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Collider Accelerator Department

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RHIC PROJECT

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ENHANCED IGNITION OF COLD CATHODE GAUGES THROUGH THE USE OF RADIOACTIVE ISOTOPES[†]

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ABSTRACT

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) comprises vacuum systems that range in pressure from 10^{-4} to 10^{-11} Torr. For cost savings associated with commonality, it was desirable to use one UHV-compatible high vacuum gauge throughout the accelerator. Work was done with radioactive isotopes to enhance ignition of inverted magnetron gauges (IMGs) at very low pressures (i.e., $<10^{-10}$ Torr). Tests were initially conducted using cobalt-coated copper washers with a nickel flash to prevent oxidation. Solid nickel washers were also activated and tested. Problems with these sources will be discussed. Finally, an americium source was tested. These UHV compatible sources regularly yielded ignition times of 10 minutes at 4×10^{-11} Torr. The addition of the americium source produced a gauge suitable for operation at UHV pressures, and as a consequence all of the RHIC.

[†] Work performed under the auspices of the United States Department of Energy

I. INTRODUCTION

The construction of the Relativistic Heavy Ion Collider (RHIC) is well under way at Brookhaven National Laboratory (BNL). The RHIC vacuum system requires in excess of 500 High Vacuum (HV) and Ultra-High Vacuum (UHV) gauges. Initial plans called for the use of both cold cathode and hot cathode gauges: the bakeable hot cathode gauges for use on the UHV beam pipe vacuum systems, and unbaked cold cathode gauges for use on the high vacuum superconducting magnet insulating cryostat. It was decided early on that the use of the same bakeable thermocouple gauges on both baked and unbaked systems would realize savings stemming from buying only one type of thermocouple gauge. There would be similar fiscal and logistical advantages if one used the same cold cathode gauge to serve in both HV and UHV applications.

When the possibility of using cold cathode gauges throughout the RHIC became plausible (gauges were commercially available that could read pressures to 1×10^{-11} Torr), efforts were concentrated on how to quickly reestablish the negative space-charge cloud in the gauge at very low pressures. However, the problem with cold cathode gauges is that at very low pressures, if power to the gauge is interrupted, the gauge may take several hours to start. This is because, short of field emission, the discharge can only be reignited by an energetic (i.e., cosmic) particle dislodging a surface electron, which is then launched into the gauge volume to start a Townsend Avalanche. The usefulness of radioactive isotopes within the gauge volume to trigger the gauge discharge was reported by Hayashi[1].

II. THE APPARATUS

A schematic representation of the bakeable stainless steel UHV test dome is shown in Figure 1. The dome stand is made so that fiberglass insulated panels can be put in place for bakeouts. The cold cathode gauges used in the experiment are inverted magnetron type gauges, with separate feed-throughs for the anode high voltage and the cathode current. The gauges were purchased from the HPS Division of MKS Instruments.

An IBM-compatible 486 personal computer (PC) was used to acquire the test data. The gauges were controlled by an HPS Series 937 Cold Cathode gauge controller through a serial port of the PC. The gauge ion current was sampled using a Keithley model 486 picoammeter. The PC communicated with the picoammeter through a GPIB interface. LabVIEW® graphical programming software was run on the PC to coordinate the experiment and log data.

III. THE EXPERIMENT

For each test configuration the dome was roughed with a cryo-sorption pump and then baked to 250 C for ~24 hrs into a turbo pump. The TSP filament was powered momentarily to remove surface gases, and the Bayard-Alpert gauge and ion pump were turned on prior to valving out the turbo station. When the system cooled to ambient, the TSP was flashed at ~50 amps for 30 minutes. The Bayard-Alpert gauge was turned off for at least an hour before start time testing began. Only one gauge was tested at a time, and all with the same controller, power supply, and cable.

The goal of the experiment was to accurately record the time needed for a gauge to establish a discharge. The ion current was first recorded, then the high voltage was turned off for a period of one hour. After one hour, high voltage was again applied to the gauge, and the time necessary for the ion current to return to its previous level was recorded. This procedure was automated so testing could be done around the clock to establish a good statistical base.

