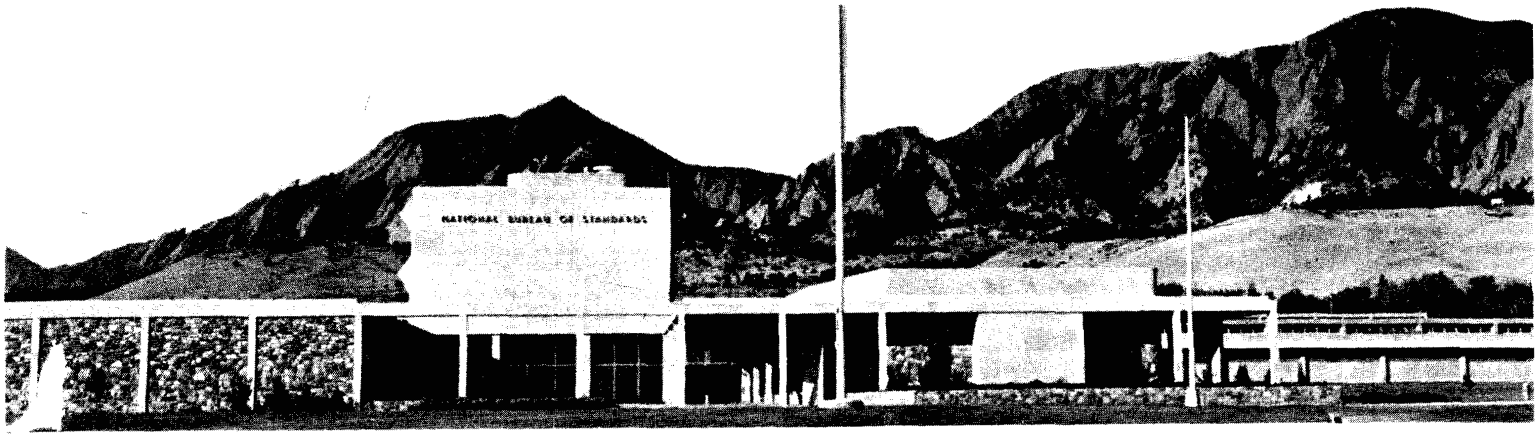

NBS REPORT

10 761

PERFORMANCE OF He-Ne LASERS WITH VARIOUS He AND Ne PRESSURES AND VARIOUS CAPILLARY SIZES

James C. Bergquist and Helmut Hellwig

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
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Boulder, Colorado 80302

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ADDENDUM

NBS Report 10 761

PERFORMANCE OF He-Ne LASERS WITH VARIOUS He AND Ne PRESSURES AND VARIOUS CAPILLARY SIZES

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The isotope ^{22}Ne (refer to page 6) was used with good results. As expected, much lower pressures of helium were required to match the line center of the gain curve to the methane line center. This resulted in good low noise performance over a wider range of operating parameters than that of the ^{20}Ne isotope.

As was noted in our conclusion, the coincidence of line centers of the emission profile and methane, while maintaining good noise performance, was only slightly achievable with ^{20}Ne for the three capillary sizes used. This limited range was between .1 to .2 torr ^{20}Ne, 4.6 to 4.7 torr He, and a small range of discharge currents. With ^{22}Ne, however, good low noise performance and coincident line centers was possible with approximately 1.1 to 1.3 torr He, .05 to .2 torr ^{22}Ne, and a wide range of discharge currents (typically for 2 mA to 7 mA). The capillary used was of inner diameter 3.5 mm, but similar results are expected for the 2.9 mm and 4.0 mm capillaries.

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Abstract

The performance of the 3.39-μm He-Ne laser is investigated as a function of partial pressure fillings of the respective gases and of the inner diameter of the capillary tube. In particular, this experiment studied the laser oscillation threshold, the threshold of coherent output fluctuations, and the threshold of excessive noise as functions of these parameters. The experimental setup is described in some detail. The results are stated with no attempt at theory.

Key Words: Amplitude noise; Helium neon laser; Lasers; Methane-stabilized laser.

INTRODUCTION

The performance of the 3.39-μm He-Ne laser depends on the partial pressure fillings of the respective gases and on the inner diameter of the capillary tube. The performance is also a function of several additional parameters, but this paper treats in some detail only the operational dependence on the above-mentioned parameters. To the authors' knowledge there has been little or no documented data in this area.

The immediate concern in the present experiment is our continuing investigation into the performance of CH_4-stabilized He-Ne lasers [1]. It is very desirable in these investigations that the noise contribution of the laser signal be less than the receiver noise.* This facilitates the

*Noise discussed is typically (amplitude) noise in 1 MHz bandwidth.

design and operation of the locking electronics. It is also desirable, for accuracy and stability reasons, that the line center of the emission profile of the gain cell corresponds as closely as possible to the line center of methane. Unfortunately, in pressure shifting the gain curve in order to achieve this coincidence of the line centers, it is difficult to achieve low noise performance of the laser. Typically, 0.2 torr of ^{20}Ne had been pressure shifted with 4.65 torr of ^{3}He in order to place the center of the laser gain profile at the methane saturated absorption resonance. As mentioned, these partial pressure fillings were not always completely satisfactory because noise levels sometimes exceeded eight percent of total laser power at some of the desired discharge current settings. Thus, we investigated the noise performance as a function of partial pressure fillings and capillary sizes while at the same time monitoring the relative size of the methane absorption peak and the relative offset of the center of the single-mode laser emission profile from the methane absorption. Our intent was to pressure shift as much as possible toward the conditions quoted above while still maintaining good noise performance.

EXPERIMENTS

In figures 1 and 2, the measurement setup and the laser device are depicted. The capillary of each gain cell was 18 cm long, and inner diameters of 2.9, 3.5, and 4.0 mm were used. The lasers were initially "baked in" when made: after they had been attached to the pumping-filling station, the entire system was heated to reduce outgassing as much as possible. The system was then pumped to 2×10^{-7} torr before filling. The system was mounted on a steel plate partially buffered against vibration. The laser frequency was modulated by means of a piezoelectric transducer driven at 60 Hz with sufficient amplitude to continually observe the methane peak and emission profile.

DC excitation was used for the laser discharge. The ripple and noise of the constant voltage power supply was less than one millivolt rms with a line regulation of better than ±0.1 percent with 10 percent line voltage change. The load regulation was better than 0.05 percent from no load to full load. A 300-kΩ resistor was placed in series with the laser. The cathode and anode were 2 cm in diameter and 5 cm long and both located in concentric positions at the end of the discharge capillary. The electrodes were made of pure aluminum. The mirrors consisted of one with 95 percent reflectivity, the second with 98.5 percent reflectivity, with approximately one- and two-meter radii respectively. Most measurements were made immediately after filling. However we did not observe any significant change in laser performance after many hours of operation.

The system was filled systematically with ^{20}Ne and ^{3}He. As noted in figure 1, only one gain cell was monitored through a methane absorption cell; the second laser was monitored for the purpose of a consistency check as it had the same dimensions and pressures (both lasers were connected by a common line to the filling station). The performance of the laser for each pressure filling and capillary size was subdivided into three areas of consideration: (1) laser oscillation, (2) laser oscillation with coherent output fluctuations, and (3) laser oscillation with significant (> 8%) amplitude noise. The discharge current at the threshold of each of the above areas was measured and noted. With increasing discharge current the thresholds were crossed into the respective regions of laser oscillation, coherent output fluctuations, and noise. The discharge current was measured and its fluctuations were displayed on a multichannel oscilloscope in conjunction with the laser signals. It was observed that fluctuations in the discharge current corresponded to correlated fluctuations in the laser output.

