AN ACTIVE FILTER FOR THE CARRIER GAS EMISSION OF HIGH CURRENT HOLLOW CATHODES

by

KLAUS SOMMER

A Thesis submitted for the Diploma of Membership of the Imperial College

Department of Physics
Spectroscopy Group
Imperial College of Science
and Technology
London

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I. ABSTRACT

A low pressure (1 - 6 mbar), low current (1 - 10 mA) glow discharge in neon or argon, kept clean by a titanium getter pump, is used as a spectral filter for the carrier gas emission of a high current (100 - 450 mA) iron hollow cathode discharge lamp, running in the same inert gas as the filter discharge.

The reduction of the intensity of lines arising from transitions within the set of $np^5\,(n+1)s - np^5\,(n+1)p$ levels (where n = 2 for Ne and n = 3 for Ar) has been measured for different combinations of pressure and current in both discharges; and the optimum conditions for the efficient operation of the filter have been determined. The intensity of lines arising from transitions to one of the two metastable s-levels could be reduced by a factor of between six and ten.

The results of additional experiments in neon, such as reversal temperature and equivalent width for the filter discharge and relative intensities, line widths, and line shifts for the hollow cathode, are used to calculate the intensity reductions by simulating the radiative transfer problem on a computer.

II. INTRODUCTION

Due to the many feasible ways to construct and operate a hollow cathode lamp and the possibility of using a great variety of materials for the cathode, hollow cathode discharge lamps have been used frequently for a wide range of investigations, ever since their introduction by Paschen /1/ and Schueler /2/ in the 1920's. The high intensity and sharpness of the emitted spectral lines, which makes it a suitable wavelength standard (Crosswhite /3/), and the relative ease of changing the material under investigaton by using different inserts for the hollow cathode are considered as the main advantages. Tolansky /4/ gives a summary of hollow cathode features.

In many cases, the spectrum due to the excitation of the carrier gas (normally one of the inert gases) will be more intense than that of the material which is sputtered inside the hollow cathode, the latter usually being the object of the investigation (Crosswhite /5/). This is in most cases not a serious disadvantage as long as the spectral lines of interest are isolated lines, that is to say at least a few line widths away from the nearest carrier gas line, and a conventional spectrograph or interferometer is used to analyse the spectra, but scattered light can still be a problem with a grating.

In contrast to this, the use of a Fourier transform spectrometer (FTS) means one serious drawback, since the signal-to-noise ratio for the detection is determined by the fact that the magnitude of the white photon noise depends on the total signal detected in the bandwidth interval under investigation (Brault /6/). If the intensity of the carrier gas lines can be reduced relative to the other lines, this will allow one to detect weaker lines in the spectrum of the sputtered material.

It can be expected that this would have a bearing on investigations currently undertaken to increase the knowledge about the spectra of transition metals, such as chromium, nickel, and manganese, in order to unveil less dominant features in stellar spectra, especially that of the sun.

These considerations sparked off the idea of using a low current, low pressure discharge in the same inert gas as is used to run the hollow cathode as an active filter to reduce the intensity of the carrier gas lines in the hollow cathode light, when this is viewed through the filter discharge. The discharge is necessary to populate the lower states of the lines in question which lie some 10-15 eV above the ground state.

The lines I was concerned with are transitions between the first excited state and the next highest; they fall in the red and near infrared part of the electromagnetic spectrum of neon and argon apart from the resonance lines in the vacuum ultra-violet.

From previous work using such discharges in inert gases for absorption and negative dispersion experiments (Ladenburg /7/, Pery-Thorne and Chamberlain /8/), it was concluded that a discharge of about 1 m length and 2 cm diameter, with the electrodes and a getter pump in sidearms so that the positive column could be viewed end-on, would give the best chances of high absorption.

The method chosen to determine the factor by which the total intensity of a particular inert gas line is reduced is now described. The region of bright glow in the hollow cathode discharge was imaged in the middle of the filter discharge and from there onto the slit of a grating spectrograph. The intensity reduction of a line was determined by means of a photomultiplier, measuring once with and once without the filter discharge running. This method allows one to avoid any systematic error arising from instabilities in the hollow cathode, as both measurements can be done directly one after the other. Short term fluctuations with periods less than a tenth of a second were smoothed out by the picoammeter which was used to measure the photomultiplier current. Line scans with the photomultiplier were also possible.

The experimental reduction factors have been compared with those calculated from a simple radiative transfer model and good agreement was found. In order to obtain data for the modelling, a number of subsidiary experiments were performed. The shifts and widths of the hollow cathode lines were obtained photographically using a microdensitometer. The equivalent width and reversal temperature of the filter discharge lines were measured by replacing the hollow cathode lamp by a calibrated tungsten ribbon lamp which provided the necessary continuous background radiation.

Except for the first one, all these experimental methods are frequently used for similar experiments and will be discussed in due course. The somewhat unusual method of measuring 'reduction factors' was dictated by the special purpose of this study.

III. THEORY

1. Radiative Transfer - Emission and Absorption Coefficient

One suitable starting point for the theoretical discussion of the phenomena encountered in this study is the derivation and solution of the equation of radiative transfer in terms of the emission and absorption coefficients.

Consider first the light from a background source of intensity $I(\nu,x=0)$ $(=:I_o(\nu))$ being passed through an absorbing slab of excited gas; ν is the frequency and x the distance along the axis of propagation. The incident beam is considered to be collimated and is thus confined to the solid angle $d\Omega$. Furthermore, the incident radiation is assumed to be unpolarized and of a frequency close to an absorption line in the layer of gas.

The equation of radiative transfer can be obtained by considering the change in the radiant energy in the frequency interval $d\nu$, per time interval dt, as the beam passes through a cylindrical volume-element of cross-section dS and length dx. For dx << 1, the change in intensity is described by

$$(I(\nu,x+dx)-I(\nu,x))\; dS\, d\nu\, d\Omega\, dt = \frac{dI(\nu,x)}{dx}\, dx\, dS\, d\nu\, d\Omega\, dt \tag{1.1}$$

The energy absorbed from the beam as it passes through the volume element is given by the product of the energy of one photon and the number of upward transitions occurring in the time interval dt. If there are $N_1(x)$ atoms per unit volume in the lower state l at the position x in the absorbing cell, we can write

$$E_{absorbed} = h\nu \; N_l(x) \; B_{lu} \; L(\nu) \; I(\nu,x) \; dS \; d\nu \; dx \; \frac{d\Omega}{4\pi} dt \qquad (1.2)$$

The line shape function $L(\nu)$ describes the frequency response of the absorbing atoms and the term $\frac{d\Omega}{4\pi}$ takes account of the fact that we are considering transitions induced by a collimated beam.

Due to spontaneous and induced emission, the atoms in the absorbing cell will not only absorb radiation from the incident beam, but will also emit radiation into the beam. The emitted energy per solid angle $d\Omega$, frequency interval $d\nu$, and time interval dt is given by

$$E_{emitted} = h\nu \; N_u(x) \; A_{ul} \; L(\nu) \; dS \; d\nu \; dx \; \frac{d\Omega}{4\pi} dt \; +$$
$$+ \; h\nu \; N_u(x) \; B_{ul} \; L(\nu) \; I(\nu,x) \; dS \; d\nu \; dx \; \frac{d\Omega}{4\pi} dt \qquad (1.3)$$

Using Equs. 1.2 and 1.3 in Equ. 1.1, the equation of radiative transfer becomes

$$\frac{dI(\nu,x)}{dx} = \frac{d\Omega}{4\pi} \left(A_{ul}N_u(x) + (B_{ul}N_u(x) - B_{lu}N_l(x)) \; I(\nu,x)\right) \; L(\nu)$$

Using $g_u B_{ul} = g_l B_{lu}$ (g_u and g_l are the statistical weights of the upper and the lower level respectively), we can define the emission and the absorption coefficients $\varepsilon(\nu,x)$ and $\varkappa(\nu,x)$ as

$$\varepsilon(\nu,x) = \frac{h\nu}{4\pi} \; A_{ul} \; N_u(x) \; L(\nu) \qquad (1.4)$$

$$\varkappa(\nu,x) = \frac{h\nu}{4\pi} B_{lu} N_l (x) \left(1 - \frac{g_l N_u(x)}{g_u N_l(x)} \right) L(\nu) \tag{1.5}$$

This allows one to rewrite the equation of radiative transfer as

$$\frac{dI(\nu,x)}{dx} = \varepsilon(\nu,x) - \varkappa(\nu,x) I(\nu,x) \tag{1.6}$$

Once the emission and the absorption coefficients of the gas are specified as functions of frequency and position, this equation can be solved and the intensity at any frequency and any position can be calculated. We will now do so for the especially simple case of a homogeneous absorption cell, for which N_u, N_l, $L(\nu)$, and hence also ε and $\varkappa$ are independent of position.

Multiplying Equ. 1.6 by $e^{-\varkappa(\nu) x}$ and integrating over x from 0 to l, the length of the absorbing cell, yields

$$I(\nu,l) = I_o(\nu) e^{-\varkappa(\nu) l} + \frac{\varepsilon(\nu)}{\varkappa(\nu)} \left(1 - e^{-\varkappa(\nu) l} \right) \tag{1.7}$$

The ratio $\frac{\varepsilon(\nu)}{\varkappa(\nu)}$ is known as the source function S_ν, and the product $\varkappa(\nu) l$ is called the optical thickness, sometimes designated as τ. The latter determines the amount by which the intensity of the incident beam is attenuated as it passes through the absorbing cell. In the general case, where $\varkappa(\nu)$ is also a function of the position, the optical depth is given by

$$\tau(l) = \int_o^l \varkappa(\nu,x) \, dx$$

An optical depth of about one means that a photon either incident or emitted at one end of the absorbing cell has a fair chance (~37%) to reach the other end. A cell with $\tau \ll 1$ is called optically thin and if $\tau \gg 1$, it is called optically thick.

To apply Equ. 1.7 to the problem under consideration in this study, both sides are integrated over the whole line being investigated to give

$$\int_{line} I_1(\nu)d\nu = \int_{line} (I_o(\nu)\; e^{-\varkappa(\nu)\,l})d\nu + S_\nu \int_{line} (\,1 - e^{-\varkappa(\nu)\,l})d\nu$$

Introducing the line shape function $L_{h.c.}(\nu)$ for the distribution of the incident light (the index 'h.c.' is chosen, because this will be the hollow cathode emission) and $L'_{f.d.}(\nu)$ for the distribution of the absorbing cell ('f.d.' for filter discharge) allows one to rewrite the above equation as

$$\int_{line} I_1(\nu)\; d\nu = \int_{line} (\; I_o\; L_{h.c.}(\nu)\; e^{-\varkappa_o\, L'_{f.d.}(\nu)\; l}\;)\; d\nu \; + $$
$$+ \; S_\nu \int_{line} (\; 1 - e^{-\varkappa_o\, L'_{f.d.}(\nu)\; l}\;)\; d\nu \qquad (1.8)$$

where the following expressions were used for substitution

$$\varkappa(\nu) = \varkappa_o\; L'_{f.d.}(\nu) \qquad (1.9)$$

$$I_o(\nu) = I_o\; L_{h.c.}(\nu) \qquad (1.10)$$

In this special case it is convenient to think of the hollow cathode line shape function as being normalized to unit area, so that $\int_{line} L_{h.c.}(\nu)\; d\nu = 1$, while the filter discharge line shape function shall be normalized to ordinate one at line centre, i.e. $L'_{f.d.}(\nu_o) = 1$. Using these definitions, I_o

is the total intensity of the hollow cathode line ($= \int_{line} I_o(\nu)\, d\nu$) , while $\varkappa_o$ is the peak value of the absorption coefficient; multiplying $\varkappa_o$ by l yields the peak optical depth τ_o. Dividing Equ. 1.8 by $\int_{line} I_o(\nu)\, d\nu$ leads to

$$\frac{\int_{line} I(\nu)\, d\nu}{\int_{line} I_o(\nu)\, d\nu} = \frac{I_o \int_{line} \left(L_{h.c.}(\nu)\, e^{-\varkappa_o L'_{f.d.}(\nu)\, l} \right) d\nu}{\int_{line} I_o(\nu)\, d\nu} + \frac{S_\nu \int_{line} \left(1 - e^{-\varkappa_o L'_{f.d.}(\nu)\, l} \right) d\nu}{\int_{line} I_o(\nu)\, d\nu} \qquad (1.11)$$

This equation gives the ratio of the total intensity of the line under consideration after passing through the absorbing cell to the total intensity of the same line without an absorption.

For convenience, the reduction factor RF of a spectral line is now introduced as the reciprocal of the expression in Equ. 1.11. The relevant form of the solution of the equation of radiative transfer for this problem then finally becomes

$$\frac{1}{RF} = \int_{line} \left(L_{h.c.}(\nu)\, e^{-\varkappa_o L'_{f.d.}(\nu)\, l} \right) d\nu + \frac{S_\nu}{I_o} \int_{line} \left(1 - e^{-\varkappa_o L'_{f.d.}(\nu)\, l} \right) d\nu \qquad (1.12)$$

The elements of this equation will now be discussed in detail.

2. The Hollow Cathode Line Shape - Line Broadening Effects

The hollow cathode line shapes are determined by several different effects leading to broadening and shift of the lines. They can be divided into three groups, namely those leading to, first, a Gaussian line shape, second, a Lorentzian line shape, and third, a line shape which is neither Gaussian nor Lorentzian.

The broadening effect commonly dominant in lines emitted by low-density plasmas like the one in the hollow cathode is Doppler broadening, arising from the thermal motion of the emitting atoms and the wavelength shift of each emitted wavetrain due to the Doppler effect. Since the Doppler width $\Delta\lambda_D$ (FWHM), given by

$$\Delta\lambda_D = \lambda_o \sqrt{8 \ \ln 2 \ \frac{R\,T}{Mc^2}} \approx \lambda_o \ 7.16 \sqrt{\frac{T}{M}} \qquad (2.1),$$

is a function of the gas kinetic temperature T and the mass M of the emitters, the determination of the temperature is the major difficulty in estimating the Doppler width. The fact that the square-root dependence makes the Doppler width relatively insensitive to small changes in temperature simplifies the problem slightly.

Doppler broadening leads to spectral lines of Gaussian shape which can be expressed analytically as a function of the distance from the line centre $(\lambda-\lambda_o)$, with the line width $\Delta\lambda_G$ as the only parameter

$$I = I_o \, e^{-\left(2\sqrt{\ln 2}\left(\frac{\lambda-\lambda_o}{\Delta\lambda_G}\right)\right)^2} \qquad (2.2)$$

Using $\beta_G = \frac{2\sqrt{\ln 2}}{\Delta\lambda_G}$ one can rewrite Equ. 2.2 as

$$I = I_o \, e^{-\left(\frac{\lambda-\lambda_o}{\Delta\lambda_G}\right)^2}$$

or with $$x = \frac{\lambda-\lambda_o}{\Delta\lambda_G} \qquad (2.3)$$

$$I = I_o \, e^{-x^2} \qquad (2.4)$$

Natural broadening belongs to the group of line broadening effects which lead to Lorentzian line shapes, but is negligibly small for the hollow cathode lines. The natural lifetimes of all ten $2p^5$ 3p levels in neon are approximately equal to $2\ 10^{-8}$ sec (Bridges and Wiese /9/), leading to natural line widths of typically a tenth of a milliangstrom (FWHM), according to

$$\Delta\nu = \frac{1}{2\pi\tau} \qquad \text{and} \qquad \Delta\lambda = \frac{\lambda^2}{c}\,\Delta\nu$$

A Lorentzian line shape can be described by

$$I(\lambda) = I_o \frac{1}{1 + \left(\frac{2\,(\lambda-\lambda_o)}{\Delta\lambda_L}\right)^2} \qquad (2.5).$$

Using $\beta_L = \frac{1}{2}\Delta\lambda_L$ we can rewrite Equ. 2.5 to get

$$I(\lambda) = I_o \frac{1}{1 + \left(\frac{\lambda-\lambda_o}{\beta_L}\right)^2} \qquad (2.6)$$

Another effect leading to Lorentzian line shapes is more important for this case, namely Stark broadening by electron impact. This is the dominant form of pressure broadening in a low pressure discharge. Theoretical calculations based on this assumption are within 20% agreement with the results of most experiments (Griem /10/).

This is also true for the line shifts due to the Stark effect, although far fewer experiments have been carried out on shift than on width measurements. As both width and shift scale with the electron density only, using for instance Griem's tables /10/, line shift measurements can be employed to determine the electron density; and hence the corresponding pressure broadening width can be estimated.

If line broadening effects which produce Gaussian and Lorentzian line shapes occur simultaneously, this leads to a combined line shape which is a Voigt profile and which can be described by

$$V(x) =: I(x) = I_o \frac{a}{\beta_D \pi^{1.5}} \int_{-\infty}^{+\infty} \frac{e^{-y^2}}{(x-y)^2 + a^2} \, dy \qquad (2.7),$$

which is in fact a convolution of the Gaussian and Lorentzian profiles in Equs. 2.4 and 2.6 . x is again the distance from line centre in the same terms as in Equ. 2.3, and the other parameter a, called the damping ratio, is essentially the ratio of the Lorentzian and Gaussian widths

$$a = \sqrt{\ln 2} \; \frac{\Delta\lambda_L}{\Delta\lambda_G} = \frac{\beta_L}{\beta_G} \qquad .$$

Consequenntly a = 0 for a pure Gaussian and a = ∞ for a pure Lorentzian profile.

If several contributions to either the Lorentzian or the Gaussian distribution are important, the combined half widths can be calculated according to

$$\beta_{L,tot} = \sum_n \beta_{L,n} \quad \text{and} \quad \beta_{G,tot} = \sum_n \beta^2_{G,n} \qquad (2.8).$$

If a Voigt profile is used in a calculation, the problem arises that Equ. 2.7 cannot be integrated analytically. Three ways to tackle this are conceivable. Either a numerical integration of the convolution integral must be attempted, or tabulated values, such as for example those by Davies and Vaughan /11/, can be used. The third possibility is to employ analytical approximations for the Voigt function, which can be found for different levels of accuracy (Armstrong /12/, Landheer and Durant /13/, Kielkopf /14/, Jon-Sen Lee /15/).

Another effect which should be mentioned in this context is the isotope shift. It is due to the fact that the corresponding electronic levels of different isotopes have slightly different energies, because the nuclei have different mass, size, and shape. Since different levels are shifted by different amounts, the corresponding lines of two isotopes are slightly displaced from one another.

There are three different effects which are important in different parts of the periodic system. The 'normal mass shift', due to different reduced masses $\mu = \frac{m_e M}{m_e + M}$ of the electrons in different isotopes, leads to a shift of spectral lines of

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta\nu}{\nu} = \frac{\Delta\mu}{\mu} = \frac{m\,\Delta M}{M^2}$$

and is only important in the first half of the periodic system, because of its $1/M^2$- dependence. This is also true for the 'specific mass shift', which arises from correlations of the motion of electron pairs and can neither easily nor reliably be calculated. It should be noted that both effects lead to the lines of the heavier isotopes being blue-shifted.

For heavy elements, the 'field effect' becomes dominant. This is due to the change in the charge distribution for different composition of the nuclei, arising from different sizes and shapes of the nuclei. This leads to a variation in the interaction with those electrons, which have a significant probability of being found inside the nucleus, namely the s- and $p_{1/2}$- electrons. Field shifts can be as high as 1.7 cm^{-1} (Mayer-Kuckuk /16/).

In the case of neon, for which the field effect is negligible (Keller /17/), accurate measurements of the ^{22}Ne-^{20}Ne mass shifts are available (Odintsov /18/). For the neon lines of interest, Odintsov has found line shifts of about 25 mÅ.

If the lines shifted by the isotope effect are resolved, this results in a number of slightly shifted lines of intensities corresponding to the abundances of the isotopes. If, however, the isotope shifts are of the order of the line width, the observed profile of the most abundant isotope will become asymmetric through the contribution from other isotopes. It is clear that in such a case it may be difficult or impossible to find the centre of the spectral lines of all isotopes, especially if the lines from less abundant isotopes lead to an apparent shift of the profile maximum of the dominant line.

Another effect which can seriously influence an observed line shape is known as self-absorption or radiation trapping. This is not due to influences occurring when the light is first emitted by an atom, but arises from the re-absorption of light inside the emitting slab of gas, before it can leave the slab, by atoms of the same species as the emitting ones. For this to happen in a homogeneous layer, the optical depth at line centre of the emitting cell has to be greater than about 0.2, which can be due to either a long cell or a high absorption coefficient. The latter is often the case when the lower state of the transition giving rise to the spectral line is a metastable, resonance, or ground level. Since the effects of self-absorption are greatest at line centre (where the absorption coefficient is greatest), the peak intensity of the emission line is reduced, leading to an apparently greater line width.

If the emitting cell is not homogeneous, which usually means that there is a negative temperature gradient towards the boundaries, the stronger absorption in the cooler outer layers can even lead to dips occurring in the centre of the line. This is then called self-reversal.

There is no easy way to describe the profile of a self-absorbed or self-reversed line, but, if self-absorption/reversal is relatively weak, increasing the width of the Gaussian contribution to the Voigt profile used to describe the line will account for the broadening of the core at least in an approximate way. This can be explained as follows. In those frequently occurring cases where the damping constant a is fairly small, the central part of a line will be dominated by the Gaussian component, which has a compact core and wings which drop rapidly with increasing distance from the line centre. In contrast to this, the wings of the Lorentzian component fall off much more slowly and hence dominate the line shape in the wings. As these wings are much less affected by self-absorption or self-reversal, the Lorentzian component must remain unchanged when correcting for these effects.

3. The Reversal Temperature of an Absorption Line

The reversal temperature of a spectral line in an excited gas is usually found by observing the line against a background of continuous radiation. The temperature of the background source is changed until the spectral line just disappears in the continuous spectrum, i.e. cannot be observed as either an emission or an absorption line. The temperature of the background source at which this occurs is called the reversal temperature T_R of the line.

It may be assumed that the reversal temperature determines the population ratio of the two atomic levels involved, according to Boltzmann's Equation

$$\frac{N_u}{N_l} = \frac{g_u}{g_l} \; e^{-\left(\frac{E_u - E_l}{k \, T_R} \right)} \qquad (3.1).$$

Thus, for a source in thermal equilibrium, the reversal temperature for all spectral lines should be the same. On the other hand it must be stressed that the filter discharge discussed here is certainly not in thermal equilibrium, and the reversal temperature is therefore purely a convenient measure of N_u/N_l.

4. The Filter Discharge Line Shape - Equivalent Width

The filter discharge line shape function is, generally speaking, determined by the same effects as the hollow cathode line shape, but with different weighing of the effects. Again, Doppler broadening will be dominant, but this time pressure broadening like natural broadening will only be important for the line shape in the far wings. This question is discussed comprehensively in Chapter VII.

Obviously, if a theoretical calculation of the results of the experiments described in this thesis is to be attempted, the quantity $\varkappa_o\, l\, L'_{f.d.}(\nu)$ which appears in Equ. 1.12 must be determined. This time, $L'_{f.d.}(\nu)$ does not represent a severe problem, as reasonable estimates for all broadening effects can be made (see again Chapter VI).

The situation with respect to the determination of the peak optical depth $\tau_o = \varkappa_o l$ is more complicated. To explain this, let us go back to Equ. 1.7 . Neglecting emission from the absorbing cell for the time being, we rewrite it here as

$$I(\nu,l) = I(\nu,x{=}0)\; e^{-\varkappa(\nu)\; l} \qquad (4.1).$$

Thus, in an absorption experiment with a known intensity distribution of the incident light $I(\nu,x{=}0)$, the absorption coefficient $\varkappa(\nu)$ can be determined from the observed absorption profile using

$$\varkappa(\nu) = -\ln\left(\frac{I(\nu,0)}{I(\nu,l)}\right)$$

For this to be a feasible method, the line has to be completely resolved by the instrument used. Otherwise, contributions to the observed line due to the instrumental profile have to be taken account of by the assumption that the observed profile is a convolution of the actual profile and a known instrumental profile.

This disadvantage can be overcome by using the concept of equivalent width. Let us assume that the intensity incident on the absorbing slab is constant over the whole absorption line. Then, the absorption profile will be a dip in the otherwise constant intensity distribution of, for example, a tungsten filament lamp or a high pressure arc. If the intensity of the background continuum is I_o, the equivalent width W_ν is defined as the width of a rectangle of height I_o and the same area as the dip. Expressing this mathematically leads to the equation

$$W_\nu I_o = \int_{\text{line}} (I_o - I(\nu,l)) \, d\nu$$

or

$$W_\nu = \int_{\text{line}} \left(1 - \frac{I(\nu,l)}{I_o} \right) d\nu \quad ,$$

where the integral is taken over the whole absorption line. Substituting Equ. 4.1 yields

$$W_\nu = \int_{\text{line}} (1 - e^{-\mathcal{K}(\nu)\, l}) \, d\nu \qquad (4.2).$$

It has been shown that W_ν is independent of the instrumental width for all practical purposes.

In an actual experiment, one has to bear in mind that the absorbing medium might itself emit light and that the measured equivalent widths have to be corrected for this finite emission.

If we assume a background intensity per frequency interval I_o and a filter discharge intensity $I_{f.d.} L(\nu)$, where $L(\nu)$ is the line shape function such that $\int_{\text{line}} L(\nu) \, d\nu = 1$, the apparent equivalent width W'_ν obtained in the usual way is

$$W'_\nu = \int_{line} \frac{I_o - (I_o e^{-\mathcal{K}(\nu)\, l} + I_{f.d.} L(\nu))}{I_o} d\nu \qquad ,$$

since for a band of $\delta\nu$, $I_o \delta\nu$ and $(I_o e^{-\mathcal{K}(\nu) l} + I_{f.d.} L(\nu))\delta\nu$ are the signals without and with the filter respectively. Therefore,

$$W'_\nu = \int_{line} (1 - e^{-\mathcal{K}(\nu)\, l})\, d\nu - \frac{I_{f.d.}}{I_o} \int_{line} L(\nu)\, d\nu \qquad .$$

The first term on the right is the true equivalent width W_ν.

We can now write $I_o = B_o(\nu, T)$, where B_o is the black-body function for the background source at temperature T, and

$$I_{f.d.} L(\nu) = B_o(\nu, T_R)\ (1 - e^{-\mathcal{K}(\nu)\, l}) \qquad ,$$

where $B_o(\nu, T_R)$ is the source function for the line, which can be taken as a black-body function at the reversal temperature T_R, since this simply describes the equilibrium between the upper and the lower states. Therefore,

$$I_{f.d.} \int_{line} L(\nu)\, d\nu = B_o(\nu, T_R) \int_{line} (1 - e^{-\mathcal{K}(\nu)\, l})\, d\nu$$

by definition of W_ν. Therefore,

$$W'_\nu = W_\nu - \frac{B_o(\nu, T_R)}{B_o(\nu, T)} W_\nu$$

$$W'_\nu = W_\nu \ (1 - \frac{e^{-h\nu/kT_R}}{e^{-h\nu/kT}}) \qquad (4.3).$$

As an example, we find $W'_\nu = 1.21\ W_\nu$ for a spectral line at $\lambda = 6200$ Å with $T_R = 2150$ K and $T = 2570$ K.

There is a variety of ways to find $\varkappa(\nu)$ from an observed equivalent width and the most important ones will be reviewed briefly now. By far the simplest situation is encountered if the absorbing cell is optically thin, i.e. $\varkappa(\nu)1 << 1$, over the whole profile, so that the exponential in Equ. 4.2 can be expanded as

$$e^{-\varkappa(\nu)\ 1} = 1 - \varkappa(\nu)\ 1 + \ldots$$

to give

$$W_\nu = 1 \int_{line} \varkappa(\nu)\ 1\ d\nu \qquad (4.4),$$

or in the notation of Equ. 1.9

$$W = 1\, \varkappa_o \int_{line} L(\nu)\ d\nu \qquad .$$

This means that the experimental width is a direct measure of the integral of the absorption coefficient taken over the whole line. Thus, if $L(\nu)$ is known, $\varkappa(\nu)$ is determined. It is also possible to substitute Equ. 1.5 in Equ. 4.4 and we obtain

$$W = \frac{h\nu_o}{4\pi} B_{1u}\, N_1\, 1\, \left(1 - \frac{g_1 N_u}{g_u N_1} \right) \int_{line} L(\nu)\ d\nu \qquad (4.5).$$

Consequently, if $\frac{g_1 N_u}{g_u N_1}$ is known, for instance from reversal temperature measurements or can be assumed to be much less than one anyway, the number of atoms in the lower state per unit volume can be calculated using tabulated f-values to calculate B_{1u}. On the other hand, knowledge of N_1 allows one to calculate the f-values.

As the optical depth increases, the expansion of the exponential in Equ. 4.2 can no longer be terminated after the second term and the complete expression for the equivalent width must be used. It is only in the case where $L(\nu)$ is a pure Gaussian profile that the problem can be tackled for all optical depths in a fairly simple way. If we expand the exponential, we obtain

$$W_\nu = \int_{\text{line}} \left(\varkappa(\nu) l - \frac{(\varkappa(\nu) l)^2}{2!} + \frac{(\varkappa(\nu) l)^3}{3!} - + \dots \right) d\nu$$

Using $\varkappa(\nu) = \varkappa_o \, e^{-\omega^2}$ with $\omega = 2\sqrt{\ln 2}\,\frac{\nu - \nu_o}{\Delta\nu_G}$

we can write

$$W_\nu^G = \frac{\Delta\nu_G}{2\sqrt{\ln 2}} \int_{\text{line}} \left(\varkappa_o l \, e^{-\omega^2} - \frac{(\varkappa_o l)^2}{2!} e^{-2\omega^2} + \frac{(\varkappa_o l)^3}{3!} e^{-3\omega^2} - + \dots \right) d\omega$$

since $\frac{d\omega}{d\nu} = \frac{2\sqrt{\ln 2}}{\Delta\nu_G}$. Introducing the peak optical depth

$\tau_G = \varkappa_o^G \, l$ we obtain

$$W_\nu^G = \frac{\Delta\nu_G}{2\sqrt{\ln 2}} \sum_{n=1}^{\infty} \left\{ (-1)^{n+1} \frac{\tau_G^n}{n!} \int_{\text{line}} e^{-n\omega^2} \, d\omega \right\}$$

With $$\int_{-\infty}^{\infty} e^{-n\omega^2} \, d\omega = \frac{1}{\sqrt{n}} \int_{-\infty}^{\infty} e^{-n\omega^2} \, d(\sqrt{n}\,\omega) = \sqrt{\frac{\pi}{n}}$$

we finally find $$W_\nu^G = \frac{\Delta\nu_G \sqrt{\pi}}{2\sqrt{\ln 2}} \, \tau_G \sum_{n=1}^{\infty} (-1)^{n+1} \frac{\tau_G^n}{n!\,\sqrt{n}}$$

or
$$W_\nu^G = \frac{1}{2}\sqrt{\frac{\pi}{\ln 2}}\ \Delta\nu_G\ \tilde{\tau}_G\ \left\{ \sum_{n=1}^{\infty} (-1)^{n+1} \frac{\tilde{\tau}_G^{\,n-1}}{n!\ \sqrt{n}} \right\}.$$

Calling the terms in curly brackets S_G yields

$$W_\nu^G = \frac{1}{2}\sqrt{\frac{\pi}{\ln 2}}\ \Delta\nu_G\ \tilde{\tau}_G\ S_G \quad .$$

Thus, if W_ν^G is known from the experiment, $\tilde{\tau}_G S_G$ can be calculated. Finally, to find $\tilde{\tau}_G$, either tables of $\tilde{\tau}_G$ and $\tilde{\tau}_G S_G$ (see for example Ladenburg and Levy /19/) or a computer iteration of S_G in $\tilde{\tau}_G$ can be used.

If the line shape function is not a pure Gaussian, the Voigt function is frequently used, but, as was mentioned above, the Voigt function cannot be integrated analytically, so that the mentioned numerical approximations have to be employed in calculations to let

$$\varkappa(\nu) = \varkappa_o\ V'(\nu)$$

Thus, again, if $V'(\nu)$ is either known or can be confidently estimated, $\varkappa_o l$ can be found from iteration of Equ. 3.4 .

In special situations, various authors have expanded the exponential in Equ. 3.4 to third or fourth order and expressed $\varkappa_o l$ as a series in W_ν and derived approximate analytical expressions for $\varkappa_o l$ as a function of W_ν (see for example Hill /20/). But these approximations are only asymtotic for small optical depths or large damping constants and thus cannot be used in cases with strong absorption by mainly Gaussian shaped lines.

If the absorbing medium is optically thick, again, a simple relation between W_ν and $\varkappa_o l$ can be found. Once the Doppler core of the line is completely absorbed, further increases in the absorption can be ascribed entirely to the Lorentzian wings, which allows one to derive

$$W_\nu = \sqrt{\frac{e^2}{2\varepsilon_o mc} \quad \Delta\nu_L \; N_l \; f_{lu} \; l} \quad .$$

What has been said about Equ. 4.5 applies here as well, allowing one to find $\varkappa_o$ from W_ν. There are also publications available, which give plots of the curves of growth (e.g. Yamada /21/).

5. Influence of the Instrumental Profile on an Observed Line Profile

The theoretical resolving power R of a grating spectrograph is given by the product of the number of grooves N, used to form the spectral image, and the order n in which the spectral line is observed

$$R = n\,N \qquad (5.1).$$

The minimum wavelength difference for two spectral lines at wavelength λ to be clearly identified as separate is given by

$$\Delta\lambda_R = \frac{\lambda}{R} \qquad (5.2),$$

by Rayleigh's criterium. If either emission or absorption line shapes are analysed, it is only in those cases, where $\Delta\lambda_R$ in Equ. 5.2 is much smaller than the intrinsic line width, that no corrections for the distortion of the intrinsic profile by the instrumental profile have to be made. Otherwise the following points have to be considered.

In many cases, the assumption that the instrumental profile is a Gaussian has been justified experimentally (/22/, /23/). This is not surprising as the following considerations show. In an ideal case, the instrumental profile should be the diffraction pattern of a single slit of width d convoluted with the diffraction pattern of the grating. The first has the form

$$I = I_o \left(\frac{\sin\alpha}{\alpha} \right)^2 \quad \text{with} \quad \alpha = \frac{\pi d}{\lambda} \sin\varphi \quad \text{where } \varphi \text{ is}$$

the angular spread from the maximum or, since φ is small, $\alpha = \frac{\pi d}{\lambda}\varphi$. The factor $x =: \frac{d}{\lambda}\varphi$ is the path difference between the limitting rays of the beam of light passing through the slit under an angle φ (see Fig. 5.1) expressed as the number of slit widths d in terms of the wavelength λ, where the sinc^2-function is to be evaluated. Thus, if the intensity distribution shall be expressed as a function of the distance from line centre in terms of d, we introduce

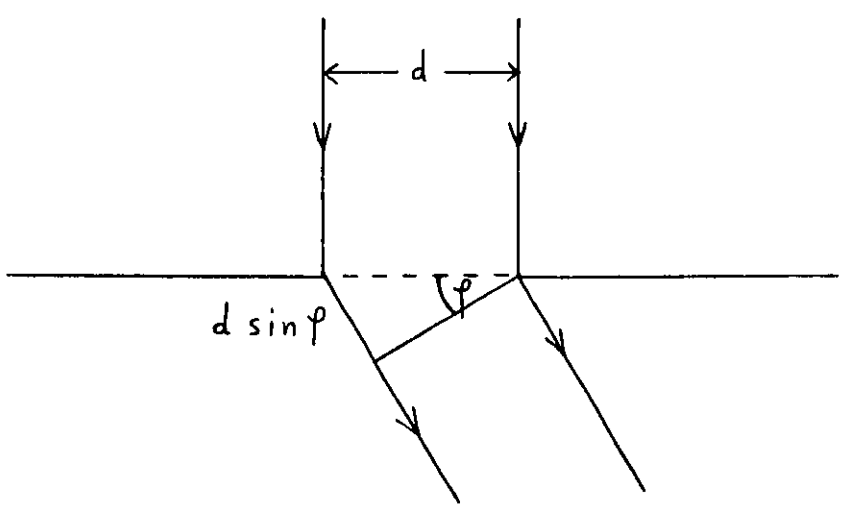
$$I = I_o \left(\frac{\sin \pi x}{\pi x} \right)^2 \qquad (5.3)$$

as a suitable representation. A Gaussian as a function of the same variable x, with the same peak height I_o, must have the form

$$I = I_o \, e^{-(x/c)^2} \qquad (5.4),$$

where c is a constant which has to be chosen so that Equs. 5.3 and 5.4 show as similar a dependence on x as possible.

Fig 5.1: A beam of light passing through a single slit.



A good choice is c = 0.52, which makes the ordinates at x = 0.5 d the same. From Table 5.1 and Fig. 5.2 one can see that up to x = 0.65 away from the line centre, the difference in ordinate between the two functions remains below 10%, but further outwards, the basically different behaviour of the two functions becomes obvious: the sinc^2-function goes through zero for x = 1, while the Gaussian never reaches the abscissa.

Certainly, the Gaussian is a good choice to describe the complete instrumental function, as experiments have shown, but sometimes Lorentzian wings may have to be assumed to dominate the regions far away from the line centre (/23/).

Using this result, the half width of an observed Voigt profile can be corrected for instrumental errors by decreasing the width of the Gaussian component with parameter $\beta_{obs} = \frac{1}{2\sqrt{\ln 2}} \Delta\lambda_{obs}$ by the width of an instrumental Gaussian which has as parameter the square root of the quadratic sum of the parameters of the slit Gaussian (β_{slit} = 0.52 d i.l.d. , with 'i.l.d.' being the inverse linear dispersion of the spectrograph, here 1Å/mm) and the grating Gaussian ($\beta_{grating} = \frac{1}{2\sqrt{\ln 2}} \Delta\lambda_R$) :

$$\beta_{instr} = \sqrt{\beta^2_{slit} + \beta^2_{grating}} \quad .$$

The instrumental width can also be calculated using the following formula, which is a result of diffraction theory (/24/).

$$R_{pr} = R_{th} \frac{\lambda}{s\,\frac{d}{f} + \frac{\lambda^2}{2s\,\frac{d}{f} + \lambda}} \tag{5.5}$$

with:

R_{pr} = practical resolving power

R_{th} = theoretical resolving power = $(1/g)d$
$1/g$ = reciprocal grating constant
d = width of the wave front falling onto the grating
s = slit width
f = focal length of spectrograph
λ = wavelength .

Both ways to determine the instrumental width yield to remarkably similar results. If we assume

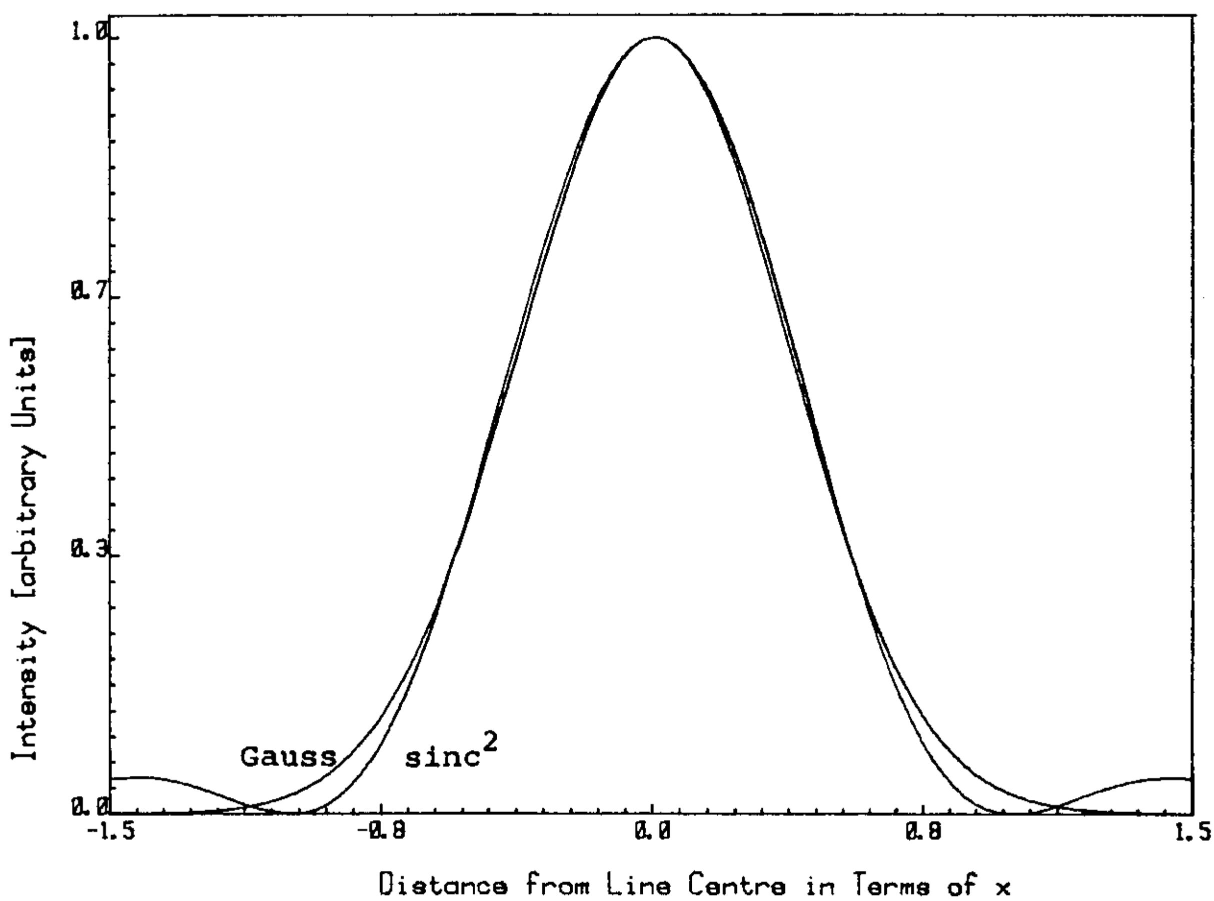
$1/g$ = 2160 mm^{-1}
d = 8.1 cm
s = 20 μ
f = 3 m
λ = 6200 Å , we obtain
β_{slit} = 0.52 s i.l.d. = 10.4 mÅ .

Therefore $\Delta\lambda_{slit}$ = 17.3 mÅ . With $\Delta\lambda_{grating} = \frac{\lambda}{R_{th}}$ = 35.4 mA we obtain $\Delta\lambda_{instr}$ = 39.4 mÅ, while the result according to Equ. 5.5 is $\Delta\lambda_{instr}$ = 43.8 mÅ.

Table 5.1 : Comparison of $sinc^2$-function and a Gaussian with c = 0.52.

x	$sinc^2(x)$	$e^{-(x/c)^2}$
0.0	1.0	1.0
0.25	0.811	0.794
0.4	0.573	0.553
0.5	0.405	0.397
0.6	0.255	0.264
0.65	0.190	0.210
0.75	0.090	0.125
0.9	0.012	0.050

Fig. 5.2: Comparative plots of a $sinc^2$-function and a Gaussian with c = 0.52 .



6. The Spectra of Neon and Argon

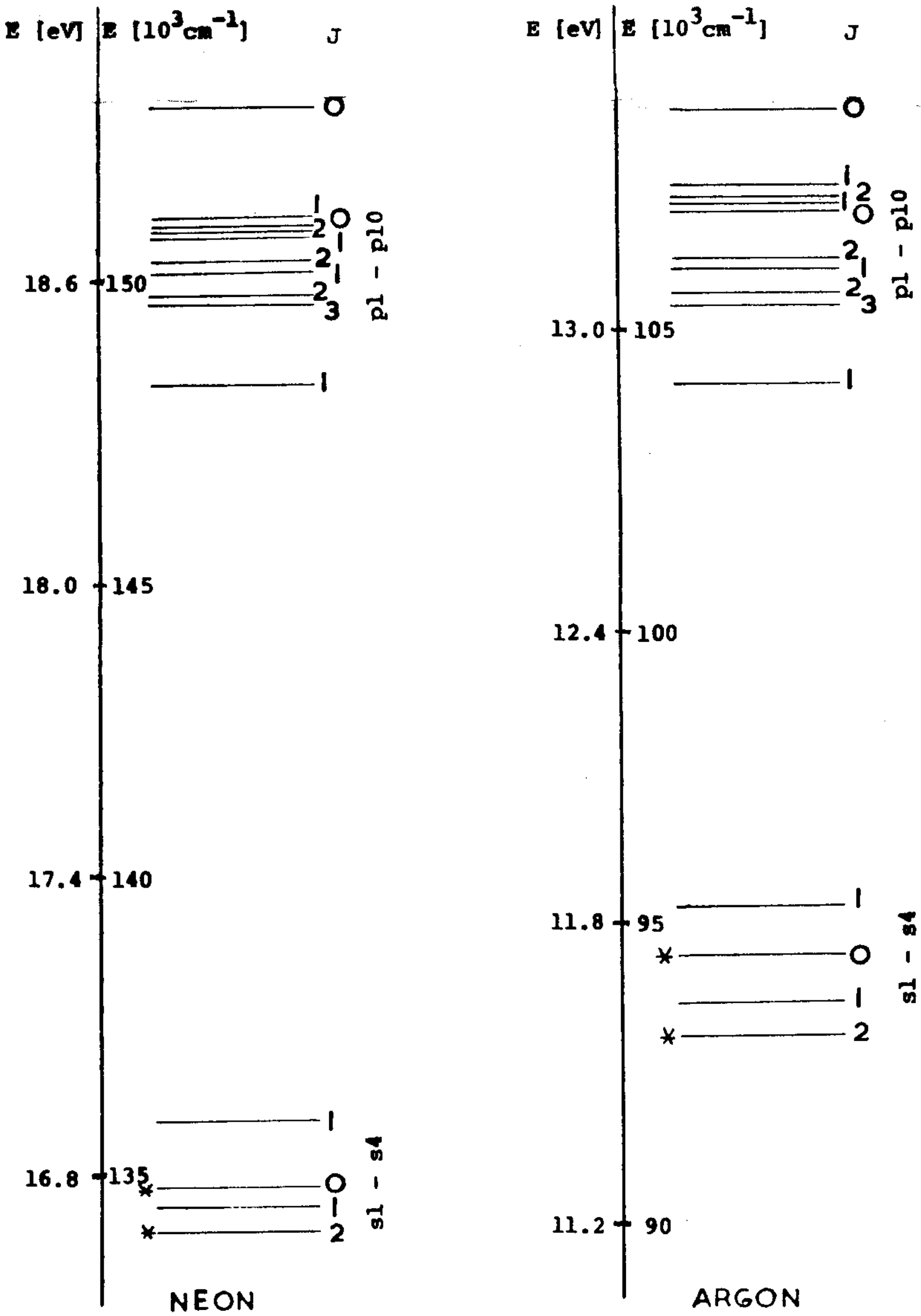
The term diagrams of neon and argon are very similar (Moore /25/). In the atomic ground state ^1S_o the outer shells (n = = 2 and n = 3 respectively) are complete and thus of the form $ns^2\ np^6$. The ground term of the ion is $ns^2\ np^5$, and all excited states of the atom are derived from this term which is an inverted doublet consisting of the two levels $^2P_{\frac{3}{2},\frac{1}{2}}$.
To bring the atom to one of the four levels forming the first excited state $ns^2\ np^5(n+1)s$ large energies are required (neon: 16.7 eV, argon: 11.7 eV). Two of these levels have J-values of 0 or 2, so that transitions to the ground state are dipole forbidden because of the selection rule $\Delta J = 1,0$, but no J=0 —> J=0 transitions allowed.

For the description of the term scheme of neon and argon, neither LS- not jj-coupling applies regidly. Intermediate coupling models, as for example calculated by Garstang and Blerkom /26/, describe the situation much more satisfactorily. As Fig. 6.1 shows, the energy levels are divided into two groups, the lower consisting of four and the upper of ten levels. Half of each group is built on each of the limits $^2P_{\frac{3}{2}}$ and $^2P_{\frac{1}{2}}$. The energy spread within the groups is small compared with the energy difference between the groups, as Table 6.1 shows.

As neither of the notations of the two extreme coupling cases may be used exclusively, a combination of both in the form

$$^{2s+1}L_J \quad (j_1,j_2)_J$$

Fig. 6.1: Term schemes of neon and argon for the (n+1)s - (n+1)p set of levels.



* metastable levels

Table 6.1 : Energy differences within the (n+1)s - (n+1)p set of levels. (For notation see Table 6.2)

	neon	argon
$E_{s4} - E_{s1}$	0.23 eV	0.28 eV
$E_{p10} - E_{p1}$	0.58 eV	0.56 eV
$E_{p9} - E_{p2}$	0.17 eV	0.26 eV
$E_p - E_s$	2 eV	1.5 eV

leads to the following representation for the four levels of the first excited state $ns^2\ np^5 (n+1)s$:

$$^1P_1 \quad (\tfrac{1}{2},\tfrac{1}{2})_1 \qquad {}^3P_0 \quad (\tfrac{1}{2},\tfrac{1}{2})_0$$

$$^3P_1 \quad (\tfrac{3}{2},\tfrac{1}{2})_1 \qquad {}^3P_2 \quad (\tfrac{3}{2},\tfrac{1}{2})_2 \quad .$$

The $^3P_1$ and $^1P_1$ levels give rise to resonance lines, and the ^3P_o and $^3P_2$ levels are metastable. It should be noted that the energy difference between the $^3P_1$ and the metastable levels is very small (neon: 0.045 eV and 0.052 eV; argon: 0.1 eV and 0.075 eV) so that, depending on the temperature of the excited gas, collisional population of the $^3P_1$ level from the neighbouring metastable levels is possible (Ladenburg /27/) ($kT = 0.025$ eV for $T = 300$ K); this level may therefore be called 'semi-metastable'.

As the levels are not easily fitted to customary notations, Paschen /28//29/ suggested the labelling as below, but Bacher and Goudsmit /30/ revised this; Table 6.2 gives the levels and the notations. The Bacher/Goudsmit notation will be used in this thesis, and spectral lines are simply referred to by the significant numbers in the notation for the levels involved, '3-9' for example denoting the transition between the s3 and p9 levels.

For the np^5 (n+1)p series the coupling gives rise to a complex pattern of ten levels, the arrangement of the highest of these being different for neon and argon (see Fig. 6.1). It should be noted that in both neon and argon, the p1 and p10 levels lie relatively far below and above the other eight levels, so that some difference in the behaviour of transitions from these levels can be expected.

The transitions discussed here give rise to a set of strong lines in the red for neon and in the near infrared for argon. In both gases the 1-2 line (λ6402 and λ8115 respectively) is the strongest line with a metastable lower state, as this is the only transition allowed from the s2 level, because of its J-value of 3 which permits only transitions to the s1 level, where J = 2. The 1-2 line is the third strongest in both spectra, while the 3-6 line in neon and the 3-7 line in argon (λ6266 and λ7948) are the seventh and ninth strongest lines in the spectra; these lines are the strongest lines ending on the s3 levels (Garstang and Blerkom /26/ and Wiese and Martin /31/).

Table 6.2: Bacher/Goudsmit and Paschen notation

np^5 (n+1)p levels

Level Neon	Level Argon	Bacher/Goudsmit	Paschen
^1S_o	^1S_o	(n+1) p10	(n+1) p_1
$^3P_1$	$^3P_1$	p9	p_2
^3P_o	$^3P_2$	p8	p_3
$^3P_2$	$^1P_1$	p7	p_4
$^1P_1$	^3P_o	p6	p_5
$^1D_2$	$^1D_2$	p5	p_6
$^3D_1$	$^3D_1$	p4	p_7
$^3D_2$	$^3D_2$	p3	p_8
$^3D_3$	$^3D_3$	p2	p_9
$^3D_1$	$^3D_1$	p1	p_{10}

np^5 (n+1)s levels

Level Neon and Argon	Bacher/Goudsmit	Paschen
$^1P_1$	(n+1) s4	(n+1) s_2
^3P_o	s3	s_3
$^3P_1$	s2	s_4
$^3P_2$	s1	s_5

IV. EXPERIMENTAL AND APPARATUS

1. Introduction

In the course of the work for this thesis, five different experiments were conducted, namely the investigation of the reduction factors and four subsidiary experiments to increase the knowledge about the constituent parts of the experiment and to obtain the data needed for the modelling of the reduction process. The latter involved measurements of hollow cathode line profiles, filter discharge reversal temperatures and equivalent widths, and absorption profiles.

The general outline of all experiments was such that the light from the background source, either hollow cathode discharge lamp or tungsten ribbon lamp, was passed through the filter discharge. The resulting radiation was then analysed by means of a grating spectrograph and either photoelectric or photographic detection. Both the hollow cathode and the filter discharge were connected to complete vacuum pumping systems, though of significantly different nature. Each piece of the equipment will now be described in detail.

2. The Hollow Cathode Lamp

As has been mentioned above, high current hollow cathode lamps have been used in this laboratory for more than a decade. Different types, made entirely of metal or partly of glass, with cooled anodes, cooled cathodes, or both, have been tested at currents between 50 mA and 2 A. Different carrier gases have been used, namely helium, neon, and argon, and a great variety of cathode materials has been investigated at temperatures between room temperature and the melting point of the metal under investigation.

The hollow cathode lamp used in this study is shown schematically in Fig. 2.1 . The cathode was made from a brass cylinder of 6.5 cm length and 5.5 cm diameter which was drilled out along the axis of symmetry so that hollow cathode inserts of 20 mm length and 12 mm outer diameter could be used. The inner diameter of the inserts was 8 mm . Length and inner diameter of all inserts recently used for high current hollow cathodes in this laboratory have been standardized to the above sizes in order to simplify comparison and exchange of inserts between different lamps.

Both ends of the cathode cylinder were machined conically from the ends of the insert canal to the outer rims. Two hollow pyrex cylinders of 7 cm length, which were sealed to the cathode block by silicon rubber, connect the cathode block to two brass rings, serving as anodes and window holders. One glass tube each was sealed onto the glass cylinders, one of smaller diameter used as gas inlet and a bigger one to connect the pumping line. The glass end-windows were gently pressed onto large o-rings to ensure vacuum tightness when pumping down from atmospheric pressure. The hollow cathode is depicted in Fig. 2.2 .

The hollow cathode was operated as a flow-through system, Fig 2.1: The hollow cathode lamp (schematically).

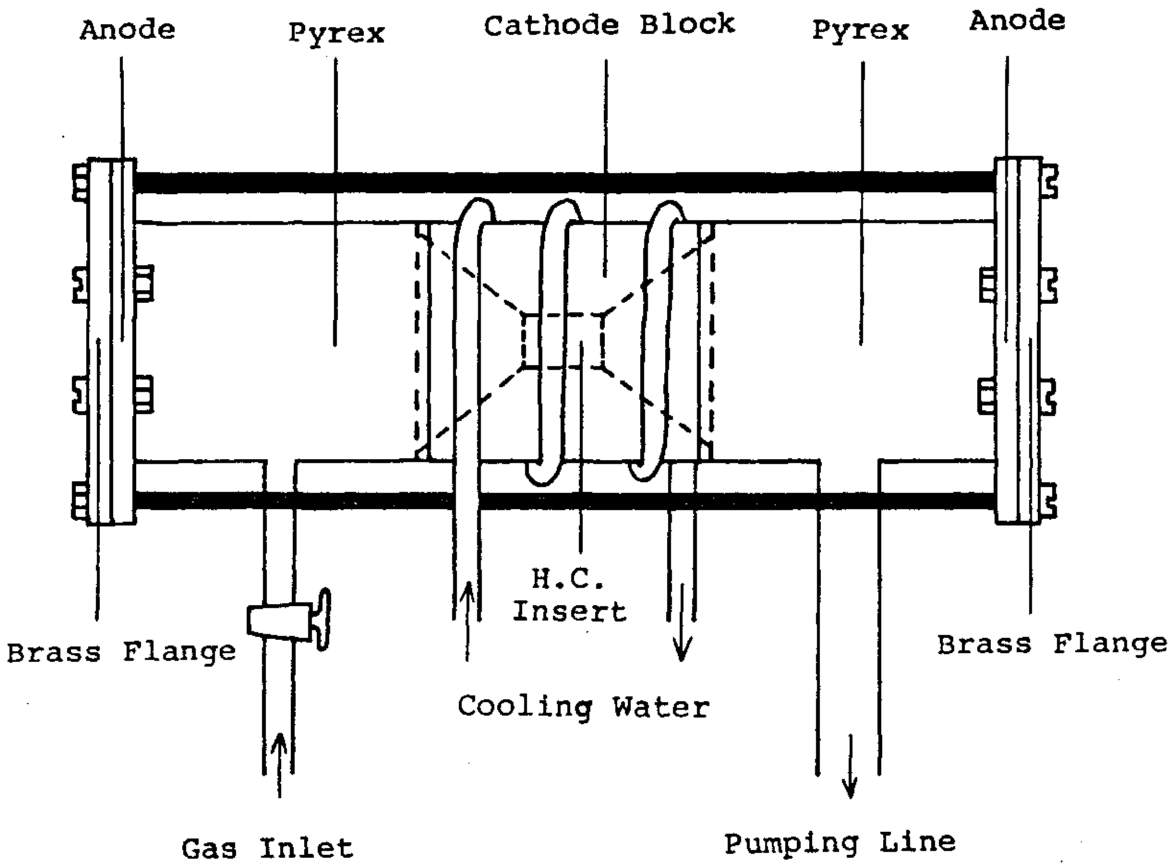
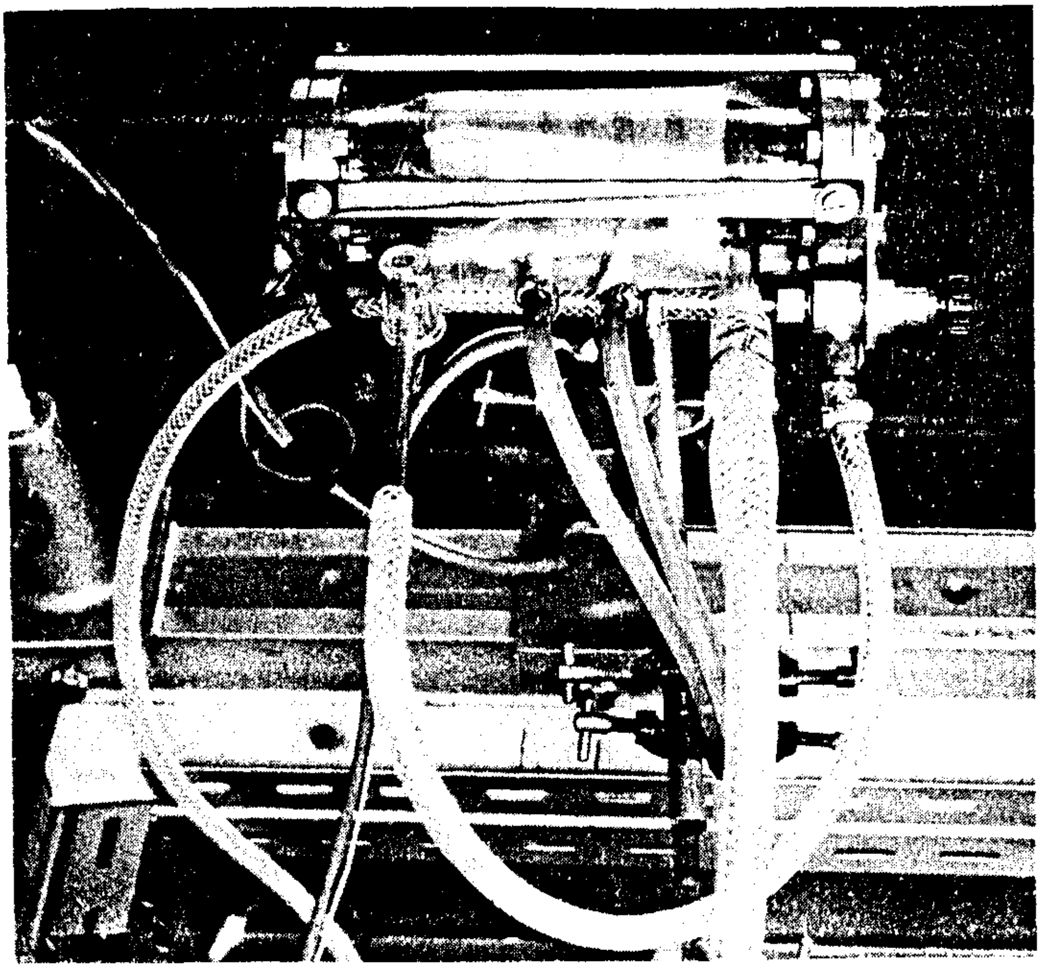


Fig 2.2: Photograph of the hollow cathode lamp.



the gas being admitted from a gas cylinder via a needle valve and permanently pumped by a throttled rotary pump (Edwards BS 2412 - G) through a coldfinger, immersed in liquid nitrogen. The pressure in the discharge chamber was monitored by means of a capsule dial gauge and a carefully calibrated Pirani vacuum gauge (Edwards P 12). A flow-through system had to be used, since the impurities produced by the sputtering action at high currents would have led to an unknown composition of the gas in the lamp.

Two cooling mechanisms were employed. A spiral of copper tube, wound around the cathode block and soldered onto it, was used for the water cooling of the cathode. This method can be considered as intermediate between those cases, where the insert is cooled directly by a water jacket and those, where it is uncooled, as for the study of metals near the melting point. Apart from this, the hollow cathode lamp was placed in the airflow of a fan, mainly to cool the anode rings which are heated by radiation and convection from the cathode.

In the beginning, an aluminium hollow cathode insert was used, as this metal is known for not being easily sputtered. This had the advantage that emission from aluminium lines was less likely to complicate the analysis of the carrier gas emission, but the hollow cathode was found to run very unstably. Furthermore, it was only at pressures well below 1.5 mbar that a bright and uniform hollow cathode glow could be achieved, and the hollow cathode glow tended to jump out of the hollow cathode insert, 'preferring' the adjacent conical parts of the surrounding brass block. This problem was solved by using an iron hollow cathode insert. The hollow cathode was then found to run stably up to about 350 mA in neon and up to 450 mA in argon, at pressures of about 2.5 mbar. Additionally, the hollow cathode being a combined glass-metal system, the current was not raised permanently to higher values for fear of cracking the glass, especially near the anode rings which warmed up to about $50^{o}C$ on the outside, despite the fan cooling.

Although in experiments to investigate the line emission from the sputtered material, the pressure is usually carefully adjusted such that the carrier gas emission is as weak as possible, the pressure for these experiments was chosen such that the carrier gas emission intensity was near its maximum for a particular current. This was done to simplify measurements and, as these pressures were found to lie in the regime of usually chosen running conditions anyway, the choice of pressure was not critical. Taking this into consideration and in order to keep the number of parameters down, which was anyhow uncomfortably high, the hollow cathode pressure was held pratically constant throughout all investigations.

After about 15 minutes warming-up time, the hollow cathode was found to give fairly constant line intensities. Slight intensity variations with time constants greater than about three minutes were of no importance, as ratios of the intensity with and without the filter could be measured within, say, 20 seconds. Larger intensity variations indicating a change in the running conditions inside the lamp have not been observed. Furthermore, the temperature of the cooling water was not found to change after the initial 15 minutes.

The power supply for this lamp was a home-made construction consisting of mains transformer, variac, smoothing capacitor and 900 Ω of ballast resistance, achieved by the combination of 36 100 Ω/55 Watt resistors. The operating voltage across the hollow cathode was about 300 volts.

3. The Filter Discharge

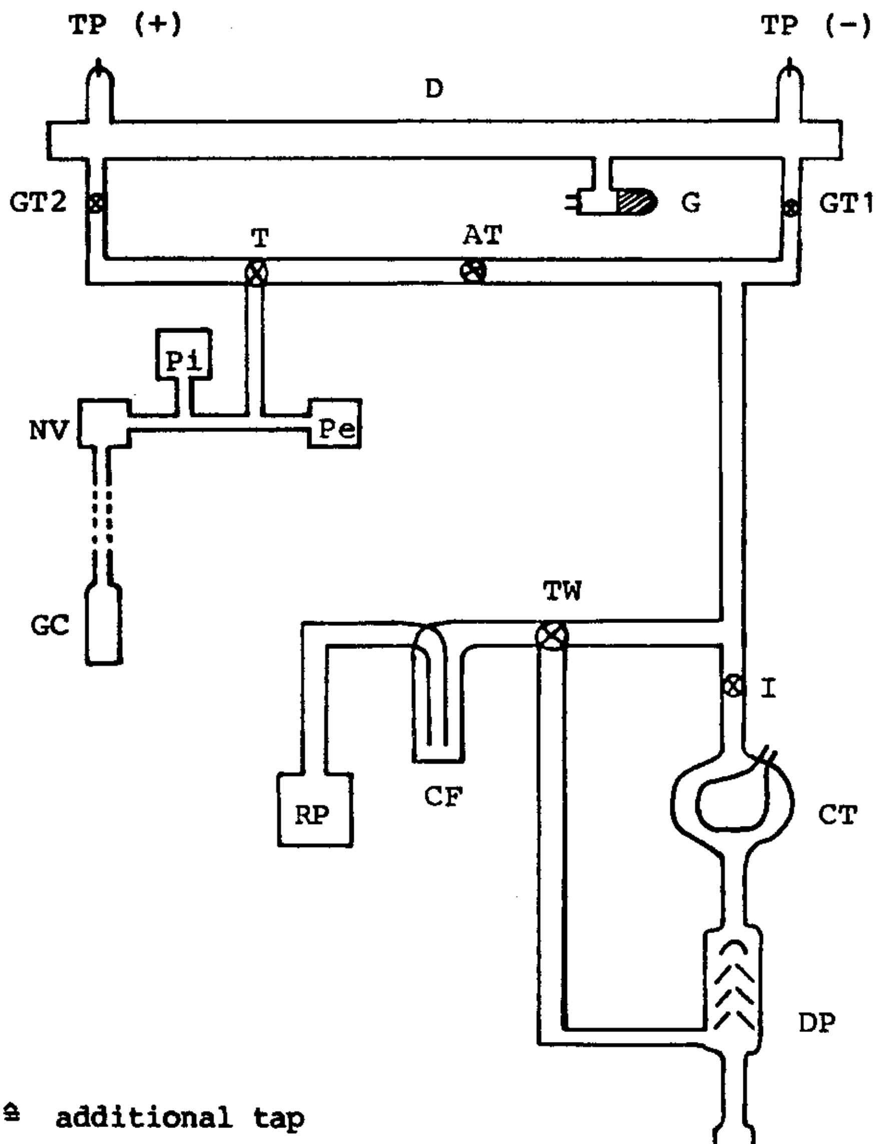
At the initial stage of the work for this thesis, my major task was to design, construct, and make operational the filter discharge system. The design was based on the design given by Chamberlain /32/, but included new features, most important being greaseless tabs to allow very clean sealing of the discharge tube and a titanium getter pump connected to the tube to allow long term sealed-off operation of the discharge. Furthermore, the windows are now sealed to the ends of the discharge tube, which avoids a complicated window holder construction, which is usually another source of impurity and leak problems.

The main part of the filter discharge system, which is shown schematically in Fig. 3.1, consists of a pyrex tube (D), 1 m long and of 2 cm outer diameter, with two pyrex windows (W) sealed onto the ends of it. 5 cm from either end, two sidearms, some 10 cm long, were attached to the main discharge tube, each ending in a glass-to-metal seal for a tungsten pin (TP), 3 cm long, being used as electrodes. Another sidearm contains a titanium getter pump (G), manufactured by S.A.E.S. GETTERS S.p.A. as model AP 10GP. This was placed closer to the cathode since, owing to the ion bombardement, this is more likely to give off impurities. Opposite the two electrode housings, another two glass tubes are connected which can each be sealed by a greaseless tab (GT1 and GT2) with neoprene diaphram.

A Pirani type vacuum gauge (Pi) (Edwards P 12) for accurate pressure determination at around 1 mbar, a Penning type high vacuum gauge (Pe) (Edwards Penning 8), and a needle valve (NV) were installed. The latter is used as a gas inlet from the gas cylinder (GC). The pumping system consists of a two-stage glass mercury diffusion pump (DP) with a liquid nitrogen cold trap (CT) on top, a rotary pump (RP) (Edwards

EDM 2), and the roughing and backing lines. The main part of the actual system is depicted in Fig 3.2 .

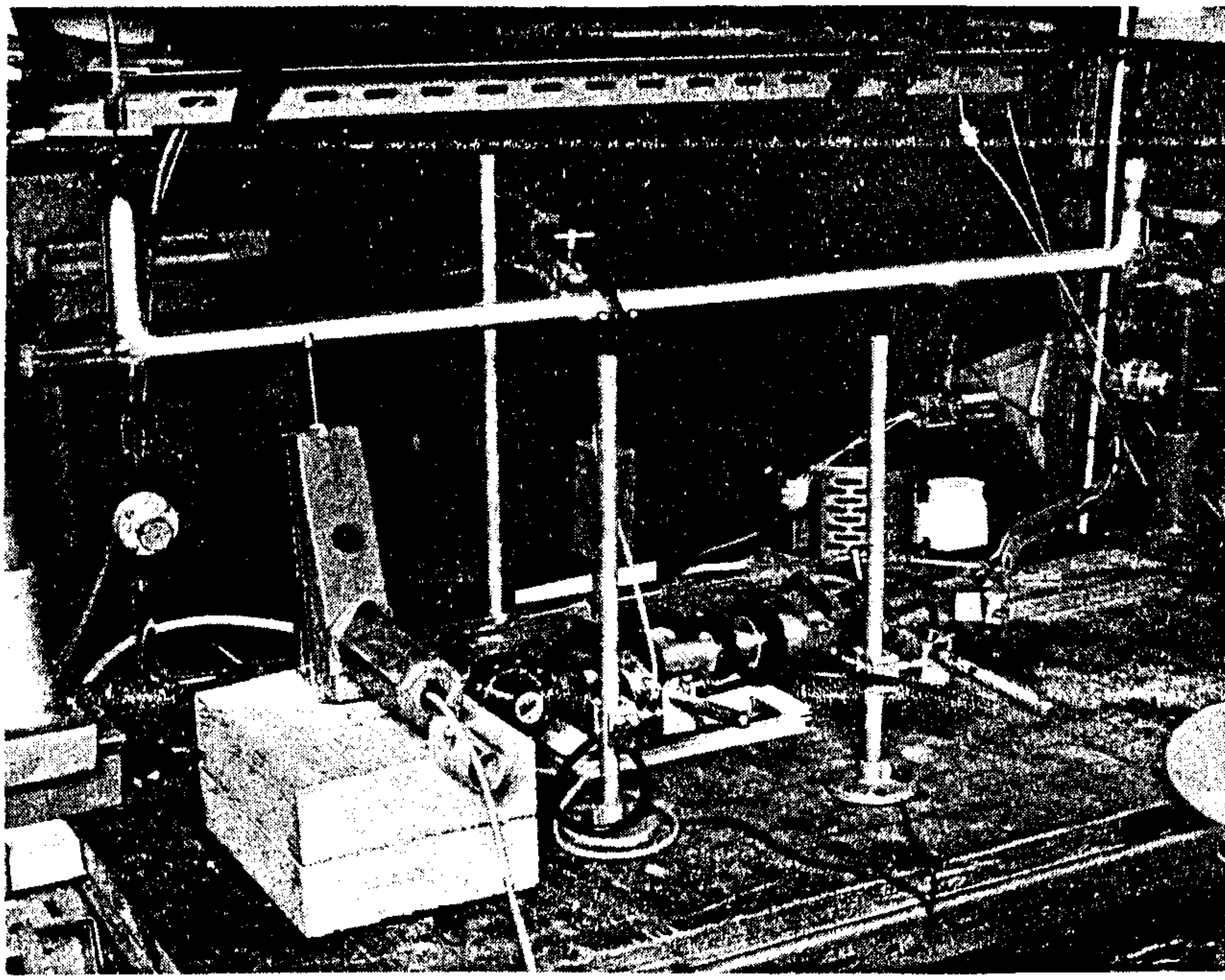
Fig 3.1: The filter discharge system (schematically).



AT ≙ additional tap
TW ≙ three-way tap
CF ≙ cold finger
CT ≙ cold trap
I ≙ main isolation valve

Other symbols see text

Fig 3.2: Photograph of the filter discharge.



It was intended to devise a system which, once having been thoroughly cleaned, could be filled with gas and operated sealed off, with the getter pump taking care of the purity of the gas. High purity of the gas was considered as absolutely essential, as the population of the metastable levels is easily destroyed by collisions with impurity atoms, especially with hydrogen (Meissner/33/ and Dorgelo /34//35/). For this reason, the whole system was kept under high vacuum by the diffusion pump for many days, and to support outgassing, the glassware was gently heated with a hot-air-blower. The electrodes were outgassed by running the discharge at fairly high currents (15 mA) for some hours, while the polarity was changed twice to outgas both of them as much as possible. After this had been done, the getter was activated by passing a current of 1 A through it for about 15 minutes, while the vacuum had to be better than 10^{-3} mbar. Thus heating the getter makes it give off the inherent impurities into the surrounding vacuum. Hereafter, the discharge tube was sealed off and the rest of the system was flushed with the inert gas in use, which was pumped to atmosphere by the rotary pump. It was found to be of major importance to keep the PTFE-tubing, connecting gas cylinder and needle valve, under a pressure above atmospheric all the time. If this rule was not observed, air entered the tubing, leading to pinkish discharge colours, so that all the gas in the line had to be wasted in order to regain high purity.

After flushing the system for about one minute, the greaseless tabs were opened and the tab AT was closed. After thus flushing the discharge tube for about 30 seconds, the pressure in the chamber was adjusted on the Pirani gauge and fixed by closing GT2 and the needle valve simultaneously.

When both tabs were closed, the pressure was checked a last time, and, finally, GT1 was closed. Henceforth, the pressure could no longer be monitored. Then the discharge was struck. Any admixtures of air would give the discharge initially a characteristic pink hue which disappeared after only about 30 seconds, indicating that the getter was purifying the gas, supported by the stirring action of the discharge. A discussion of the time dependence of hydrogen impurities and its bearing on the population of the metastable states can be found in Chapter V.2 .

The getter had to be reactivated occasionally, at intervals depending on the purity of the gas admitted to the tube when changing the filling, and not on the length of time the gas was left in the chamber. In fact, it was never observed that the cleanliness of a filling deteriorated at all, even after several weeks.

The gases used in this experiment were chemically pure argon and research grade neon, both supplied by B.O.C.

The discharge was operated by a high voltage power supply manufactured by Chelsea Instruments, using 300 kΩ of ballast resistance in series with the tube. The operating voltage across the tube was about 1000 V in argon and 1300 V in neon at currents of about 2 mA.

During the early stages of the experiment, it became already clear that it would be essential to be able to run the filter discharge at very low currents down to about 2 mA. Due to the length of the discharge, the small electrode surface area, and also the incomplete smoothig of the power supply currents of 4-5 mA were the minimum before the discharge quenched. However, it was possible to run at lower currents by placing an Edwards Spark Tester in permanent operation at the lowest possible intensity with its tip about 3 cm away from the discharge tube. It must be emphasized that the 'Tesla' thus became an essential part of the experiment.

4. The Spectrograph

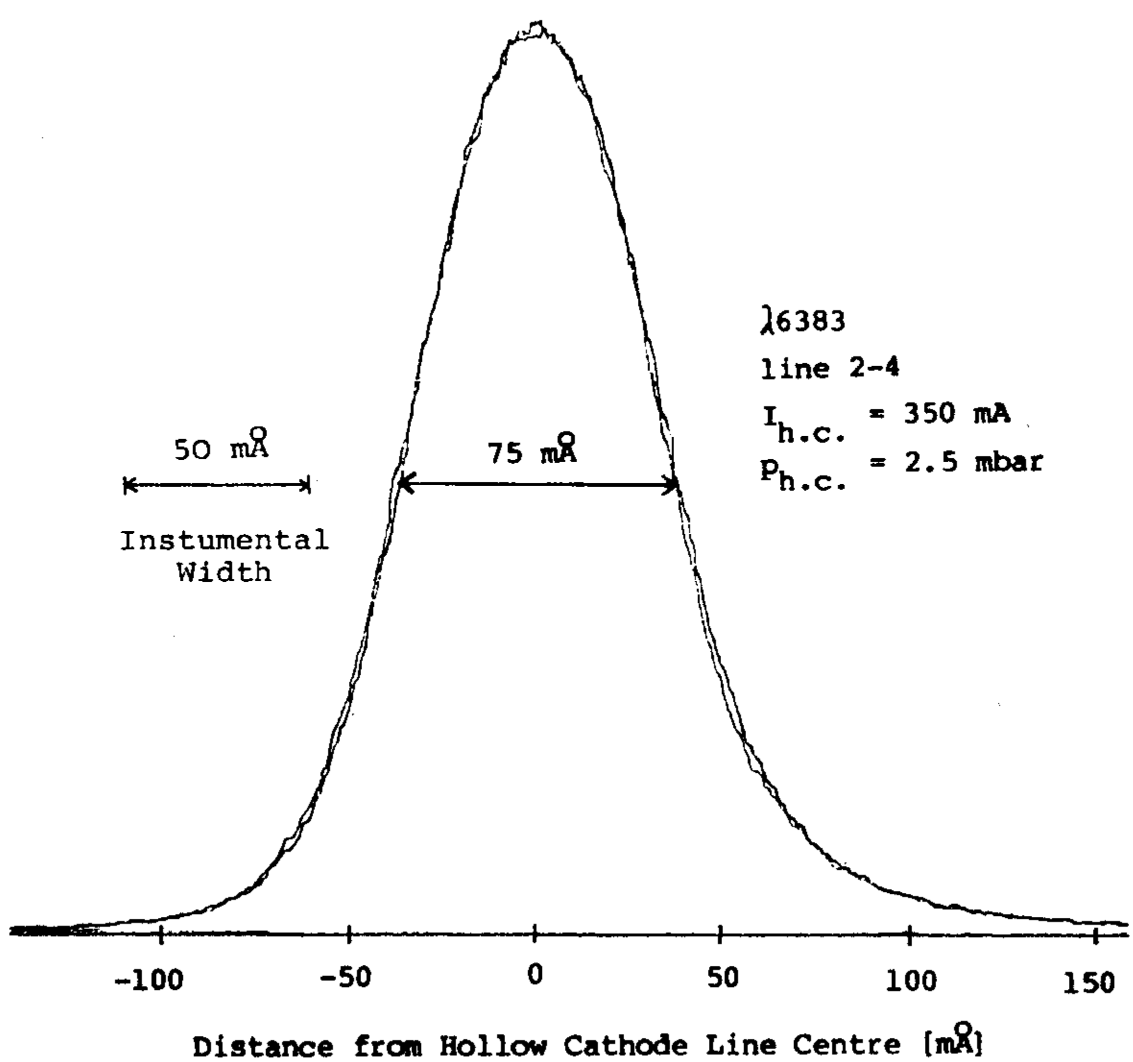
For the spectral analysis of the radiation, a 3 meter grating spectrograph with Littrow-mounting was used; with a plane grating of 2160 grooves/mm, a ruled area of 130 x 100 mm^2 , a collimating lens of 10 cm diameter, and a resolving power of better than 175,000 in the first order (theoretically 275,000). The grating was blazed at 5000 Å in the first order. The aperture of the spectrograph was f/30 and the inverse linear dispersion was 1 Å/mm in the first order. The instrument was originally built for photographic work, but had an adaption for photoelectric detection, which was the method used for all measurements except those of the hollow cathode line widths and shifts. Two different photomultiplier tubes were employed; an EMI 9526 with S 11 photocathode, selected for low dark current, and an EMI 9728 red-sensitive tube with S 20 photocathode, selected for high red-sensitivity. Both were end-window type tubes of 30 mm diameter and fitted into a special housing which could be attached to the spectrograph instead of the regular plate holder. The secondary slit was a fixed-width $50\,\mu \mathrel{\hat{=}} 50$ mÅ slit. Both photomultipliers were operated at 950 Volts from a low wattage EHT power supply (Fluke 412 B). To monitor the intensity proportional output, the photomultiplier current was measured by means of a picoammeter manufactured by Chelsea Instruments, which was capable of detecting currents between 10^{-11} and 10^{-5} A. Furthermore, it produced an output voltage of about 0.5 V proportional to the input signal, which allowed one to monitor the signal on a chart recorder.

