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خصایص الکتریکی ناحیه ستون مثبت تخلیه‌های الکتریکی در نئون

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چکیده

روابط الکتریکی (ولتاژ ـ جریان) ناحیه ستون مثبت تخلیه های نورانی مورد بررسی قرارگرفته‌اند در رابطه با مطالعه و تحقیق درباره مکانیزم های تحریکی در تخلیه های الکتریکی باگاز نئون.

این اندازه‌گیرها برای فشارهائی بین ۱۵ - ۰٫۱ میلی بار و جریاناتی تاحدود ۳۰ میلی آمپر در لوله های تخلیه‌ای باقطرهائی بین ۲۰ - ۳ میلی‌متر انجام پذیرفته‌اند. سیستم‌های متنوع کاتدی (ساده و مسطح ـ توخالی ـ داغ روکش‌دار) مورد استفاده قرارگرفته‌اند که دراین مقاله برتری وایرادهای سیستم‌های گوناگون کاتدی بکار رفته مورد بحث وگفتگو قرارگرفته‌اند.

رابطه های ولتاژ ـ جریان‌برای‌شرایط متفاوت تخلیه های‌الکتریکی(فشارـجریان ـ سیستم کاتدیـقطر وطول لوله‌ها) بررسی شده‌اند و برای هر مرحله ازاین اندازه‌گیری‌ها دامنه الکتریکی و دگرگونی‌های‌آن نیز مورد محاسبه قرارگرفته است.

برای این بررسی‌ها لوله های تخلیه‌ای که مستقیماً «به دستگاه خلا» (قادر به رسیدن به‌فشارهائی حدود ۸-۱۰ میلی‌بار) برای ایجاد تخلیه های الکتریکی خالص مورد استفاده قرارگرفته‌اند که بعضی از این لوله ها دارای دو آند بوده که بدینوسیله اندازه‌گیری دامنه الکتریکی را در شرایط یکسان ایجاد نموده‌اند.

در مقاله بعدی خصایص طیفی و روابط شدت نور ـ جریان ستون مثبت تخلیه های نورانی نئون و آرگون و بررسی تعداد اتم‌های شبه پایدار آنها مورد بحث قرارگرفته و نتایج این تحقیقات نیز ارائه خواهد گردید.

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Electrical characteristics of the positive column of glow discharges in neon

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Abstract

Voltage - Current (V— i) characteristics in low pressures electrical discharges in neon have been studied as part of an investigation of the excitation processes in the positive column of glow discharges .

Measurements have been carried out over pressure range of 0. 1 - 15 m. bar, and currents up to 30 mA, and tubes with bores 3 - 20 mm. Various cathode systems (plane, hollow and heated coated) have been used, the advantages and drawbacks of different cathode systems will be discussed.

Voltage - current relationships for various discharge conditions (pressure, current cathode system, tube's diameter and length) have been investigated and the electric fileld also has been measured in each case.

Similar experiments have been carried out using argon and argon - neon mixtures.

1 - Introduction

It is necessary to determine whether the electrical characteristics of the discharges are stable, and reproducible over the current and pressure range used. Large changes in the electrical characteristics during the optical and spectral measurements would affect the electron and ion distribution within the discharge and cause the intensities of the spectral lines to be varied.

Although many works have been carried out on the electrical and spectral relationships for hollow cathode discharges (Pillow, 1981 and Howard, 1983) but very little work has been published on the electrical characteristics of the positive column discharge when a hollow cathode has been used .

Glass or fused silica discharge tubes with a spectrosil viewing window were used for these measurements. Demountable positive column tubes were employed on a U. H. V. system (capable of achieving preesures of order of 10^{-8} m. bar) to give high purity conditions, and the discharge tubes were filled with research grade neon or argon to the required pressures. The positive column discharge tube with alternative anodes was employed, allowed an estimation to be made of the field strength (X), (Zendeh - nam, 1987) .

2 - Voltage - current (V - i) relationships

a - Plane cathode

Voltage - current curves for different pressures using neon as the carrier gas are given in Fig. 1 for discharge tube with plane cathode, shown in Fig. 2 . It can be seen from the graphs that, the voltage increases with increasing discharge current, this is one of the characteristics of an abnormal discharges, where X/P (X is the potential gradient and P is the pressure) is no longer optimum, and increasing current needs higher tube voltage, as otherwise the glow could not be maintained .

The V - i curves for the abnormal discharge has an increasing positive slope, The required voltage for a given current increased when pressure diminished, this is another characteristics of an abnormal discharge. An abnormal discharge was obtained in this work since the cathode surface was fully covered by the negative glow .

For a given gas pressure (neon) and discharge current a higher tube voltage was needed for a narrower tube, and longer positive colun length required a greater potential than short column length. A very similar results were obtained when argon was used as a carrier gas. The plane cathode used in this work were made of tungsten (W), the reason being that the sputtering effects is apparently less from the tungsten cathodes, (Francis, 1968) .

This effect (sputtering) is due to bombardment of the cathods surface by ions from the discharge, and results in the deposition of the cathode material on the glass envelope .