This would imply that a constant current supply could be of possible benefit in attempting to quiet the laser discharge. It is noted that we observed two types of amplitude fluctuations, one was a coherent fluctuation with frequencies of the order of 100 kHz, the other was a fluctuation with the characteristics of white noise.

We found that the discharge current for all capillary sizes

(1) for threshold of lasing action (refer to figs. 3-5):

  a) increased for increasing He pressures at constant Ne pressure

  b) decreased for increasing Ne pressures at constant He pressure

(2) for threshold of coherent output fluctuations (fig. 6):

  a) generally decreased for increasing He pressure at constant Ne pressure

  b) generally decreased for increasing Ne pressure at constant He pressure

(3) for noise threshold (fig. 7):

  a) decreased for increasing He pressure at constant Ne pressure

  b) decreased for increasing Ne pressure at constant He pressure.

Although the data were insufficient for effective prognosis, it did appear that there was an increase of the corresponding threshold currents with increasing capillary diameter (compare figs. 3, 4, and 5). Otherwise the different capillary sizes led to similar performance of the lasers with respect to the various He and Ne pressures. It was also noted that the power

(1) at threshold of coherent output fluctuations (refer to figs. 8-10):

   a) decreased for increasing He pressure at constant Ne pressure

   b) decreased for increasing Ne pressure at constant He pressure, and peaked for the 4-mm capillary size

(2) at noise threshold (figs. 11 and 12):

   a) decreased for increasing He pressure at constant Ne pressure

   b) decreased for increasing Ne pressure at constant He pressure, and peaked for the 4-mm capillary size.

In figure 13 is plotted the normalized offset of the methane peak on the gain curve of the laser. As depicted, the normalized offset remains basically unchanged at constant He pressure over our limited range of Ne pressures. The normalized offset decreases approximately linearly with increasing He pressure for all Ne pressures and all capillary sizes.

CONCLUSION

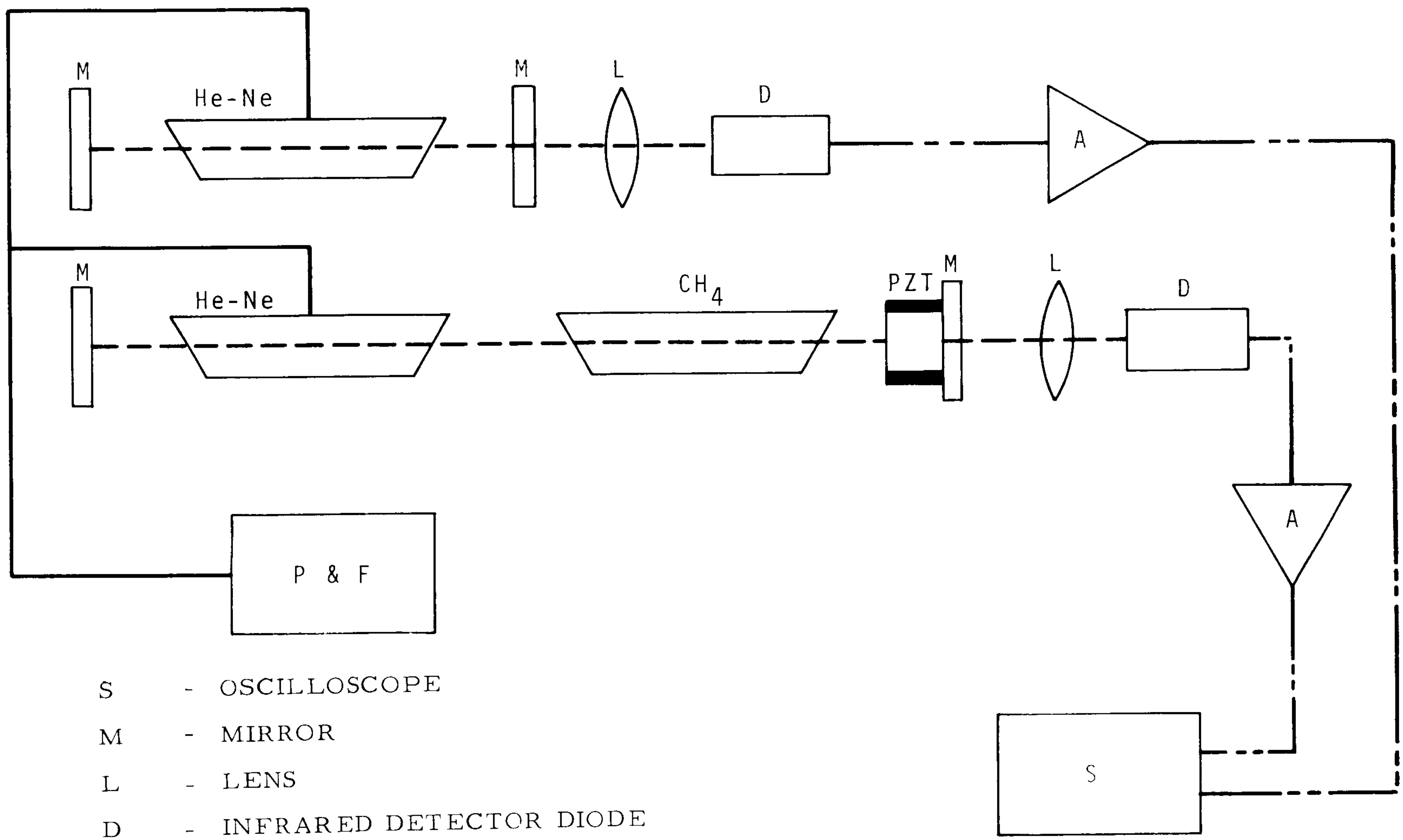
With careful study of the graphs, it is seen that the three capillary sizes lead to relatively insignificant differences in the performance of our lasers with the exception of the power performance of the different capillary sizes (at the threshold of coherent output fluctuations). It is further noted that the coincidence of line centers of the gain curve and methane, while at the same time maintaining good noise performance, was only slightly achievable with any capillary size. This limited range of both coincident line centers and low noise performance existed for all three capillary sizes at Ne pressures between approximately .1 to .2 torr and He pressures of 4.6 to 4.7 torr. We have concluded from these experiments that the optimum condition for us (at least for our present pursuits) is typically a pressure filling of 3.0 to 3.5 torr He with .12 to .15 torr Ne. The low noise performance in this range for any of the capillary sizes was good, while the offset of the methane line from the center of the emission profile was tolerable. The available output power within these above-mentioned pressure and noise limits was adequate for saturated absorption of the methane. The use of the isotope ^{22}Ne which requires lower He pressures for matching the gain profile peak to the methane line, promises to allow good low noise performance at partial pressures which are optimum for an accurate device over a much wider range of operating parameters.

ACKNOWLEDGEMENT

The authors wish to thank Howard E. Bell for his assistance in some phases of the experimental work.

REFERENCE

[1] "Frequency Stability of Methane-Stabilized He-Ne Lasers," Helmut Hellwig, Howard E. Bell, Peter Kartaschoff, and James C. Bergquist, J. Appl. Phys., Vol. 43, No. 2, February 1972.



S - OSCILLOSCOPE
M - MIRROR
L - LENS
D - INFRARED DETECTOR DIODE
A - AMPLIFIER
P & F - PUMPING & FILLING STATION
PZT - PIEZOELECTRIC TRANSDUCER

Fig. 1 Block diagram of the measurement system.

