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Calibration of Ionization Gauges Operated Without a Glass Envelope

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Abstract

Previously reported discrepancies between enveloped and nude Bayard-Alpert type gauges have not been observed for a vacuum system containing a well baffled oil diffusion pump. The collector current varies more with changes in collector potential for a nude gauge than for one operated with a metal screen replacing the glass envelope of the normal gauge. For some modes of operation of the screened gauge, noticeable departure of collector current from linearity with emission current change has been observed. Calibration of a nude gauge at usual emissions of 1-10 ma appears to be unsatisfactory unless a screen is present.

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I. Introduction

During the course of vacuum research as a part of the Reactor Chemistry Division's support program for the Thermonuclear Division in ORNL it has become evident that additional information concerning the behavior of nude, exposed, or non-enveloped ionization gauges is needed. Such information would be of interest to the vacuum program of the Thermonuclear effort in facilitating the measurement of the low pressures now being obtained and as an aid in understanding the behavior of an ionization gauge, either nude or enveloped especially while it is operating under conditions peculiar to the thermonuclear machines.

It is well known that a nude or exposed ionization gauge is superior to the enveloped gauge in its ability to give a faster response to small pressure or gas concentration changes. One of the greatest disadvantages of an enveloped gauge is the necessity for mounting the gauge outside the vacuum region connecting it by some type of tubulation, which in cases of multiple wall systems necessary in large high vacuum systems leads to long tubulations. This allows only poor conductance and requires extreme conditions of bake-out, or complicated designs for decreasing the out-gassing of the tubulation walls. Gas adsorbtion by such walls, however, will still prevent the ion gauge from monitoring all the gases present in the vacuum system.

Investigations made by others using exposed and enveloped gauges in the same system have reported unresolved dissimilarities. In a paper given by R. A. Metcalfe of Consolidated Vacuum Corporation titled "Performance of a Double-Walled Ultra-high Vacuum Chamber" at the 1961 American Vacuum Society Symposium in Washington, D. C. was reported the use of an

exposed ionization gauge in a double walled 20 ft^3 system in conjunction with an enveloped gauge on a long tubulation. Metcalfe reported higher pressure readings for the tubulated gauge until very rigorous bake out conditions had been met. Investigation of the dissimilarities of the exposed and unexposed gauge was initiated at ORNL by C. E. Normand, who reported in ORNL-3104, p. 133-135 and CF-61-5-109, the consistently lower and unreliable pressure readings of three different types of nude gauges as compared with two daily calibrated Veeco enveloped gauges. Normand found that for the pressure range around 10^{-7} - 10^{-4} Torr the nude gauge pressures were from 20% to two orders of magnitude lower than the enveloped gauges, although the calibrations of the enveloped gauges remained constant during this period.

Because of the uncertainty and lack of confidence by other observers of nude and enveloped gauge readings, a study of the behavior and reliability of these gauges was undertaken. In this report are given preliminary observations of a nude gauge compared with an enveloped gauge of the same type under different conditions of operation. Also mentioned are additional experiments currently underway which were suggested by the results of this study.

The reading obtained by using an ionization gauge is a function of much more than the geometrical arrangement of gauge tube elements, tubulation, etc. for a given electronic control network. The material used in the vacuum system, location and magnitude of leaks, and presence of electrical insulators near the gauge tube orifice may all be expected to affect ion gauge behavior.

II. Apparatus and Description of the Experiment

The gauges used in these experiments were the Bayard-Alpert type, the Veeco model RG 75, which in the case of the nude gauge was modified by removing the glass envelope and tubulation. The nude gauge was mounted inside the vacuum chamber. The vacuum chamber, a glass cross having a diameter of 4-inches and a height of 14-inches, was connected by two baffles in series, one cooled to 25°C and the other to - 50°C, to a PMC 720 diffusion pump. Flanges with neoprene O-rings were used throughout.

For comparison with the nude gauge a standard tubulated RG 75 was mounted on one of the flanged ports and an Edwards leak valve was incorporated for adjusting the pressure in the test chamber. A copper cylindrical shield enveloping the exposed gauge was used in some experiments to simulate conditions a gauge would encounter in a metal vacuum chamber. In order to simulate the glass envelope a cylindrical copper or stainless steel screen (approximately 20 mesh) surrounding the nude gauge was used on which the potential could be observed and biased. It should be noted that the glass envelope probably does not have an equal potential on all of its surface. This makes this simulation quite approximate.

The Bayard-Alpert ionization gauge is designed to operate with a filament potential 30-volts positive on the outside of a helical grid having a positive potential of 180-volts. Electron emission of 10 milliamperes and a grid potential of 150-volts positive with respect to the filament produces positive ions upon collision of electrons with gas molecules in the vicinity of the grid. These ions are collected on the collector wire located in the center of the grid. The collector wire is maintained at 30-volts negative with respect to filament. The gauge is enveloped in borosilicate glass having a 2-inch nonex or pyrex tubulation.

The variables studied were collector current and voltage, screen current and voltage, and emission current. The current measurements were made with a Keithley Model 410 micro-microammeter. Voltage biases were made using a Keithley regulated high voltage supply model 240 for potentials in excess of 90-volts, while lower voltages were obtained from a battery driven potentiometer circuit. Only the modified RG 75 type was used in the studies reported here.