Since the photomultiplier housing could only be moved by about 3 mm along the image plane (corresponding to 3 Å), the grating rotation scale of the spectrograph had to be calibrated very carefully to allow a spectral line to be located mainly by rotating the grating.

The spectral lines themselves could be scanned with the photomultiplier through a new mechanism which I installed. The micrometer screw which drives the photomultiplier was coupled to a potentiometer by spanning an o-ring as driving belt around the axis of the micrometer screw and the potentiometer. The voltage drop across the potentiometer determined the x-deflection of the chart recorder pen, while the corresponding photomultiplier signal was converted into a y-deflection by means of the voltage output of the picoammeter. The reproducibility of the line scans with this design is demonstrated in Fig 4.1 which actually shows two scans of the same hollow cathode line done directly one after the other.

For the photographic measurements Kodak High Speed IR black and white 35 mm-film was used which has an extended red-sensitivity up to about 8500 Å.

Fig 4.1: Two hollow cathode line scans done directly one after the other to prove reproducibility.



5. The White Light Background Source

A tungsten ribbon lamp manufactured by Philips Nat. Lab. (Type No. W2GGV22) and supplied with a temperature - current calibration was employed as continuum background source. The maximum current of 18.5 A, which could be achieved with the power supply in use, corresponded to a black-body temperature of about 2570 K.

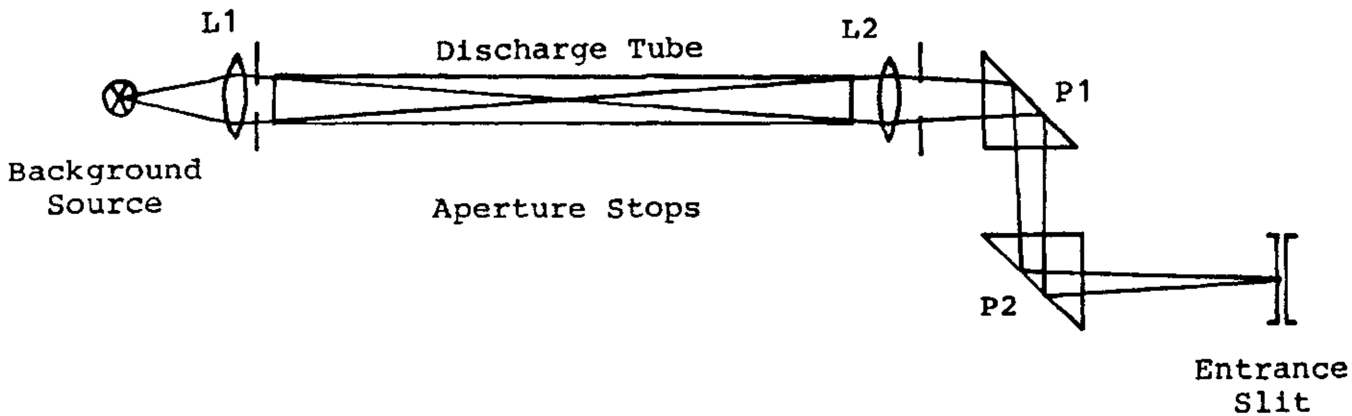
6. The Optical System

Two major considerations determined the lay-out of the optical system shown in Fig 6.1 . First, all light from the hollow cathode that entered the spectrograph, must have passed through the positive column of the filter discharge and, secondly, only light from regions of the filter discharge which served to filter the hollow cathode light, should be detected.

Thus, the hollow cathode was imaged into the middle of the filter discharge by means of the positive lens L1, and this point was focussed on the entrance slit of the spectrograph by the lens L2. A circular aperture stop of 9 mm diameter was placed close to each lens. As the lens closer to the spectrograph was about 33 cm away from the entrance slit, the f-number of the optical system (330 mm/9 mm = 37) was smaller than that of the spectrograph (300 cm/10 cm = 30). This limitation of aperture was unavoidable because two right-angle reflections (prisms P1 and P2) were necessary to bring the beam down to the height of the entrance slit and to align the optical system.

The illuminated width of the grating for f/37 is (3000/37) mm = 81 mm and therefore the effective resolving power for a grating of 2160 lines/mm is 175,000.

Fig 6.1: The optical system.



P1 and P2 ≙ Prisms

L1 and L2 ≙ Positive Lenses

V. SUBSIDIARY EXPERIMENTS

1. Time Analysis of the Light Output from the Hollow Cathode and the Filter Discharge

In order to analyze the time dependence of the light output of both discharges under investigation, a series of photographs of oscilloscope traces were taken with a polaroid camera. The traces are reproduced in the figures of this section. The time base settings are given on the photographs (usually 2 msec/cm, with the exception of Fig. 1.3 where it is 0.5 msec/cm), time is running from left to right, and intensity from top to bottom (with the exception of Fig. 1.3). If a spectral line is investigated, it is always the 1-5 line in argon. In the following, it will be assumed that the findings for argon hold for neon, too.

As it is clear that smoothing of high voltage DC power supplies operated at high currents is often fairly difficult and involves large capacitors, a series of oscilloscope traces of the photomultiplier output when detecting the 1-5 carrier gas line in the hollow cathode spectrum of argon was photographed at different currents. The traces are reproduced in Fig. 1.1 . The voltage zero is indicated by the broad white lines. The last photograph in Fig. 1.1 shows a trace, which gives the dark current of the photomultiplier.

It can be easily seen that the smoothing of the power supply becomes less efficient for higher currents, leading to a higher value of the maximum-to-minimum ratio of the 100 Hz-ripples. Furthermore, even at a current as low as 50 mA, the smoothing is found to be insufficient. Taking these results into consideration, it seems to be desirable to run the filter discharge with a power supply which is as inefficiently smoothened, since the filter should be 'on' only when the hollow cathode is 'on', too.

Fig. 1.1: Time dependence of the light output from the hollow cathode at currents between 450 and 50 mA at 1 torr pressure in argon and time dependence of the dark current.

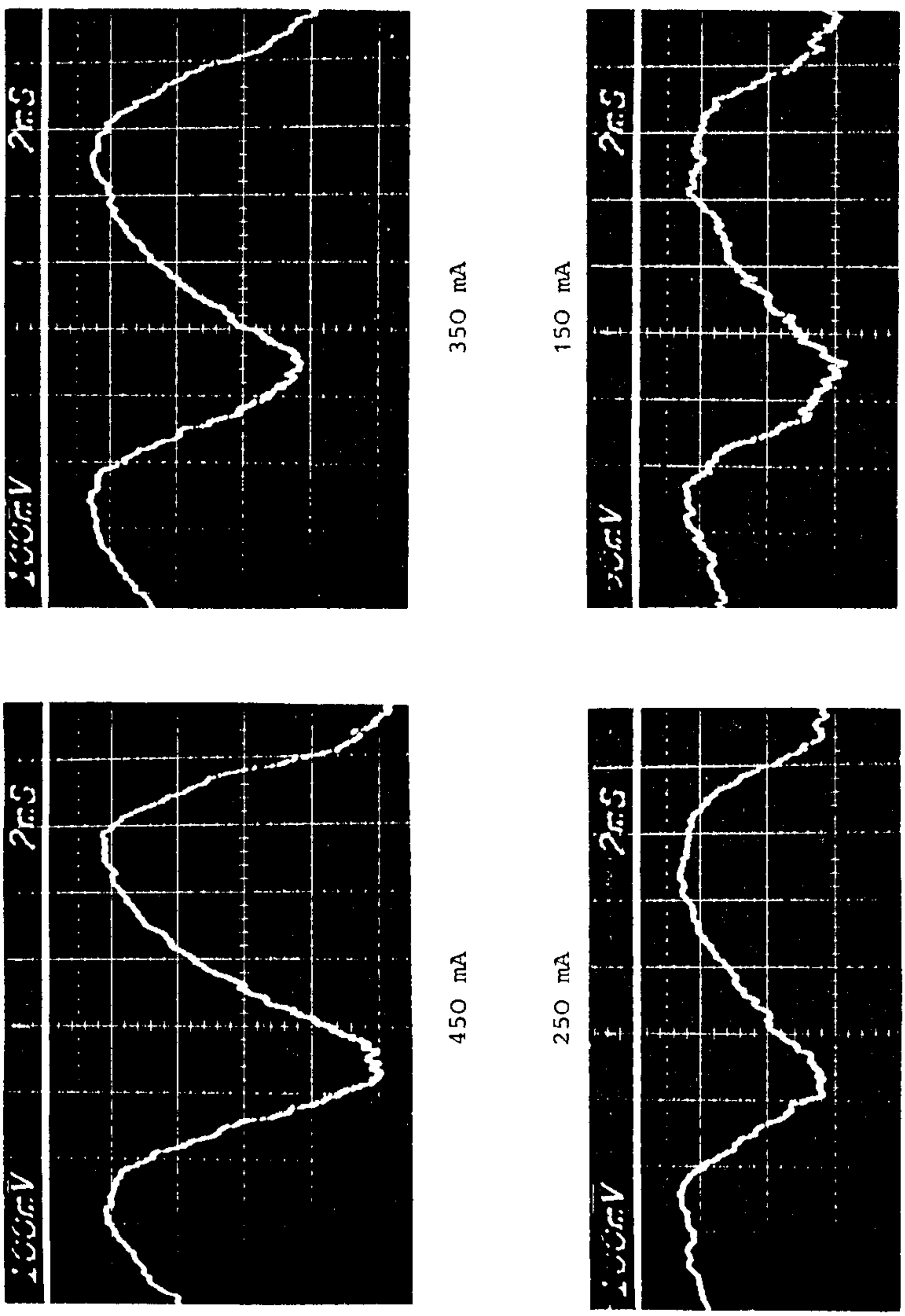
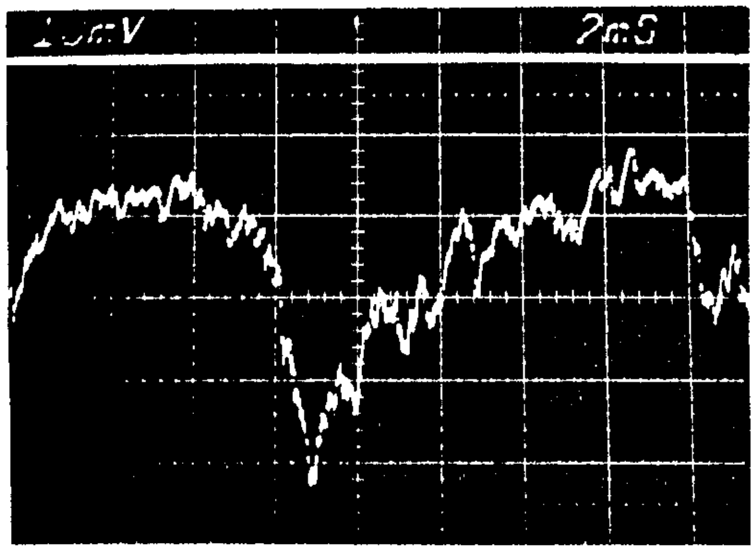
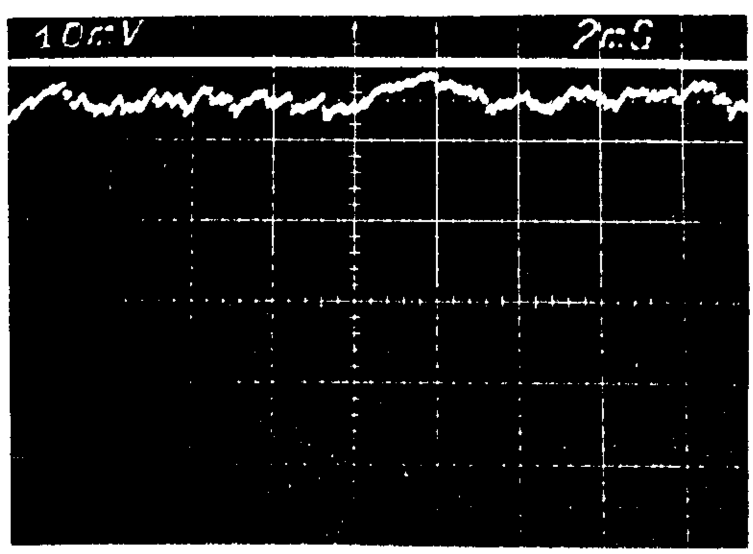


Fig. 1.1 continued:



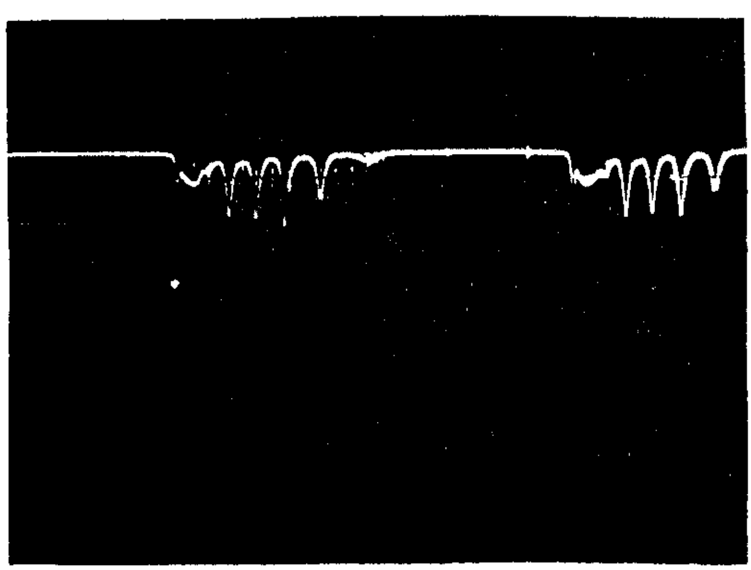
50 mA



Dark Current

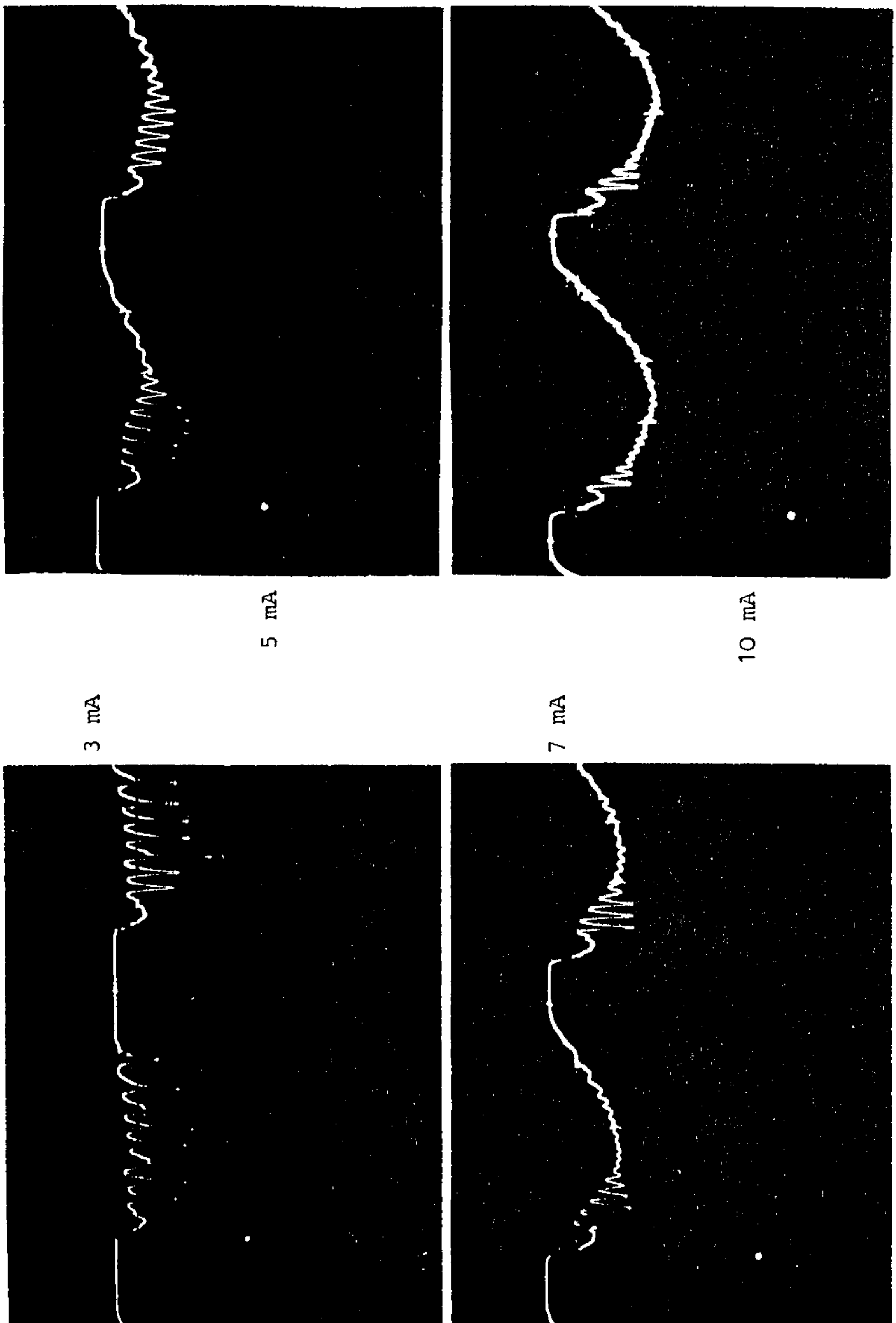
In order to find out something about the light output from the filter discharge, an indirect method was used. A 100 Ω resistor was included in the earth lead of the filter discharge and the difference between the electric potential on either side of the resistor was analysed by an oscilloscope with differential input unit. The results are given in Fig. 1.2 . They show that for low discharge currents, the expected 100 Hz-ripples are completely distorted by an oscillation of the current with a frequency which is roughly ten times as high. Increasing the current from 1.6 to 10 mA causes the frequency of the oscillations to increase, while their amplitude becomes almost insignificant against the finally dominating 100 Hz-ripples. It should be noted that, assuming that the trace for 10 mA represents the voltage output of the power supply, the filter discharge only strikes when the voltage has reached about 50% of its peak value and quenches at about the same voltage on the falling flank of the voltage 'pulse'.

Fig. 1.2: Time dependence of the filter discharge current for I = 1.6 - 10 mA. (x: 2 msec/cm)



1.6 mA

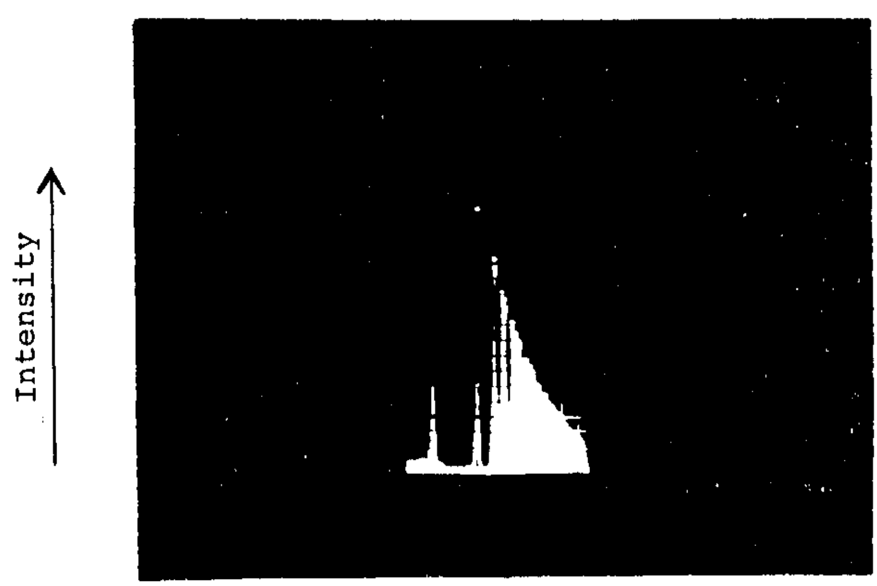
Fig. 1.2 continued:



Another observation is represented in Fig. 1.3 . It shows a high peak in the current which occurred before every 100 Hz 'pulse'. These peaks could be observed on the oscilloscope for every trace in Fig. 1.2, but, unfortunately, they were too weak to show up on the photographs. The white spots at the beginning of each ripple and at about double maximum intensity indicate the height of the initial peak.

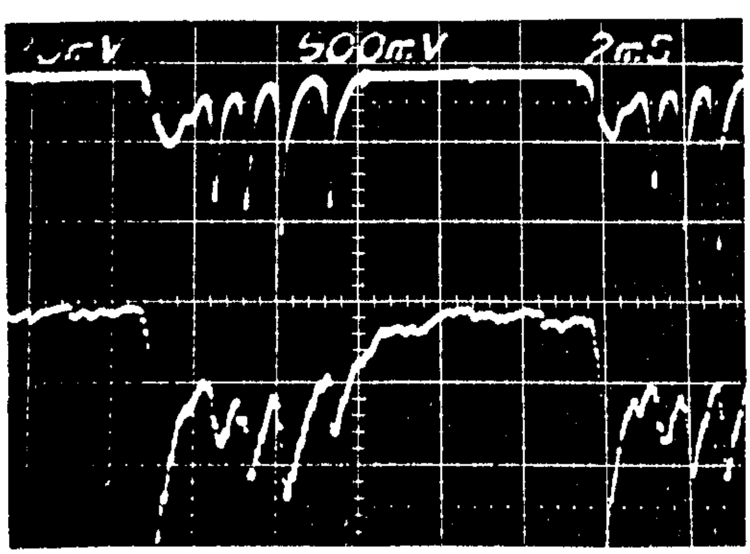
A qualitative interpretation of these phenomena may proceed like this. Between two mains cycles, the filter discharge quenches. When the next mains voltage 'pulse' has reached a sufficient value, obviously earlier and earlier for higher integrated output voltages, the discharge strikes with a sudden break-down resulting in a short current peak which triggers a current oscillation of unknown origin in the plasma, though it may be speculated that the 'Tesla' plays a role in this respect. The current oscillations are overlaid on the 100 Hz-ripples of the current caused by insufficient smoothing of the power supply. These oscillations become less important with increasing current.

Fig. 1.3: Peak at the beginning of each filter discharge 100 Hz current ripple. (x: 0.5 msec/cm)



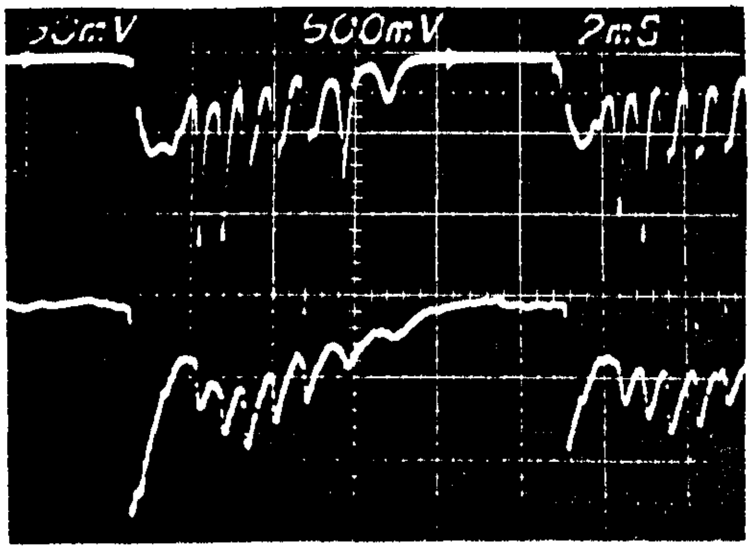
It is assumed that the voltage across the resistor in the earth lead of the filter discharge, which is proportional to the current through the filter discharge, is thus directly proportional to the total light output from the discharge. Moreover, the emission from every single line is assumed to be proportional to the total light output. These assumptions are justified by the traces in Fig. 1.4 which show the current through the filter (upper trace) and the intensity of the argon 1-5 line detected simultaneously by the photomultiplier (lower trace). These traces were obtained with a two beam oscilloscope with the same time base settings for both channels. Note how the (invisible) initial peak in the current causes a broader decay peak in the light output. It can also be seen that the light output is very slightly delayed with respect to the current.

Fig. 1.4: Correlation of the time dependence of the current through the filter discharge (upper trace) and the light output of the 1-5 line (lower trace) for currents between 1.6 and 7 mA.

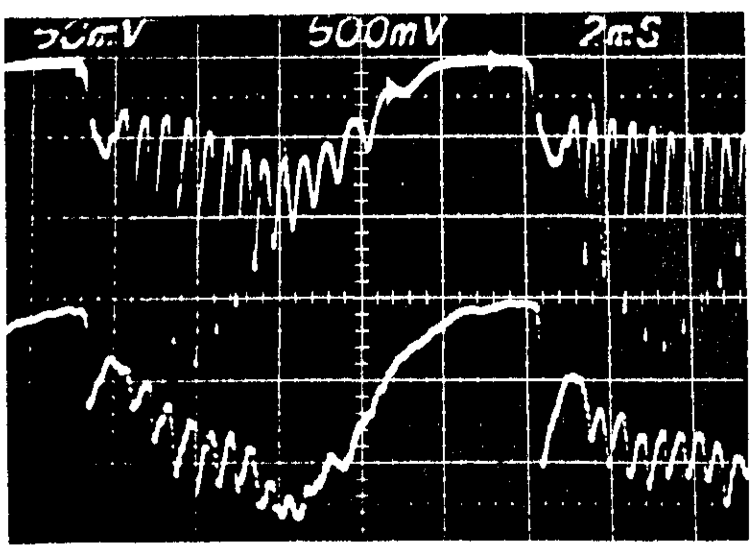


1.6 mA

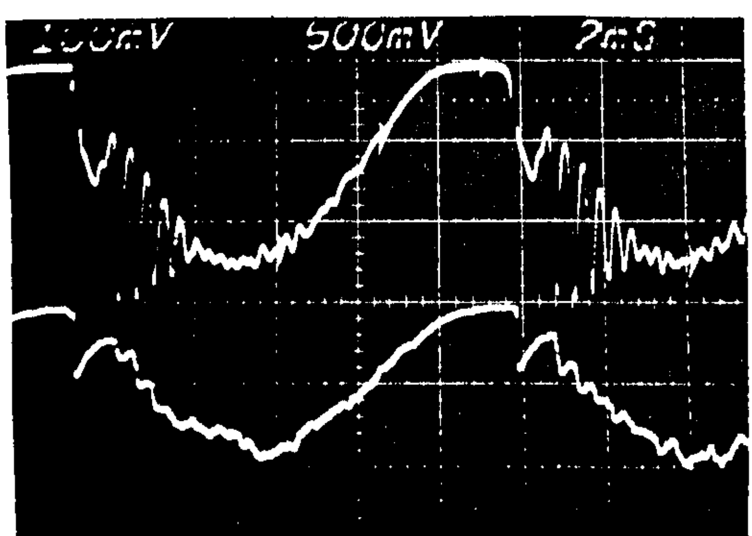
Fig. 1.4 continued:



3 mA



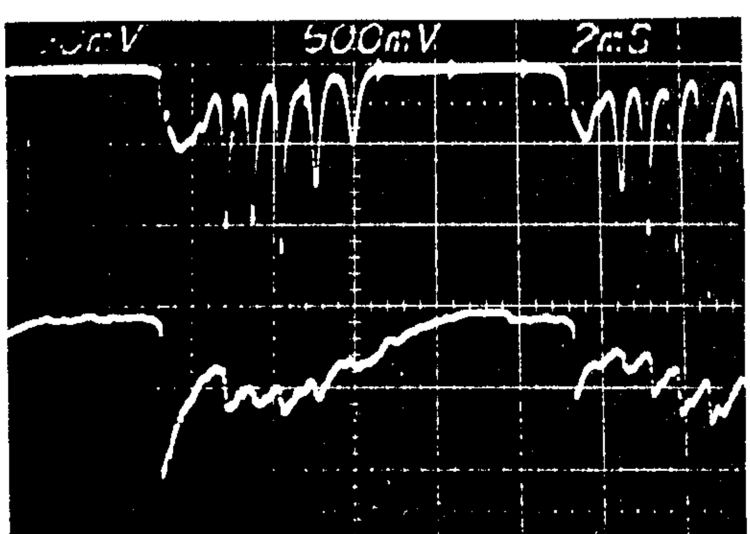
5 mA



7 mA

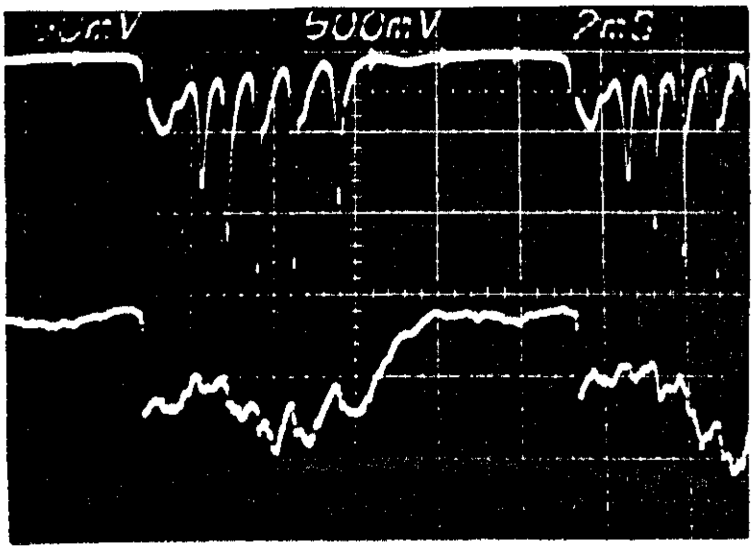
The final set of traces in Fig. 1.5 shows the current through the filter discharge (upper trace) and the intensity of the hollow cathode line emission after passing through the filter discharge (lower trace) for hollow cathode currents between 150 and 450 mA. The filter discharge parameters were kept constant to 2 mA and 3.7 mbar. It can be seen that both traces are in fact about zero at the same time. Note that for low hollow cathode currents the initial peak in the filter discharge emission, which could be seen in Fig. 1.2, becomes visible in the combined light output and may thus be one cause for the deterioration of the reduction factors for low hollow cathode currents, as it will be dicussed in Chapter VI.

Fig. 1.5: Time dependence of the current through the filter discharge (2 mA - 3.7 mbar, upper trace) and the intensity of the hollow cathode line emission after passing through the filter discharge (lower trace) for hollow cathode currents between 150 and 450 mA.

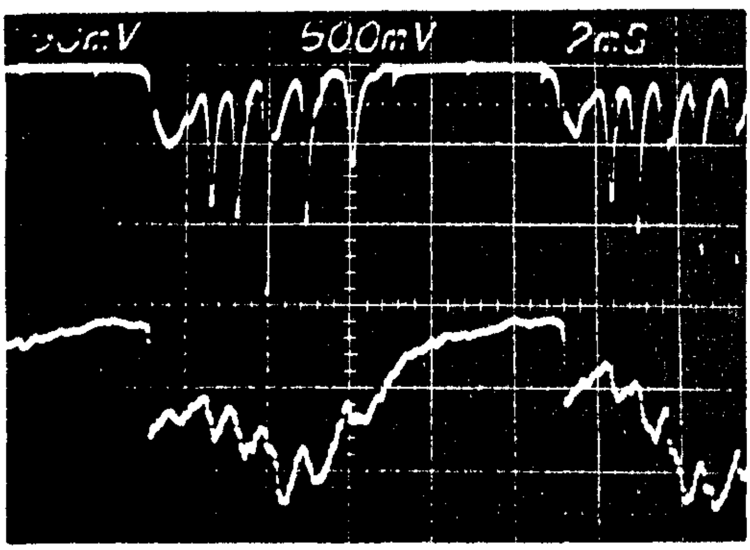


150 mA

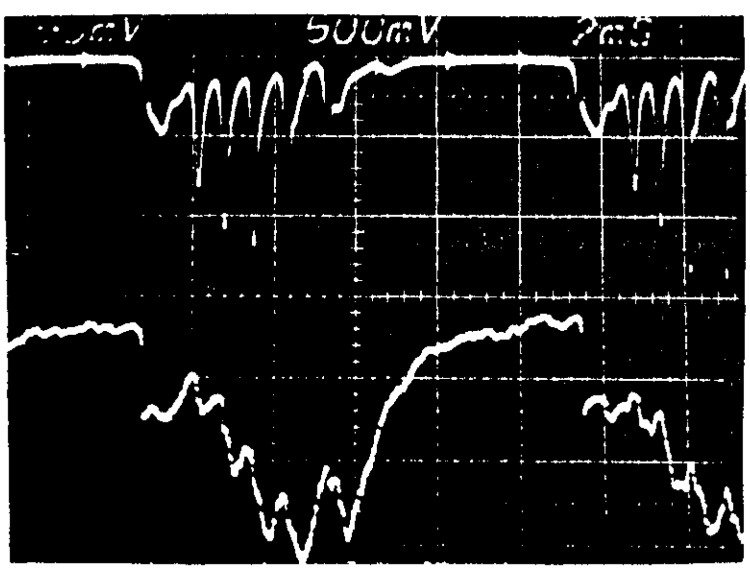
Fig. 1.5 continued:



250 mA



350 mA



450 mA

2. Filter Discharge Reversal Temperatures - Impurities

For the inert gases and the lines arising from transitions within the (n+1)s - (n+1)p set of levels, one would expect the reversal temperature (for constant discharge conditions) to have roughly the same value for all lines with metastable lower states and to have another, significantly higher value, for all lines with non-metastable lower states. An increase in discharge current should also lead to higher reversal temperatures.

In this study, the reversal temperatures were determined by spectrally scanning across the line under investigation repeatedly, each time changing the current through the standard lamp, until the line could no longer be observed. The standard lamp current was then converted into a black-body temperature using the calibration chart supplied with the lamp.

An important result was found by measuring the reversal temperature of a particular spectral line under the same discharge conditions at different times after switching on the discharge. This observation was undertaken because it was expected that the abundance of impurities in the discharge would decrease while the discharge was running, due to the increase in efficiency of the getter pump from the stirring action of the discharge. Fig. 2.1 shows the decrease of the reversal temperature for the neon 1-5 line in a discharge at 1.15 mbar and 3.6 mA. It can be seen that the reversal temperature seems to tail off to a constant value after about 3-4 hours. The changes in the measured reversal temperature due to different times of measurement after striking are very small in comparison to those changes induced by different discharge currents. Thus, it was considered as sufficient to measure all reversal temperatures after the filter discharge had been running for longer than four hours. To support this, Fig. 2.2 shows the intensity of the H_β line (hydrogen I, 4861 Å) in the same discharge as a function of time. The H_β intensity also tails off to a fairly constant value after about 3-4 hours. The intensities of H_β lie only marginally above the dark current of the photomultiplier, which was very low in any case ($\sim 10^{-10}$ A), while a strong neon line would have been measured as 10^{-5} A. This indicates the extreme weakness of the H_β line, and thus the low concentration of hydrogen.

Fig. 2.1: Time dependence of the reversal temperature of the 1-5 line in neon ($p_{f.d.}$ = 1.15 mbar, $I_{f.d.}$ = 3.6 mA).

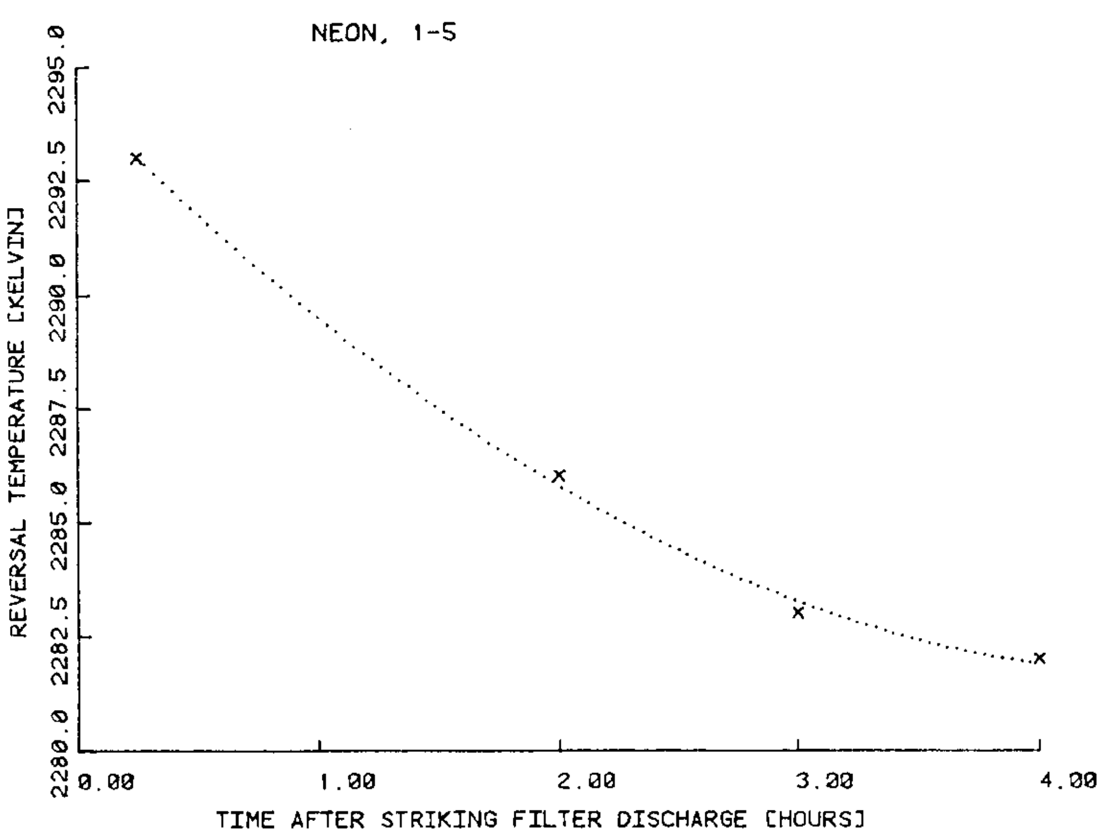


Fig. 2.2: Time dependence of the H_β intensity in a neon discharge ($p_{f.d.}$ = 1.15 mbar, $I_{f.d.}$ = 3.6 mA).

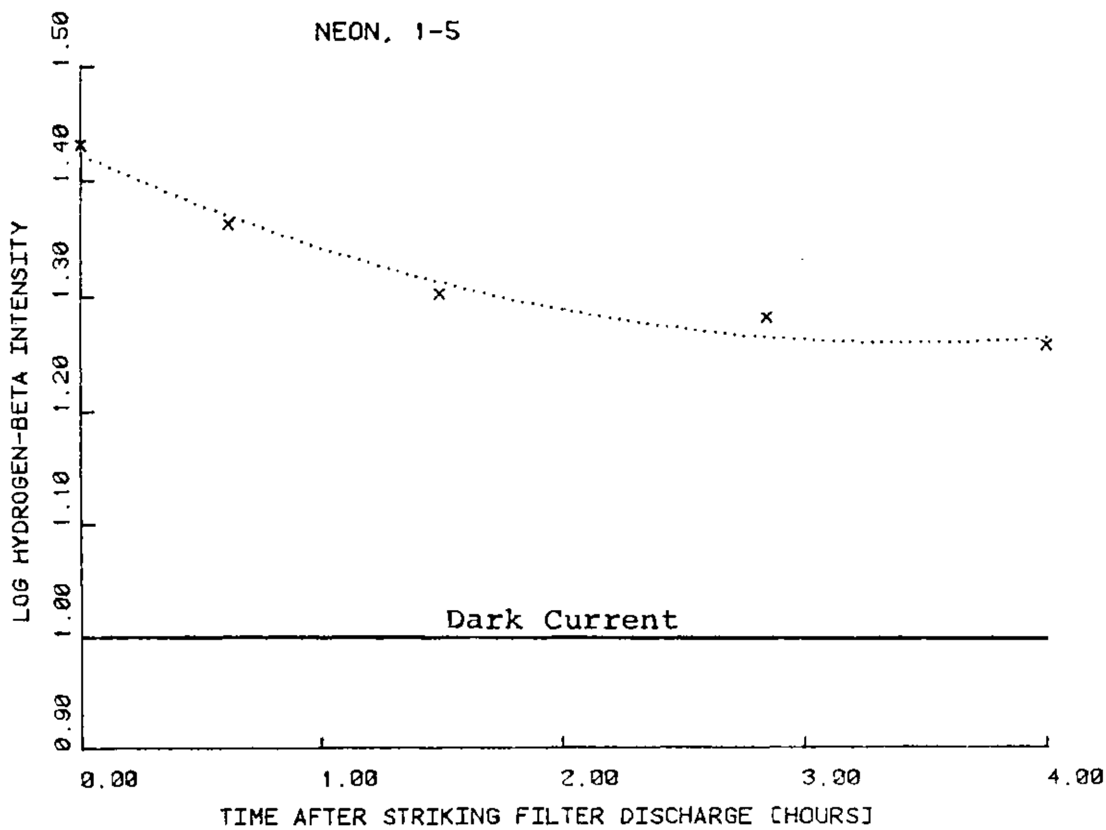
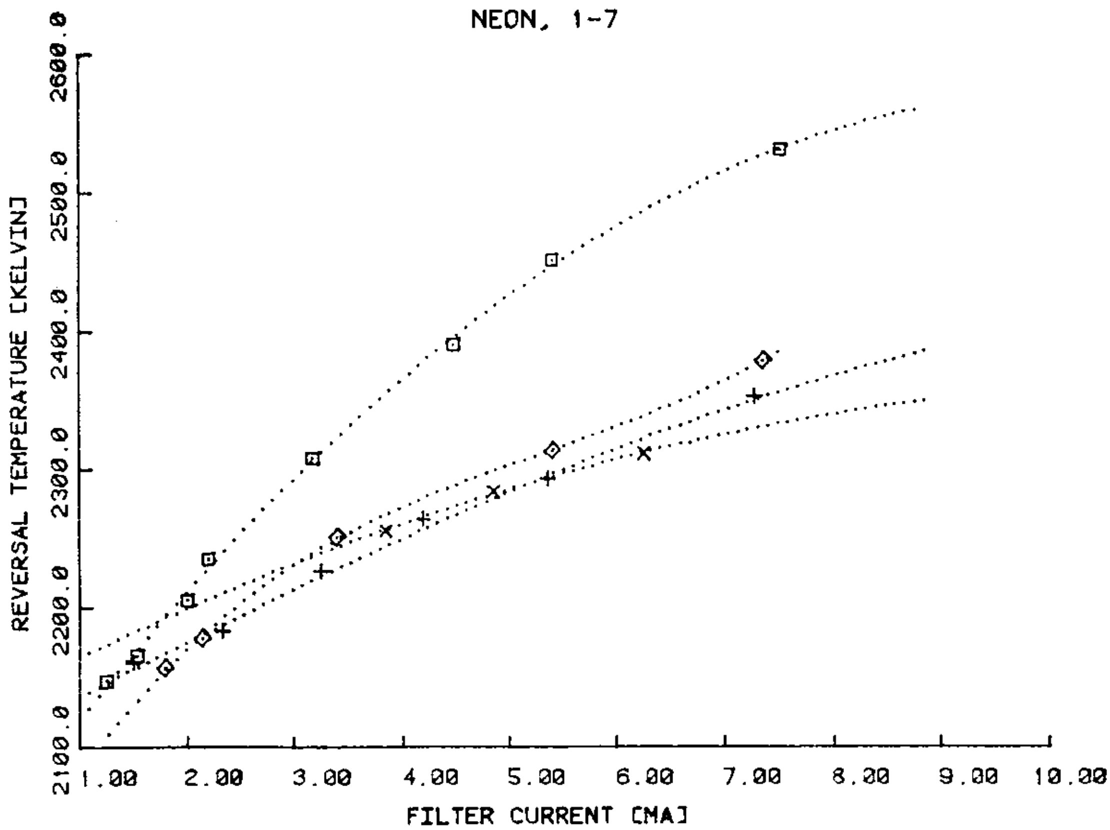


Fig. 2.3 shows the reversal temperatures obtained for seven lines in neon at four different filter discharge pressures and currents between 1.6 and 10 mA. The symbols for the measured data points distinguish the different filter discharge pressures according to the following key:

X ≙ 1 mbar
\+ ≙ 2 mbar
◇ ≙ 2.6 mbar
□ ≙ 4.4 mbar

Fig. 2.3: Reversal temperature measurement results for neon. The labels of the plots give the transition.



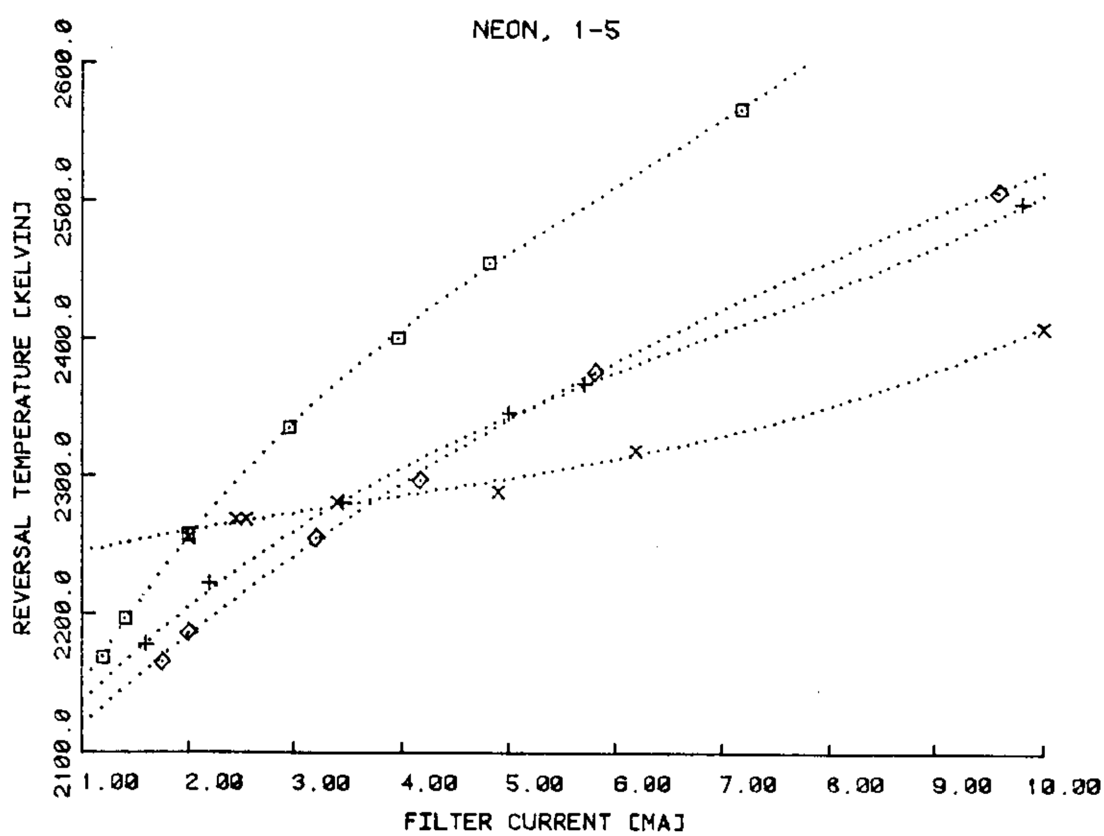


Fig. 2.3 continued:

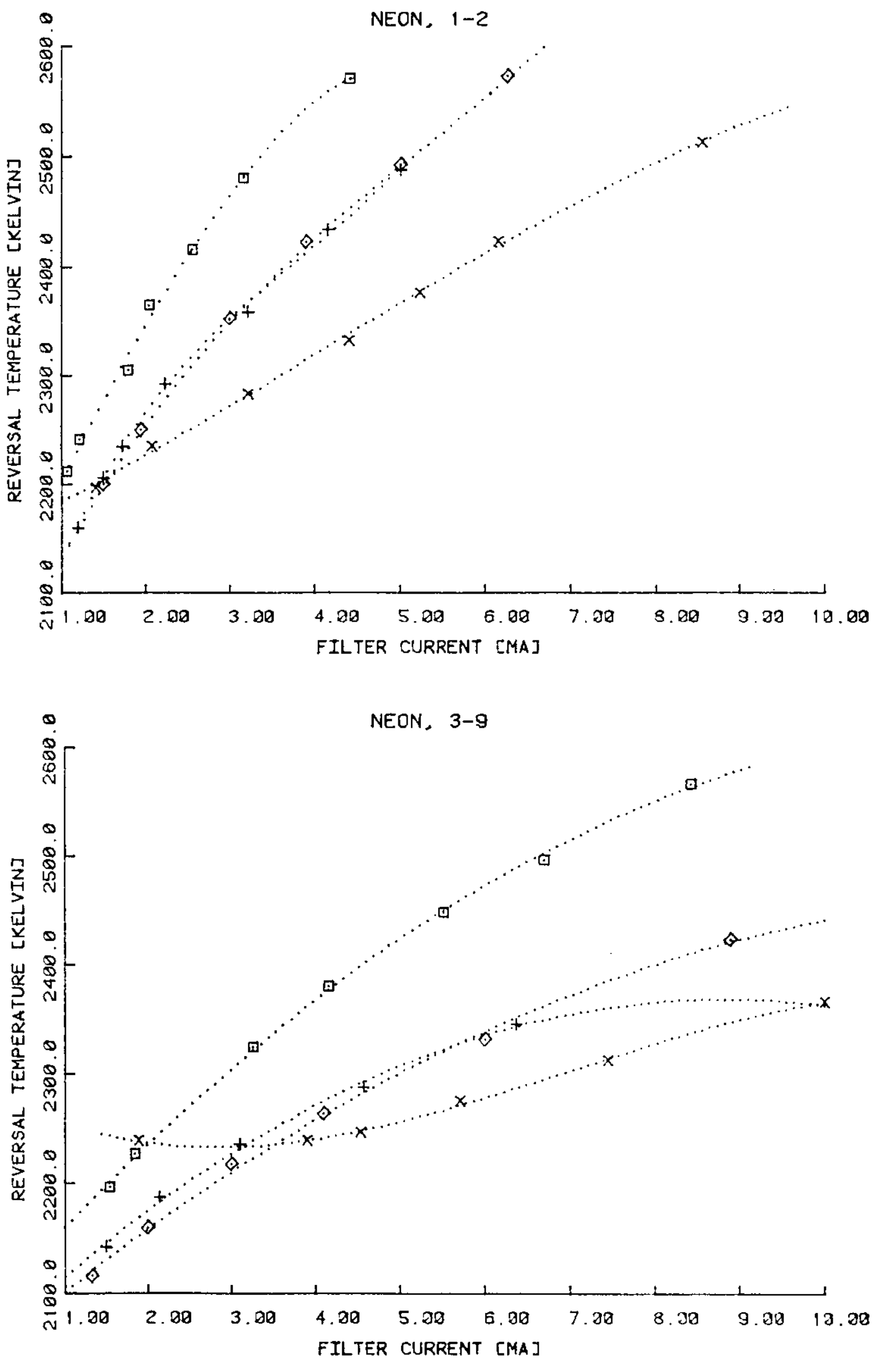
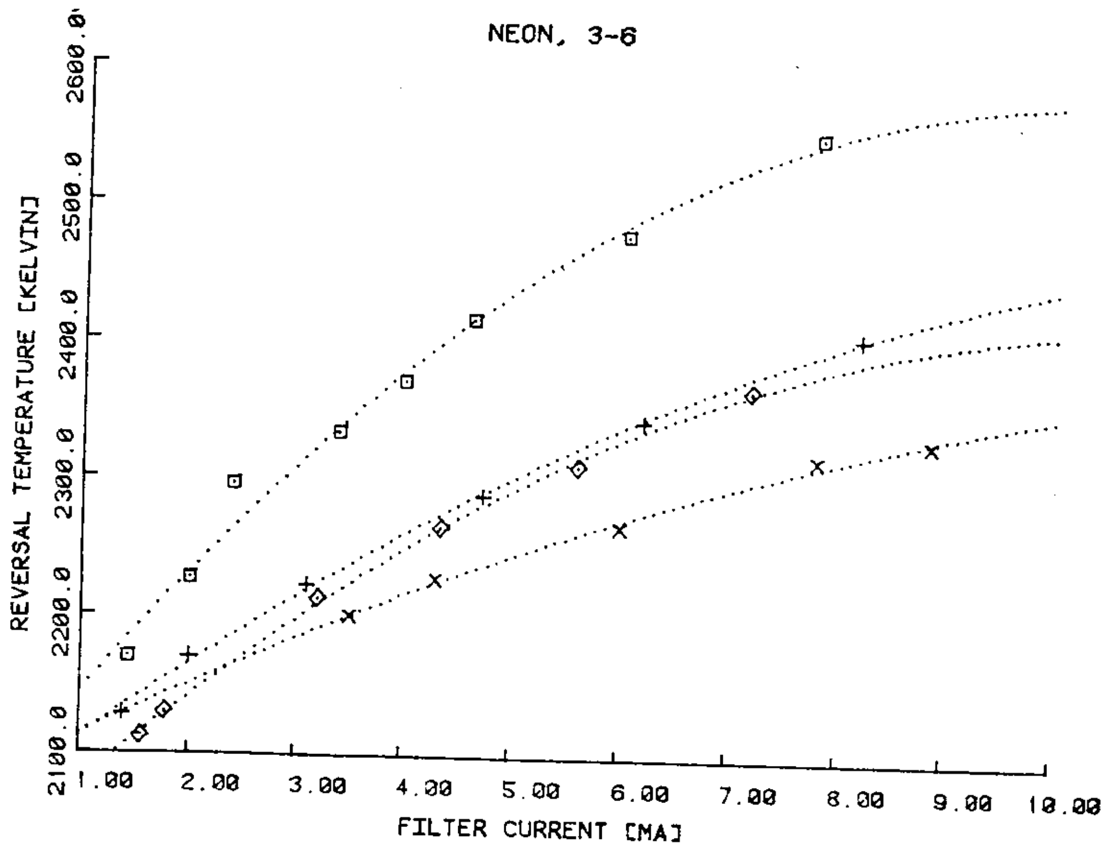


Fig. 2.3 continued:



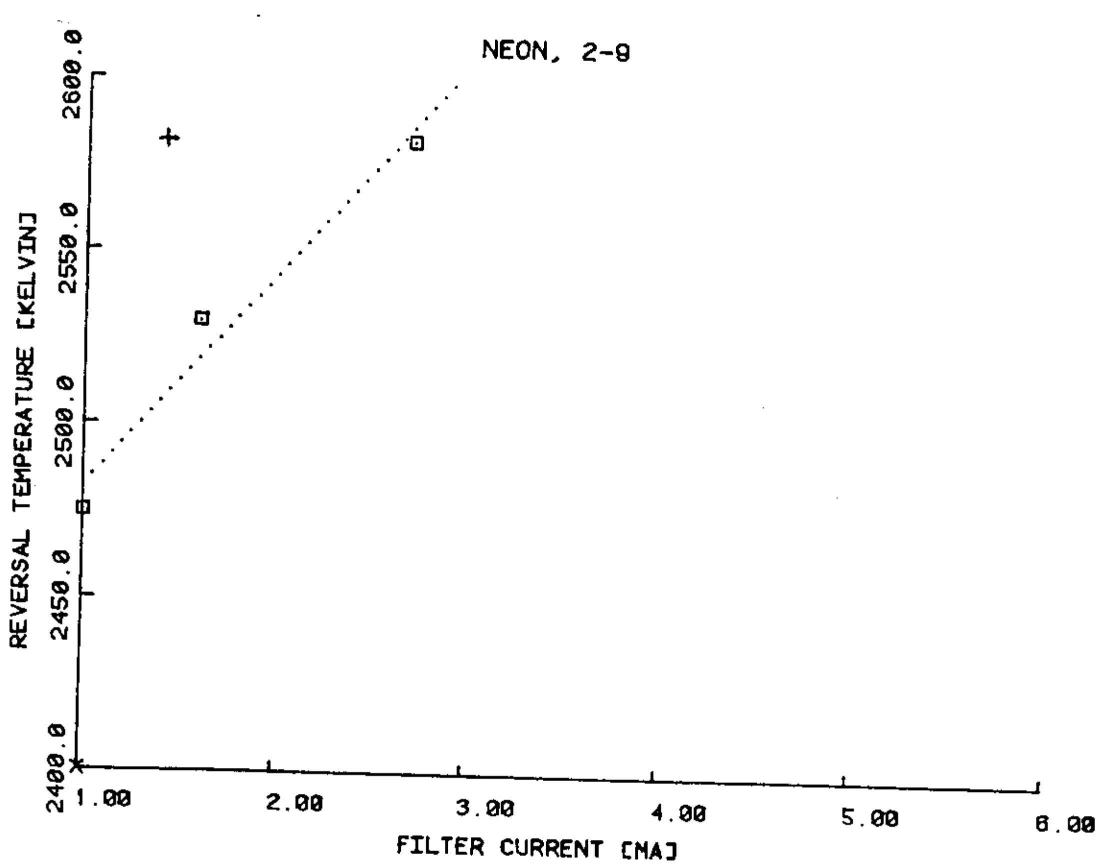
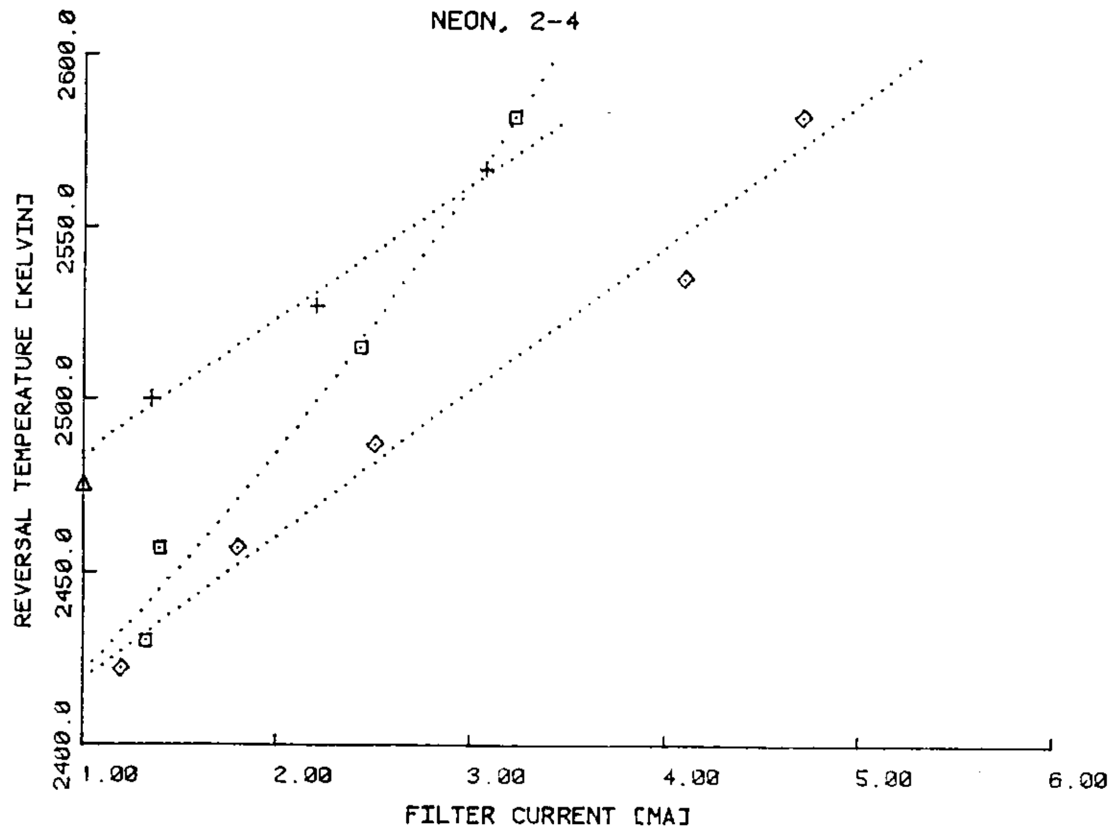


Fig. 2.3 continued:



The lowest reversal temperatures were found for the metastable lines. They lie at about 2150 K, but it should be noted that due to an improved efficiency of the 'Tesla', the minimum current could be lowered to 1.2 mA, while the minimum for the reduction factor measurements was about 2 mA. The figures show that for decreasing current the differences in the reversal temperatures due to different pressures become less significant. For currents above 3 mA, the reversal temperature is strictly higher for higher pressures. At about 2 mA, the reversal temperatures for the metastable lines are approximately 2200 K at all but the highest pressure. If this temperature is used in Equ. 2.1 , a value for $N_u g_l/N_l g_u$ of about 2 10^{-5} results.

The reversal temperatures for the two lines with the s2-level as lower state lie considerably higher than those for the metastable lines, with differences of up to 100 K between the values for different pressures. The lowest reversal temperature for the 2-4 line is 2460 K at 2.6 mbar.

To convert the standard lamp currents into black-body temperatures, the accompanying calibration chart was used. Considering the old age of this, a systematic error of up to $\pm$ 50 K cannot be excluded, while statistical errors of measurement are expected to lie within $\pm$ 10 K, which is confirmed by the scatter of the experimental data.

3. Filter Discharge Equivalent Width

It has been pointed out in Chapter III.3 that a measurement of the equivalent width of an absorption line is a suitable method to determine the optical depth of an absorption line if the background intensity is much greater than the emission intensity of the absorbing medium itself. As a knowledge of the optical depth of the filter discharge lines was essential for the intended computer modelling of the absorption process, a comprehensive set of equivalent widths has been measured for different filter currents and pressures in neon.

The method employed was as follows. The standard lamp, running at the highest possible current to ensure that the effect of the finite emission of the filter discharge was smallest, was viewed through the filter discharge and the resulting absorption profile was scanned with the photomultiplier and recorded on a x-y-recorder. For these measurements the primary slit and secondary slit were matched. The intensity of the background continuum was also recorded. The area of the absorption line then had to be divided by the background intensity, giving an equivalent width in terms of wavelength as result.

This scanning method was very laborious, as the scans had to be done by hand by turning the micrometer screw which drove the photomultiplier across the line. The scans were done on graph paper and the area of the resulting absorption profiles had to be determined by counting squares.

To reduce the effort, the equivalent width measurements were repeated with the photomultiplier stationary at the centre of the filter discharge line. This was done by measuring the intensity once with (I_2) and once without (I_1) the filter discharge in operation and calculating the equivalent width according to

$$W_\lambda = \frac{I_1 - I_2}{I_1} \Delta\lambda \qquad ,$$

where $\Delta\lambda$ is the spectral slit width (here 50 mÅ). The results of these measurements were compared with the results obtained by the scan method and the deviations could then be used to correct further equivalent width measurements with a stationary photomultiplier.

As was expected, the measurements with the stationary photomultiplier yielded equivalent widths smaller by typically 30% than those which were done by the scan method, since the invariable slit width of 50 μ, corresponding to 50 mÅ, was too narrow to measure the absorption in the wings of the line. The scans yielded equivalent widths of typically 45 mÅ for metastable lines and favourable filter discharge parameters. If this is compared to the 17 mÅ typical Doppler width, it becomes immediatementIy obvious that the lines must have been optically thick at line centre.

Furthermore, the measured equivalent widths still had to be corrected for the finite emission of the filter discharge. This correction can be calculated from the black-body temperature of the standard lamp and the reversal temperature of the lines in the filter discharge, according to Equ. III.4.3 .

In addition to this, any scattered light will also decrease the equivalent width. Two sources for scattered light are conceivable. First, although a small aperture stop of 9 mm diameter about 30 cm away from the lamp was used, the light from the background source would still be sufficiently divergent, so that some of it could reach the entrance slit after multiple reflections off the glass walls of the filter discharge tube without traversing the whole length of the absorbing positive column. Secondly, the grating had a bad reputation for scattered light which was strongly supported by a distinct fingerprint which could be seen on its surface. Moreover, the absorption profile scans cannot be used to find any contribution to the wings of the line as the signal-to-noise ratio does not allow this.

Considering all this, it seems to be justified to assume that the measured equivalent widths lie considerably below the actual values, say, by about a third according to the above example.

The problem of finding number densities from the equivalent widths was solved by using a computer programme for the calculation of the curve of growth (i.e. the dependence of the equivalent width on the number density of absorbers), which I wrote mainly using Equ. III.3.2 and

$$\int_{line} \varkappa(\nu)\ d\nu = \frac{e^2}{4\varepsilon_o mc} N_1\ f_{1u}$$

(Thorne /36/, Equ. 9.24) to calculate the peak optical depth from N_1. A listing of the programme, which was called 'COG', can be found in Appendix VI.

Runs for several filter lines showed that column densities of about 2 10^{13} cm^{-2} could be achieved for the population of the s1 and s3 levels, corresponding to a number density of about 2 10^{11} cm^{-3}.

It is instructive to compare this with the total number density of atoms at 2 mbar, which is about 6 10^{16} cm^{-3}. Thus, up to every 300,000th atom can be found in the s1 or s3 state under favourable conditions. To achieve this population ratio in thermal equilibrium would require a temperature, as determined by Boltzmann's equation, of 35,000 K. Comparing this with the reversal temparatures of about 2150 K demonstrates how far from thermal equilibrium the filter discharge is.

The following table gives a summary of interesting data.

Table 3.1: Summary of interesting data on the problem of the determination of equivalent widths and peak optical depths.

transition	1-7	1-5	3-9	3-6	2-4	1-2
wavelength [Å]	5945	6143	6163	6266	6383	6402
T_R [K]	2178	2186	2160	2144	2457	2250
$W_\lambda' = W_\lambda^{exp.}$ [mÅ]	45.1	51.3	44.8	51.9	9.7	60.1
calc. correction	1.22	1.25	1.22	1.20	3.01	1.40
used correction	1.33	1.33	1.33	1.33	3.30	1.53
W_λ [mÅ]	60.0	68.3	59.6	69.0	31.9	91.1
col. dens. [$10^{10} cm^{-2}$]	4620	3310	950	1450	115	3780
peak optical depth	40.3	65.8	42.9	95.9	3.4	239.1

4. Hollow Cathode Relative Intensities - Self - reversal

The intensity of an emission line is proportional to the number of downwards transitions, which is in turn proportional to $A_{ul}N_u$, if stimulated emission is ignored and no self-absorption or self-reversal occurs. Thus, if two spectral lines have the upper state in common, the ratio of their intensities should be determined solely by the ratio of the Einstein probability coefficients

$$\frac{I_1}{I_2} = \frac{A_{ul,1}}{A_{ul,2}} \quad .$$

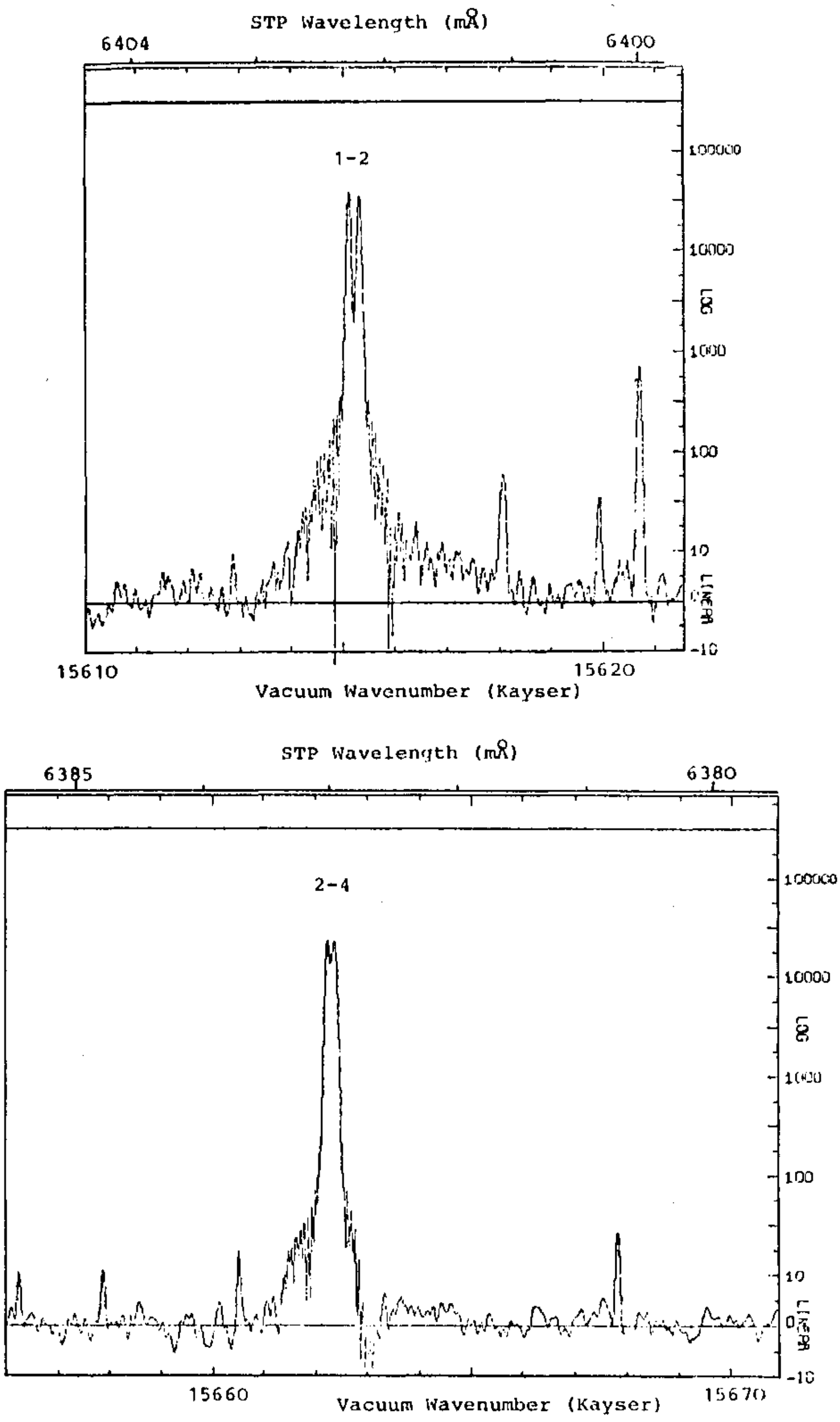
As self-absorption/reversal is proportional to the strength of the line, it tends to level out intensity differences between spectral lines. Since reliable experimental results for the A-values are available (Wiese and Martin /31/), it is possible to check for self-absorption/reversal if relative emission line intensities can be obtained. To be able to use the measured line intensities, the spectral response of the combination of spectrograph and photomultiplier had to be determined by using the standard lamp at a certain temperature as a gray-body emitter. Table 4.1 gives the ratio of the A-values and corrected measured intensities for a number of neon lines. In every case, self-absorption/reversal decreases with falling hollow cathode current, but the intensity ratios remain up to 50% below the ratio of the A-values. This indicates that self-absorption/reversal is very strong for all lines.

To support this, two high resolution Fourier transform spectrometer line profiles (resolution about 500,000) from an iron-neon hollow cathode operated at 900 mA and 4 torr are given in Fig 4.1 (Note the log-intensity scale). A complete set of FTS line scans can be found in Appendix I (by courtesy of R.C.M. Learner; profiles taken at Kitt Peak National Observatory, Tucson, Arizona, USA, 1981). An examination of the complete set reveals that, in fact, the stronger lines show stronger self-absorption/reversal. Furthermore, the lines with the s1 level as lower state exhibit the strongest effects followed by the s3, s2, and s4 lines. It should be noted that the 1-2 line (see Fig. 4.1) is most severely affected, leading to apparently two lines being observed.

Table 4.1 :

lines	ratio of A-values	Intensity ratios at filter discharge current			
		100 mA	150 mA	250 mA	350 mA
4-9/2-9	4.14	3.11	3.00	2.78	2.35
3-9/2-9	2.60	2.04	2.04	2.01	1.94
4-10/2-10	75.8	55.5	53.9	50.7	50.2
1-5/4-5	1.62	0.96	0.95	0.95	0.92
2-4/3-4	2.97	1.80	1.61	1.61	1.62

Fig. 4.1: FTS line scans of hollow cathode lines 1-2 and 2-4 in neon at 900 mA and 4 torr.

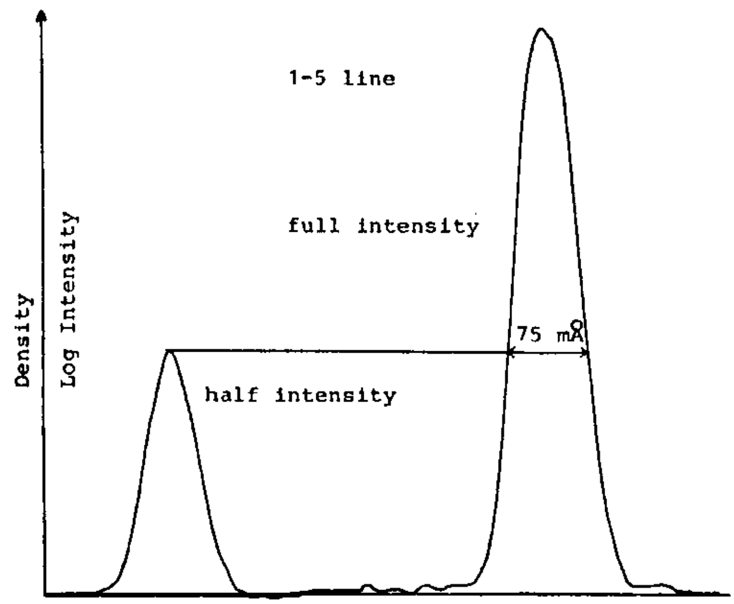


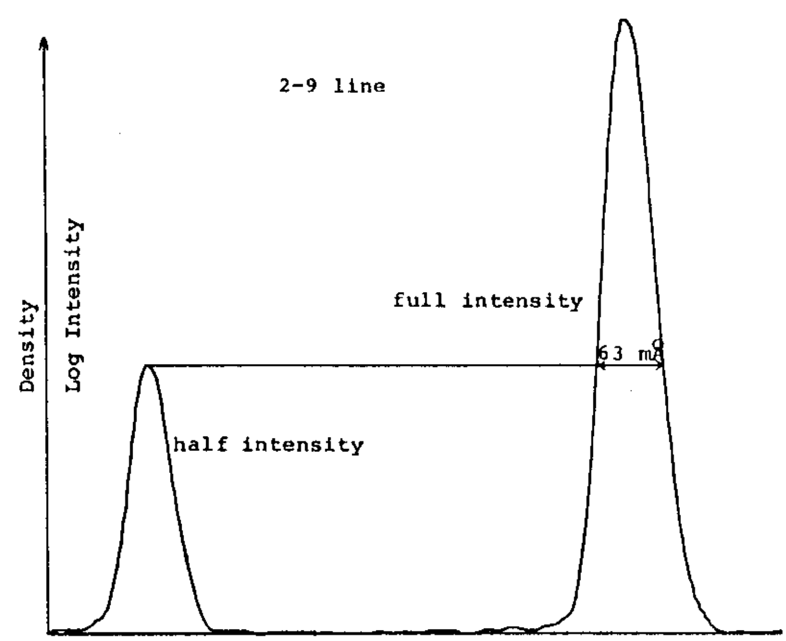
5. Hollow Cathode Line Shapes and Shifts

The fixed width of the secondary slit of the photomultiplier housing did not allow the full resolving power of the spectrograph to be used. Thus, to obtain hollow cathode line profiles, the photomultiplier was replaced by a 35 mm-film-holder which I built and Kodak high speed IR black and white film was used to photograph the spectral lines. The films were analysed by means of a microdensitometer and two of the traces obtained are reproduced in Fig. 5.1 . The micro-densitometer measured the density of the film rather than its transmission and, moreover, it was not certain that the exposures corresponded to the linear part of the film characteristic. Thus, an indirect method was used to determine the half width of the lines. Two exposures of a particular line were taken with the full and the half time of exposure, and the width of the first one was measured at a height corresponding to the peak of the second. It must be stated that this method ignores departures from the reciprocity law, on the grounds that other errors are likely to be at least as large.

In addition to these measurements, the Hartmann diaphram of the entrance slit was used to photograph the hollow cathode lines with the same line in the filter discharge on top and below. The hollow cathode line shifts were determined on a measuring microscope and the corresponding Stark line widths could then be obtained from Griem's tables /10/, assuming that the shift was due to the Stark effect. The shifts of all hollow cathode lines were found to be 3 mÅ $\pm$ 1 mÅ at 350 mA/2.5 mbar and 2 mÅ $\pm$ 1 mÅ at 250 mA/2.25 mbar in neon. The corresponding Stark widths (FWHM) of about 3 mÅ and 2 mÅ respectively were employed to de-convolute the experimental line widths from their Lorentzian components. The resulting

Fig. 5.1: Microdensitometer traces of hollow cathode lines taken at 350 mA and 2.5 mbar in neon.





total Gaussian widths could then be corrected for the Gaussian instrumental function, as described in Chapter III.4 . The intrinsic Gaussian component cannot be attributed solely to Doppler broadening because of the self-absorption/reversal. It would therefore be expected to vary from one line to another, and this is borne out by Table 5.1, which shows the reduced intrinsic Gaussian widths for a hollow cathode current of 350 mA and a pressure of 2.5 mbar in neon, and calculated Doppler widths for a gas kinetic temperature of T = 700 K, which is thought to lie close to the actual temperature in the hollow cathode for these running conditions. In fact, it can be concluded that the broadening increases with the f-value of the line; the 1-2 line shows very strong self-absorption/reversal and the 1-5 and the 3-6 lines are also considerably broadened, while the other lines in the table seem to be less affected. These findings could have been expected from the results described in Chapter V.4 .

The isotope broadening, which was discussed in Chapter III.2, will be taken account of in Chapter VII.

Table 5.1: Hollow cathode Gaussian widths for different currents calculated from measured line widths, and expected Doppler widths in neon for T = 700 K.

transition	1-7	1-5	3-9	3-6	2-4	1-2
experim. FWHM [mÅ]	54.4	59.5	57.5	60.5	56.8	74.9
Lorentz. FWHM [mÅ]	3	3	3	3	3	3
tot. Gauss. FWHM [mÅ]	52.8	57.9	55.9	58.9	55.2	73.3
instr.Gauss.FWHM [mÅ]	42.9	43.6	43.7	44.0	44.4	44.5
intr.Gauss. FWHM [mÅ]	30.7	38.1	34.9	39.2	32.8	58.2
calc.Doppl. FWHM [mÅ]	25.1	26.0	26.1	26.5	27.0	27.1
f-value	0.060	0.159	0.249	0.440	0.196	0.443
A [10^7 sec^{-1}]	1.13	2.82	1.46	2.49	3.21	5.14

VI. REDUCTION FACTOR MEASUREMENTS

1. Introduction

The reduction factors, defined in Chapter III.1 as the ratio of hollow cathode line intensity without and with the filter discharge in operation, were measured for every combination of the following number of lines and parameters.