The current and pressure ranges in this work were limited due to sputtering when a plane cathode was used. A lower pressure and higher currents results in a heavy sputtering (Stocker, 1961). Stocker found an empirical relation between the sputtering rate (R) proportional to the number density of cathode atoms in the discharge) and discharge current (i) and pressure (p) in the form :

$$R \propto (i/P)^{2.5}$$

b - Hollow cathode

The differences in electrical potential between anode and cathode required to maintain a given dischargecurrent is consideably lower in the case of employing a hollow cathode in a positive column tube than that of a plane cathode of similar dimensions.

The discharge current in a low pressure inert gas discharge is largely determined by the efficiency of the processes related to releasing electrons from cathods. The dominant processes contributing to electron release are considered to be collisions by inert gas ions that are accelerated by the cathode fall, and photoelectric emission caused by the ultra - violet - resonance radiation from the inert gas.

When a plane cathode is used in a discharge tube, a reduction of the pressure or an increase of the discharge current resulted a shorter positive column length, and a longer negative glow, whilst in the hollow case the length of the negative glow remained constant and stayed within the hollow cathode. This means that the probability of either ions or photons produced by the discharge stricking the cathode is much higher than if the cathode is plane. For this reason the effi - ciency of electron release from a hollow cathods is much higher than of a plane cathode, more efficient electron release gives a greater current density and therefore higher current for a given potential .

Voltage - current curves for various gas press - ures for the discharge tube shown in Fig. 4, show a flat characteriatics (see Fig. 3). A«bump» at the beginning of the V - i graphs at low current current could be linked to widening of the discharge to fill the tube's cross - section, and change of discharge colour .

c - Hot coated cathode

The V - i graphs are shown in Fig. 5 for neon discharge for various gas pressures in a discharge tube with heated coated filament cathode which is given in Fig. 6, as can be seen a much lower running voltage was required for similar discharge conditions(pressure, current, and tube's size) compared with column tubes with plane or hollow cathode. The main factor in the heated cathode case was the correct filament voltage (right temperature).

A hot cathode may be oxide - coated (barium) or thoriated, which improves its emission, but bom - bardment with positive ions with enough energy to cause secondary emission would destroy the emission surface of the cathode, and shorten its lilfe. An oxide-coated cathode also can get chemically poisoned if exposed to air or other reactive gases after its activation . Fig. 7- shows the V - i curves for various cathode filament voltage for a given pressure .

d - Comparison of the cathode systems:

The drawbacks of the plane cathode were due to:

i - High voltage was required(500 - 2000 volts), specially in low pressure range.

ii - Limitation of the current and pressure range due to heavy sputtering from the cathode , which changed the electrical and spectral characteristics of the discharge .

iii - Because of sputtering, after one or two sets of measurements, the tube had to be changed, which would be expensive and time consuming .

The advantages of the positive column tube with hollow cathode were :

i - Less maintaining tube voltage was requireyd

ii- Much less sputtering was produced compared with plane cathode under the same discharge condi - tions .

iii - Using hollow cathode was more economical than plane cathode case, since changing the tube was not needed so often .

The only disadvantage of using hollow cathode was that, end on viewing observations for spectral measurements could not be carry out, since the negative glow was present in the discharge.

By using a heated coated cathode the above mentioned problems were solved, and absence of the negative glow (with right cathode temperature) allowed the spectral investigations for end on viewing of the positive column be carried out. The main pro - blem with using heated - coated cathode was that , once the cathode has been activated it gets chemically poisoned when it is exposed to air (leakage from vacuum system) or it is required to be changed; the. tube has to be sealed otherwise is on longer reusable

3 - Measurements of the field strength (X)

The longitudinal field usualy is measured in various ways :

i - By inserting two or three floating probes in the discharge and measuring the diffference between the potential they acquired .

ii - Having movable electrodes and then mea - sure the extra voltage required for longer positive column .

iii - Using Langmuir probe .

All these ways of measurements give the average field strength (X).

$$X = \frac{\Delta v}{\Delta x}$$

Where (Δ V) is the variation of voltage, and (Δ X) is length difference of the positive column .

In this work tubes with alternative anode and hollow or hot cathode were employed to measure the extra voltage needed for longer positive column , and hence calculate the electric field; under similar discharge conditions .

Fig. 8 shows the variation of the field strength with tube radius for different pressures(1 and 5m. bar) for a given discharge current .

4 - Summary

To asertain that characteristics of the glow discharge do not vary with time or over the optical and spectral measurements period, the electrical relation ships of the discharge has to be monitored (Light, Steers, Zendehnam 1985), (Steers, Zendehnam 1986) .

Effects of impurities can cause variation in the spectral and electrical characteristics of the positive column discharge (Zendehnam 1987), so that an att - empt should be made for maximum purity .

Using plane cathode could limit the current and pressure range due to heavy sputtering; hence variation of the discharge characteristics, so employing a hollow or heated cathode is suggested .