III. Performance

In the first three graphs in which the collector current is plotted against the collector voltage are a number of curves showing the effect of the screen and shield on ion current to the ion collector at a pressure of 1.8×10^{-6} Torr using 10 Ma.emission. In Fig. 1 two assemblies are represented, one without screen or shield and another with the screen and shield at ground. A curve for an unmodified gauge as published by the manufacturer is shown for comparison. The curve for the nude gauge with screen and shield absent shows a falling off of the collector current as the negative collector voltage decreases, indicating a decrease of ion collection efficiency by the collector as it becomes more positive. When the screen and shield are grounded, as shown by the other curve, for negative collector voltages the ion collection efficiency remains relatively constant. For the case without screen the change in ion current to the collector probably relates to the efficiency of collecting ions streaming out the end of the grid cage. In Fig. 2 are curves showing the effect of a floating screen. Also shown for comparison are curves for the conventional gauge and the nude gauge with screen and shield assembly at ground. The curves for the floating copper and stainless steel screens are more

similar to that for the unmodified gauge than is the curve for the nude gauge with grounded screen and shield. This shows that the behavior of the screened nude gauge does simulate that of the enveloped gauge the wall of which is expected to float at some positive potential also. There is no substantial difference between the copper and steel screen. In Fig. 3 is shown a curve comparing an unmodified gauge mounted in the system with the manufacturer's published curve for the same type of gauge. The dissimilarity between the two curves may relate to different system conditions under which the gauges were operated. The curve for the experimental unmodified gauge is similar in slope and collector current values to the curve for the grounded screen and shield shown in Fig. 1. In these plots, while only values for positive current are shown, in all experiments observations were made for positive collector potentials to 90-volts. Electron capture at the collector was observed for potentials above +27 volts.

It is shown in Fig. 4 that the presence of a shield outside of the screen has little effect on the efficiency of ion collection at the collector. This indicates merely that the nude gauge with screen will operate in the same manner in a glass or metal system. However, as shown in Fig. 5, the presence of a floating screen suppresses the ion current. This may be due to some "self evacuation" of the gauge when the screen is at a positive voltage because of ion pumping. This effect is also shown in Fig. 6 in which are plotted collector current against emission current for two values of the screen potential. The two curves are typical for collector potential from zero to -90 volts. The amount of ion collection fall off at 10 Ma. emission for the pressure range investigated, from 1.8 s 10^{-6} to 2 x 10^{-5} Torr regardless of screen material is roughly 10%.

The slopes of the curves for the experiments with stainless steel are greater than those for copper and at full emission the collector currents are about 10% higher than for copper. This effect was also shown in Fig.2. For comparison are shown two curves in Fig. 7 representing the behavior of a nude gauge without a screen and an unmodified gauge. These two curves as well as the one showing the behavior of a grounded screen are linear. However, with a screen floating (at + 30 V) the collector current is depressed for emission currents from 3 to 10 Ma. depending on pressure, indicating possibly a depletion of ions in the collection region or of gas molecules in the region of the gauge itself which would affect the total electron density. When the screen is grounded no such loss occurs, as the ions neutralized on the screen are no longer lost from the gauge region due to ion ejection by the positive screen.

A number of measurements of the screen current for copper and stainless steel as a function of screen voltage at three pressures were made. In general, the efficiency of the screen as an ion collector increases very slightly as the negative potential decreases. This behavior is shown in Fig. 8.

Summary

The observations made in this preliminary investigation of the behavior of a nude Bayard-Alpert gauge compared with an enveloped gauge of the same type disclosed no factor that would account for a pressure reading difference of an order of magnitude between the two gauges for the test vacuum system used. However, it was found that in the pressure range about - 10^{-6} Torr -- the ion current was suppressed by about 10% at full emission when the nude gauge was enclosed in a stainless steel or copper

screen floating at a positive potential of about 30 volts due to the loss of ions from the gauge region. The degree of ion depletion from the gauge region with its consequent electron density decrease is greatest when the screen is absent at this pressure range. With a screen the ion loss is greater for positive screen voltage than for zero voltage.

These results show that emission currents of about 10 Ma. are too high for the gauges tested to allow a satisfactory correlation between nude and enveloped gauges. For any workable gauge calibration procedures involving nude gauges such correlations must be established. Preliminary work on calibration using lower emissions has been undertaken along with a continuing study of other vacuum system parameters which influence gauge behavior.

