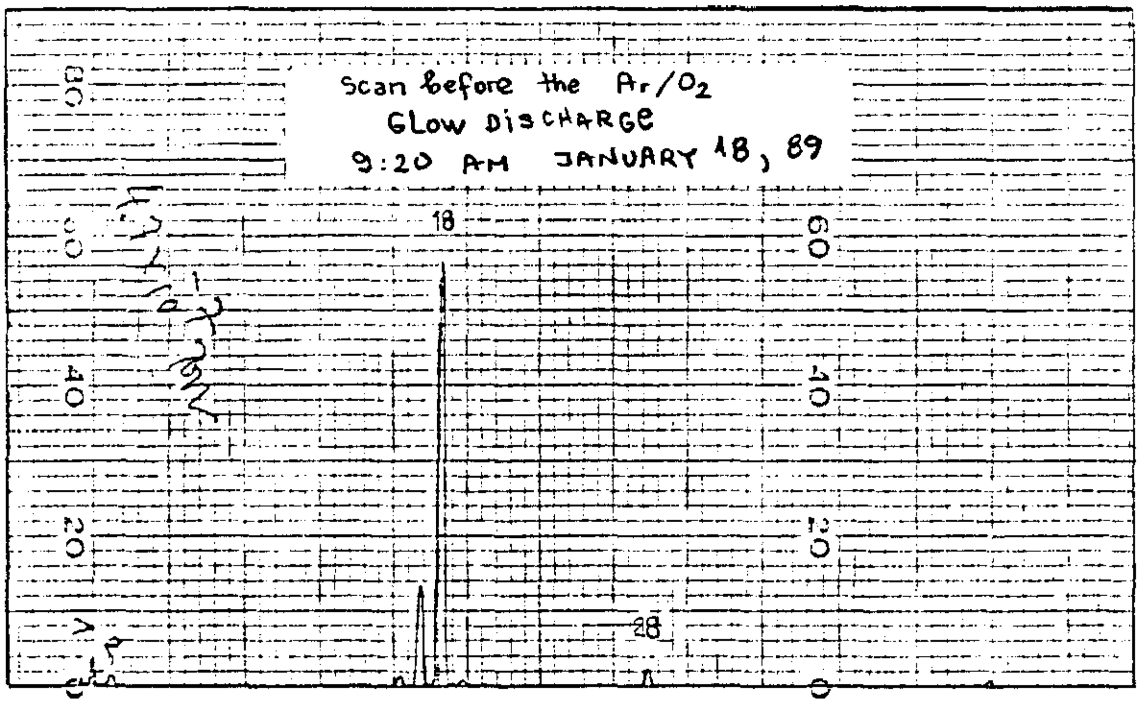
The experimental setup simulated the vacuum conditions in the Main Ring magnets. The vacuum pipe and the ion pump used were part of the regular Main Ring vacuum system. The setup is presented in figure 1. The experimental setup consisted of a Main Ring beam pipe with a standard cross section (2 x 4 inches 6.05 meters long) and two vacuum chambers at both ends (1), turbo-molecular pump (2) connected to the chamber with an all-metal valve, a rebuilt ion pump (3) regularly used in the Main Ring, two Bayart-Alpert ion gauges (4) for pressure measurements in the ultrahigh vacuum regime and two termocouple gauges (5) for the glow discharge pressure measurements, a quadrupole mass spectrometer (6) for analysis of the vacuum gas pressure content before and after the glow discharge, a molybdenum wire (7) with two ultrahigh vacuum feedthroughs (8), an optical spectrometer (9) for the analysis of visible light emission during the glow discharge, three ultrahigh vacuum quartz glass windows (10), two power supplies (500V, 2A), gas supplies with flowmeters connected to the variable leak valve, etc. The vacuum system was not baked before and during the experiment in order to simulate real conditions in the Main Ring. All parts were first wiped with freon and later with ethanol. The system was first pumped down for ten days with an ion pump until the pressure levelled to a value of 1.6×10^{-7} Torr.