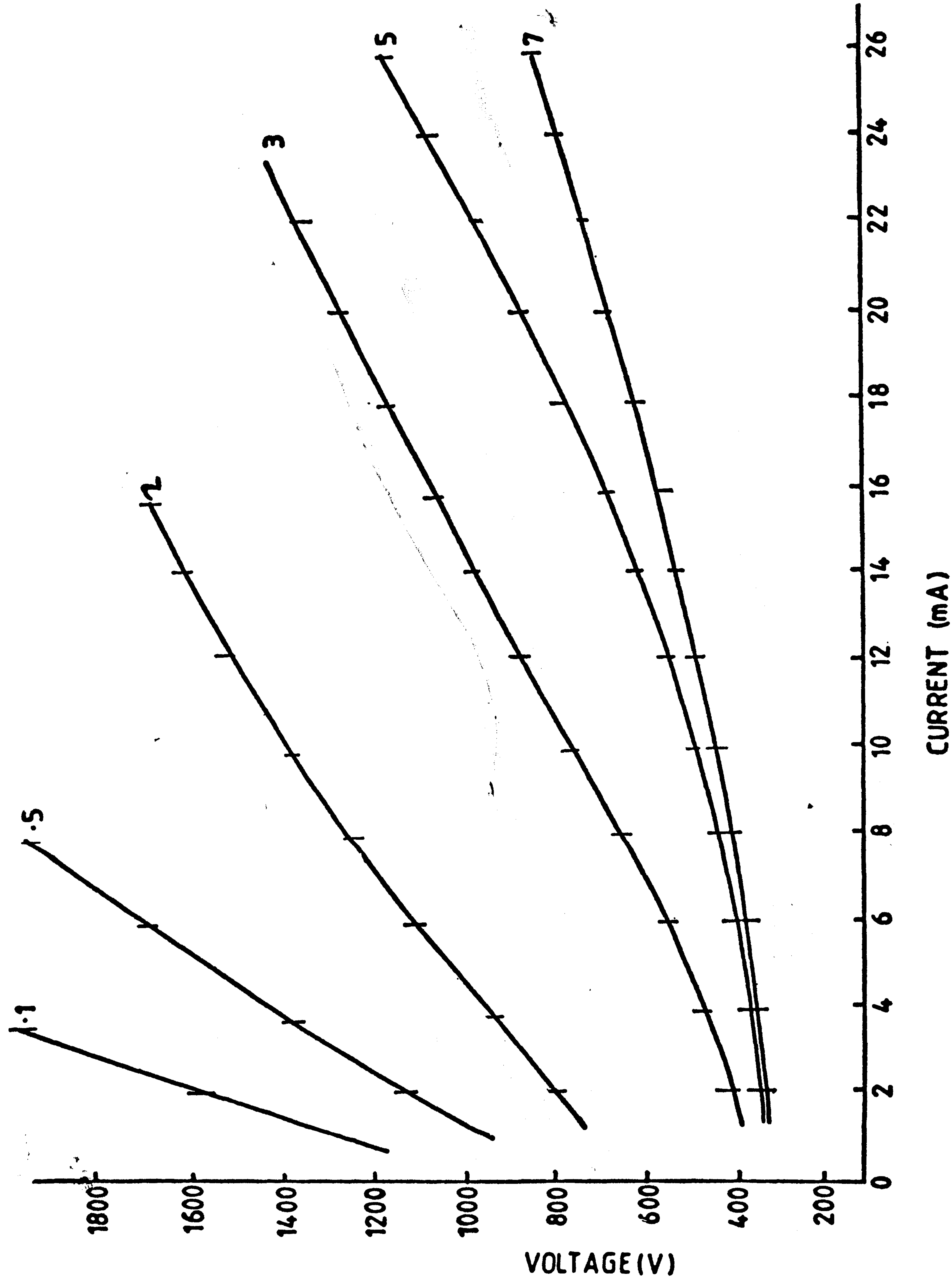

Fig. 1. V - i chacteristics for various neon pressures (mbar) of column tube with plane cathode