Neon:

12 spectral lines

4 hollow cathode running conditions:
100 mA - 2 mbar
150 mA - 2.1 mbar
250 mA - 2.25 mbar
350 mA - 2.5 mbar

5 filter discharge pressures:
1 mbar
1.3 mbar
2 mbar
4.4 mbar
6.4 mbar

about 7 filter discharge currents between 2 mA and 10 mA, depending on the behaviour of the reduction factors

Argon:

6 spectral lines

4 hollow cathode running conditions:
150 mA - 2.4 mbar
250 mA - 2.4 mbar
350 mA - 2.4 mbar
450 mA - 2.4 mbar

4 filter discharge pressures:
0.7 mbar
1.7 mbar
3.0 mbar
3.7 mbar

about 6 filter discharge currents between 1.6 mA and 8 mA, depending on the behaviour of the reduction factors

It was decided to present the roughly 2000 measured reduction factors as plots of reduction factor against filter current. For each spectral line the five (four) curves obtained for different pressures in the filter discharge were plotted on one graph. This was done because in most applications the decision about the hollow cathode current is dictated by the nature of the experiment, and the filter will be a piece of equipment to be adapted to the particular situation. The complete sets of plots for neon and argon can be found in the Appendices II (neon) and III (argon).

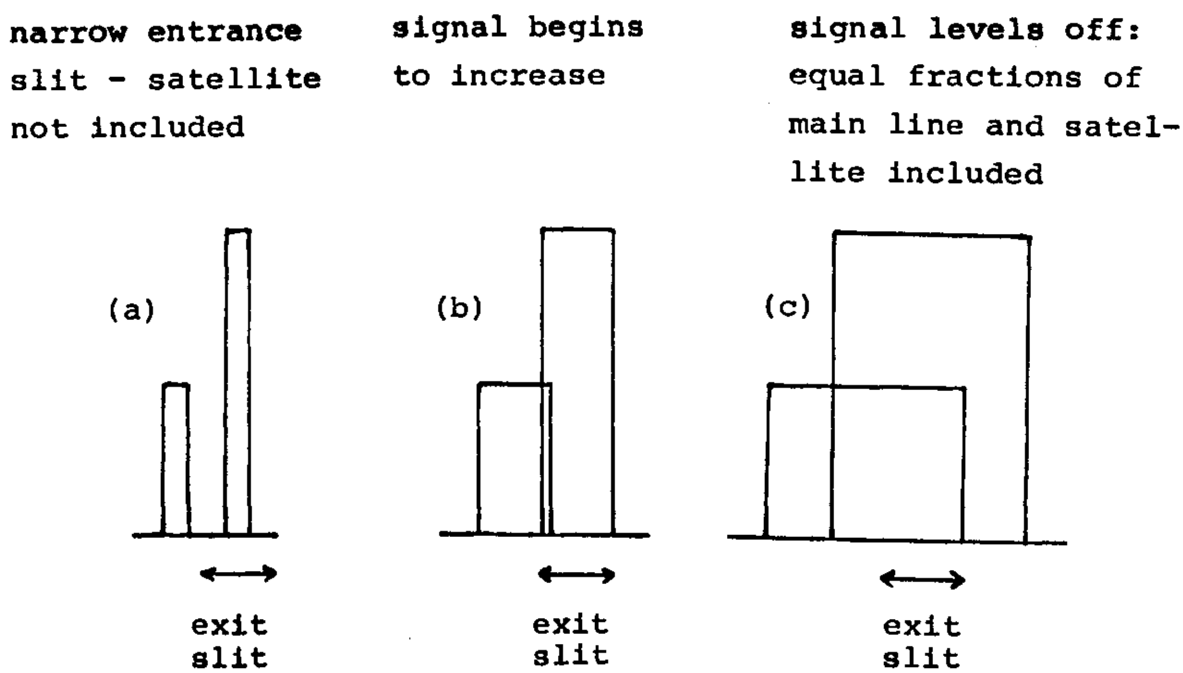
The reduction factors were measured in the following way. The filter discharge, previously filled with the inert gas at one of the pressures under investigation (previously can mean anything between a few minutes and a week before), was struck and run at a medium current (~5 mA) for about four hours to allow the discharge to clean up (see Chapter V.2). Then the hollow cathode discharge was struck and run up to the desired current.

The reduction factors were then measured for each spectral line at different filter currents. This sequence had to be repeated for the remaining three hollow cathode currents. Hereafter, the pressure in the filter discharge was changed, and all these measurements were repeated and so again for each remaining filter discharge pressure.

The reduction factor was defined as the ratio of the hollow cathode emission line intensity measured by the photomultiplier without the filter discharge in operation to that with it; the readings on the picoammeter were corrected for the dark current of the photomultiplier where necessary. This was usually only the case for the long-wavelength lines for which the sensitivity of the photocathode fell off and for low hollow cathode currents. The primary slit of the spectrograph was opened sufficiently widely that no significant increase in line intensity could be observed if the slit width was further increased.

It can be argued that this ensures that the hollow cathode line profiles, which have about the same width as the exit slit (50 μ = 50 mÅ, see Table V.5.1), are measured so far out into the wings that the reduction factors reflect the absorption process integrated practically over the whole line. A simple argument to make this understandable runs as follows. Consider a spectral line and a less intense satellite so far away from the main line that with a narrow entrance slit only the main line is imaged on the exit slit (see Fig. 1.1 a). If the entrance slit is opened, the intensity detected behind the exit slit will increase since the broader image of the satellite will partly fall onto the exit slit (b). When the whole exit slit receives light from the satellite, the intensity will no longer increase if the entrance slit is opened even further and the light from the main line and from the satellite is detected with the ratio of their total intensities (c).

Fig. 1.1: Influence of the entrance slit width on image-forming process for a strong line and a satellite.



A thorough check of the reduction factors measured in this way against results obtained from complete line scans is included at the end of this chapter. It will show that no noticable systematic error has been introduced.

The relative intensity of the filter discharge emission with respect to the hollow cahtode emission was also recorded, as this has to be known for the computer calculations described in Chapter VII.

The large amount of data which was to be presented made it necessary to find an efficient way to produce the plots. For this purpose I wrote a computer programme which allows one to plot up to five sets of data in one coordinate system and also offers the option of plotting a polynomial of any desired order to fit the data points. These fits served to connect the points which belong together and to indicate the probable behaviour of the reduction factors between data points. The latter is not always the case, as a polynomial is not necessarily a suitable means to smooth the data. It should be noted that there is no theoretical significance in using a polynomial fit.

Each set of plots has a title giving the gas , the spectral line, and the hollow cathode current and pressure. The data curves for different filter discharge pressures can be identified by the symbols used to plot the measured data points. The keys to the symbols are given in the appropriate sections.

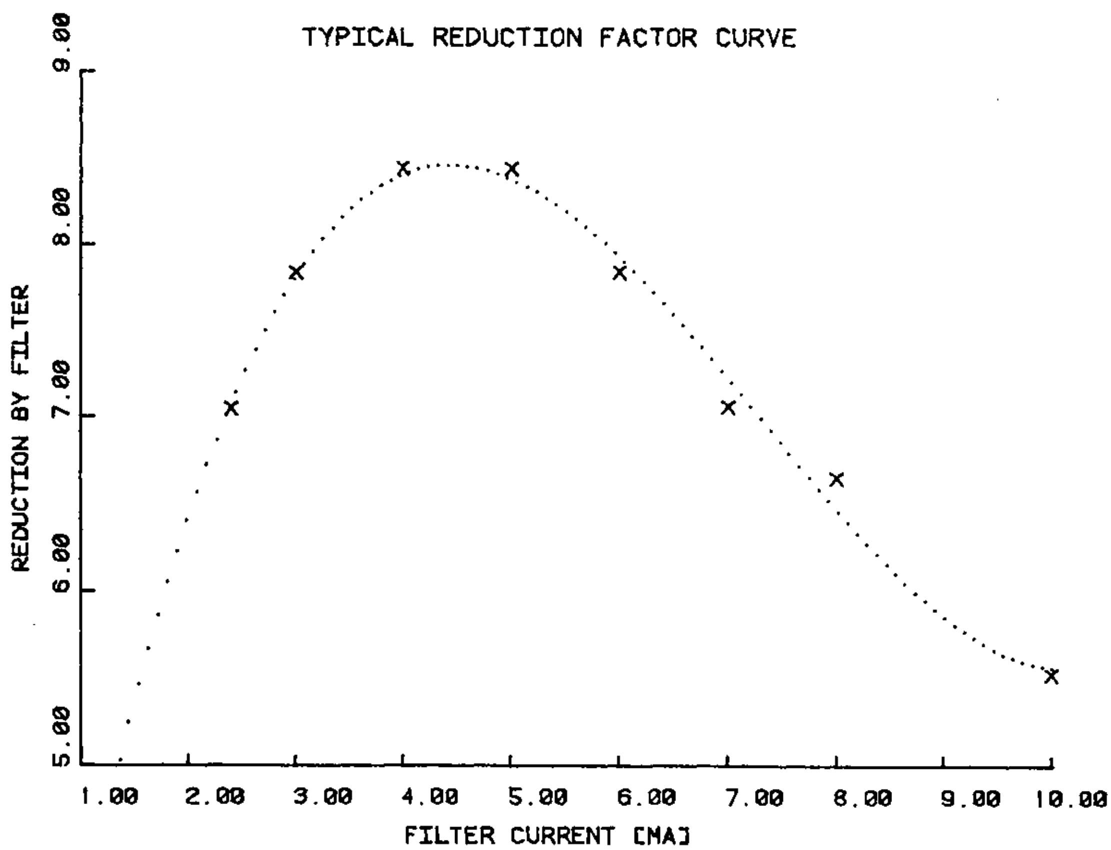
2. Neon

a) Hollow Cathode Current 350 mA

i) Results

In general, it can be stated that all reduction factor curves seem to have the same shape, which is exemplified by Fig. 2.1 . The reduction factor starts with a low value for low filter currents and increases to a maximum with increasing current before tailing off in a relatively long 'wing' for high filter currents. Obviously, the experimental results often comprise only certain parts of this general curve, but it is still a useful idea to remember.

Fig 2.1: Typical behaviour of the reduction filter against filter current.



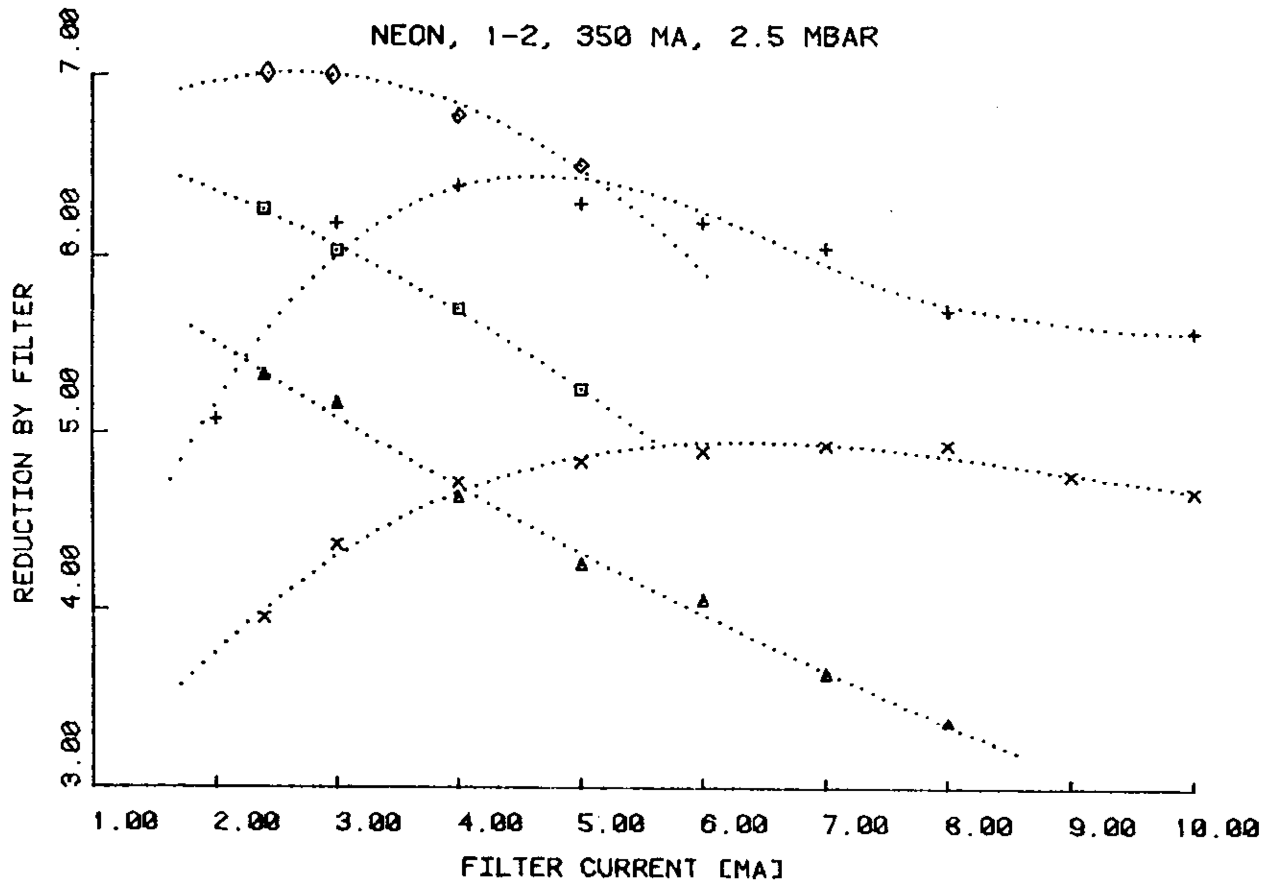
The description of the reduction factor results will be commenced with those obtained at a current of 350 mA and a pressure of 2.5 mbar in the hollow cathode. Fig. 2.2 shows the results for the neon lines with metastable lower levels s1 and s3 . The key to the symbols is as follows:

X	≙	1	mbar
+	≙	1.3	mbar
◇	≙	2	mbar
□	≙	4.4	mbar
△	≙	6.4	mbar

If the curves are considered in the sequence of increasing filter discharge pressure, it can be noted that the maxima of the curves are continuously shifted towards lower filter discharge currents. For high filter pressures, the maxima lie outside the range of the experiments but may be expected at very low currents.

The maximum reduction factor reached for each filter pressure increases with the pressure to a maximum at 2 mbar and decreases again for high pressures. As this is so for all metastable lines, it becomes clear that a pressure of about 2 mbar produces the optimum reduction factors. Henceforth, the shorthand 'ORF' will be used for the 'optimum reduction factor' with respect to a particular line at a particular hollow cathode current and pressure. Thus, the ORF corresponds to the highest ordinate in a particular figure. The filter currents at which the ORFs occur for the metastable lines lie between 3.5 mA and 4.5 mA, with the exception of the 1-2 line, where the optimum is found at 2.5 mA. All these ORFs lie between 8.5 and 9.5, again with the exception of the 1-2 line, where the optimum is about 7.

Fig. 2.2: Reduction factor measurement results for the metastable lines in neon. The labels of the plots give the gas, the transition, hollow cathode current and pressure.



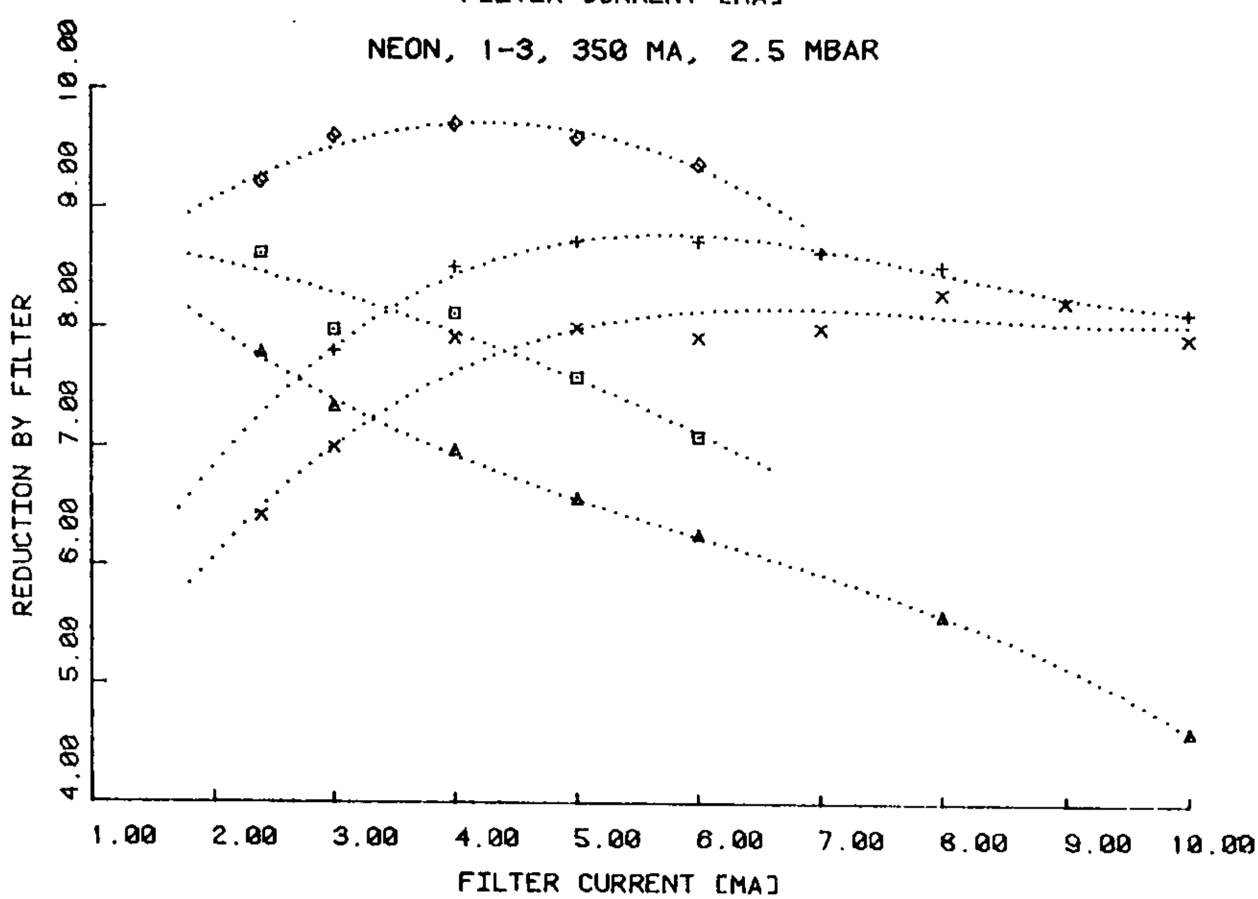
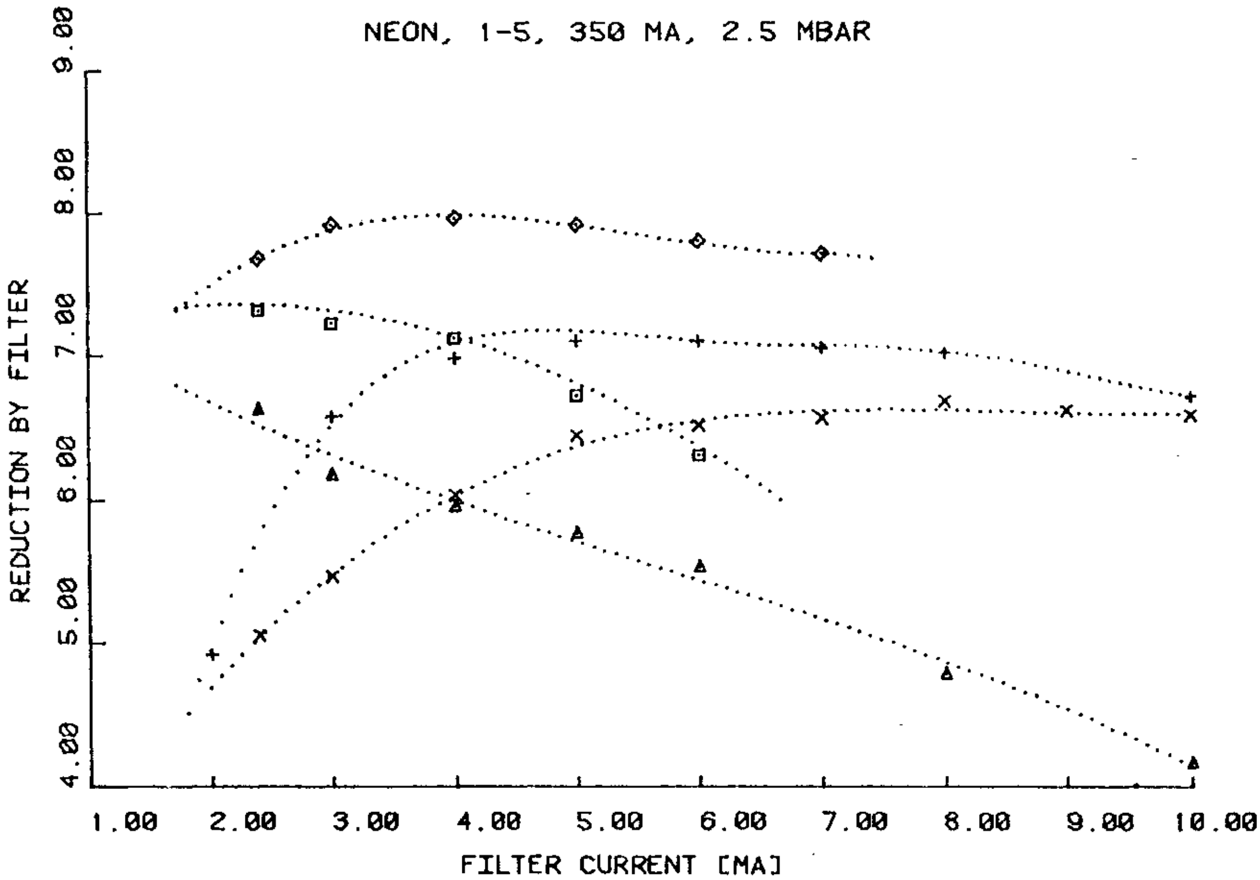


Fig. 2.2 continued:



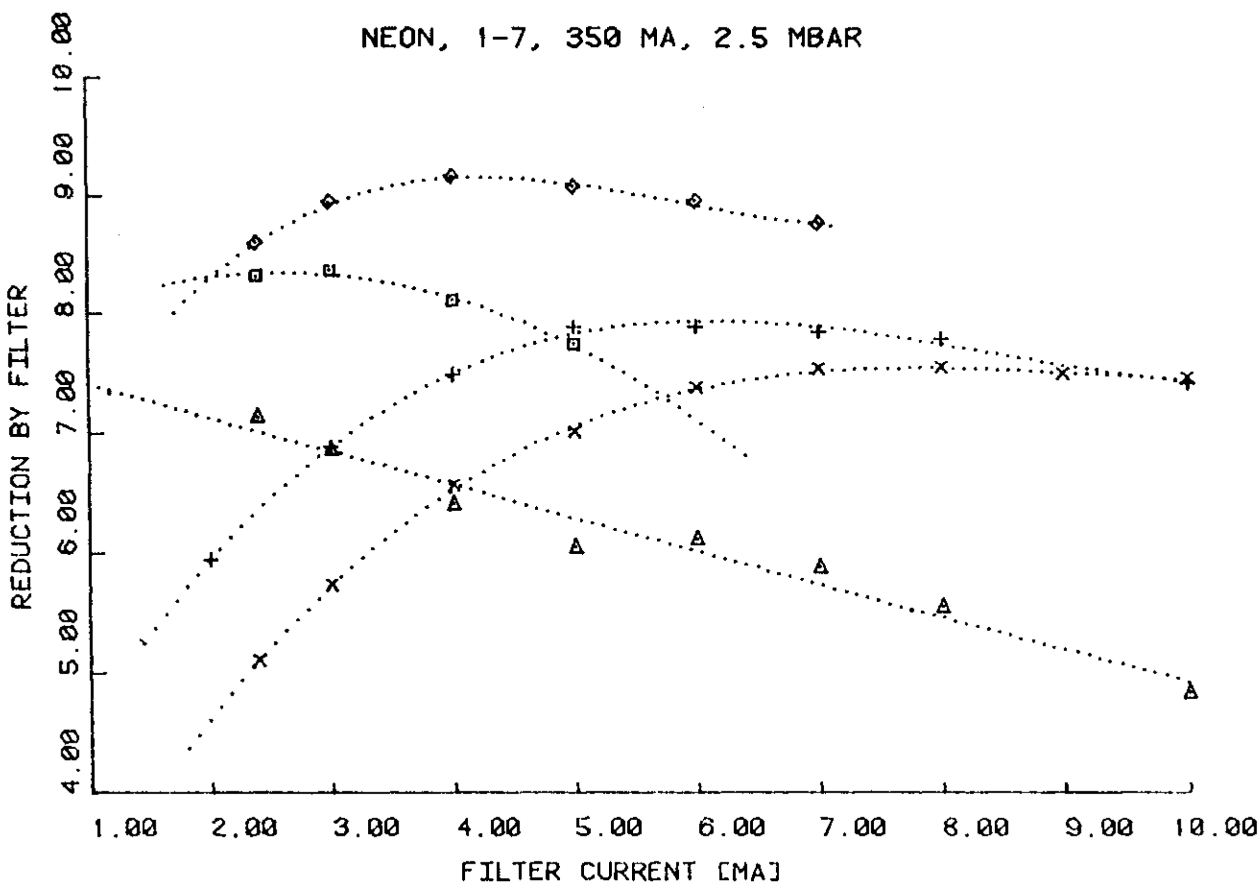
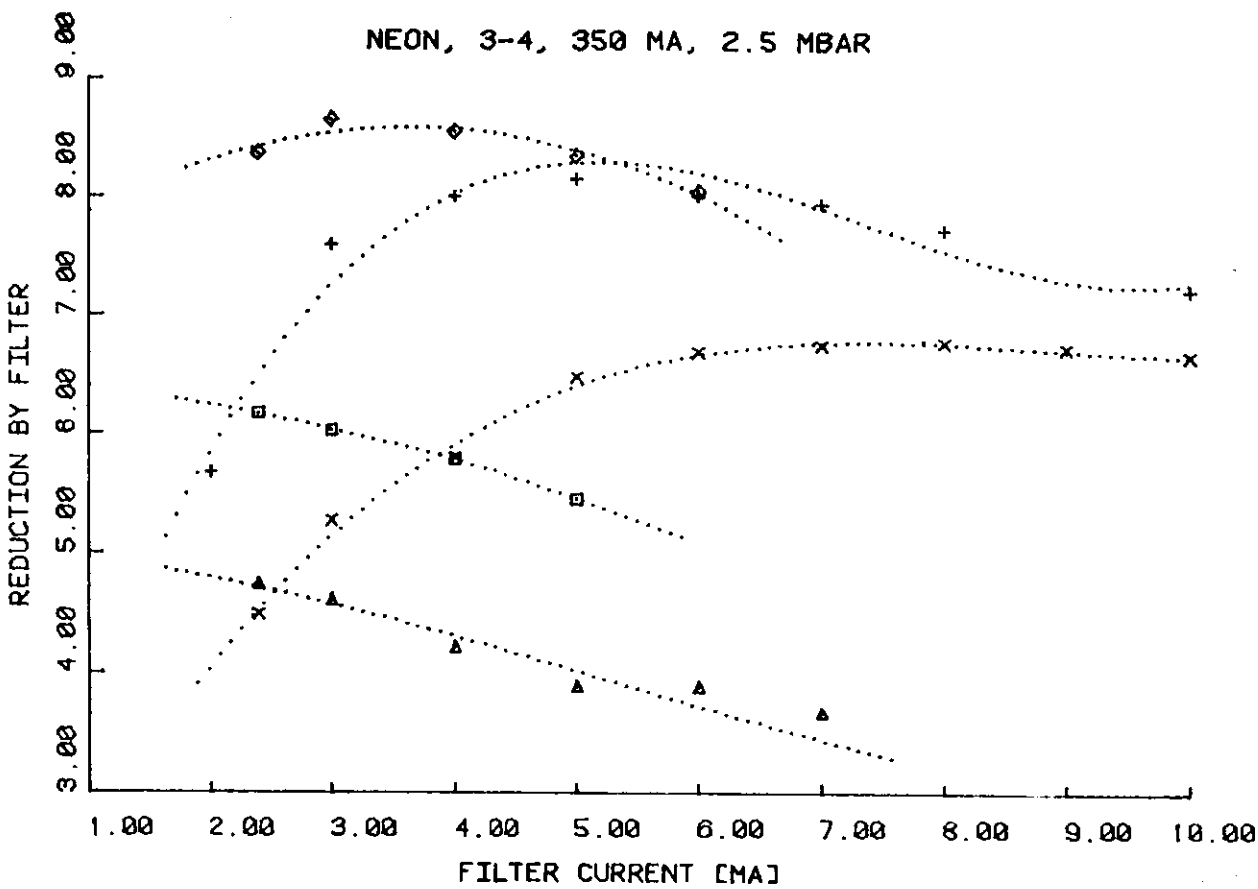


Fig. 2.2 continued:



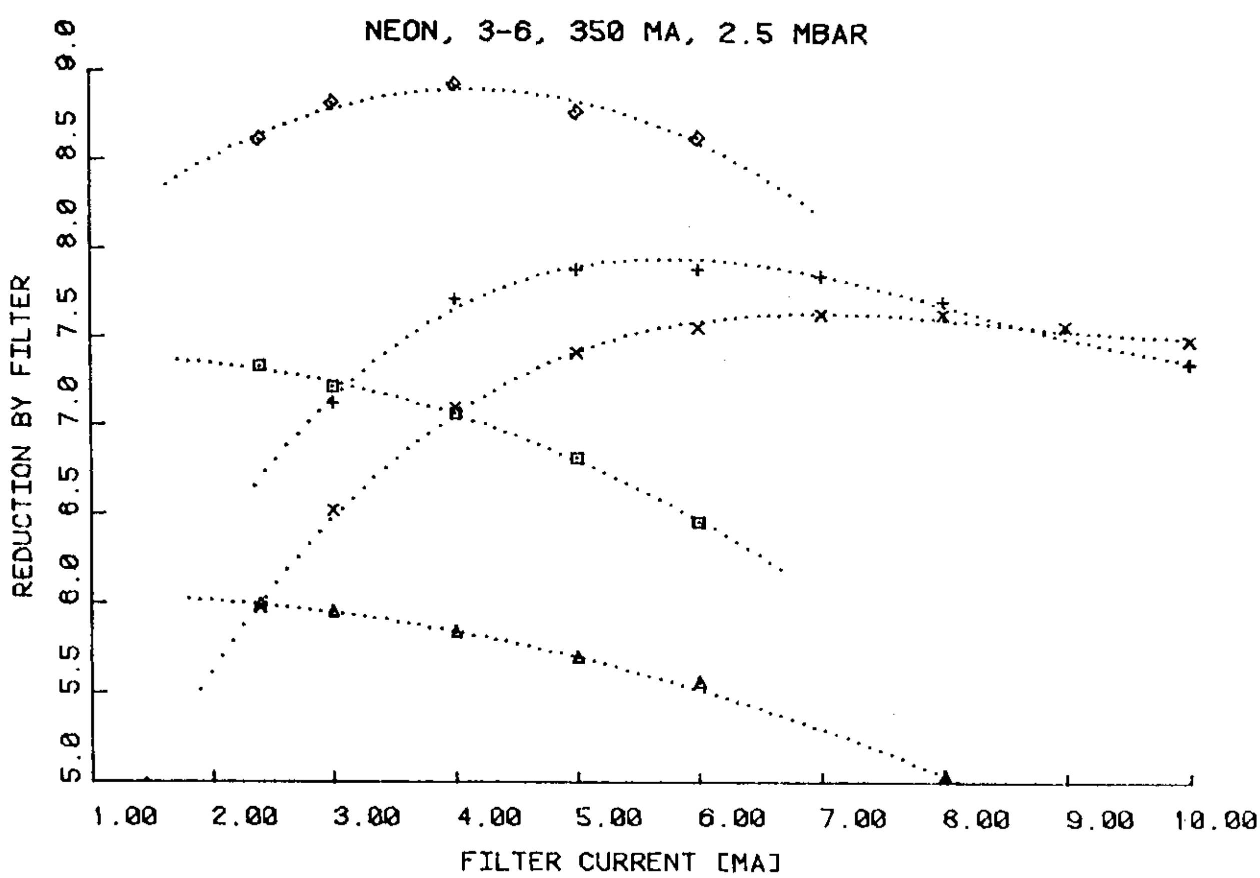
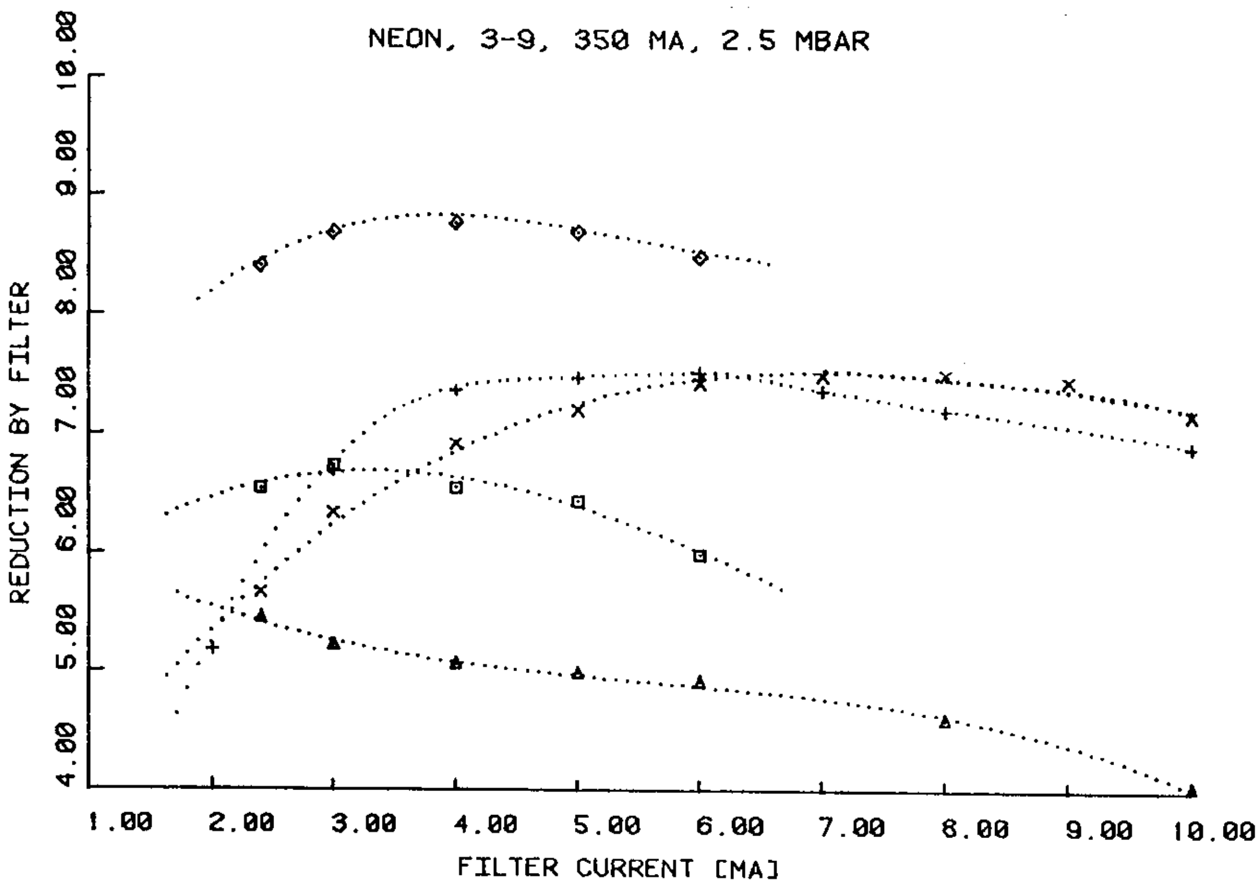


Fig. 2.2 continued:



In the light of these findings, the behaviour of the non-metastable lines will now be discussed. After what has been said in Chapter III.5, the behaviour of the lines with the s2 level as lower state must be expected to resemble somewhat that of the lines to the metastable levels. This is in fact so for the 2-4 and 2-9 lines, as can be seen from Fig. 2.3, although the following differences occur. Generally speaking, higher currents are needed to reach lower maximum reduction factors. The ORFs are reached at pressures of 2 and 4.4 mbar and at currents of 5 and 7 mA respectively. It can also be noted that high pressures are not as unfavourable as for the metastable lines. The ORFs deteriorate rapidly for rising energy of the upper state of the line, which can also be seen from Fig. 2.3 .

Fig. 2.3: Reduction factors for the lines from the s2 level in neon. The labels of the plots give the gas, the transition, hollow cathode current and pressure.

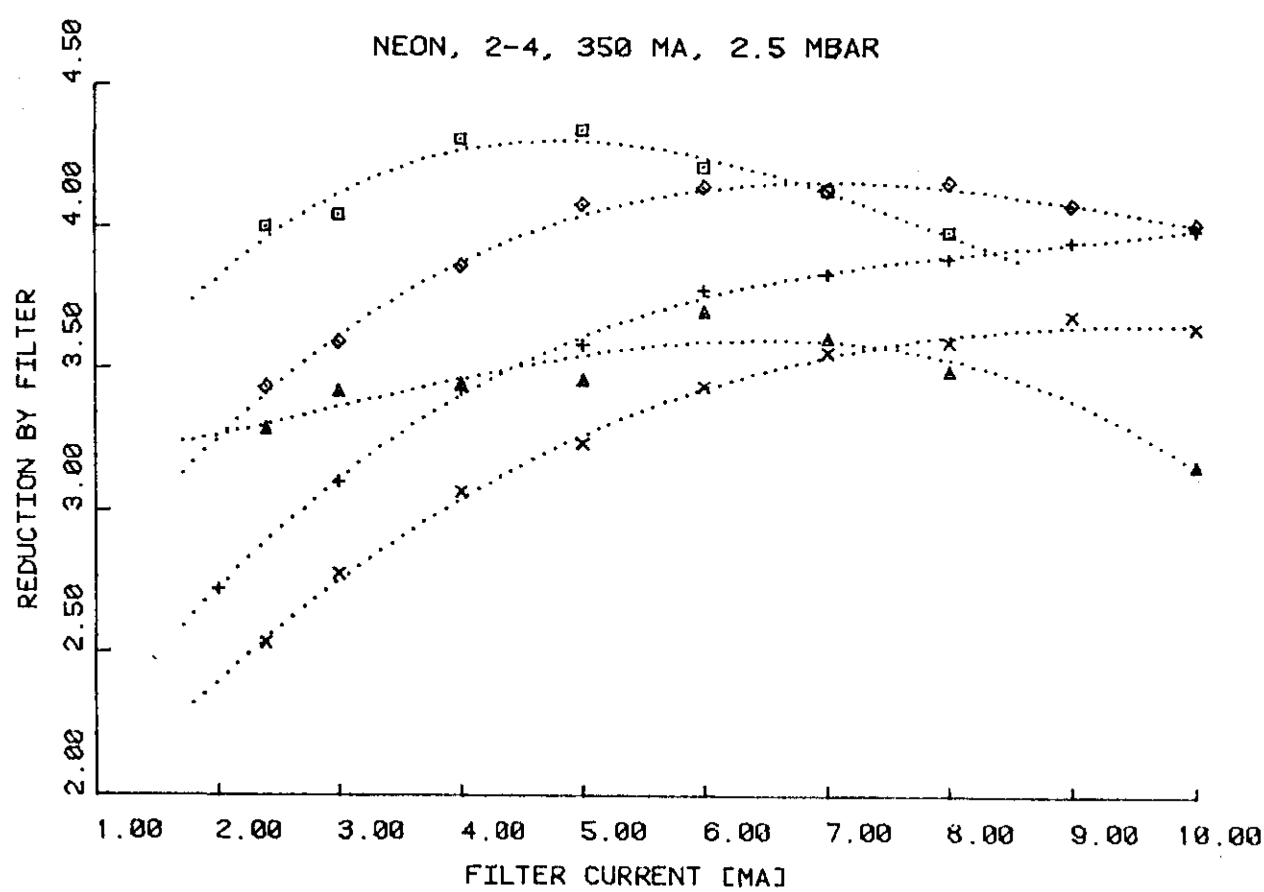
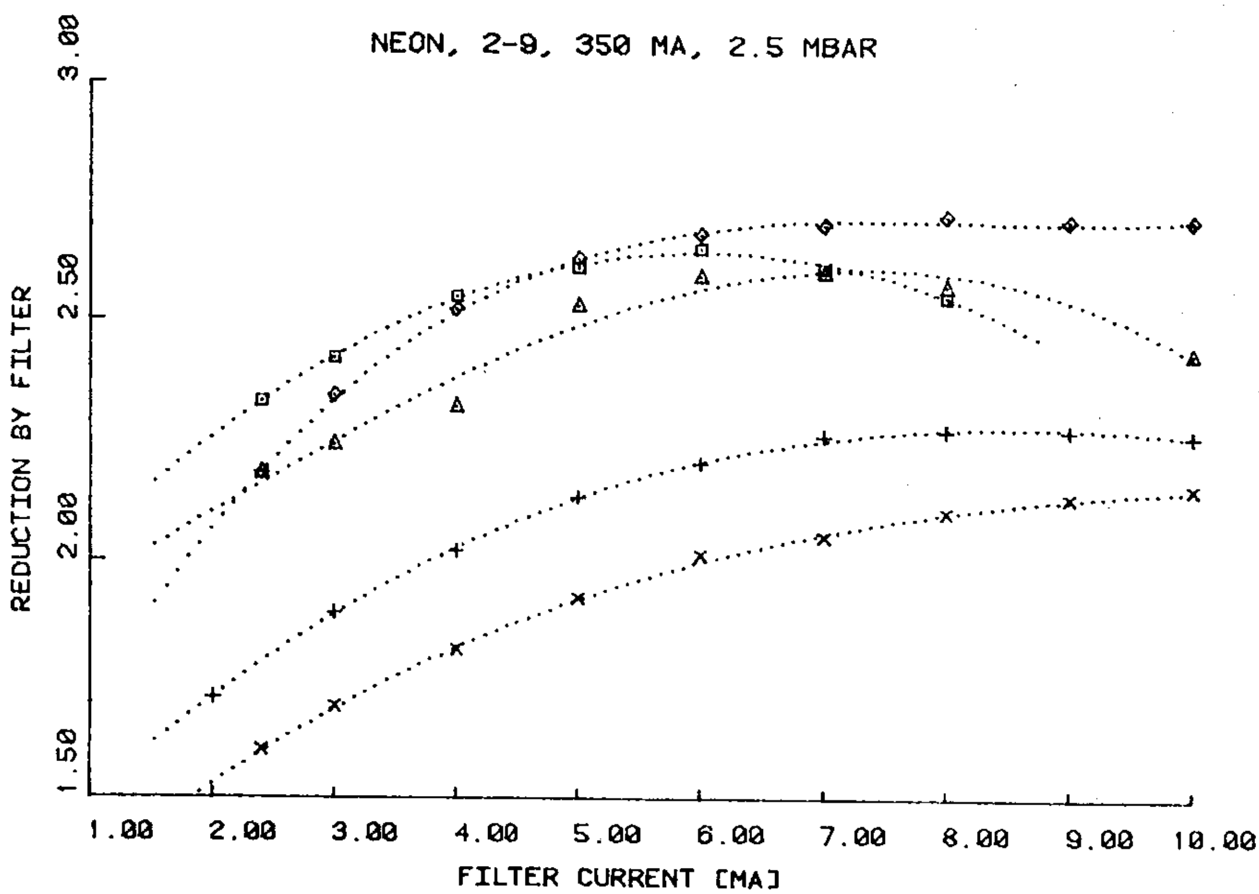
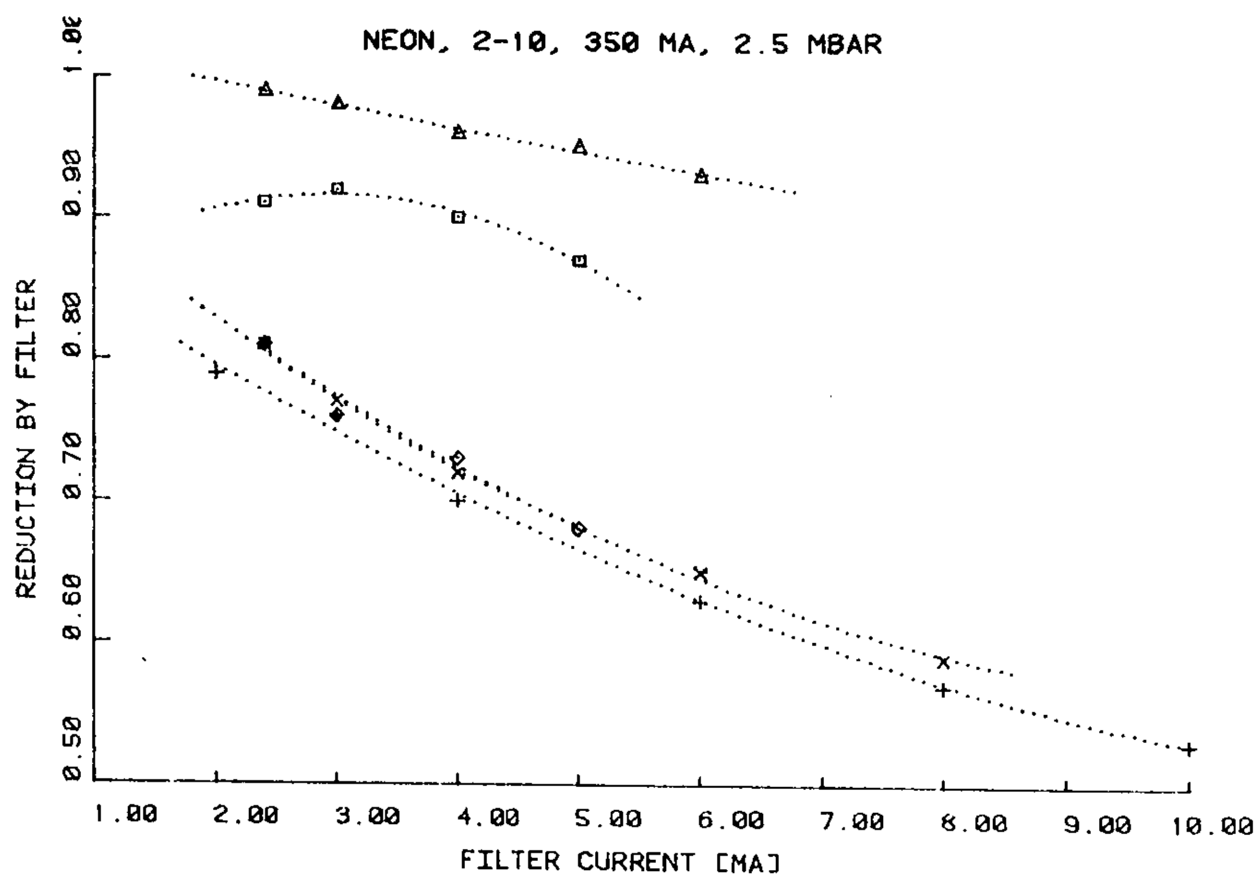


Fig. 2.3 continued:





The 2-10 line behaves differently from the other two lines from the s2 level that have been measured. In particular, no reduction whatsoever occurs for any parameters, with high pressures and low filter currents being less unprofitable. This behaviour is similar to that of the 4-10 line (Fig. 2.4), but the measurements for this line are incomplete.

For the 4-9 line, low pressures and high currents are favourable. The reduction factors of the 2-10 line and all the s4 lines lie close to one and confirm that the filter does not operate on these lines to any appreciable extent.

Fig. 2.4: Reduction factor measurement results for the lines from the s4 level in neon. The labels of the plots give the gas, the transition, hollow cathode current and pressure.

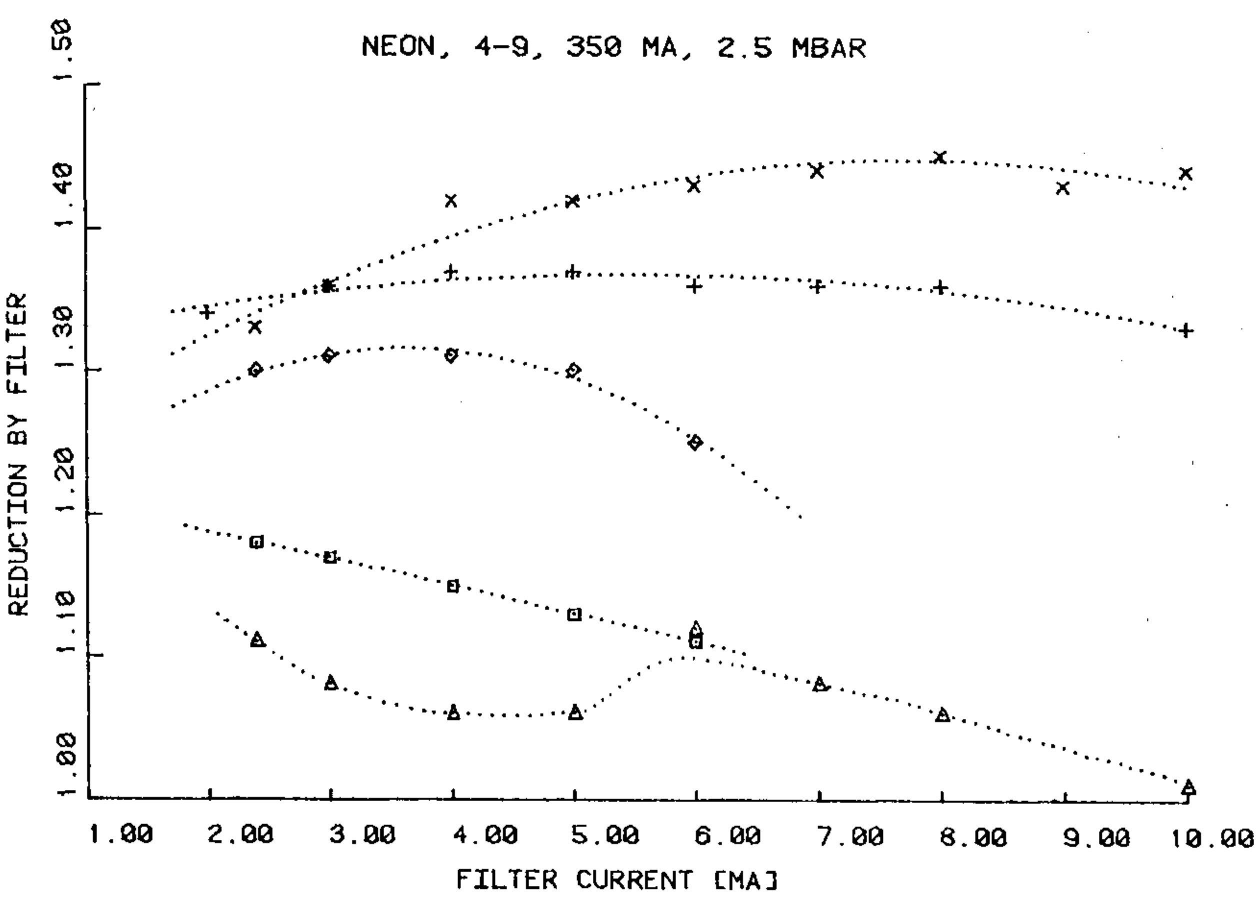
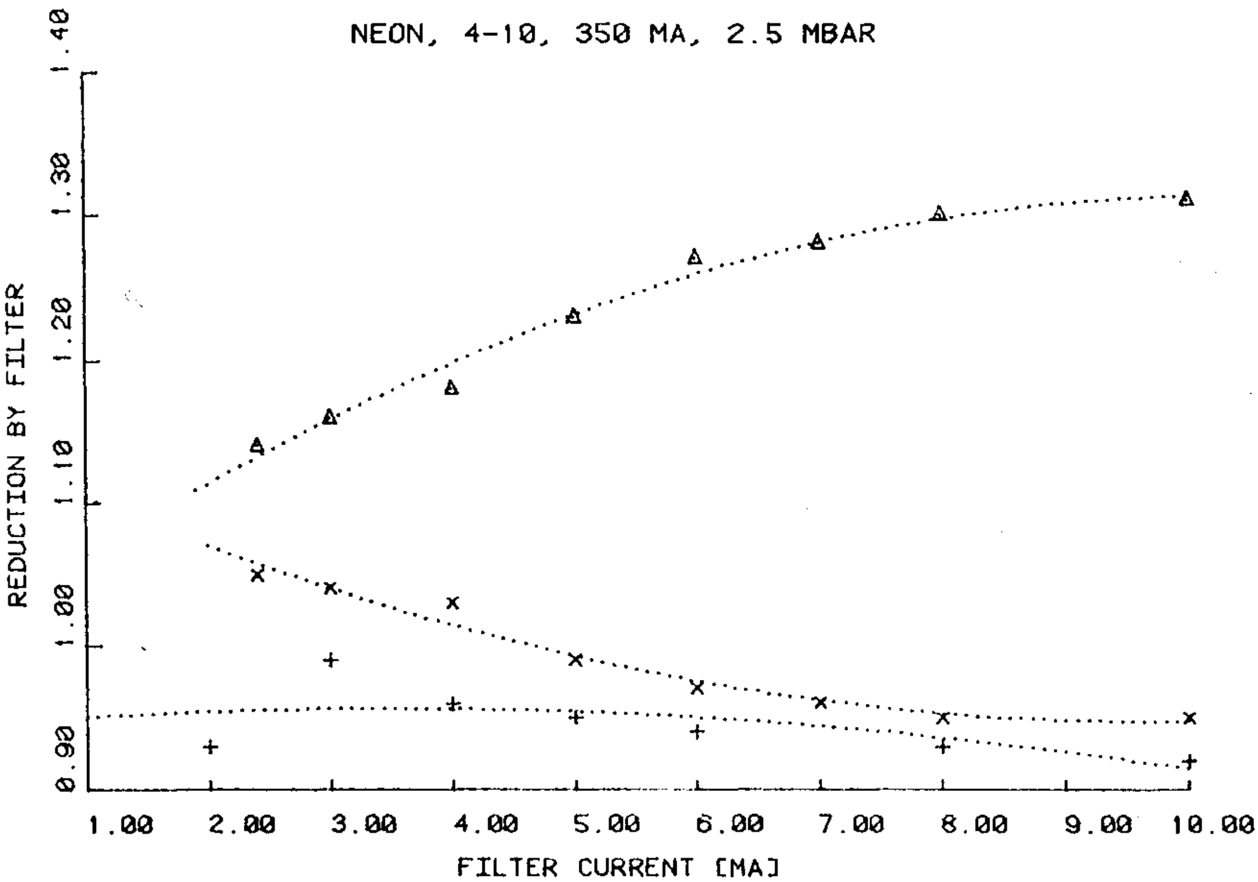


Fig. 2.4 continued:



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ii) Discussion

The shift of the reduction factor maxima towards lower filter currents with increasing pressure within a particular plot is to be expected, as higher pressures provide a higher number density of absorbers so that lower currents are sufficient to produce a high population of the metastable levels. Low currents are advantageous, since they mean a low N_u/N_l ratio (as was shown by the reversal temperature measurements) and thus cause only weak emission. It is also no surprise that an intermediate pressure gives best reduction, as this may be considered as compromise between a sufficient number density of absorbers and not too many emitters.

As was already mentioned in Chapter V.4, the 1-2 line in neon exhibits the strongest self-absorption/reversal in the hollow cathode spectrum. This must necessarily lead to lower reduction factors to be measured for this line, as the hollow cathode line becomes broader relative to the filter discharge line, and the background light starts 'to leak around the edges' of the filter line.

The similarity of the behaviour of the 2-4 and 2-9 lines to that of the lines from the s1 and the s3 level was expected, as they have the 'semi-metastable' s2 level as lower state (see Chapter III.6). The decreasing reduction with increasing energy of the upper state can be attributed to the corresponding decrease in f-value of the lines (Wiese and Martin /31/), which leads to the emission term in Equ. III.1.12 being small compared with the absorption term.

Those lines with the s4 level as lower state show no reduction, since there is no mechanism which could provide an appreciable population of the lower states.

If the reduction factor curves for the highest filter pressure (6.6 mbar $-\Delta$) are examined closely, a kink between 5 and 6 mA can be found in many of them (1-2, 2-4, 2-9, 2-10, 4-9, 4-10), most noticeably for the 4-9 line because of the enlarged ordinate scale. The occurrence of this upward jump for rising currents was observed to coincide with an unsteadiness in the appearence of the filter discharge. It could be seen that at around these currents one of the dark spaces of the glow discharge, which had previously been located in the cathode sidearm, 'jumped' into the main part of the discharge tube. This was obviously associated with a change in the composition of the parts of the plasma used for filtering, which resulted in a small unsteadiness of the reduction factors.

b) Comparison with Lower Hollow Cathode Currents

i) Results

The complete discussion of all aspects of the dependence of the reduction factors on the spectral lines , hollow cathode current, filter pressure and current is an overtaxing task. It must be left to the user of the filter to find out about his particular points of interest. Nevertheless, a number of general remarks will be made.

The lower hollow cathode currents investigated were 250, 150, and 100 mA. Down to 150 mA, the ORFs for the metastable lines exhibit little change, but all of them peak at 150 mA hollow cathode current and 2 mbar filter pressure, with the exception of the 1-2 line (250 mA, 1 mbar). However, it should be noted that the next highest pressure (4.4 mbar) is a serious competitor (see 3-6/100 mA and 1-5/150 mA), especially since the lowest currents used (2.4 mA (2 mA)) might be lowered in another experiment through a more sophisticated animation mechanism than the 'Tesla'. For the non-metastable lines, a continuous decline of the ORFs with decreasing hollow cathode current coincides with a shift of the optima to lower currents. The optima for the 2-4 and 2-9 lines stay above a value of one, their worst values being about 3.5 and 1.5 respectively. The 2-10 and 4-10 lines exhibit ORFs of about one only for the highest filter pressure (6.4 mbar). The ORF is only 0.5 (corresponding to an increase in line intensity by a factor of two) for the 2-10 line at 2 mbar filter pressure.

ii) Discussion

A decrease in hollow cathode current leads to a more unfavourable ratio of hollow cathode emission to filter discharge emission, as the hollow cathode temperature approaches that of the filter. This disadvantage is obviously outweighed by the corresponding decrease in hollow cathode line width, as long as the hollow cathode current is greater than or equal to 150 mA. The Doppler, Stark, and self-absorption/reversal broadening all decrease as the current and hence the temperature and electron density is lowered.

As was mentioned in Chapter V.4, the metastable lines in the hollow cathode show much more liability to self-absorption/ reversal than the non-metastable lines. Thus, the latter are much less broadened by self-absorption/reversal at high hollow cathode currents so that a decrease in current does not decrease the line width as much as for the metastable lines. Hence, the continuous decline of the ORFs for the non-metastable lines with decreasing hollow cathode current is comprehensible.

The explanations of the other effects were already given in Section 1.a) ii) of this chapter.

c) Summary and Recommendations

The following table gives a summary of the optimum combination of parameters and the resulting reduction factors for some groups of spectral lines as found in the course of this study.

Table 2.1:

Neon:

hollow cathode parameters	recommended filter discharge parameters	measured reduction factors for lines 1-2	1-5	3-4	2-4
350 mA, 2.5 mbar	4 mA, 2 mbar	6.8	8.0	8.5	3.7
250 mA, 2.25 mbar	4 mA, 2 mbar	6.0	9.0	8.1	3.4
150 mA, 2.1 mbar	2 mA, 2 mbar	8.5	10.5	9.0	3.3
100 mA, 2 mbar	2 mA, 2/4.4 mbar	6.5	9.0	6.5	3.0

Notes:

- The results seem to indicate that for 250, 150 and 100 mA a combination of a lower current and a higher pressure in the filter, such as e.g. 1 mA/4 mbar, could be advantageous.
- The recommended set of parameters give optimum reduction of the metastable lines. The reduction of lines from the s2 level is relatively small. The 4-9 and 4-10 lines are hardly affected, but, as the latter is the strongest line in the spectrum, it should be ensured that a rather higher filter pressure is chosen to avoid enhancing the intensity of this line.

3. Argon

a) Results

The complete set of reduction factor plots for argon can be found in Appendix III. The key to the symbols for different filter discharge pressures is given below:

X ≙ 0.7 mbar
+ ≙ 1.7 mbar
◇ ≙ 3 mbar
□ ≙ 3.7 mbar

Only eight argon lines were measured, but the consistency of the data justifies this restriction in retrospect. As the behaviour of the reduction factors is less comlex than in the case of neon, all four hollow cathode currents can be dealt with at the same time.

It was found that in every plot of the argon results, the optimum reduction factor ORF (the highest reduction factor for a particular spectral line at a particular hollow cathode current) occurs for the lowest filter pressure which was investigated (0.7 mbar). All curves can be understood as derived from the general curve which was already found to be typical for the neon lines (see Section 2.a)i) and Fig. 2.1).

For the metastable lines it is also true that in all cases the lowest filter current used leads to the greatest reduction, i.e. the optimum current can be assumed to be less than 1.6 mA. Only when the hollow cathode current was 450 mA did the optimum filter current appear actually to have been reached at about 2 mA.

Further close similarities to the findings for neon can be seen; the lower the hollow cathode current the further to the right of an imaginary maximum at very low filter currents do the reduction factor curves seem to be shifted. Furthermore, higher filter pressures seem to shift this maximum even further towards small currents, although this effect is only clearly noticable for high hollow cathode currents.

For the two non-metastable lines, it was found, as in neon, that the maxima (this time clearly observed), generally occur at higher filter currents than for the metastable lines.

The absolute values of the ORFs for the metastable lines start at values of between 6 and 7 for the highest hollow cathode current (450 mA), they reach their greatest values of between 7 and 10 at 250 mA and start falling again for 150 mA, though this effect is not yet noticable for the 1-3 line.

b) Discussion

The most remarkable difference to the neon results must be seen in the fact that lower currents and lower pressures in the filter produce the optimum reduction factors. A possible explanation is the much lower energy of the first excited state of argon (11.7 eV as compared with 16.7 eV for neon). All the other observations can be explained by the same arguments as those used in the case of neon.

c) Summary and Recommendations

The following table gives a summary of the optimum combination of parameters and the resulting reduction factors for some groups of spectral lines as found in the course of this study.

Table 2.2:

Argon

hollow cathode parameters	recommended filter discharge parameters	measured reduction factors for lines		
		1-2	1-5	2-4
450 mA, 2.4 mbar	2 mA, 1 mbar	5.3	5.6	2.3
350 mA, 2.4 mbar	1.6 mA, 1 mbar	6.2	6.6	2.6
250 mA, 2.4 mbar	1.6 mA, 1 mbar	6.0	7.4	2.6
150 mA, 2.4 mbar	1.6 mA, 1 mbar	4.8	7.0	1.8

Notes:

- The results seem to indicate that for all hollow cathode currents a combination of lower current and higher pressure in the filter, such as e.g. 1 mA/ 2 mbar, could be advantageous.

4. The Significance of the Hollow Cathode Pressure

In the early stages of the experiment, it was found that lower hollow cathode currents require lower pressures for maximum intensity of the carrier gas lines. Thus, as already mentioned, the running conditions for the neon measurements were:

350 mA, 2.5 mbar
250 mA, 2.25 mbar
150 mA, 2.1 mbar
100 mA, 2 mbar .

By contrast, the hollow cathode pressure for the argon measurements was always 2.4 mbar. Comparing the results for both gases reveals no obvious dependence on the very small changes in hollow cathode pressures. For lack of time, no systematic investigation of the significance of the hollow cathode pressure was undertaken, but the result of a short run, which was accidentally done at 1 mbar for a current of 350 mA in neon indicates that much lower hollow cathode pressures lead to considerably higher reduction factors for those lines with the s1 level as lower state. Table 2.3 compares two runs at 2.5 mbar and 1 mbar for the 1-2 line.

Table 2.3: Example of the dependence of the reduction factors on the hollow cathode pressure.

Gas: neon line: 1-2 hollow cathode current: 350 mA
filter discharge pressure: 4.4 mbar

	filter current [mA]			
hollow cathode pressure	2.4	3	4	5
1 mbar	10.5	9.4	7.8	6.6
2.5 mbar	6.3	6.0	5.7	5.2

Since it is mainly those lines from the s1 level which show very strong self-absorption/reversal, the decreasing tendency for self-absorption/reversal with decreasing hollow cathode pressure in combination with the diminishing importance of pressure broadening is the obvious explanation for this observation.

Hence, one may find it advantageous to decrease the hollow cathode pressure when a filter discharge is employed, provided that the lower intensity of the lines of the sputtered material does not cancel this advantage.

5. Errors

The statistical errors in the measurements of the reduction factors due to inaccurate reading of the picoammeter are certainly less than 2% and thus insignificant in comparison to other errors.

The dark current of the photomultiplier was measured frequently and found to be almost constant and usually very small in comparison with the detected signal. Therefore, the signal-to-noise ratio can be regarded as very good.

Systematic errors due to long term changes, as for example changes of temperature during a particular run, cannot have occurred to any large extent as no inconsistencies have been found, which could be attributed to such an effect. Furthermore, no significant change in line intensity occurred during any particular run (~1 h).

To check for systematic errors, a set of scans of hollow cathode lines once with and once without the filter in operation were done. Two examples are shown in Fig. 5.1 and a set of experimental traces of hollow cathode emission profiles and hollow cathode absorption profiles can be found in Appendix IV. The results are given in Table 5.1 and indicate that a random error of $\pm$ 5% must be assumed for the reduction factors. Nevertheless, the results show no systematic shift towards greater reduction factors for the measurements with stationary photomultiplier, which would have occurred if the method of opening the entrance slit widely had not led to the signal behind the exit slit being integral over the whole hollow cathode line.

Table 5.1: Comparison of reduction factors measured by a stationary photomultiplier and in a photomultiplier scan.

Hollow cathode:	350 mA / 2.5 mbar		250 mA / 2.25 mbar	
Filter discharge:	2 mA / 2.5 mbar		2 mA / 2.5 mbar	
line	stationary	scan	stationary	scan
1-7	8.3	8.3	9.5	9.9
1-2	7.0	6.5	7.5	7.3
3-6	8.0	7.7	8.5	8.9
2-4	3.0	3.1	3.5	3.7

Fig. 5.1: Photomultiplier scans of the 1-5 and the 2-4 lines in neon at a hollow cathode current of 350 mA and a pressure of 2.5 mbar.

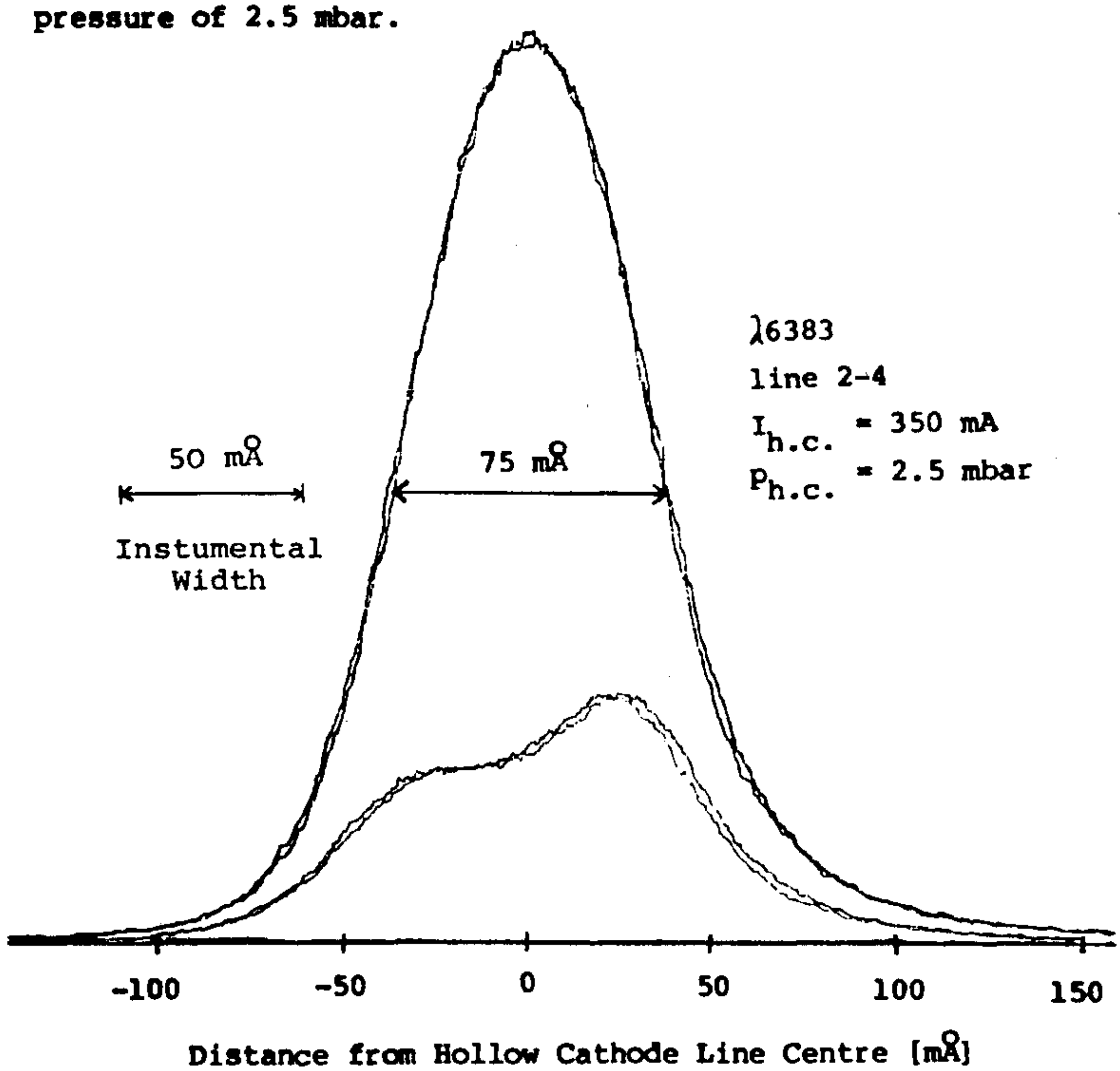
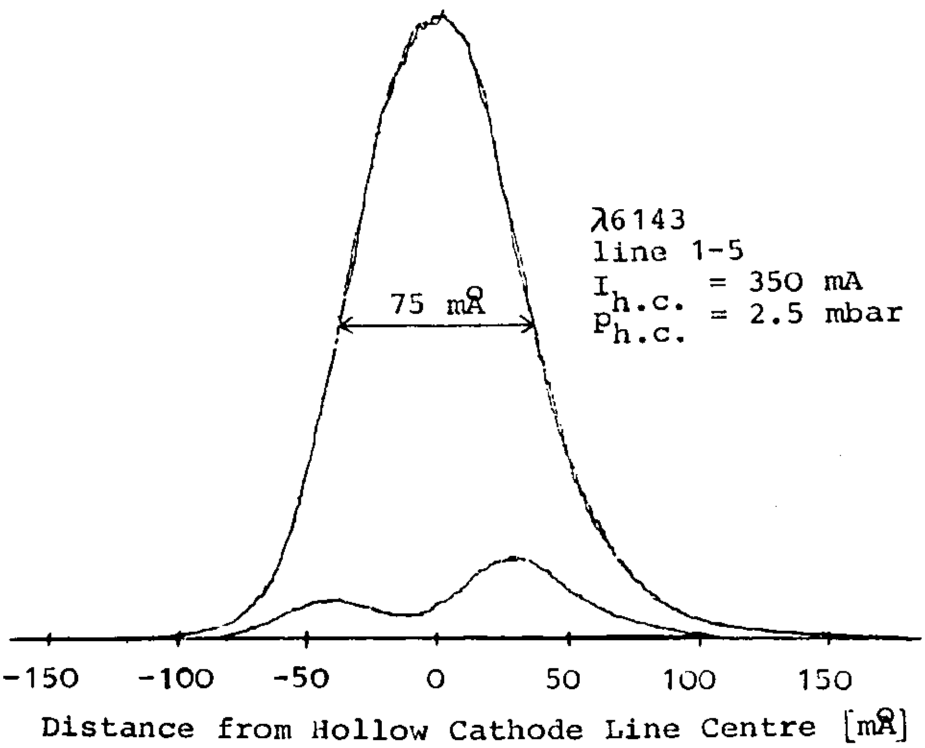


Fig. 5.1 continued:



Although the reduction factors may have a 5% random error, the relative error (scatter) of those reduction factors which were measured for a particular line during the same run (and are thus displayed in the same reduction factor plot) are even smaller (~2%), which is supported by the small deviation of the measured data points from the curves fitted to them (see Chapters VI.2.a)i) and VI.3.a)), and Appendix II).

From the design of the optical system (see Chapter IV.6), it is possible that some light from the hollow cathode may enter the spectrograph without traversing the full length of the positive column of the filter discharge (through reflections from the glass walls of the discharge tube), and it is also possible that some light is detected from parts of the filter discharge not traversed by hollow cathode radiation. Both these effects will lower the reduction factor. The measured values are therefore a lower limit and somewhat higher reduction factors might conceivably be achieved with a more sophisticated optical system, e.g. anti-reflection coating on the tube walls.

VII. COMPUTER MODELLING

1. Introduction

In order to model the measured reduction factors, to study the influence of the different parameters, and to plot synthesized spectrum profiles, I wrote an interactive computer programme which was called 'REFA'. The FORTRAN IV listing of this can be found in Appendix V.

The programme asks the user to enter a number of parameters and then calculates the corresponding reduction factor and some other interesting results. Finally, it offers the options, first, to plot the filter discharge line profiles, secondly, to plot the absorption profile for a continuum source as background source, and, thirdly, to plot the hollow cathode line profile with and without the filter in operation. Kielkopf's Voigt function approximation was used for the computer modelling and a listing of the function subroutine 'VOIGT' can also be found in Appendix V.

The computing was done on DEC PDP-11 and PDP-10 computers, the first in combination with a Tektronix Digital Plotter and the second with a Hewlett Packard HP 7221 plotter.

The input parameters required are:

- a - wavelength
- b - hollow cathode Lorentzian FWHM
- c - hollow cathode Gaussian FWHM
- d - hollow cathode line shift
- e - transition-probability-sum of the upper state
- f - filter discharge pressure FWHM
- g - isotope shift
- h - ratio of filter discharge to hollow cathode line intensity

i - additional filter discharge Gaussian FWHM

j - peak optical depth

The programme calculates the:

- filter discharge Doppler FWHM
- filter discharge natural FWHM
- filter discharge Voigtian FWHM
- hollow cathode Voigtian FWHM
- filter dischaege damping ratio
- hollow cathode damping ratio
- reduction factor

2. Short Review of how the Input Parameters were obtained

The above list of input parameters will now be commented on by a short review of the ways by which the parameters were obtained and a summary of the relevant data. It should be noted that the computer analysis was performed only on data for neon, a restricted number of lines (1-7, 1-5, 3-9, 3-6, 2-4, 1-2), and the following parameters for the discharges:

hollow cathode current = 350 mA
hollow cathode pressure = 2.5 mbar

filter discharge current = 2.0 mA
filter discharge pressure = 2.55 mbar

ad b-c-d; hollow cathode parameters

From the photographic analysis of the hollow cathode lines (see Chapter V.5), a Stark shift of about 3 mÅ for all lines at 350 mA hollow cathode current and 2.5 mbar pressure were found. Griem /10/ gives Stark shift and width data for an electron temperature of 5000 K (which is probably the temperature closest to the one in the hollow cathode), an electron number density n^- of 10^{16} cm^{-3} , and the following lines:

line	1-2	1-7	2-3	2-7	3-6
$\Delta\lambda^{Griem}_{Stark}$ [mÅ]	15.0	14.6	15.7	15.2	15.8
shift [mÅ]	15.8	16.4	15.9	16.3	17.3

The mean values for these lines are:

$$\langle\Delta\lambda^{Griem}_{Stark}\rangle = 15.3 \text{ mÅ}$$
$$\langle shift\rangle = 16.6 \text{ mÅ} \quad .$$

Stark width and shift are proportional to the electron number density. Thus, the measured hollow cathode line shifts of 3 mÅ correspond to a Stark width of about 3 mÅ.

(Note: The electron number density n^- and the degree of ionization can be estimated in the following way:

$$n^- = \frac{\langle \text{experimental shift} \rangle}{\langle \text{Griem's shift} \rangle} \; 10^{16}\ \text{cm}^{-3}$$

$$n^- = \frac{3}{16.6} \; 10^{16}\ \text{cm}^{-3} = \underline{2\ 10^{15}\ \text{cm}^{-3}}$$

The pressure in the hollow cathode was 2.5 mbar. Thus, the number density of atoms is $n = p/(kT) = 6\ 10^{16}\ \text{cm}^{-3}$. Therefore, the degree of single ionization is about $n^-/n = 20/600 = 3\%$.)

The hollow cathode Gaussian FWHMs were obtained in the following way. The line widths, as obtained from the photographic analysis, were de-convoluted from 3 mÅ Lorentzian width (ab-)using the 'REFA' programme and thus implicitely Kielkopf's Voigt approximation. The results are the total hollow cathode Gaussian widths of the lines:

line		1-7	1-5	3-9	3-6	2-4	1-2
$\Delta\lambda^{h.c.}_{exp.}$	[mÅ]	54.4	59.5	57.5	60.5	56.8	74.9
$\Delta\lambda^{h.c.}_{Lorentz}$	[mÅ]	3	3	3	3	3	3
$\Delta\lambda^{h.c.}_{G,tot}$	[mÅ]	52.8	57.9	55.9	58.9	55.2	73.3

The instrumental width can be calculated using Equ. VII.5.4 and the following parameters:

$1/g$ = reciprocal grating constant = 2160 mm^{-1}

d = width of the wave front falling onto the grating = (300/37) cm = 8.1 cm

s = slit width = 20 μ

f = focal length of spectrograph = 3 m

line	1-7	1-5	3-9	3-6	2-4	1-2
$\Delta\lambda^{instr.}_{Gauss}$ [mÅ]	42.9	43.6	43.7	44.0	44.4	44.5

Now, the intrinsic Gaussian widths can be calculated according to:

$$\Delta\lambda^{h.c.}_{G,intrinsic} = \sqrt{(\Delta\lambda^{h.c.}_{G,tot})^2 - (\lambda^{instr.}_{G})^2}$$

line	1-7	1-5	3-9	3-6	2-4	1-2
$\Delta\lambda^{h.c.}_{G,intrinsic}$ [mÅ]	30.7	38.1	34.9	39.2	32.8	58.2

Due to the spectral line arising from the second isotope (^{22}Ne), the main line (^{20}Ne) is apparently broadened. This can be taken into account by comparing the width of plotted synthesized hollow cathode line profiles with the Voigtian width which was used as input parameter to compute the profiles. Here some examples:

line	3-9	2-4	1-2
measured width on plot [mÅ]	37.0	35.0	59.1
computed Voigtian width [mÅ]	34.6	32.6	56.6
ratio	1.069	1.074	1.044

If this isotope broadening is included, the following corrected intrinsic Gaussian widths result (rounded):

line	1-7	1-5	3-9	3-6	2-4	1-2
$\Delta\lambda^{h.c.}_{G,\ intrinsic}$ [mÅ]	29	36	33	37	31	55

ad e; transition-probability-sum of the upper state

These were taken from Bridges' and Wiese's paper /9/.

line	1-7	1-5	3-9	3-6	2-4	1-2
A [10^7 sec^{-1}]	5.22	5.01	5.19	5.13	5.02	5.06

ad f; filter discharge pressure FWHM (see Chapter III.2)

Kuhn and Lewis /37/ measured pressure broadening for the relevant neon lines. Their values for T = 77 K and T = 270 K were linearly extrapolated to T = 300 K and to a pressure of 2.55 mbar. If a line in my set had not been measured by Kuhn and Lewis, the data for the most similar line were used:

line	1-7	1-5	3-9	3-6	2-4	1-2
$\Delta\lambda^{f.d.}_{pressure}$ [mÅ]	0.5	0.4	0.2	0.2	0.2	0.4

ad g; isotope shift (see Chapter III.2)

Odintsov's data /18/ were used:

line	1-7	1-5	3-9	3-6	2-4	1-2
isot. shift [mÅ]	20.2	22.9	20.9	21.9	22.9	22.5

ad h; ratio of filter discharge to hollow cathode intensity

The values I measured in the course of my experiments are:

line	1-7	1-5	3-9	3-6	2-4	1-2
$I_{f.d.}/I_{h.c.}$	0.011	0.011	0.013	0.012	0.034	0.016

ad i; additional f.d. Gaussian FWHM

This parameter could be chosen arbitrarily to increase the filter discharge Gaussian line width artificially to simulate an additional broadening. It must be noted that the Gaussian width was just additively increased by the input value and that the equation for the combination of two Gaussian lines (Equ. III.2.8) $\beta_{tot} = \sqrt{\beta_1^2 + \beta_2^2}$ was not used. Thus, by setting the additional Gaussian width equal to e.g. 20 mÅ, a filter discharge Doppler width of, say, 17 mÅ would be increased to 37 mÅ. Obviously, no special type of broadening is described this way, but the effect of somehow broadening the filter discharge lines (e.g. through the Zeeman effect in a magnetic field) can be estimated.