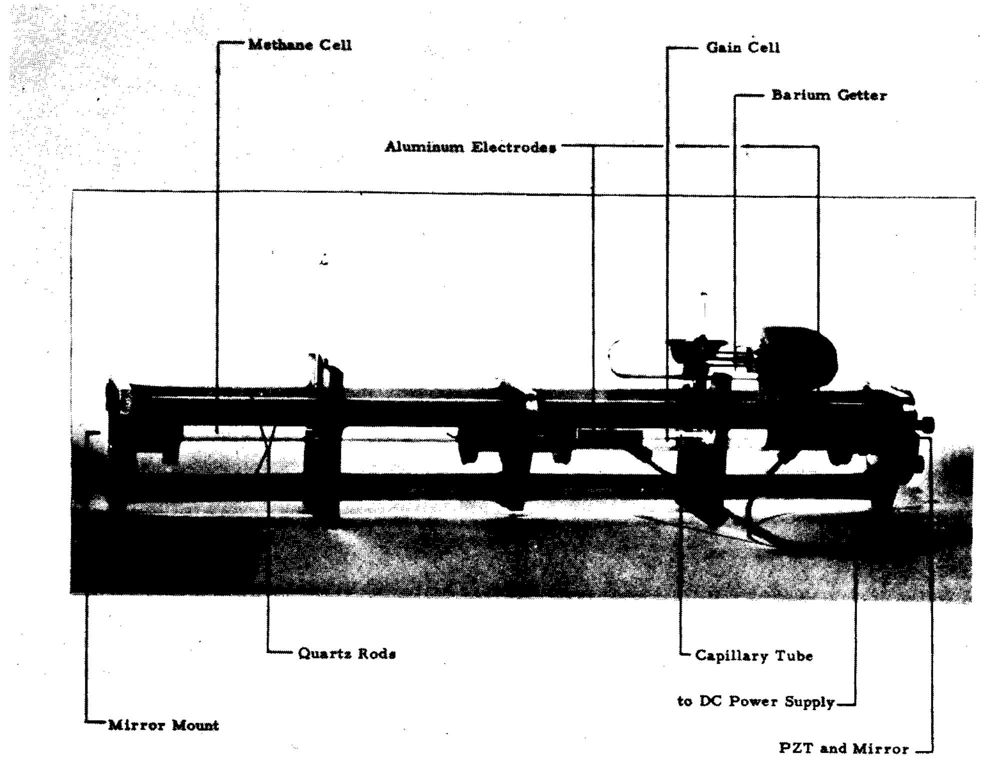


Fig. 2 Methane stabilized He-Ne laser.

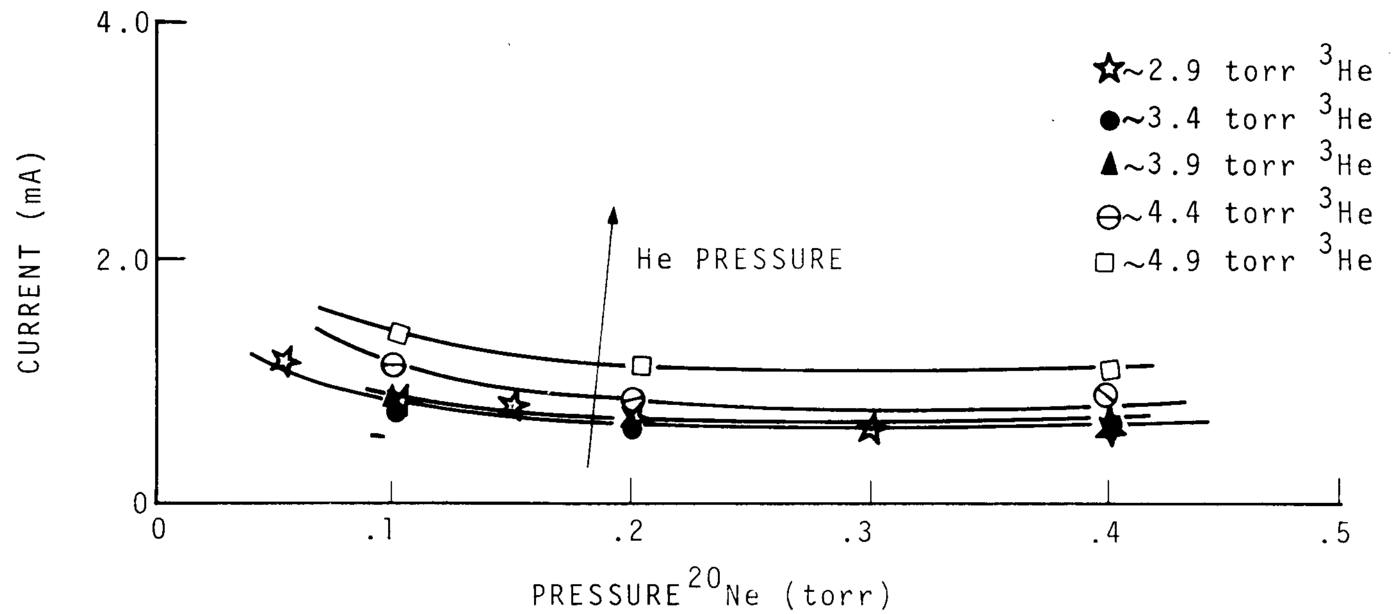


Fig. 3 DC current for laser oscillation threshold as a function of neon partial pressure.
Capillary size: 2.9 mm
Parameter: Helium partial pressure