Using LabVIEW® software, a program was written to communicate with both the picoammeter and the gauge controller. The program would first turn the gauge off and then reapply the high voltage. Then, the ion current was sampled and compared with the expected "on" ion current once every ten seconds. Once the ion current reached that threshold for at least two samples, the current readings were logged to a data file for 20 minutes. It usually took about five minutes for the ion current to build up to the threshold at 4×10^{-11} Torr, and about one minute at 10^{-9} Torr. Each gauge high voltage on/off event was logged to a data file. Ten start times were collected for each gauge in each test configuration.

IV. EXPERIMENT CONFIGURATIONS -- PRESSURES & ISOTOPES

Several source and pressure configurations were tested. A summary of the tests is shown in Table 1. Two test pressures in the approximate range of gauge operation were selected: 1×10^{-9} Torr and 4×10^{-11} Torr. Three radioactive isotope materials were tested: cobalt, nickel, and americium. The isotope ^{60}Co was initially chosen for the experiment. It has a half life of 5.27 years, with a maximum beta particle energy of ~318 keV and gamma ray energies of 1.17 MeV and 1.33 MeV. The second isotope produced was ^{63}Ni, which has a maximum beta particle energy of ~63 keV and an 80 year half-life. The third isotope chosen was ^{241}Am, which has alpha particle energies near 5.4 MeV and a half-life of 470 years.

The first activated samples were copper washers coated with cobalt. The electrolytic copper washers replaced the original aluminum washer from the gauge, depicted in Fig. 2a. Cobalt was e-beam evaporated onto several copper washers in three thicknesses. The coated washers were baked for 2 hrs. at 250 C and then bombarded with primarily thermal neutrons in the BNL High Flux Beam Reactor. The activity of the washers, related to the thickness of the cobalt coating, was between 0.02 and 0.5 μCi. Tests on these washers would be performed to determine the lowest activation level that would reduce start times. However, the cobalt-coated washers proved troublesome as the cobalt mildly corroded, and the oxide dust presented contamination problems; i.e., the radioactive cobalt coating could be wiped off.

Depositing $\sim$1000 Å of nickel on the cobalt film solved this problem, but at added cost. The contribution of the nickel isotopes to the over-all washer activity was about two percent. These sources, referred to as Ni-Co-Cu sources, had an activity level of $\sim$0.1 micro curies (μCi). At the same time, some of the copper washers were coated with $\sim$1 micron of nickel, to determine if a thin nickel coating would work. If using the nickel-only coating on the copper washers worked, the need for coating the washers twice could be eliminated. These sources, with activity levels of $\sim 0.2\mu$Ci, are referred to as the Ni-Cu sources.

To eliminate the need for coating the copper washers altogether, washers made from solid nickel were obtained from HPS and activated. If these sources worked, there would be substantial savings over the coated copper washers. The solid nickel washers had an activity of $\sim$0.5 μCi.

We then sought to explore the effectiveness of alpha-emitters such as those used in the venerable Alphatron[2]. The use of americium was suggested by Mars Hablanian. The effectiveness of an ^{241}Am smoke detector source was tested. Three smoke detectors were purchased at a local hardware store for about $5 each, including batteries. The source comprises an americium rolled foil pressed into a stainless steel holder, commercially available for about a dollar. The americium source is a sealed source, sandwiched between layers of gold. Americium has a very low vapor pressure[3], and can therefore be baked in a UHV system without concerns of system contamination. The americium sources had an activity level of ~0.9 μCi. By happenstance, the source holder fit into one of the cathode perforations. The source holder was staked into place using only a spring-loaded center punch. The position of the source in the gauge is shown in Figure 2b.

V. EXPERIMENT TRIALS

In the first experiment trial, no radioactive sources were used, and the ion pump, shown in Fig. 1, was located at port W. With the ion pump at this location, the start times for the B gauge were misleadingly short, due to stray charges particles from the pump reaching the gauge. The ion pump was moved to the port shown in Fig. 1 for the remainder of the tests to avoid this problem.