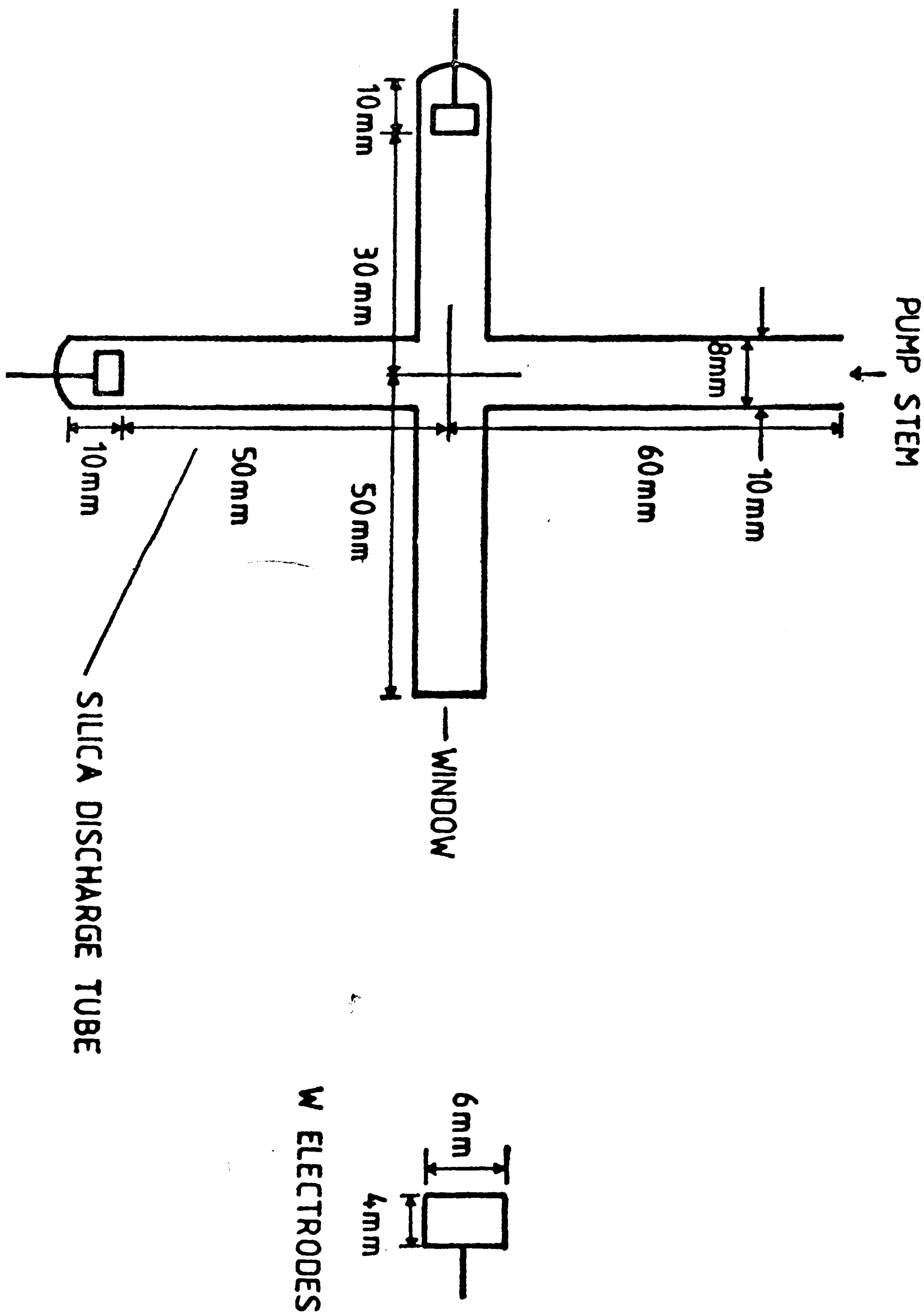

Fig. 2. Discharge tube with plane cold cathode