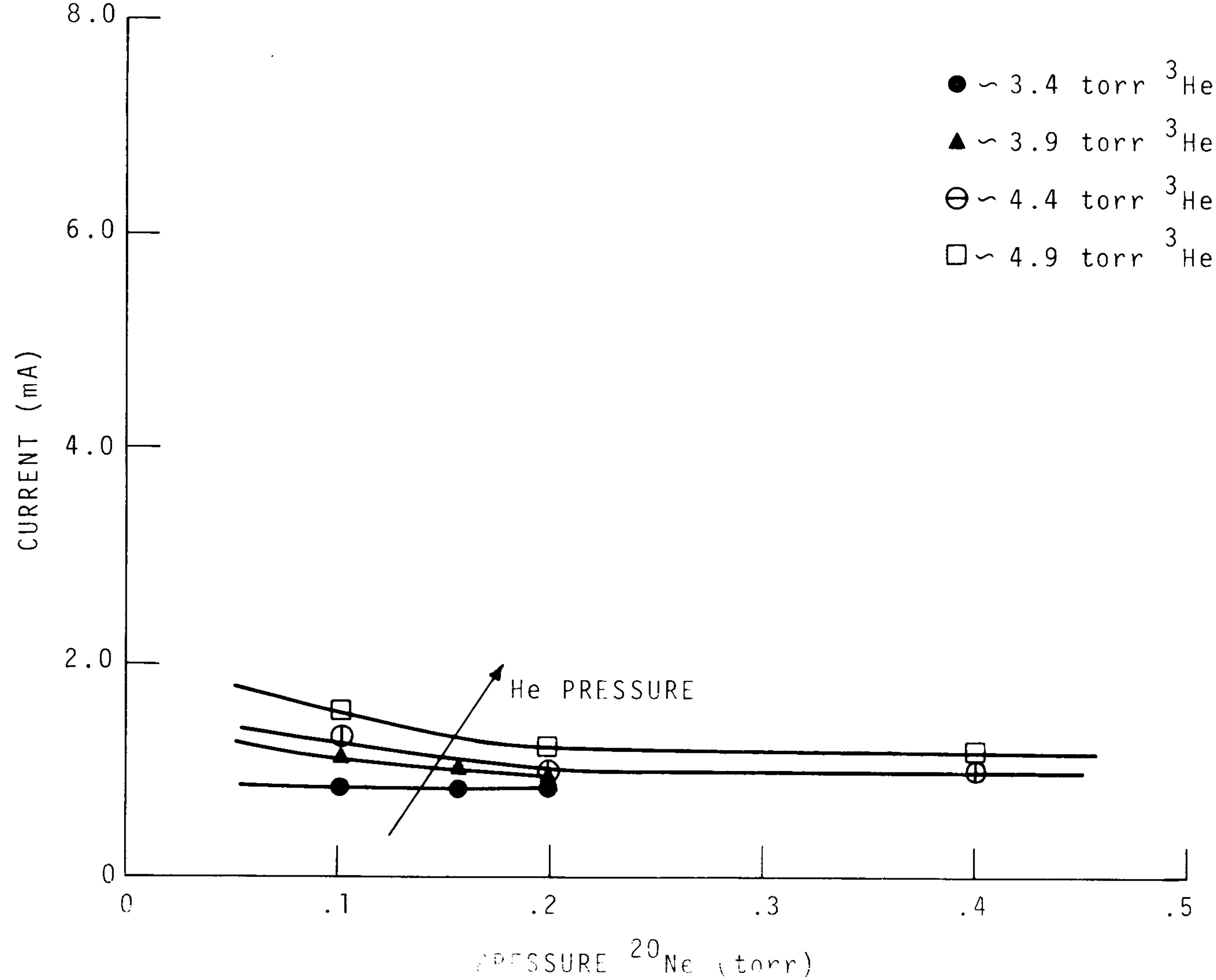


Fig. 4 DC current for laser oscillation threshold as a function of neon partial pressure.
Capillary size: 3.5 mm
Parameter: Helium partial pressure

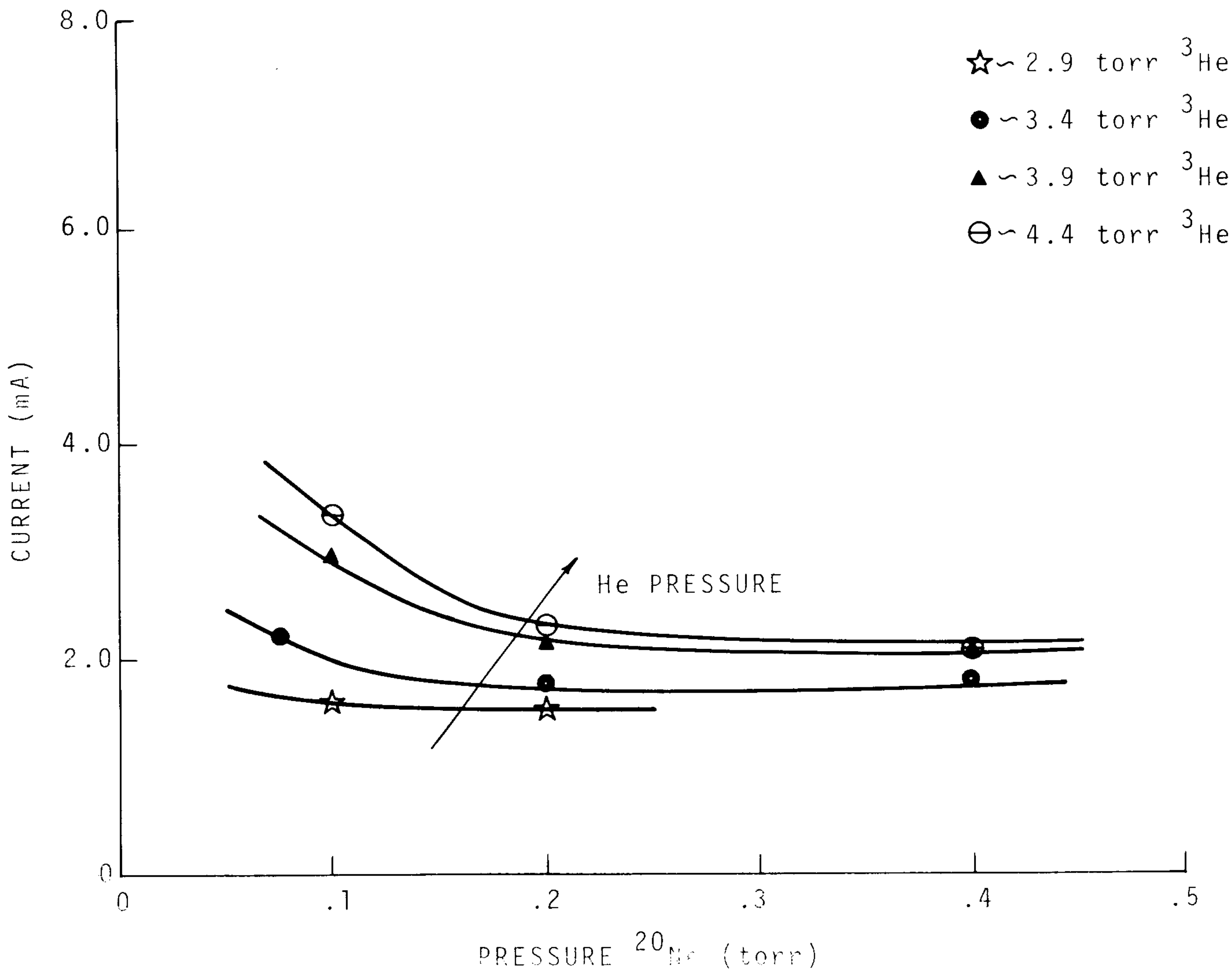


Fig. 5 DC current for laser oscillation threshold as a function of neon partial pressure.
Capillary size: 4.0 mm
Parameter: Helium partial pressure