All three gauges were outfitted with the solid nickel sources for the second trial. However, it was not possible to determine if the gauge discharge had been established at UHV pressures. The ion current fluctuated over a wide range, possibly due to the perturbation of the magnetic field by the magnetic washers.

For the third trial, gauges A and C had Ni-Cu washer sources, gauge B had a Ni-Co-Cu washer source (refer to Fig. 2a). Gauges with the Ni-Cu sources had average starting times lower than the same gauges without sources at both the 10^{-9} and 10^{-11} Torr pressures, but the starting times were inconsistent at the higher pressure, varying from less than a minute to over two hours.

The gauge with the Ni-Co-Cu source had starting times between 1 and 16 minutes.

The locations of gauges A and C on the experiment dome were switched for the fourth trial, i.e., gauge A was bolted in port Z, and gauge C was moved to port X. Also, the source from gauge B was removed. During dome preparation a leak was found in gauge C; this was later attributed to a crack on the ion current feed-through. Port X was blanked-off for this experiment run. Gauge A was moved to port Z to determine if the ion pump contributed to the start time of the gauge. The start times increased moderately (the average rose from 15 to 30 minutes) with the change in port location. The start times for gauge B increased from an average of 6 minutes with the Ni-Co-Cu source, to an average of 52 minutes without a source at a pressure of $\sim 1 \times 10^{-9}$ Torr.

In the last experiment configuration, americium sources were placed into gauges A and B, and a replacement gauge C was installed with no source (refer to Fig. 2b). At a pressure of $\sim 4 \times 10^{-11}$ Torr, the starting times of gauges A and B ranged between 8 and 12 minutes, and gauge C start times ranged between 14 minutes and nine hours. At the higher pressure, gauges A and B started in one minute, while the C gauge took from 2 to 42 minutes to start.

VI. DISCUSSION OF TEST RESULTS

The comparisons of gauge start times are summarized in Figures 3, 4, and 5, where start times are plotted for each gauge without sources and with different sources. Each sample grouping shows the minimum, average, and maximum start times for a single gauge with the noted source (e.g., the sample titled *A, Am* represents the cluster of ten start times for gauge A with an americium source). The gauge start times were recorded ten times. In all instances shown, the average start time of a given gauge without a radioactive source is significantly longer than the average start time of the same gauge with a source, regardless of pressure or source material.

Figure 3 shows the summary of gauge starting times for a dome pressure of $\sim 1\times10^{-9}$ Torr. Gauge ignition is improved on average with the addition of any source material. The gauges with the Am sources started in less than one minute every time. The start times for the gauges with start times less than 20 minutes is shown in Figure 4.

The summary of gauge start times for a dome pressure of $\sim 4\times10^{-11}$ Torr is shown in Figure 5. At this UHV pressure, gauges without sources took on average four hours to establish ignition; some sample times were as high as nine hours. Gauges with sources started in an average of ~ 10 minutes, regardless of source type. Figure 6 shows the start times for the activated gauges in a finer scale.

VII. CONCLUSIONS

The addition of the nickel-and-cobalt coated washers and the nickel-coated washers had a favorable effect on gauge start times on average. However, the procedures executed to have the washers coated are prohibitively costly. The regularity and brevity of the americium-enhanced start times, coupled with the low cost of the source will enable us to use one common UHV-compatible gauge in all of the accelerator vacuum systems.

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1. C. Hayashi, J. Vac. Sci. Technol. **3**, 286 (1966).

2. *Scientific Foundations of Vacuum Technique*, 2nd ed. edited by S. Dushman and J. M. Lafferty (Wiley, New York, 1962), pp 317-321.

3. *The Chemistry of Americium*, W. W. Schulz (ERDA Technical Information Center, Tennessee, 1976), p 125.

	Gauge A		Gauge B		Gauge C	
	Port	Source	Port	Source	Port	Source
Trial 1	X	---	Y	---	Z	---
Trial 2	X	Ni	Y	Ni	Z	Ni
Trial 3	X	Ni-Cu	Y	Ni-Co-Cu	Z	Ni-Cu
Trial 4	Z	Ni-Cu	Y	---	*	
Trial 5	Z	Am	Y	Am	X	---

--- No source installed.
* Gauge C was not installed for this trial; port X was blanked off.