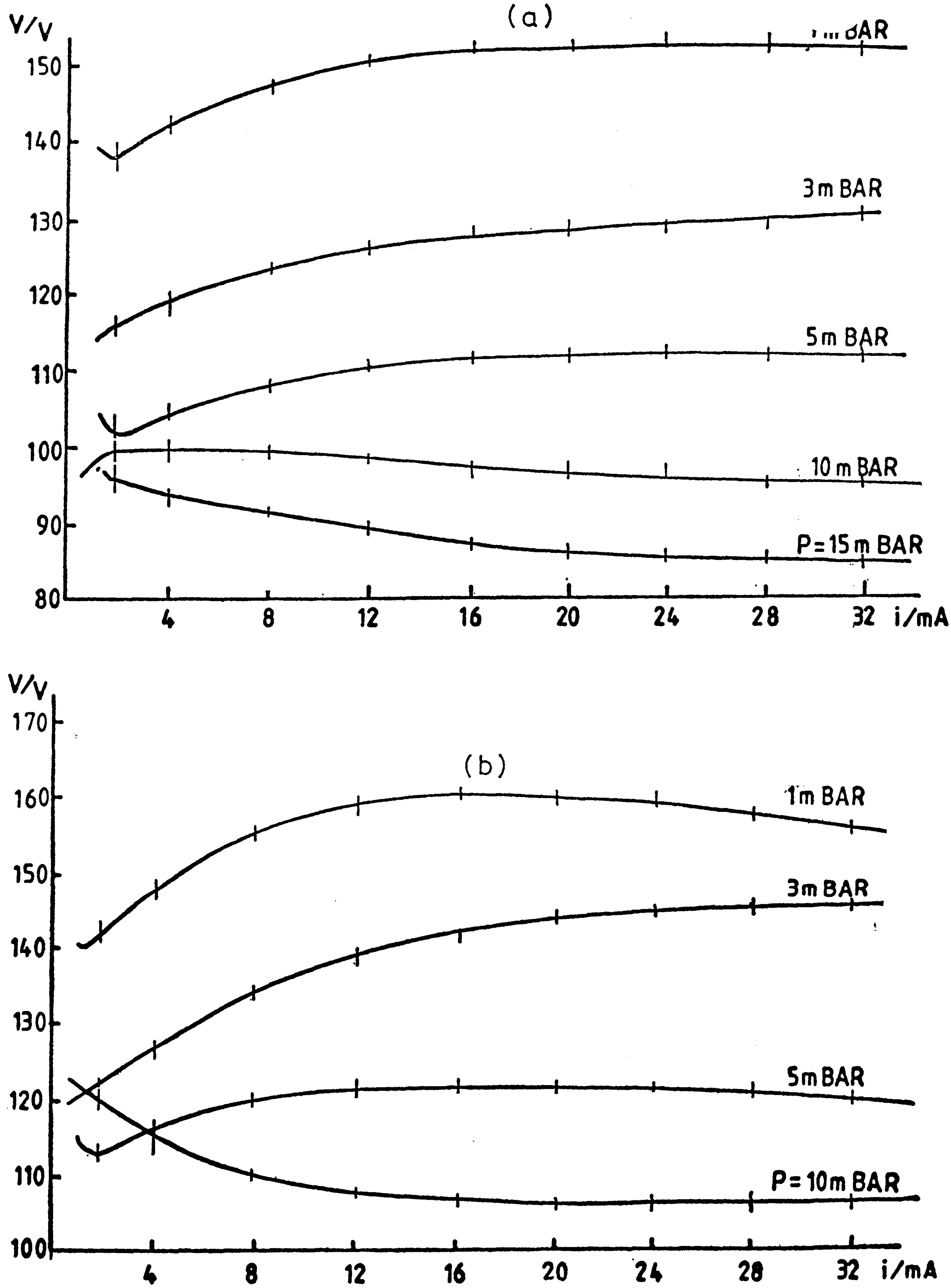

Fig. 3. V - i characteristics for tube with hollow cathode (a) in neon (b) in argon