In the course of the computer modelling, the additional filter discharge Gaussian width was chosen to be equal to 0, 5, 10, 20, 40, 60, and 80 mÅ.

ad j; peak optical depth (see Chapter III.4)

The experimental equivalent widths W_λ^{exp} for a filter discharge current of 2 mA and a pressure of 2.55 mbar were:

line	1-7	1-5	3-9	3-6	2-4	1-2
W_λ^{exp} [mÅ]	45.1	51.3	44.8	51.9	9.7	60.1

The correction factors for these values according to Equ. III.4.3 calcultated using the measured reversal temperatures T_R (see Chapter III.3) and a temperature T = 2570 K of the standard lamp are:

line	1-7	1-5	3-9	3-6	2-4	1-2
T_R [K]	2178	2186	2160	2144	2457	2250
corr. for emiss.	1.22	1.25	1.22	1.20	3.01	1.40
total correction	1.33	1.33	1.33	1.33	3.3	1.53
W_λ^{exp} [mÅ]	60.0	68.3	59.6	69.0	31.9	91.1

The last but one line in the above table gives the correction factors I finally used which include an additional correction for stray light and scattered light. The corrected equivalent widths are given in the last line.

I wrote a curve of growth computer programme (called 'COG', listing in Appendix VI) which allows one to calculate equivalent widths W_λ and peak optical depths POD from column densities of absorbers N and the line shape parameters. By repeatedly running this programme, the following Ns and PODs were found to correspond to the above corrected equivalent widths:

line	1-7	1-5	3-9	3-6	2-4	1-2
N [10^{10} cm^{-2}]	4620	3310	950	1450	115	3780
peak opt. depth	40.3	65.8	42.9	95.9	3.4	239.1

Fig. 2.1 shows the output from 'COG' when calculating the above data.

Fig. 2.1: Output from the computer programme 'COG' when calculating the column densities and peak optical depths given in the above table.

```
WAVELENGTH [ANGSTROM].............? 5945
GU................................? 5
GL................................? 5
AUL [1E7*SEC**-1].................? 1.05
ISOTOPE SHIFT [MILLIANGSTROM].....? 20.2
A (DAMPING RATIO).................? 0.0302
VOIGTIAN FWHM [MILLIANGSTROM].....? 16.808
COLUMN DENSITY N [1E10*CM**-2]....? 4620
PEAK OPTICAL DEPTH................=          40.3
EQUIV. WIDTH [MILLIANGSTROM]......=          60.0

WAVELENGTH [ANGSTROM].............? 6143
GU................................? 5
GL................................? 5
AUL [1E7*SEC**-1].................? 2.16
ISOTOPE SHIFT [MILLIANGSTROM].....? 22.9
A (DAMPING RATIO).................? 0.0245
VOIGTIAN FWHM [MILLIANGSTROM].....? 17.304
COLUMN DENSITY N [1E10*CM**-2]....? 3310
PEAK OPTICAL DEPTH................=          65.8
EQUIV. WIDTH [MILLIANGSTROM]......=          68.3

WAVELENGTH [ANGSTROM].............? 6163
GU................................? 3
GL................................? 1
AUL [1E7*SEC**-1].................? 1.6
ISOTOPE SHIFT [MILLIANGSTROM].....? 20.9
A (DAMPING RATIO).................? 0.0148
VOIGTIAN FWHM [MILLIANGSTROM].....? 17.254
COLUMN DENSITY N [1E10*CM**-2]....? 950
PEAK OPTICAL DEPTH................=          42.9
EQUIV. WIDTH [MILLIANGSTROM]......=          59.6

WAVELENGTH [ANGSTROM].............? 6266
GU................................? 3
GL................................? 1
AUL [1E7*SEC**-1].................? 2.23
ISOTOPE SHIFT [MILLIANGSTROM].....? 21.9
A (DAMPING RATIO).................? 0.0147
VOIGTIAN FWHM [MILLIANGSTROM].....? 17.541
COLUMN DENSITY N [1E10*CM**-2]....? 1450
PEAK OPTICAL DEPTH................=          95.9
EQUIV. WIDTH [MILLIANGSTROM]......=          69.0

WAVELENGTH [ANGSTROM].............? 6383
GU................................? 3
GL................................? 3
AUL [1E7*SEC**-1].................? 2.79
ISOTOPE SHIFT [MILLIANGSTROM].....? 22.9
A (DAMPING RATIO).................? 0.0145
VOIGTIAN FWHM [MILLIANGSTROM].....? 17.866
COLUMN DENSITY N [1E10*CM**-2]....? 115
PEAK OPTICAL DEPTH................=          .3.4
EQUIV. WIDTH [MILLIANGSTROM]......=          31.9


WAVELENGTH [ANGSTROM].............? 6402
GU................................? 7
GL................................? 5
AUL [1E7*SEC**-1].................? 4.33
ISOTOPE SHIFT [MILLIANGSTROM].....? 22.5
A (DAMPING RATIO).................? 0.0239
VOIGTIAN FWHM [MILLIANGSTROM].....? 18.027
COLUMN DENSITY N [1E10*CM**-2]....? 3780
PEAK OPTICAL DEPTH................=         239.1
EQUIV. WIDTH [MILLIANGSTROM]......=          91.1
```

As one can see, the column density for lines with the same lower level differ slightly from one another. Thus, I used the following mean values for the column densities of atoms in the s-states:

state	s1	s2	s3
N [$10^{10}cm^{-2}$]	4000	115	1300

With these Ns 'COG' was run again and calculated:

line	1-7	1-5	3-9	3-6	2-4	1-2
N [10^{10} cm^{-2}]	4000	4000	1300	1300	115	4000
W_λ [mÅ]	58.3	70.6	62.6	67.8	31.9	92.4
POD	34.9	79.6	58.7	85.9	3.4	253.1

These peak optical depths were used for the computer modelling.

A rough comparison of these column densities with those obtained by J.E. Chamberlain /32/ shows that the results are almost identical. The actual ratios of number densities as found in this experiment to J.E.C.'s are about 0.6 (s1), 0.2 (s2), and 1.4 (s3).

Note: The filter discharge damping ratios and filter discharge Voigtian FWHMs, which are required as input parameters for 'COG', were obtained in preliminary runs with 'REFA', which gives the required data as a by-product. The transition probabilities were taken from data collected by Wiese et al. /38/.

3. Explanation of the Computer Output and the Spectrum Profile Plots

a) Computer Output

In Appendix VII, 296 reduction factor calculations are documented by the corresponding computer output. The whole set of results has the following order. It consists of eight subsets, each subset consisting of six pages; each page corresponds to one spectrum line (lines 1-7, 1-5, 3-9, 3-6, 2-4, 1-2). The first four lines are 'normal' metastable lines, i.e. relatively strong and moderately affected by self-absorption/reversal. The 2-4 line is a strong line with the 'semi-metastable' s2 level as lower state (see Chapter III.6), and the 1-2 line is the strongest line with a metastable lower state and is strongly affected by self-absorption/reversal.

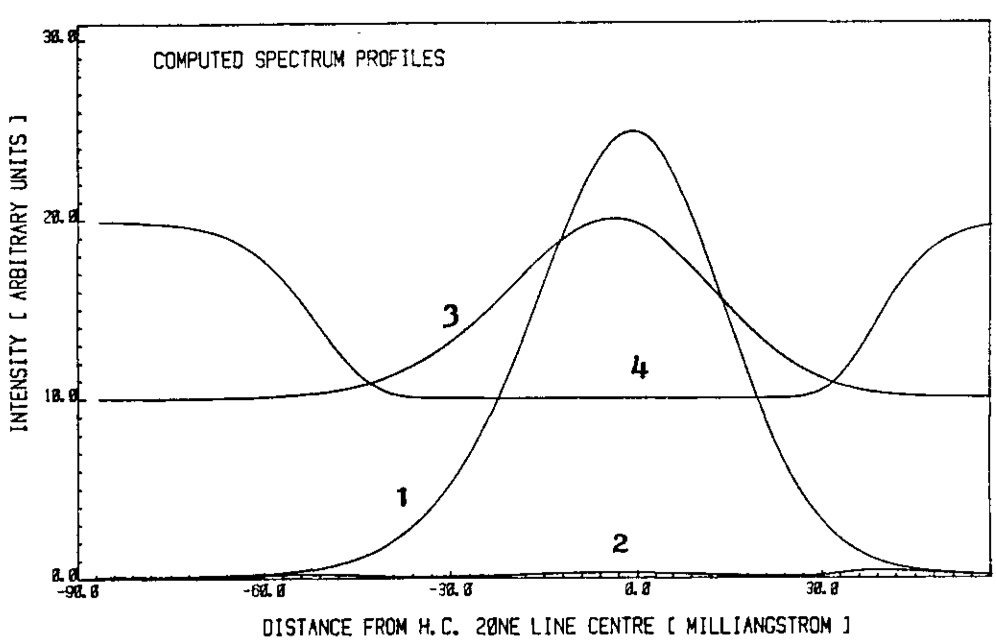
The eight subsets give results for different situations, which will be discussed in section 4 of this chapter. The first three lines on each page give information on the spectrum line and the particular situation. Each page comprises 6 (7) runs, each run for a different filter discharge Gaussian width; the differences are manifested by different 'additional f.d. Gaussian FWHM [mÅ]' which have been chosen to be equal to 0, 5, 10, 20, 40, 60 (,80) mÅ.

b) Spectrum Profile Plots

There are 30 'cases' marked among the runs in Appendix VII, which give the data for which synthesized spectrum profile plots have been computed. Appendix VIII contains these plots. The 3-9 line was taken as representative for the group of four 'normal' metastable lines (1-7, 1-5, 3-9, 3-6).

Here some explanations on the plots. Fig. 3.1 shows 'case 3' as an example. The dominant spectral line sitting on the zero-intensity axis is the hollow cathode emission line (1). If the filter discharge is running, the hollow cathode absorption profile is produced, which is plotted in the same intensity scale (2). Usually, the two outer parts of the hollow cathode line which 'leak around the edges' of the filter discharge line can be seen as well as the small hump at the centre of the hollow cathode absorption profile, which is due to the filter discharge emission.

Fig. 3.1: Plots of computed spectrum profiles for the 3-9 line in neon.



Both the filter discharge line profile (3) and a continuum absorption profile (4) (without filter discharge emission, thus showing the actual equivalent width) have been shifted upwards by 10 intensity units, so that they do not obscure the hollow cathode absorption profile. The last two plots do not have the same intensity scales and both scales are different from those used for the hollow cathode profiles. The intensity-equals-20 line is the full intensity line for both the continuum and the filter discharge spectrum line profiles.

The last two plots have been included for the following reasons:

i) the filter discharge line profile:
   - to show the two isotope lines
   - to show the hollow cathode Stark shift
   - to allow line width comparisons
   - to show where the filter discharge line intensity commences to be significantly $\neq 0$.

ii) the continuum absorption profile:
   - to show how far into the wings the absorption reaches.

The following figure shows the computer output from 'REFA' corresponding to the plots in Fig. 3.1 .

Fig 3.2: Computer output from 'REFA' corresponding to the plots in Fig. 3.1 .

```
GAS AND LINE................? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 33
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM].................? 20.9
RATIO OF F.D. TO H.C. INTENSITY...............? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=       17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       34.6325
CALCULATED F.D. A..............................=        0.0148
CALCULATED H.C. A..............................=        0.0757
F.D. PEAK OPTICAL DEPTH.......................? 58.6
CALCULATED REDUCTION FACTOR....................=        7.4734
```

4. Analysis

The analysis of the computer modelling results (as given in Appendices VII and VIII) will be carried out subset by subset, each subset corresponding to a particular situation.

On subset 1; data corresponding to the experimental situation

The first subset shows the computer output which is produced if those input parameters are used which were found to describe the experimental situation as it was during the reduction factor measurements. Obviously, the runs with the additional filter discharge Gaussian width not equal to zero have a hypothetic character as do the corresponding runs in the other subsets. Comparison of calculated and measured reduction factors for five lines starting from the s1 and s3 levels shows that the calculated values are between 4% too high and 16% too low. For the sixth line investigated, 2-4, the discrepancy is 22%, but this is scarcely surprising in view of the large correction to the equivalent width of this line resulting from its high reversal temperature. Here the actual data:

line	1-7	1-5	3-9	3-6	2-4	1-2
measured RF	8.4	7.5	8.2	8.5	2.8	7.0
computed RF	7.7	7.8	7.5	7.3	2.3	6.0
deviation [%]	-9.1	+3.5	-9.3	-16.4	-21.7	-16.7

Generally speaking, the computed reduction factors tend to be too small, but, nevertheless, the agreement is good in view of the many sources of error.

A direct comparison of experimental and computed hollow cathode absorption profiles is also possible. Fig. 4.1. shows the two profiles for the 1-7, 2-4, and 1-2 line respectively. Considering that the experimental resolution was only about 50 mÅ and that the hollow cathode line profiles were only very crudely corrected for self-absorption/reversal, the similarities are surprisingly obvious. On the other hand, the profiles for the 1-2 line reveal that in this case of extreme self-absorption/ reversal the deviations in line shape become significant. Here, the use of a well resolved empirical line profile could probably improve the accuracy of the modelling.

The fact that the four 'normal' metastable lines behave very similarly can be proven by comparing the corresponding spectrum profile plots labelled 'cases 1, 2, 3, and 7'. In all cases, the filter discharge absorption commences as soon as the filter discharge line intensity becomes significantly $\neq 0$, but yet not far enough in the wings to avoid that some light from the broader hollow cathode line 'leaks around the edges' of the filter discharge line.

The effect of the less intense lines of the heavier isotope ^{22}Ne can be observed easily in both the hollow cathode and the filter discharge line profiles. For the hollow cathode it causes a broadening and an asymmetry of the emission line profile while two overlapping lines can be distinguished in the case of the filter discharge. The hollow cathode absorption profile shows that the blue-shift of the heavier isotope line in combination with the red-shift of the hollow cathode line, due to the Stark effect, leads to more hollow cathode light being absorbed in the blue than in the red wing of the line.

In the centre of the filter discharge line, the high optical depths lead to complete absorption. Thus, it can be expected that if the absorbing atoms were spread over a greater spectral range by somehow broadening the line, the optical depth would still be high enough to maintain a high degree of absorption at the line core.

This is proven by the sequence of plots labelled 'cases 3, 4, 5, and 6'. Here, the additional filter discharge Gaussian FWHM is set to be equal to 0, 5, 20, and 60 mÅ respectively, and the peak optical depth is reduced so that the total number of absorbing atoms is conserved. With the additional filter discharge Gaussian FWHM equal to 20 mÅ, the hollow cathode 'leak emission' is already dramatically reduced and virtually eliminated if the filter discharge line width is further increased. It is very interesting to see that even with the additional filter discharge Gaussian equal to 60 mÅ (see 'case 6'), the peak optical depth remains much greater than 1 (τ_0 = 14.2), and the absorption is thus still more or less complete out to about 60 mÅ from the line centre. This is due to the fact that an optical depth of only 3 still causes the background intensity to be reduced to about 1/20 (e^{-3} = 0.05).

The plots labelled 'case 8' show the spectrum profiles for the 2-4 line using the parameters corresponding to the experimental situation as input. Here, the peak optical depth is only 3.3 and, hence, the absorption is not complete even near the filter discharge line centre. Therefore, broadening the filter discharge line (see 'case 9') does not improve the situation to any appreciable extent (RF: 2.3 —> 2.6 for the additional filter discharge Gaussian: 0 —> 20 mÅ).

'Cases 10 - 12' show profiles for the very strong 1-2 line, which is strongly broadened by self-absorption/reversal in the hollow cathode. Although the peak optical depth is extremely high (250), the reduction factor is not (6.0), since the hollow cathode line is very broad. Here, stronger broadening of the filter discharge line is necessary to achieve very high reduction factors.

The following table gives a short summary of computed data for the additional filter discharge Gaussian FWHM equal to 0, 5, 20, and 60 mÅ respectively.

line	1-7	1-5	3-9	3-6	2-4	1-2
add. f.d. Gauss. FWHM						
0 mÅ	7.7	7.8	7.5	7.3	2.3	6.0
5 mÅ	11.3	11.5	11.2	10.9	2.5	8.0
20 mÅ	25.8	27.9	26.2	26.9	2.6	18.6
40 mÅ	40.6	45.2	40.6	43.4	2.2	35.5

According to $\Delta E = g \frac{e}{m} \hbar B$, a magnetic field of 500 Gauss leads to $\Delta\lambda = 18$ mÅ at $\lambda = 6200$ Å, if $g = 1$, due to the Zeeman effect. A field of some hundred Gauss is easily achievable, so that it is certainly worth while trying to broaden the filter discharge lines by applying such a field to the discharge plasma.

Nevertheless, one has to wait and see, whether the stability of the discharge in the filter will not be affected by the field. Heating the discharge is probably not a good idea, because doubling the Doppler width means increasing the temperature by a factor of four (4 x 300 K = 1200 K). This would make the filter very ackward to operate and might be even not feasible.

<u>On subsets 2 and 3; reduced filter discharge length</u>

As was said above, the reduction factors are more favourably influenced by broadening the filter discharge line (or by reducing the hollow cathode line width; see below), than by an increase in optical depth, since the latter is very high anyway. In fact, it would be very convenient, if the length of the filter discharge tube could be reduced by a factor of two or even more. In order to analyse this possibility, the computer runs in subsets 2 and 3 were carried out with peak optical depths corresponding to the column density of absorbing atoms being reduced by a factor of two and four respectively. The following table gives a summary.

line	1-7	1-5	3-9	3-6	2-4	1-2
full length RF	7.7	7.8	7.5	7.3	2.3	6.0
half length RF	5.7	6.2	6.0	6.0	1.7	4.8
quatre length RF	4.1	4.8	4.6	4.7	1.3	4.0

Obviously, the loss in reduction factor is rather small when halving the filter discharge length, but is already relatively high, if the length is quatered. The next table allows one to judge whether broadening the filter discharge lines might compensate the losses.

Additional filter discharge Gaussian = 20 mÅ

line	1-7	1-5	3-9	3-6	2-4	1-2
full length RF	25.8	27.9	26.2	26.9	2.6	18.6
half length RF	17.0	20.8	19.4	20.4	1.6	14.5
quatre length RF	8.3	13.5	12.0	13.7	1.3	11.0

It can be concluded that reducing the length of the filter discharge tube by more than a factor of two will probably not be a suitable solution, because the loss in reduction factor cannot be justified by the gain in convenience.

On subset 4; reduced hollow cathode Gaussian width

The hollow cathode Gaussian widths which were used as input parameters have been reduced by about 10%, and, as expected, the computed reduction factors went up, but not dramatically.

line	1-7	1-5	3-9	3-6	2-4	1-2
RF	7.7	7.8	7.5	7.3	2.3	6.0
RF'	10.8	10.4	10.1	9.6	2.6	7.0

On subset 6; hollow cathode line width = Doppler width (T = 700 K); reduced pressure width and shift

This describes a purely hypothetic situation with the hollow cathode Gaussian line width being determined only by the Doppler effect, with T = 700 K and the Lorentzian components of the lines being as small as in subset 5. Now, the improvement is substantial, but not realistic.

line	1-7	1-5	3-9	3-6	2-4	1-2
RF	7.7	7.8	7.5	7.3	2.3	6.0
RF'	14.6	21.4	16.9	20.3	2.9	29.9

On subsets 7 and 8

These calculations were carried out to demonstrate what would happen if either self-absorption/reversal or the temperature dependent Doppler broadening (subset 7) or the pressure broadening and shift (subset 8) were increased. As expected, the reduction factors decrease in all cases.

Subset 7:

line	1-7	1-5	3-9	3-6	2-4	1-2
RF	7.7	7.8	7.5	7.3	2.3	6.0
RF'	6.4	6.4	6.0	6.0	2.2	4.9

Subset 8:

line	1-7	1-5	3-9	3-6	2-4	1-2
RF	7.7	7.8	7.5	7.3	2.3	6.0
RF'	5.2	5.5	5.2	5.3	2.1	5.0

In each case, the loss in reduction factor can be easily (over-) compensated by increasing the filter discharge line width, as the following tables show.

Additional filter discharge Gaussian = 20 mÅ

Subset 7:

line	1-7	1-5	3-9	3-6	2-4	1-2
RF'	6.4	6.4	6.0	6.0	2.2	4.9
RF''	21.8	22.8	21.5	22.0	2.4	13.8

Subset 8:

line	1-7	1-5	3-9	3-6	2-4	1-2
RF'	5.2	5.5	5.2	5.3	2.1	5.0
RF''	15.7	17.5	16.5	17.0	2.3	13.5

Increasing the hollow cathode pressure may be necessary in some cases to optimize the sputtered metal line intensities.

VIII. CONCLUSION AND FUTURE WORK

Summarizing the experimental results, one can say that under the optimum running conditions, which were found in the course of this study, the active filter works unexpectedly well for the metastable lines in neon and argon.

The most important features of the filter like easy, clean, sealed-off operation make it possible to put the filter in use in an actual application in combination with a Fourier transform spectrometer in the near future. Then, it will be possible to judge, whether the improvement of the signal-to-noise ratio is worth the effort. In this context, it should be noted that in these experiments, the hollow cathode lamp was run only up to currents of 350 mA in neon and 450 mA in argon. Much higher currents must lead to a more pronounced Stark broadening of the hollow cathode lines and this will therefore increase the need of broadening the filter discharge lines.

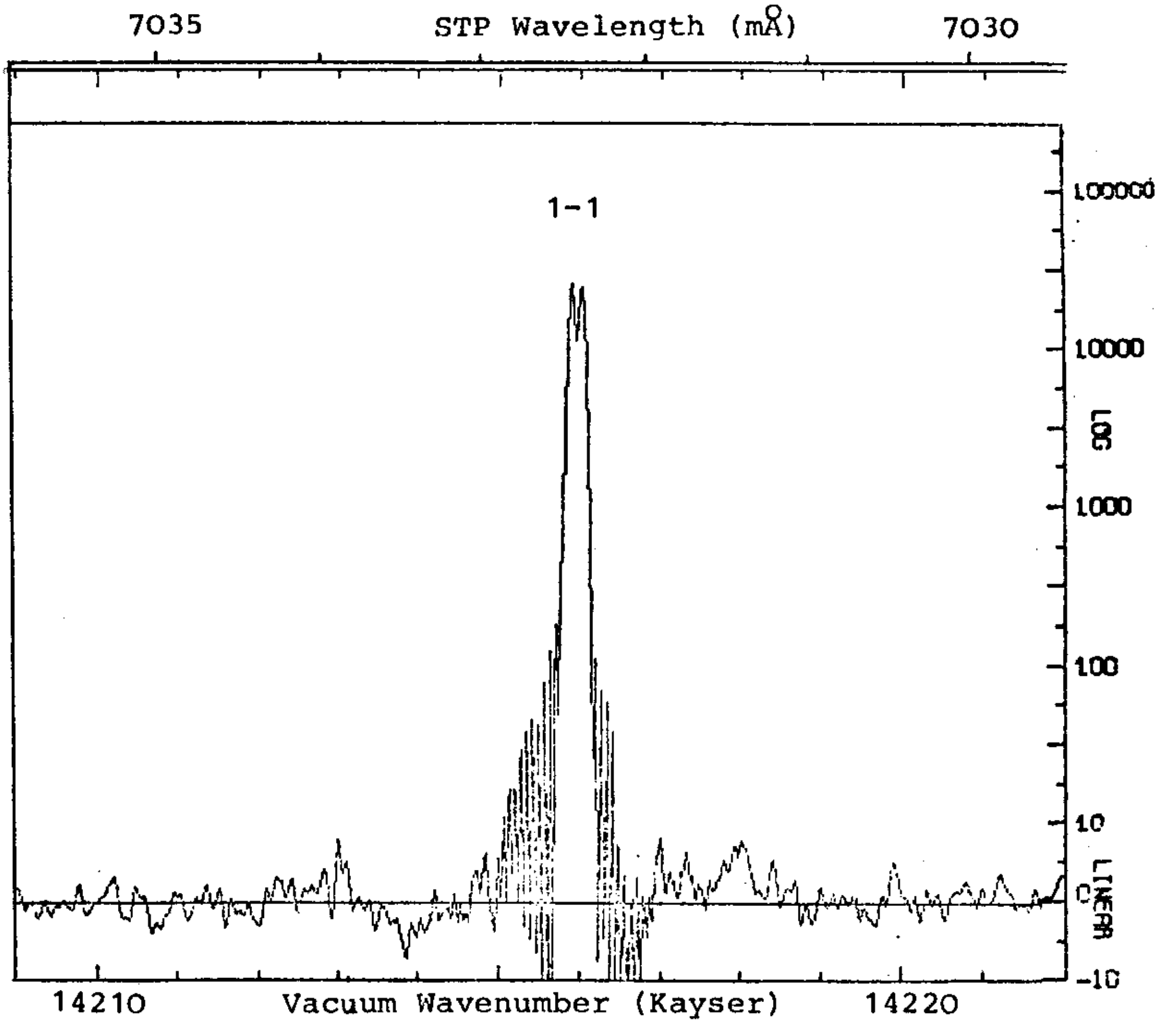
The success of the computer modelling justifies to be confident that the radiative transfer process is well understood.

Additional computer runs show that increasing the filter discharge line width would almost certainly increase the reduction factors dramatically. It should be easy to achieve this increase by applying a magnetic field of some hundred Gauss to the filter discharge plasma.

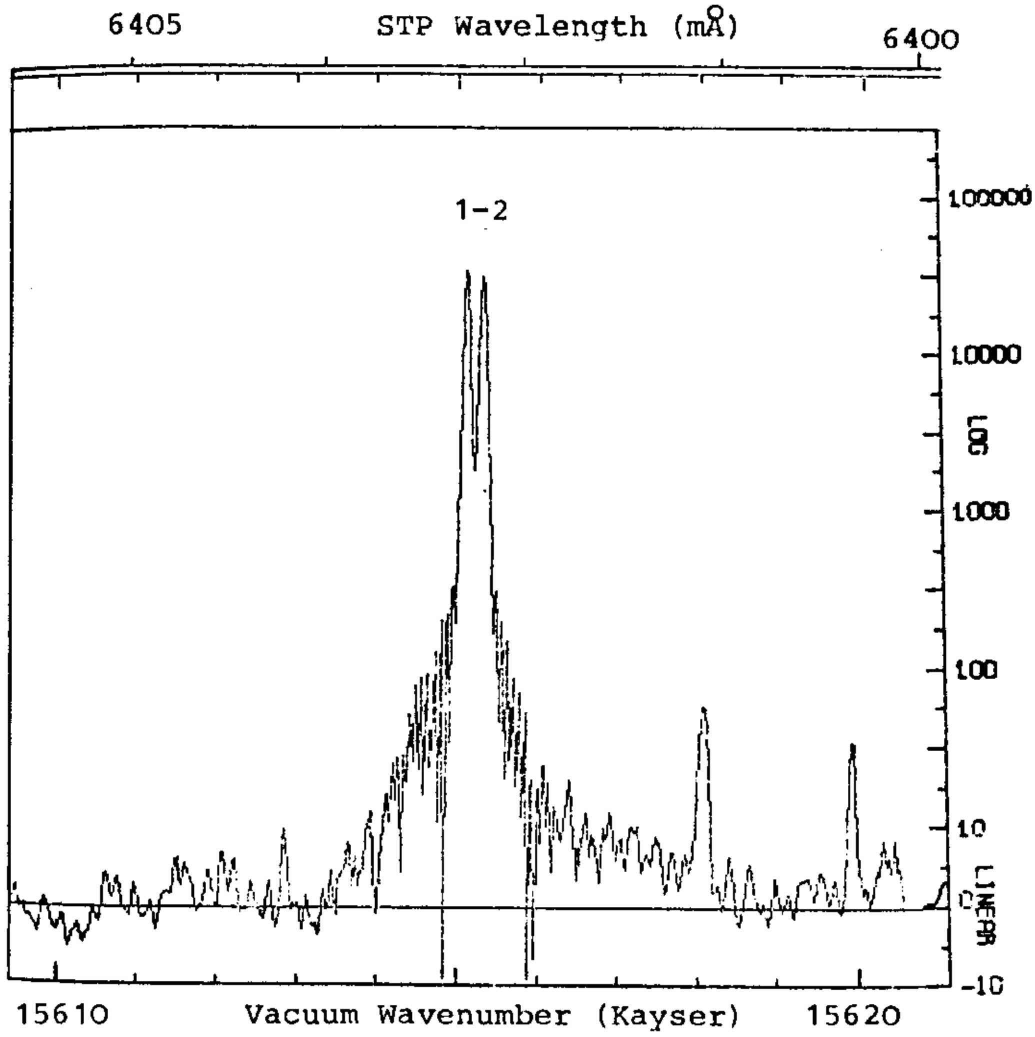
The other possible changes in order to improve the reduction factors are probably not worth the effort and would involve changes in the hollow cathode design or operation parameters, which could be avoided, if an optimized filter was used.

Appendix I: FTS Hollow Cathode Line Profiles

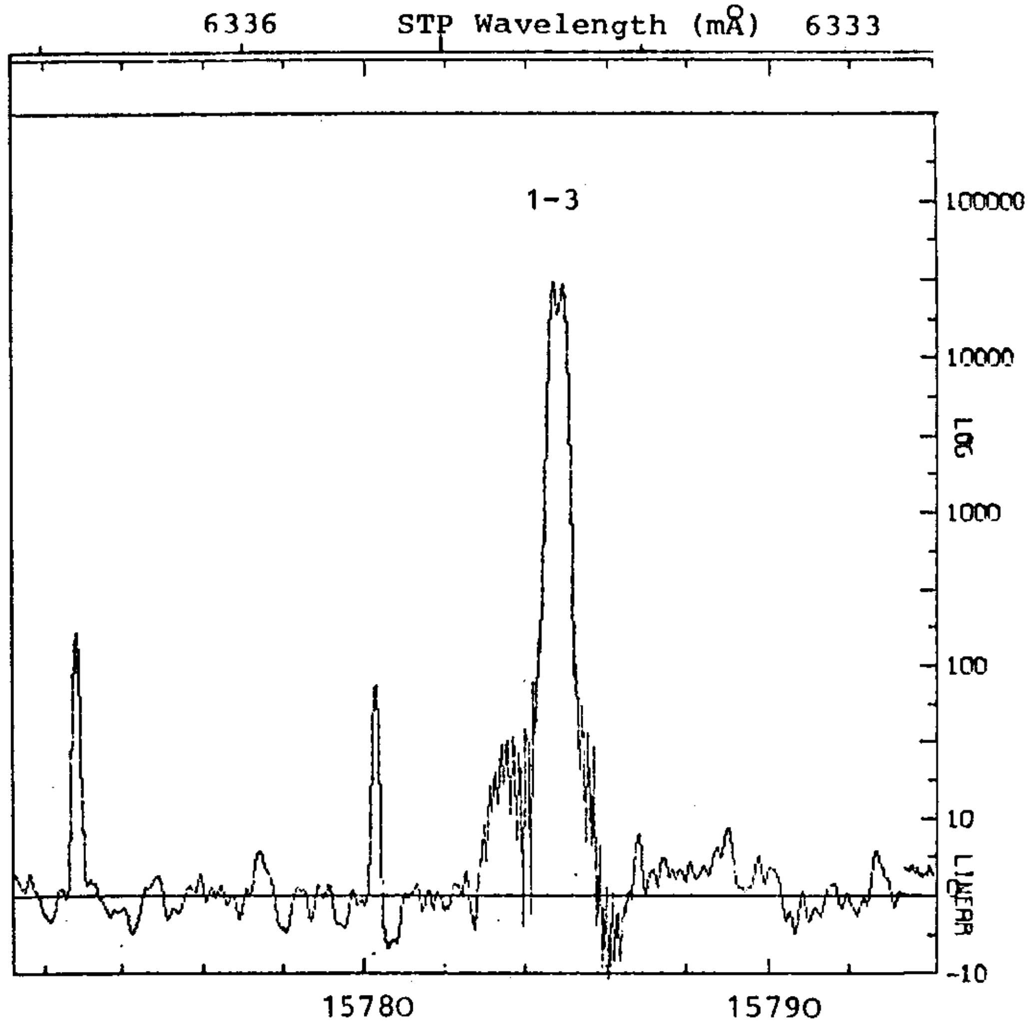
The figures in this appendix show a comprehensive set of hollow cathode line profiles in neon. The hollow cathode had an iron insert and was run at 900 mA and 4 Torr. The spectrum was taken with the Fourier transform spectrometer at the Kitt Peak National Observatory, Tucson, Arizona, USA (by courtesy of R.C.M. Learner, Imperial College, London). The spectral resolution was about 500,000. On the plots, wavelength and wavenumber scales are given and the lines are indicated.

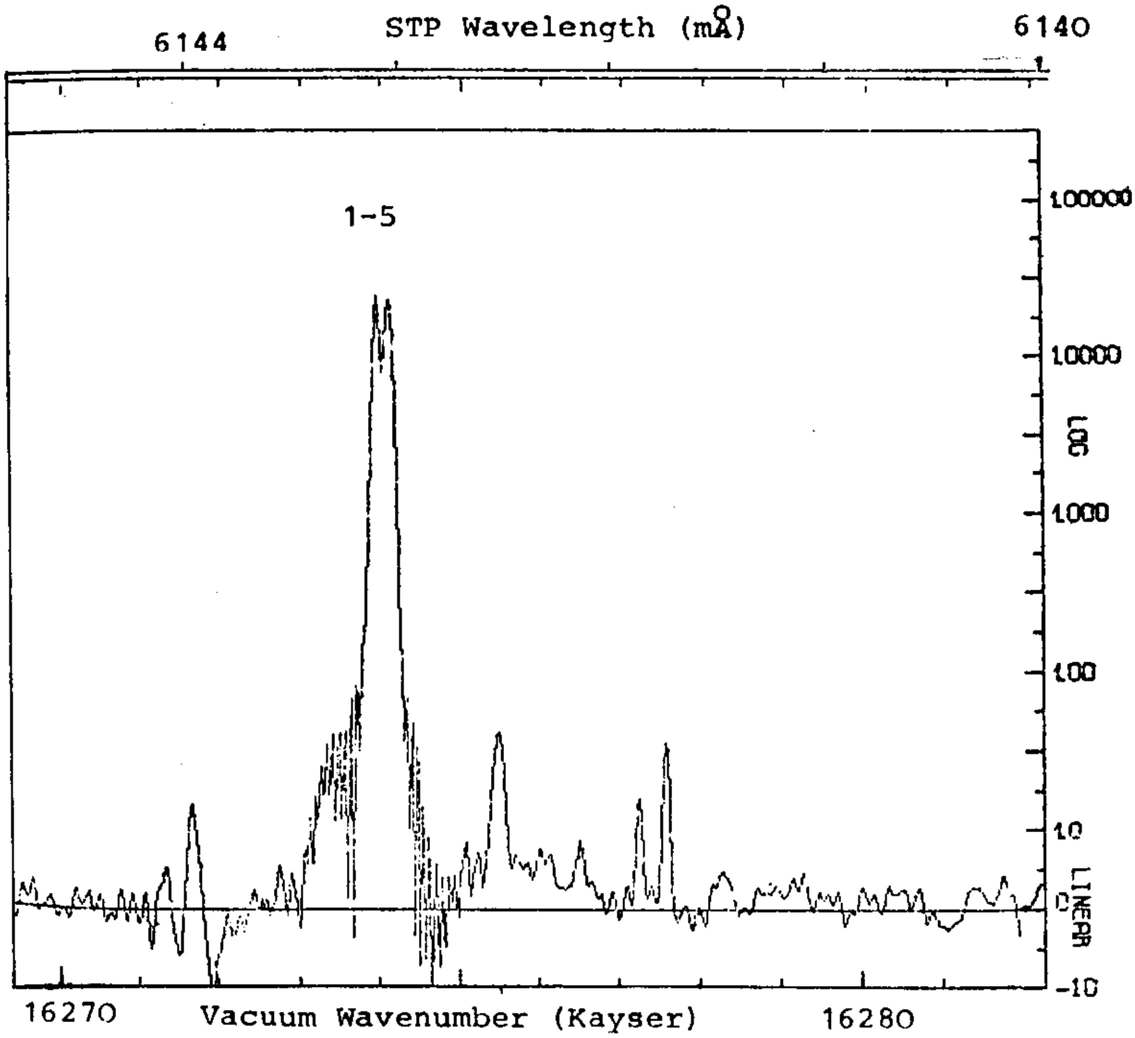


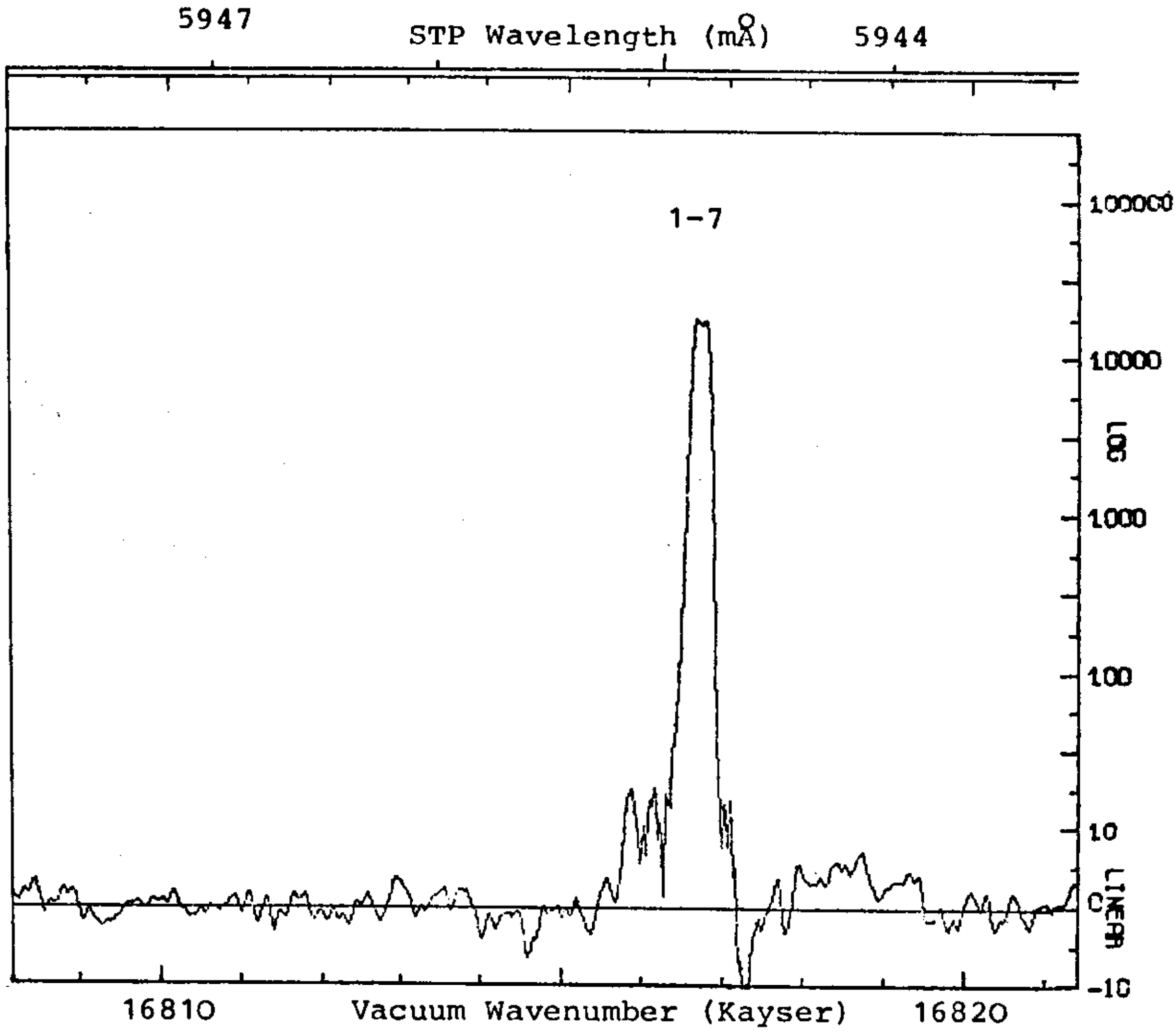
7035
STP Wavelength (mÅ)
7030
1-1
100000
10000
LOG
1000
100
10
0
LINEAR
-10
14210
Vacuum Wavenumber (Kayser)
14220

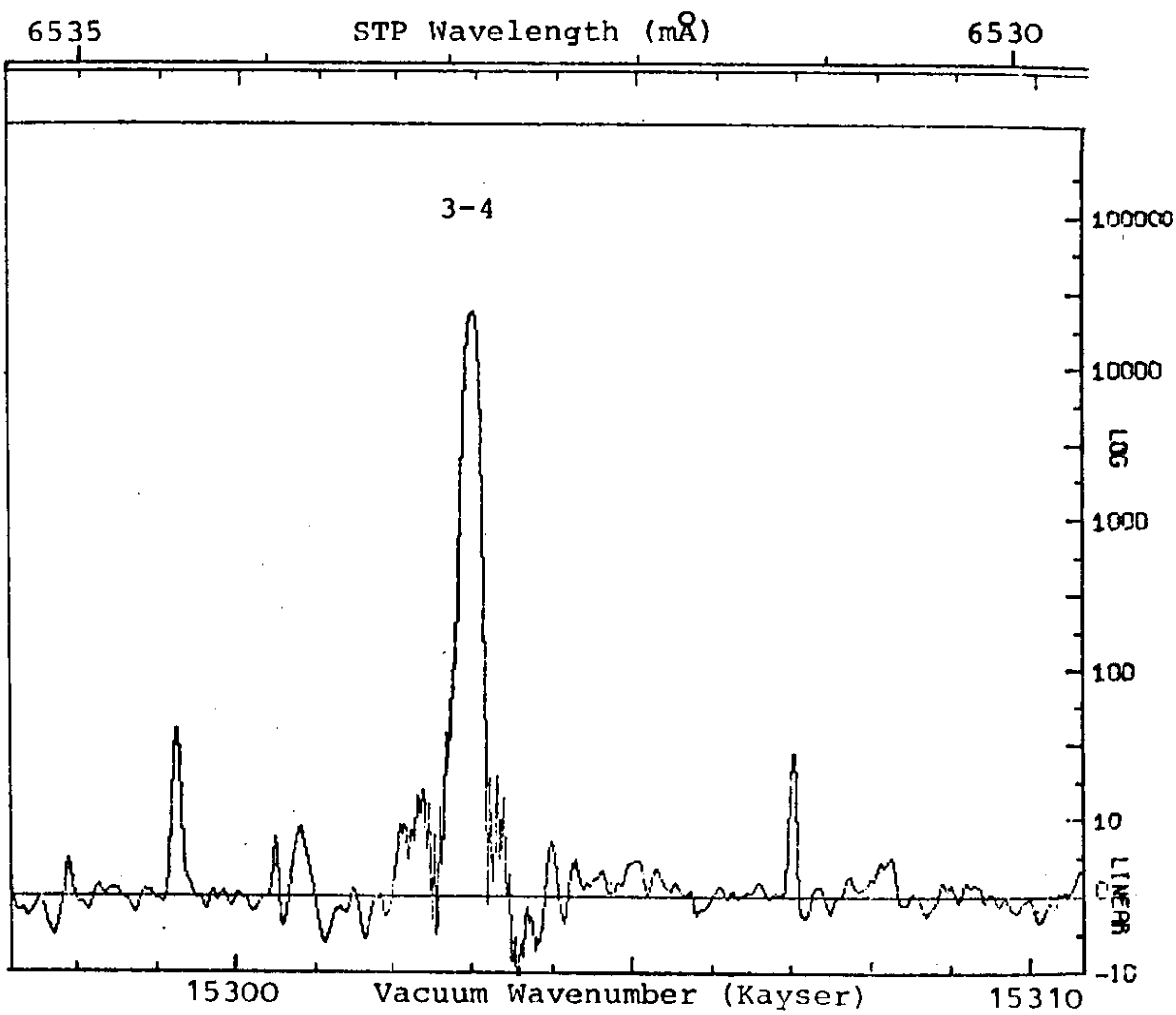


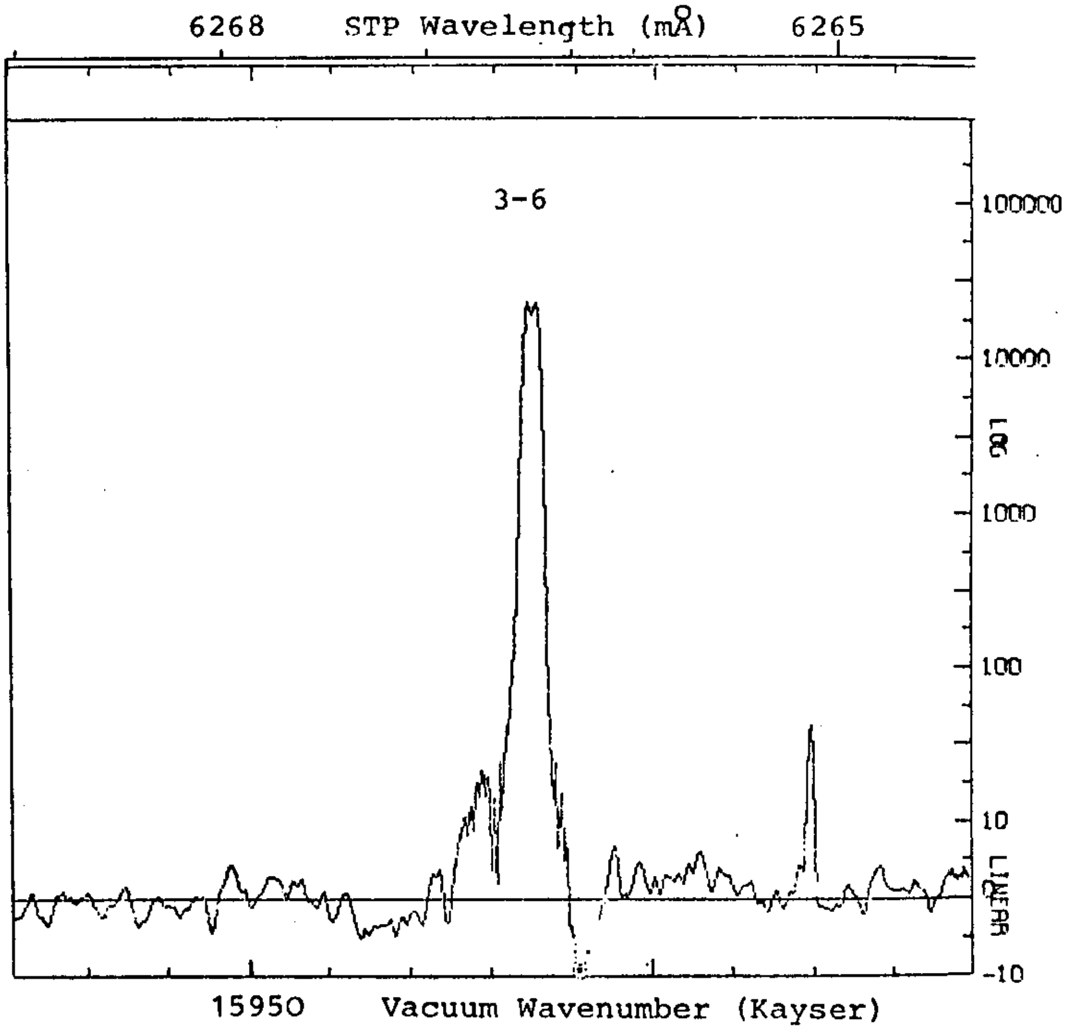
6405
STP Wavelength (mÅ)
6400
1-2
100000
10000
LOG
1000
100
10
0
LINEAR
-10
15610
Vacuum Wavenumber (Kayser)
15620

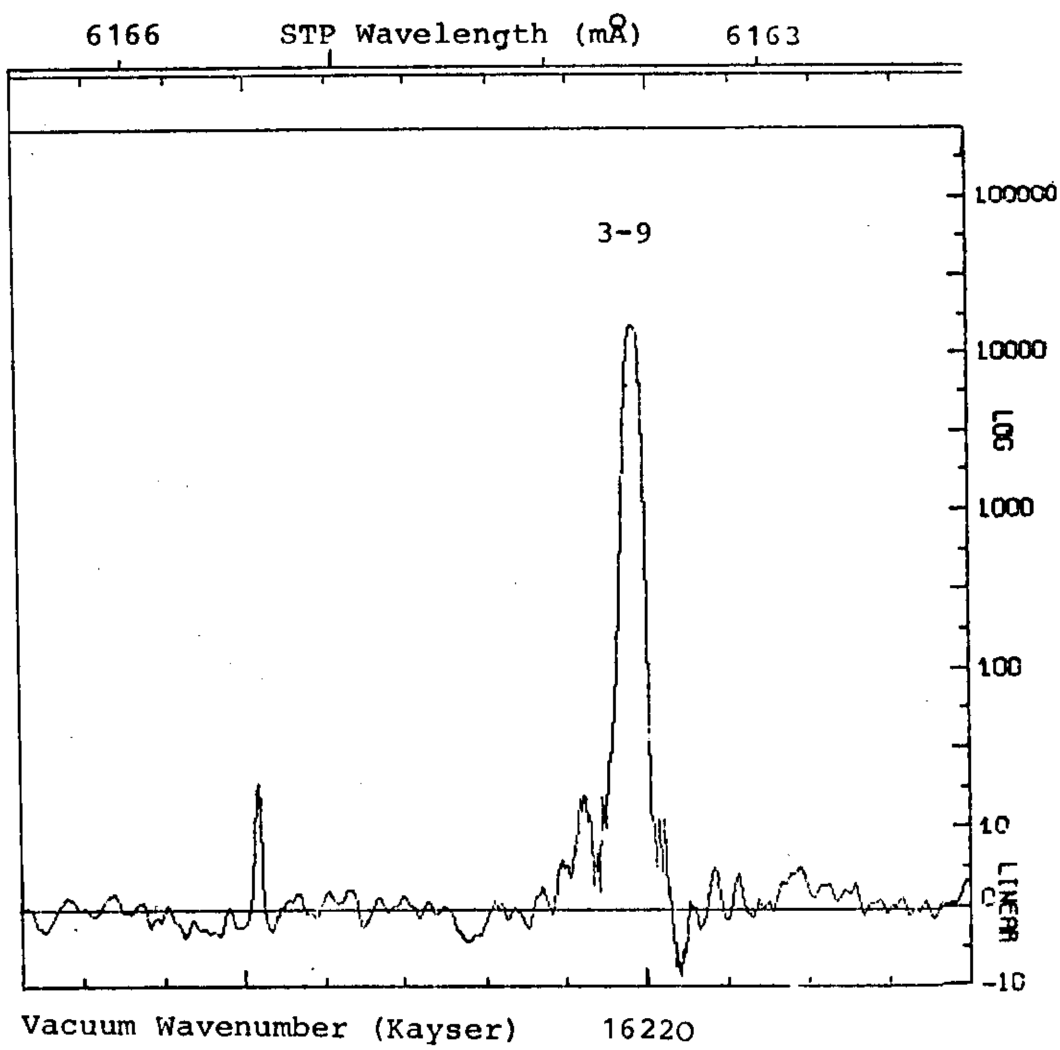

6336
STP Wavelength (mÅ)
6333
1-3
100000
10000
LOG
1000
100
10
LINEAR
-10
15780
15790

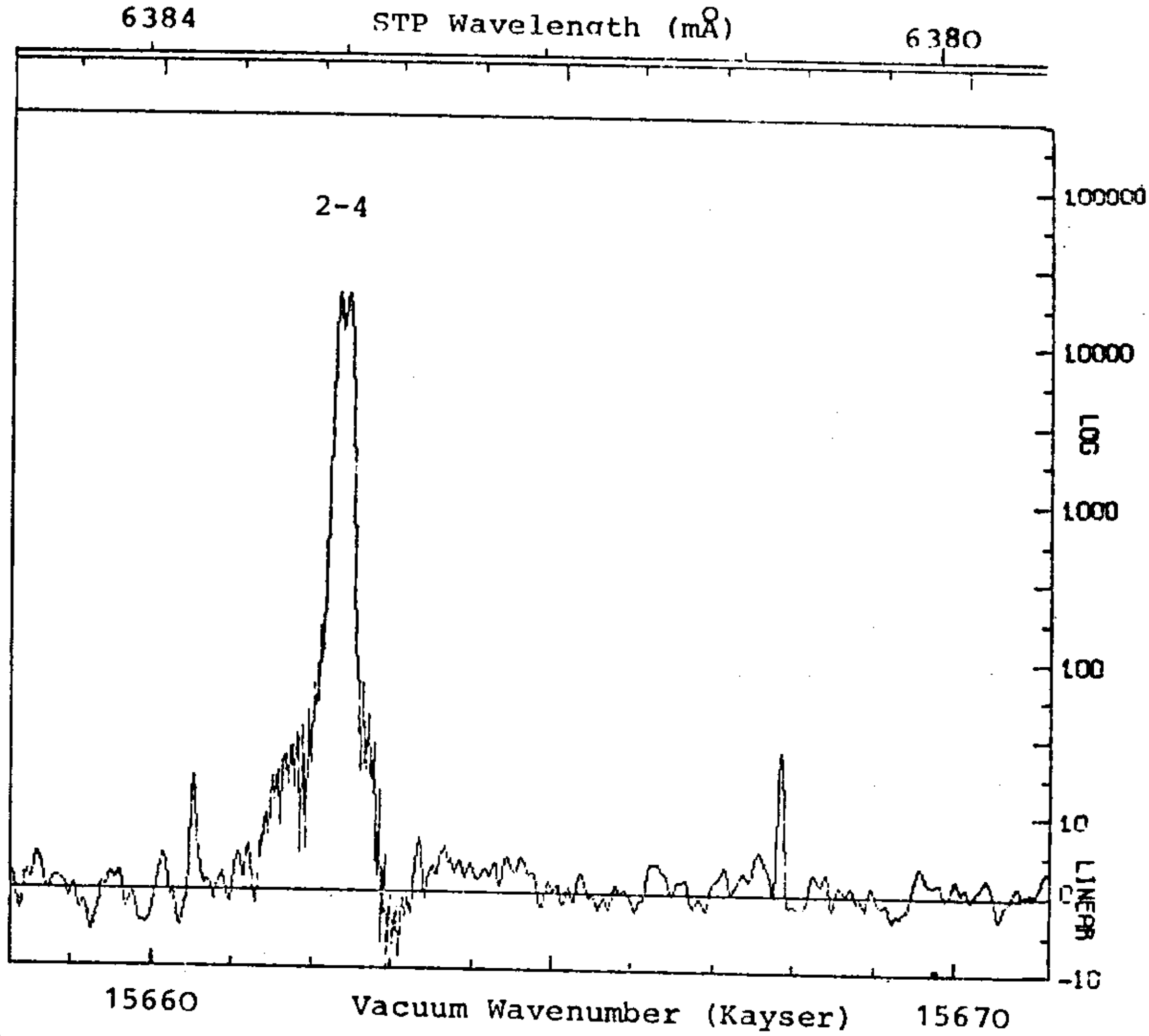

6144
STP Wavelength (mÅ)
6140
1-5
100000
10000
LOG
1000
100
10
LINEAR
0
-10
16270
Vacuum Wavenumber (Kayser)
16280

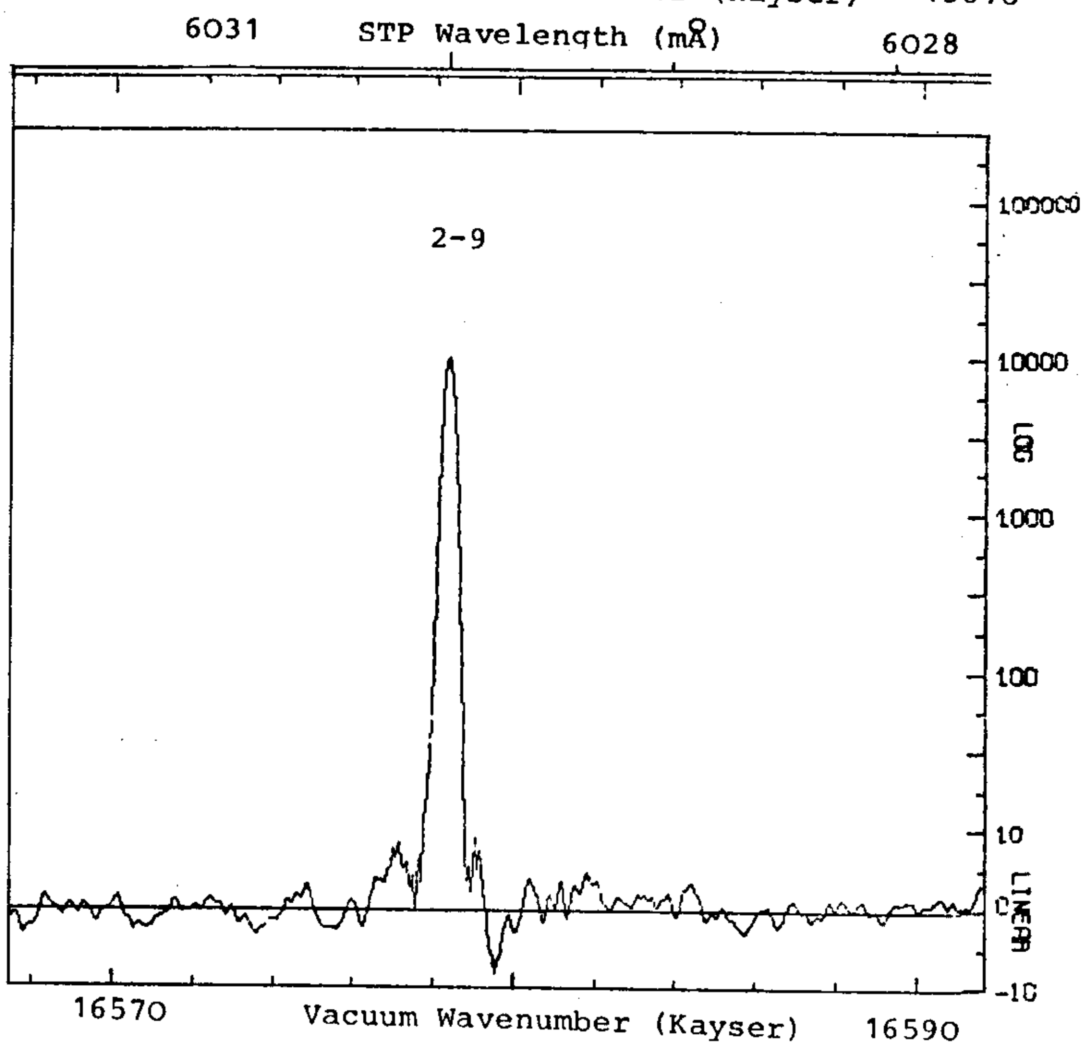

5947
STP Wavelength (mÅ)
5944
1-7
100000
10000
LOG
1000
100
10
0
LINEAR
-10
16810
Vacuum Wavenumber (Kayser)
16820

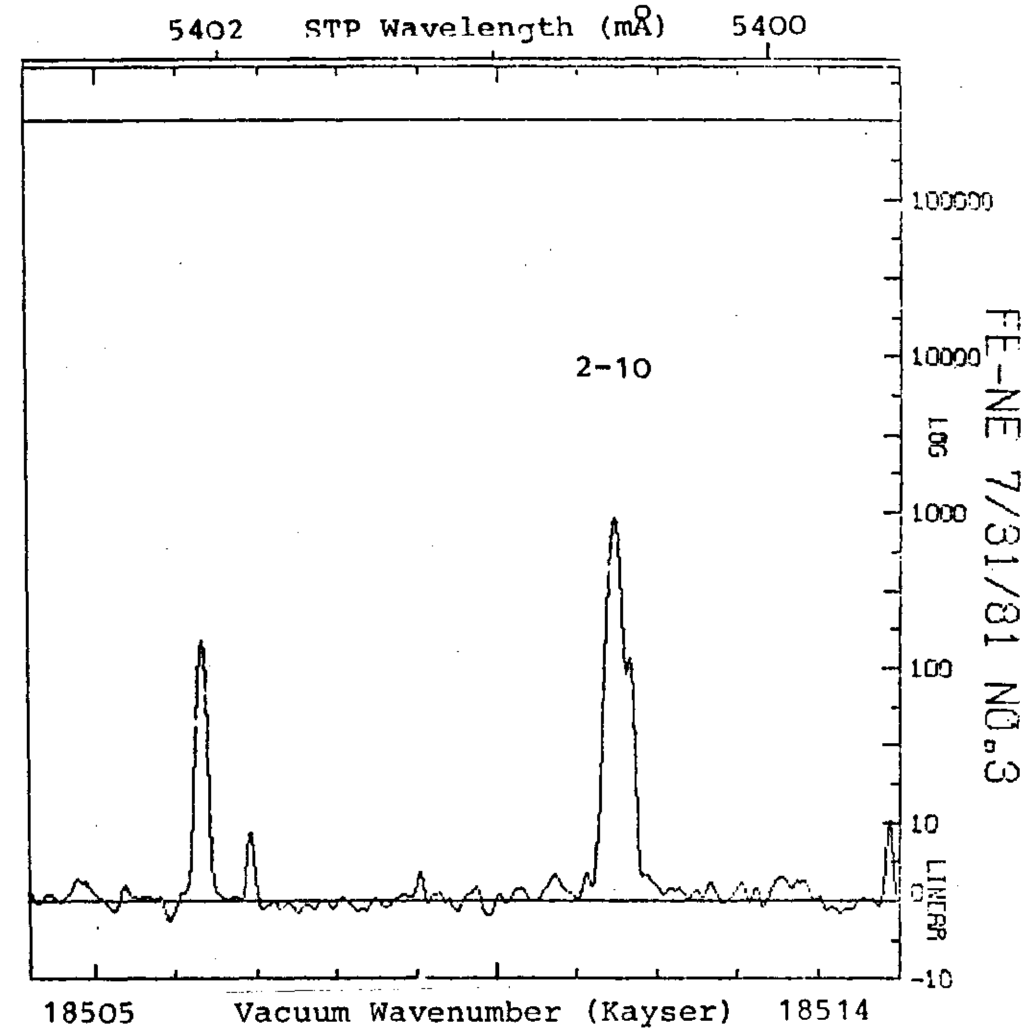

6535
STP Wavelength (mÅ)
6530
3-4
100000
10000
LOG
1000
100
10
0
LINEAR
-10
15300
Vacuum Wavenumber (Kayser)
15310

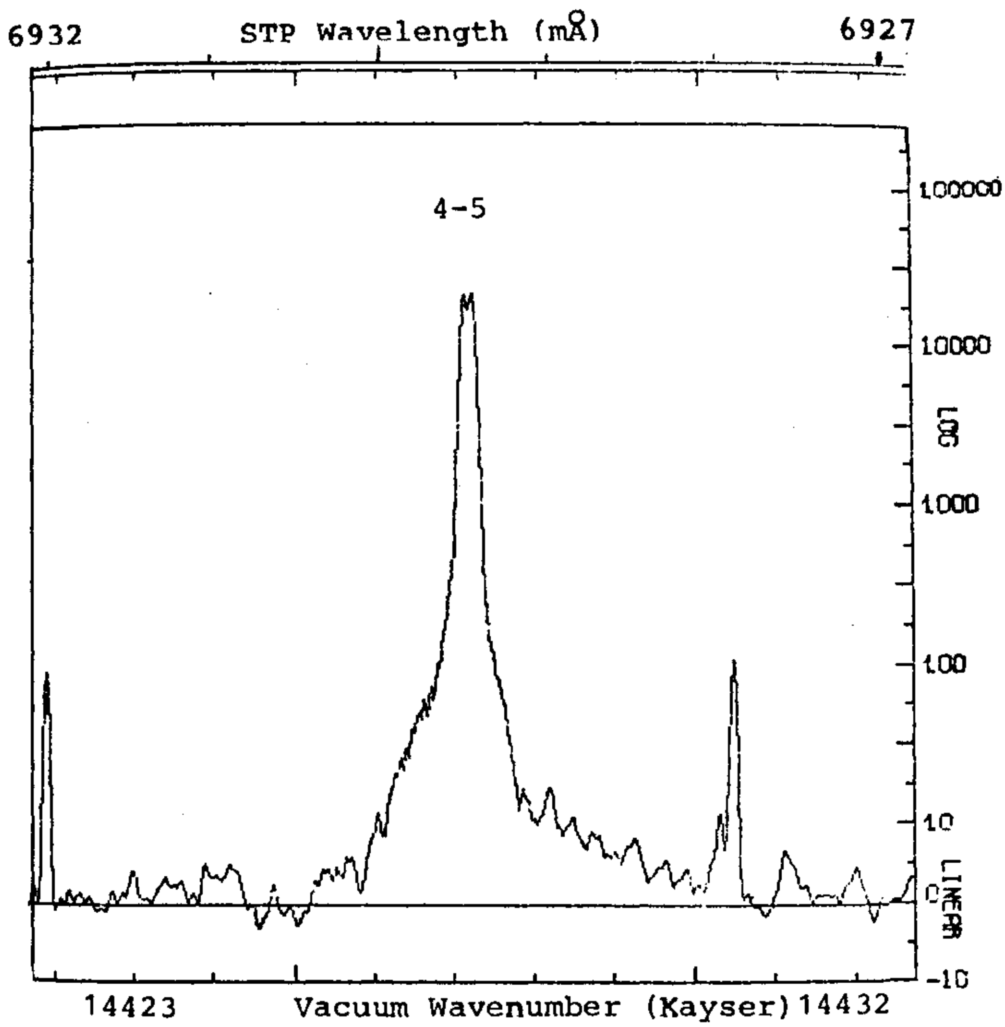

6268
STP Wavelength (mÅ)
6265
3-6
100000
10000
LOG
1000
100
10
LINEAR
-10
15950
Vacuum Wavenumber (Kayser)

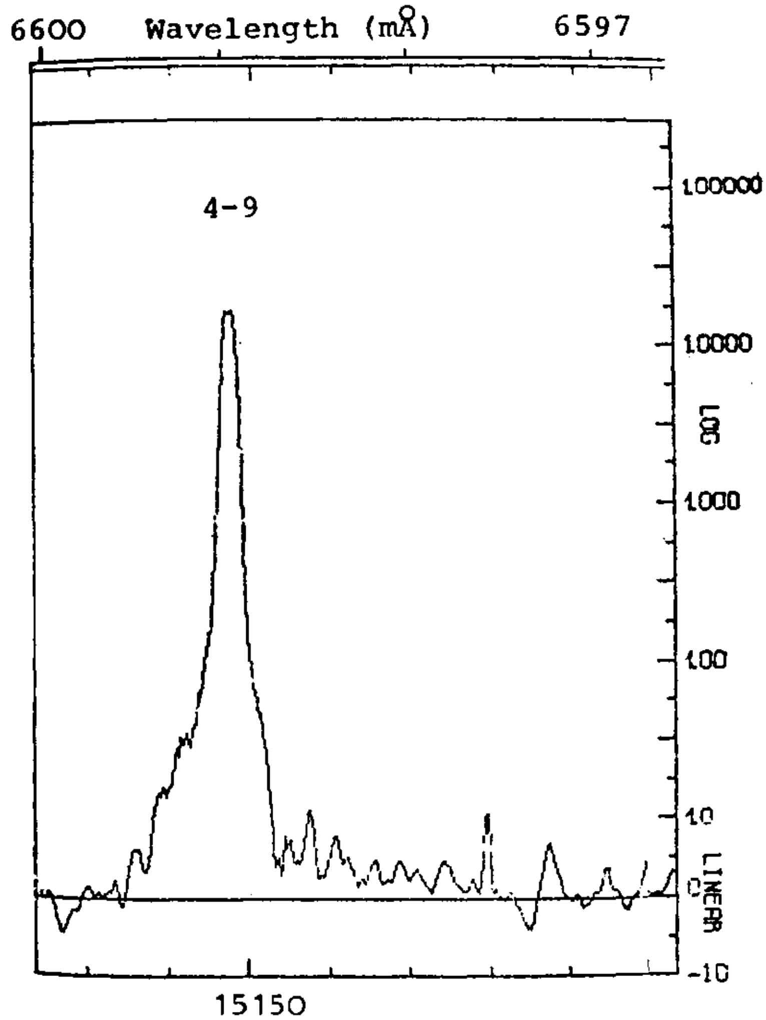

6166
STP Wavelength (mÅ)
6163
3-9
100000
10000
LOG
1000
100
10
LINEAR
-10
Vacuum Wavenumber (Kayser)
16220


6384
STP Wavelength (mÅ)
6380
2-4
100000
10000
LOG
1000
100
10
0
LINEAR
-10
15660
Vacuum Wavenumber (Kayser)
15670

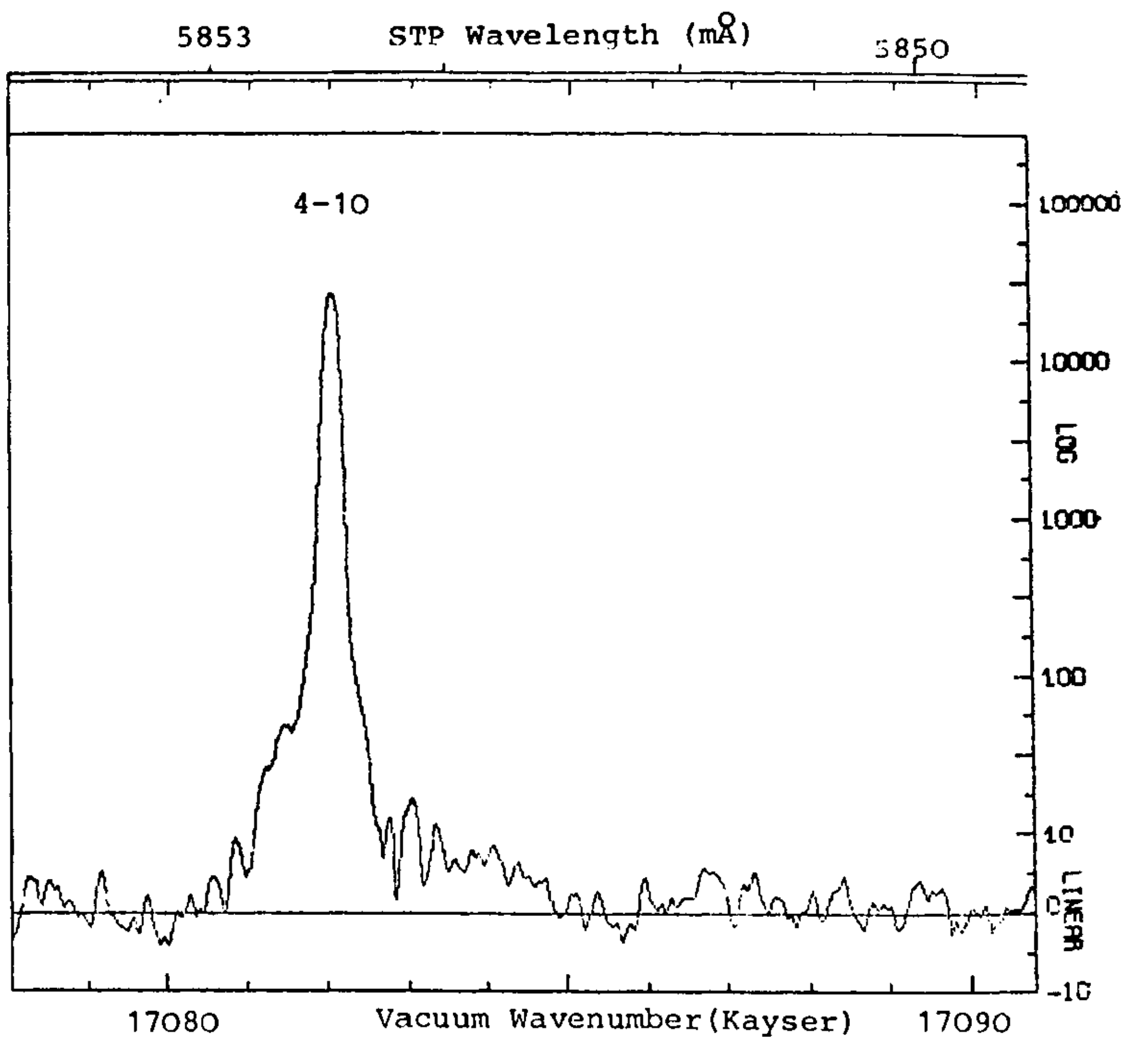

6031
STP Wavelength (mÅ)
6028
2-9
100000
10000
LOG
1000
100
10
0
LINEAR
-10
16570
Vacuum Wavenumber (Kayser)
16590


5402
STP Wavelength (mÅ)
5400
2-10
100000
10000
LOG
1000
100
10
0
LINEAR
-10
FE-NE 7/31/81 NO.3
18505
Vacuum Wavenumber (Kayser)
18514


6932
STP Wavelength (mÅ)
6927
4-5
100000
10000
LOG
1000
100
10
0
LINEAR
-10
14423
Vacuum Wavenumber (Kayser)
14432



6600
Wavelength (mÅ)
6597
4-9
100000
10000
LOG
1000
100
10
LINEAR
0
-10
15150



5853
STP Wavelength (mÅ)
5850
4-10
100000
10000
LOG
1000
100
10
LINEAR
0
-10
17080
Vacuum Wavenumber(Kayser)
17090

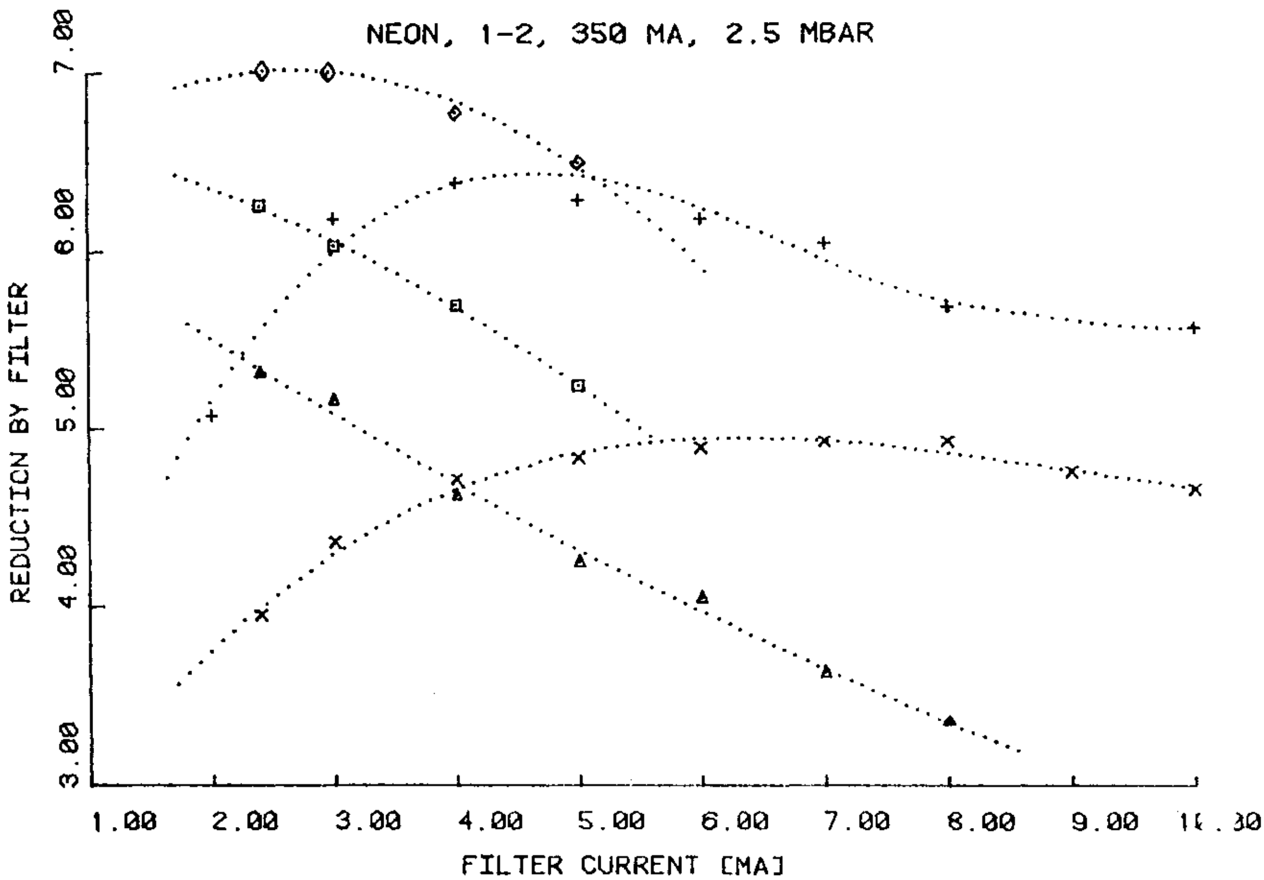
Appendix II: Neon Reduction Factor Measurement Results

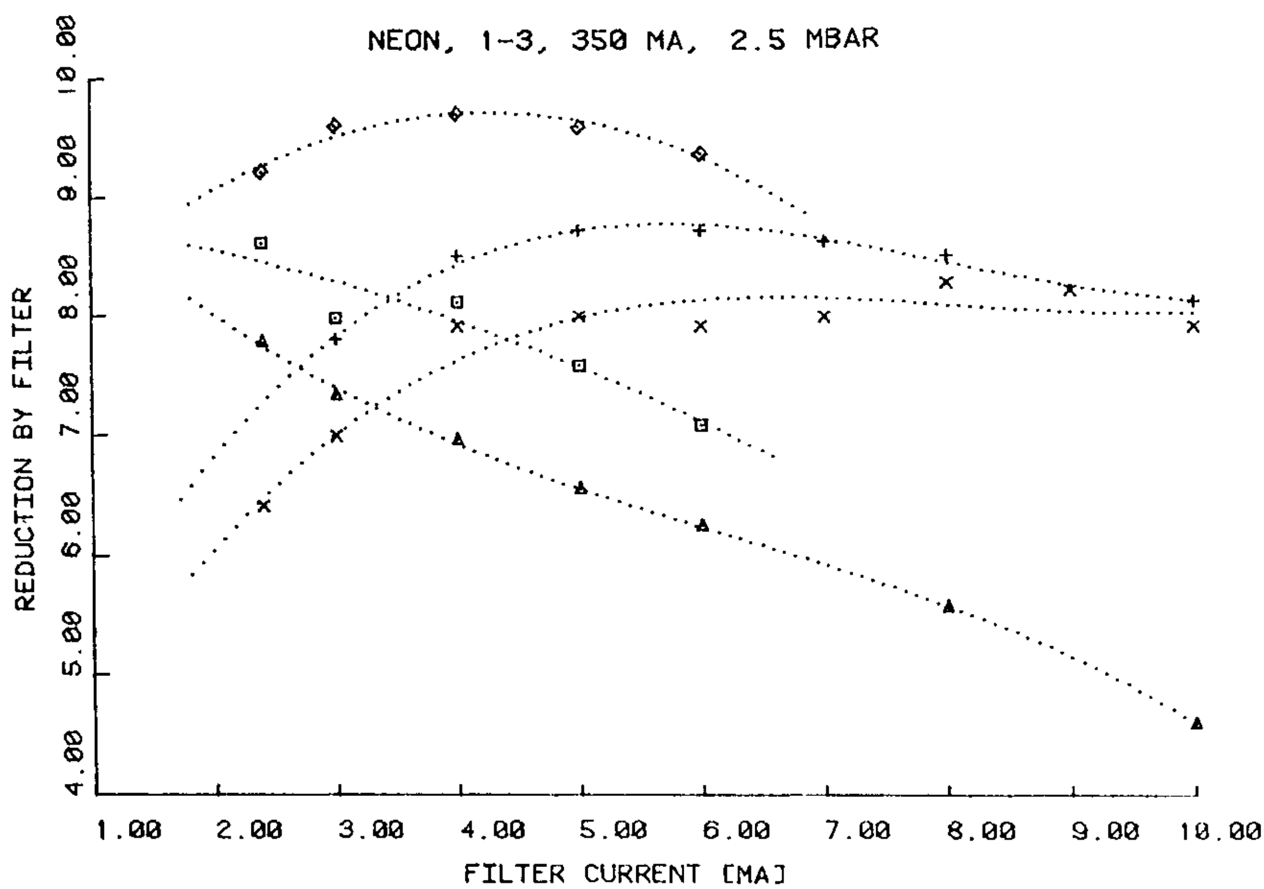
The plots in this appendix show the complete set of reduction factor measurement results for neon. The different symbols for the measured data points distinguish the filter discharge pressures according to the following key:

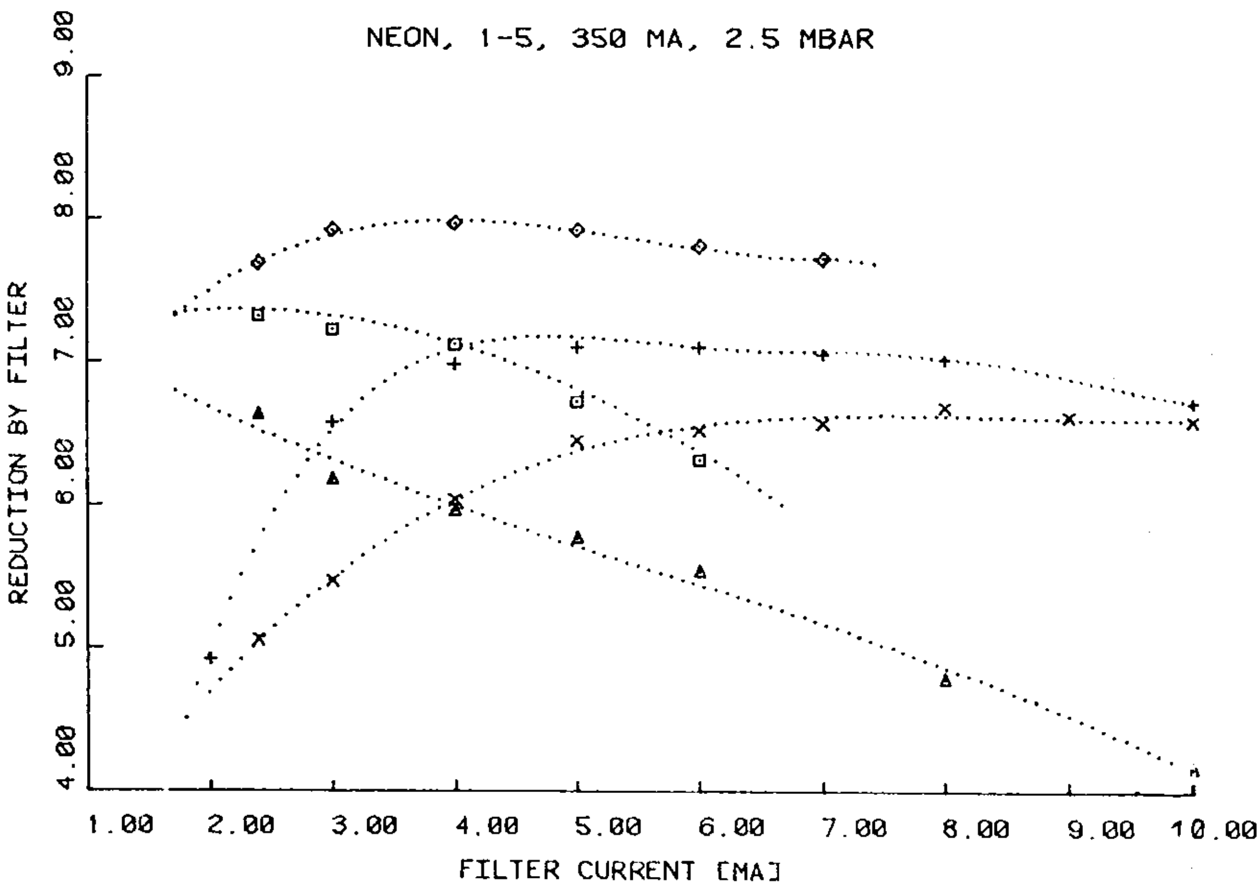
X	≙	1 mbar
+	≙	1.3 mbar
◇	≙	2 mbar
□	≙	4.4 mbar
Δ	≙	6.4 mbar

The titles of the plots give the gas, the spectral line, the hollow cathode current and pressure.