Table 1. EXPERIMENT CONFIGURATIONS

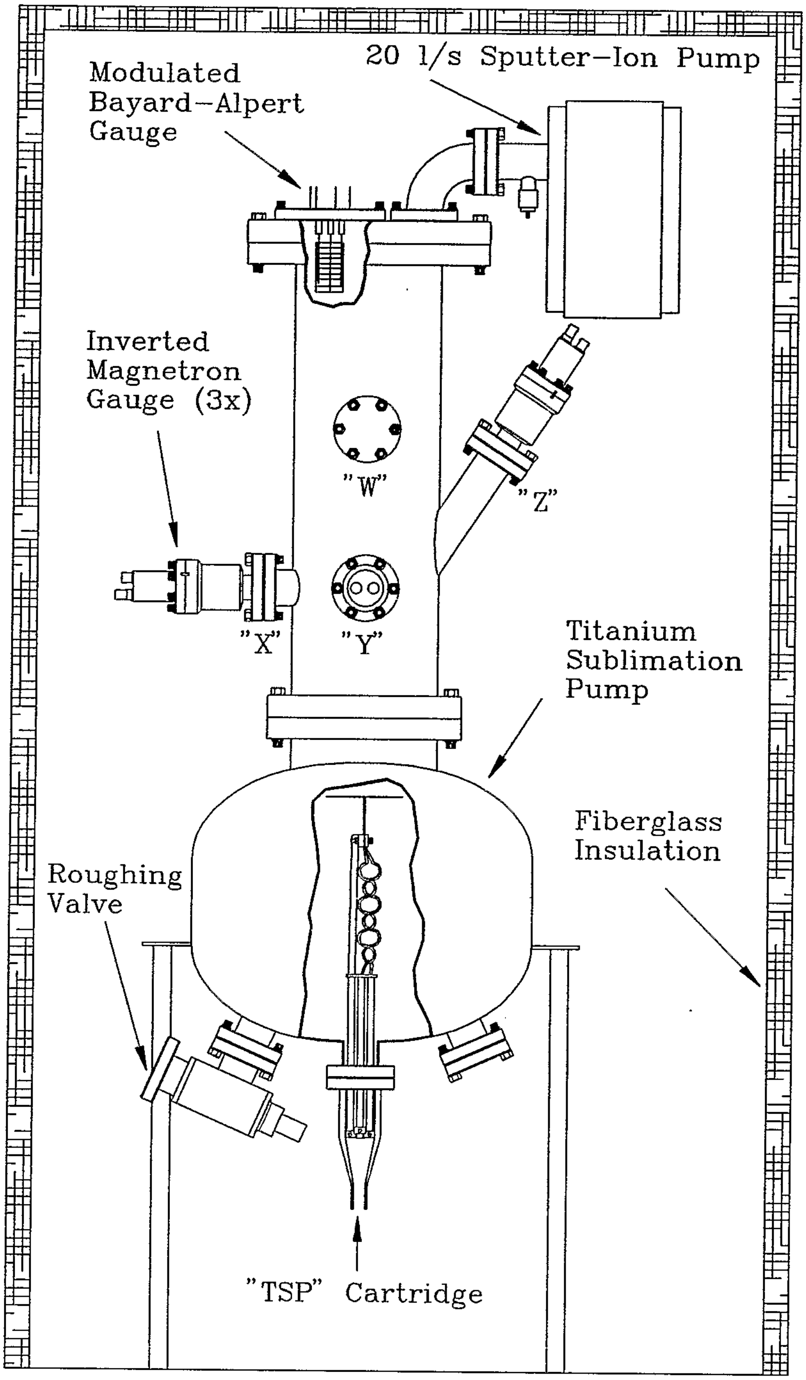

Figure 1. Ultra–High Vacuum Dome for Testing Inverted Magnetron Gauges