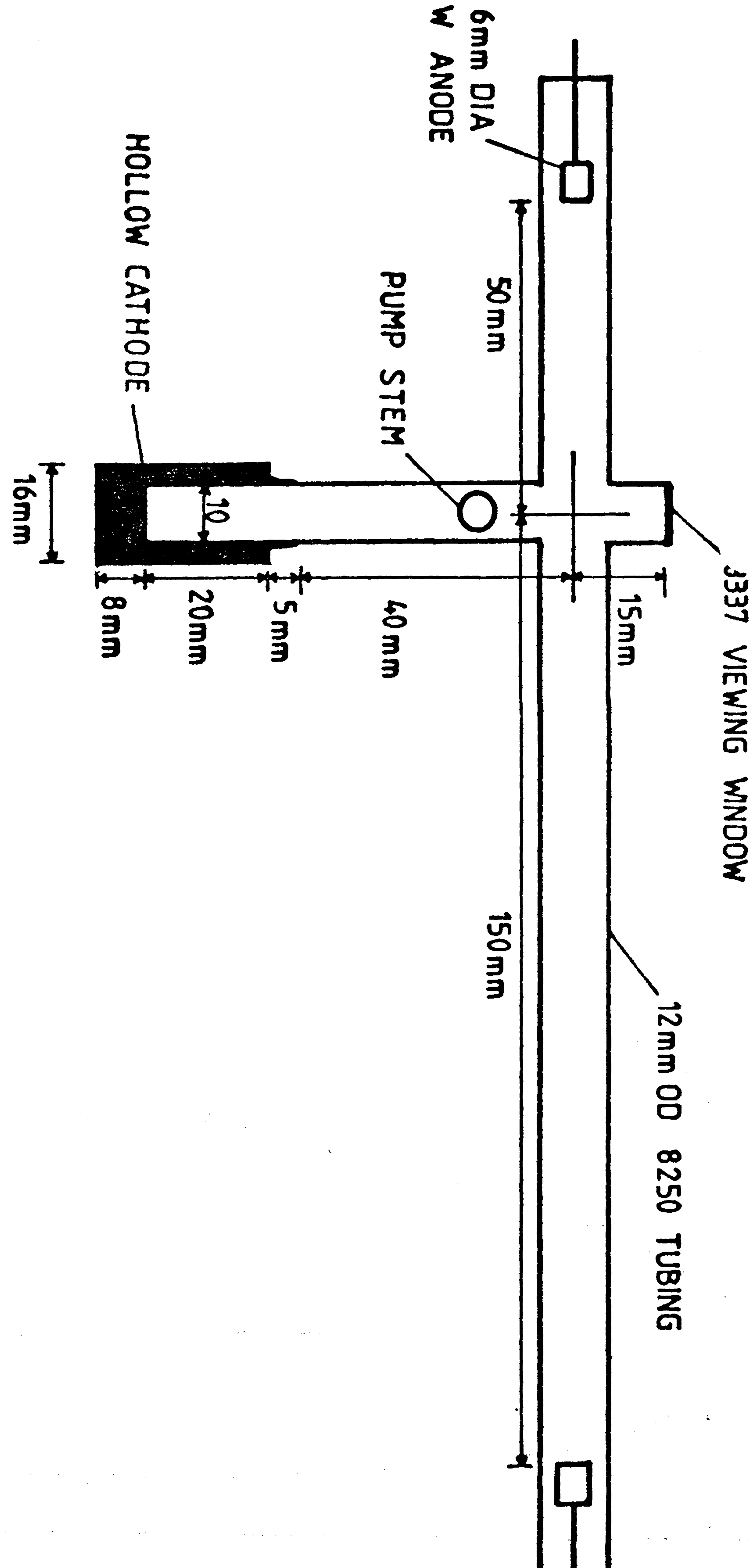

Fig. 4. Column tube with hollow cathode

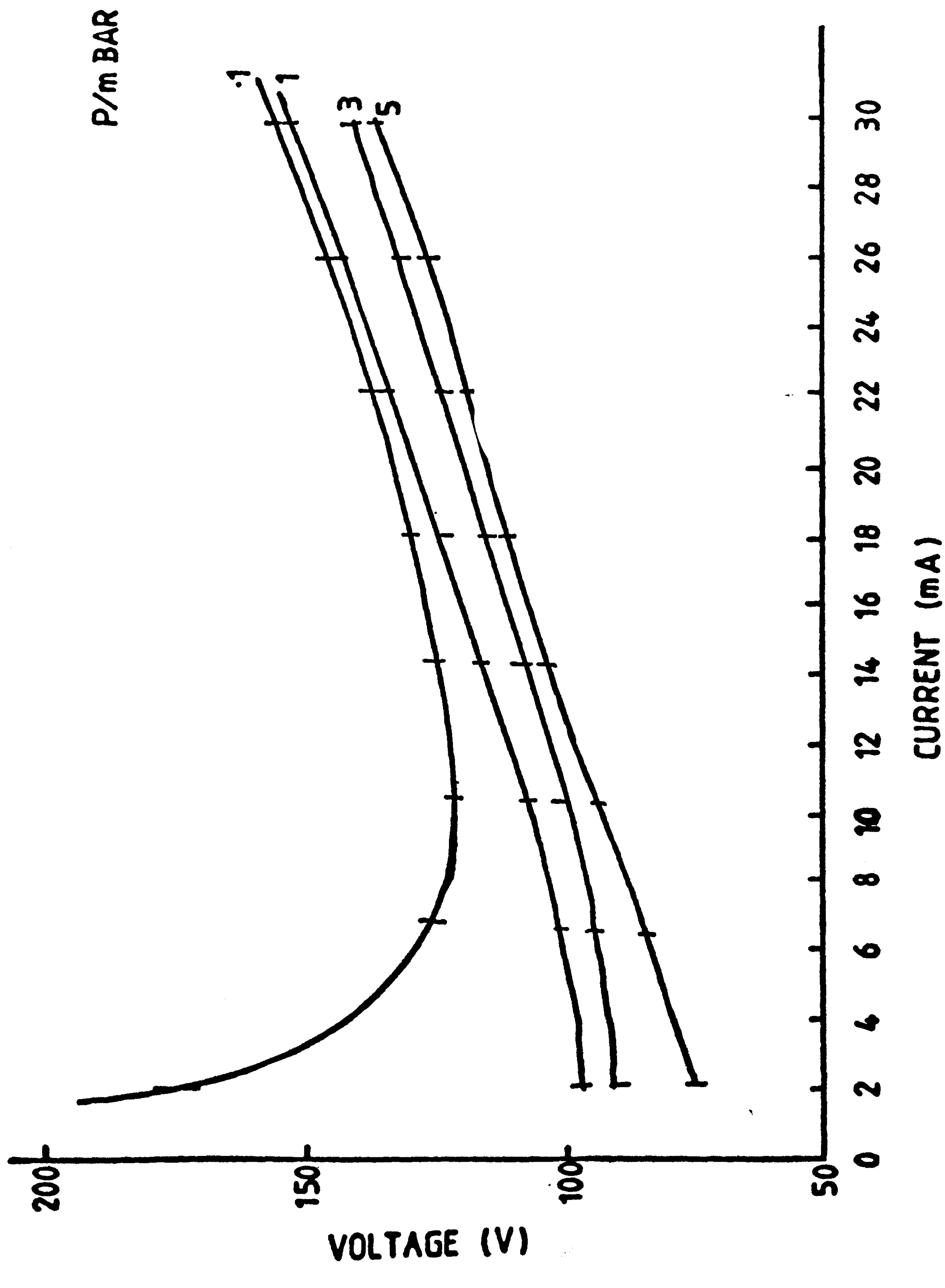

Fig. 5. V - i graphs for tube with heated coated cathode in neon for various pressures