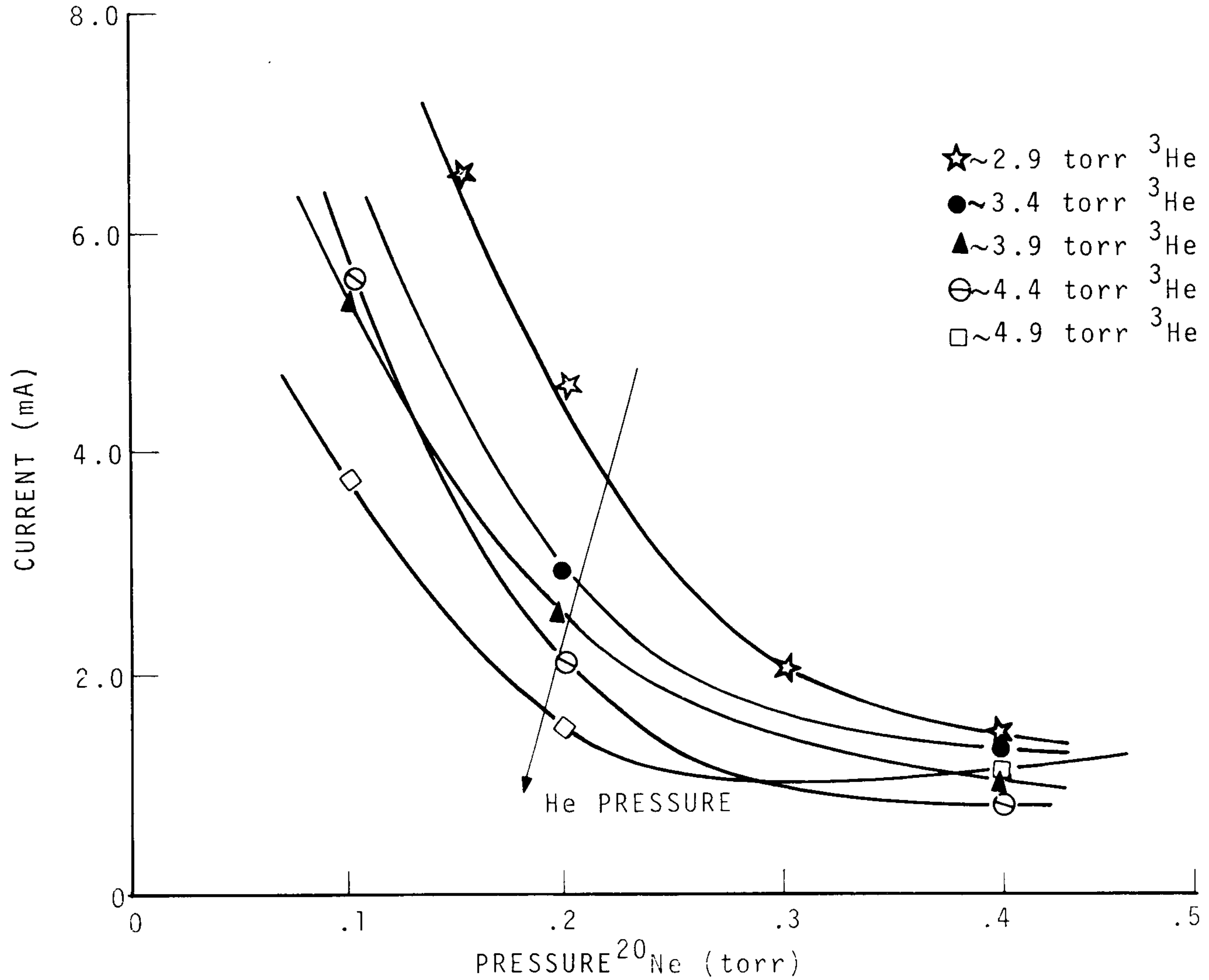


Fig. 6 DC current for coherent output fluctuations threshold as a function of neon partial pressure.
Capillary size: 2.9 mm (similar behavior for capillary sizes of 3.5 and 4.0 mm)
Parameter: Helium partial pressure

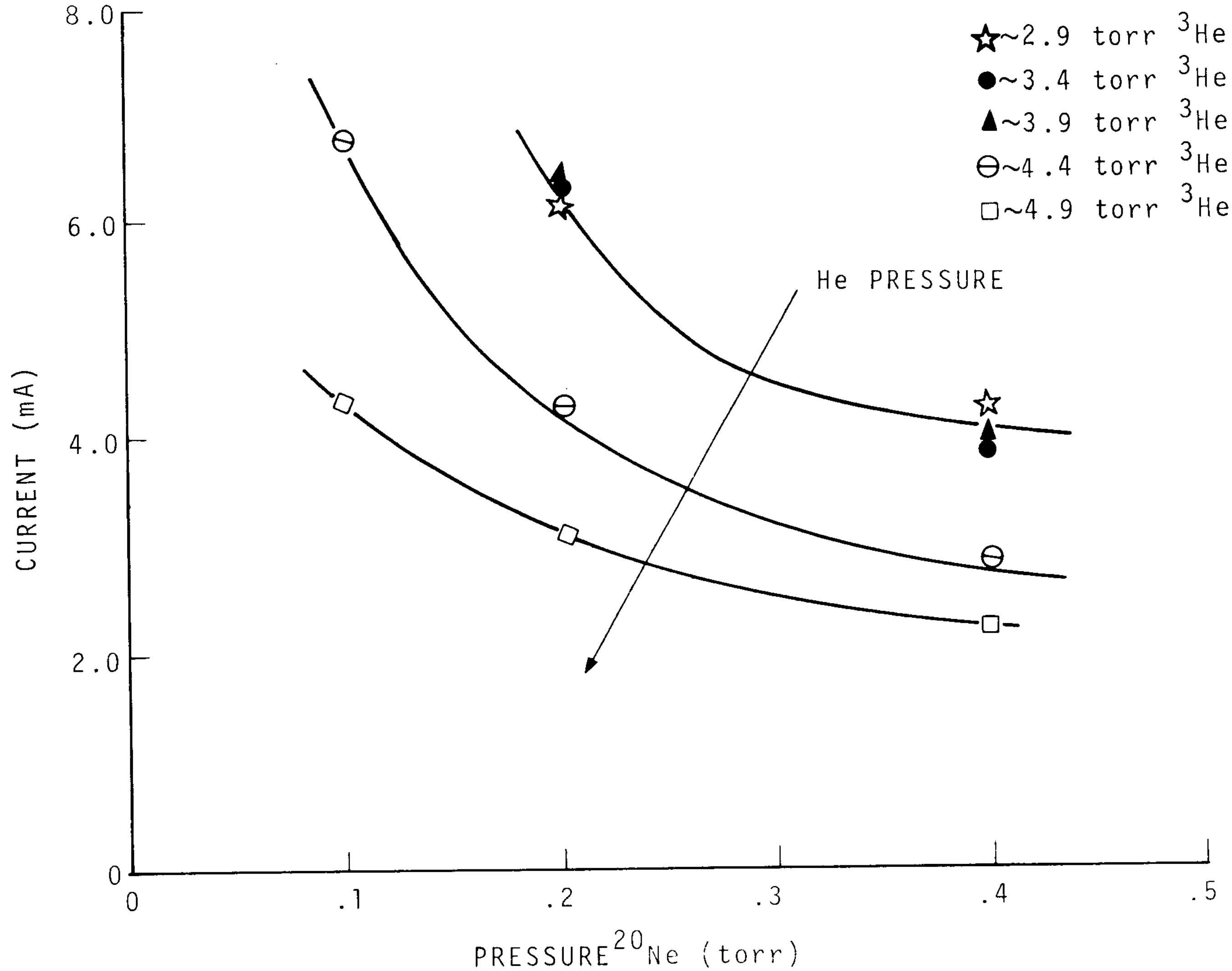


Fig. 7 DC current for amplitude noise threshold as a function of neon partial pressure.
Capillary size: 2.9 mm (similar behavior for capillary sizes of 3.5 and 4.0 mm)
Parameter: Helium partial pressure