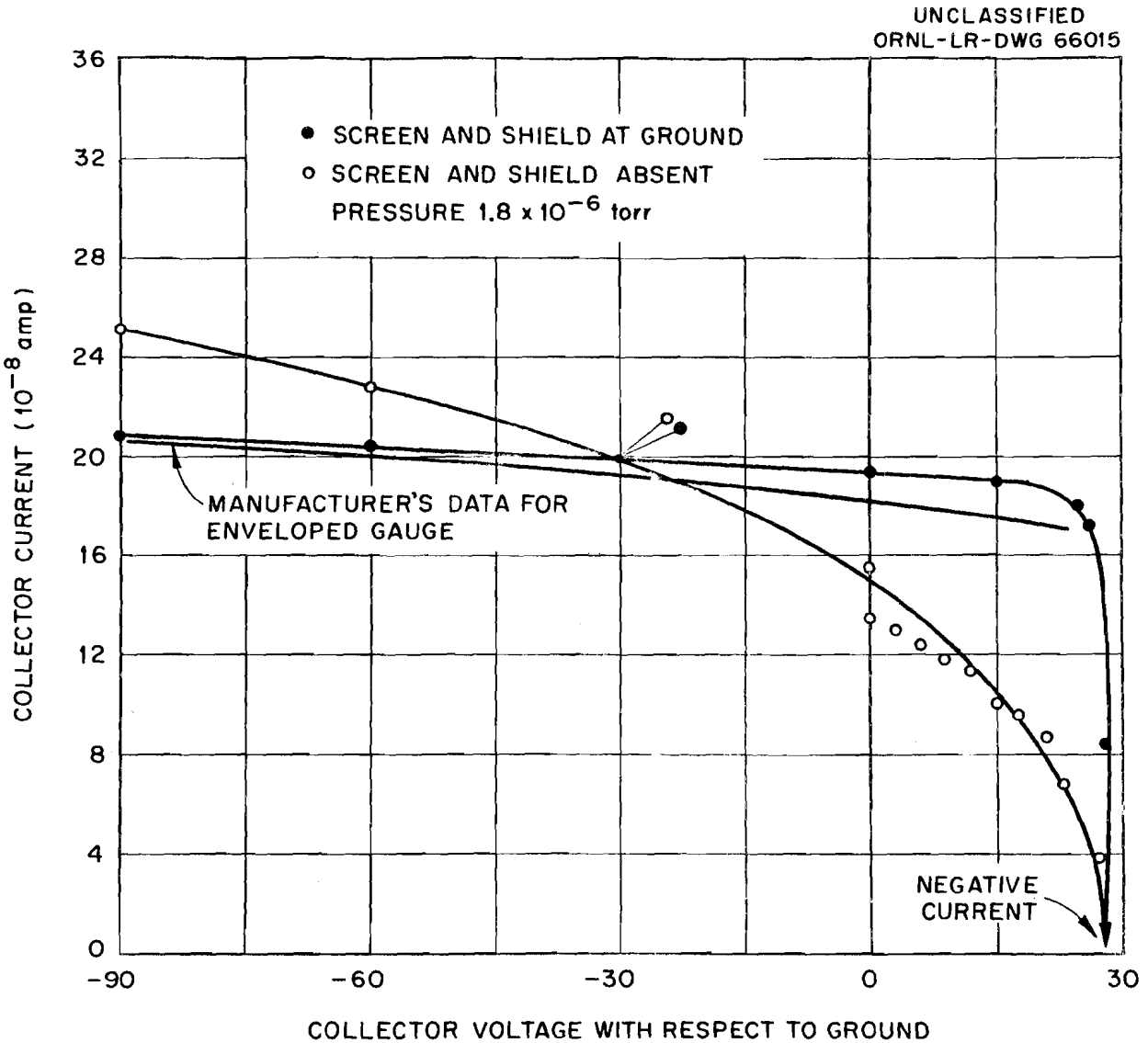

Fig. 1. Collector Current vs Collector Voltage; I- For Nude Gauge with Screen and Shield.