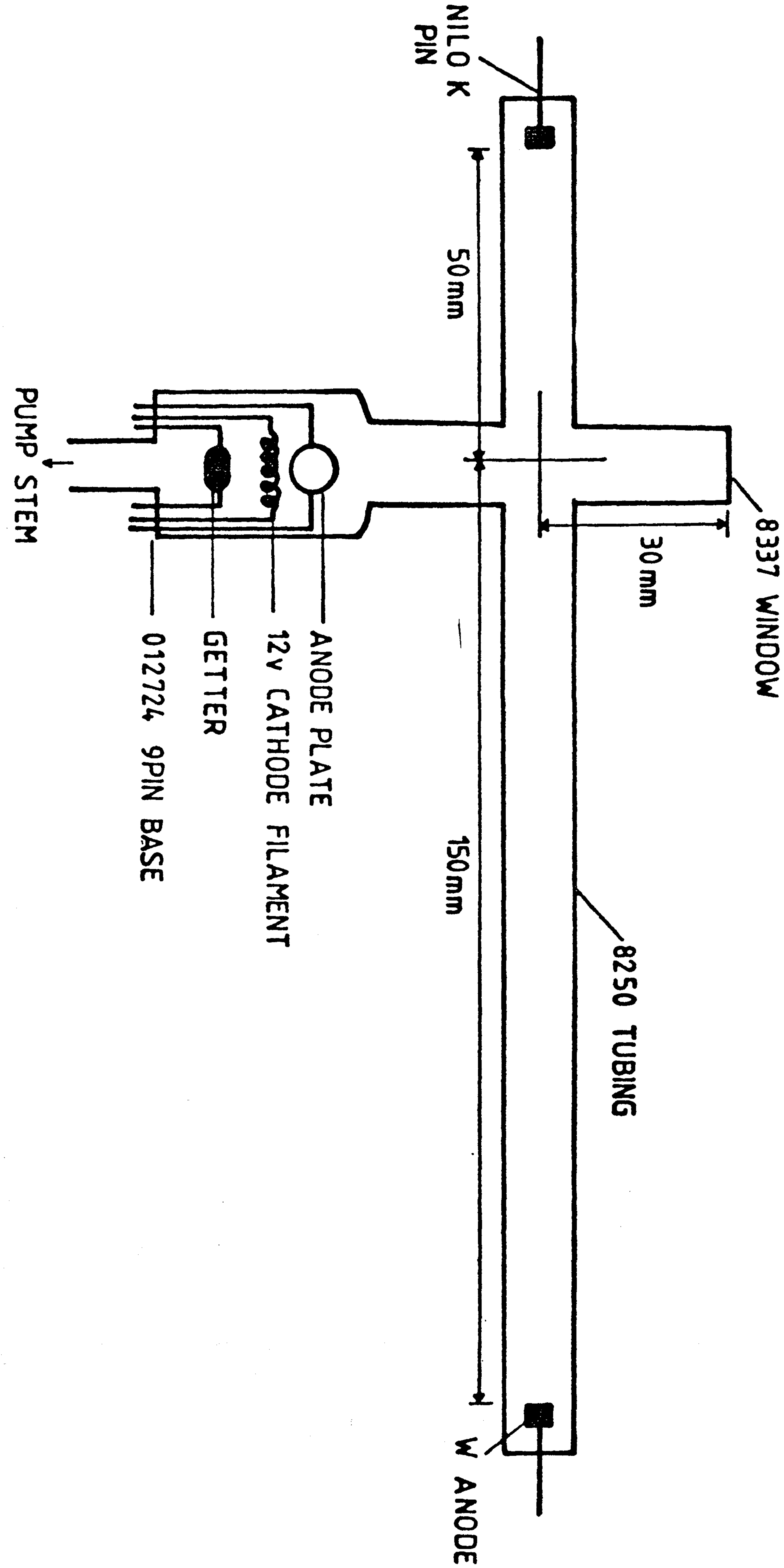

Fig. 6. new design discharge tube with hot coated cathode

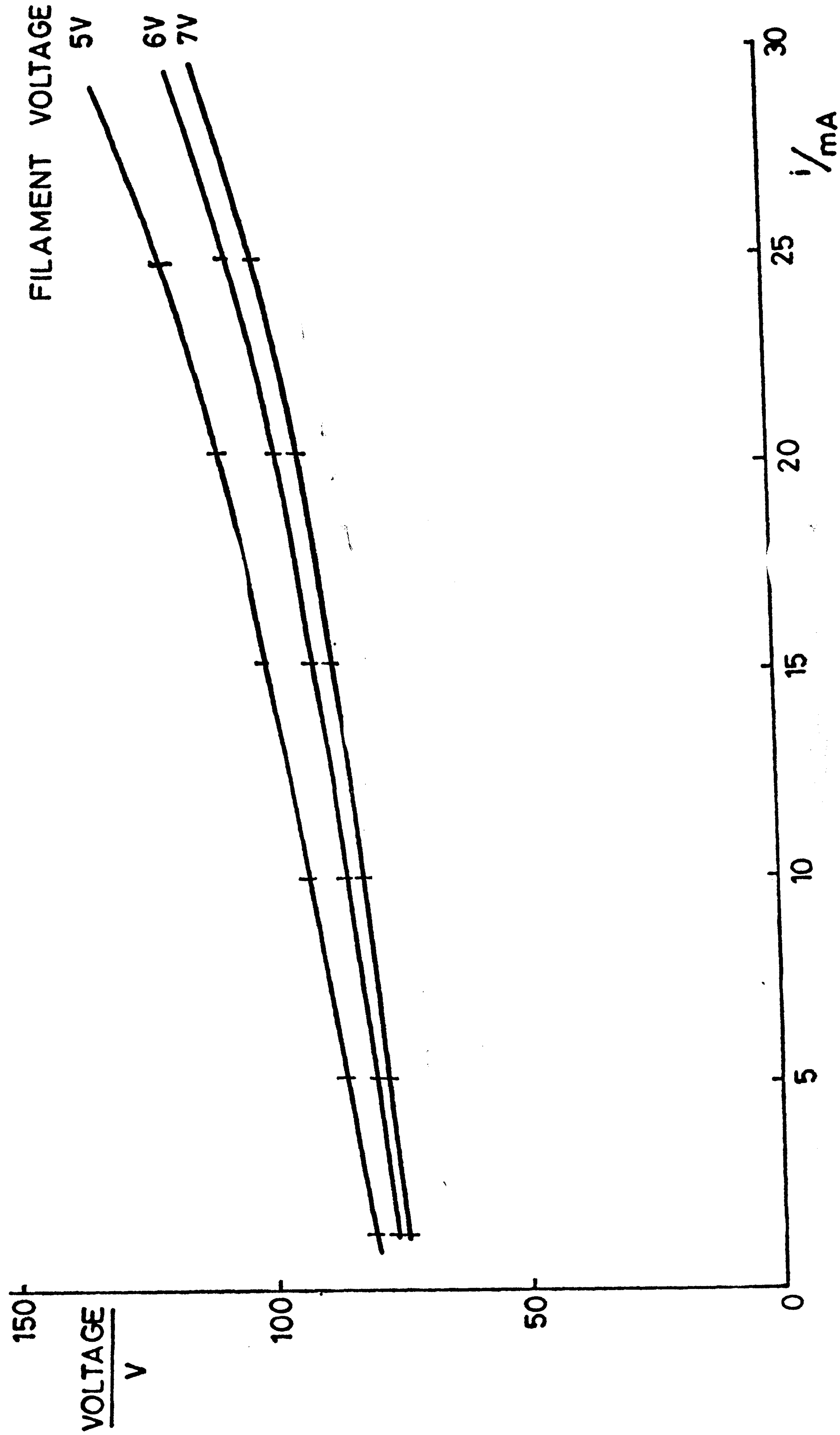

Fig. 7. V - i graphs for column tube with heated coated cathode