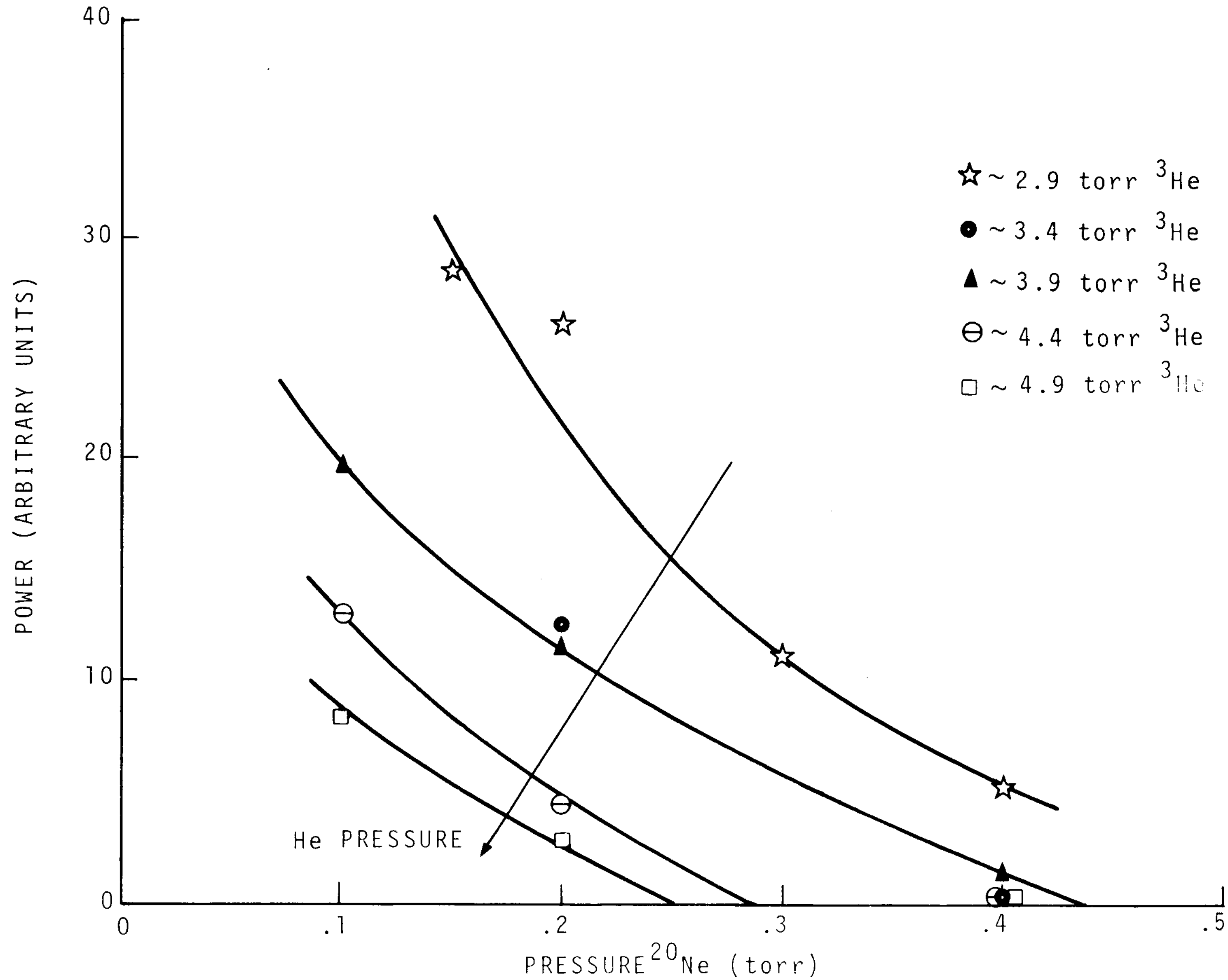


Fig. 8 Power output at threshold of coherent output fluctuations as a function of neon partial pressure.
Capillary size: 2.9 mm
Parameter: Helium partial pressure

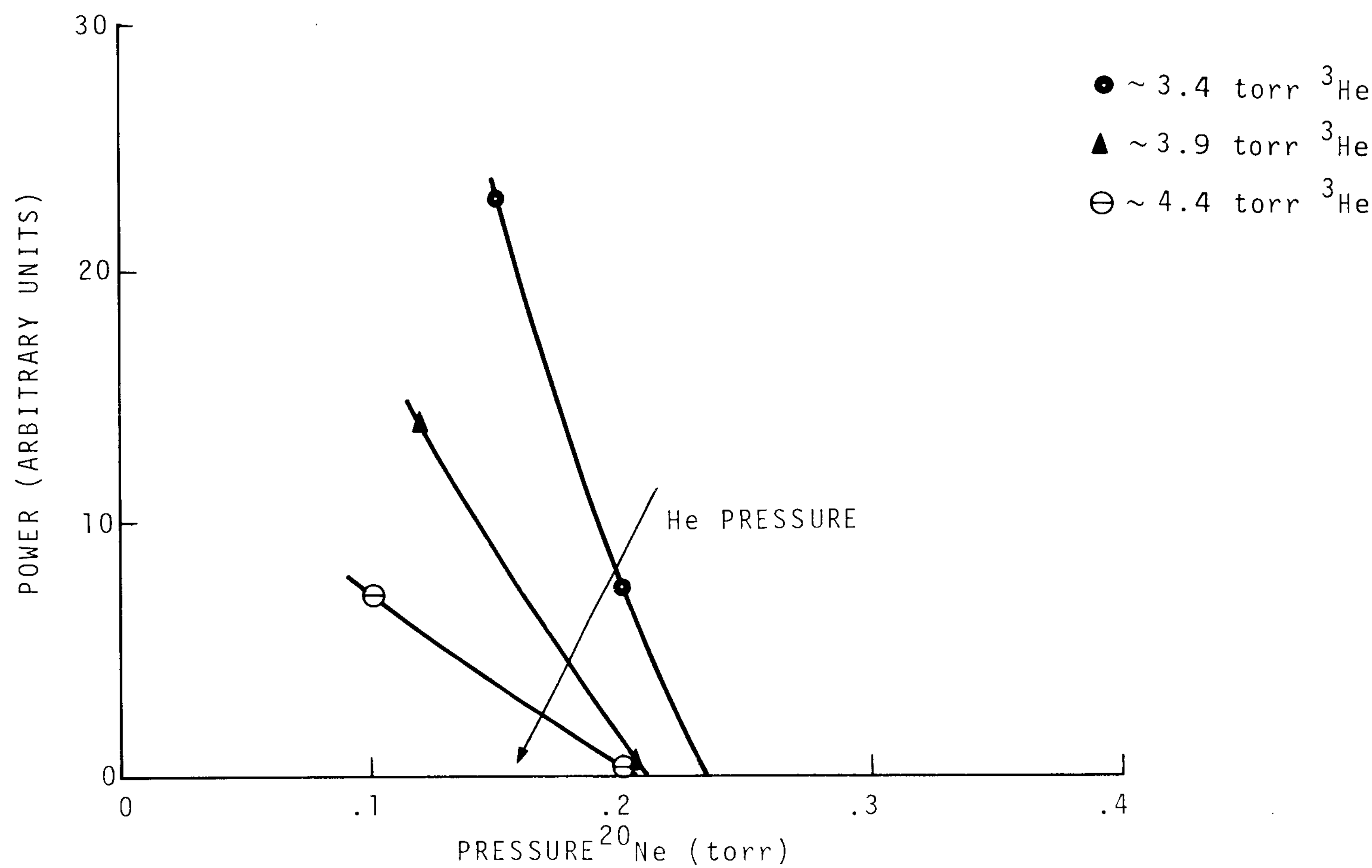


Fig. 9 Power output at threshold of coherent output fluctuations as a function of neon partial pressure.
Capillary size: 3.5 mm
Parameter: Helium partial pressure