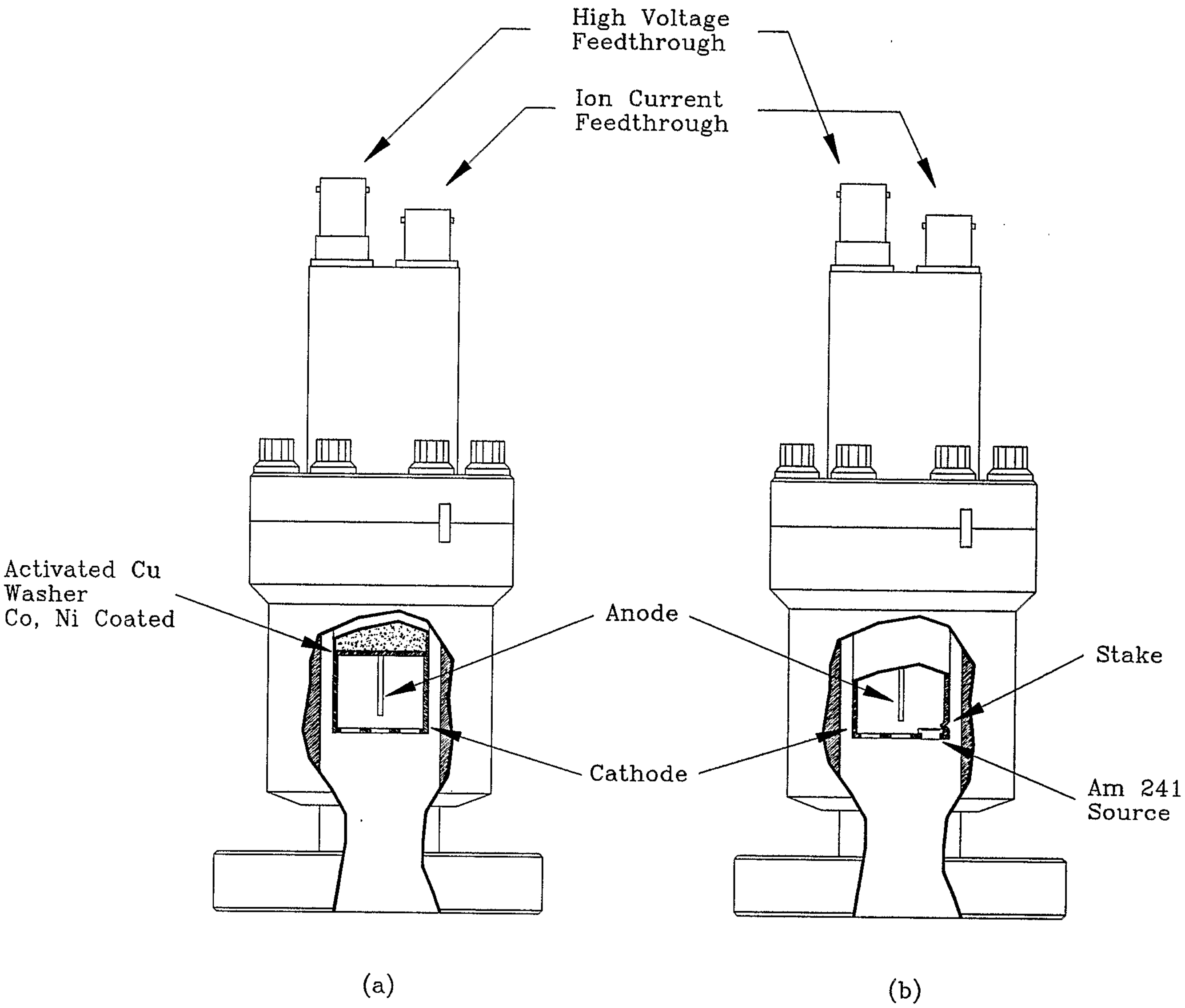

Figure 2. Location of Activated Sources Used in the Inverted Magnetron Gauge