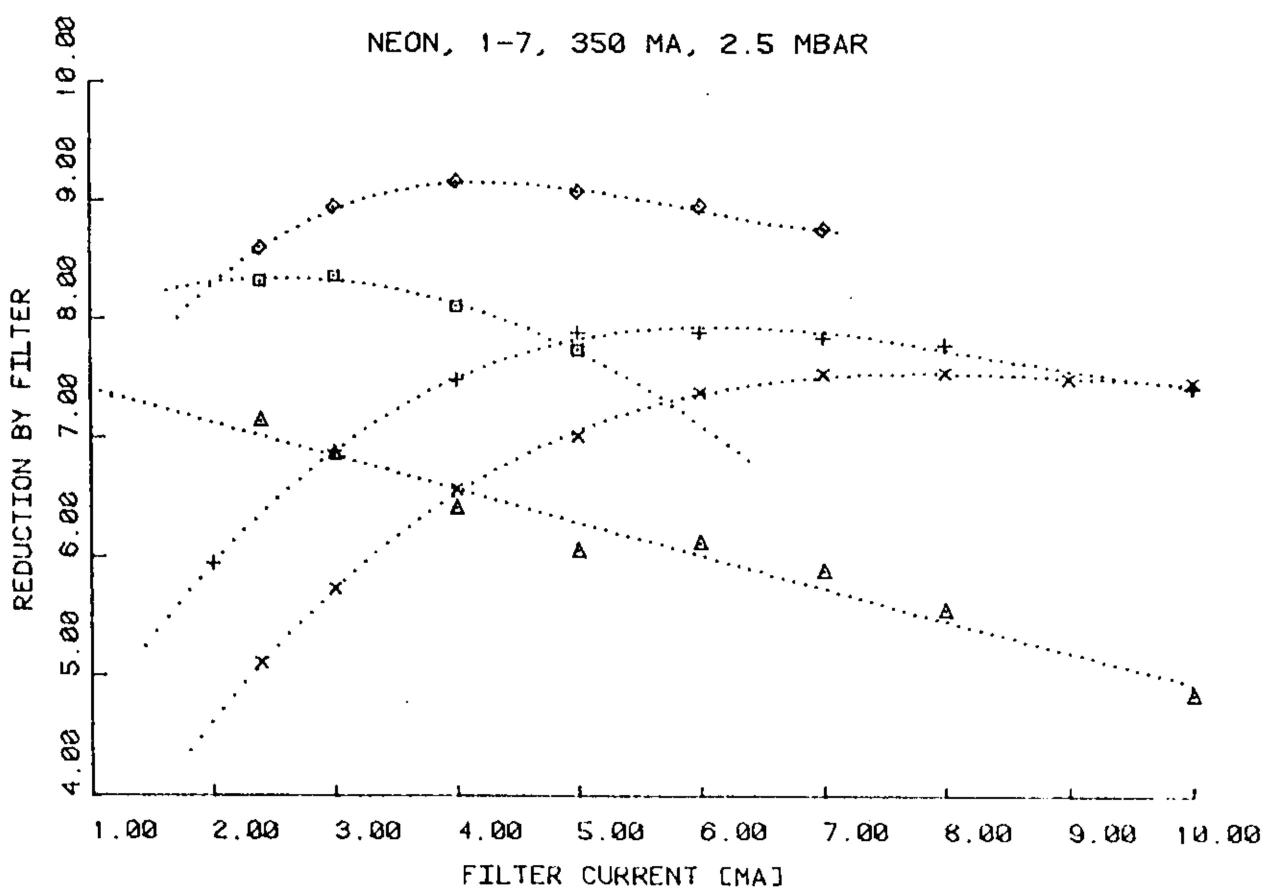
1. $I_{h.c.}$ = 350 mA


NEON, 1-2, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
3.00
4.00
5.00
6.00
7.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

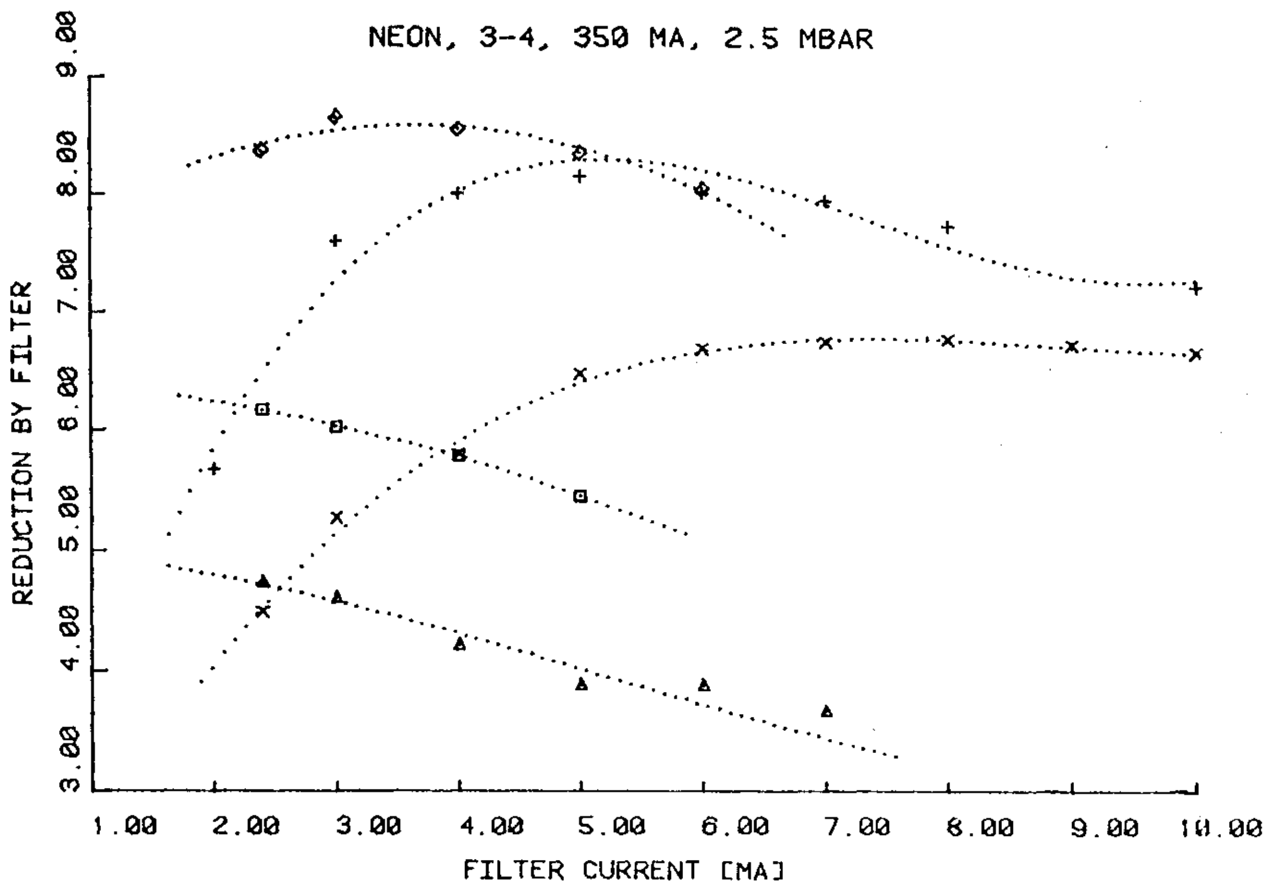

NEON, 1-3, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

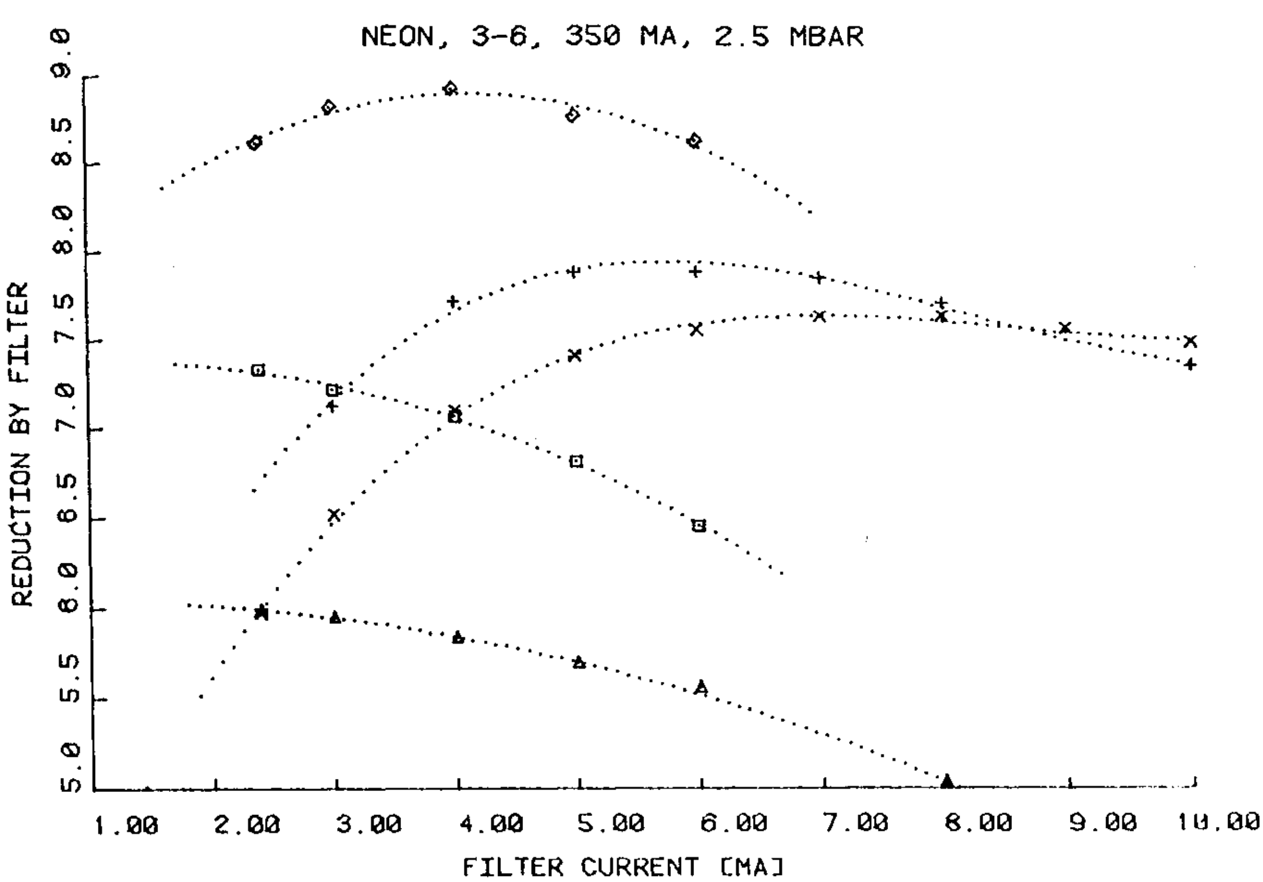


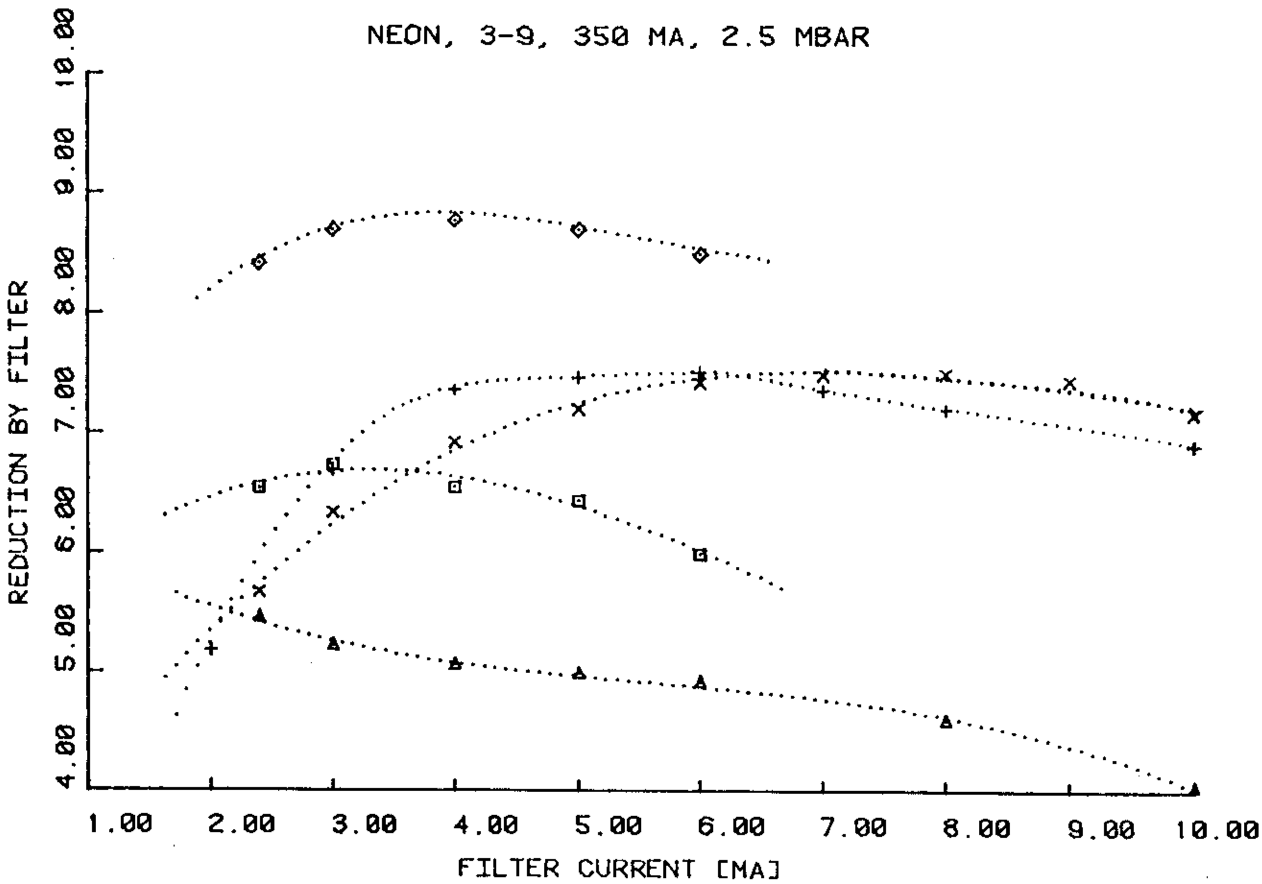
NEON, 1-5, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
4.00
5.00
6.00
7.00
8.00
9.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

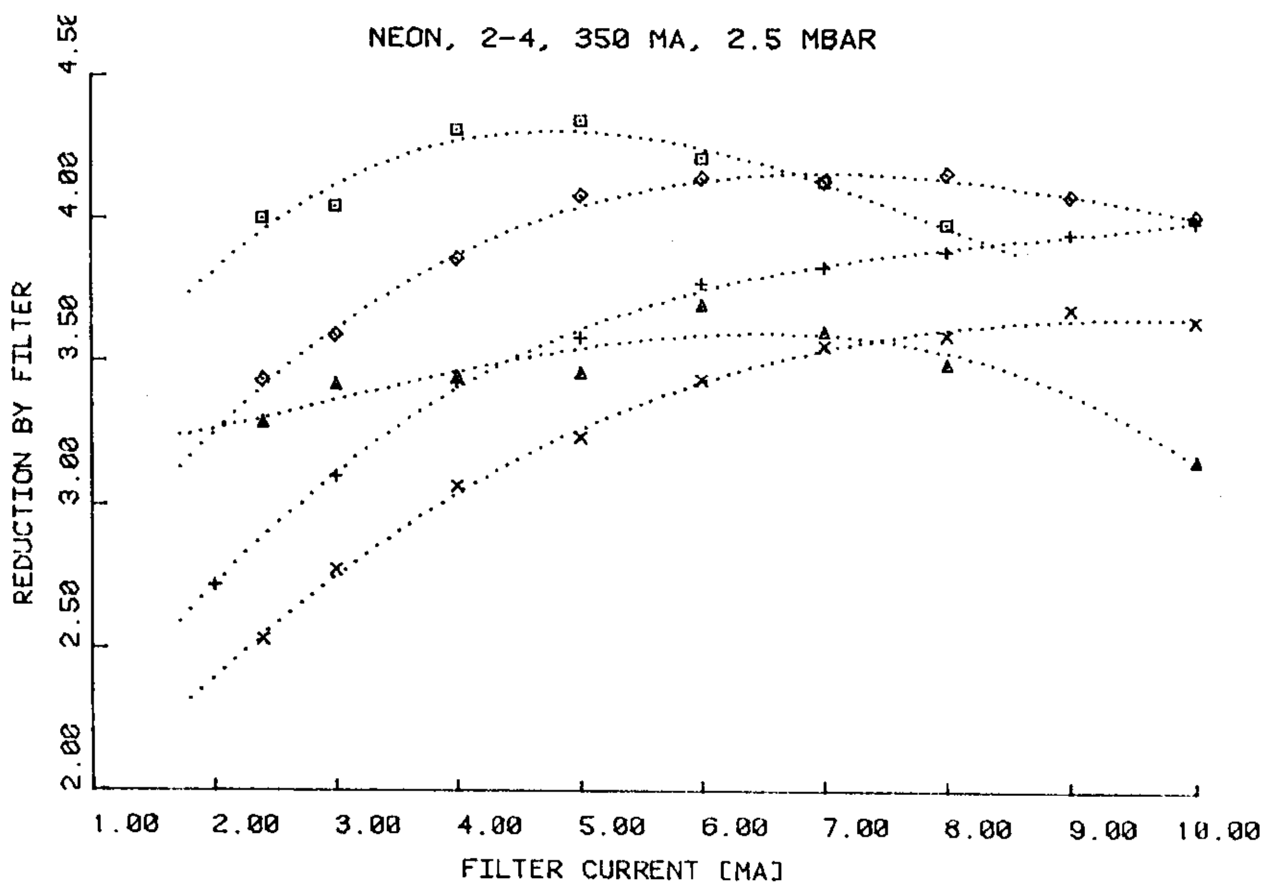


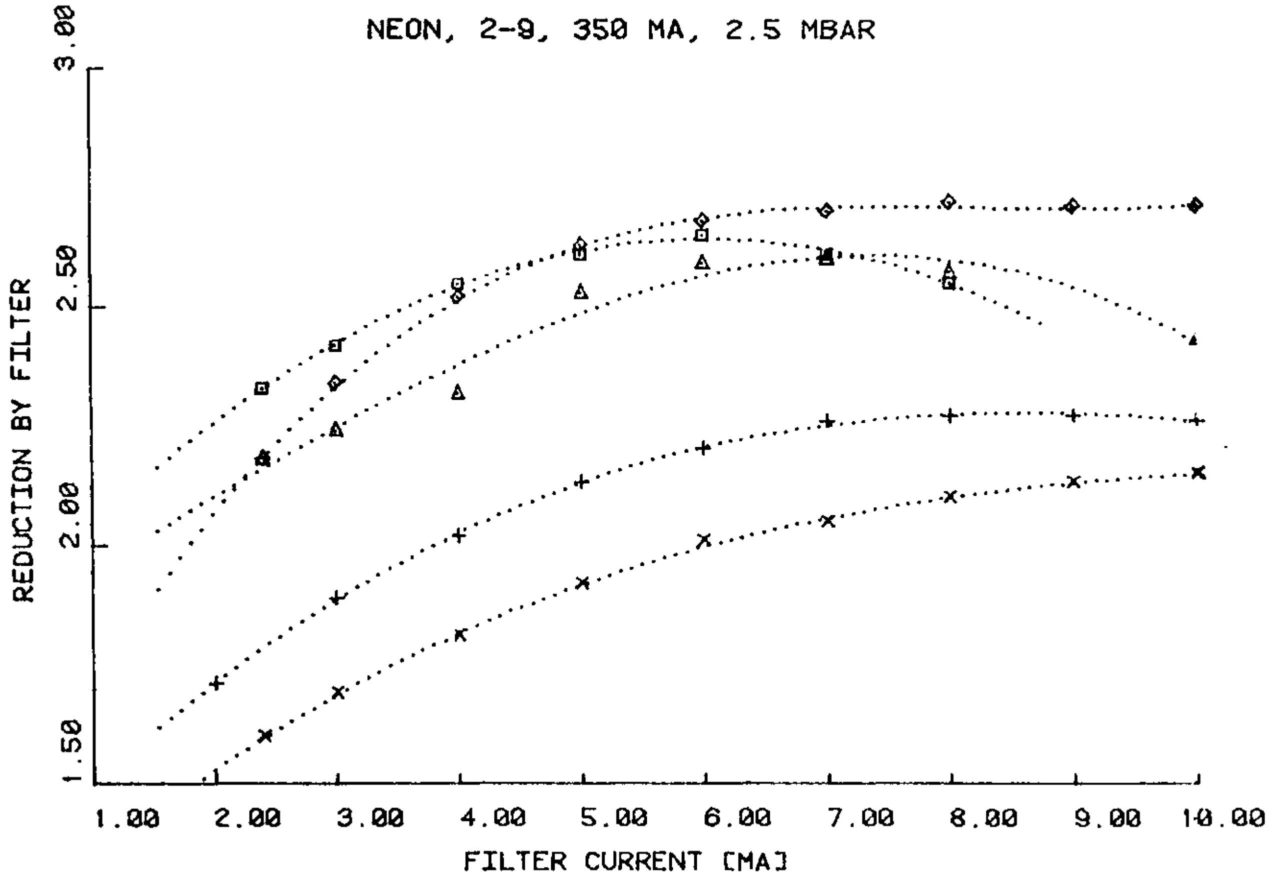
NEON, 1-7, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

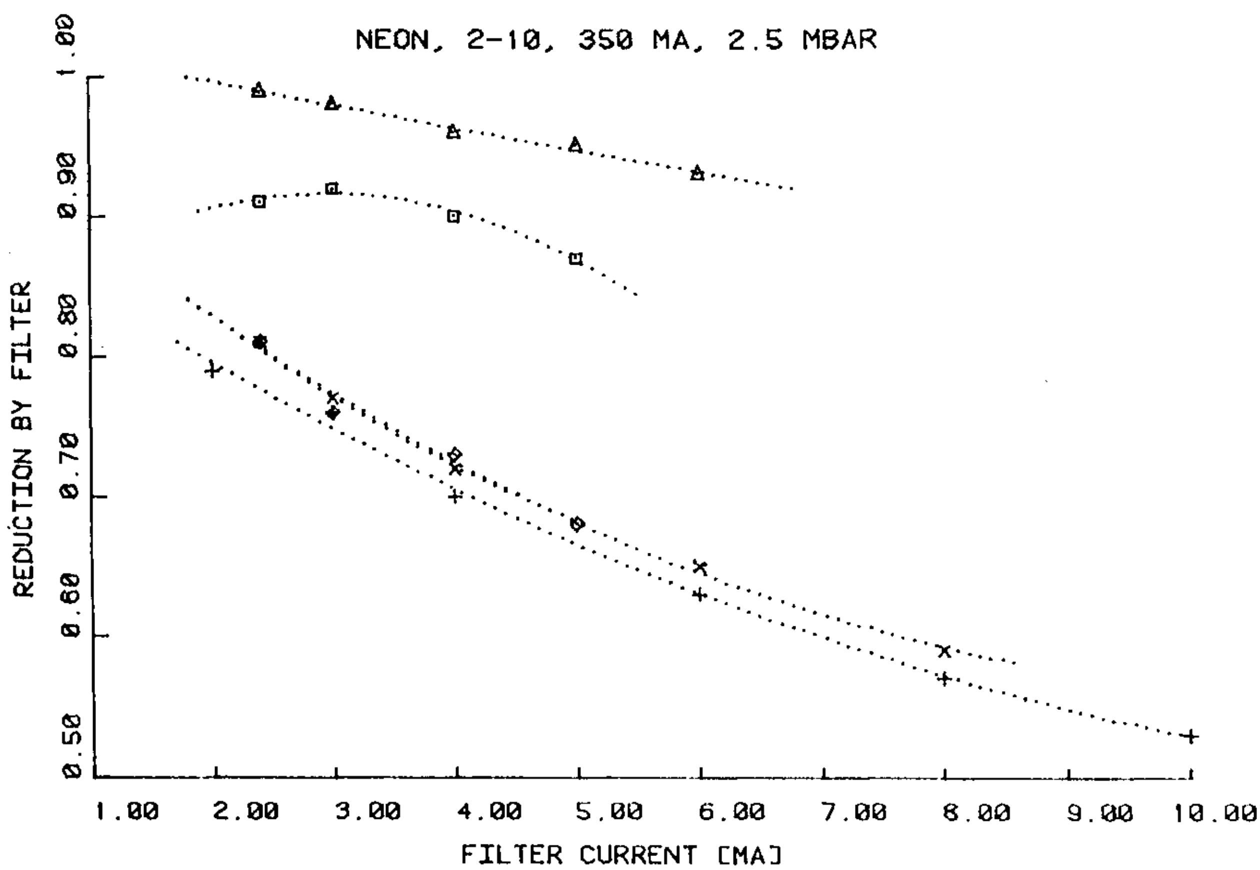

NEON, 3-4, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
3.00
4.00
5.00
6.00
7.00
8.00
9.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

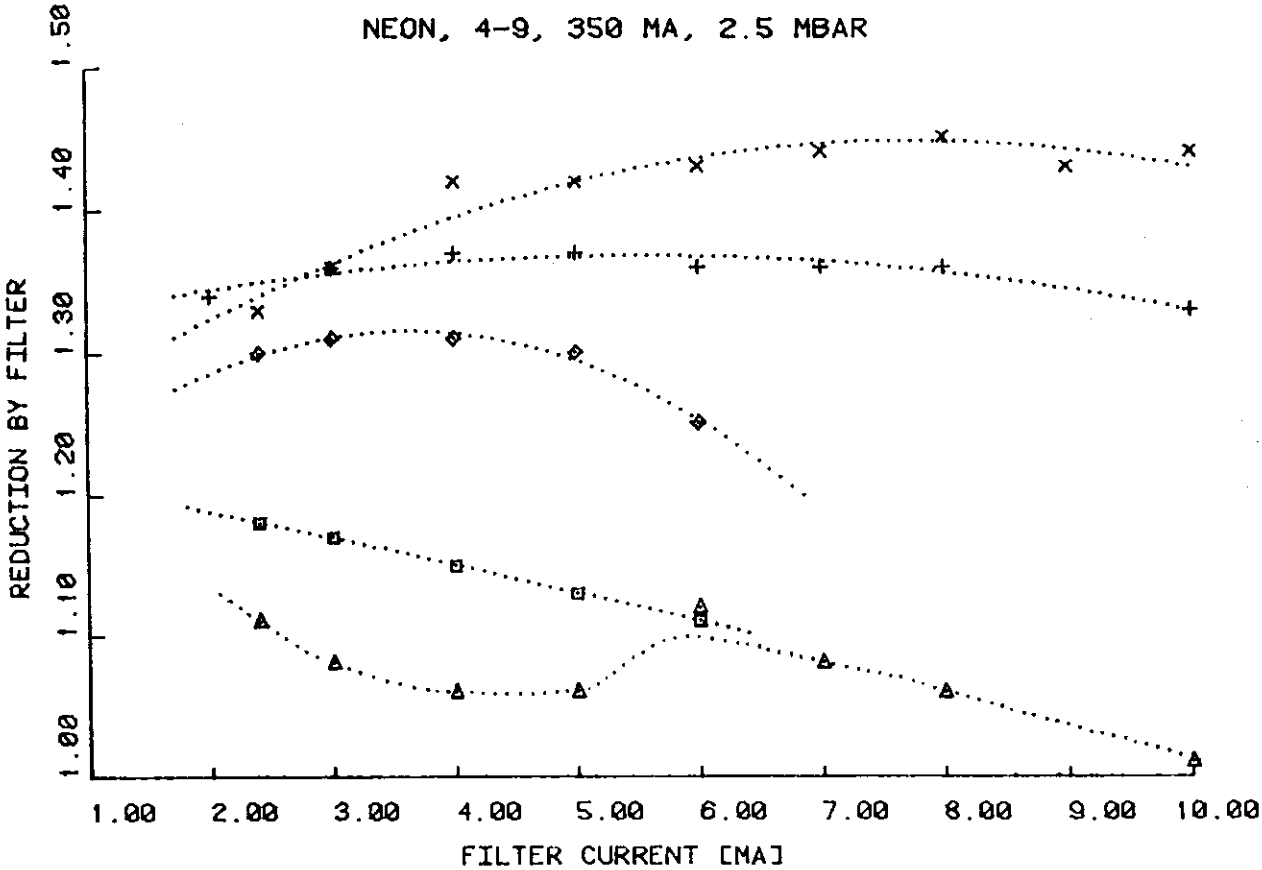

NEON, 3-6, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

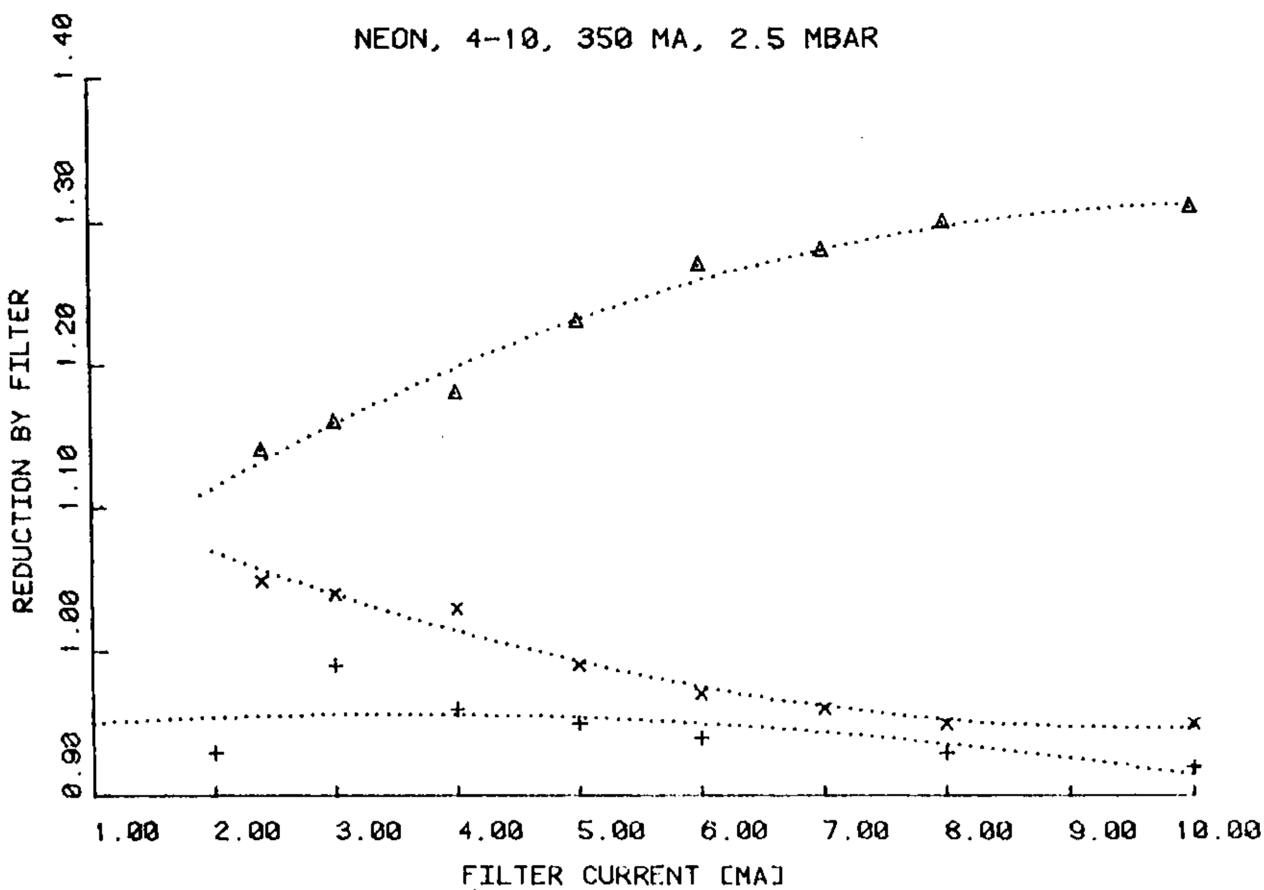

NEON, 3-9, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 2-4, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
2.00
2.50
3.00
3.50
4.00
4.50
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

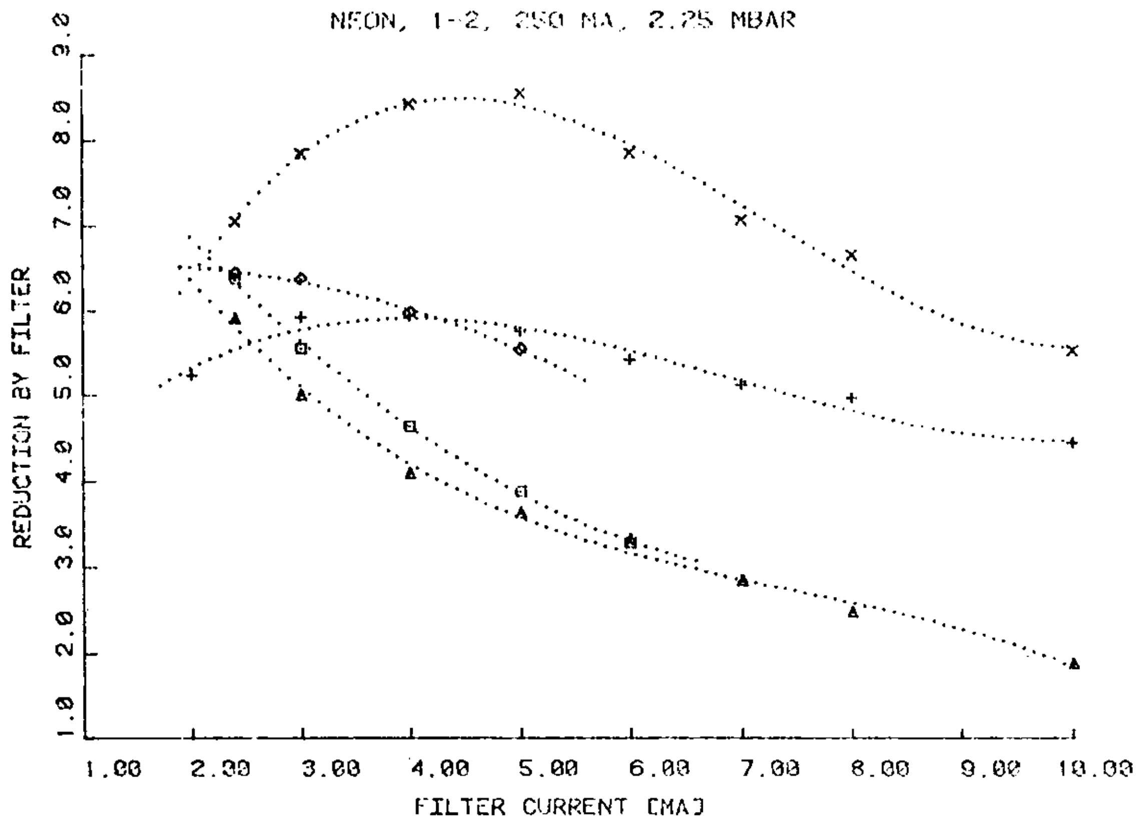

NEON, 2-9, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
1.50
2.00
2.50
3.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

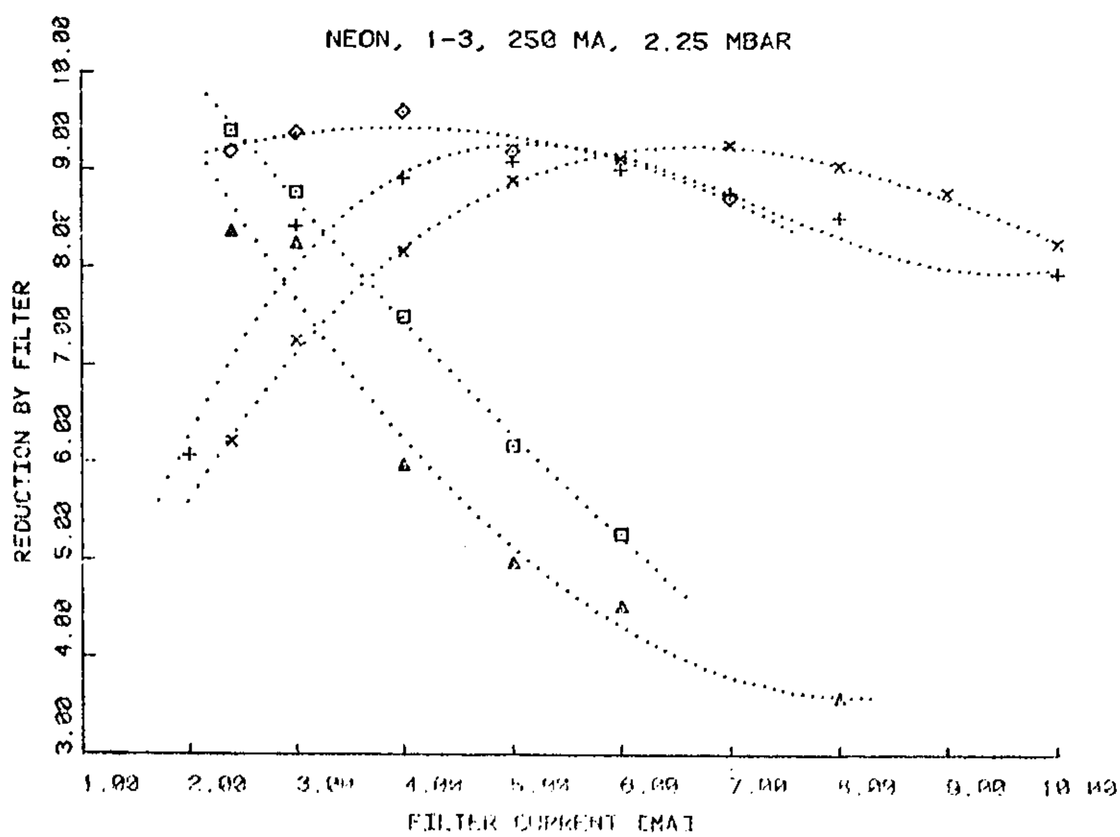

NEON, 2-10, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
0.50
0.60
0.70
0.80
0.90
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

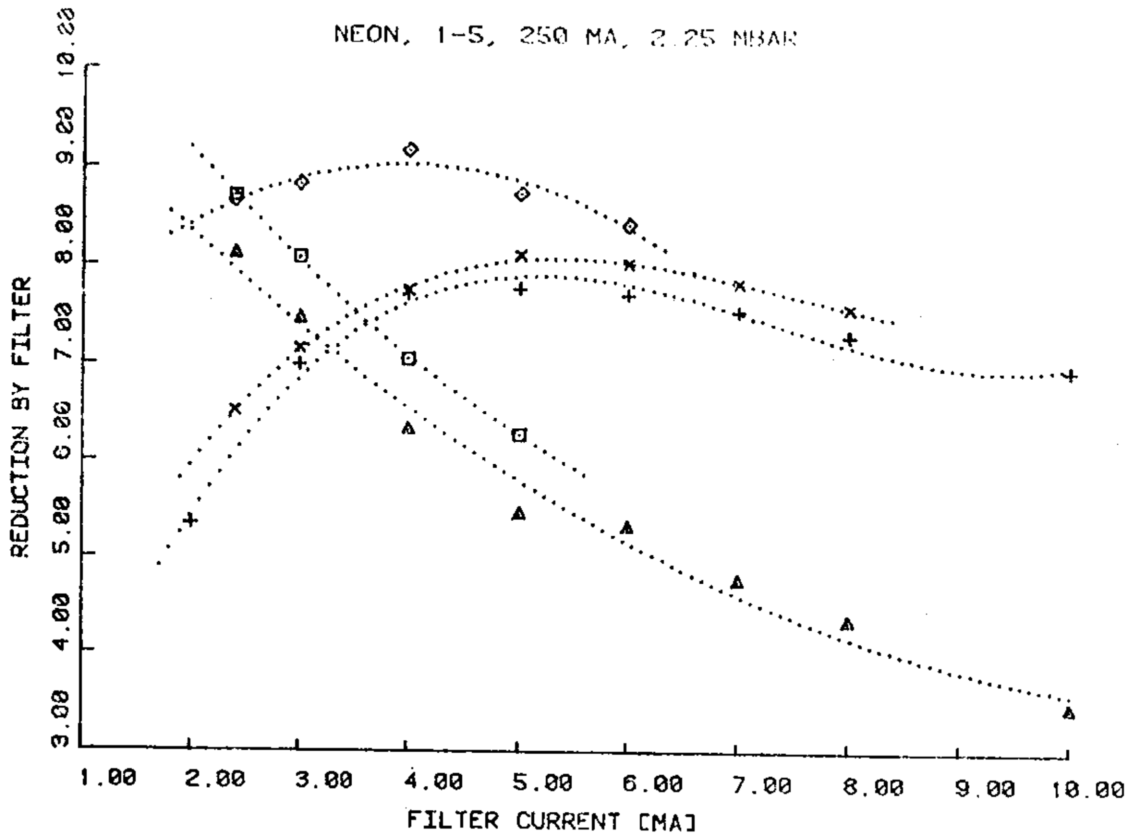

NEON, 4-9, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
1.00
1.10
1.20
1.30
1.40
1.50
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00
FILTER CURRENT [MA]

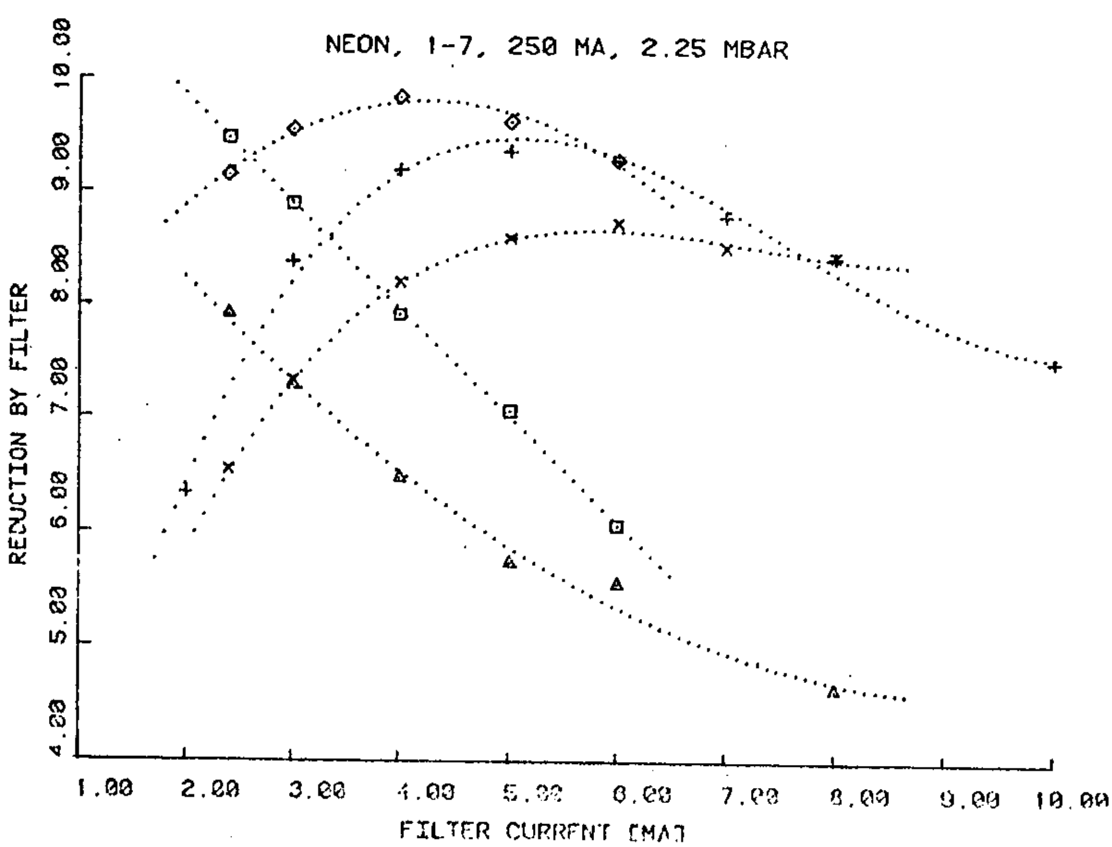

NEON, 4-10, 350 MA, 2.5 MBAR
REDUCTION BY FILTER
0.90
1.00
1.10
1.20
1.30
1.40
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00
FILTER CURRENT [MA]

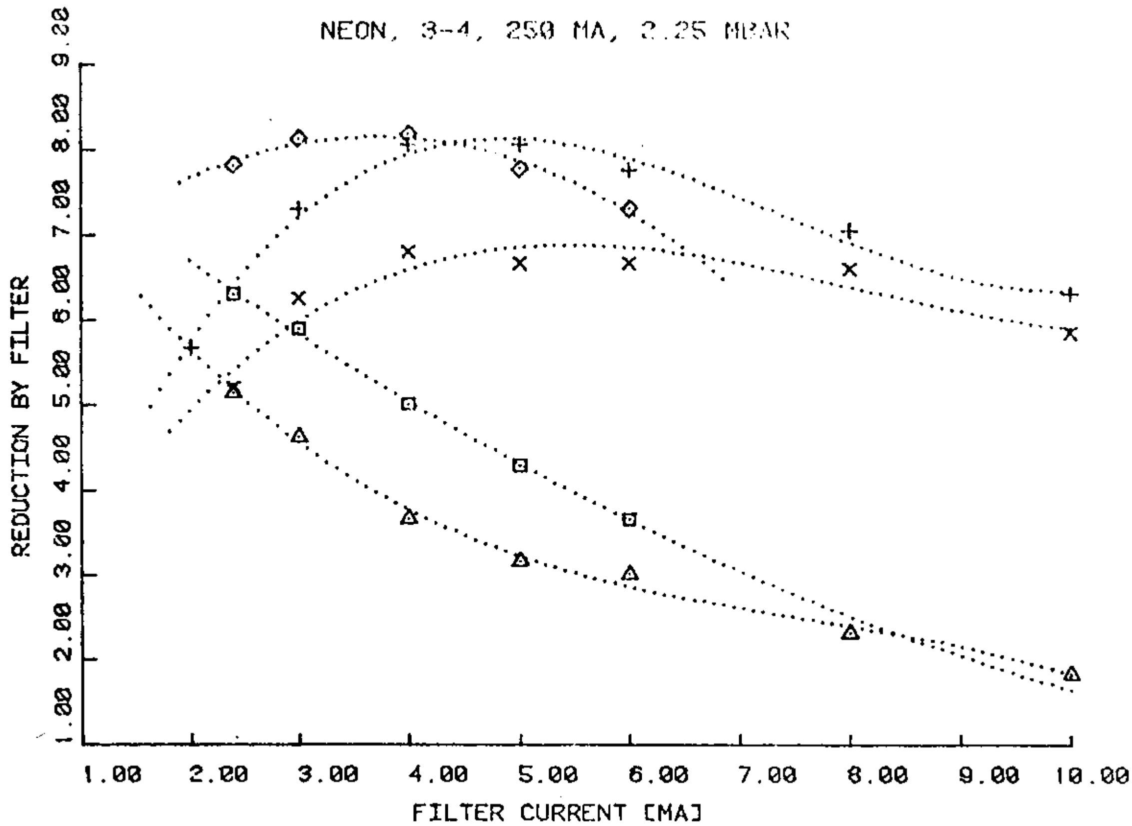
2. $I_{h.c.}$ = 250 mA

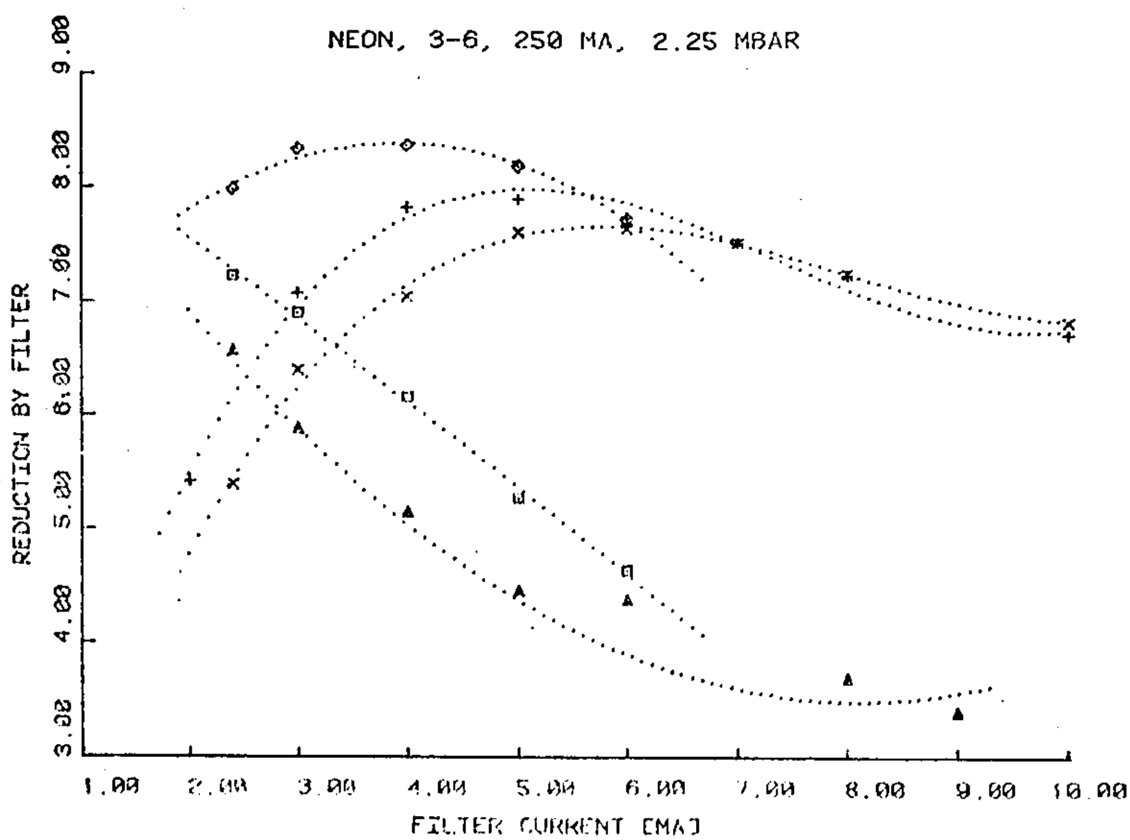

NEON, 1-2, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]

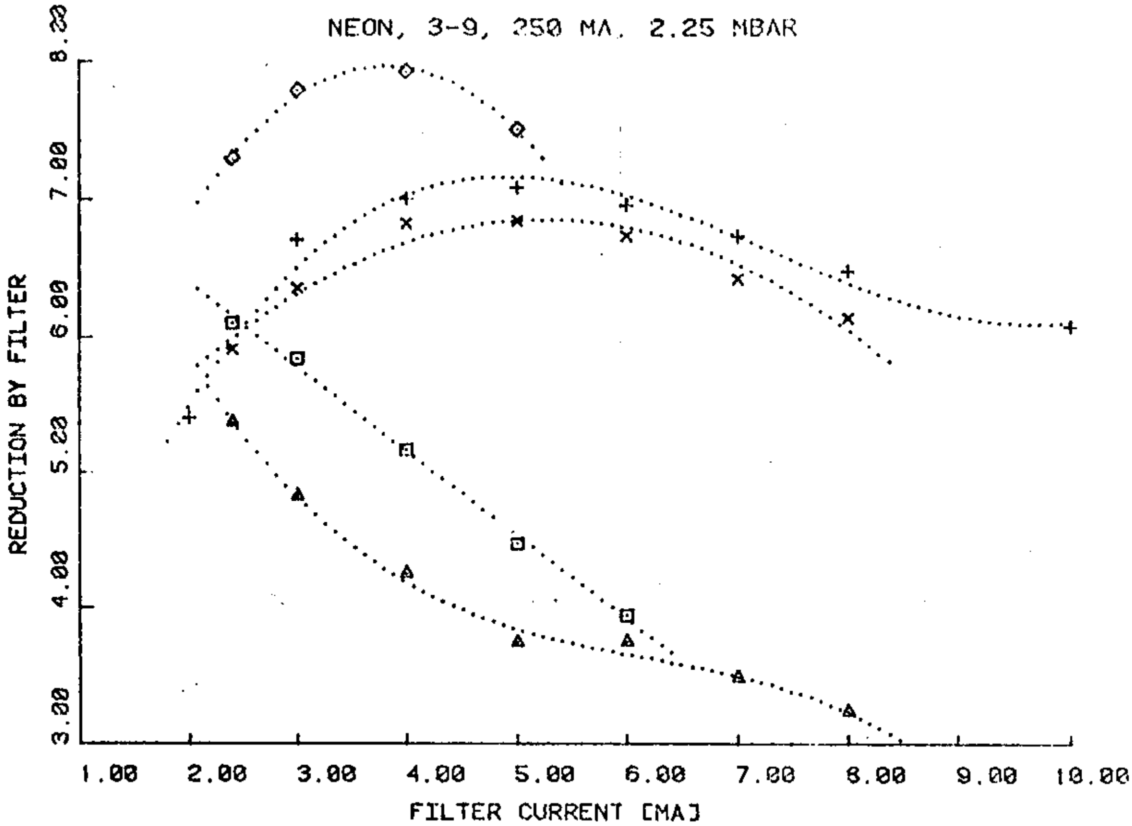

NEON, 1-3, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]

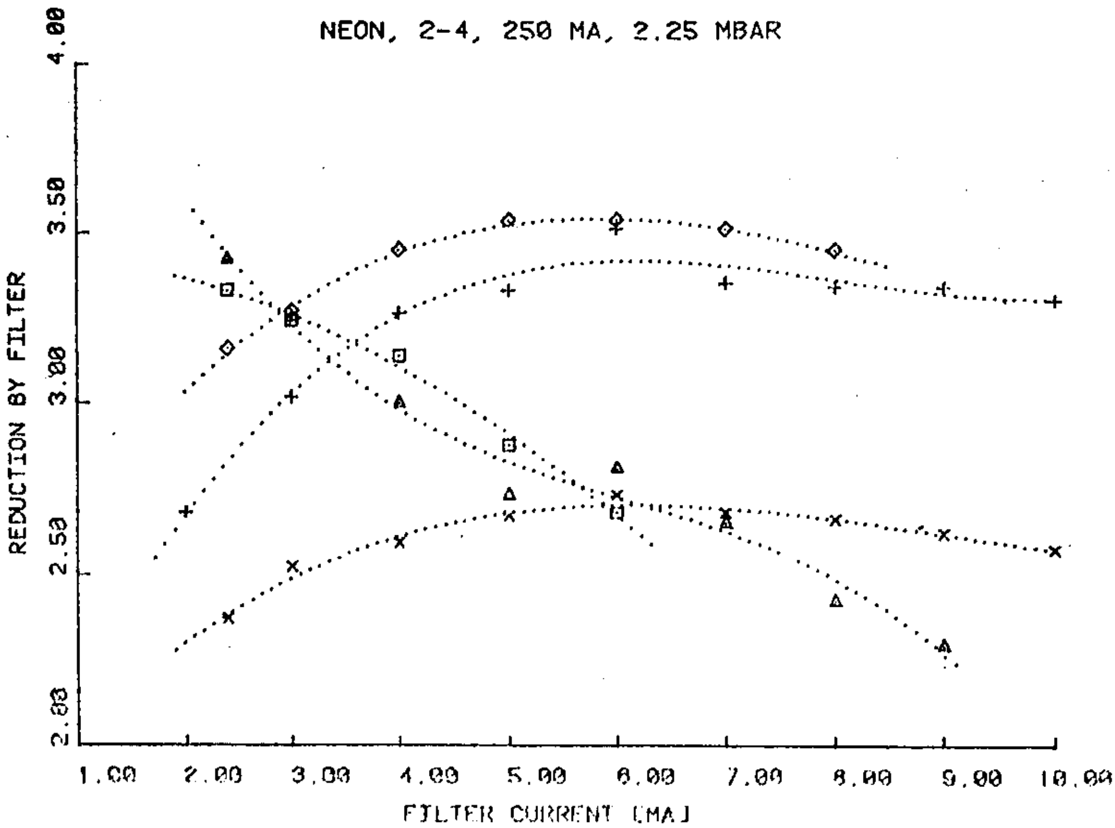

NEON, 1-5, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

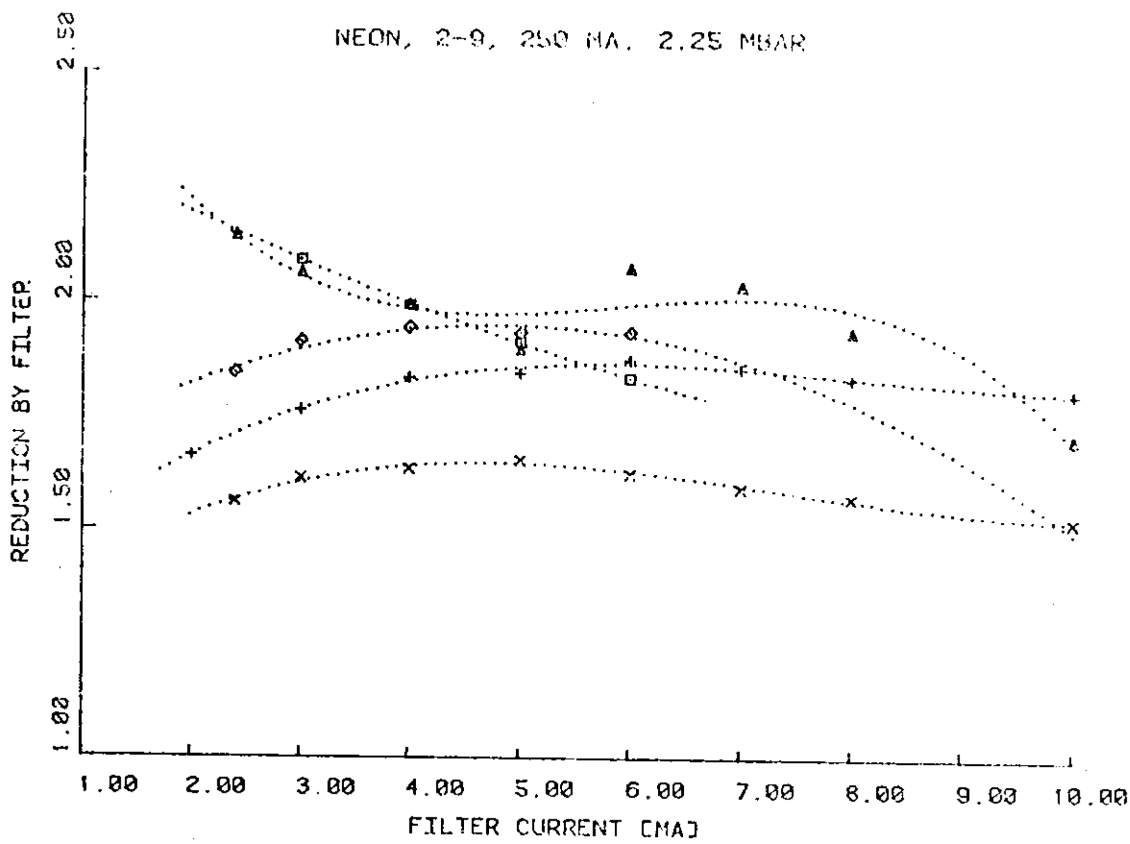

NEON, 1-7, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

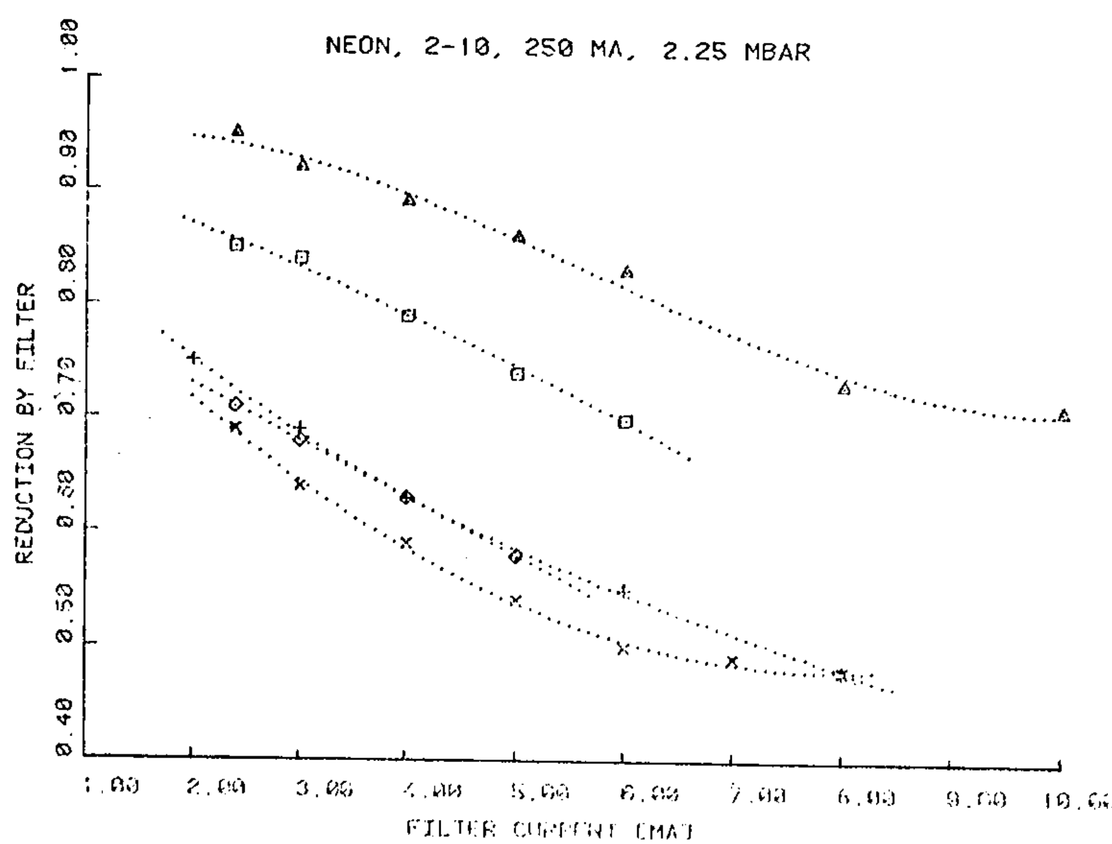

NEON, 3-4, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00
FILTER CURRENT [MA]

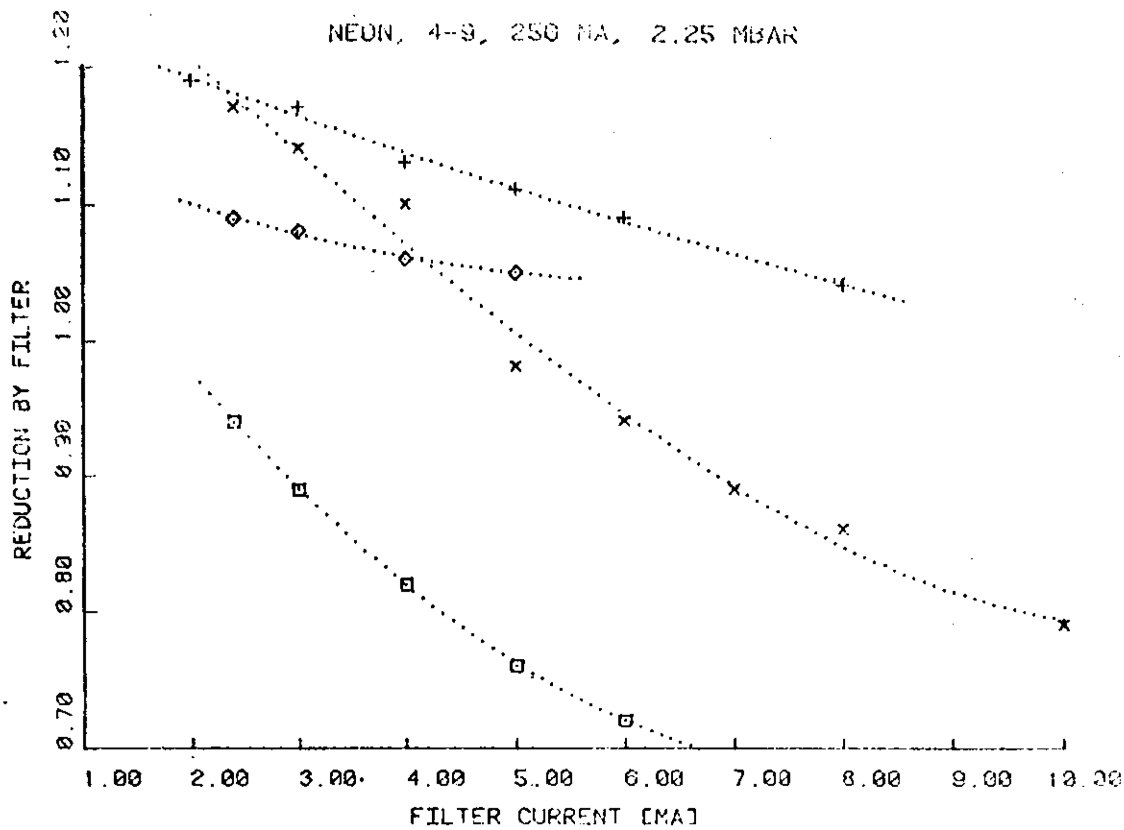

NEON, 3-6, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
3.00 4.00 5.00 6.00 7.00 8.00 9.00
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00
FILTER CURRENT [MA]

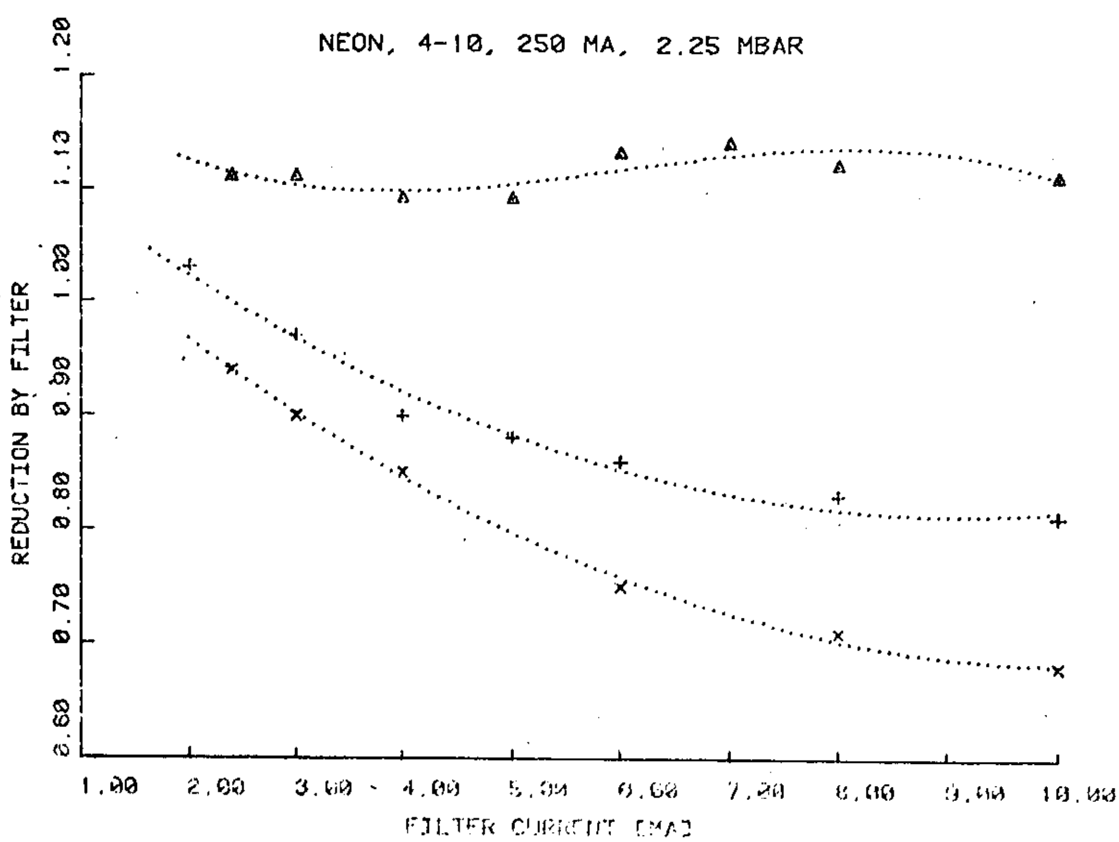

NEON, 3-9, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
3.00
4.00
5.00
6.00
7.00
8.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 2-4, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
2.00
2.50
3.00
3.50
4.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

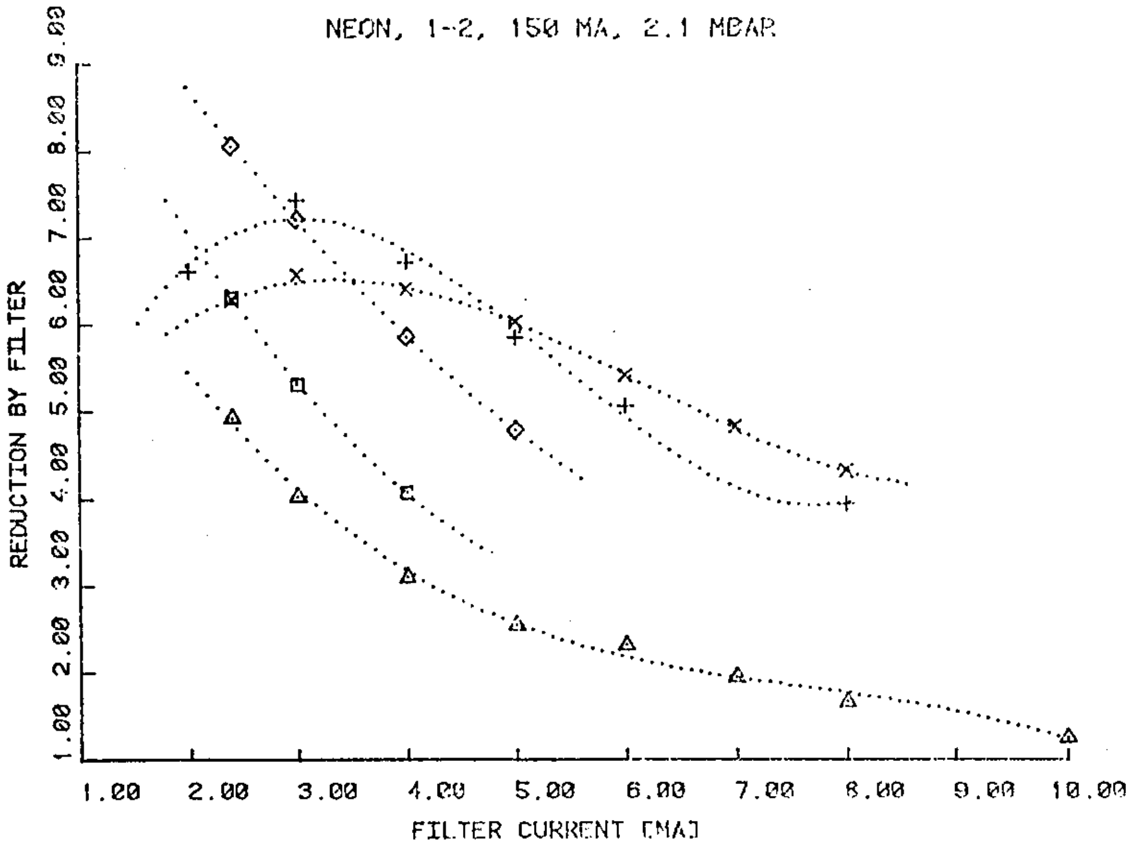

NEON, 2-9, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
2.50
2.00
1.50
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