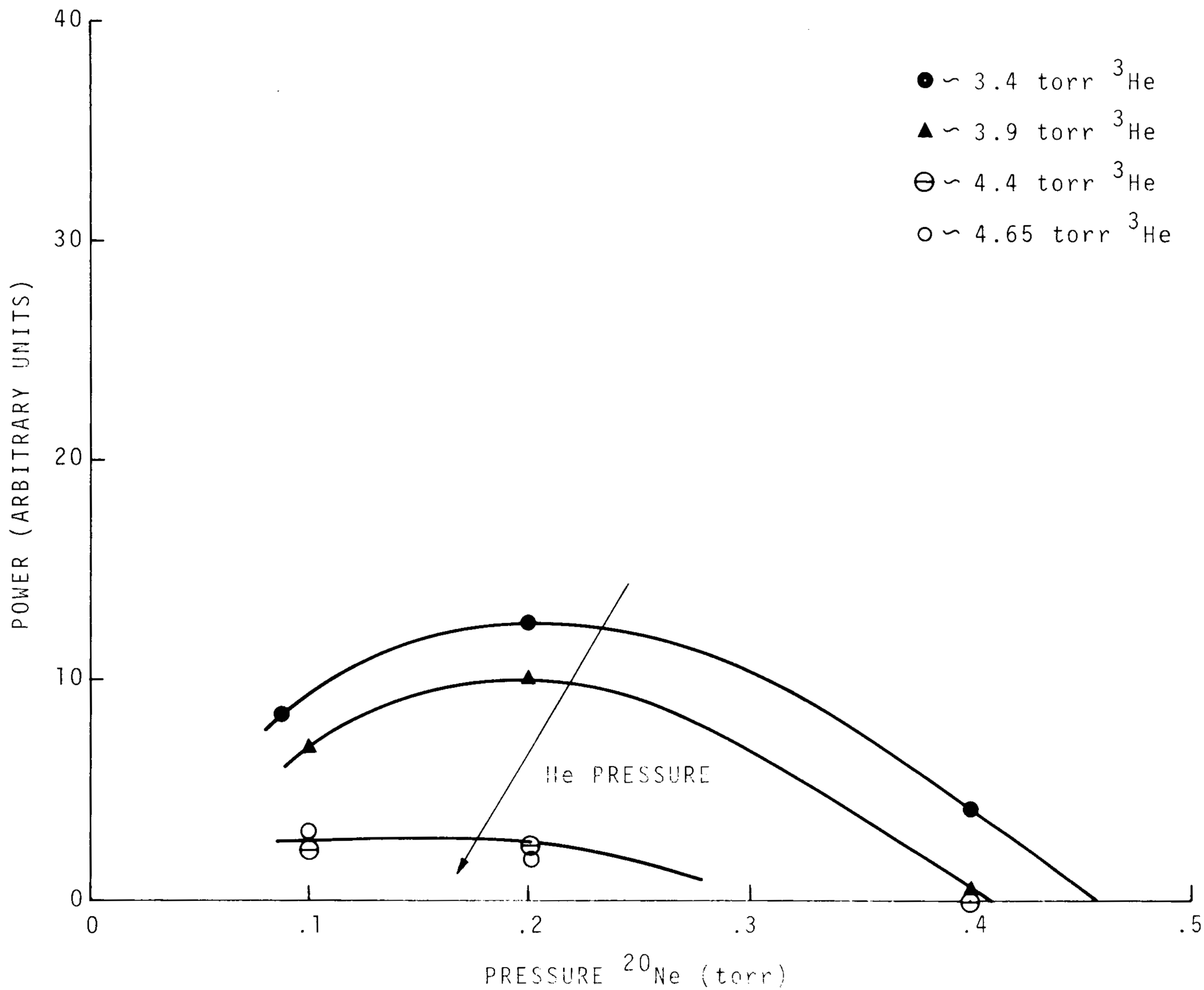


Fig. 10 Power output at threshold of coherent output fluctuations as a function of neon partial pressure.
Capillary size: 4.0 mm
Parameter: Helium partial pressure

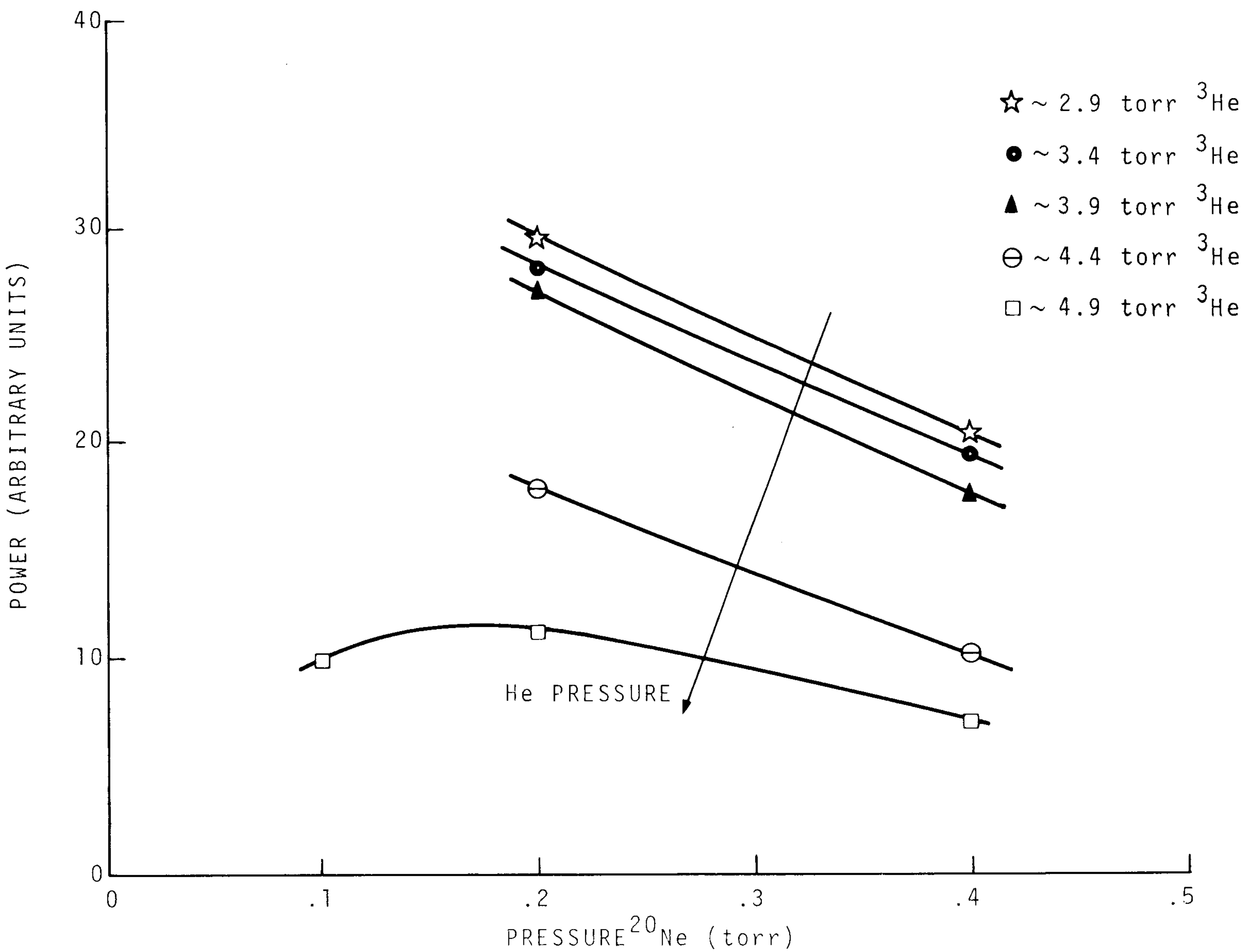


Fig. 11 Power output at threshold of amplitude noise as a function of neon partial pressure.
Capillary size: 2.9 mm
Parameter: Helium partial pressure