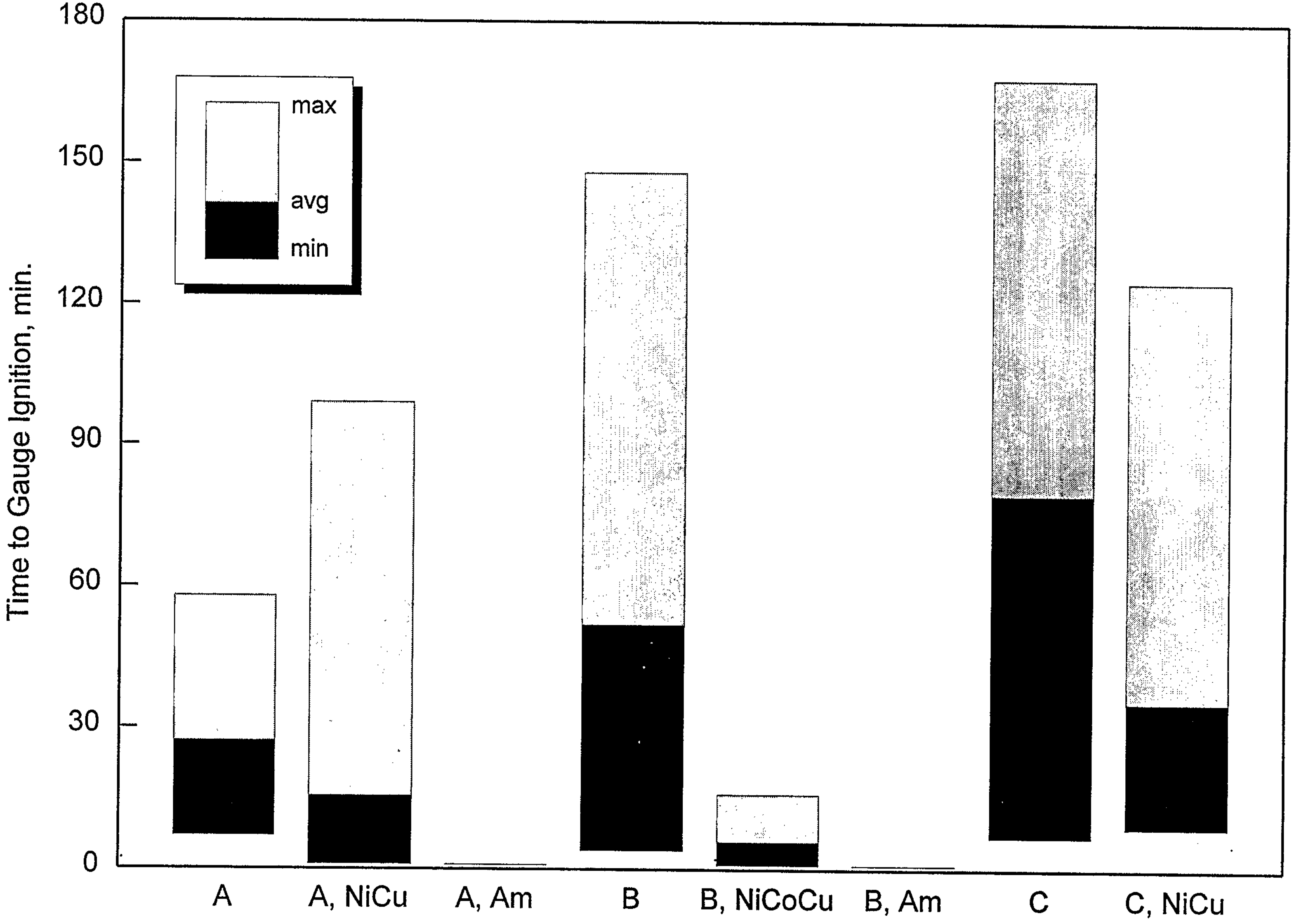

Figure 3. Gauge Start Time Summary for 1E-9 Torr Pressure

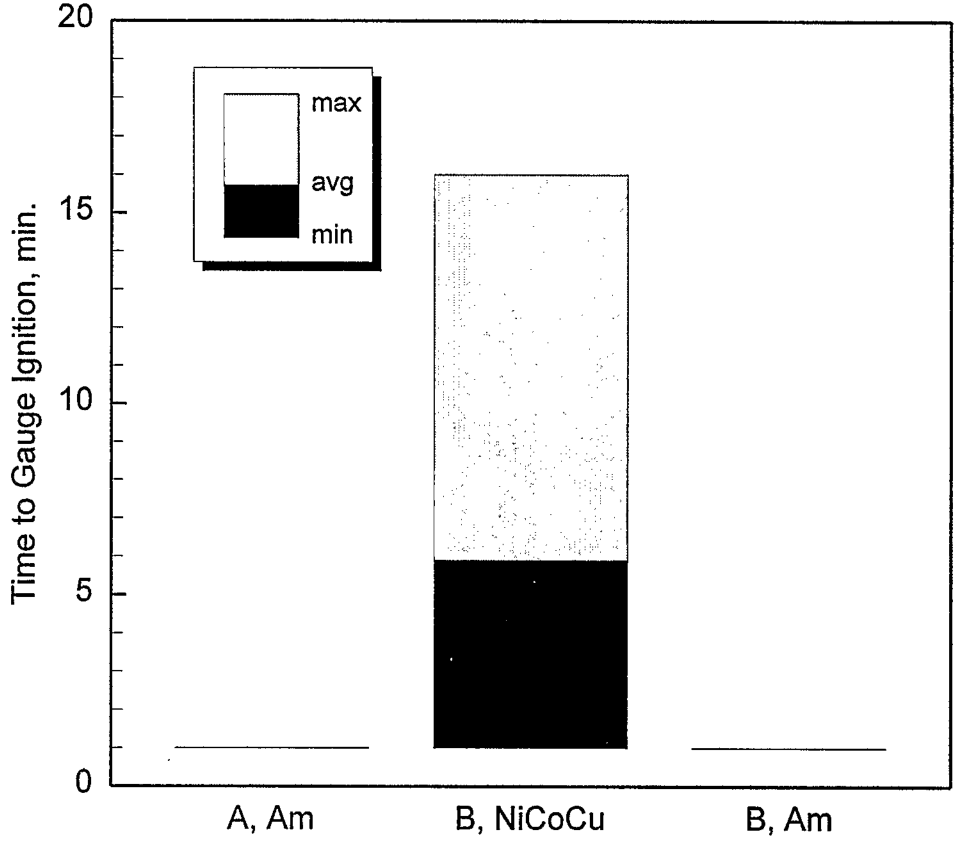