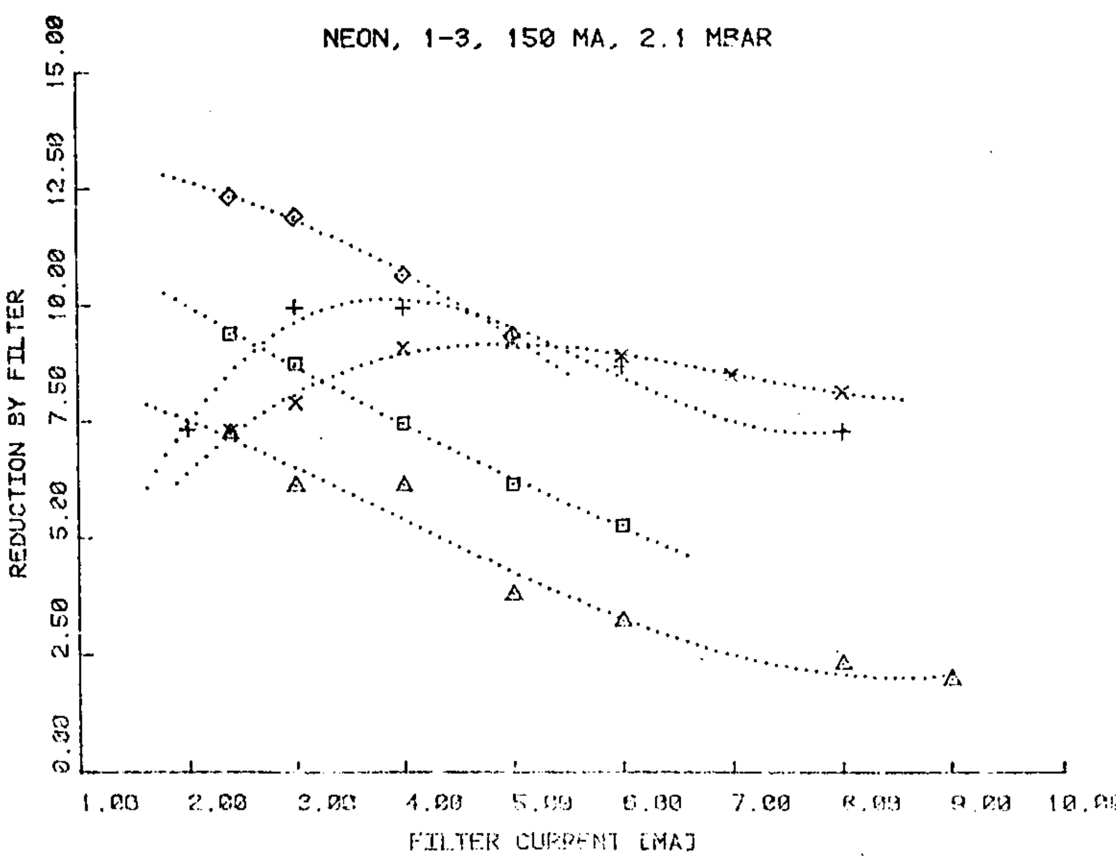

NEON, 2-10, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
1.00
0.90
0.80
0.70
0.60
0.50
0.40
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

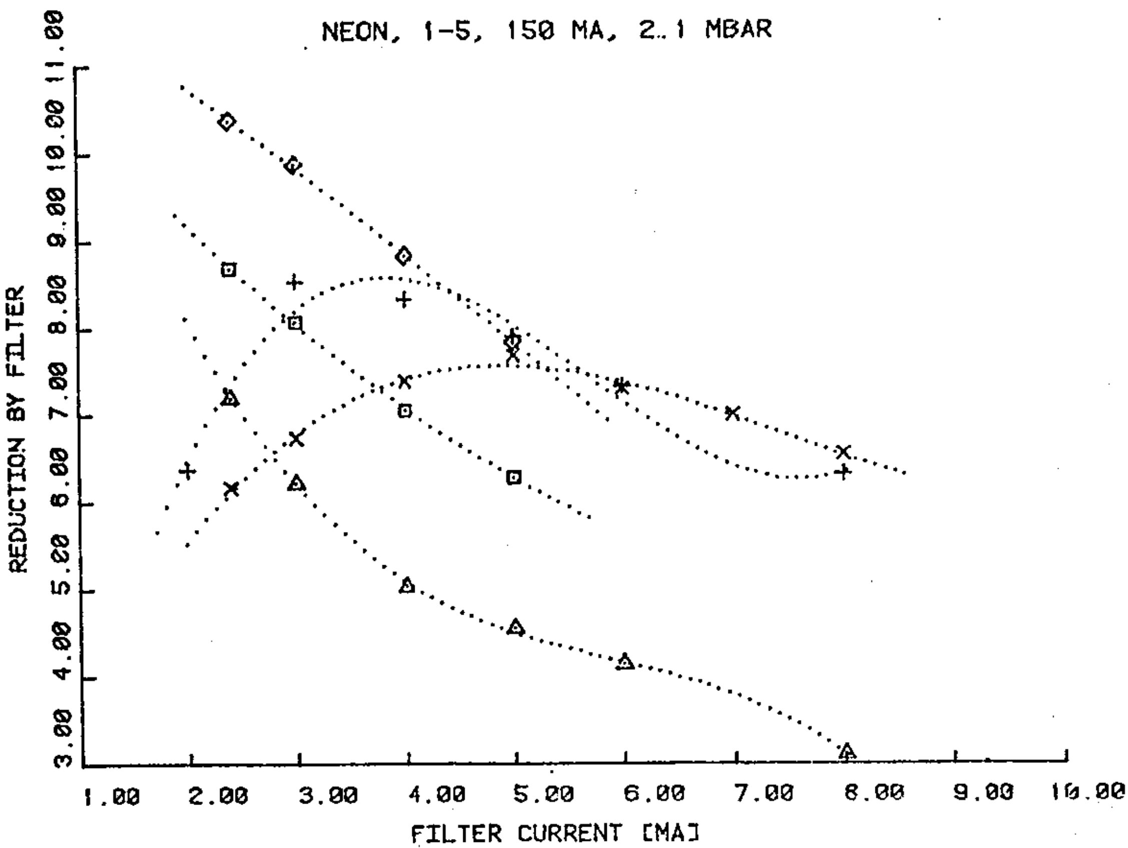

NEON, 4-9, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00

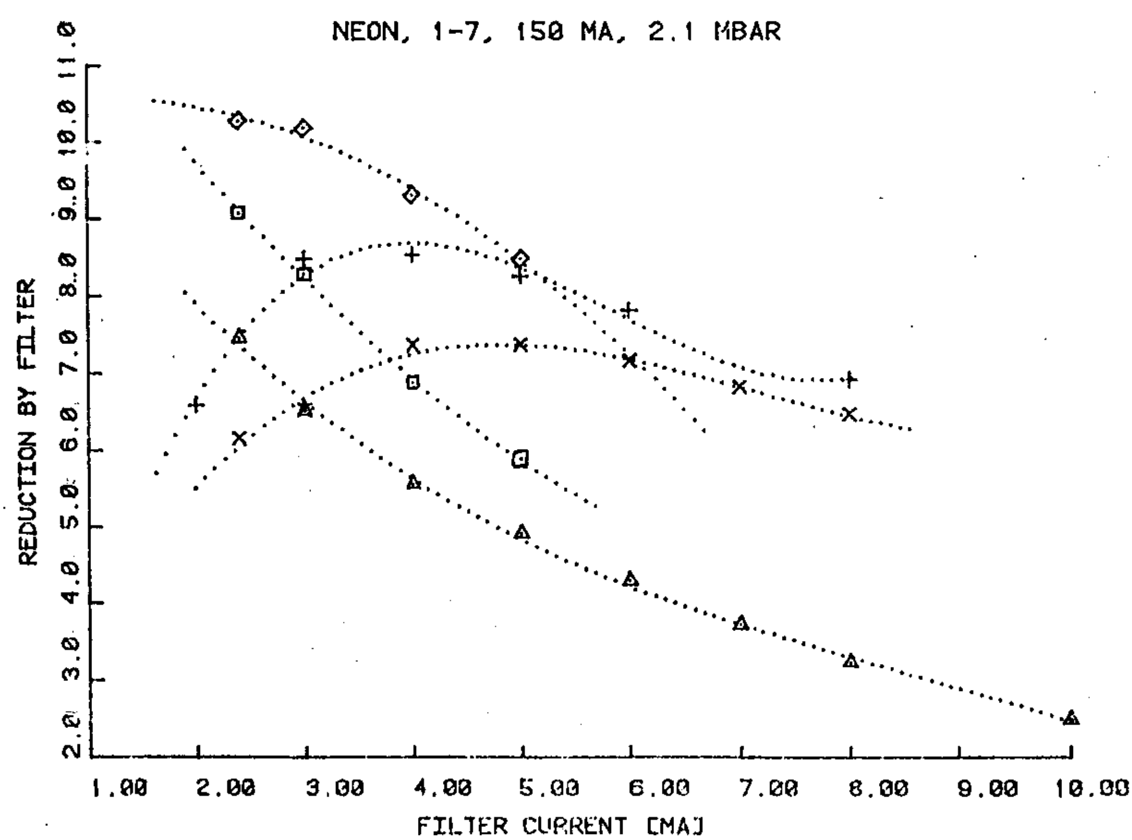

NEON, 4-10, 250 MA, 2.25 MBAR
REDUCTION BY FILTER
1.20 1.10 1.00 0.90 0.80 0.70 0.60
FILTER CURRENT [MA]
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00

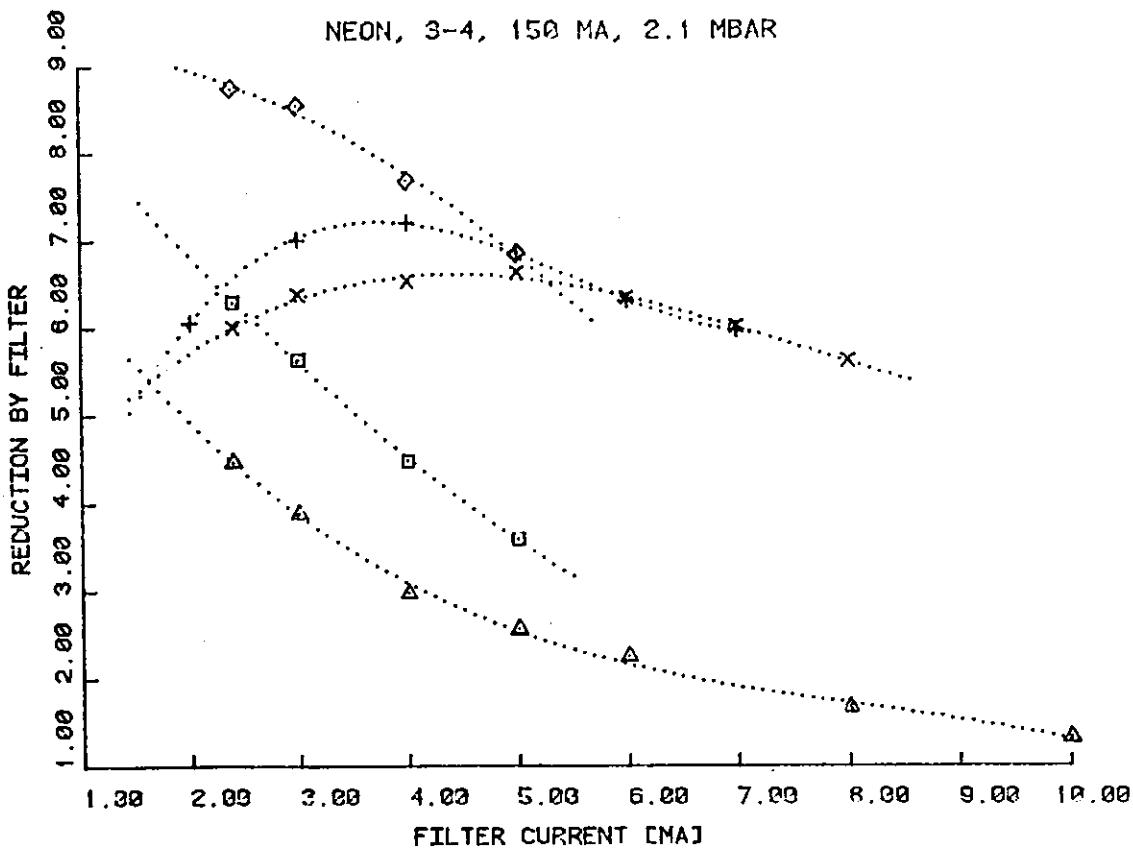
3. $I_{h.c.}$ = 150 mA

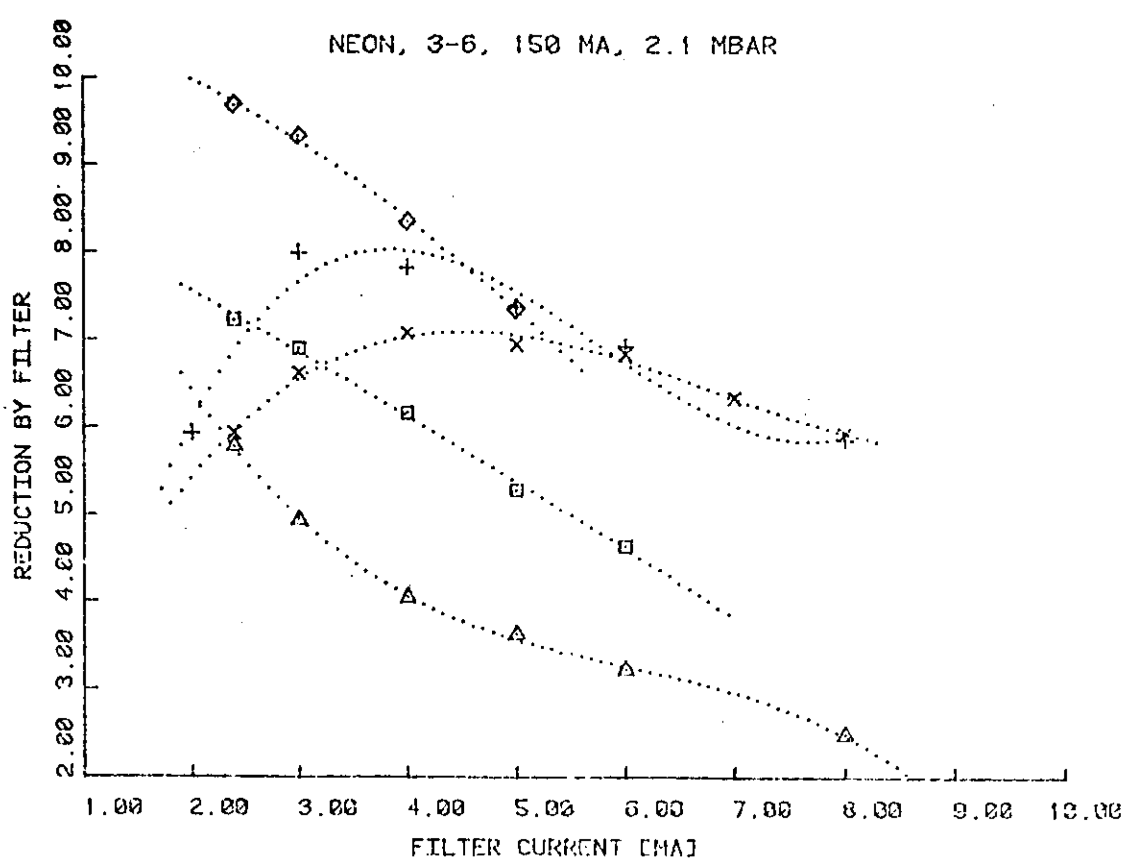

NEON, 1-2, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

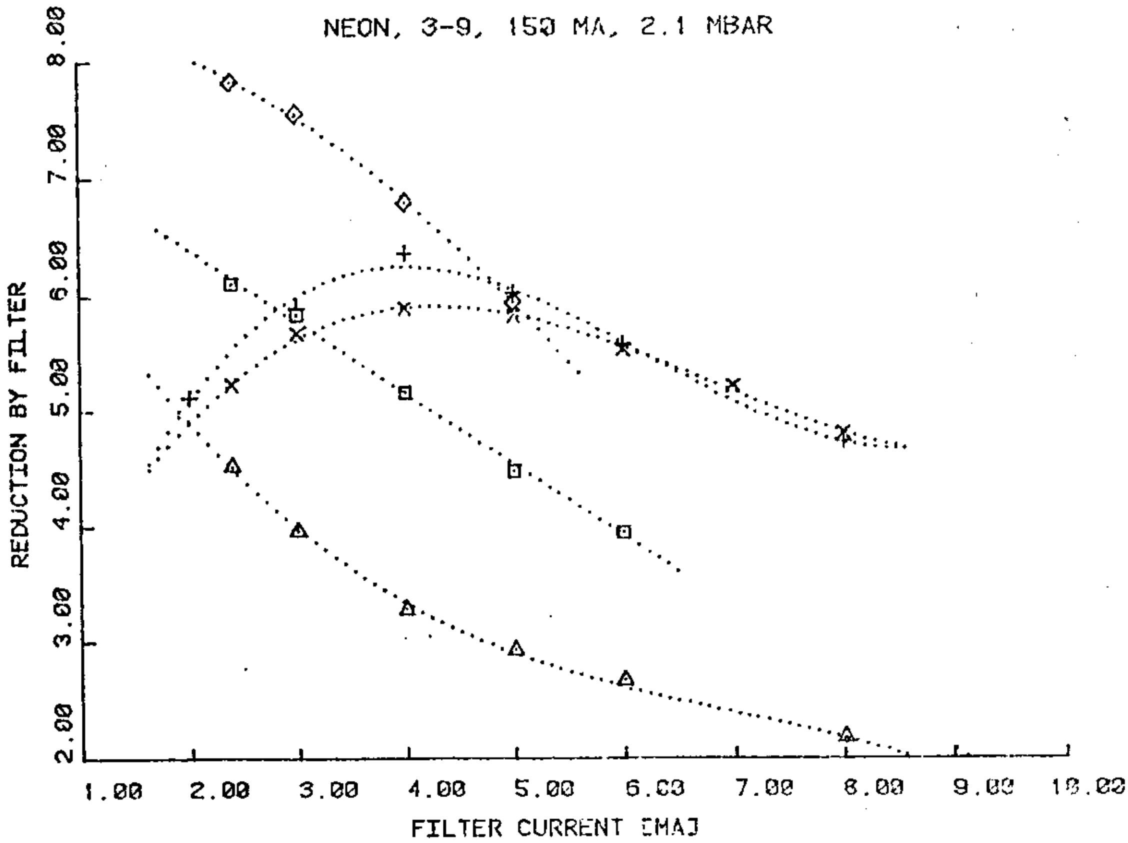

NEON, 1-3, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
0.30
2.50
5.20
7.50
10.00
12.50
15.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

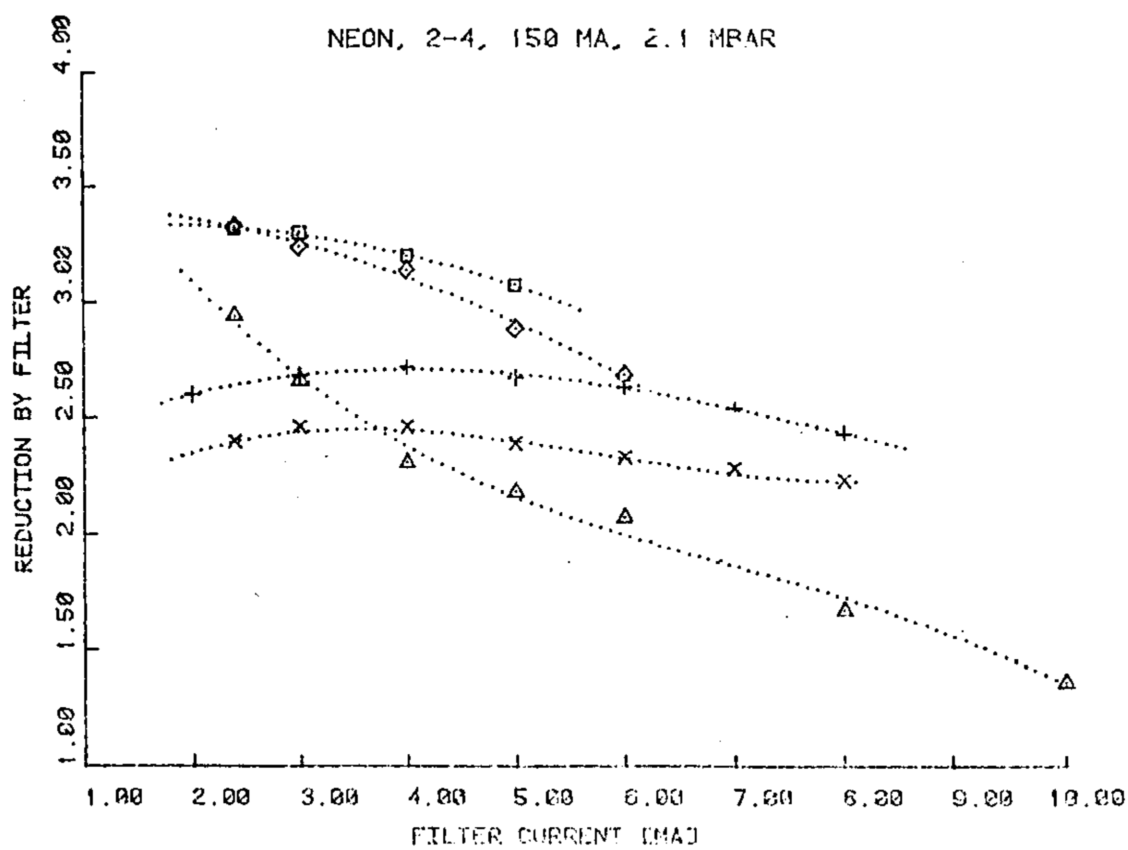

NEON, 1-5, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

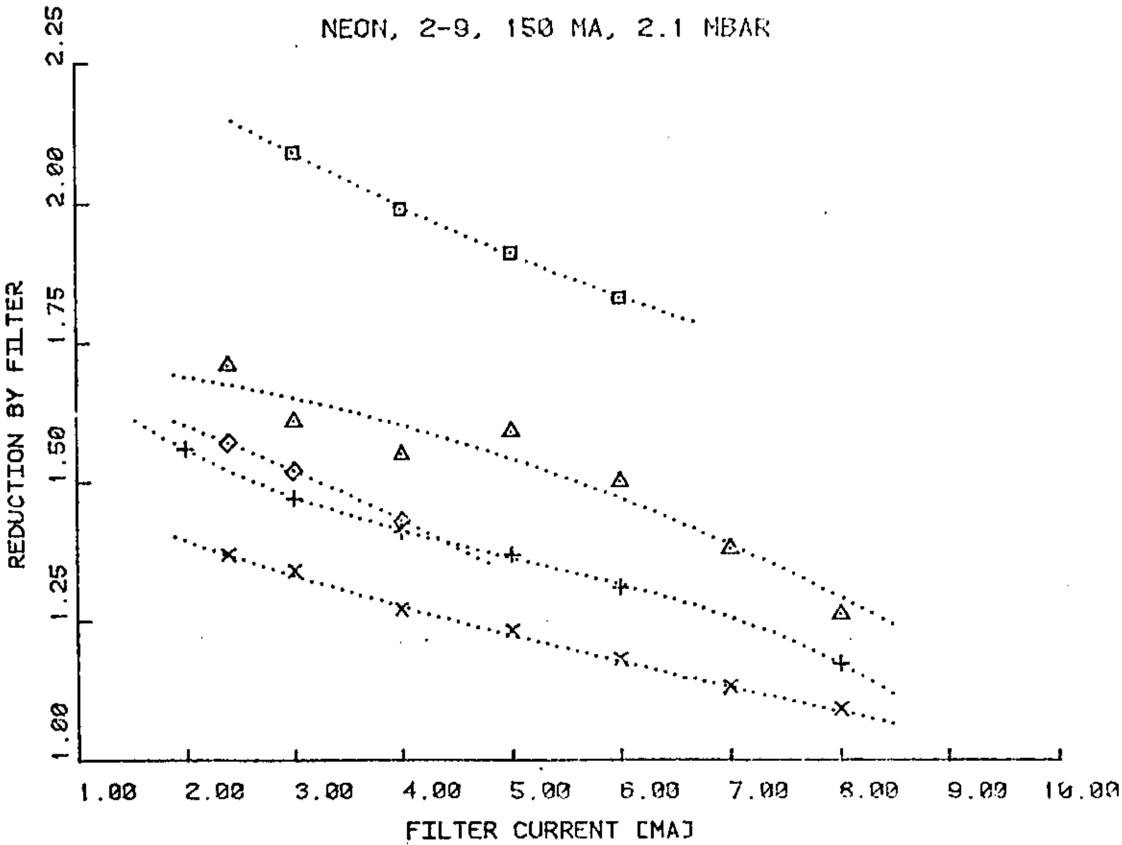

NEON, 1-7, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 3-4, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

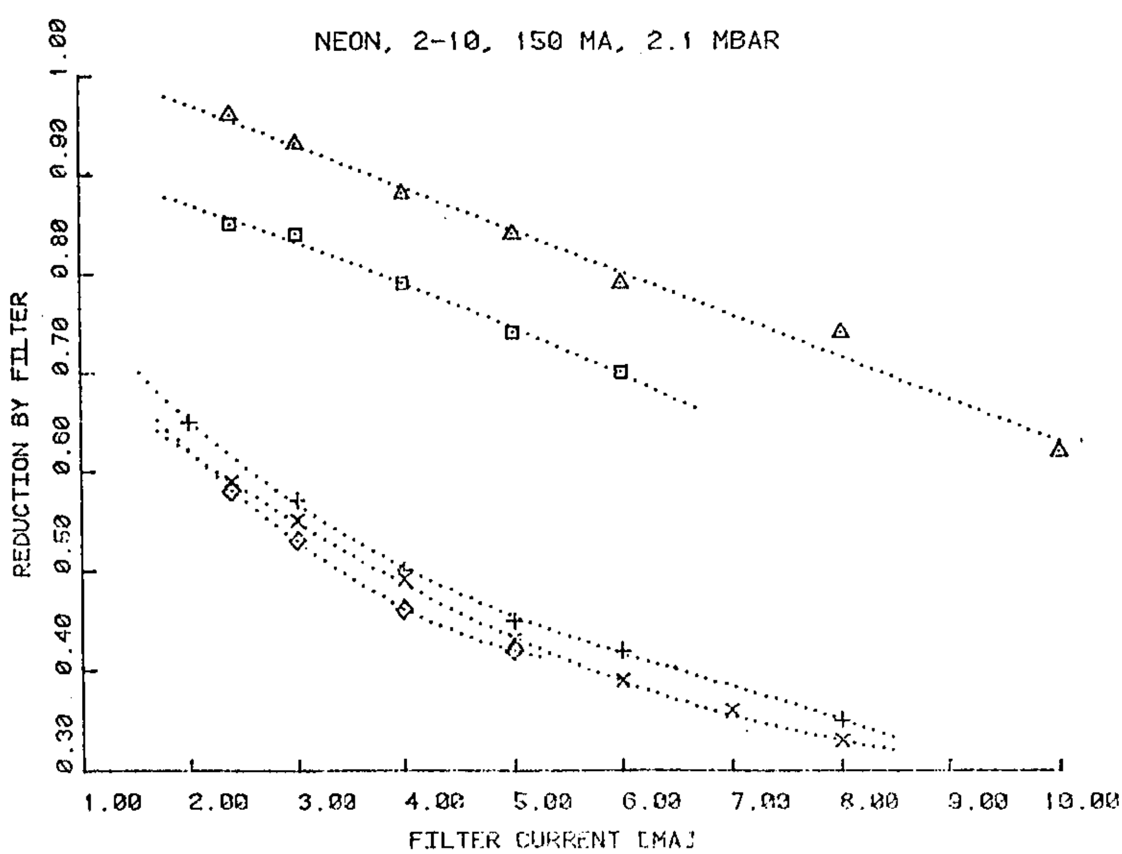

NEON, 3-6, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 3-9, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
2.00
3.00
4.00
5.00
6.00
7.00
8.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

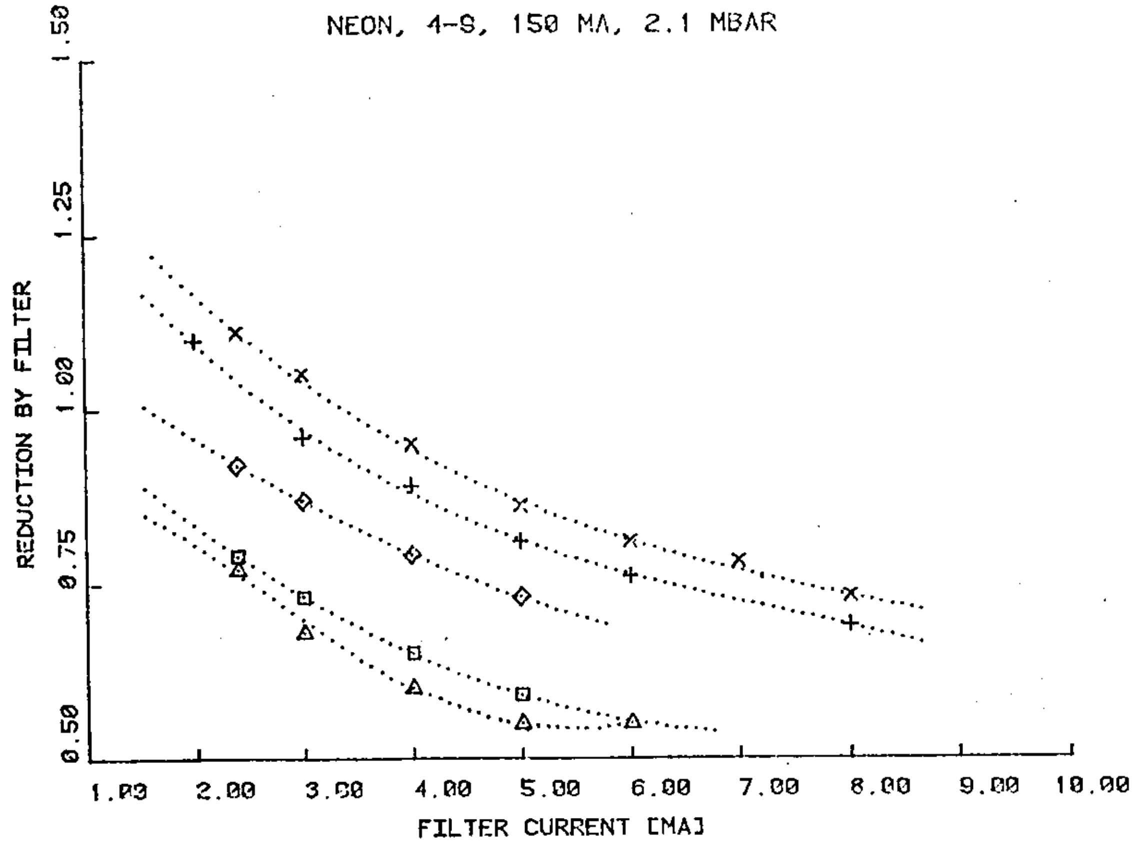

NEON, 2-4, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
1.00
1.50
2.00
2.50
3.00
3.50
4.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

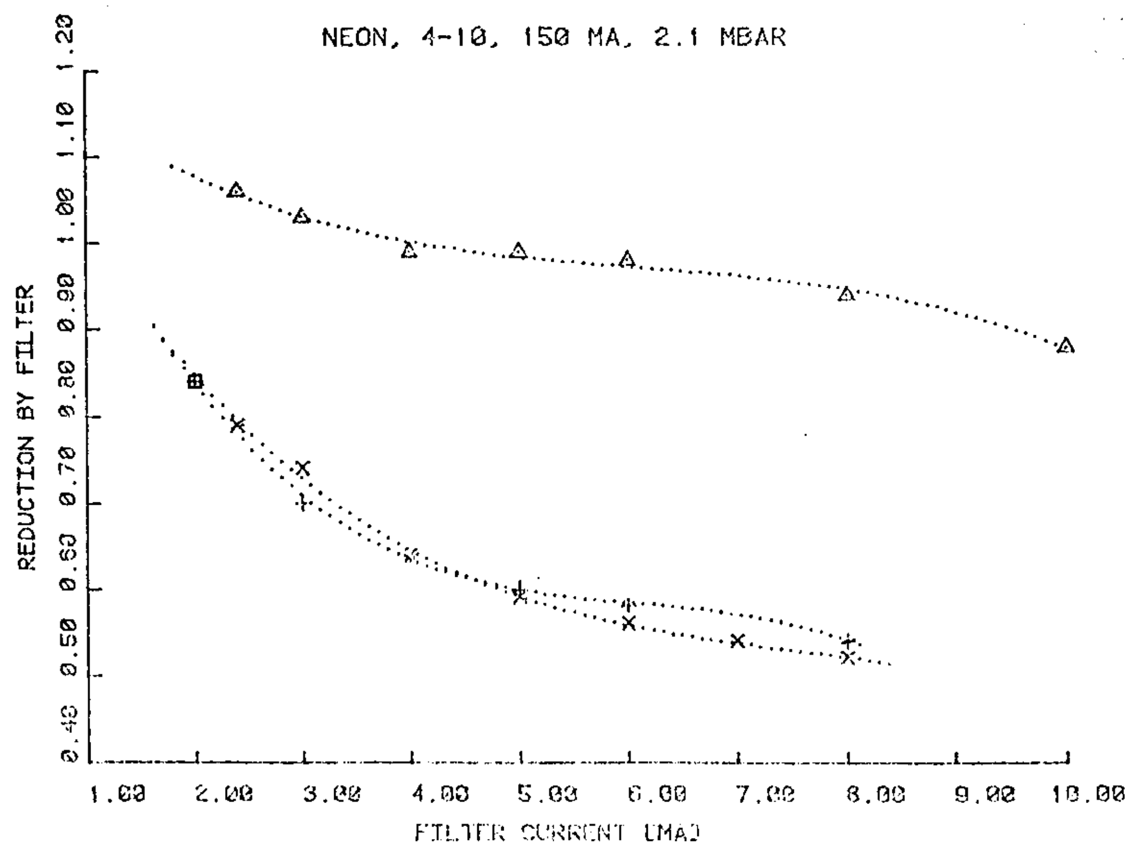


NEON, 2-9, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
1.00
1.25
1.50
1.75
2.00
2.25
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

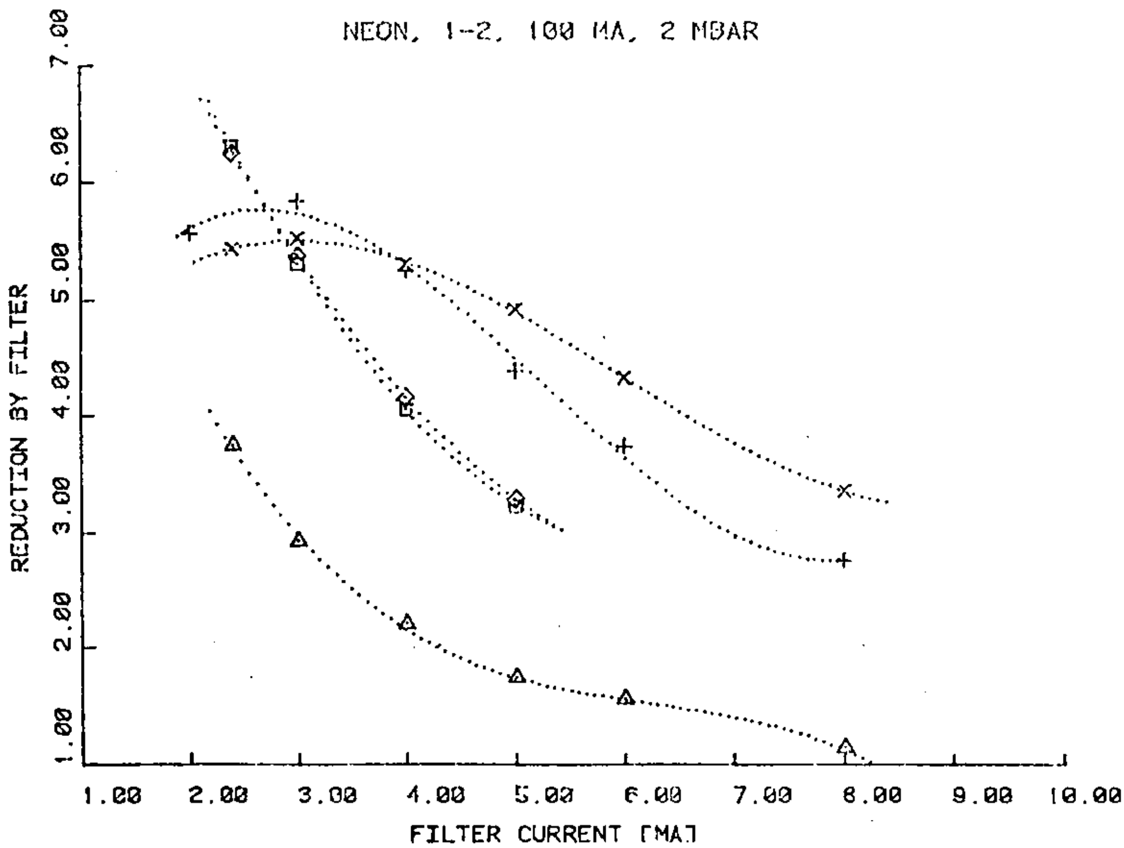


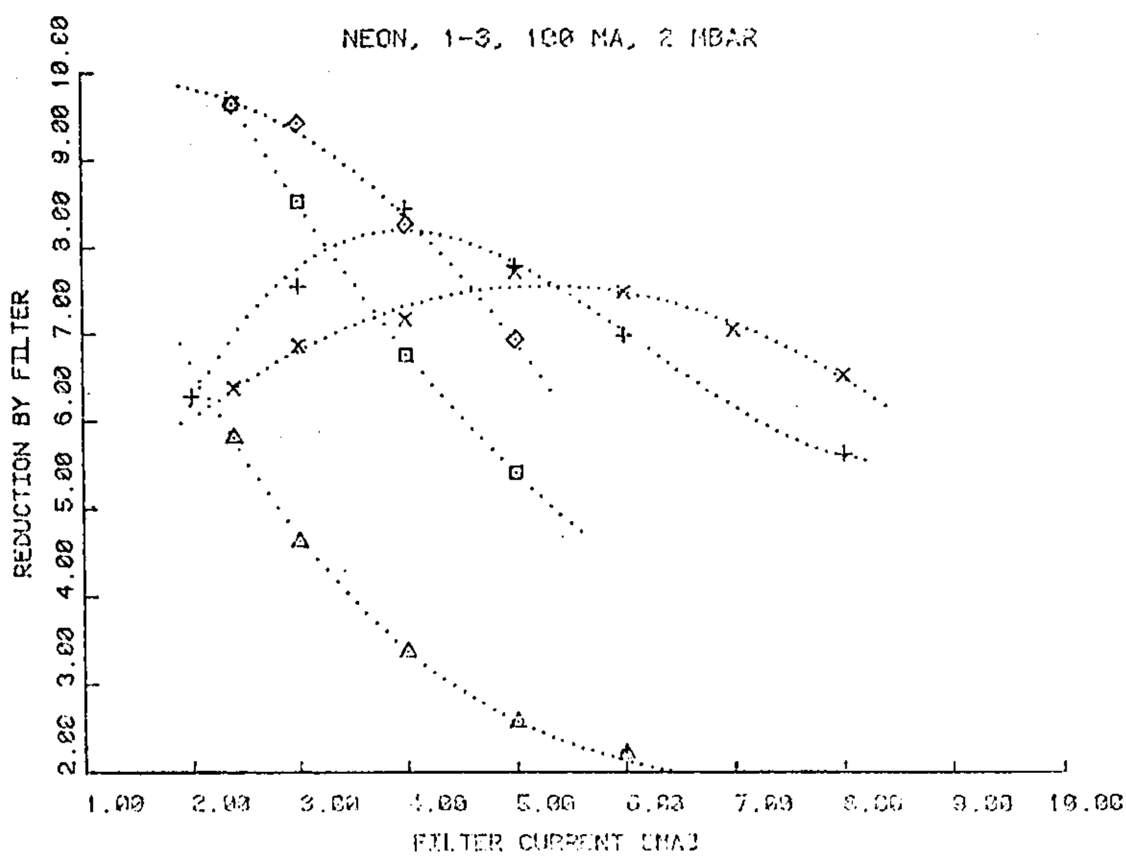
NEON, 2-10, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

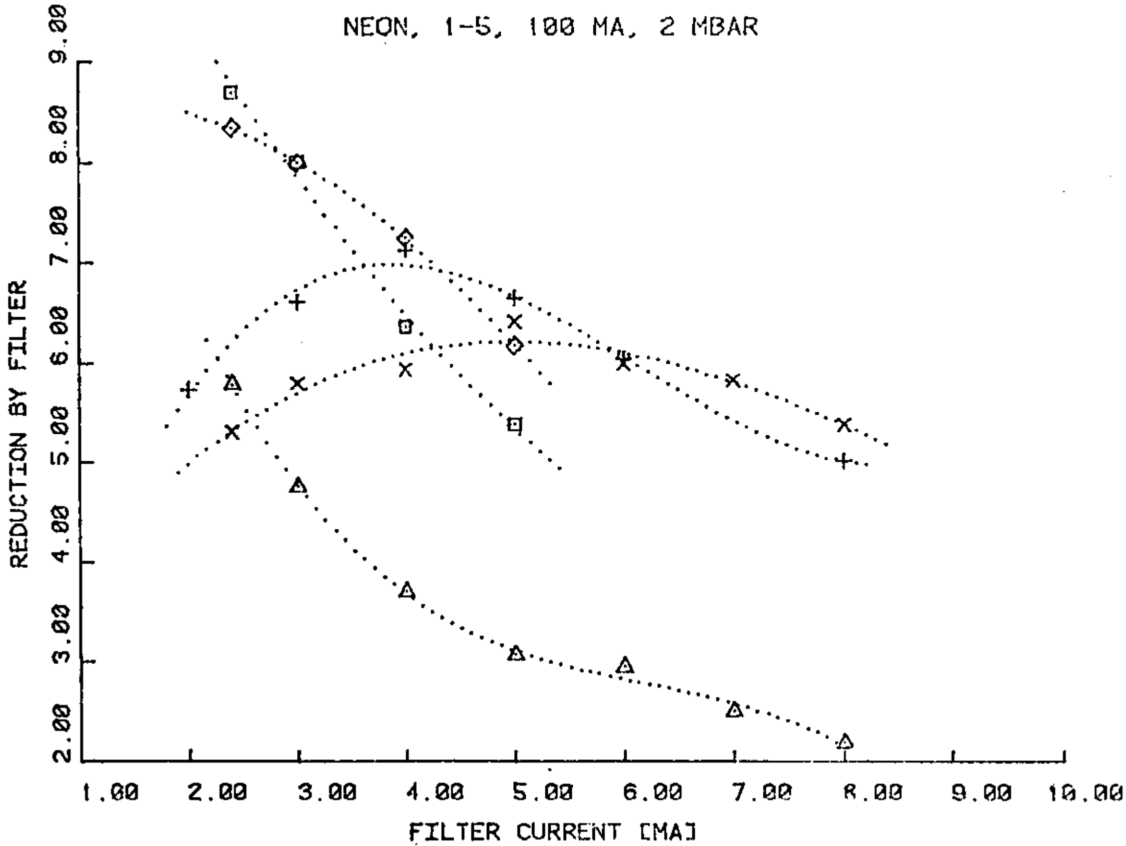

NEON, 4-9, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
0.50
0.75
1.00
1.25
1.50
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 4-10, 150 MA, 2.1 MBAR
REDUCTION BY FILTER
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

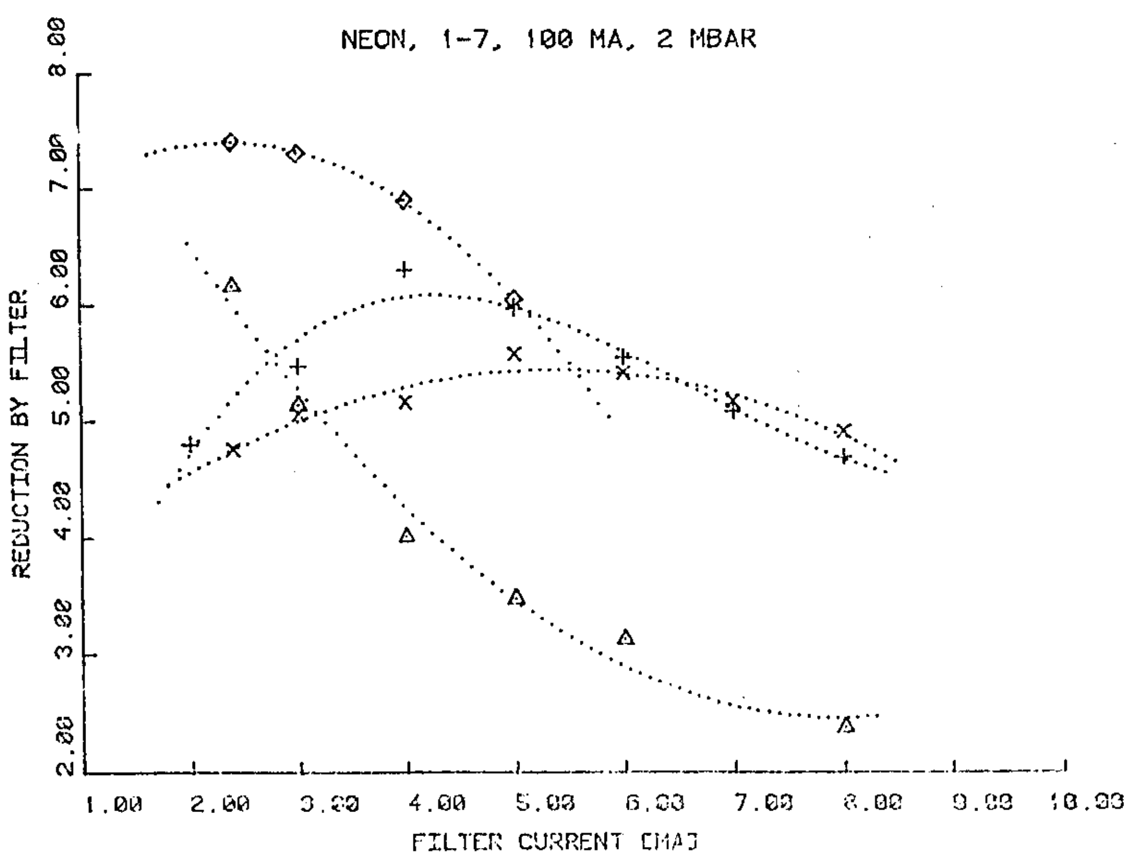
4. $I_{h.c.}$ = 100 mA


NEON, 1-2, 100 MA, 2 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
7.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

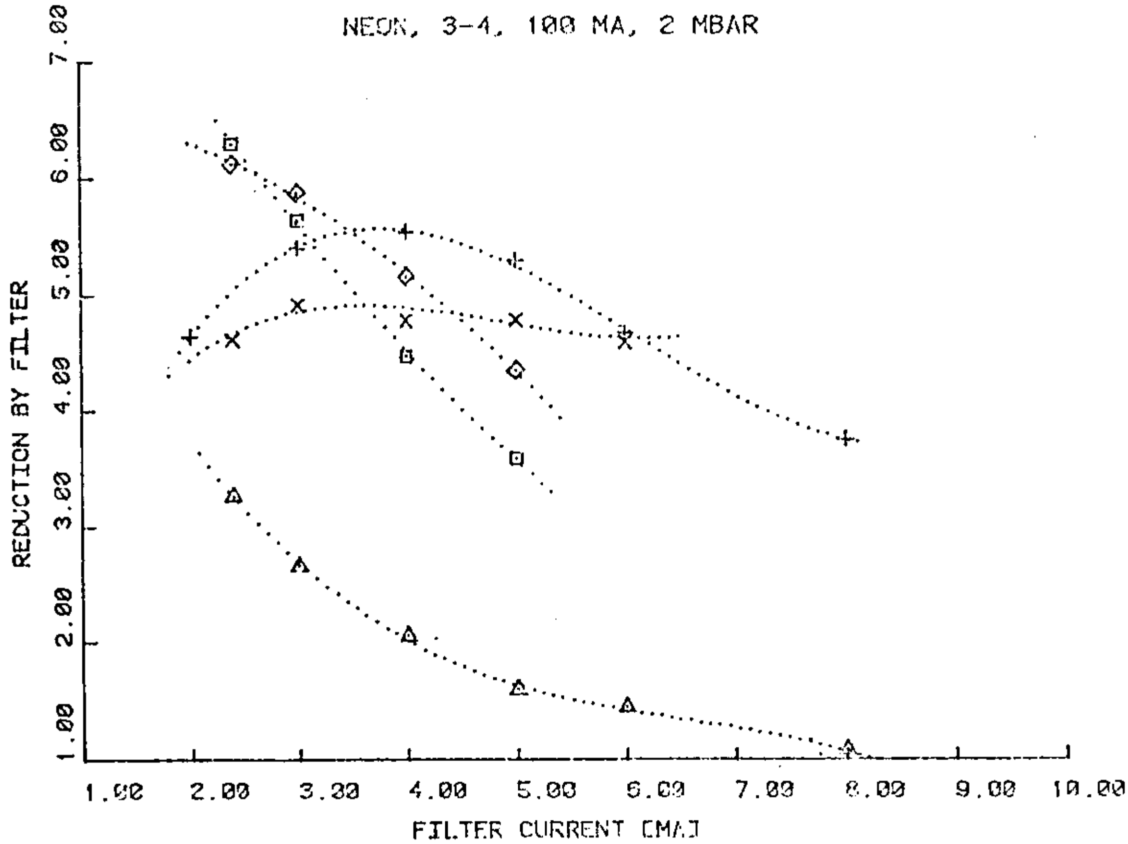

NEON, 1-3, 100 MA, 2 MBAR
REDUCTION BY FILTER
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

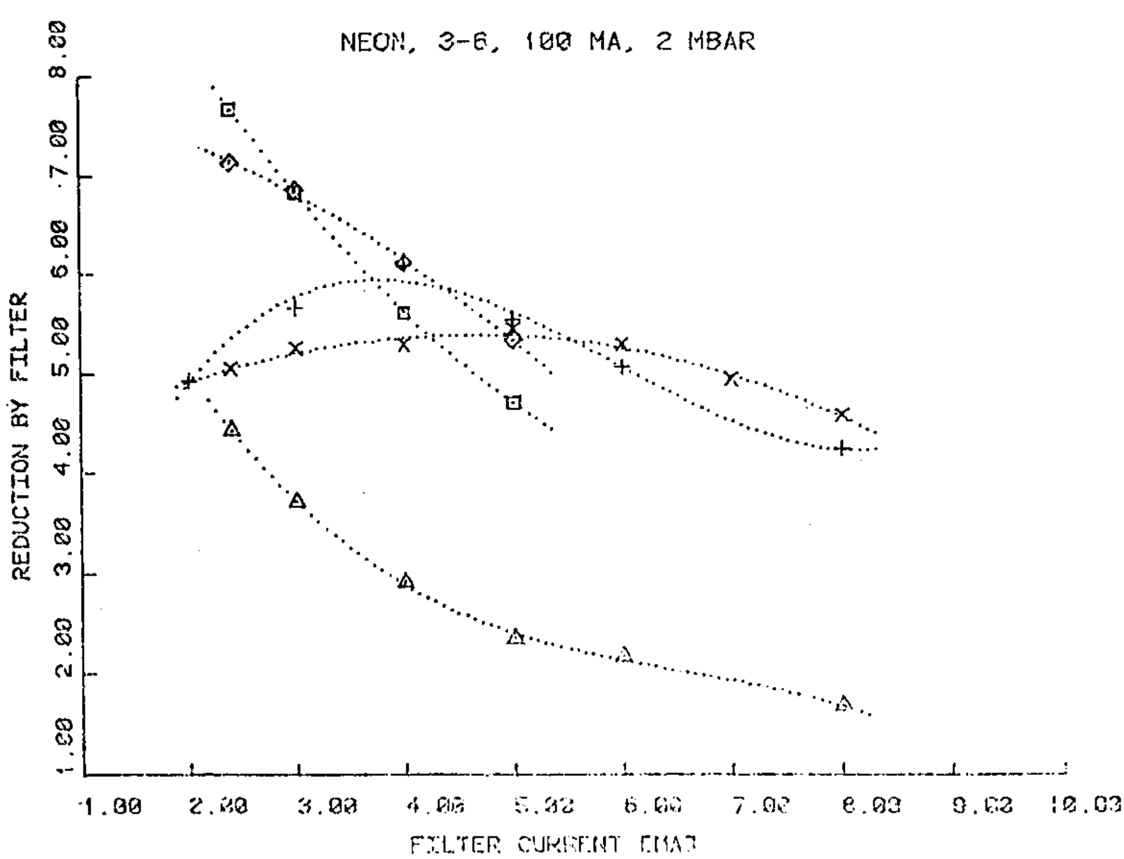


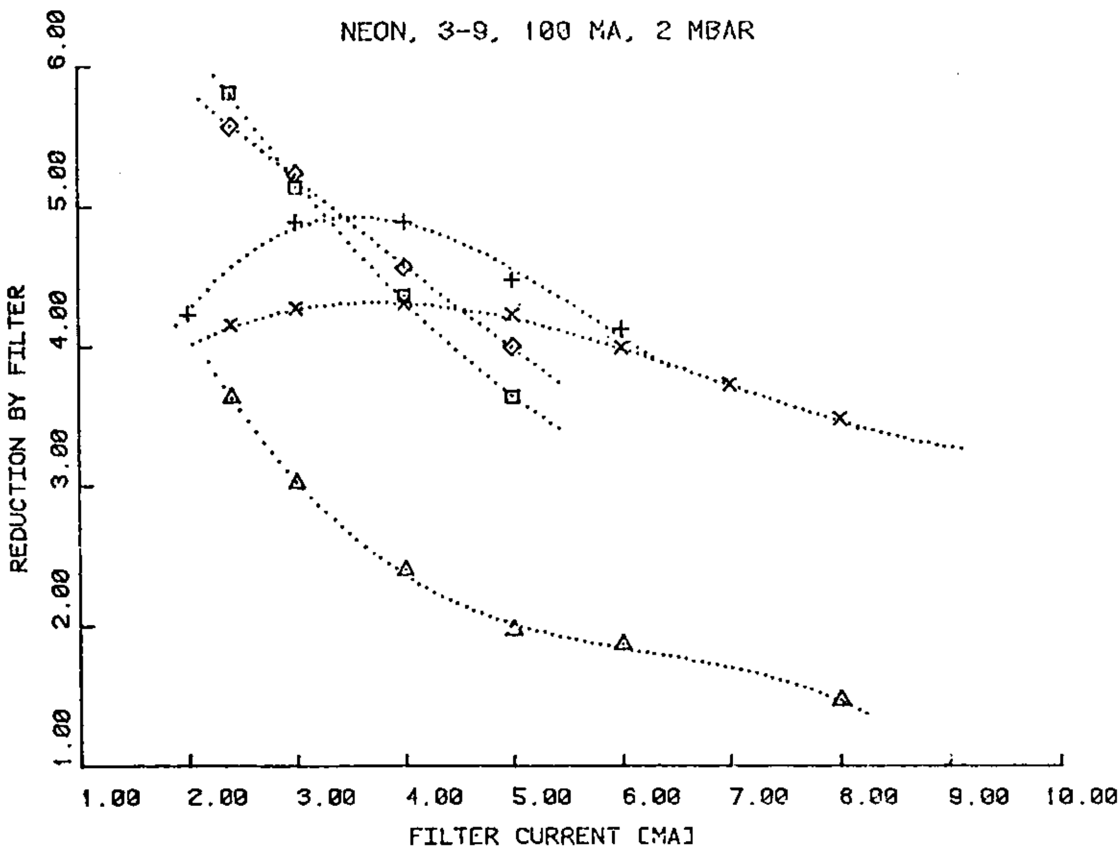
NEON, 1-5, 100 MA, 2 MBAR
REDUCTION BY FILTER
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

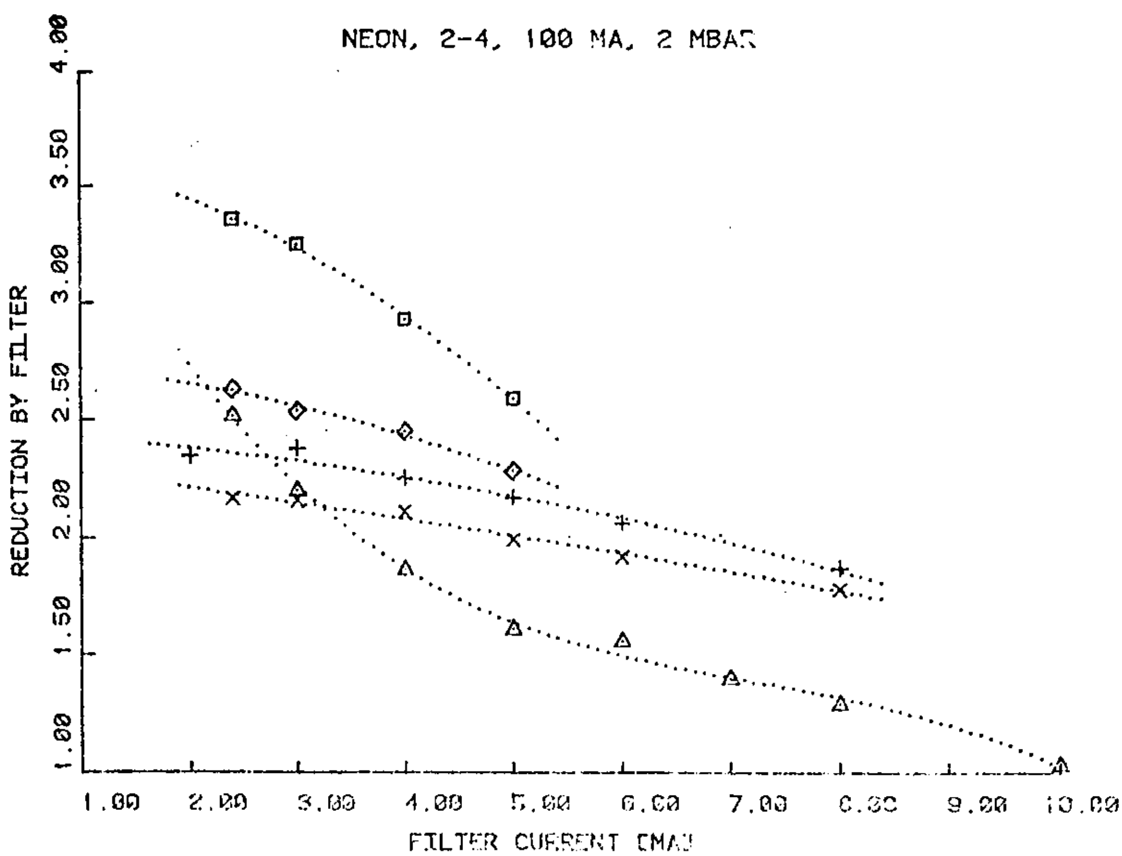


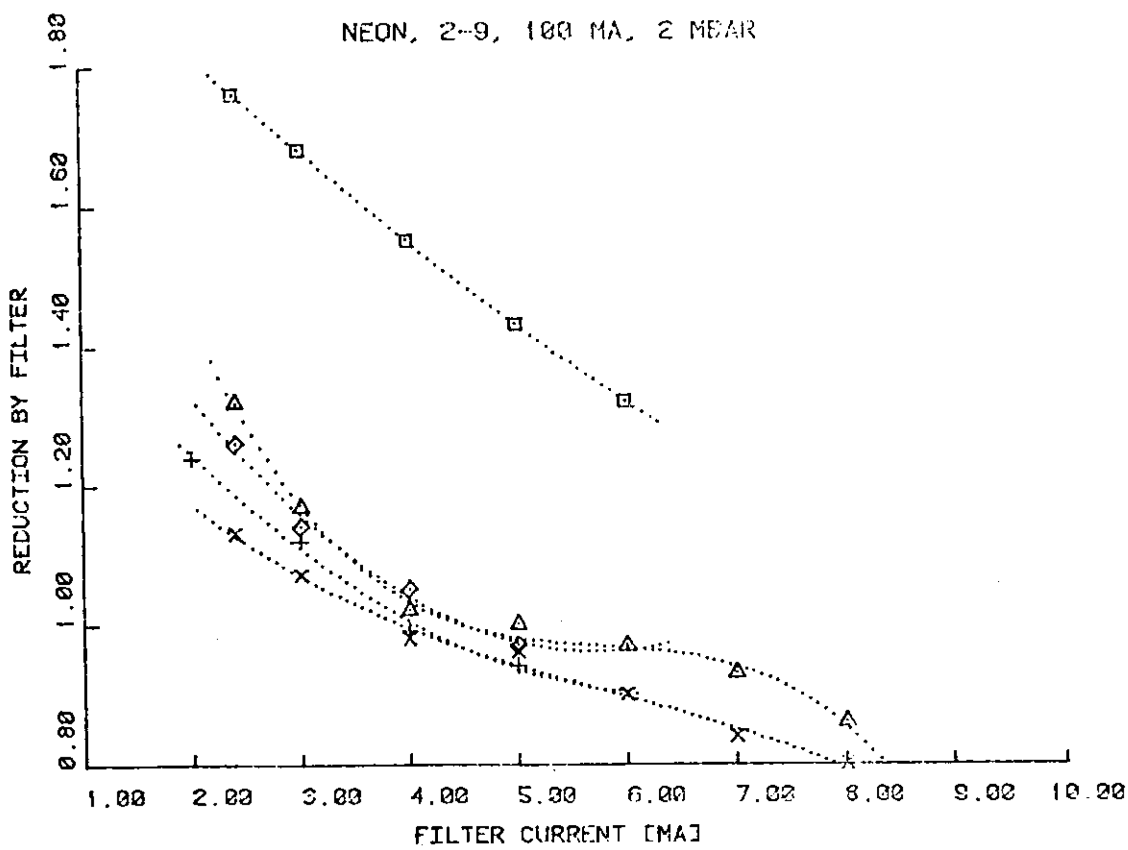
NEON, 1-7, 100 MA, 2 MBAR
REDUCTION BY FILTER
2.00
3.00
4.00
5.00
6.00
7.00
8.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

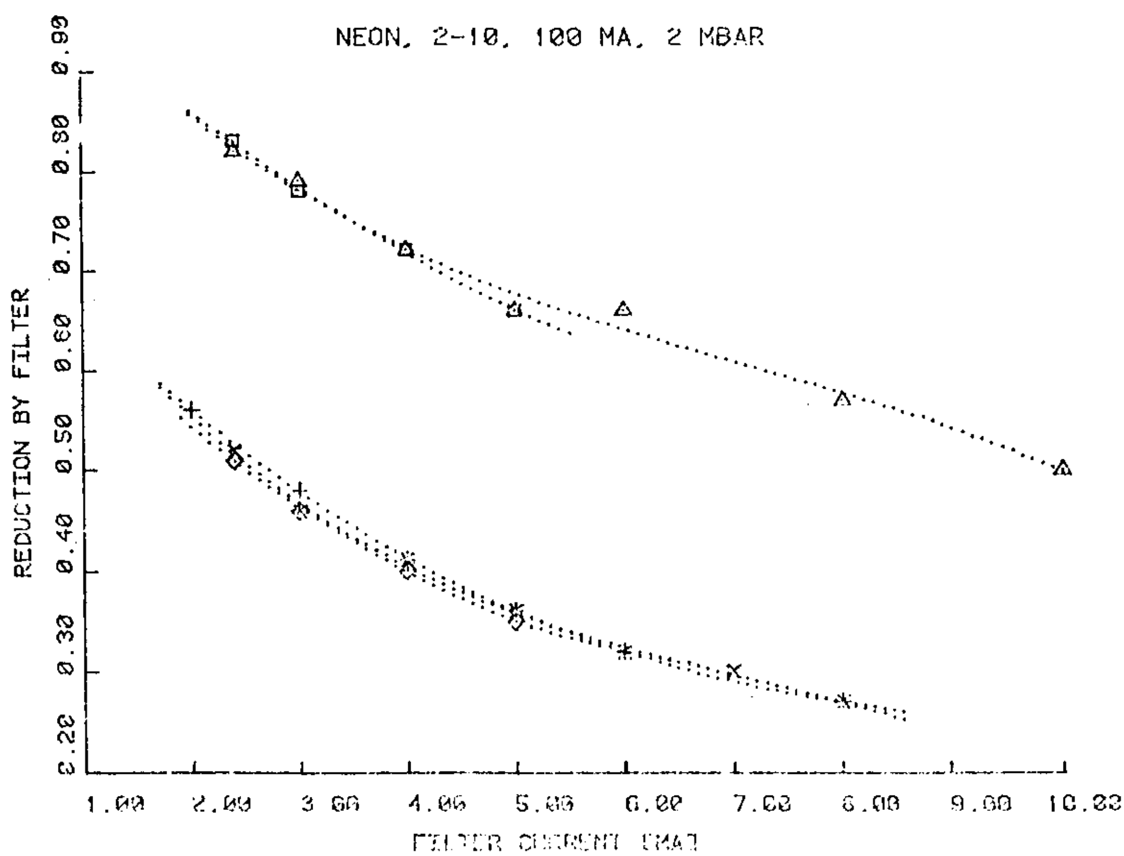

NEON, 3-4, 100 MA, 2 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

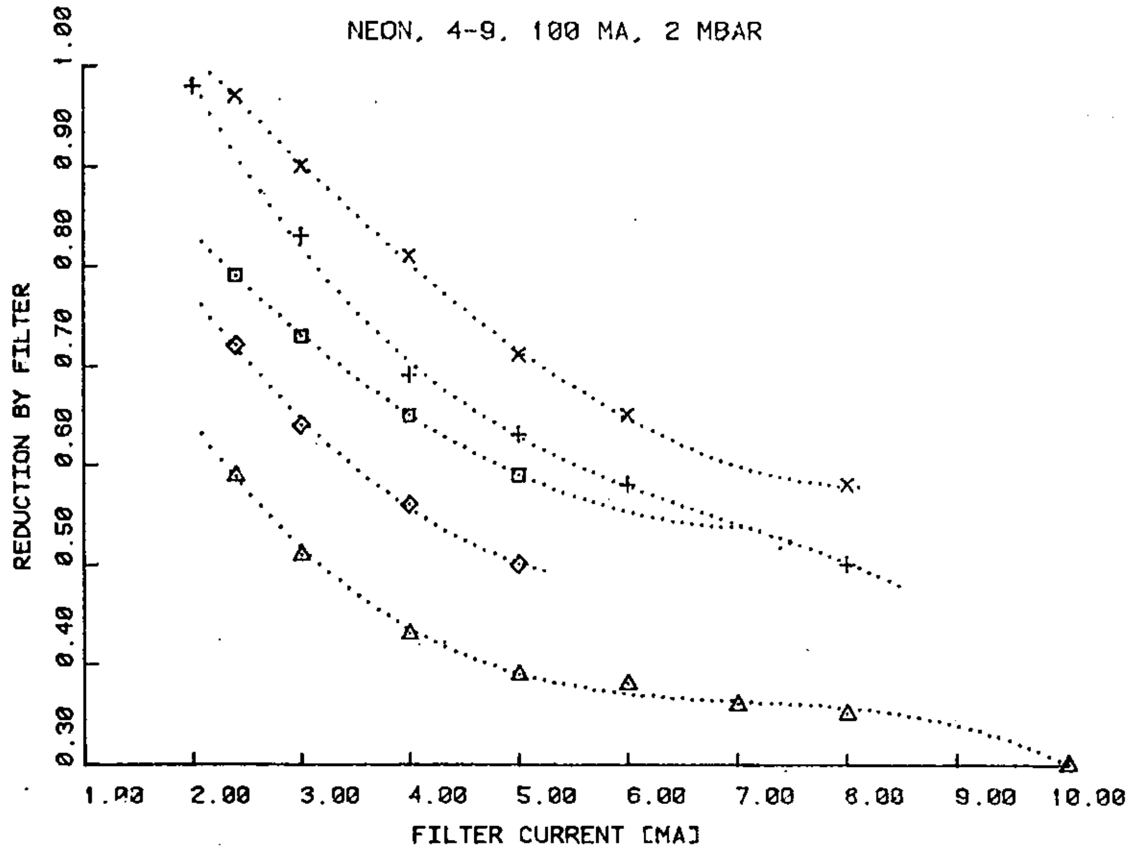

NEON, 3-6, 100 MA, 2 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

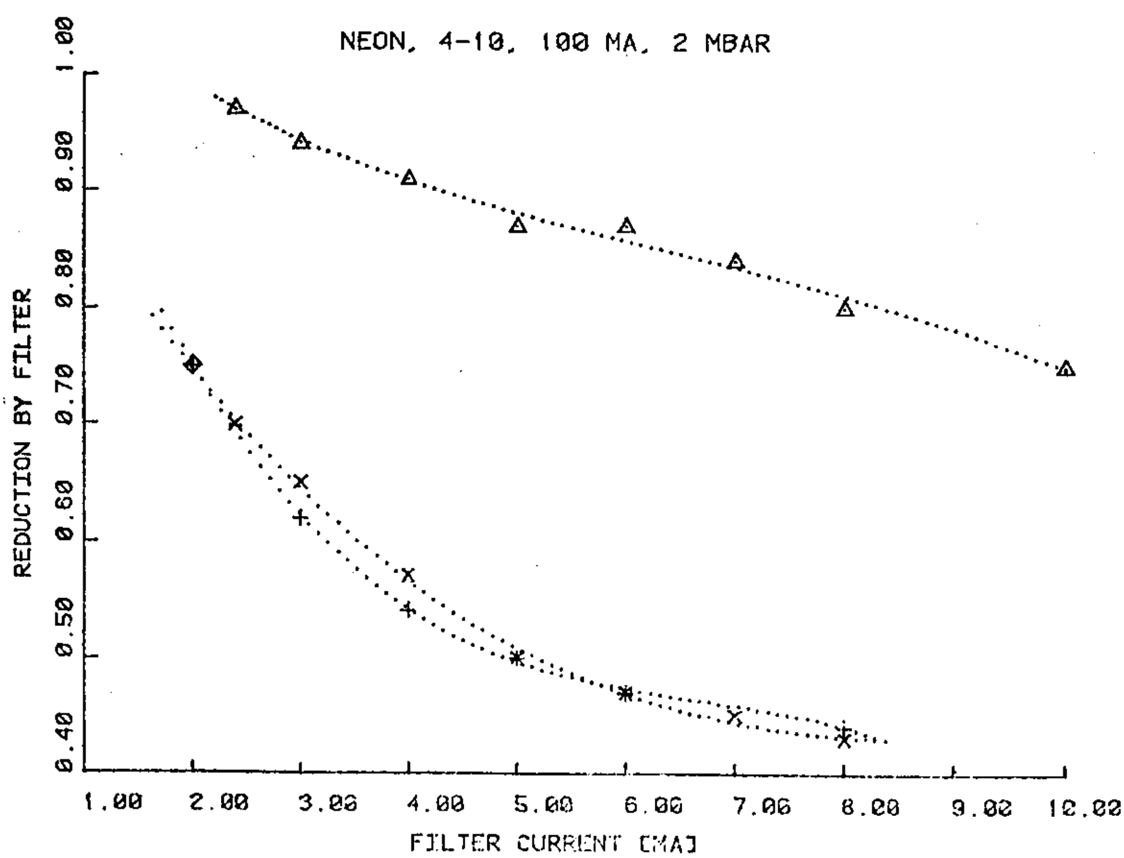

NEON, 3-9, 100 MA, 2 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 2-4, 100 MA, 2 MBAR
REDUCTION BY FILTER
1.00
1.50
2.00
2.50
3.00
3.50
4.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 2-9, 100 MA, 2 MBAR
REDUCTION BY FILTER
0.80
1.00
1.20
1.40
1.60
1.80
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 2-10, 100 MA, 2 MBAR
REDUCTION BY FILTER
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00


NEON, 4-9, 100 MA, 2 MBAR
REDUCTION BY FILTER
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]


NEON, 4-10, 100 MA, 2 MBAR
REDUCTION BY FILTER
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
FILTER CURRENT [MA]

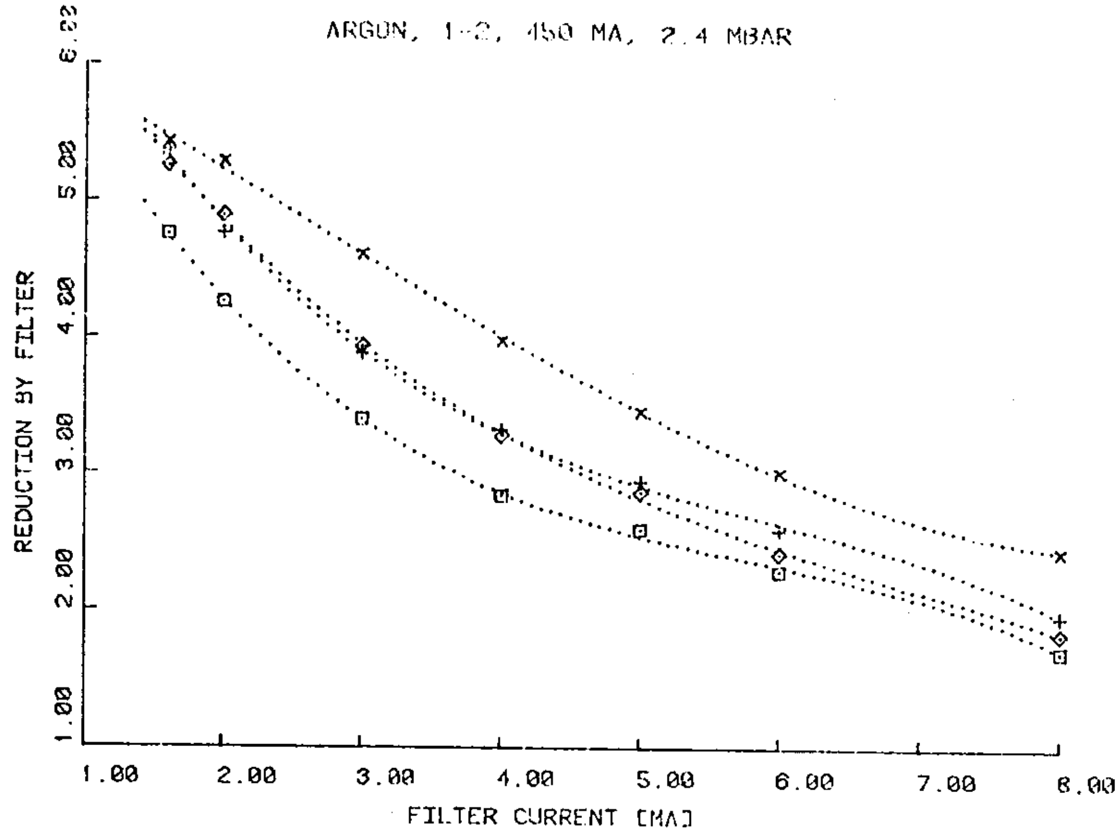
Appendix III: Argon Reduction Factor Measurement Results

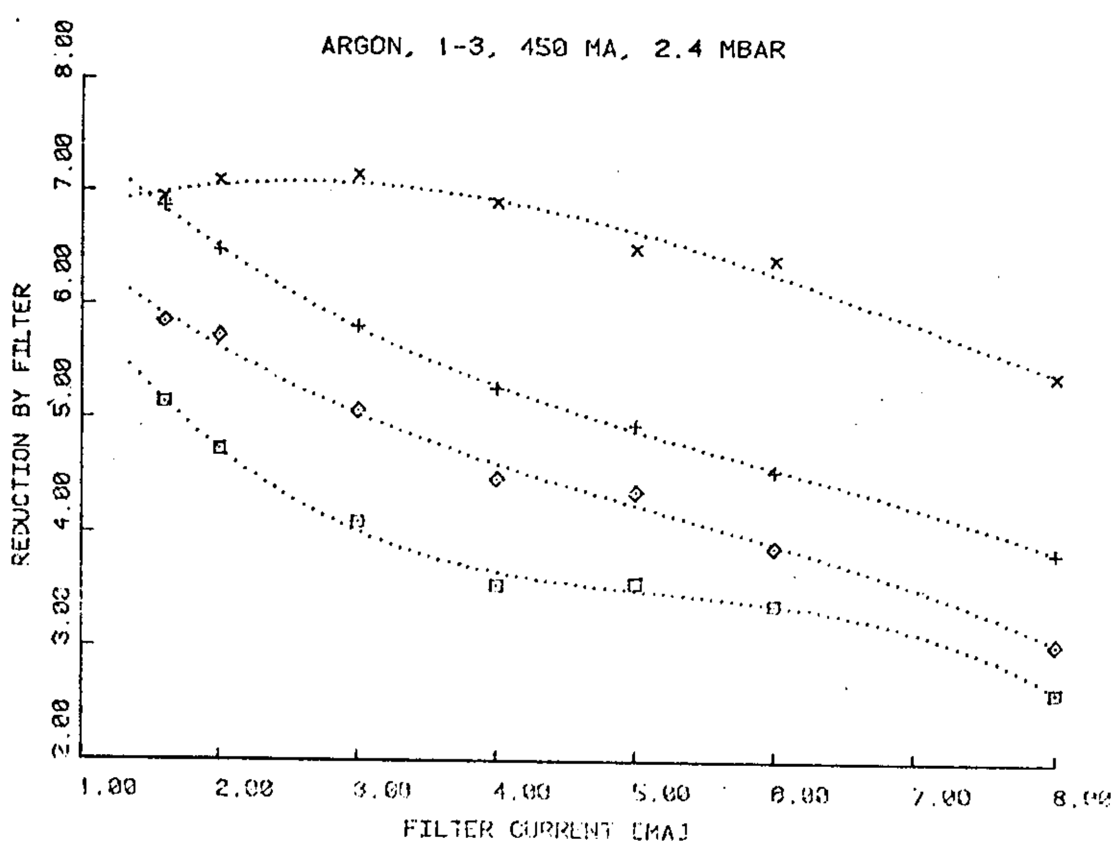
The plots in this appendix show the complete set of reduction factor measurement results for argon. The different symbols for the measured data points distinguish the filter discharge pressures according to the following key:

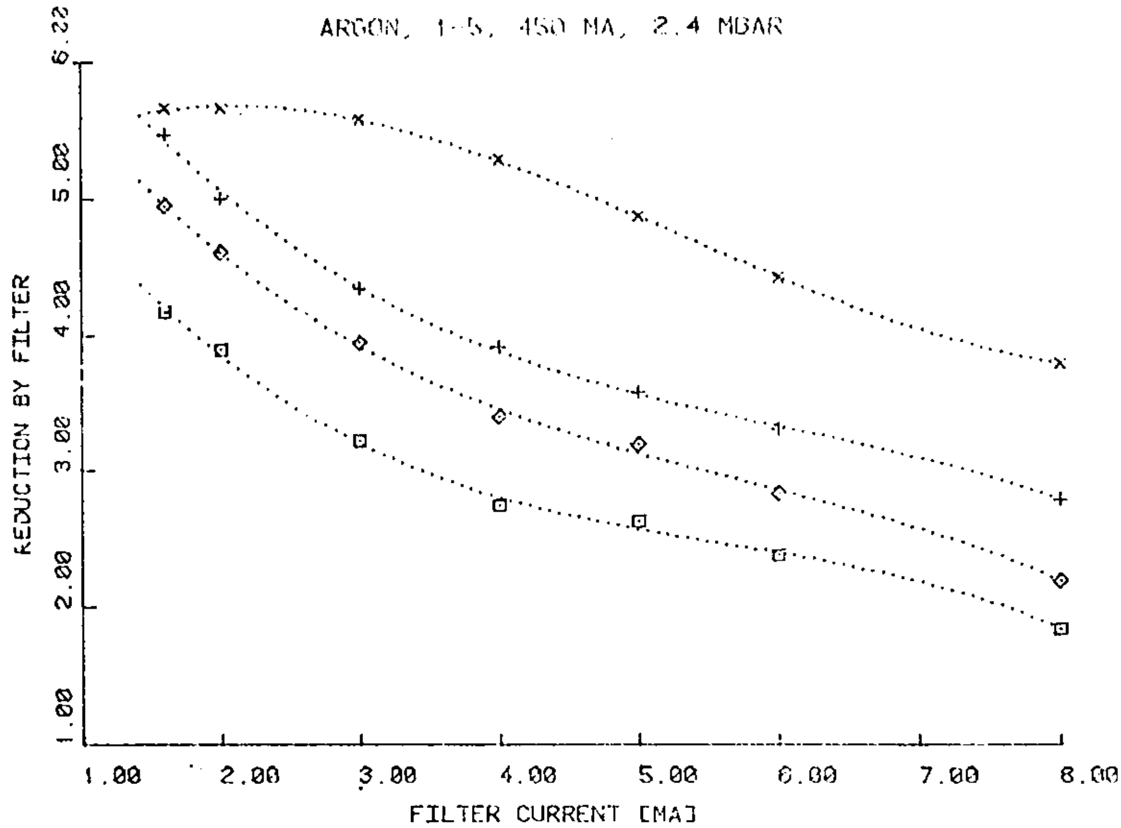
X ≙ 0.7 mbar
+ ≙ 1.7 mbar
◇ ≙ 3.0 mbar
□ ≙ 3.7 mbar

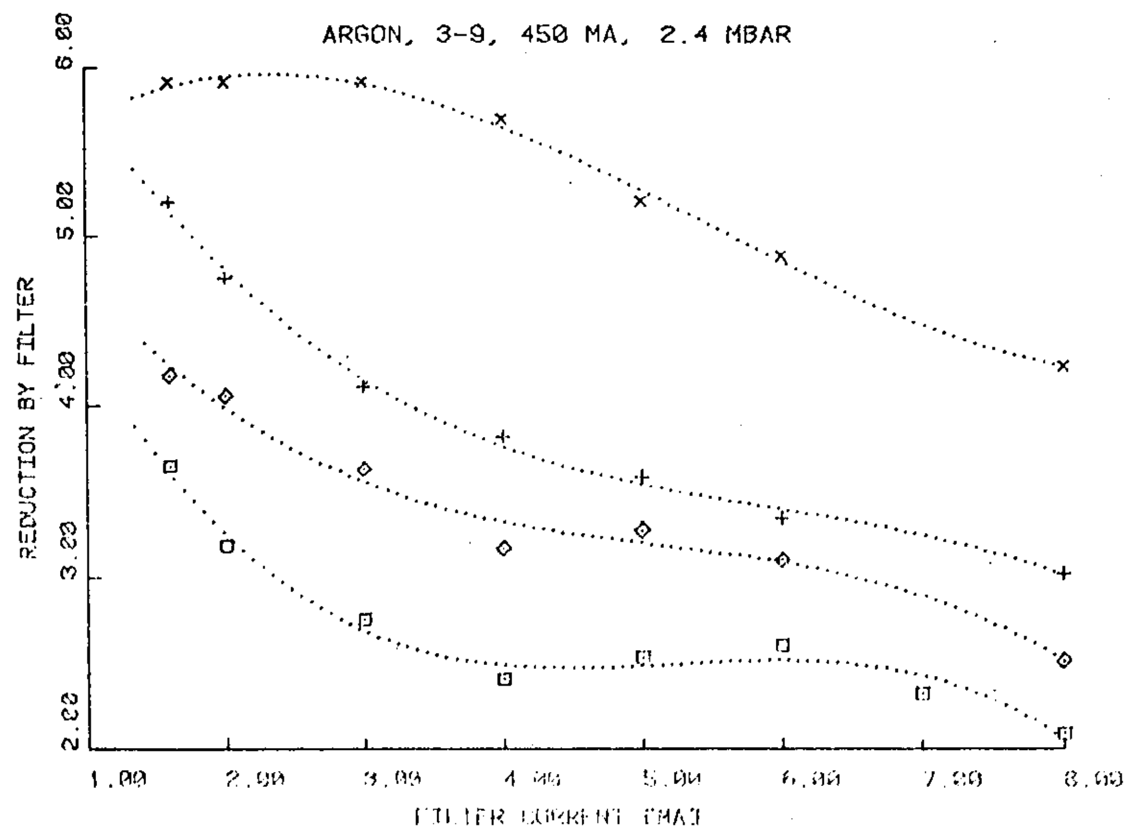
The titles of the plots give the gas, the spectral line, the hollow cathode current and pressure.