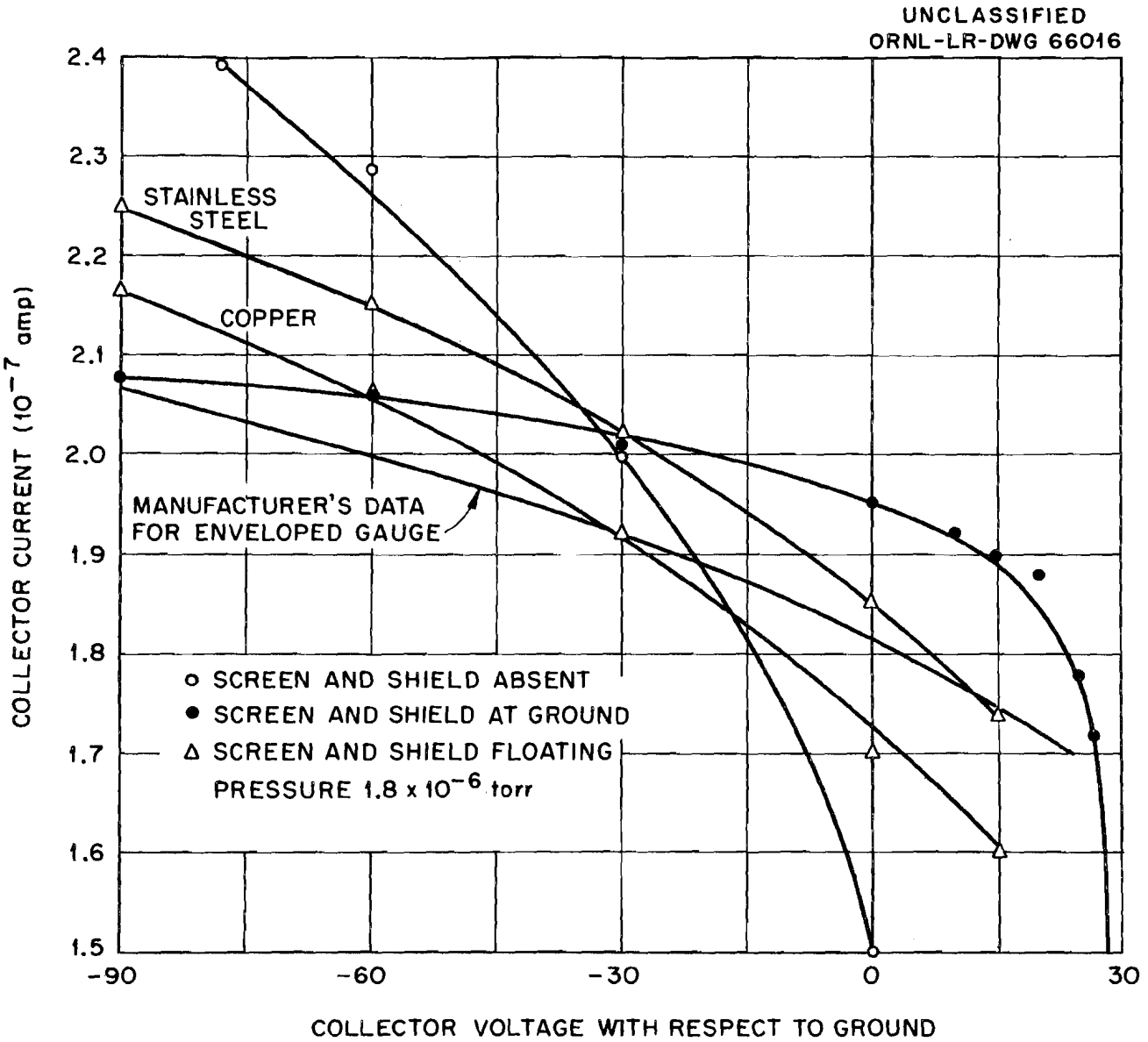

Fig. 2. Collector Current vs Collector Voltage; II-As Affected by the Screen Material.