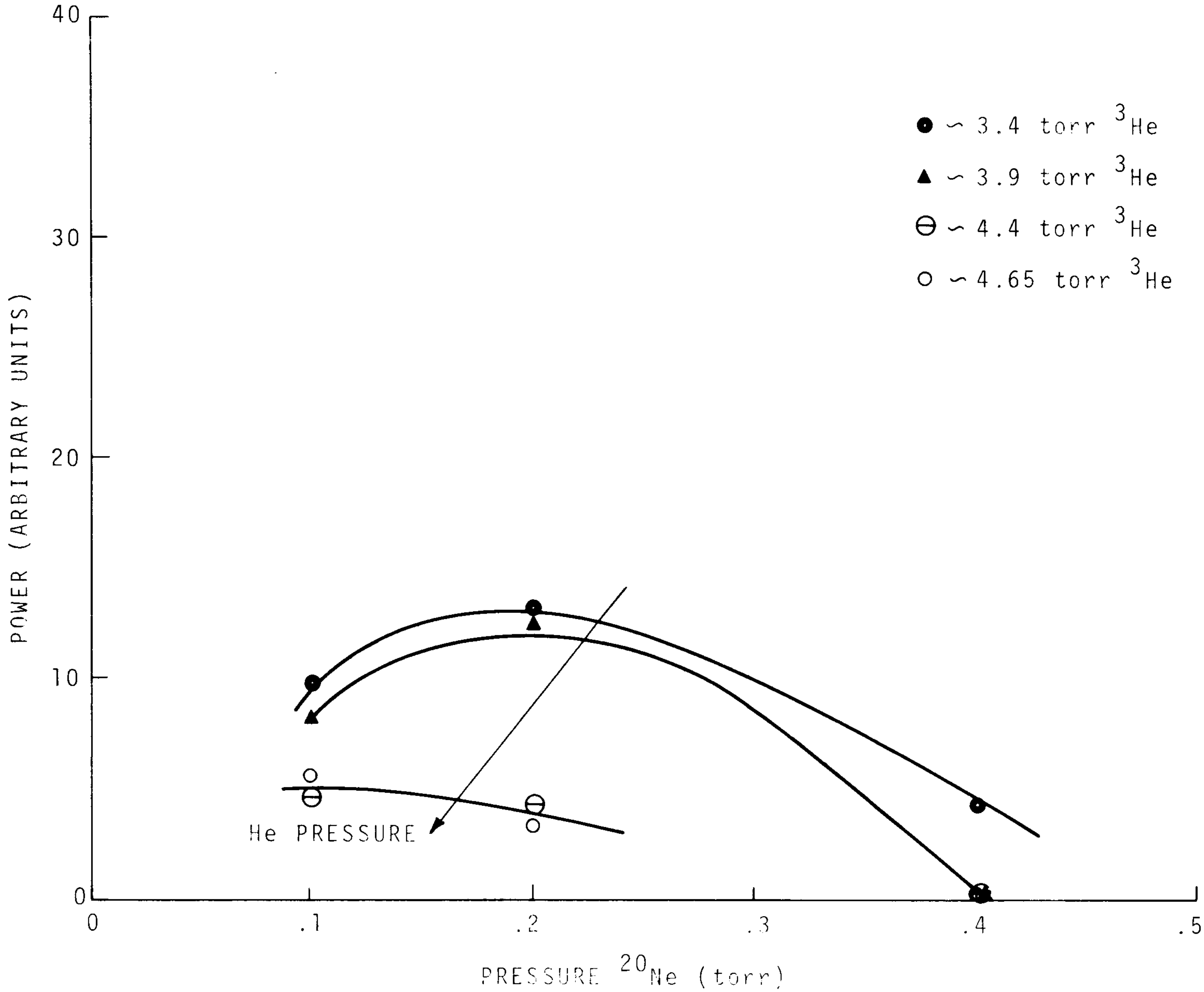


Fig. 12 Power output at threshold of amplitude noise as a function of neon partial pressure.
Capillary size: 4.0 mm
Parameter: Helium partial pressure

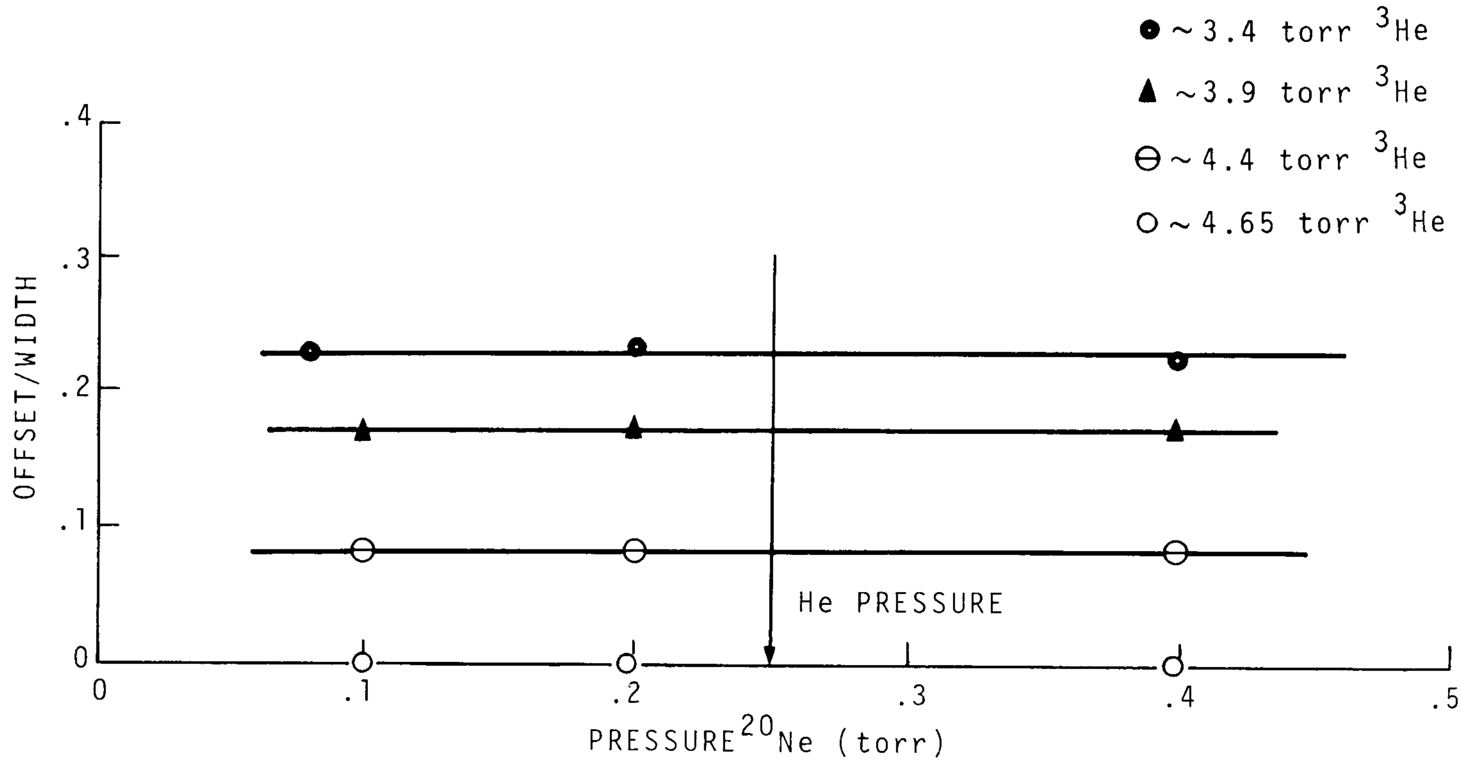


Fig. 13 Normalized offset of line center of CH_4 to center of He-Ne emission profile as a function of neon partial pressure. Plotted on the ordinate is the ratio of the distance separating line centers (offset) to the width of the emission profile. Capillary size: 4.0 mm Parameter: Helium partial pressure

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