in neon for various filament voltages

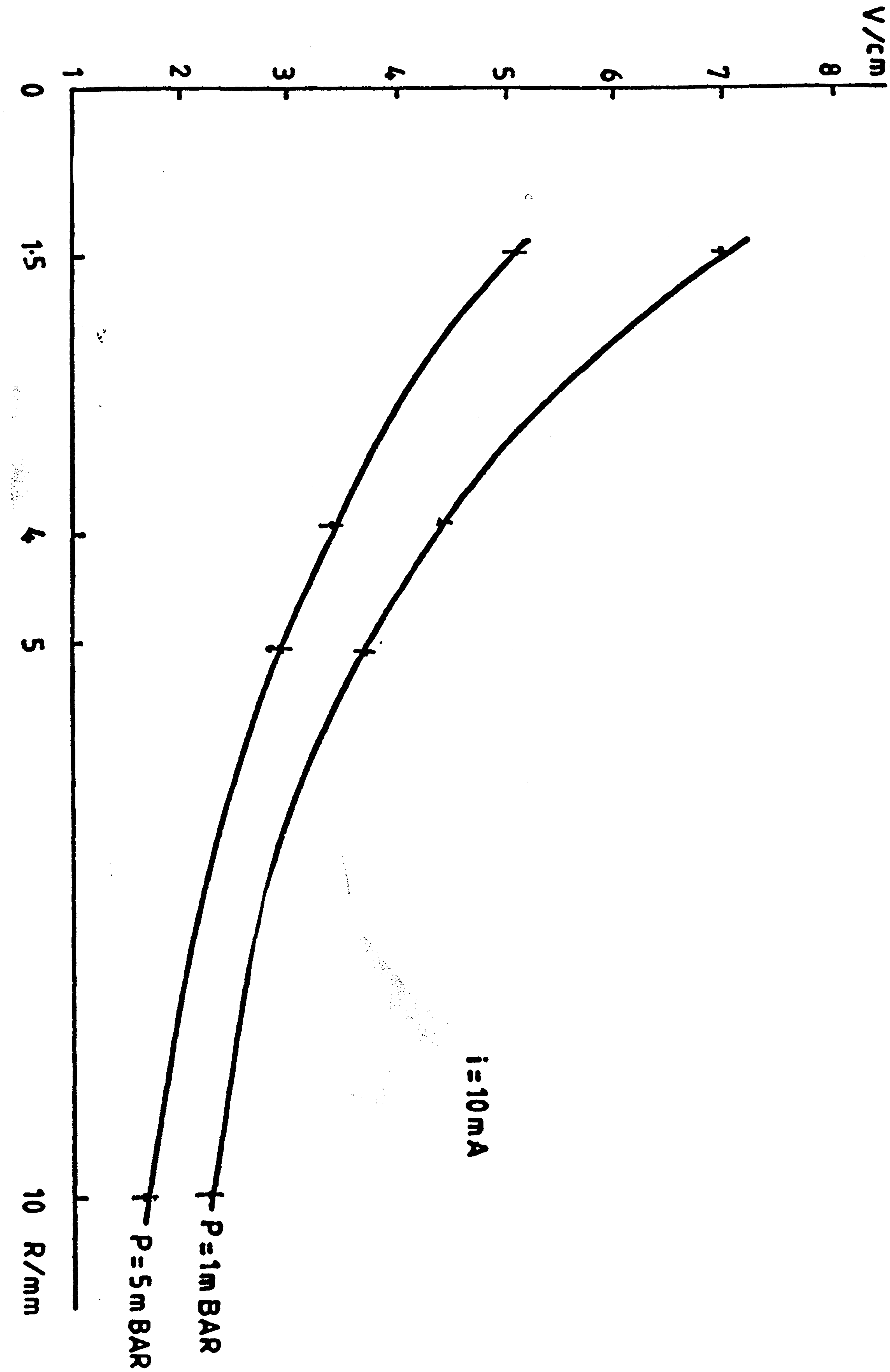

Fig. 8. Varition of the gradient with tube radius in neon discharge

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