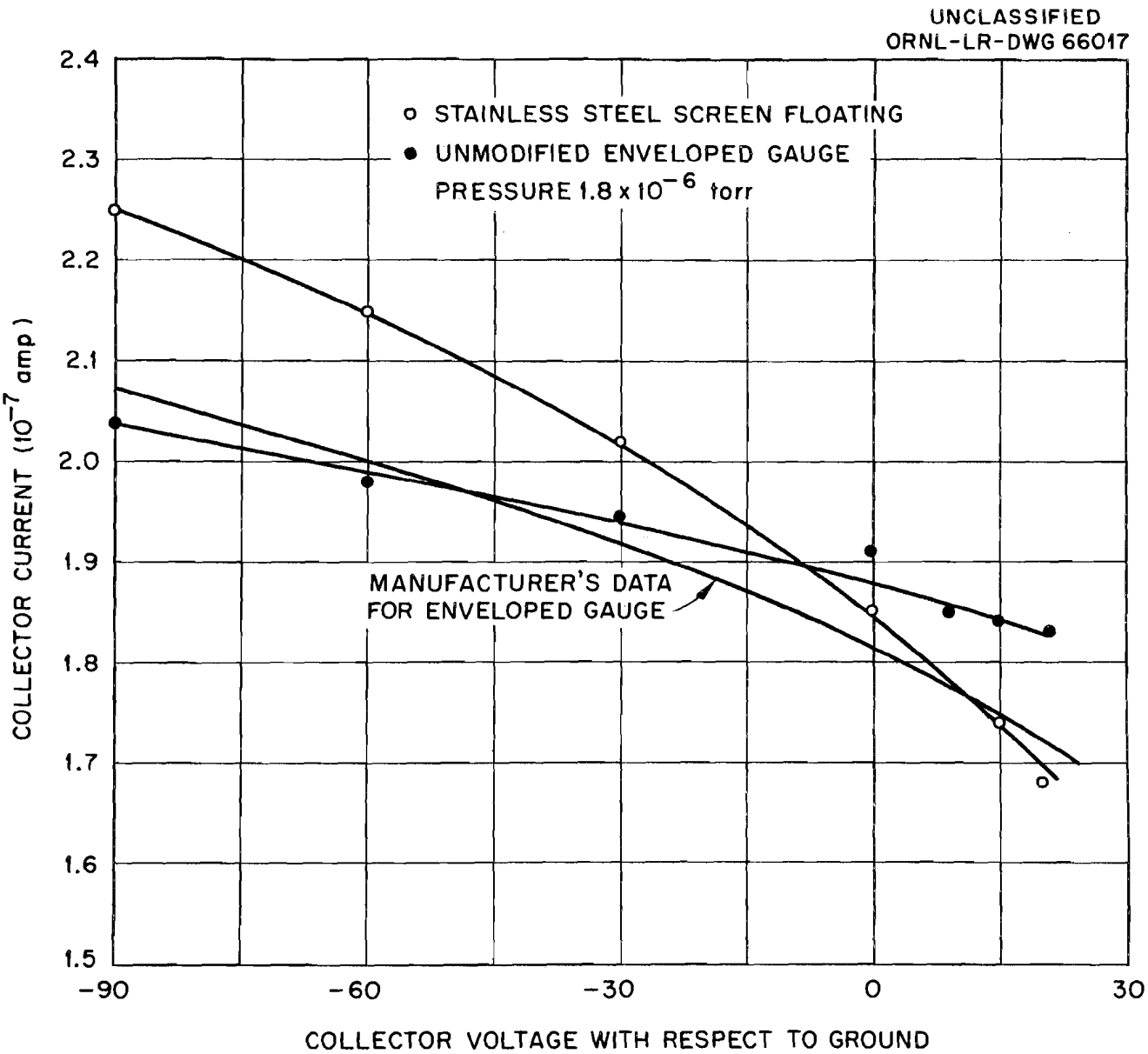

Fig. 3. Collector Current vs Collector Voltage; III-For Unmodified Gauge

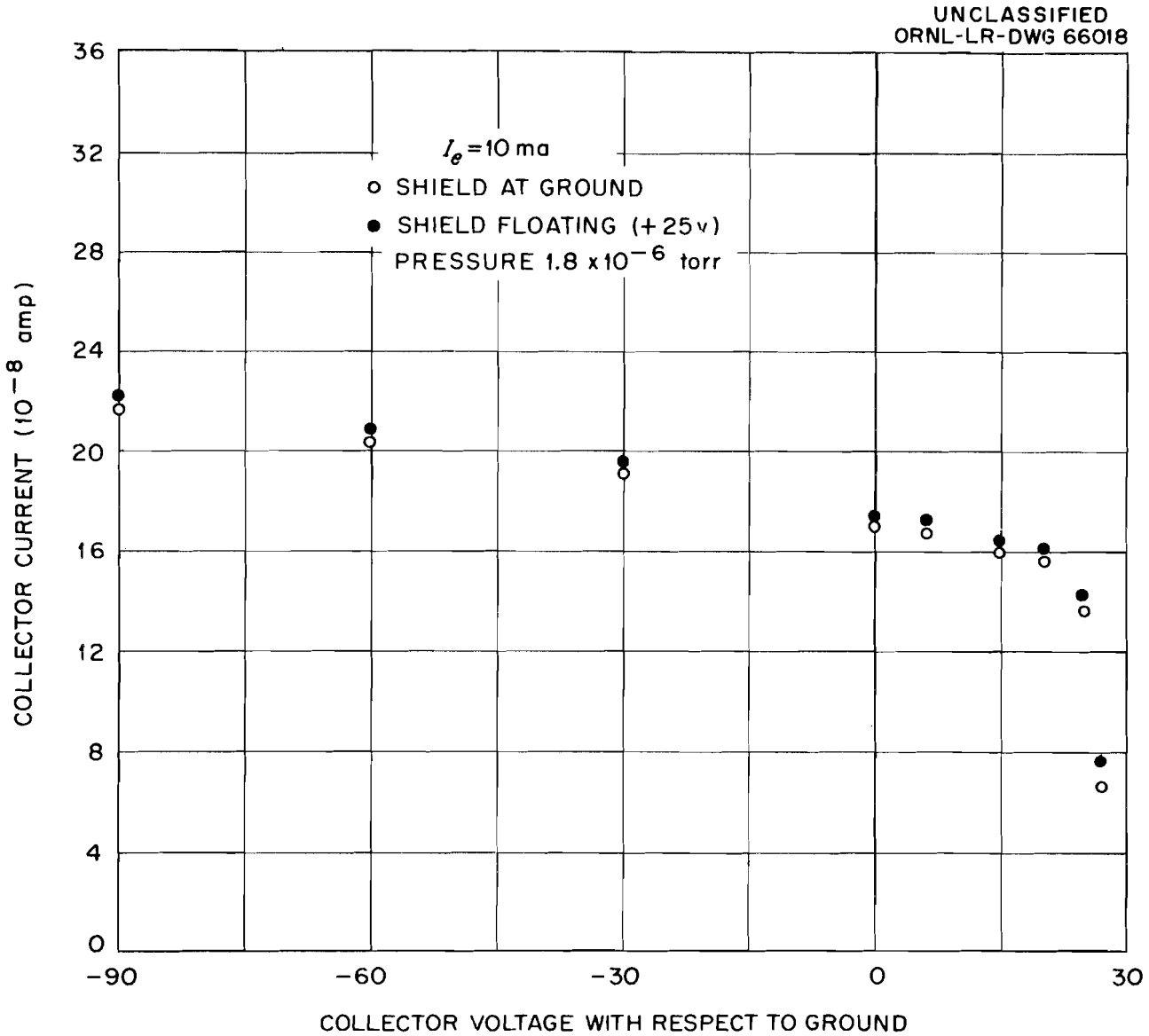

Fig. 4. Collector Current vs Collector Voltage; IV- With Floating Screen for Two Shield Potentials.