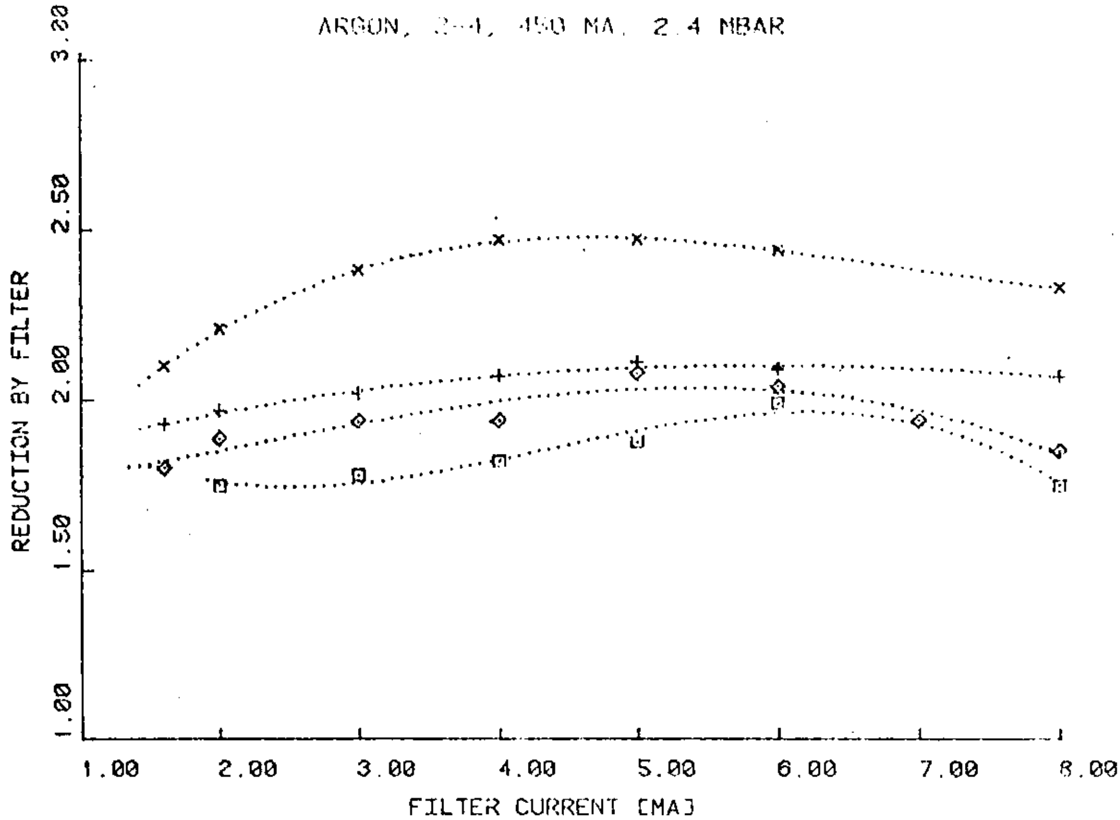
1. $I_{h.c.}$ = 450 mA

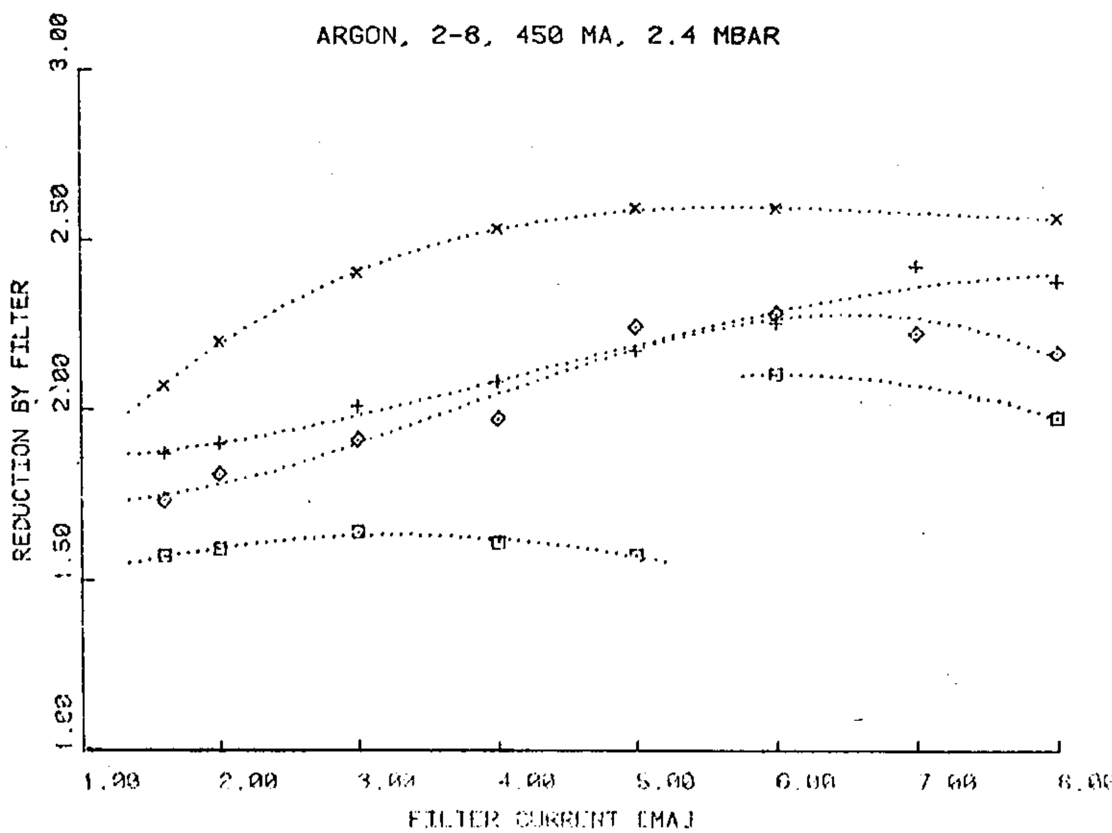

ARGON, 1-2, 450 MA, 2.4 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00


ARGON, 1-3, 450 MA, 2.4 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00

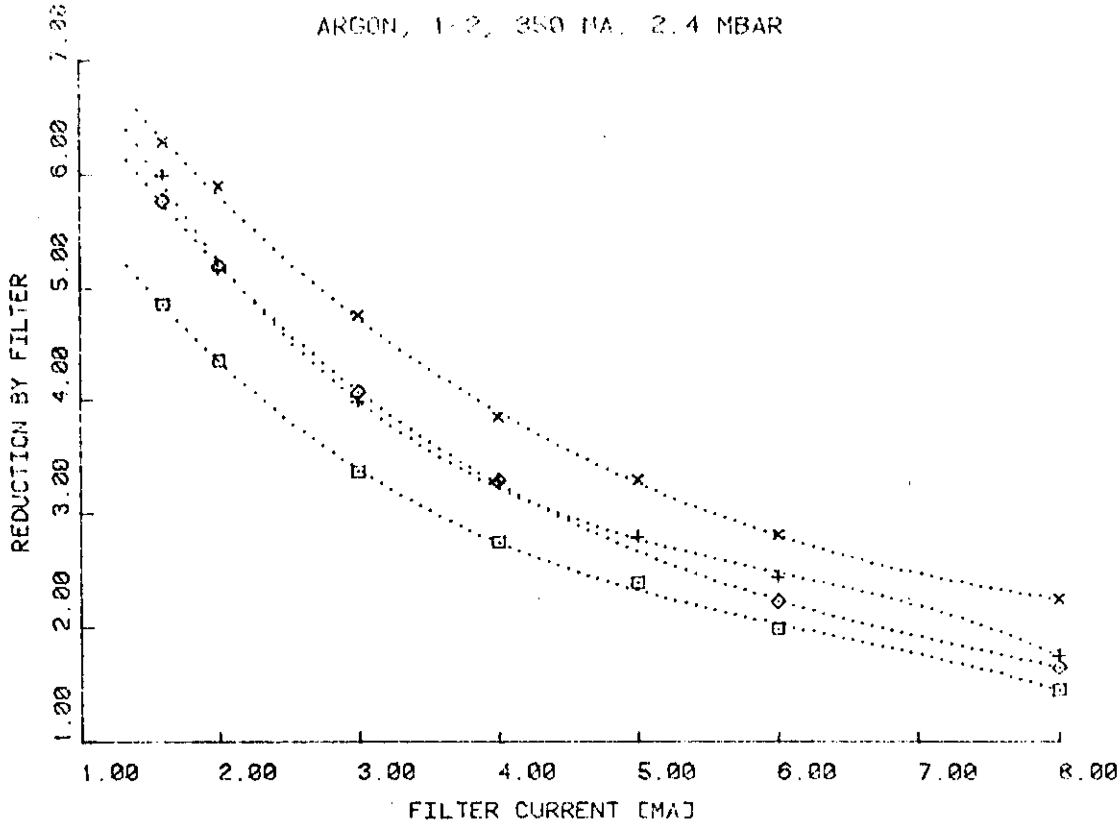

ARGON, 1-5, 450 MA, 2.4 MBAR
REDUCTION BY FILTER
6.22
5.00
4.00
3.00
2.00
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

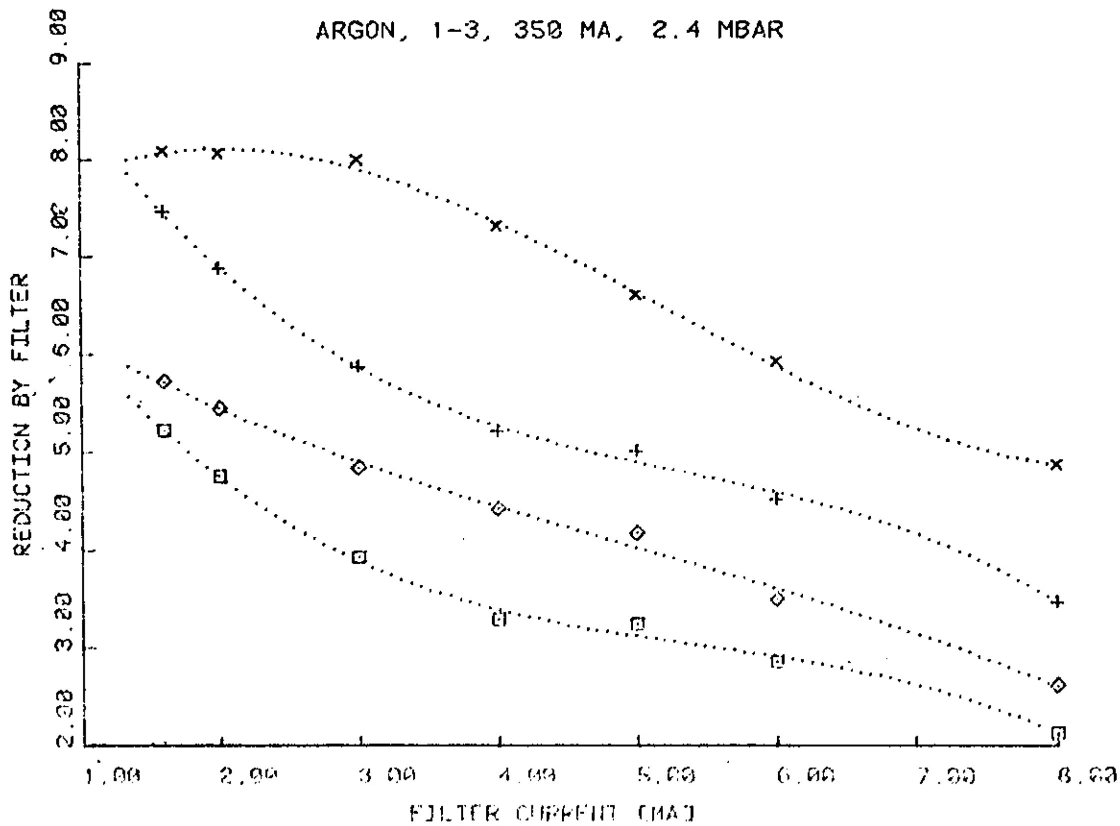

ARGON, 3-9, 450 MA, 2.4 MBAR
REDUCTION BY FILTER
6.00
5.00
4.00
3.00
2.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00

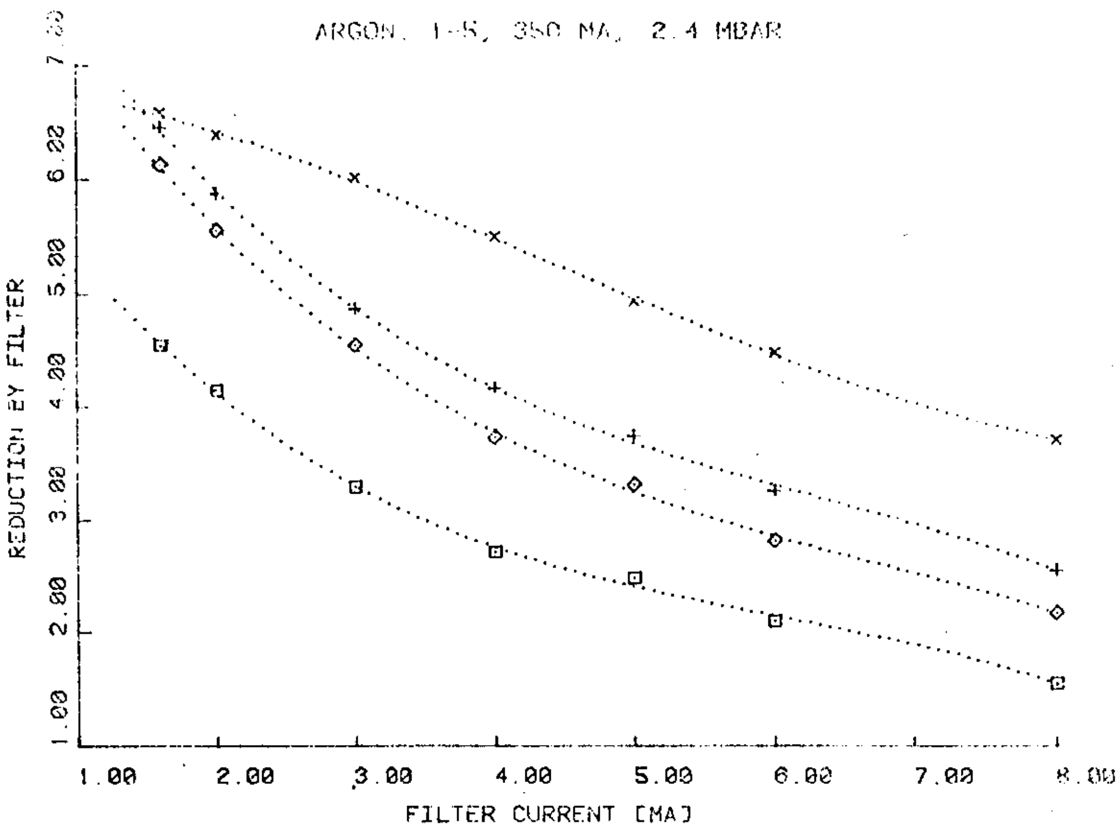

ARGON, 2-4, 450 MA, 2.4 MBAR
REDUCTION BY FILTER
3.00
2.50
2.00
1.50
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

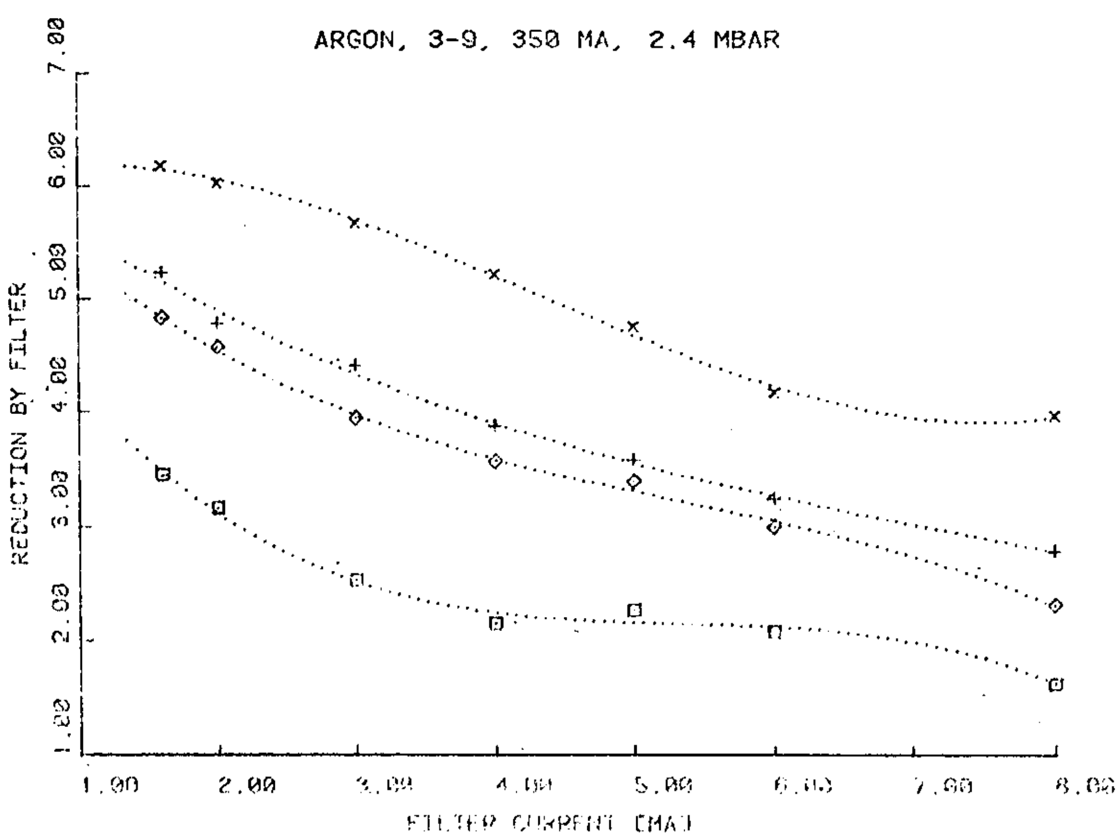

ARGON, 2-8, 450 MA, 2.4 MBAR
REDUCTION BY FILTER
3.00
2.50
2.00
1.50
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

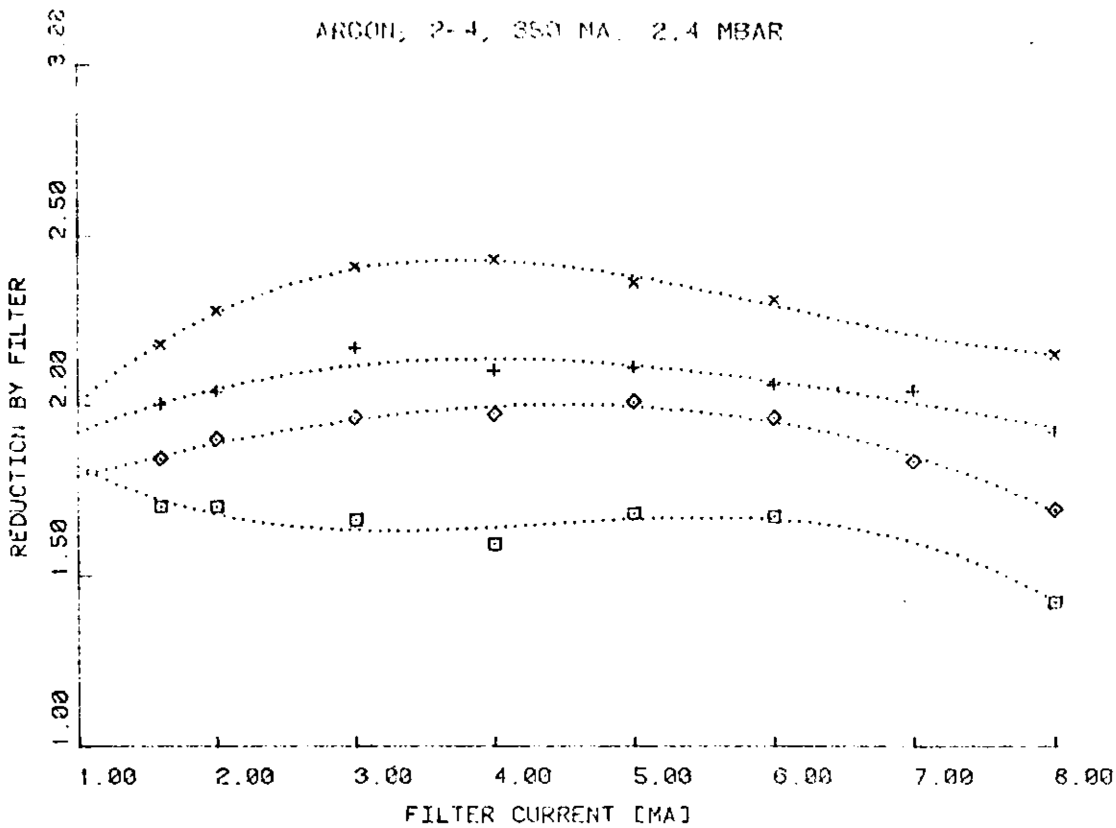
2. $I_{h.c.}$ = 350 mA

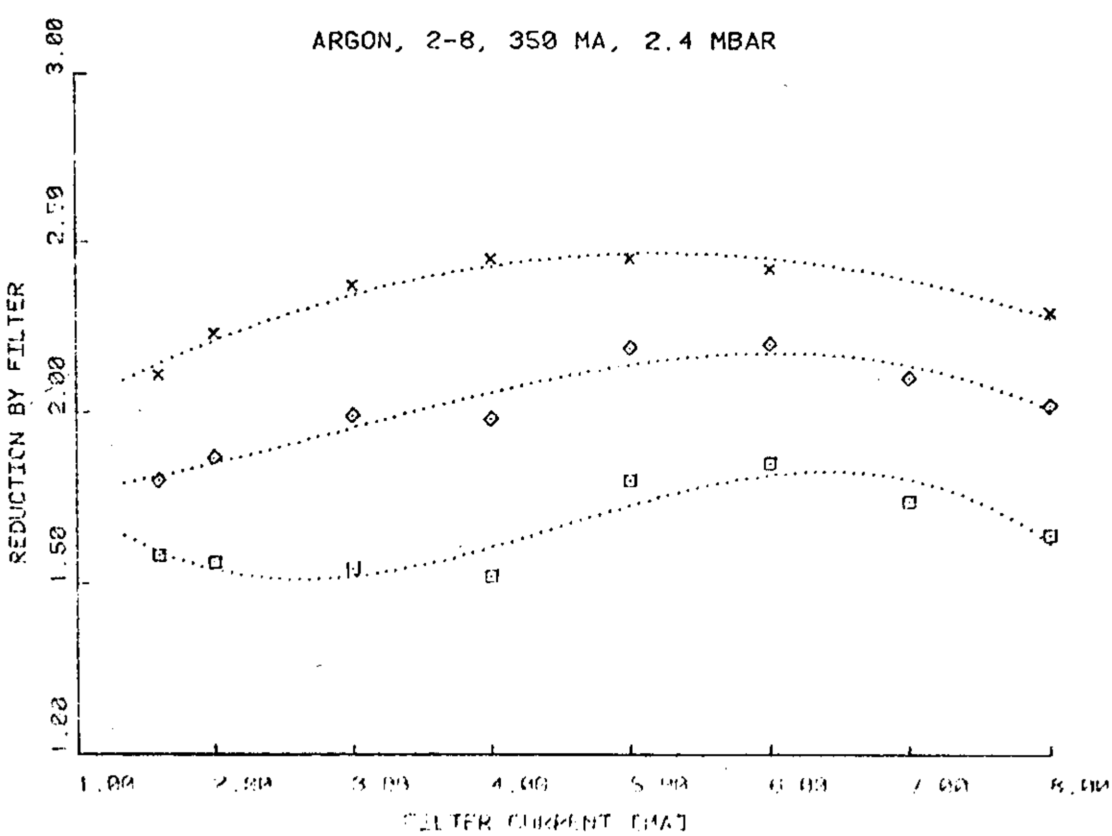

ARGON, 1-2, 350 MA, 2.4 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00


ARGON, 1-3, 350 MA, 2.4 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
1.00

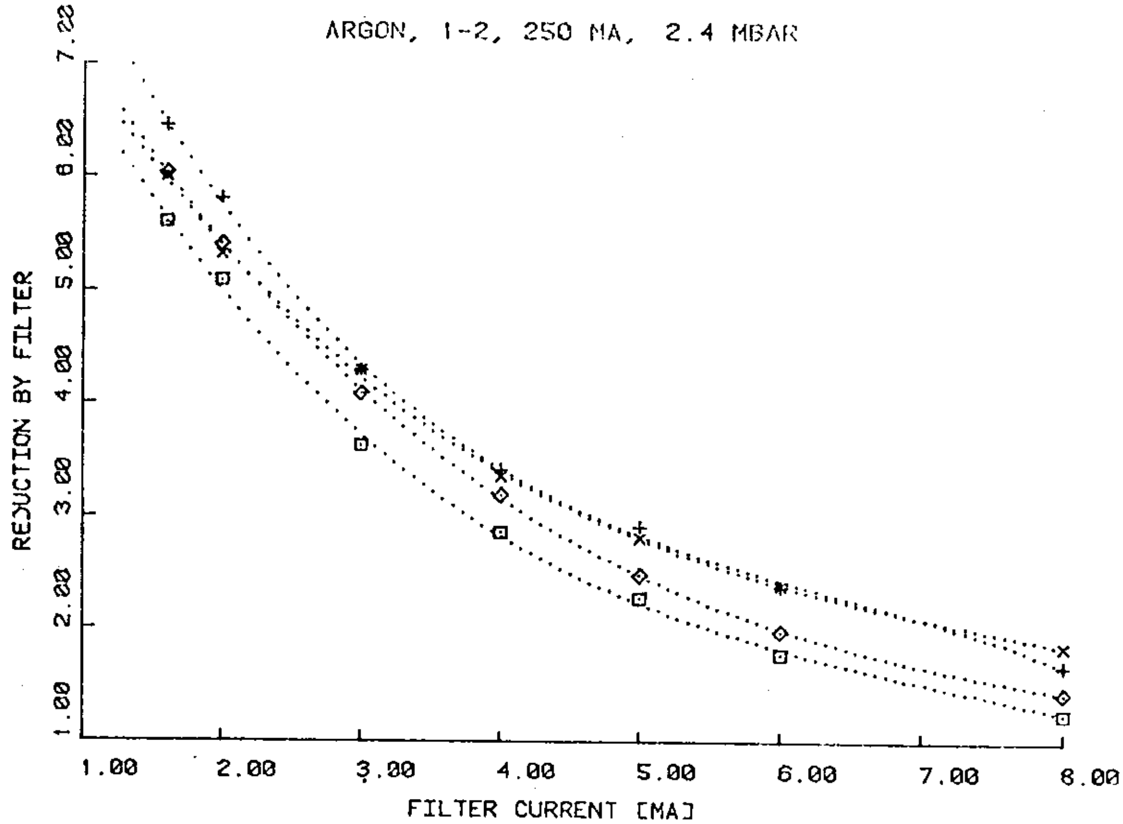

ARGON, 1-5, 350 MA, 2.4 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

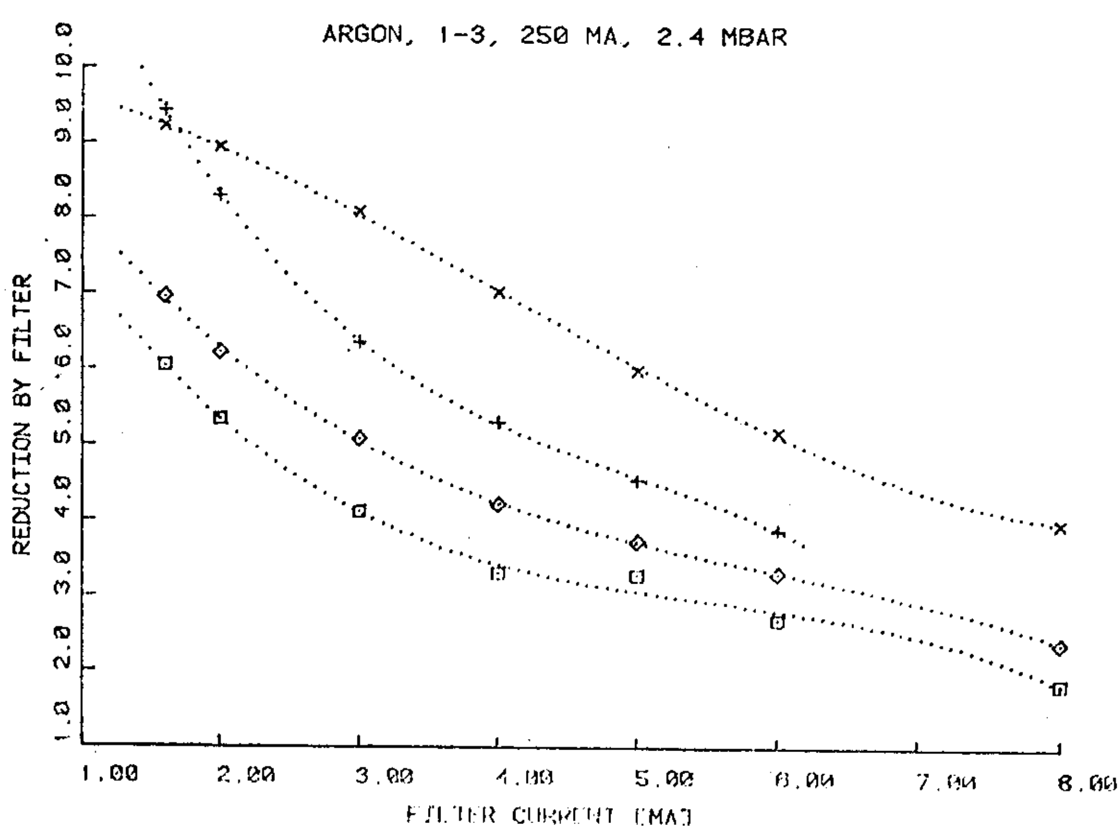

ARGON, 3-9, 350 MA, 2.4 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

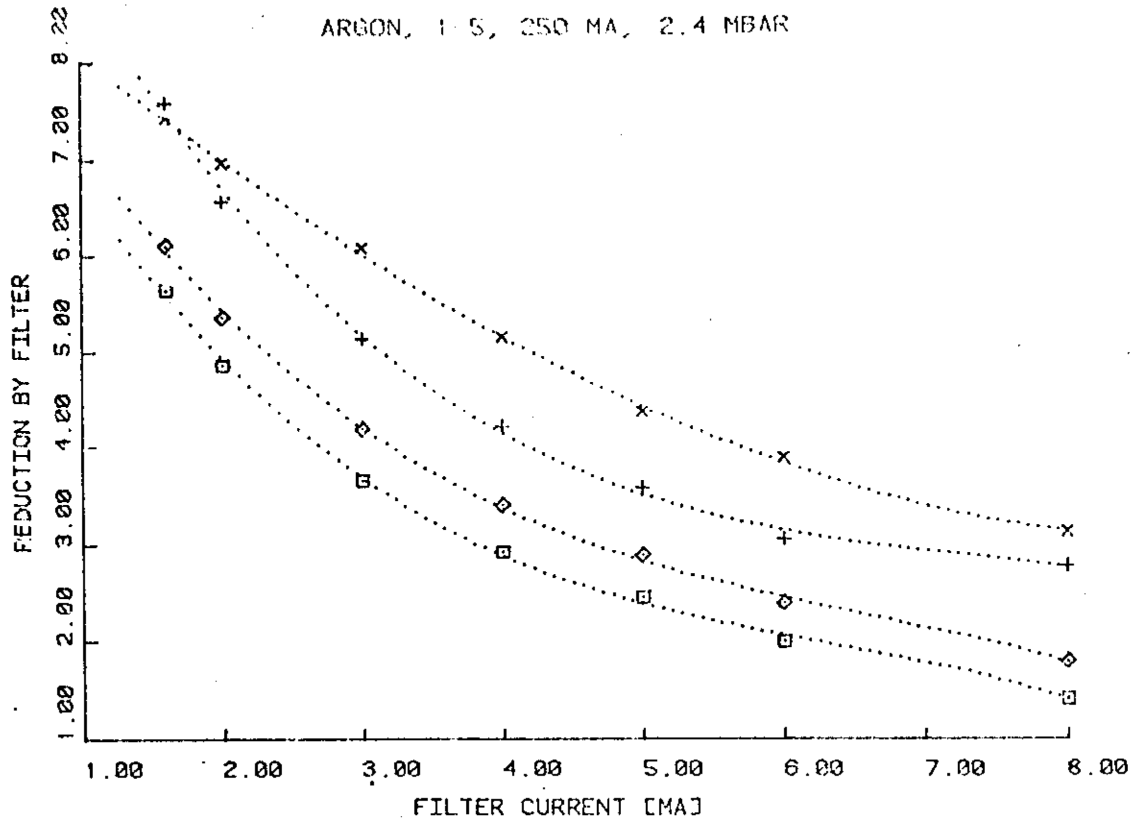

ARGON, 2-4, 350 MA, 2.4 MBAR
REDUCTION BY FILTER
3.00
2.50
2.00
1.50
1.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

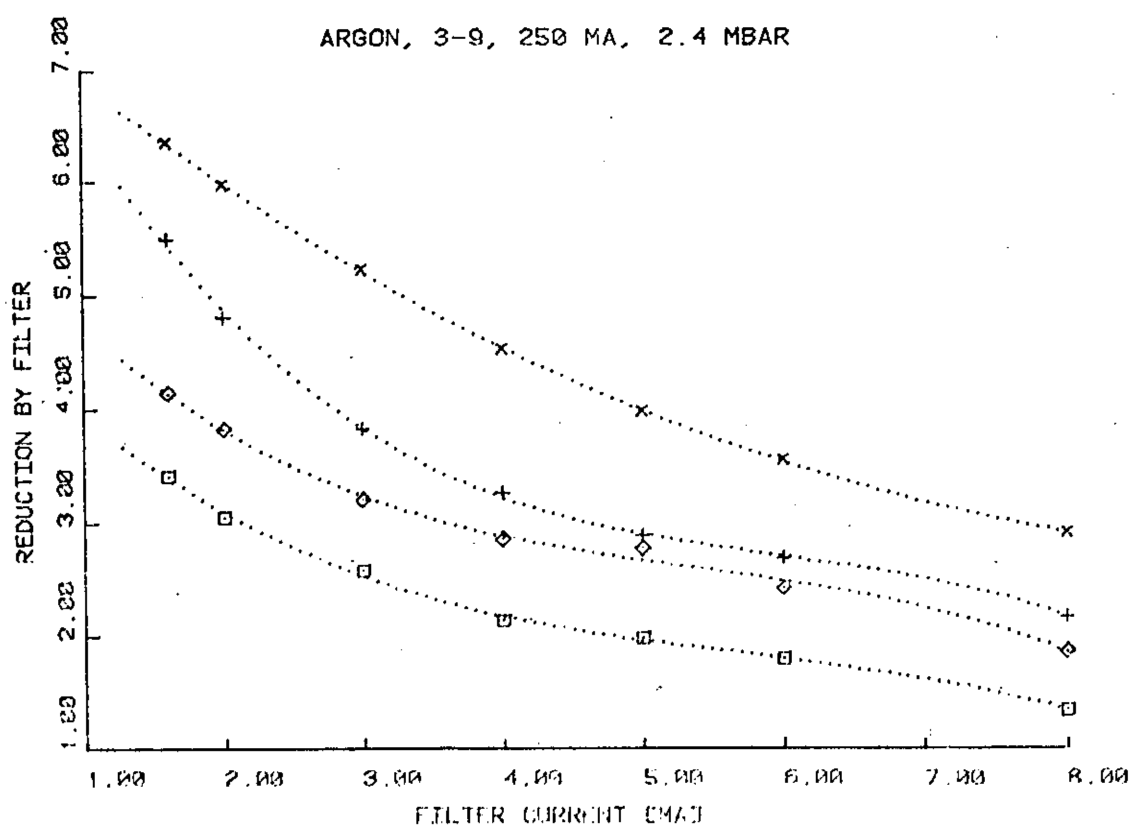

ARGON, 2-8, 350 MA, 2.4 MBAR
REDUCTION BY FILTER
3.00
2.50
2.00
1.50
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

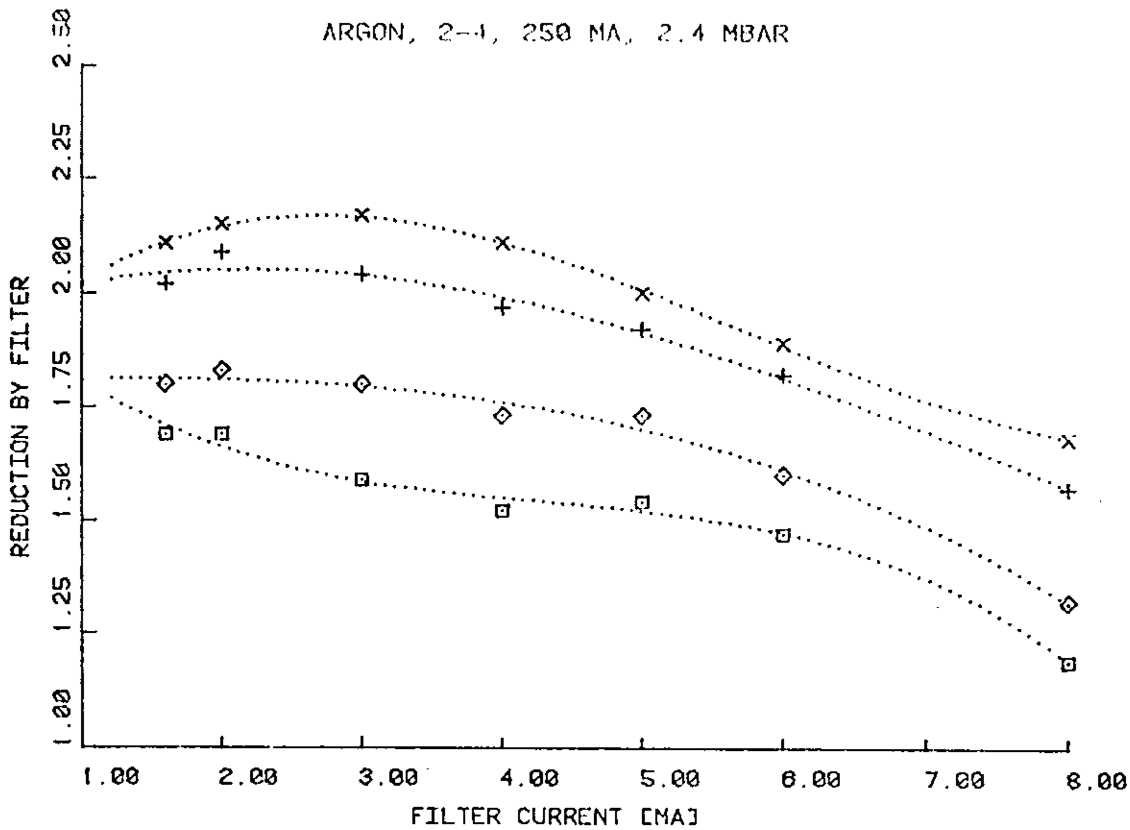
3. $I_{h.c.}$ = 250 mA

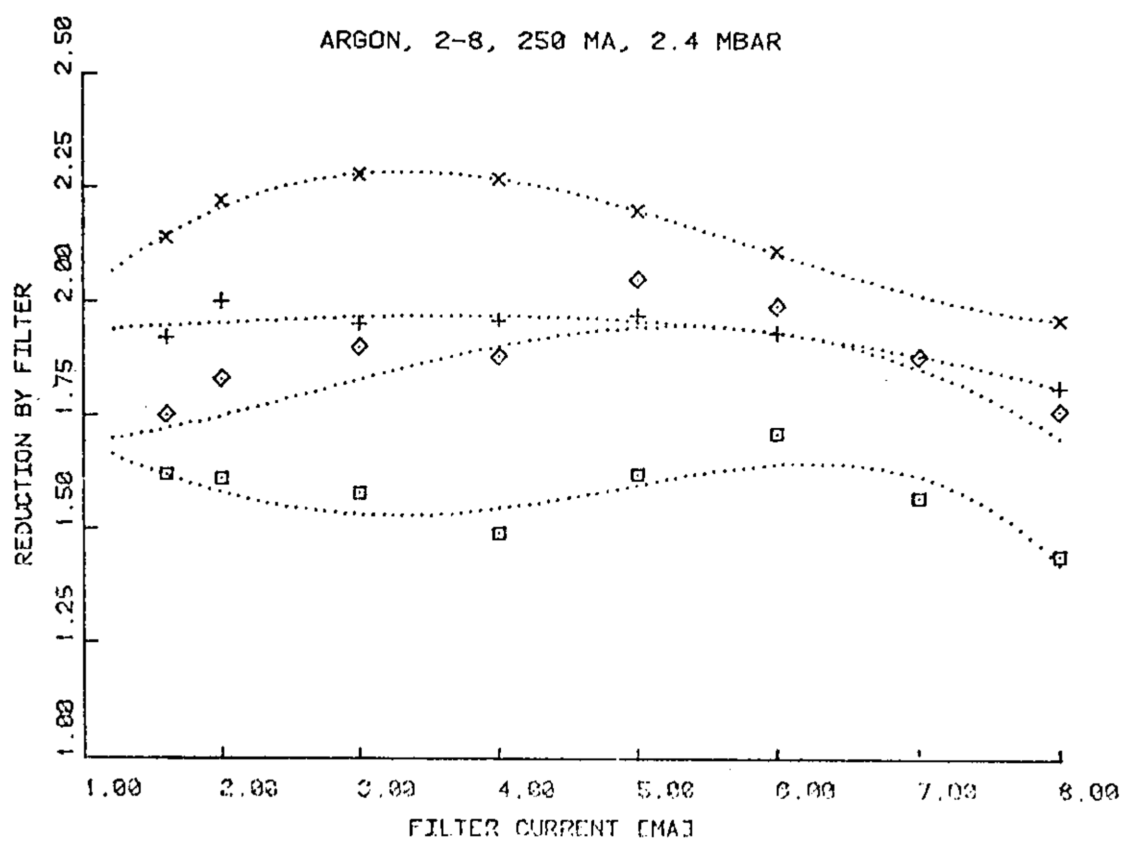

ARGON, 1-2, 250 MA, 2.4 MBAR
REDUCTION BY FILTER
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]


ARGON, 1-3, 250 MA, 2.4 MBAR
REDUCTION BY FILTER
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

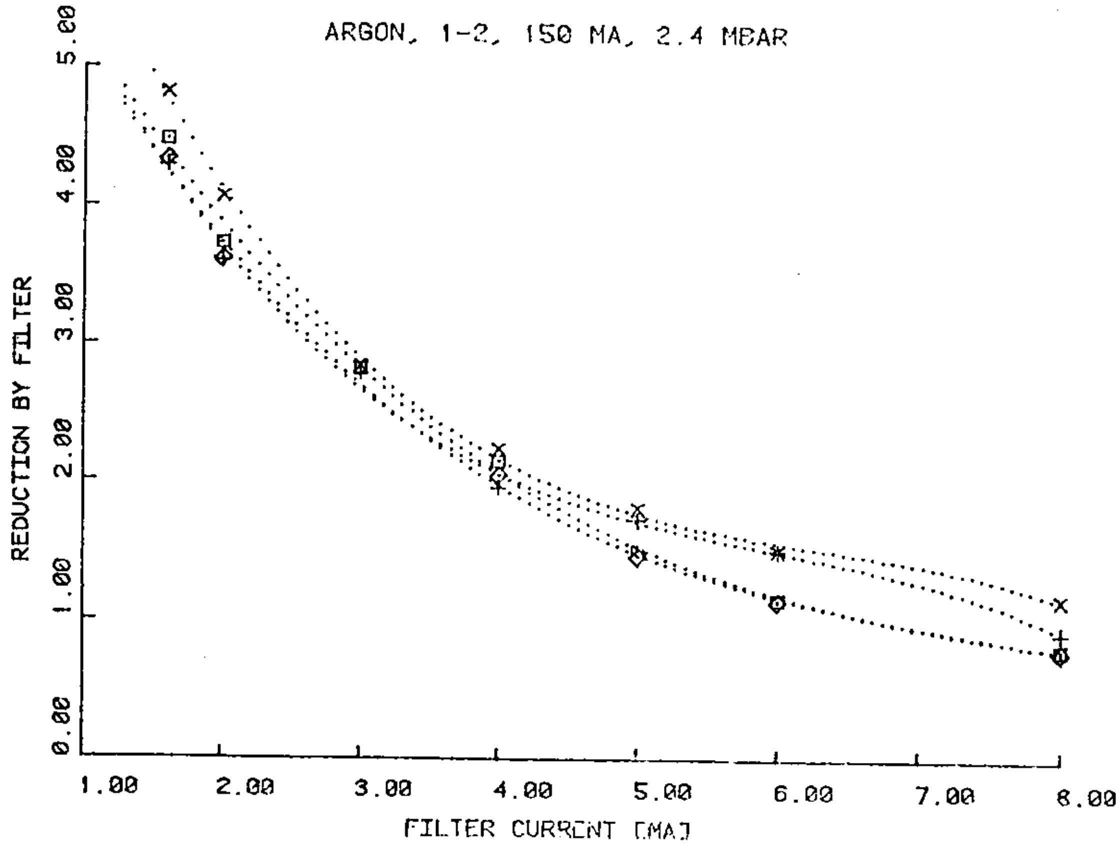

ARGON, 1-5, 250 MA, 2.4 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00

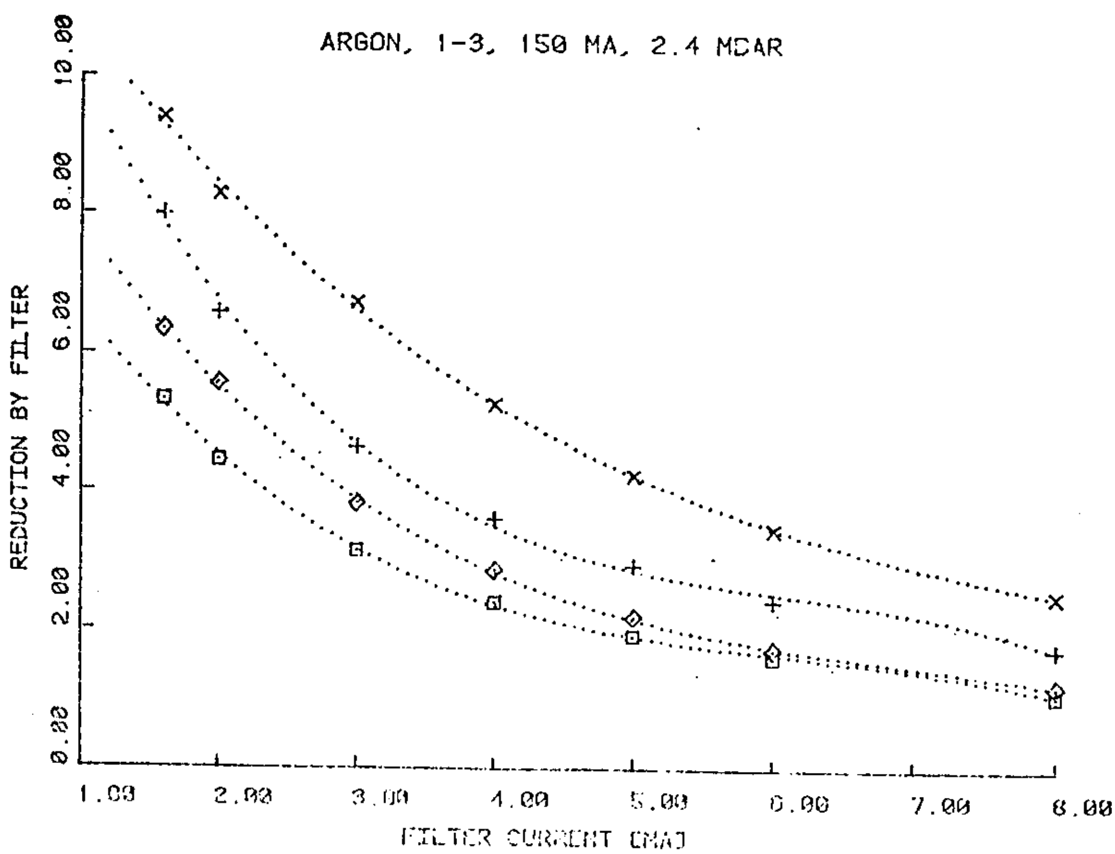

ARGON, 3-9, 250 MA, 2.4 MBAR
REDUCTION BY FILTER
FILTER CURRENT [MA]
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00

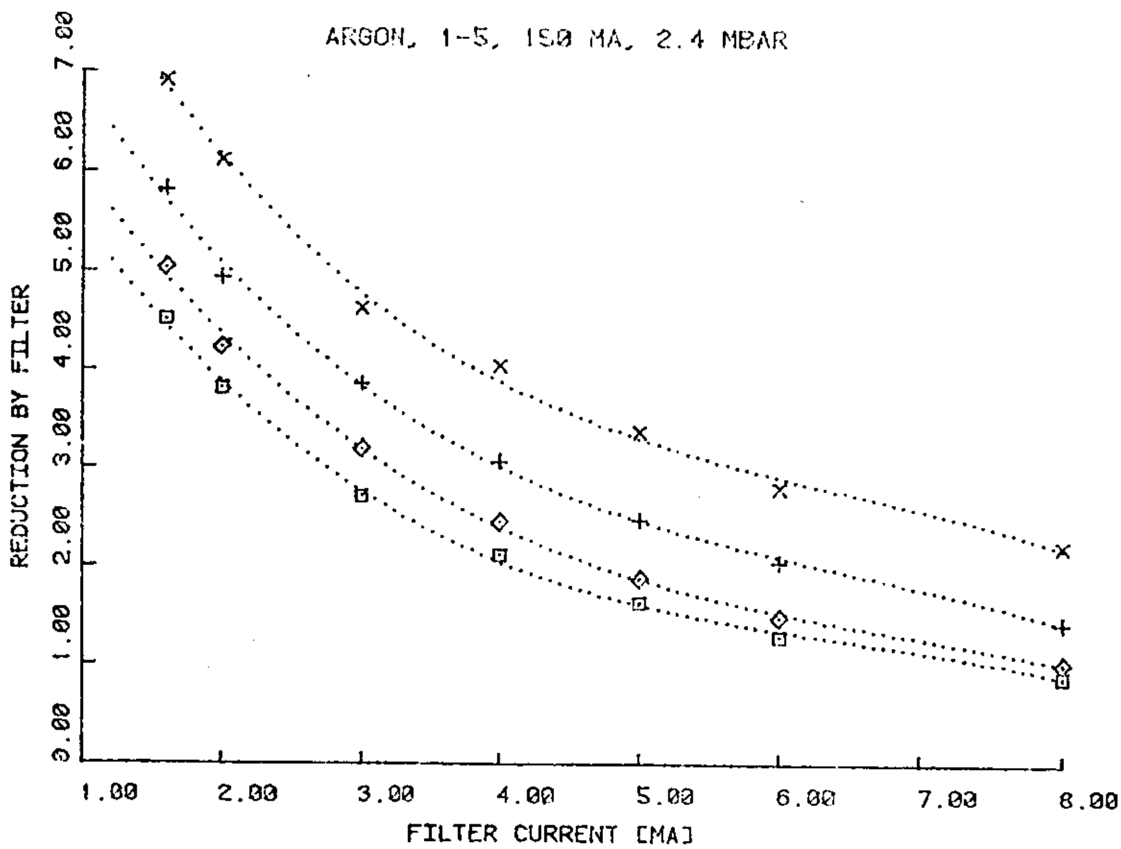

ARGON, 2-4, 250 MA, 2.4 MBAR
REDUCTION BY FILTER
1.00
1.25
1.50
1.75
2.00
2.25
2.50
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

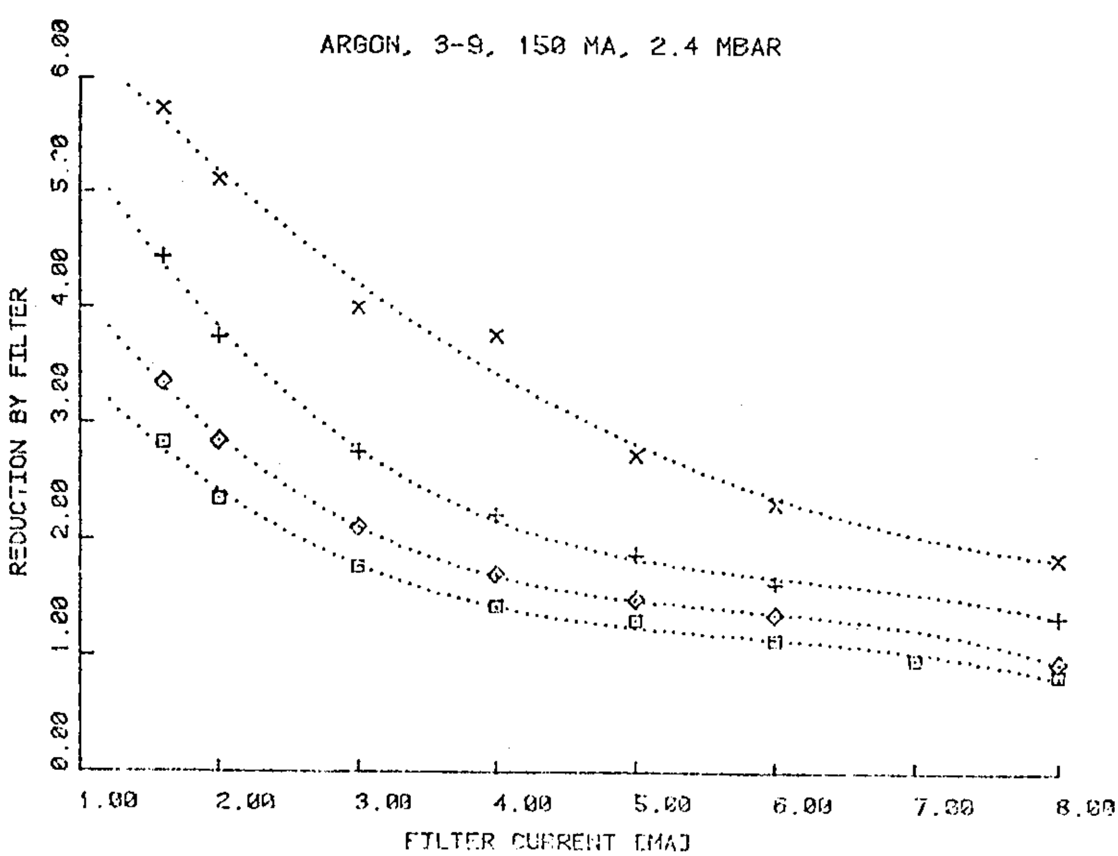

ARGON, 2-8, 250 MA, 2.4 MBAR
REDUCTION BY FILTER
1.00
1.25
1.50
1.75
2.00
2.25
2.50
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

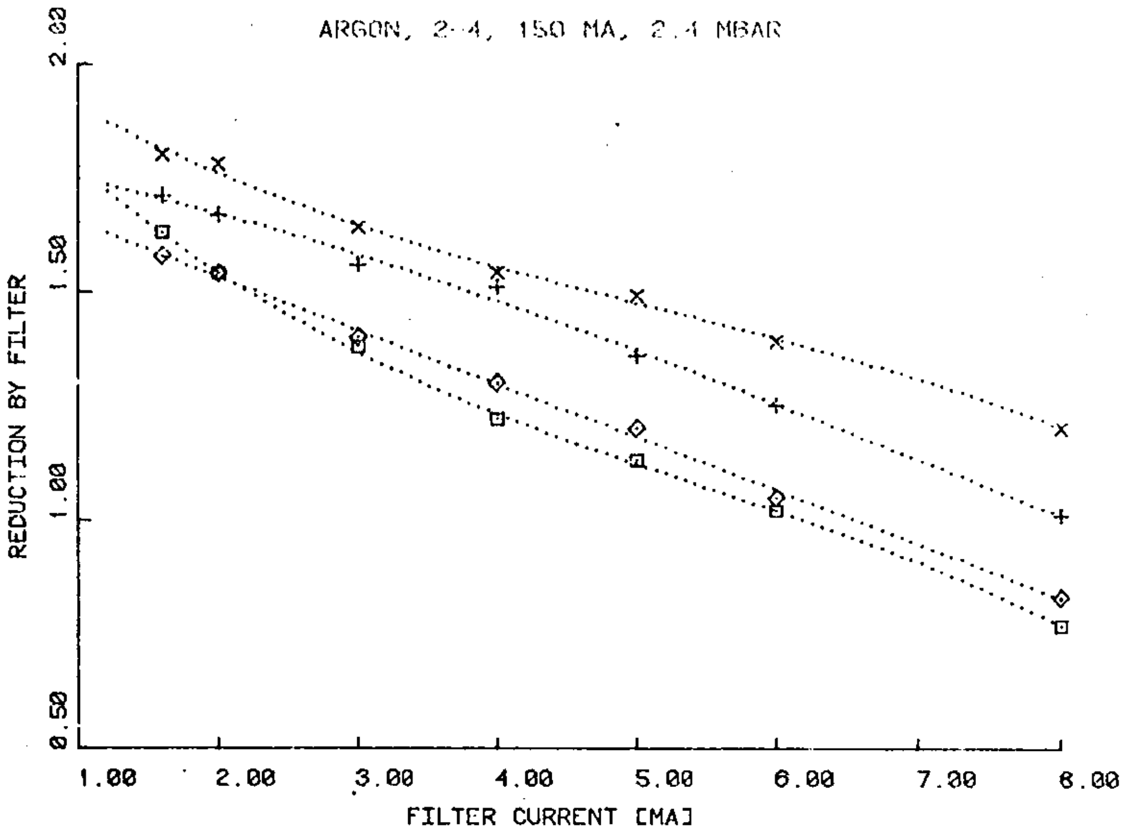
4. $I_{h.c.}$ = 150 mA


ARGON, 1-2, 150 MA, 2.4 MBAR
REDUCTION BY FILTER
0.00
1.00
2.00
3.00
4.00
5.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

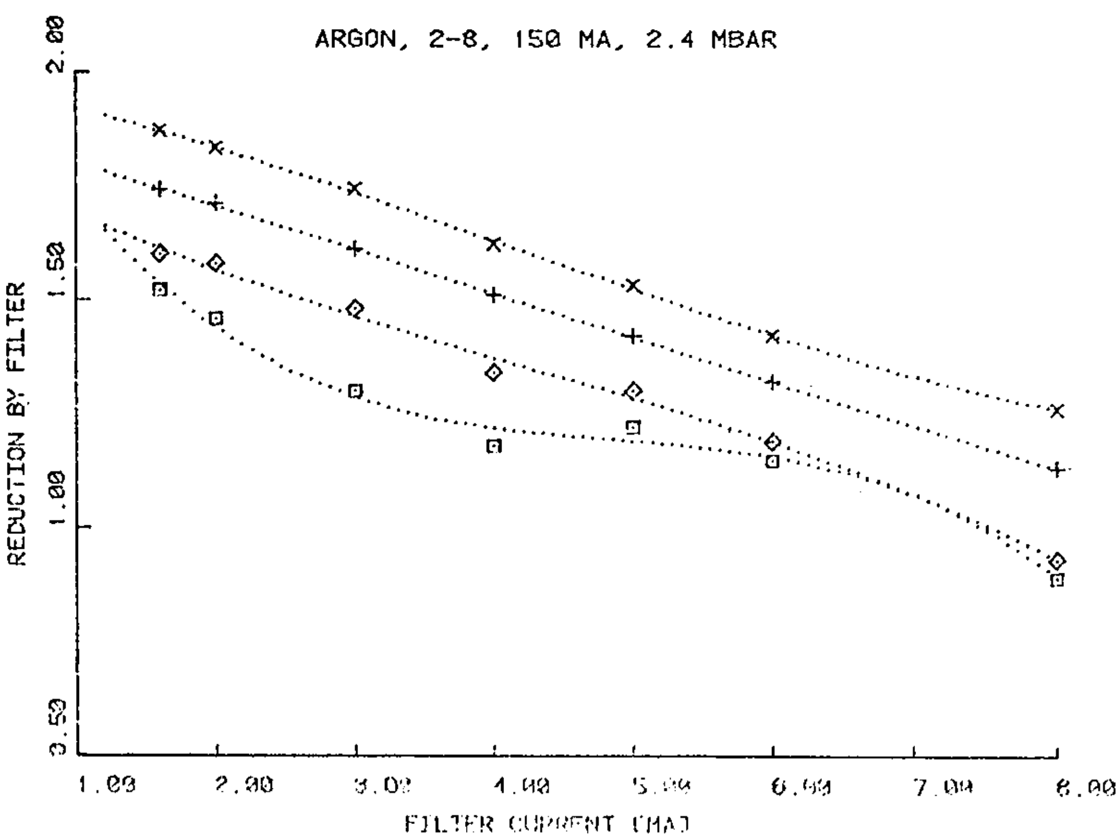

ARGON, 1-3, 150 MA, 2.4 MBAR
REDUCTION BY FILTER
0.00
2.00
4.00
6.00
8.00
10.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]


ARGON, 1-5, 150 MA, 2.4 MBAR
REDUCTION BY FILTER
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]


ARGON, 3-9, 150 MA, 2.4 MBAR
REDUCTION BY FILTER
0.00
1.00
2.00
3.00
4.00
5.00
6.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]



ARGON, 2-4, 150 MA, 2.4 MBAR
REDUCTION BY FILTER
2.00
1.50
1.00
0.50
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
FILTER CURRENT [MA]

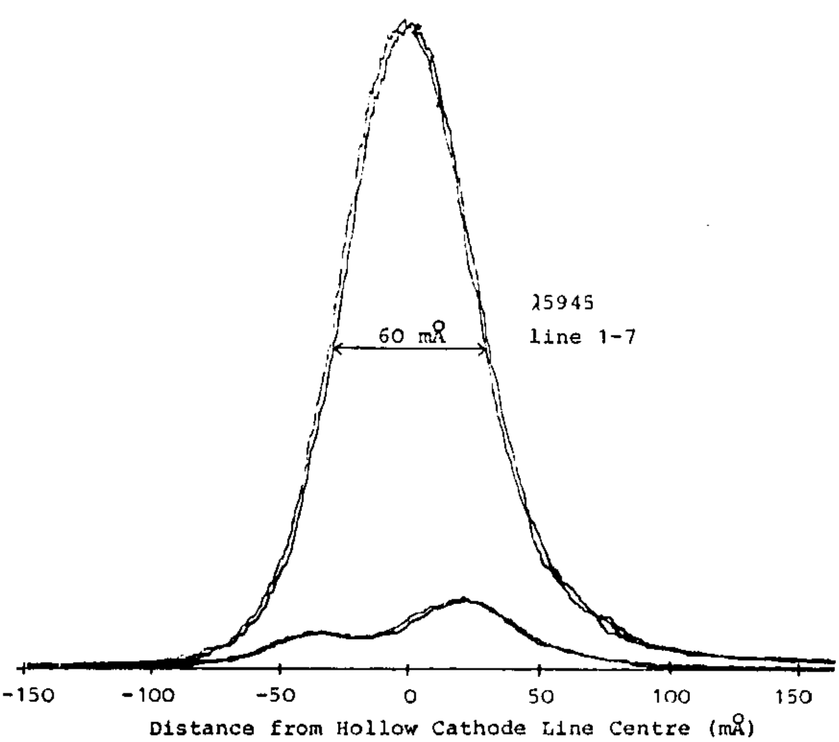


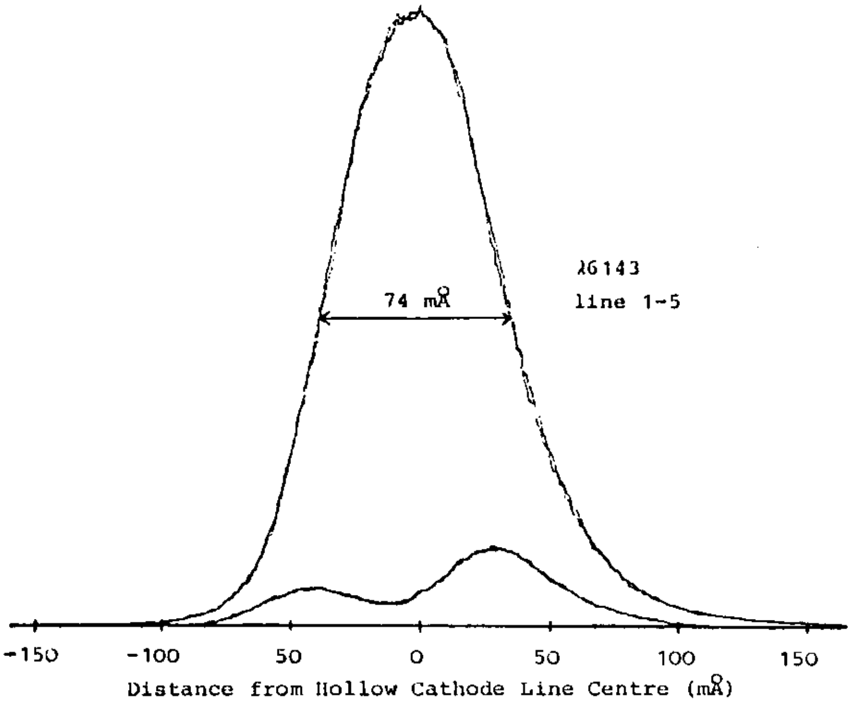
ARGON, 2-8, 150 MA, 2.4 MBAR
REDUCTION BY FILTER
2.00
1.50
1.00
1.00
2.00
4.00
6.00
7.00
8.00

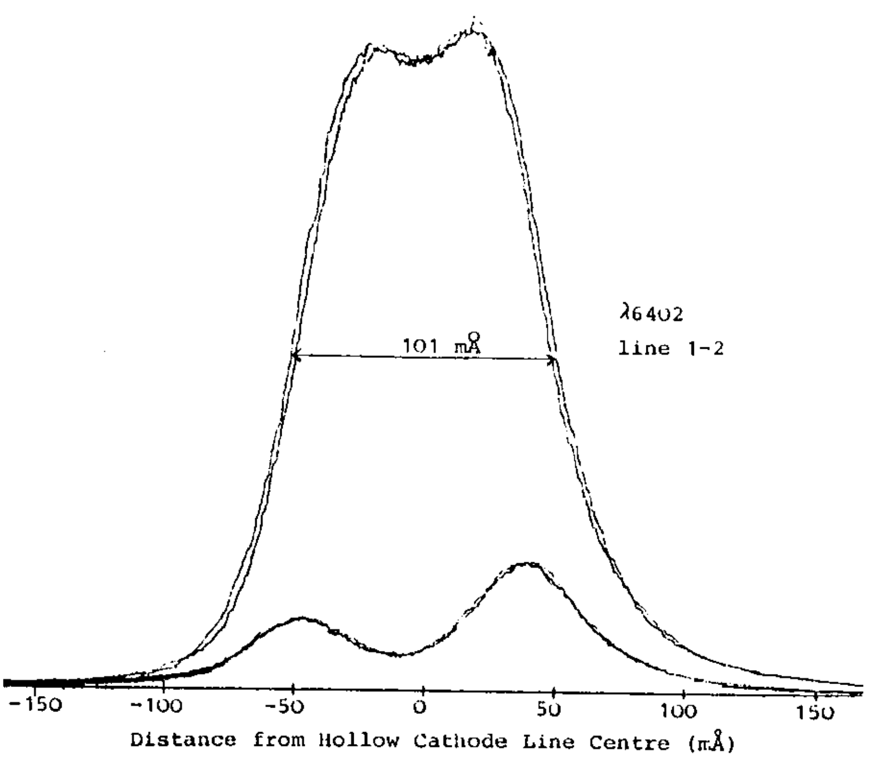
Appendix IV: Experimental Traces of Hollow Cathode Line Profiles with and without Filter

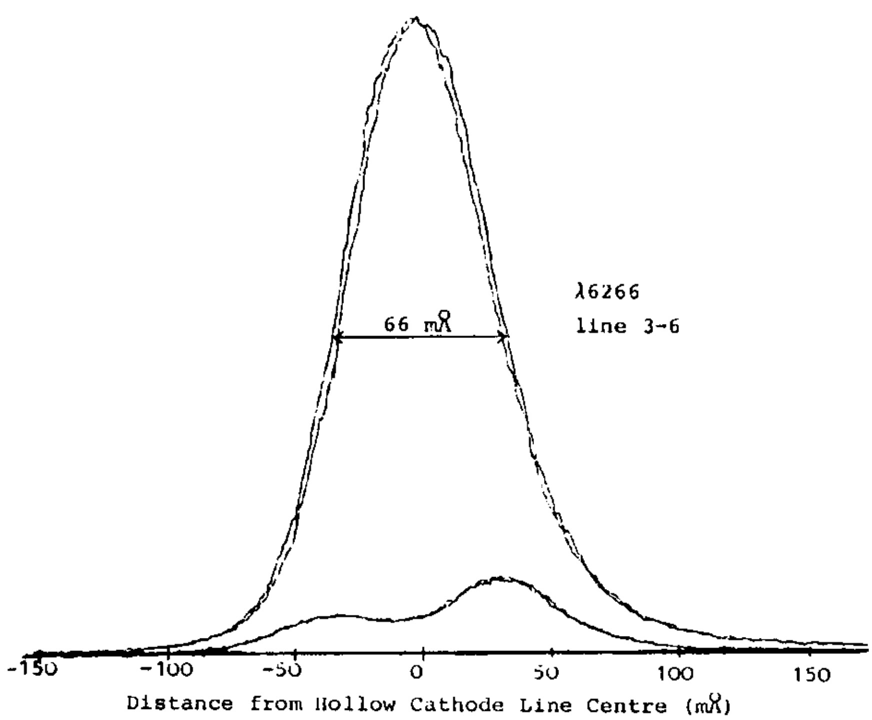
This appendix gives experimental traces of hollow cathode lines with and without the filter discharge in operation. The first set of five was recorded for a hollow cathode current of 350 mA and a pressure of 2.5 mbar, while the second set gives the profiles of the same lines for $I_{h.c.}$ = 250 mA and $p_{h.c.}$ = 2.4 mbar.