Figure 4. Gauge Start Time Summary for 1E-9 Torr Pressure

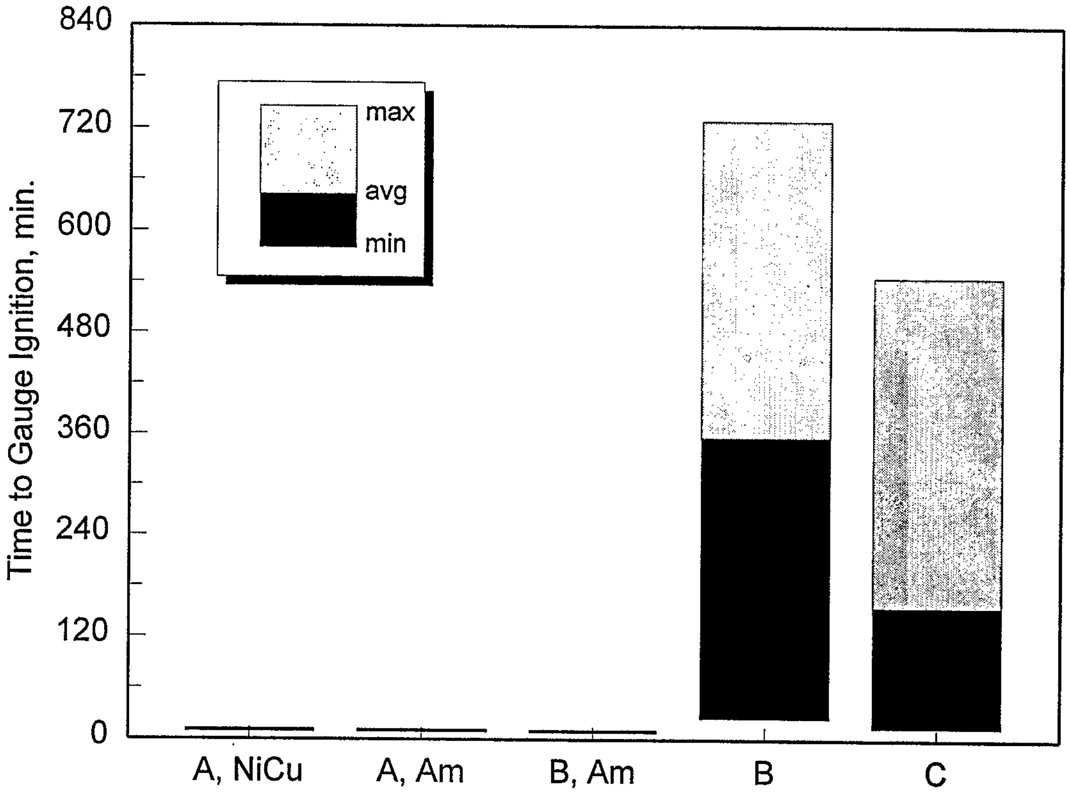