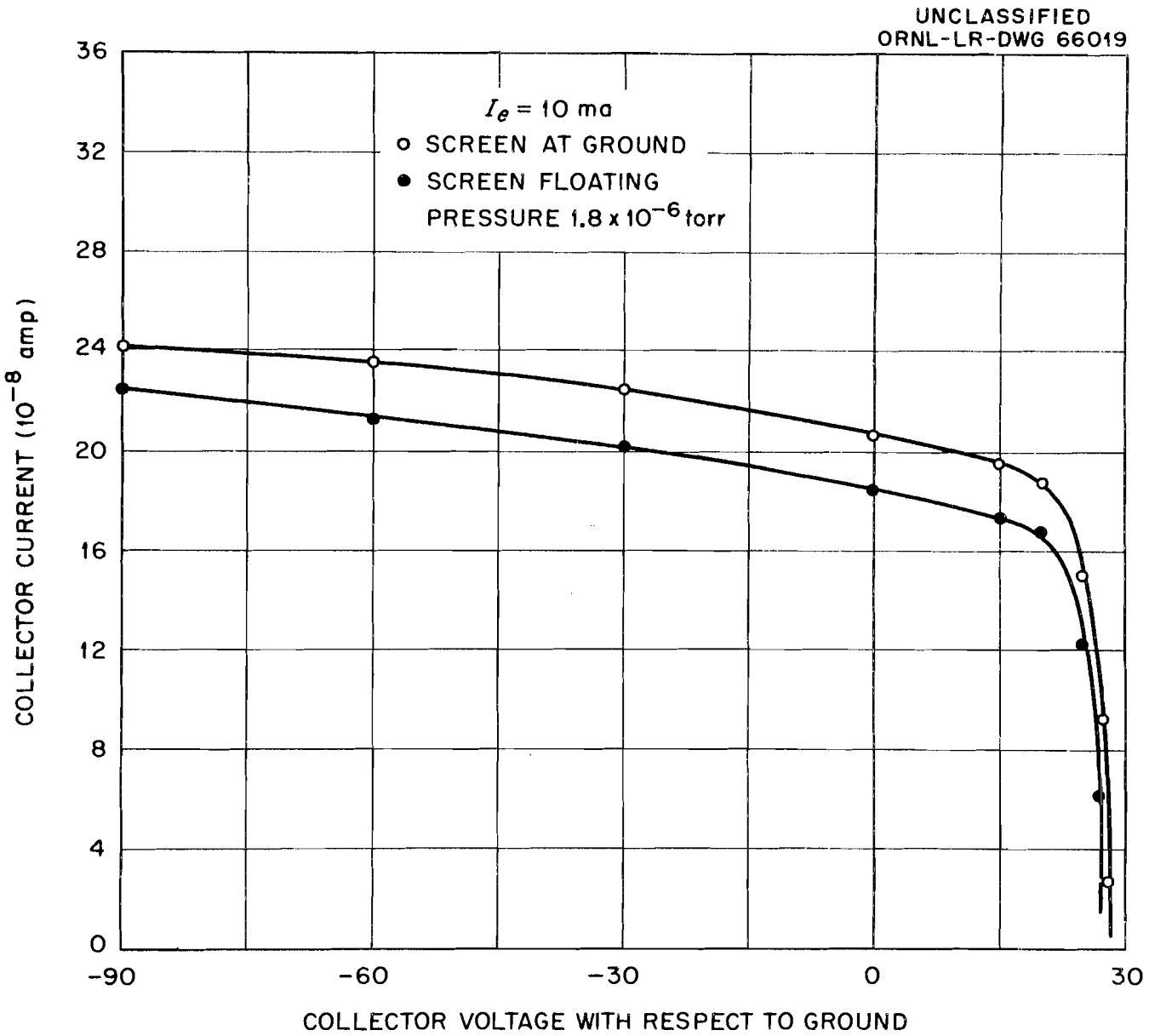

Fig. 5. Collector Current vs Collector Voltage.