- Figure 1 -

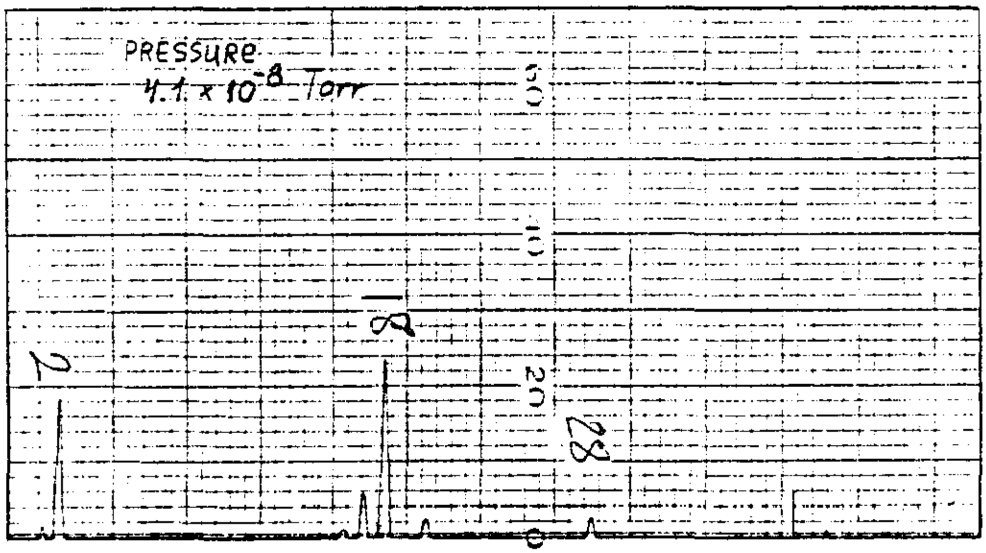
The residual gas spectrum, measured by a quadrupole mass spectrometer (Varian AGA-100, model 981-9800) before the glow discharges, showed a constantly appreciable amount of water vapor, followed by a peak of carbon-monoxide or nitrogen (the same 28 mass), hydrogen (H_2), methane (CH_4), hydroxide (OH), etc. Other gases were present in much lower quantities.

The following parameters were examined during the glow discharge experiments which were started in the middle of October 1988 and were successfully completed at the end of January 1989: the values of the pressure during the glow, the pumping speed of the turbo system, two different positions of the input output valves, gas composition (pure argon glow discharge, argon-oxygen mixture, helium-nitrogen-oxygen etc.), D.C. and A.C. voltage supplies, and different current-voltage conditions. Before the glow discharges the system was usually left open in very humid conditions and then pumped down with a turbomolecular pump. Figure 2 represents the residual gas spectrum during the turbo pumpdown before the most successful glow discharge when the pressure measured 4.7 x 10^{-7} Torr. The water vapor pressure was the dominating peak.



- Figure 2 -

Figure 3 shows the residual gas spectrum when pumping was continued with the ion pump. The water vapor peak was again the dominating peak.

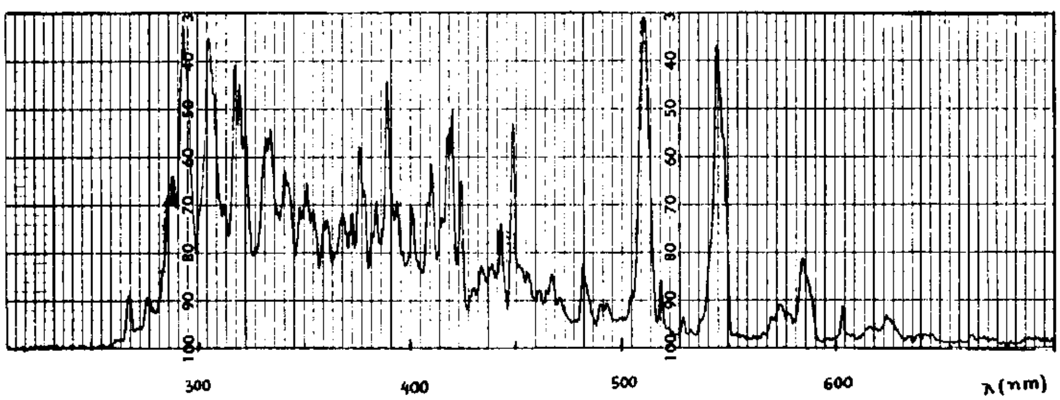


- Figure 3 -

The quadrupole mass spectrometer was also used to set up the correct gas composition for the glow discharge. The argon-oxygen gas mixture was introduced into the system through the variable leak valve raising the pressure up to 5 x 10^{-6} Torr. The argon and oxygen peaks were the dominating peaks in the residual gas spectrum in this case. After the pressure was stabilized in the system by a correct combination of the pumping speed and variable leak valve opening, voltage was applied to the wire. The glow discharge was generally immediately initiated. During the most successful A.C. glow discharge the pressure was set up to 16-17 mTorr while the voltage between the wire and the wall chamber was 297 Volts with a current reaching 1.8 A. During the glow the temperature of the pipe as well as of all parts of the system was estimated to be at least 70-80°C. This glow was maintained for three hours.