Figure 5. Gauge Start Time Summary for 4E-11 Torr Pressure

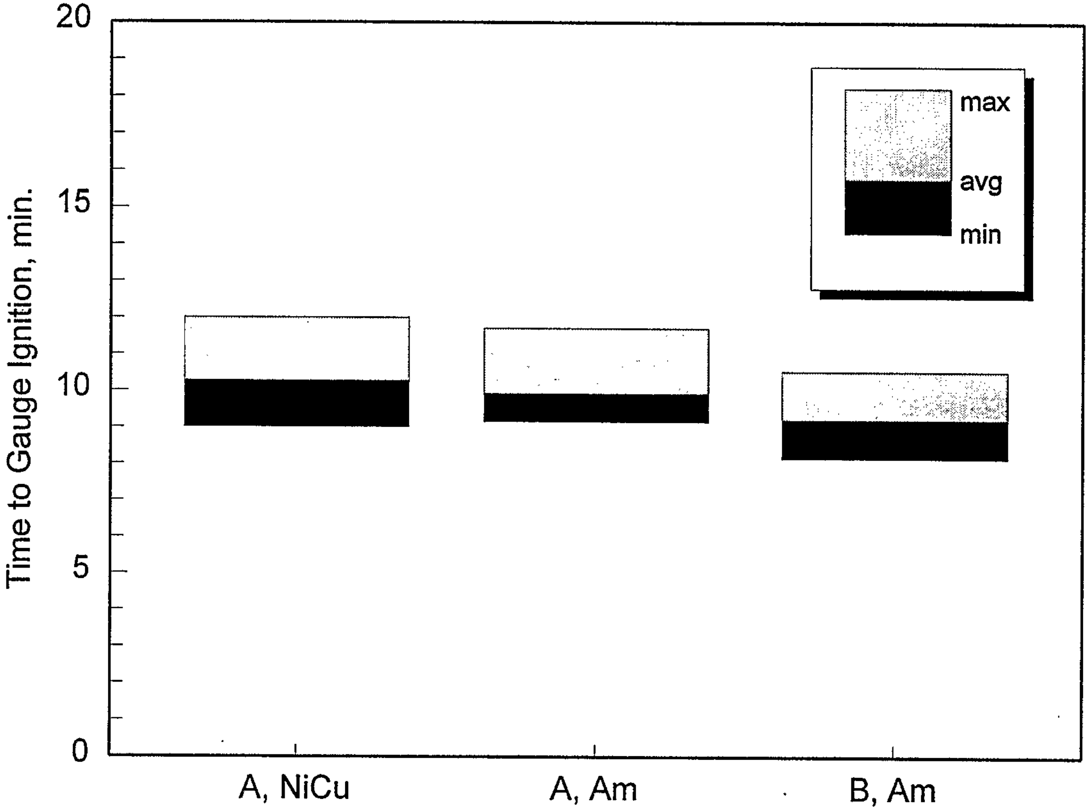

Figure 6. Gauge Start Times for 4E-11 Torr Pressure