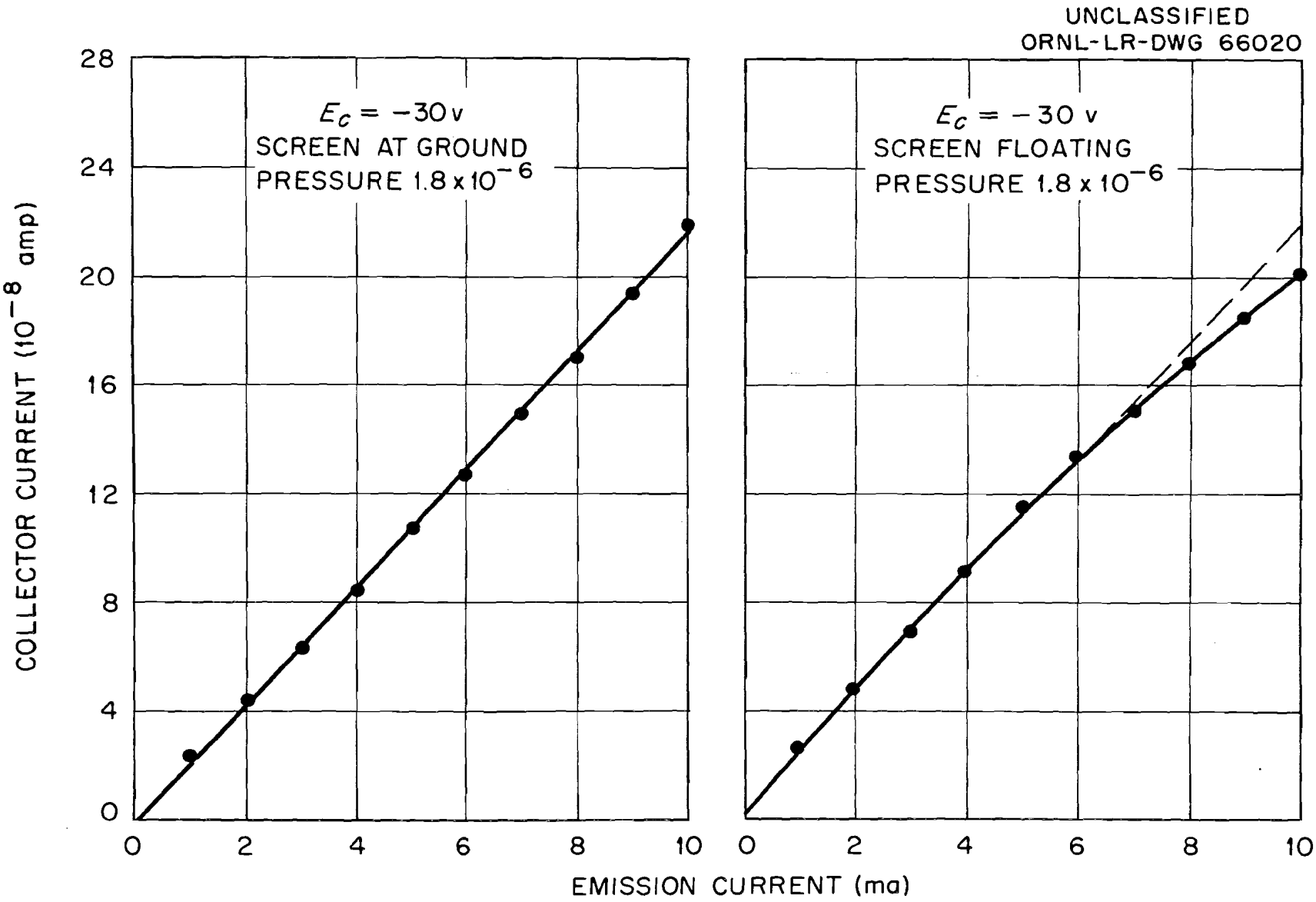

Fig. 6. Collector Current vs Emission Current (Stainless Steel Screen).