Figure 4 presents the optical spectrum measured during one of the argon-oxygen glow discharges. The optical spectra were measured by a Mac Pherson monochromator with a resolution of about 2 Angstroms. The most pronounced peaks in the optical spectrum were:

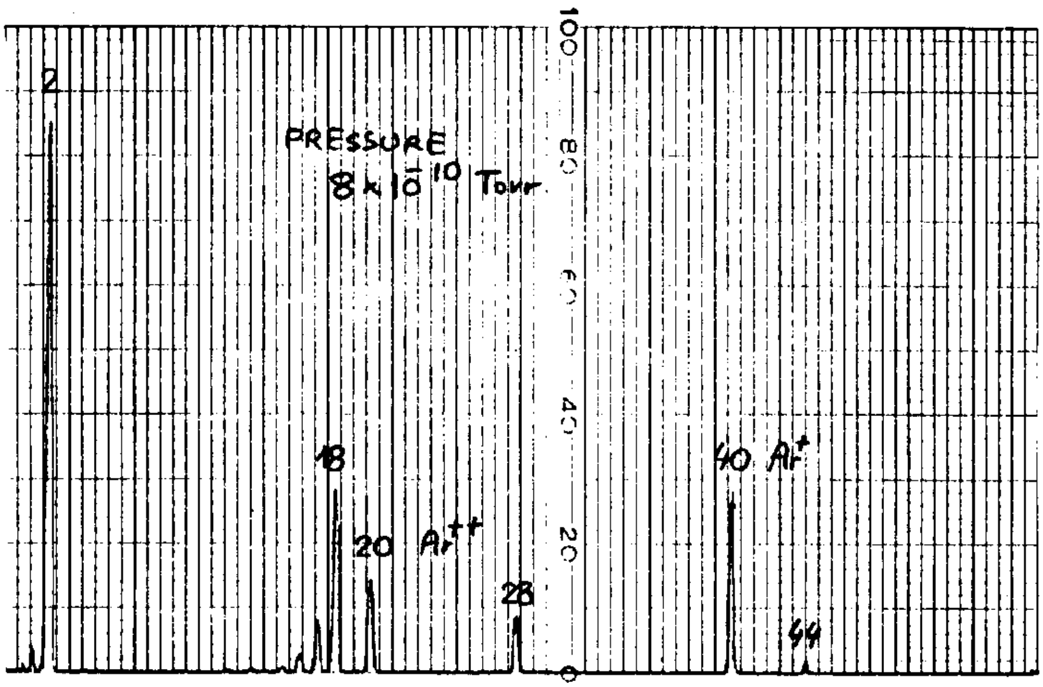
- iron line FeI (4271 A, 4064 A, 4308 A, 4383.5 A, and 3569 A),
- carbon line CII (4267.3 A),
- chromium CrI (5204 A and 4254 A),
- nickel NiI (3461 A),
- molybdenum MoI (3798 A and 3964 A),
- nitrogen NII (4109 A),
- hydrogen HI (4861 A) and molecular hydrogen H_2 with lines (4205 A, 4177 A, and 4069 A).



- Figure 4 -

It should be mentioned that the sensitivity of the photomultiplier connected at the output slit of the monochrometer had a very limited wavelength range within the visible part of the spectrum. This was the major reason why the intensity of the argon lines was very weak. The strong optical signals from the excited iron ions and atoms showed that the 300 eV argon ions performed an intense sputtering from the stainless steel walls.

The lowest pressure reading was 8 x 10^{-10} Torr and it was a result of the glow disharge where the temperature of the system during the glow reached the highest value. The sputtering, diffusion, and disorption processes of gas molecules from the walls were greatly affected by the temperature of the walls. The residual gas spectrum measured after the glow discharge is shown in fig. 5. The composition of the spectrum demonstrates the effectiveness of the method. The water peak was drastically lowered as may be seen by comparison of the spectra before and after the glow.



- Figure 5 -

Conclusion:

We demonstrated that a pressure of the order of 10^{-10} Torr could be obtained in the vacuum system without bakeout. An intense argon-oxygen glow discharge cleans the vacuum system very effectively especially if the temperature of the walls is increased during the glow. We presented here the conditions when the glow is most effective. The application of this kind of glow discharge in the accelerator tunnel might pose some difficulties because the wire would have to be pulled through the vacuum system during the glow and after the glow removed from the accelerator. To apply this method in the tunnel (for example in the Tevatron straights and in the Main ring magnets and straights) an additional vacuum chamber would be required in which the wire would be placed after the glow.

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