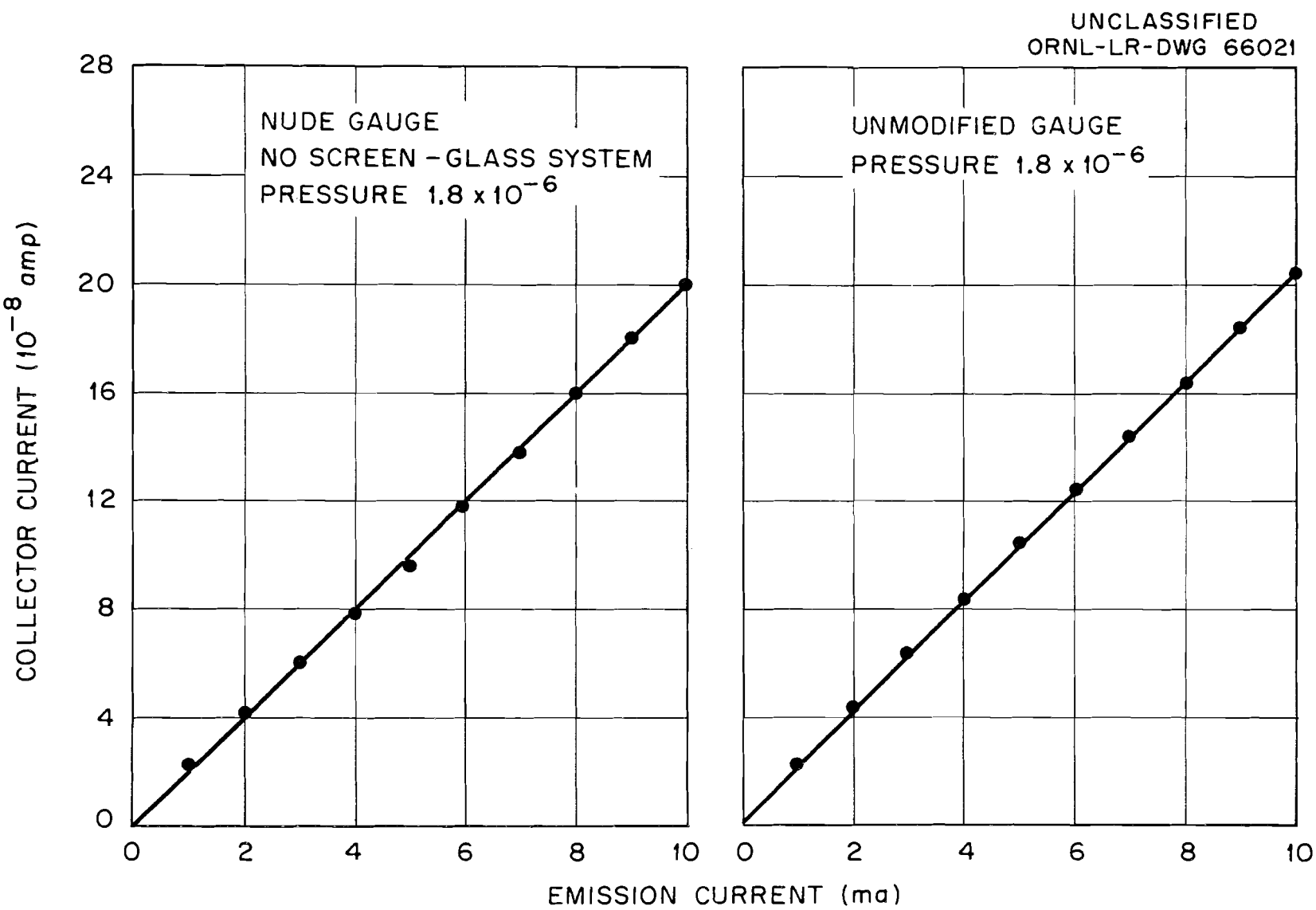

Fig. 7. Collector Current vs Emission Current for Unmodified Gauge and Nude Gauge Without Screen.

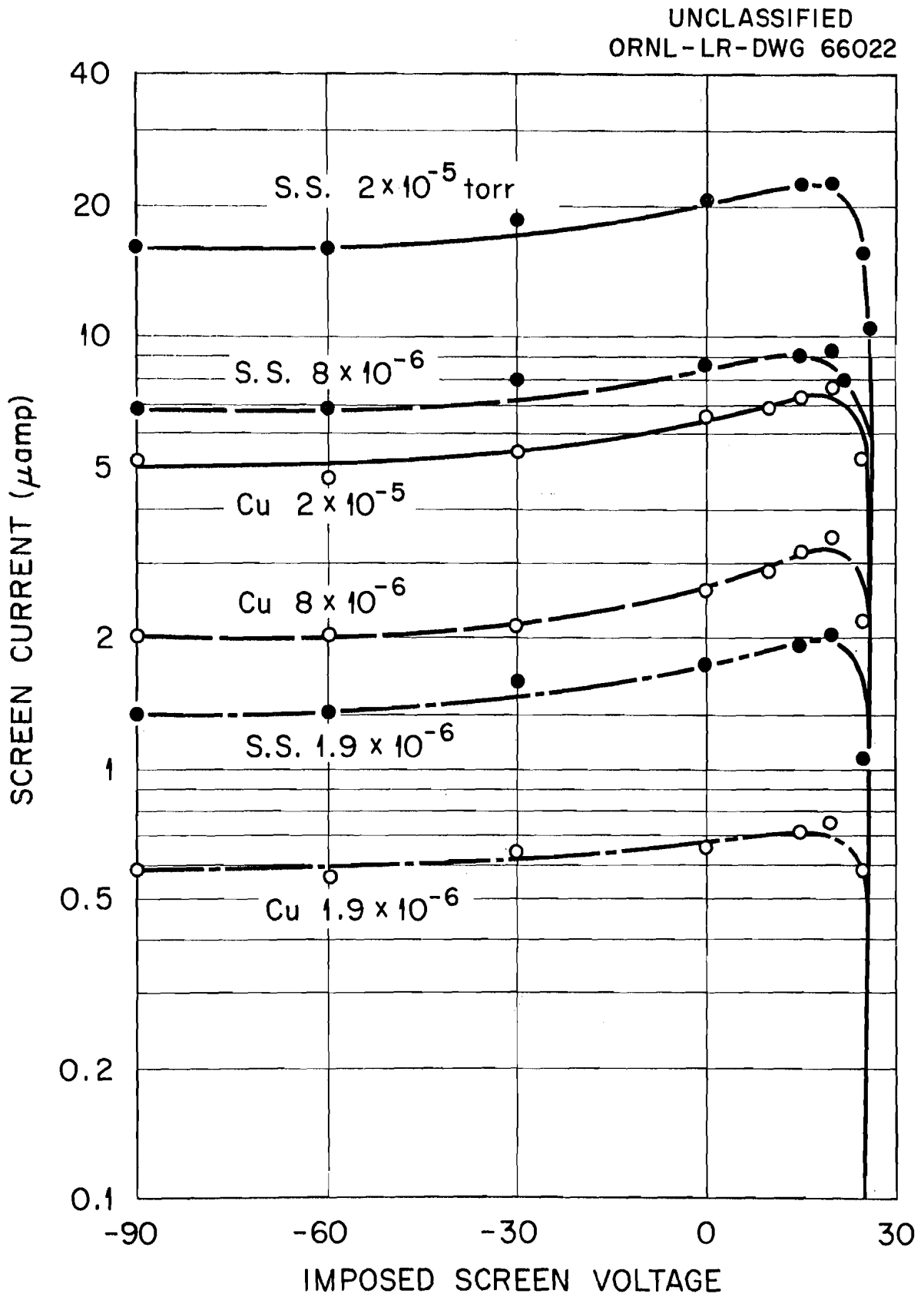

Fig. 8. Screen Current vs Screen Voltage for Two Screen Materials at Three Pressures.

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