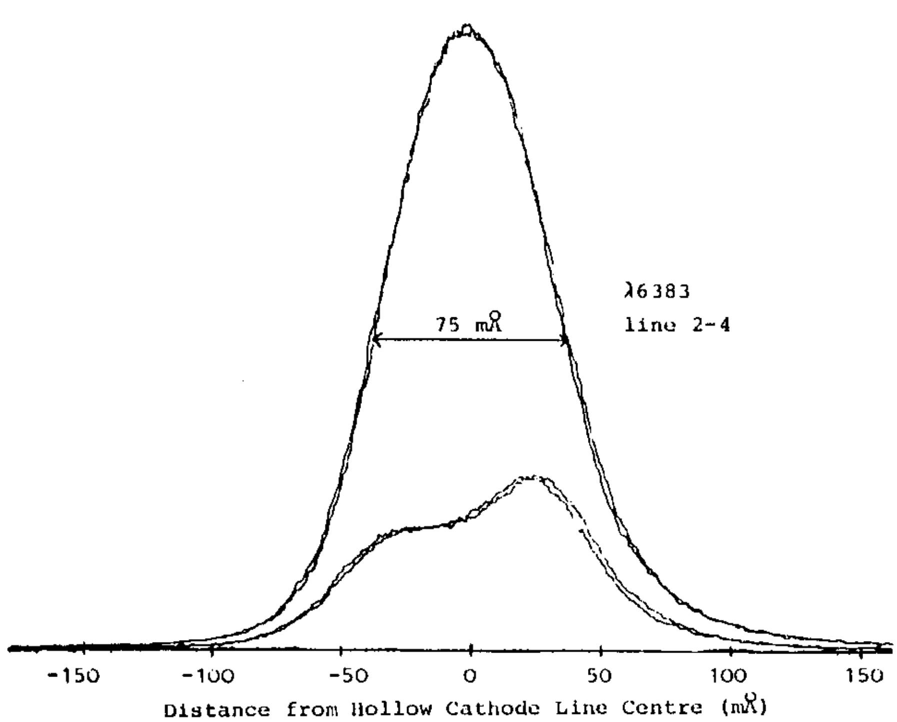
1. Set: $I_{h.c.}$ = 350 mA



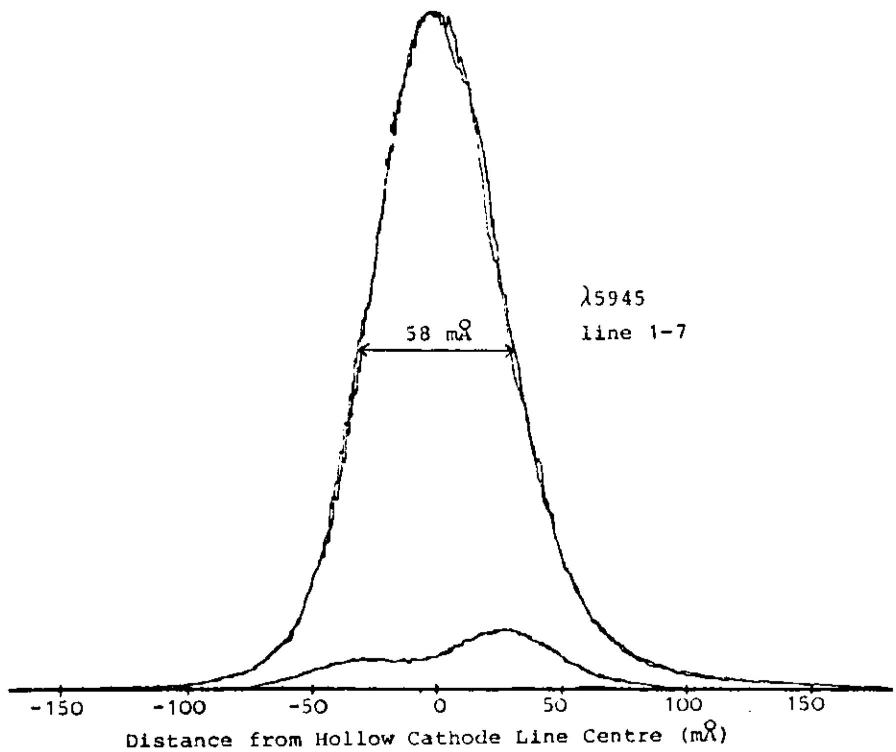

λ6143
line 1-5
74 mÅ
-150
-100
50
0
50
100
150
Distance from Hollow Cathode Line Centre (mÅ)

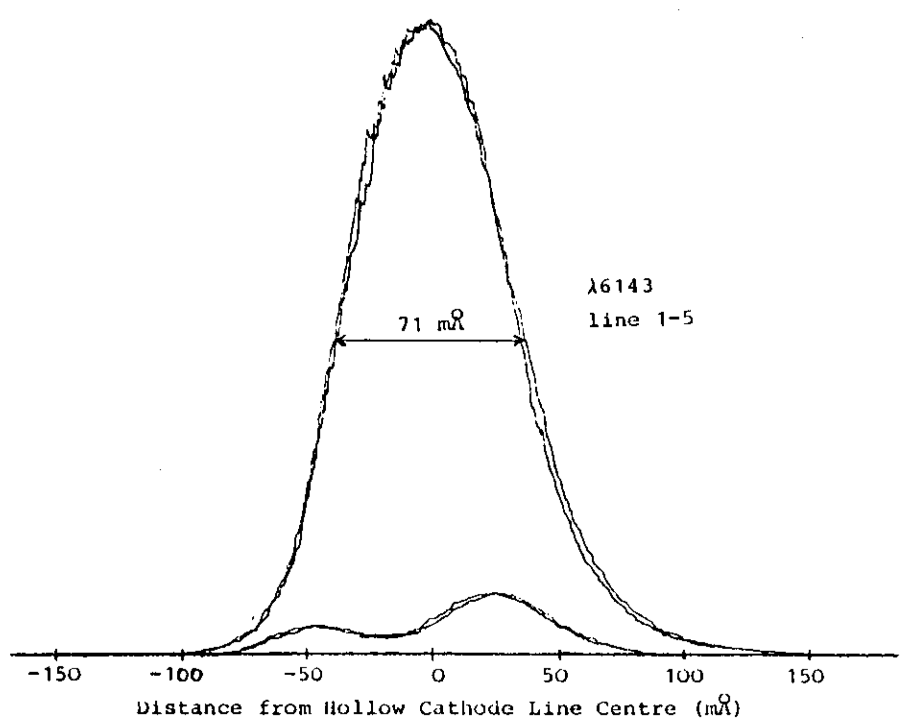

λ6402
line 1-2
101 mÅ
-150
-100
-50
0
50
100
150
Distance from Hollow Cathode Line Centre (mÅ)

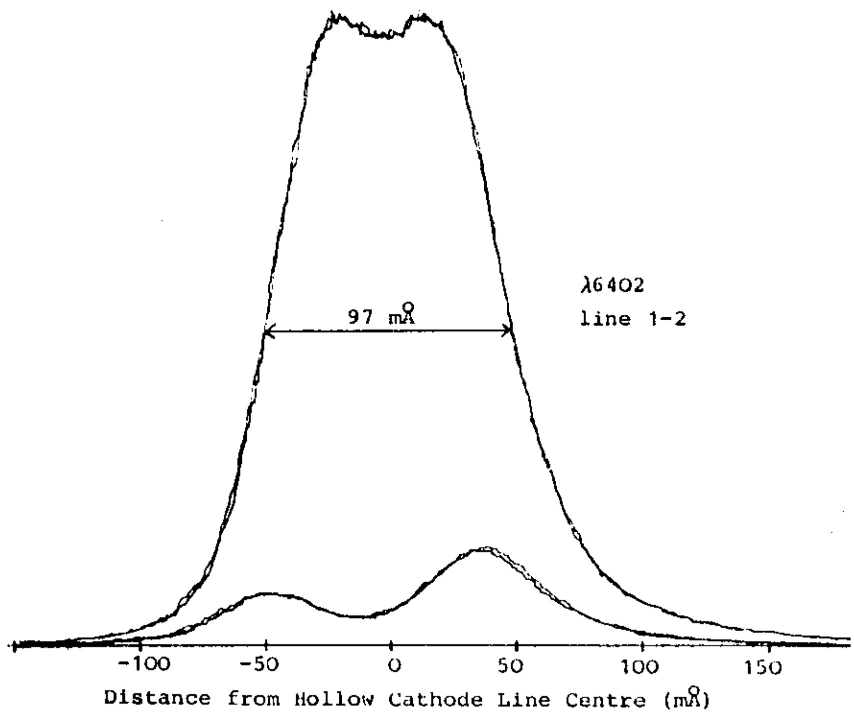

λ6266
line 3-6
66 mÅ
-150
-100
-50
0
50
100
150
Distance from Hollow Cathode Line Centre (mÅ)

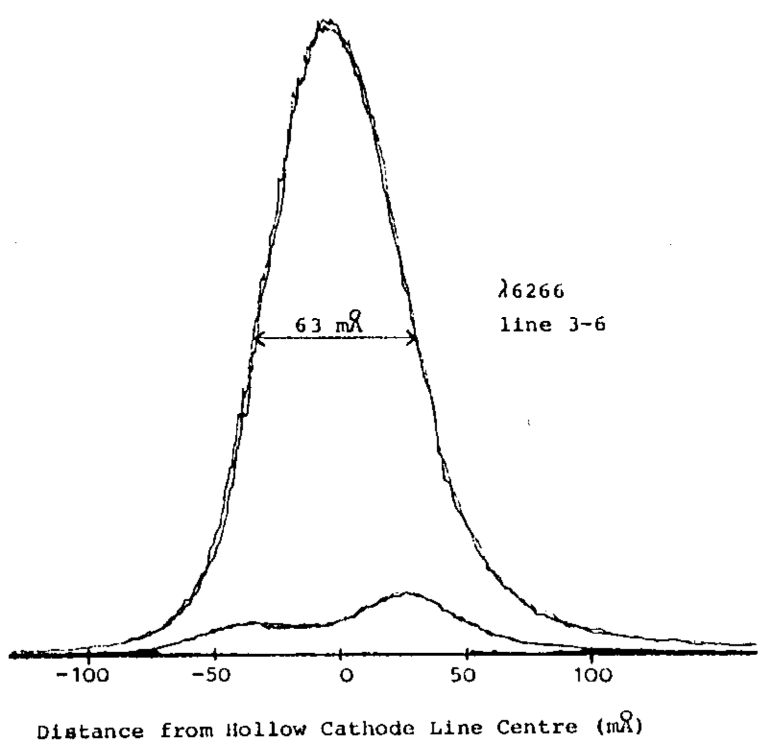

λ6383
line 2-4
75 mÅ
-150
-100
-50
0
50
100
150
Distance from Hollow Cathode Line Centre (mÅ)

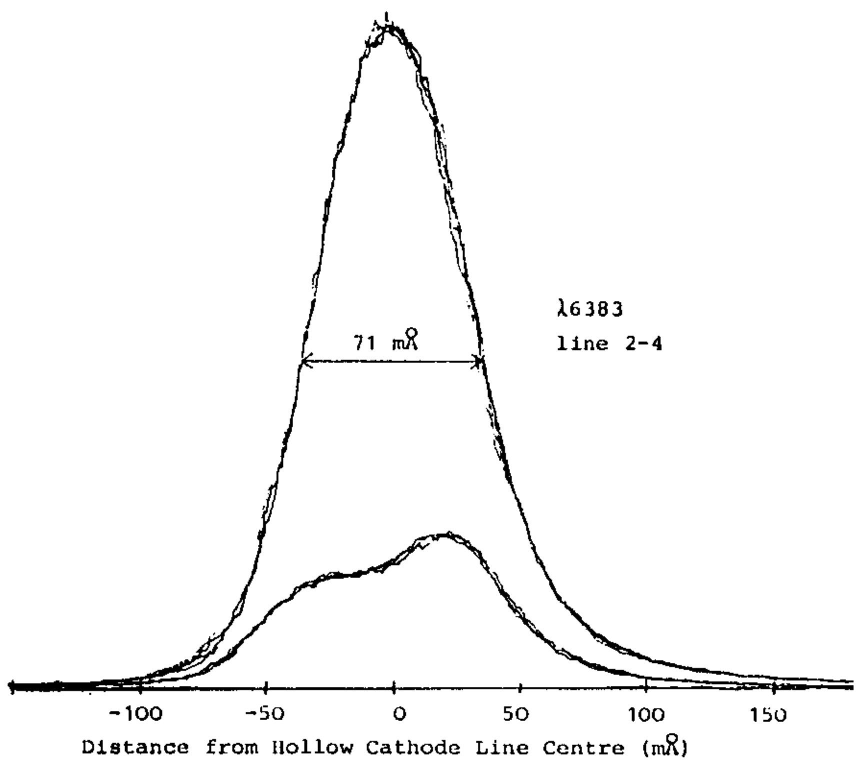
2. Set: $I_{h.c.} = 250$ mA






λ6402
line 1-2
97 mÅ
-100
-50
0
50
100
150
Distance from Hollow Cathode Line Centre (mÅ)


λ6266
line 3-6
63 mÅ
-100
-50
0
50
100
Distance from Hollow Cathode Line Centre (mÅ)


λ6383
line 2-4
71 mÅ
-100
-50
0
50
100
150
Distance from Hollow Cathode Line Centre (mÅ)

Appendix V: Listing of Programmes 'REFA' and 'VOIGT'

This appendix gives the listing of the reduction factor programme 'REFA' discussed in Chapter VII and the Voigt approximation function subroutine 'VOIGT' (after Kielkopf /14/). The programmes were written in FORTRAN IV.

```
      PROGRAM REFA
C
C
C     THIS PROGRAM SIMULATES THE FOLLOWING RADIATIVE TRANSFER
C     PROBLEM: THE LINE EMISSION OF A BACKGROUND SOURCE (HERE: HOLLOW
C     CATHODE, H.C.) IS VIEWED THROUGH AN ABSORBING SLAB OF GAS
C     (HERE: FILTER DISCHARGE, F.D.). THE GASES IN THE H.C.
C     AND IN THE F.D. ARE THE SAME. SINCE THE H.C. IS MUCH HOTTER
C     THAN THE F.D. ABSORPTION OCCURS. THE FACTOR BY WHICH THE H.C.-
C     INTENSITY IS REDUCED IS CALCULATED.
C     N.B.:  -  X = DISTANCE FROM LINE CENTRE IN TERMS OF HWHM
C            -  ALL DELTA LAMBDA'S IN MILLIANGSTROM, EXCEPT THE
C               WAVELENGTH OF THE LINE ITSELF
C            -  I AND LAMBDA INCREASE IN THE SAME DIRECTION,
C               I.E. FROM LEFT TO RIGHT.
C
      DIMENSION FVAL(1001),HVAL(1001),XARMA(1001),COAB(1001),HCAB(1001)
C
      REAL L,LN2,IS,I1(1001),I11
C
      L(T)=2./(1.+EPSI*LN2+SQRT((1.-EPSI*LN2)**2+(4.*LN2/T**2)))
C
C
C     WRITE FORMATS
C
 900  FORMAT ('+',$,'DATA FILE CREATION ? (Y/ ) ')
 1000 FORMAT (X,$,'GAS AND LINE................? ')
 1010 FORMAT ('+',$,'HOLLOW CATHODE (H.C.).......? ')
 1030 FORMAT ('+',$,'FILTER DISCHARGE (F.D.).....? ')
 1040 FORMAT ('+',$,'MEASURED REDUCTION FACTOR...? ')
 1050 FORMAT ('+',$,'WAVELENGTH (ANGSTROM).........................? ')
 1060 FORMAT ('+',$,'H.C. LORENTZIAN FWHM (MILLIANGSTROM)...........? ')
 1070 FORMAT ('+',$,'H.C. GAUSSIAN FWHM (MILLIANGSTROM).............? ')
 1080 FORMAT ('+',$,'SHIFT OF H.C. LINE (RED=+) (MILLIANGSTROM).....? ')
 1083 FORMAT ('+',$,'TRANS.-PROB.-SUM OF UPPER STATE (1E7*SEC**-1)..? ')
 1086 FORMAT ('+',$,'F.D. PRESSURE FWHM (MILLIANGSTROM).............? ')
 1088 FORMAT ('+',$,'ISOTOPE SHIFT (MILLIANGSTROM)..................? ')
 1090 FORMAT ('+',$,'RATIO OF F.D. TO H.C. INTENSITY................? ')
 1100 FORMAT (X,$,'F.D. PEAK OPTICAL DEPTH.........................? ')
 1120 FORMAT ('+',$,'CALCULATED F.D. DOPPLER FWHM (MILLIANGSTROM)...= ')
 1130 FORMAT (X,$,'ADDITIONAL F.D. GAUSSIAN FWHM (MILLIANGSTROM)..? ')
 1150 FORMAT ('+',$,'CALCULATED F.D. NATURAL FWHM (MILLIANGSTROM)...= ')
 1153 FORMAT (X,$,'CALCULATED F.D. A...............................= ')
 1156 FORMAT (X,$,'CALCULATED H.C. A...............................= ')
 1160 FORMAT (X,$,'CALCULATED F.D. VOIGTIAN FWHM (MILLIANGSTROM)..= ')
 1170 FORMAT (X,$,'CALCULATED H.C. VOIGTIAN FWHM (MILLIANGSTROM)..= ')
 1180 FORMAT ('+',F12.4)
 1200 FORMAT ('+',$,'CALCULATED REDUCTION FACTOR....................= ')
C
C
C     READ FORMATS
C
 2000 FORMAT (80A1)
 2010 FORMAT (A1)
C
C
C     DECIDE WHETHER DATA FILES FOR PLOTTING SHALL BE CREATED
C
      WRITE (5,900)
      READ (5,2010) IPLDEC
```

```
C
C
C       READ PARAMETERS
C
 5      WRITE (5,1000)
        READ (5,2000) NLN
        WRITE (5,1010)
        READ (5,2000) NHC
        WRITE (5,1030)
        READ (5,2000) NFD
        WRITE (5,1040)
        READ (5,2000) NRF
        WRITE (5,1050)
        READ (5,*) WL
        WRITE (5,1060)
        READ (5,*) HWLOHC
        WRITE (5,1070)
        READ (5,*) HWGAHC
        WRITE (5,1080)
        READ (5,*) HCSH
        WRITE (5,1083)
        READ (5,*) ASUM
        WRITE (5,1086)
        READ (5,*) HWPRFD
        WRITE (5,1088)
        READ (5,*) IS
        WRITE (5,1090)
        READ (5,*) RIFDHC
C
C
C       NEON ABUNDANCES
C
        A20NE=0.907
        A22NE=0.093
        ARAT=A22NE/A20NE                   !  = 0.103
C
C
        PI=3.1415926
        LN2=ALOG(2.)
        SRLN2=SQRT(LN2)
        EPSI=0.099
C
C
C       CALCULATE H.C. A AND VOIGTIAN FWHM
C
        AHC=SRLN2*(HWLOHC/HWGAHC)                 !  = YHC
        BLHC=0.5*HWLOHC
        BVHC=BLHC/L(AHC)
        HWVOHC=BVHC*2.                            !  = HWLOHC/L(AHC)
C
C
C       FIND H.C. LINE SHAPE
C       FILL HVAL-ARRAY WITH KIELKOPF´S VALUES FOR 20NE KOMPONENT
C
        XMAX=10.                           !  = 10 VOIGTIAN HWHM = 5 FWHM
        XINCHC=2.*XMAX/1000.               !  = 1/50 (1001 VALUES)
        WLINC=XINCHC*(HWVOHC/2.)           !  = 1/50 HWHMVOHC
        HVAL(501)=U(0.,AHC)
        DO 10 I=1,500
        X=FLOAT(I)*XINCHC
 10     HVAL(501+I)=U(X,AHC)
        DO 20 I=1,500
 20     HVAL(I)=HVAL(1002-I)
C
C       ADD SECOND LINE COMPONENT DUE TO ISOTOPE SHIFT.
C       DETERMINE HOW MANY STEPS THE 22NE COMPONENT IS AWAY FROM
C       THE MAIN COMPONENT. EXACT TO WITHIN 1/50 HWHMVOHC (<1 MILANG).
C       (N.B.: THE SECOND ISOTOPE SHOULD HAVE A DIFFERENT DOPPLER
C       WIDTH. NOT CONSIDERED HERE.)
C
        IIS=IFIX(IS/WLINC+0.5)
C
        DO 22 I=1,1001
        IF ((I+IIS).GT.1001) GOTO 22
        HVAL(I)=HVAL(I)+ARAT*HVAL(I+IIS)          !  LINE FROM HEAVIER ISOTOPE IS
                                                  !  BLUE-SHIFTED
 22     CONTINUE
```

```
C
C
C       STORE X-VALUES FOR PLOTTING (IN MILLIANGSTROM)
C
        DO 25 I=1,1001
 25     XARMA(I)=-XMAX*(HWVOHC/2.)+FLOAT(I-1)*WLINC
C
C
C       NORMALIZE H.C. LINE SHAPE TO UNIT AREA (MILLIANGSTROM-UNITS !)
C       INTEGRATE OVER UNNORMALIZED H.C. LINE
C
        CALL SIMINT (HVAL,1,1,1001,WLINC,HINT)
C
C       NORMALIZE VOIGT PROFILE
C
        DO 30 I=1,1001
 30     HVAL(I)=HVAL(I)/HINT
C
C
C       STORE H.C. LINE PROFILE IN DATA FILE
C
        IF (IPLDEC.EQ.'Y') CALL DATFIL (1001,XARMA,HVAL,1000.,0.)
C
C
C       CALCULATE F.D. DOPPLER AND GAUSSIAN WIDTH
C
        TFD=300.                                !  TEMPERATURE OF F.D.
        HWDOFD=7.16E-7*SQRT(TFD/20.)*WL*1000.   !  ONLY O.K. FOR 20NE
        WRITE (5,1120)
        WRITE (5,1180) HWDOFD
 35     WRITE (5,1130)
        READ (5,*) ADGAFD
        HWGAFD=HWDOFD+ADGAFD
C
C
C       CALCULATE F.D. A AND NATURAL WIDTH
C
        HWNAFD=(WL*WL*ASUM*1.E-8)/(6.*PI)
        WRITE (5,1150)
        WRITE (5,1180) HWNAFD
C
C       CALCULATE F.D. LORENTZIAN WIDTH
C
        HWLOFD=HWPRFD+HWNAFD
        AFD=SRLN2*(HWLOFD/HWGAFD)
C
C
C       CALCULATE F.D. VOIGTIAN WIDTH
C
        BLFD=0.5*HWLOFD
        BVFD=BLFD/L(AFD)
        HWVOFD=BVFD*2.            !  = HWLOFD/L(AFD)
C
C
C       CALCULATE H.C. LINE SHIFT IN TERMS OF F.D. VOIGTIAN FWHM.
C       BUT F.D. LINE SHAPE IS CALCULATED WITH OFFSET ORIGIN.
C
        HCSHX=HCSH/(HWVOFD/2.)
C
C
C       FIND F.D. LINE SHAPE
C
        XINCFD=XINCHC*(HWVOHC/HWVOFD)
        XMAXFD=XMAX*(HWVOHC/HWVOFD)
        FVAL(501)=U(HCSHX,AFD)   !  F.D. LINE 'BLUE-SHIFTED'=
        DO 40 I=1,500            !  H.C. LINE RED-SHIFTED
 40     FVAL(501+I)=U(HCSHX+FLOAT(I)*XINCFD,AFD)
        DO 50 I=1,500
 50     FVAL(I)=U(-XMAXFD+FLOAT(I-1)*XINCFD+HCSHX,AFD)
C
C
C       ADD SECOND LINE COMPONENT DUE TO ISOTOPE SHIFT (INTENSITY
C       REDUCED ACCORDING TO ABUNDANCE RATIO)
C
        DO 52 I=1,1001
        IF ((I+IIS).GT.1001) GOTO 52
        FVAL(I)=FVAL(I)+ARAT*FVAL(I+IIS)
 52     CONTINUE
```

```
C
C
C       FIND MAXIMUM VALUE OF F.D. LINE FUNCTION
C
        FDMAX=FVAL(1)
        DO 54 I=2,1001
        IF (FVAL(I).GT.FDMAX) FDMAX=FVAL(I)
 54     CONTINUE
C
C
C       NORMALIZE F.D. LINE SHAPE TO PEAK VALUE = 1
C
        DO 56 I=1,1001
 56     FVAL(I)=FVAL(I)/FDMAX
C
C
C       CALCULATE INTEGRAL OVER F.D. LINE PROFILE
C
        CALL SIMINT (FVAL,1,1,1001,WLINC,FINT)
C
C
C       CALCULATE SCALING FACTOR FOR F.D. TO GET SAME INTENSITY
C       SCALE FOR H.C. AND F.D.
C
C       FDSCLF=1./FINT*RIFDHC*1000.
C
C
C       STORE F.D. LINE PROFILE IN DATA FILE
C
        IF (IPLDEC.EQ.'Y') CALL DATFIL (1001,XARMA,FVAL,10.,10.)
C
C
C       WRITE RESULTS EXCEPT REDUCTION FACTOR
C
        WRITE (5,1160)
        WRITE (5,1180) HWVOFD
        WRITE (5,1170)
        WRITE (5,1180) HWVOHC
        WRITE (5,1153)
        WRITE (5,1180) AFD
        WRITE (5,1156)
        WRITE (5,1180) AHC
C
C
C       READ PEAK OPTICAL DEPTH
C
        WRITE (5,1100)
        READ (5,*) POD
C
C
C       CALCULATE EXP-FACTOR
C
        DO 60 I=1,1001
        IF ((-POD*FVAL(I)).LE.-80.) GOTO 65
        COAB(I)=EXP(-POD*FVAL(I))
        GOTO 60
 65     COAB(I)=0.
 60     CONTINUE
C
C       STORE CONTINUUM ABSORTION PROFILE WITHOUT
C       F.D. EMISSION IN DATA FILE.
C
        IF (IPLDEC.EQ.'Y') CALL DATFIL (1001,XARMA,COAB,10.,10.)
C
C       CALCULATE INTEGRAL
C       CALCULATE INTEGRANT AND PUT INTO I1-ARRAY
C
        DO 70 I=1,1001
 70     I1(I)=HVAL(I)*COAB(I)
C
C
C       CALCULATE H.C. ABSORPTION PROFILE INCLUDING F.D. EMISSION
C
        DO 75 I=1,1001
 75     HCAB(I)=I1(I)+FVAL(I)*1./FINT*RIFDHC
```

```
C
C
C       STORE ABSORPTION PROFILE INCLUDING F.D. EMISSION IN DATA FILE
C
        IF (IPLDEC.EQ.'Y') CALL DATFIL (1001,XARMA,HCAB,1000.,0.)
C
        CALL SIMINT (I1,1,1,1001,WLINC,II1)
C
C
C       FIRST CONTRIBUTION TO RECIPROCAL OF R.F.
C
        RRF=II1
C
C
C       ADD SECOND TERM OF RRF
C
        RRF=RRF+RIFDHC
C
C
C       CALCULATE RECIPROCAL
C
        RF=1./RRF
C
        WRITE (5,1200)
        WRITE (5,1180) RF
C
        READ (5,2010) N
        IF (N.EQ.'Y') GOTO 35
 80     READ (5,2010) N
        IF (N.EQ.' ') GOTO 5
        STOP
        END
```

Function Subroutine 'VOIGT'

```
        FUNCTION U(X,A)
C
C       CALCULATION OF VOIGT-FUNCTION ACCORDING TO KIELKOPF
C       JOURNAL OF THE OPTICAL SOCIETY OF AMERICA, VOL. 63,
C       NO. 8,AUGUST 1973, PP. 987-995
C       X = DISTENCE FROM LINE CENTRE IN TERMS OF VOHWHM
C       A=SQRT(LOG(2))*(LORENTZIAN WIDTH/GAUSSIAN WIDTH)=BL/BG
C
        REAL LORENZ,LN2,L,LOX
        GAUSS(X)=EXP(-ALOG(2.)*X*X)
        LORENZ(X)=1./(1.+X*X)
        EFCT(X)=(0.8029-0.4207*X*X)/(1.+0.2030*X*X+0.07335*X**4)
        LN2=ALOG(2.)
        EPSI=0.099
        L=2./(1.+EPSI*LN2+SQRT((1.-EPSI*LN2)**2+(4.*LN2/A**2)))
        G2=(1./LN2)*(1.-(1.+EPSI*LN2)*L+(EPSI*LN2)*L**2)
        ETA=L/(L+G2)
        IF ((-ALOG(2.)*X*X).LE.-38.) GOTO 10
        GAX=GAUSS(X)
        GOTO 20
 10     GAX=0.
 20     CONTINUE
        LOX=LORENZ(X)
        EX=EFCT(X)
        U=(1.-ETA)*GAX+ETA*LOX+ETA*(1.-ETA)*EX*(GAX-LOX)
        RETURN
        END
```

Appendix VI: Listing of Programme 'COG'

This Appendix gives the listing of the curve of growth programme 'COG' discussed in Chapter VII. The programme was written in FORTRAN IV.

```
              PROGRAM COG
C
C
C       THIS PROGRAMME CALCULATES THE PEAK OPTICAL DEPTH
C       FOR AN ABSORPTION LINE FROM THE COLUMN DENSITY OF
C       THE ABSORBING SLAB AND THE DATA OF THE LINE
C       (VOIGTIAN WIDTH, DAMPING RATIO A=SQRT(LOG(2))*DLL/DLG,
C       G'S, ISOTOPE SHIFT AND ABUNDANCES, AND WAVELENGTH).
C       THE EQUIVALENT WIDTH OF THE ABSORPTION LINE
C       IS CALCULATED ACCORDING TO EQUATION
C       (9.28) IN A.P. THORNE, SPECTROPHYSICS, P. 306.
C
        DIMENSION FVAL(4001),ARR(4001)
        REAL N,IS
C
 1000   FORMAT (X,$,'WAVELENGTH [ANGSTROM].............? ')
 1010   FORMAT ('+',$,'GU...............................? ')
 1020   FORMAT ('+',$,'GL...............................? ')
 1030   FORMAT ('+',$,'AUL [1E7*SEC**-1]................? ')
 1035   FORMAT ('+',$,'ISOTOPE SHIFT [MILLIANGSTROM].....? ')
 1040   FORMAT ('+',$,'A (DAMPING RATIO).................? ')
 1050   FORMAT ('+',$,'VOIGTIAN FWHM [MILLIANGSTROM].....? ')
 1060   FORMAT ('+',$,'COLUMN DENSITY N [1E10*CM**-2]....? ')
 1070   FORMAT ('+','PEAK OPTICAL DEPTH................= ',F12.1)
 1080   FORMAT (X,'EQUIV. WIDTH [MILLIANGSTROM]......= ',F12.1)
C
 2000   FORMAT (A1)
C
 5      WRITE (5,1000)
        READ (5,*) WLA
        WL=WLA/10000.                    ! WAVELENGTH IN MICRONS
        WRITE (5,1010)
        READ (5,*) GU
        WRITE (5,1020)
        READ (5,*) GL
        WRITE (5,1030)
        READ (5,*) AUL
        WRITE (5,1035)
        READ (5,*) IS
 10     WRITE (5,1040)
        READ (5,*) A
        WRITE (5,1050)
        READ (5,*) VOFWHM
        VOHWHM=VOFWHM/2.
C
C
C       NEON ABUNDANCE
C
        A20NE=0.907
        A22NE=0.093
        ARAT=A22NE/A20NE                 !   < 1
C
C
C       NUMBER OF POINTS IN LINE PROFILE
C
        NPTS=1000*IFIX(VOFWHM/29.+0.5)+1
C
        XMAX=20.          ! THOUGH XMAX=10 IN REFA, SINCE HWVOFD<<HWVOHC
        XINC=XMAX*2./FLOAT(NPTS-1)       !  =  1/50
        WLINC=XINC*VOHWHM                !  <  0.17 MILLIANGSTROMS
C
C
C       CALCULATE F.D. LINE PROFILE
C
        DO 20 I=1,NPTS
 20     FVAL(I)=U(-XMAX+FLOAT(I-1)*XINC,A)
```

```
C
C       DETERMINE HOW MANY STEPS THE 22NE COMPONENT
C       IS AWAY FROM THE MAIN COMPONENT. EXACT TO WITHIN
C       1/25 HWHMVOFD ( < 2/5 MILLIANGSTROMS).
C
        IIS=IFIX(IS/WLINC+0.5)
C
C       ADD SECOND LINE COMPONENT DUE TO ISOTOPE SHIFT
C       (INTENSITY REDUCED ACCORDING TO ABUNDANCE RATIO (<1) )
C
        DO 22 I=1,NPTS
        IF ((I+IIS).GT.NPTS) GOTO 22
        FVAL(I)=FVAL(I)+ARAT*FVAL(I+IIS)
 22     CONTINUE
C
C
C       FIND MAXIMUM VALUE OF F.D. LINE FUNCTION
C
        FDMAX=FVAL(1)
        DO 24 I=2,NPTS
        IF (FVAL(I).GT.FDMAX) FDMAX=FVAL(I)
 24     CONTINUE
C
C
C       NORMALIZE F.D. LINE SHAPE TO PEAK VALUE = 1
C
        DO 26 I=1,NPTS
 26     FVAL(I)=FVAL(I)/FDMAX
C
        CALL SIMINT (FVAL,1,1,NPTS,WLINC,FINT)
C
C
 30     WRITE (5,1060)
        READ (5,*) N
C
        POD=(WL**4*(GU/GL)*AUL*N*1.326)/FINT
        WRITE (5,1070) POD
C
        DO 40 I=1,NPTS
        IF (-POD*FVAL(I).LT.-80.) GOTO 45
        ARR(I)=(1.-EXP(-POD*FVAL(I)))
        GOTO 40
 45     ARR(I)=1.
 40     CONTINUE
C
        CALL SIMINT (ARR,1,1,NPTS,WLINC,EQWI)
C
        WRITE (5,1080) EQWI
C
        READ (5,2000) N
        IF (N.EQ.'Y') GOTO 30
        READ (5,2000) N
        IF (N.EQ.'Y') GOTO 10
        READ (5,2000) N
        IF (N.EQ.' ') GOTO 5
        STOP
        END
```

Appendix VII: Modelling - Computer Output

The charts in this appendix show the computer output which was produced when running the reduction factor programme 'REFA' (for a listing see Appendix V) to calculate the modelling data discussed in Chapter VII.3. An excerpt of the explanations of the computer output which were given in Chapter VII.2 is reproduced here for convenience:

" 296 reduction factor calculations are documented by the corresponding computer output. The whole set of results has the following order. It consists of eight subsets, each subset consisting of six pages; each page corresponds to one spectrum line (lines 1-7, 1-5, 3-9, 3-6, 2-4, 1-2). The first four lines are 'normal' metastable lines, i.e. relatively strong and moderately affected by self-absorption/reversal. The 2-4 line is a strong line with the 'semi-metastable' s2 level as lower state (see Chapter III.6), and the 1-2 line is the strongest line with a metastable lower state and is strongly affected by self-absorption/reversal.

The eight subsets give results for different situations. The first three lines on each page give information on the spectrum line and the particular situation. Each page comprises 6 (7) runs, each run for a different filter discharge Gaussian width; the differences are manifested by different 'additional F.D. Gaussian FWHM [mÅ]', which have been chosen to be equal to 0, 5, 10, 20, 40, 60 (,80) mÅ. "

Subset 1

Case 1

```
GAS AND LINE................? NEON, 1-7, 5945
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 5945
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 29
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.22
F.D. PRESSURE FWHM [MILLIANGSTROM]............? .5
ISOTOPE SHIFT [MILLIANGSTROM].................? 20.2
RATIO OF F.D. TO H.C. INTENSITY...............? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=          16.4858
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          16.8076
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          30.6366
CALCULATED F.D. A..............................=           0.0302
CALCULATED H.C. A..............................=           0.0861
F.D. PEAK OPTICAL DEPTH........................? 34.8
CALCULATED REDUCTION FACTOR....................=           7.7116

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          21.8071
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          30.6366
CALCULATED F.D. A..............................=           0.0232
CALCULATED H.C. A..............................=           0.0861
F.D. PEAK OPTICAL DEPTH........................? 27.1
CALCULATED REDUCTION FACTOR....................=          11.3272

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          26.8067
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          30.6366
CALCULATED F.D. A..............................=           0.0188
CALCULATED H.C. A..............................=           0.0861
F.D. PEAK OPTICAL DEPTH........................? 22.4
CALCULATED REDUCTION FACTOR....................=          15.8682

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          36.8063
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          30.6366
CALCULATED F.D. A..............................=           0.0136
CALCULATED H.C. A..............................=           0.0861
F.D. PEAK OPTICAL DEPTH........................? 16.7
CALCULATED REDUCTION FACTOR....................=          25.7821

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          56.8060
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          30.6366
CALCULATED F.D. A..............................=           0.0088
CALCULATED H.C. A..............................=           0.0861
F.D. PEAK OPTICAL DEPTH........................? 11.1
CALCULATED REDUCTION FACTOR....................=          40.6175

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          76.8058
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          30.6366
CALCULATED F.D. A..............................=           0.0065
CALCULATED H.C. A..............................=           0.0861
F.D. PEAK OPTICAL DEPTH........................? 8.3
CALCULATED REDUCTION FACTOR....................=          49.1276
```

Case 2

```
GAS AND LINE................? NEON, 1-5, 6143
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]..........................? 6143
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 36
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.01
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=         17.0349
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         17.3038
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         37.6300
CALCULATED F.D. A..............................=          0.0245
CALCULATED H.C. A..............................=          0.0694
F.D. PEAK OPTICAL DEPTH........................? 79.4
CALCULATED REDUCTION FACTOR....................=          7.7979

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         22.3034
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         37.6300
CALCULATED F.D. A..............................=          0.0189
CALCULATED H.C. A..............................=          0.0694
F.D. PEAK OPTICAL DEPTH........................? 62.1
CALCULATED REDUCTION FACTOR....................=         11.5154

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         27.3032
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         37.6300
CALCULATED F.D. A..............................=          0.0154
CALCULATED H.C. A..............................=          0.0694
F.D. PEAK OPTICAL DEPTH........................? 51.2
CALCULATED REDUCTION FACTOR....................=         16.4163

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         37.3029
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         37.6300
CALCULATED F.D. A..............................=          0.0112
CALCULATED H.C. A..............................=          0.0694
F.D. PEAK OPTICAL DEPTH........................? 38.4
CALCULATED REDUCTION FACTOR....................=         27.9311

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         57.3027
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         37.6300
CALCULATED F.D. A..............................=          0.0073
CALCULATED H.C. A..............................=          0.0694
F.D. PEAK OPTICAL DEPTH........................? 25.8
CALCULATED REDUCTION FACTOR....................=         45.2239

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         77.3026
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         37.6300
CALCULATED F.D. A..............................=          0.0054
CALCULATED H.C. A..............................=          0.0694
F.D. PEAK OPTICAL DEPTH........................? 19.4
CALCULATED REDUCTION FACTOR....................=         55.5641
```

```
GAS AND LINE...............? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 33
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM].................? 20.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A.............................=          0.0148
CALCULATED H.C. A.............................=          0.0757
F.D. PEAK OPTICAL DEPTH.......................? 58.6
CALCULATED REDUCTION FACTOR...................=          7.4734
```

Case 3

```
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        22.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A.............................=          0.0115
CALCULATED H.C. A.............................=          0.0757
F.D. PEAK OPTICAL DEPTH.......................? 45.8
CALCULATED REDUCTION FACTOR...................=         11.1700
```

Case 4

```
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A.............................=          0.0094
CALCULATED H.C. A.............................=          0.0757
F.D. PEAK OPTICAL DEPTH.......................? 37.9
CALCULATED REDUCTION FACTOR...................=         15.8797
```

```
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.2534
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A.............................=          0.0068
CALCULATED H.C. A.............................=          0.0757
F.D. PEAK OPTICAL DEPTH.......................? 28.4
CALCULATED REDUCTION FACTOR...................=         26.2213
```

Case 5

```
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        57.2533
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A.............................=          0.0044
CALCULATED H.C. A.............................=          0.0757
F.D. PEAK OPTICAL DEPTH.......................? 19.0
CALCULATED REDUCTION FACTOR...................=         40.6072
```

```
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        77.2532
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A.............................=          0.0033
CALCULATED H.C. A.............................=          0.0757
F.D. PEAK OPTICAL DEPTH.......................? 14.2
CALCULATED REDUCTION FACTOR...................=         49.0872
```

Case 6

Case 7

```
GAS AND LINE...............? NEON, 3-6, 6266
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6266
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 37
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.13
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 21.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.012
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.3760
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        17.5405
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.6293
CALCULATED F.D. A..............................=         0.0147
CALCULATED H.C. A..............................=         0.0675
F.D. PEAK OPTICAL DEPTH........................? 85.8
CALCULATED REDUCTION FACTOR....................=         7.3199

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        22.5404
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.6293
CALCULATED F.D. A..............................=         0.0114
CALCULATED H.C. A..............................=         0.0675
F.D. PEAK OPTICAL DEPTH........................? 67.3
CALCULATED REDUCTION FACTOR....................=        10.9188

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.5403
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.6293
CALCULATED F.D. A..............................=         0.0093
CALCULATED H.C. A..............................=         0.0675
F.D. PEAK OPTICAL DEPTH........................? 55.7
CALCULATED REDUCTION FACTOR....................=        15.6872

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.5402
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.6293
CALCULATED F.D. A..............................=         0.0068
CALCULATED H.C. A..............................=         0.0675
F.D. PEAK OPTICAL DEPTH........................? 41.9
CALCULATED REDUCTION FACTOR....................=        26.9385

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        57.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.6293
CALCULATED F.D. A..............................=         0.0045
CALCULATED H.C. A..............................=         0.0675
F.D. PEAK OPTICAL DEPTH........................? 28.1
CALCULATED REDUCTION FACTOR....................=        43.3570

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        77.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.6293
CALCULATED F.D. A..............................=         0.0033
CALCULATED H.C. A..............................=         0.0675
F.D. PEAK OPTICAL DEPTH........................? 21.1
CALCULATED REDUCTION FACTOR....................=        52.7319
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GAS AND LINE...............? NEON, 2-4, 6383
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6383
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 31          Case 8
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.02
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.034
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7004
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.8658
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.6344
CALCULATED F.D. A..............................=       0.0145
CALCULATED H.C. A..............................=       0.0806
F.D. PEAK OPTICAL DEPTH........................? 3.3
CALCULATED REDUCTION FACTOR....................=       2.3352

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.8657
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.6344
CALCULATED F.D. A..............................=       0.0113
CALCULATED H.C. A..............................=       0.0806
F.D. PEAK OPTICAL DEPTH........................? 2.6
CALCULATED REDUCTION FACTOR....................=       2.5491

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.8656
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.6344
CALCULATED F.D. A..............................=       0.0093
CALCULATED H.C. A..............................=       0.0806
F.D. PEAK OPTICAL DEPTH........................? 2.2
CALCULATED REDUCTION FACTOR....................=       2.6847

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.8655         Case 9
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.6344
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0806
F.D. PEAK OPTICAL DEPTH........................? 1.6
CALCULATED REDUCTION FACTOR....................=       2.5678

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.6344
CALCULATED F.D. A..............................=       0.0045
CALCULATED H.C. A..............................=       0.0806
F.D. PEAK OPTICAL DEPTH........................? 1.1
CALCULATED REDUCTION FACTOR....................=       2.2408

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.6344
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.8
CALCULATED REDUCTION FACTOR....................=       1.8901
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GAS AND LINE...............? NEON, 1-2, 6402
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6402
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 55                 Case 10
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.06
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.5
RATIO OF F.D. TO H.C. INTENSITY................? 0.016
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.7531
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        18.0272
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.6207
CALCULATED F.D. A..............................=         0.0239
CALCULATED H.C. A..............................=         0.0454
F.D. PEAK OPTICAL DEPTH........................? 252.7
CALCULATED REDUCTION FACTOR....................=         6.0404

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        23.0269
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.6207
CALCULATED F.D. A..............................=         0.0187
CALCULATED H.C. A..............................=         0.0454
F.D. PEAK OPTICAL DEPTH........................? 199.4
CALCULATED REDUCTION FACTOR....................=         7.9628

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        28.0266
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.6207
CALCULATED F.D. A..............................=         0.0153
CALCULATED H.C. A..............................=         0.0454
F.D. PEAK OPTICAL DEPTH........................? 165.8
CALCULATED REDUCTION FACTOR....................=        10.6906

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.0264      Case 11
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.6207
CALCULATED F.D. A..............................=         0.0112
CALCULATED H.C. A..............................=         0.0454
F.D. PEAK OPTICAL DEPTH........................? 125.0
CALCULATED REDUCTION FACTOR....................=        18.6075

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        58.0261
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.6207
CALCULATED F.D. A..............................=         0.0074
CALCULATED H.C. A..............................=         0.0454
F.D. PEAK OPTICAL DEPTH........................? 84.5
CALCULATED REDUCTION FACTOR....................=        35.4524

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        78.0260      Case 12
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.6207
CALCULATED F.D. A..............................=         0.0055
CALCULATED H.C. A..............................=         0.0454
F.D. PEAK OPTICAL DEPTH........................? 63.7
CALCULATED REDUCTION FACTOR....................=        43.4687

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 80
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        98.0259
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.6207
CALCULATED F.D. A..............................=         0.0043
CALCULATED H.C. A..............................=         0.0454
F.D. PEAK OPTICAL DEPTH........................? 51.0
CALCULATED REDUCTION FACTOR....................=        47.8487
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Subset 2

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GAS AND LINE................? NEON, 1-7, 5945
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, HALF LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 5945
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 29
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.22
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.5
ISOTOPE SHIFT [MILLIANGSTROM].................? 20.2
RATIO OF F.D. TO H.C. INTENSITY...............? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=         16.4858
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         16.8076
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         30.6366
CALCULATED F.D. A..............................=          0.0302
CALCULATED H.C. A..............................=          0.0861
F.D. PEAK OPTICAL DEPTH........................? 17.5
CALCULATED REDUCTION FACTOR....................=          5.7483


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         21.8071
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         30.6366
CALCULATED F.D. A..............................=          0.0232
CALCULATED H.C. A..............................=          0.0861
F.D. PEAK OPTICAL DEPTH........................? 13.6
CALCULATED REDUCTION FACTOR....................=          7.9946


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         26.8067
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         30.6366
CALCULATED F.D. A..............................=          0.0188
CALCULATED H.C. A..............................=          0.0861
F.D. PEAK OPTICAL DEPTH........................? 11.2
CALCULATED REDUCTION FACTOR....................=         10.7583


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         36.8063
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         30.6366
CALCULATED F.D. A..............................=          0.0136
CALCULATED H.C. A..............................=          0.0861
F.D. PEAK OPTICAL DEPTH........................? 8.4
CALCULATED REDUCTION FACTOR....................=         16.9581


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         56.8060
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         30.6366
CALCULATED F.D. A..............................=          0.0088
CALCULATED H.C. A..............................=          0.0861
F.D. PEAK OPTICAL DEPTH........................? 5.6
CALCULATED REDUCTION FACTOR....................=         24.0406


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=          0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=         76.8058
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=         30.6366
CALCULATED F.D. A..............................=          0.0065
CALCULATED H.C. A..............................=          0.0861
F.D. PEAK OPTICAL DEPTH........................? 5.2
CALCULATED REDUCTION FACTOR....................=         31.0708
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GAS AND LINE................? NEON, 1-5, 6143
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, HALF LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6143
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 36
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.01
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.0349
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        17.3038
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0245
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 39.8
CALCULATED REDUCTION FACTOR....................=         6.1977


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        22.3034
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0189
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 31.1
CALCULATED REDUCTION FACTOR....................=         8.7566


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.3032
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0154
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 25.7
CALCULATED REDUCTION FACTOR....................=        12.1216


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.3029
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0112
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 19.2
CALCULATED REDUCTION FACTOR....................=        20.7578


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        57.3027
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0073
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 12.9
CALCULATED REDUCTION FACTOR....................=        37.3051

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        77.3026
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0054
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 9.7
CALCULATED REDUCTION FACTOR....................=        47.3706
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GAS AND LINE................? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, HALF LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]..........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 33
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0148
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 29.4
CALCULATED REDUCTION FACTOR....................=       5.9605
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Case 13

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0115
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 23.0
CALCULATED REDUCTION FACTOR....................=       8.4506

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0094
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 19.0
CALCULATED REDUCTION FACTOR....................=      11.6502

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.2534
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 14.2
CALCULATED REDUCTION FACTOR....................=      19.3969
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Case 14

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.2533
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0044
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 9.5
CALCULATED REDUCTION FACTOR....................=      32.4854

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.2532
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 7.2
CALCULATED REDUCTION FACTOR....................=      38.8125
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GAS AND LINE................? NEON, 3-6, 6266
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, HALF LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6266
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 37
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.13
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM].................? 21.9
RATIO OF F.D. TO H.C. INTENSITY...............? 0.012
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.3760
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.5405
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.6293
CALCULATED F.D. A..............................=       0.0147
CALCULATED H.C. A..............................=       0.0675
F.D. PEAK OPTICAL DEPTH........................? 43.0
CALCULATED REDUCTION FACTOR....................=       5.9675

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.5404
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.6293
CALCULATED F.D. A..............................=       0.0114
CALCULATED H.C. A..............................=       0.0675
F.D. PEAK OPTICAL DEPTH........................? 33.7
CALCULATED REDUCTION FACTOR....................=       8.4828

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5403
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.6293
CALCULATED F.D. A..............................=       0.0093
CALCULATED H.C. A..............................=       0.0675
F.D. PEAK OPTICAL DEPTH........................? 27.9
CALCULATED REDUCTION FACTOR....................=      11.8080

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5402
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.6293
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0675
F.D. PEAK OPTICAL DEPTH........................? 21.0
CALCULATED REDUCTION FACTOR....................=      20.4448

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.6293
CALCULATED F.D. A..............................=       0.0045
CALCULATED H.C. A..............................=       0.0675
F.D. PEAK OPTICAL DEPTH........................? 14.1
CALCULATED REDUCTION FACTOR....................=      36.5798

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.6293
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0675
F.D. PEAK OPTICAL DEPTH........................? 10.6
CALCULATED REDUCTION FACTOR....................=      46.1556
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GAS AND LINE...............? NEON, 2-4, 6383
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, HALF LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6383
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 31
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.02
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.034
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.7004
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        17.8658
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0145
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 1.7
CALCULATED REDUCTION FACTOR....................=         1.7128
```

Case 15

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        22.8657
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0113
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 1.3
CALCULATED REDUCTION FACTOR....................=         1.7223

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.8656
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0093
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 1.1
CALCULATED REDUCTION FACTOR....................=         1.7305

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.8655
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0068
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.8
CALCULATED REDUCTION FACTOR....................=         1.6325
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Case 16

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        57.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0045
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.55
CALCULATED REDUCTION FACTOR....................=         1.4902

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        77.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0033
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.4
CALCULATED REDUCTION FACTOR....................=         1.3588
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GAS AND LINE...............? NEON, 1-2, 6402
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, HALF LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6402
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 55          Case 17
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.06
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM].................? 22.5
RATIO OF F.D. TO H.C. INTENSITY...............? 0.016
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7531
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      18.0272
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A.............................=       0.0239
CALCULATED H.C. A.............................=       0.0454
F.D. PEAK OPTICAL DEPTH.......................? 126.6
CALCULATED REDUCTION FACTOR...................=       4.8113

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      23.0269
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A.............................=       0.0187
CALCULATED H.C. A.............................=       0.0454
F.D. PEAK OPTICAL DEPTH.......................? 99.9
CALCULATED REDUCTION FACTOR...................=       6.3186

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      28.0266
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A.............................=       0.0153
CALCULATED H.C. A.............................=       0.0454
F.D. PEAK OPTICAL DEPTH.......................? 83.0
CALCULATED REDUCTION FACTOR...................=       8.3891

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.0264        Case 18
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A.............................=       0.0112
CALCULATED H.C. A.............................=       0.0454
F.D. PEAK OPTICAL DEPTH.......................? 62.6
CALCULATED REDUCTION FACTOR...................=      14.5266

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.0261
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A.............................=       0.0074
CALCULATED H.C. A.............................=       0.0454
F.D. PEAK OPTICAL DEPTH.......................? 42.3
CALCULATED REDUCTION FACTOR...................=      30.6320

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      78.0260
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A.............................=       0.0055
CALCULATED H.C. A.............................=       0.0454
F.D. PEAK OPTICAL DEPTH.......................? 31.9
CALCULATED REDUCTION FACTOR...................=      40.5003

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 80
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      98.0259
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A.............................=       0.0043
CALCULATED H.C. A.............................=       0.0454
F.D. PEAK OPTICAL DEPTH.......................? 25.6
CALCULATED REDUCTION FACTOR...................=      45.5279
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Subset 3

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GAS AND LINE...............? NEON, 1-7, 5945
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, QUATRE LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 5945
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 29
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.22
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.5
ISOTOPE SHIFT [MILLIANGSTROM].................? 20.2
RATIO OF F.D. TO H.C. INTENSITY...............? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        16.4858
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        16.8076
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        30.6366
CALCULATED F.D. A..............................=         0.0302
CALCULATED H.C. A..............................=         0.0861
F.D. PEAK OPTICAL DEPTH........................? 8.7
CALCULATED REDUCTION FACTOR....................=         4.1036

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        21.8071
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        30.6366
CALCULATED F.D. A..............................=         0.0232
CALCULATED H.C. A..............................=         0.0861
F.D. PEAK OPTICAL DEPTH........................? 6.8
CALCULATED REDUCTION FACTOR....................=         5.3174

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        26.8067
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        30.6366
CALCULATED F.D. A..............................=         0.0188
CALCULATED H.C. A..............................=         0.0861
F.D. PEAK OPTICAL DEPTH........................? 5.6
CALCULATED REDUCTION FACTOR....................=         6.5416

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        36.8063
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        30.6366
CALCULATED F.D. A..............................=         0.0136
CALCULATED H.C. A..............................=         0.0861
F.D. PEAK OPTICAL DEPTH........................? 4.2
CALCULATED REDUCTION FACTOR....................=         8.3203

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.8060
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        30.6366
CALCULATED F.D. A..............................=         0.0088
CALCULATED H.C. A..............................=         0.0861
F.D. PEAK OPTICAL DEPTH........................? 2.8
CALCULATED REDUCTION FACTOR....................=         7.6976

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        76.8058
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        30.6366
CALCULATED F.D. A..............................=         0.0065
CALCULATED H.C. A..............................=         0.0861
F.D. PEAK OPTICAL DEPTH........................? 2.1
CALCULATED REDUCTION FACTOR....................=         5.7356
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GAS AND LINE................? NEON, 1-5, 6143
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, QUATRE LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6143
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 36
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.01
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM].................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.0349
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        17.3038
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0245
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 19.9
CALCULATED REDUCTION FACTOR....................=         4.7869

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        22.3034
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0189
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 15.6
CALCULATED REDUCTION FACTOR....................=         6.4103

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.3032
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0154
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 12.8
CALCULATED REDUCTION FACTOR....................=         8.4204

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.3029
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0112
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 9.6
CALCULATED REDUCTION FACTOR....................=        13.5475

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        57.3027
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0073
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 6.5
CALCULATED REDUCTION FACTOR....................=        22.9877

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        77.3026
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.6300
CALCULATED F.D. A..............................=         0.0054
CALCULATED H.C. A..............................=         0.0694
F.D. PEAK OPTICAL DEPTH........................? 4.9
CALCULATED REDUCTION FACTOR....................=        24.3792
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GAS AND LINE................? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, QUATRE LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 33
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0148
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 14.7
CALCULATED REDUCTION FACTOR....................=       4.5504
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Case 19

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0115
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 11.5
CALCULATED REDUCTION FACTOR....................=       6.0766

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0094
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 9.5
CALCULATED REDUCTION FACTOR....................=       7.9266

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.2534
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 7.1
CALCULATED REDUCTION FACTOR....................=      12.0274
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Case 20

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.2533
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0044
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 4.8
CALCULATED REDUCTION FACTOR....................=      16.6107

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.2532
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 3.6
CALCULATED REDUCTION FACTOR....................=      14.2763
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GAS AND LINE................? NEON, 3-6, 6266
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, QUATRE LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6266
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 37
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.13
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 21.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.012
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=          17.3760
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          17.5405
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          38.6293
CALCULATED F.D. A..............................=           0.0147
CALCULATED H.C. A..............................=           0.0675
F.D. PEAK OPTICAL DEPTH........................? 21.5
CALCULATED REDUCTION FACTOR....................=           4.7298


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          22.5404
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          38.6293
CALCULATED F.D. A..............................=           0.0114
CALCULATED H.C. A..............................=           0.0675
F.D. PEAK OPTICAL DEPTH........................? 16.9
CALCULATED REDUCTION FACTOR....................=           6.3498


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          27.5403
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          38.6293
CALCULATED F.D. A..............................=           0.0093
CALCULATED H.C. A..............................=           0.0675
F.D. PEAK OPTICAL DEPTH........................? 14.0
CALCULATED REDUCTION FACTOR....................=           8.4234


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          37.5402
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          38.6293
CALCULATED F.D. A..............................=           0.0068
CALCULATED H.C. A..............................=           0.0675
F.D. PEAK OPTICAL DEPTH........................? 10.5
CALCULATED REDUCTION FACTOR....................=          13.7341


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          57.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          38.6293
CALCULATED F.D. A..............................=           0.0045
CALCULATED H.C. A..............................=           0.0675
F.D. PEAK OPTICAL DEPTH........................? 7.0
CALCULATED REDUCTION FACTOR....................=          23.7215


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          77.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          38.6293
CALCULATED F.D. A..............................=           0.0033
CALCULATED H.C. A..............................=           0.0675
F.D. PEAK OPTICAL DEPTH........................? 5.3
CALCULATED REDUCTION FACTOR....................=          26.4935
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GAS AND LINE................? NEON, 2-4, 6383
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, QUATRE LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6383
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 31
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.02
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.034
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.7004
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        17.8658
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0145
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.85
CALCULATED REDUCTION FACTOR....................=         1.3393

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        22.8657
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0113
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.65
CALCULATED REDUCTION FACTOR....................=         1.3240

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.8656
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0093
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.55
CALCULATED REDUCTION FACTOR....................=         1.3173

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.8655
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0068
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.4
CALCULATED REDUCTION FACTOR....................=         1.2668

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        57.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0045
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.28
CALCULATED REDUCTION FACTOR....................=         1.2085

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        77.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        32.6344
CALCULATED F.D. A..............................=         0.0033
CALCULATED H.C. A..............................=         0.0806
F.D. PEAK OPTICAL DEPTH........................? 0.20
CALCULATED REDUCTION FACTOR....................=         1.1476
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GAS AND LINE................? NEON, 1-2, 6402
HOLLOW CATHODE (H.C.).......? 350 MA
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR, QUATRE LENGTH
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]...........................? 6402
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 55
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.06
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.5
RATIO OF F.D. TO H.C. INTENSITY................? 0.016
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7531
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      18.0272
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A..............................=       0.0239
CALCULATED H.C. A..............................=       0.0454
F.D. PEAK OPTICAL DEPTH........................? 63.3
CALCULATED REDUCTION FACTOR....................=       4.0053

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      23.0269
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A..............................=       0.0187
CALCULATED H.C. A..............................=       0.0454
F.D. PEAK OPTICAL DEPTH........................? 49.9
CALCULATED REDUCTION FACTOR....................=       5.1255

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      28.0266
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A..............................=       0.0153
CALCULATED H.C. A..............................=       0.0454
F.D. PEAK OPTICAL DEPTH........................? 41.5
CALCULATED REDUCTION FACTOR....................=       6.6114

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.0264
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A..............................=       0.0112
CALCULATED H.C. A..............................=       0.0454
F.D. PEAK OPTICAL DEPTH........................? 31.3
CALCULATED REDUCTION FACTOR....................=      10.9828

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.0261
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A..............................=       0.0074
CALCULATED H.C. A..............................=       0.0454
F.D. PEAK OPTICAL DEPTH........................? 21.1
CALCULATED REDUCTION FACTOR....................=      24.1343

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      78.0260
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A..............................=       0.0055
CALCULATED H.C. A..............................=       0.0454
F.D. PEAK OPTICAL DEPTH........................? 15.9
CALCULATED REDUCTION FACTOR....................=      35.1362

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 80
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      98.0259
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.6207
CALCULATED F.D. A..............................=       0.0043
CALCULATED H.C. A..............................=       0.0454
F.D. PEAK OPTICAL DEPTH........................? 12.8
CALCULATED REDUCTION FACTOR....................=      41.3617
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Subset 4

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GAS AND LINE...............? NEON, 1-7, 5945
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]..........................? 5945
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 26
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.22
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.5
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.2
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        16.4858
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        16.8076
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.6404
CALCULATED F.D. A..............................=         0.0302
CALCULATED H.C. A..............................=         0.0961
F.D. PEAK OPTICAL DEPTH........................? 34.8
CALCULATED REDUCTION FACTOR....................=         9.0911

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        21.8071
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.6404
CALCULATED F.D. A..............................=         0.0232
CALCULATED H.C. A..............................=         0.0961
F.D. PEAK OPTICAL DEPTH........................? 27.1
CALCULATED REDUCTION FACTOR....................=        13.5330

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        26.8067
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.6404
CALCULATED F.D. A..............................=         0.0188
CALCULATED H.C. A..............................=         0.0961
F.D. PEAK OPTICAL DEPTH........................? 22.4
CALCULATED REDUCTION FACTOR....................=        18.7268

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        36.8063
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.6404
CALCULATED F.D. A..............................=         0.0136
CALCULATED H.C. A..............................=         0.0961
F.D. PEAK OPTICAL DEPTH........................? 16.7
CALCULATED REDUCTION FACTOR....................=        28.8423

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.8060
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.6404
CALCULATED F.D. A..............................=         0.0088
CALCULATED H.C. A..............................=         0.0961
F.D. PEAK OPTICAL DEPTH........................? 11.1
CALCULATED REDUCTION FACTOR....................=        43.0923

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        76.8058
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.6404
CALCULATED F.D. A..............................=         0.0065
CALCULATED H.C. A..............................=         0.0961
F.D. PEAK OPTICAL DEPTH........................? 8.3
CALCULATED REDUCTION FACTOR....................=        51.8065
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GAS AND LINE...............? NEON, 1-5, 6143
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6143
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 32
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.01
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=       17.0349
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       17.3038
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       33.6334
CALCULATED F.D. A..............................=        0.0245
CALCULATED H.C. A..............................=        0.0781
F.D. PEAK OPTICAL DEPTH........................? 79.4
CALCULATED REDUCTION FACTOR....................=        9.4267


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       22.3034
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       33.6334
CALCULATED F.D. A..............................=        0.0189
CALCULATED H.C. A..............................=        0.0781
F.D. PEAK OPTICAL DEPTH........................? 62.1
CALCULATED REDUCTION FACTOR....................=       14.2550


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.3032
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       33.6334
CALCULATED F.D. A..............................=        0.0154
CALCULATED H.C. A..............................=        0.0781
F.D. PEAK OPTICAL DEPTH........................? 51.2
CALCULATED REDUCTION FACTOR....................=       20.1803


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       37.3029
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       33.6334
CALCULATED F.D. A..............................=        0.0112
CALCULATED H.C. A..............................=        0.0781
F.D. PEAK OPTICAL DEPTH........................? 38.4
CALCULATED REDUCTION FACTOR....................=       32.0156


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       57.3027
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       33.6334
CALCULATED F.D. A..............................=        0.0073
CALCULATED H.C. A..............................=        0.0781
F.D. PEAK OPTICAL DEPTH........................? 25.8
CALCULATED REDUCTION FACTOR....................=       47.6869


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       77.3026
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       33.6334
CALCULATED F.D. A..............................=        0.0054
CALCULATED H.C. A..............................=        0.0781
F.D. PEAK OPTICAL DEPTH........................? 19.4
CALCULATED REDUCTION FACTOR....................=       58.0994
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GAS AND LINE...............? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3                    Case 21
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 30
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        31.6354
CALCULATED F.D. A..............................=         0.0148
CALCULATED H.C. A..............................=         0.0833
F.D. PEAK OPTICAL DEPTH........................? 58.6
CALCULATED REDUCTION FACTOR....................=         8.6952

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        22.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        31.6354
CALCULATED F.D. A..............................=         0.0115
CALCULATED H.C. A..............................=         0.0833
F.D. PEAK OPTICAL DEPTH........................? 45.8
CALCULATED REDUCTION FACTOR....................=        13.1960

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        27.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        31.6354
CALCULATED F.D. A..............................=         0.0094
CALCULATED H.C. A..............................=         0.0833
F.D. PEAK OPTICAL DEPTH........................? 37.9
CALCULATED REDUCTION FACTOR....................=        18.5636

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        37.2534        Case 22
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        31.6354
CALCULATED F.D. A..............................=         0.0068
CALCULATED H.C. A..............................=         0.0833
F.D. PEAK OPTICAL DEPTH........................? 28.4
CALCULATED REDUCTION FACTOR....................=        28.9381

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        57.2533
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        31.6354
CALCULATED F.D. A..............................=         0.0044
CALCULATED H.C. A..............................=         0.0833
F.D. PEAK OPTICAL DEPTH........................? 19.0
CALCULATED REDUCTION FACTOR....................=        42.2851

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        77.2532
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        31.6354
CALCULATED F.D. A..............................=         0.0033
CALCULATED H.C. A..............................=         0.0833
F.D. PEAK OPTICAL DEPTH........................? 14.2
CALCULATED REDUCTION FACTOR....................=        50.8222
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GAS AND LINE...............? NEON, 3-6, 6266
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6266
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 33
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.13
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 21.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.012
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.3760
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.5405
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0147
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 85.8
CALCULATED REDUCTION FACTOR....................=       8.8109

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.5404
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0114
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 67.3
CALCULATED REDUCTION FACTOR....................=      13.4638

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5403
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0093
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 55.7
CALCULATED REDUCTION FACTOR....................=      19.2263

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5402
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 41.9
CALCULATED REDUCTION FACTOR....................=      30.7882

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0045
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 28.1
CALCULATED REDUCTION FACTOR....................=      45.5110

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      34.6325
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0757
F.D. PEAK OPTICAL DEPTH........................? 21.1
CALCULATED REDUCTION FACTOR....................=      54.8780
```

Case 23

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GAS AND LINE................? NEON, 2-4, 6383
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6383
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 28
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.02
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM].................? 22.9
RATIO OF F.D. TO H.C. INTENSITY...............? 0.034
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=       17.7004
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       17.8658
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       29.6378
CALCULATED F.D. A..............................=        0.0145
CALCULATED H.C. A..............................=        0.0892
F.D. PEAK OPTICAL DEPTH........................? 3.3
CALCULATED REDUCTION FACTOR....................=        2.4972

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       22.8657
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       29.6378
CALCULATED F.D. A..............................=        0.0113
CALCULATED H.C. A..............................=        0.0892
F.D. PEAK OPTICAL DEPTH........................? 2.6
CALCULATED REDUCTION FACTOR....................=        2.7239

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.8656
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       29.6378
CALCULATED F.D. A..............................=        0.0093
CALCULATED H.C. A..............................=        0.0892
F.D. PEAK OPTICAL DEPTH........................? 2.2
CALCULATED REDUCTION FACTOR....................=        2.8522
```

Case 24

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       37.8655
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       29.6378
CALCULATED F.D. A..............................=        0.0068
CALCULATED H.C. A..............................=        0.0892
F.D. PEAK OPTICAL DEPTH........................? 1.6
CALCULATED REDUCTION FACTOR....................=        2.6747

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       57.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       29.6378
CALCULATED F.D. A..............................=        0.0045
CALCULATED H.C. A..............................=        0.0892
F.D. PEAK OPTICAL DEPTH........................? 1.1
CALCULATED REDUCTION FACTOR....................=        2.2828

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       77.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       29.6378
CALCULATED F.D. A..............................=        0.0033
CALCULATED H.C. A..............................=        0.0892
F.D. PEAK OPTICAL DEPTH........................? 0.8
CALCULATED REDUCTION FACTOR....................=        1.9070
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GAS AND LINE...............? NEON, 1-2, 6402
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].......................? 6402
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 49
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.06
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM].................? 22.5
RATIO OF F.D. TO H.C. INTENSITY...............? 0.016
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7531
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      18.0272
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      50.6228
CALCULATED F.D. A..............................=       0.0239
CALCULATED H.C. A..............................=       0.0510
F.D. PEAK OPTICAL DEPTH.......................? 252.7
CALCULATED REDUCTION FACTOR...................=       7.2839
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Case 25

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      23.0269
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      50.6228
CALCULATED F.D. A..............................=       0.0187
CALCULATED H.C. A..............................=       0.0510
F.D. PEAK OPTICAL DEPTH.......................? 199.4
CALCULATED REDUCTION FACTOR...................=       9.8943

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      28.0266
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      50.6228
CALCULATED F.D. A..............................=       0.0153
CALCULATED H.C. A..............................=       0.0510
F.D. PEAK OPTICAL DEPTH.......................? 165.8
CALCULATED REDUCTION FACTOR...................=      13.5445

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.0264
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      50.6228
CALCULATED F.D. A..............................=       0.0112
CALCULATED H.C. A..............................=       0.0510
F.D. PEAK OPTICAL DEPTH.......................? 125.0
CALCULATED REDUCTION FACTOR...................=      23.1105
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Case 26

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ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.0261
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      50.6228
CALCULATED F.D. A..............................=       0.0074
CALCULATED H.C. A..............................=       0.0510
F.D. PEAK OPTICAL DEPTH.......................? 84.5
CALCULATED REDUCTION FACTOR...................=      38.1222

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      78.0260
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      50.6228
CALCULATED F.D. A..............................=       0.0055
CALCULATED H.C. A..............................=       0.0510
F.D. PEAK OPTICAL DEPTH.......................? 63.7
CALCULATED REDUCTION FACTOR...................=      44.7399

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 80
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      98.0259
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      50.6228
CALCULATED F.D. A..............................=       0.0043
CALCULATED H.C. A..............................=       0.0510
F.D. PEAK OPTICAL DEPTH.......................? 51.0
CALCULATED REDUCTION FACTOR...................=      49.0343
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Subset 5

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GAS AND LINE................? NEON, 1-7, 5945
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED H.C. PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 5945
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 29
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.22
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.5
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.2
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=          16.4858
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          16.8076
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          29.5380
CALCULATED F.D. A..............................=           0.0302
CALCULATED H.C. A..............................=           0.0287
F.D. PEAK OPTICAL DEPTH........................? 34.9
CALCULATED REDUCTION FACTOR....................=          10.8352

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          21.8071
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          29.5380
CALCULATED F.D. A..............................=           0.0232
CALCULATED H.C. A..............................=           0.0287
F.D. PEAK OPTICAL DEPTH........................? 27.2
CALCULATED REDUCTION FACTOR....................=          16.7361

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          26.8067
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          29.5380
CALCULATED F.D. A..............................=           0.0188
CALCULATED H.C. A..............................=           0.0287
F.D. PEAK OPTICAL DEPTH........................? 22.4
CALCULATED REDUCTION FACTOR....................=          24.3238

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          36.8063
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          29.5380
CALCULATED F.D. A..............................=           0.0136
CALCULATED H.C. A..............................=           0.0287
F.D. PEAK OPTICAL DEPTH........................? 16.8
CALCULATED REDUCTION FACTOR....................=          41.2977

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          56.8060
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          29.5380
CALCULATED F.D. A..............................=           0.0088
CALCULATED H.C. A..............................=           0.0287
F.D. PEAK OPTICAL DEPTH........................? 11.2
CALCULATED REDUCTION FACTOR....................=          62.0492

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          76.8058
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          29.5380
CALCULATED F.D. A..............................=           0.0065
CALCULATED H.C. A..............................=           0.0287
F.D. PEAK OPTICAL DEPTH........................? 8.4
CALCULATED REDUCTION FACTOR....................=          68.7706
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GAS AND LINE................? NEON, 1-5, 6143
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED H.C. PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6143
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 36
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.01
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.0349
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.3038
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.5373
CALCULATED F.D. A..............................=       0.0245
CALCULATED H.C. A..............................=       0.0231
F.D. PEAK OPTICAL DEPTH........................? 79.6
CALCULATED REDUCTION FACTOR....................=      10.4005

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.3034
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.5373
CALCULATED F.D. A..............................=       0.0189
CALCULATED H.C. A..............................=       0.0231
F.D. PEAK OPTICAL DEPTH........................? 62.2
CALCULATED REDUCTION FACTOR....................=      16.2573

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.3032
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.5373
CALCULATED F.D. A..............................=       0.0154
CALCULATED H.C. A..............................=       0.0231
F.D. PEAK OPTICAL DEPTH........................? 51.3
CALCULATED REDUCTION FACTOR....................=      24.2723

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.3029
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.5373
CALCULATED F.D. A..............................=       0.0112
CALCULATED H.C. A..............................=       0.0231
F.D. PEAK OPTICAL DEPTH........................? 38.4
CALCULATED REDUCTION FACTOR....................=      43.2844

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.3027
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.5373
CALCULATED F.D. A..............................=       0.0073
CALCULATED H.C. A..............................=       0.0231
F.D. PEAK OPTICAL DEPTH........................? 25.8
CALCULATED REDUCTION FACTOR....................=      66.8467

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.3026
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.5373
CALCULATED F.D. A..............................=       0.0054
CALCULATED H.C. A..............................=       0.0231
F.D. PEAK OPTICAL DEPTH........................? 19.4
CALCULATED REDUCTION FACTOR....................=      75.1520
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Case 27

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GAS AND LINE................? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED H.C. PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 33
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=          17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          33.5376
CALCULATED F.D. A..............................=           0.0148
CALCULATED H.C. A..............................=           0.0252
F.D. PEAK OPTICAL DEPTH........................? 58.7
CALCULATED REDUCTION FACTOR....................=          10.1425

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          22.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          33.5376
CALCULATED F.D. A..............................=           0.0115
CALCULATED H.C. A..............................=           0.0252
F.D. PEAK OPTICAL DEPTH........................? 45.9
CALCULATED REDUCTION FACTOR....................=          15.9987

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          27.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          33.5376
CALCULATED F.D. A..............................=           0.0094
CALCULATED H.C. A..............................=           0.0252
F.D. PEAK OPTICAL DEPTH........................? 38.0
CALCULATED REDUCTION FACTOR....................=          23.6678

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          37.2534
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          33.5376
CALCULATED F.D. A..............................=           0.0068
CALCULATED H.C. A..............................=           0.0252
F.D. PEAK OPTICAL DEPTH........................? 28.4
CALCULATED REDUCTION FACTOR....................=          40.3165

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          57.2533
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          33.5376
CALCULATED F.D. A..............................=           0.0044
CALCULATED H.C. A..............................=           0.0252
F.D. PEAK OPTICAL DEPTH........................? 19.0
CALCULATED REDUCTION FACTOR....................=          58.4556

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          77.2532
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          33.5376
CALCULATED F.D. A..............................=           0.0033
CALCULATED H.C. A..............................=           0.0252
F.D. PEAK OPTICAL DEPTH........................? 14.3
CALCULATED REDUCTION FACTOR....................=          64.8058
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GAS AND LINE...............? NEON, 3-6, 6266
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED H.C. PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6266
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 37
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.13
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 21.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.012
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.3760
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.5405
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5372
CALCULATED F.D. A..............................=       0.0147
CALCULATED H.C. A..............................=       0.0225
F.D. PEAK OPTICAL DEPTH........................? 85.9
CALCULATED REDUCTION FACTOR....................=       9.5855


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.5404
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5372
CALCULATED F.D. A..............................=       0.0114
CALCULATED H.C. A..............................=       0.0225
F.D. PEAK OPTICAL DEPTH........................? 67.4
CALCULATED REDUCTION FACTOR....................=      15.1268


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5403
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5372
CALCULATED F.D. A..............................=       0.0093
CALCULATED H.C. A..............................=       0.0225
F.D. PEAK OPTICAL DEPTH........................? 55.8
CALCULATED REDUCTION FACTOR....................=      22.7796


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5402
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5372
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0225
F.D. PEAK OPTICAL DEPTH........................? 41.9
CALCULATED REDUCTION FACTOR....................=      41.1277


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5372
CALCULATED F.D. A..............................=       0.0045
CALCULATED H.C. A..............................=       0.0225
F.D. PEAK OPTICAL DEPTH........................? 28.1
CALCULATED REDUCTION FACTOR....................=      62.8374


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5372
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0225
F.D. PEAK OPTICAL DEPTH........................? 21.1
CALCULATED REDUCTION FACTOR....................=      69.9741
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GAS AND LINE...............? NEON, 2-4, 6383
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED H.C. PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6383
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 31
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.02
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM].................? 22.9
RATIO OF F.D. TO H.C. INTENSITY...............? 0.034
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7004
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.8658
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      31.5378
CALCULATED F.D. A..............................=       0.0145
CALCULATED H.C. A..............................=       0.0269
F.D. PEAK OPTICAL DEPTH.......................? 3.4
CALCULATED REDUCTION FACTOR...................=       2.5664

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.8657
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      31.5378
CALCULATED F.D. A..............................=       0.0113
CALCULATED H.C. A..............................=       0.0269
F.D. PEAK OPTICAL DEPTH.......................? 2.6
CALCULATED REDUCTION FACTOR...................=       2.7570

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.8656
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      31.5378
CALCULATED F.D. A..............................=       0.0093
CALCULATED H.C. A..............................=       0.0269
F.D. PEAK OPTICAL DEPTH.......................? 2.2
CALCULATED REDUCTION FACTOR...................=       2.8922

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.8655
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      31.5378
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0269
F.D. PEAK OPTICAL DEPTH.......................? 1.6
CALCULATED REDUCTION FACTOR...................=       2.7137

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      31.5378
CALCULATED F.D. A..............................=       0.0045
CALCULATED H.C. A..............................=       0.0269
F.D. PEAK OPTICAL DEPTH.......................? 1.1
CALCULATED REDUCTION FACTOR...................=       2.3101

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      31.5378
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0269
F.D. PEAK OPTICAL DEPTH.......................? 0.8
CALCULATED REDUCTION FACTOR...................=       1.9219
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GAS AND LINE................? NEON, 1-2, 6402
HOLLOW CATHODE (H.C.).......? 350 MA, REDUCED H.C. PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]...............................? 6402
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 55
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.06
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.5
RATIO OF F.D. TO H.C. INTENSITY................? 0.016
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.7531
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        18.0272
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        55.5363
CALCULATED F.D. A..............................=         0.0239
CALCULATED H.C. A..............................=         0.0151
F.D. PEAK OPTICAL DEPTH........................? 253.1
CALCULATED REDUCTION FACTOR....................=         6.9783

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        23.0269
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        55.5363
CALCULATED F.D. A..............................=         0.0187
CALCULATED H.C. A..............................=         0.0151
F.D. PEAK OPTICAL DEPTH........................? 199.7
CALCULATED REDUCTION FACTOR....................=         9.4900

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        28.0266
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        55.5363
CALCULATED F.D. A..............................=         0.0153
CALCULATED H.C. A..............................=         0.0151
F.D. PEAK OPTICAL DEPTH........................? 166.0
CALCULATED REDUCTION FACTOR....................=        13.1622

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.0264
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        55.5363
CALCULATED F.D. A..............................=         0.0112
CALCULATED H.C. A..............................=         0.0151
F.D. PEAK OPTICAL DEPTH........................? 125.2
CALCULATED REDUCTION FACTOR....................=        24.2843

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        58.0261
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        55.5363
CALCULATED F.D. A..............................=         0.0074
CALCULATED H.C. A..............................=         0.0151
F.D. PEAK OPTICAL DEPTH........................? 84.5
CALCULATED REDUCTION FACTOR....................=        47.0783

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        78.0260
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        55.5363
CALCULATED F.D. A..............................=         0.0055
CALCULATED H.C. A..............................=         0.0151
F.D. PEAK OPTICAL DEPTH........................? 63.7
CALCULATED REDUCTION FACTOR....................=        54.3609

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 80
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        98.0259
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        55.5363
CALCULATED F.D. A..............................=         0.0043
CALCULATED H.C. A..............................=         0.0151
F.D. PEAK OPTICAL DEPTH........................? 51.1
CALCULATED REDUCTION FACTOR....................=        56.7810
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Subset 6

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GAS AND LINE...............? NEON, 1-7, 5945
HOLLOW CATHODE (H.C.).......? 350 MA, DOPPLER WIDTH (T = 700 K) & REDUCED PRESSURE W. & SH.
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 5945
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 25.2
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.22
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.5
ISOTOPE SHIFT [MILLIANGSTROM].................? 20.2
RATIO OF F.D. TO H.C. INTENSITY...............? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        16.4858
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        16.8076
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        25.7386
CALCULATED F.D. A.............................=         0.0302
CALCULATED H.C. A.............................=         0.0330
F.D. PEAK OPTICAL DEPTH.......................? 34.9
CALCULATED REDUCTION FACTOR...................=        14.5886

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        21.8071
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        25.7386
CALCULATED F.D. A.............................=         0.0232
CALCULATED H.C. A.............................=         0.0330
F.D. PEAK OPTICAL DEPTH.......................? 27.2
CALCULATED REDUCTION FACTOR...................=        22.7603

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        26.8067
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        25.7386
CALCULATED F.D. A.............................=         0.0188
CALCULATED H.C. A.............................=         0.0330
F.D. PEAK OPTICAL DEPTH.......................? 22.4
CALCULATED REDUCTION FACTOR...................=        31.9578

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        36.8063
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        25.7386
CALCULATED F.D. A.............................=         0.0136
CALCULATED H.C. A.............................=         0.0330
F.D. PEAK OPTICAL DEPTH.......................? 16.8
CALCULATED REDUCTION FACTOR...................=        48.7267

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.8060
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        25.7386
CALCULATED F.D. A.............................=         0.0088
CALCULATED H.C. A.............................=         0.0330
F.D. PEAK OPTICAL DEPTH.......................? 11.2
CALCULATED REDUCTION FACTOR...................=        65.9748

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        76.8058
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        25.7386
CALCULATED F.D. A.............................=         0.0065
CALCULATED H.C. A.............................=         0.0330
F.D. PEAK OPTICAL DEPTH.......................? 8.4
CALCULATED REDUCTION FACTOR...................=        71.8528
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GAS AND LINE................? NEON, 1-5, 6143
HOLLOW CATHODE (H.C.).......? 350 MA, DOPPLER WIDTH (T = 700 K) & REDUCED PRESSURE W. & SH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6143
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 26.0
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.01
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.0349
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.3038
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      26.5385
CALCULATED F.D. A..............................=       0.0245
CALCULATED H.C. A..............................=       0.0320
F.D. PEAK OPTICAL DEPTH........................? 79.6
CALCULATED REDUCTION FACTOR....................=      21.4240

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.3034
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      26.5385
CALCULATED F.D. A..............................=       0.0189
CALCULATED H.C. A..............................=       0.0320
F.D. PEAK OPTICAL DEPTH........................? 62.2
CALCULATED REDUCTION FACTOR....................=      33.8916

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.3032
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      26.5385
CALCULATED F.D. A..............................=       0.0154
CALCULATED H.C. A..............................=       0.0320
F.D. PEAK OPTICAL DEPTH........................? 51.3
CALCULATED REDUCTION FACTOR....................=      45.1958

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.3029
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      26.5385
CALCULATED F.D. A..............................=       0.0112
CALCULATED H.C. A..............................=       0.0320
F.D. PEAK OPTICAL DEPTH........................? 38.4
CALCULATED REDUCTION FACTOR....................=      59.9074

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.3027
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      26.5385
CALCULATED F.D. A..............................=       0.0073
CALCULATED H.C. A..............................=       0.0320
F.D. PEAK OPTICAL DEPTH........................? 25.8
CALCULATED REDUCTION FACTOR....................=      73.2494

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.3026
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      26.5385
CALCULATED F.D. A..............................=       0.0054
CALCULATED H.C. A..............................=       0.0320
F.D. PEAK OPTICAL DEPTH........................? 19.4
CALCULATED REDUCTION FACTOR....................=      80.1960
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Case 28

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GAS AND LINE................? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA, DOPPLER WIDTH (T = 700 K) & REDUCED PRESSURE W. & SH.
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 26.1
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=       17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       26.6385
CALCULATED F.D. A..............................=        0.0148
CALCULATED H.C. A..............................=        0.0319
F.D. PEAK OPTICAL DEPTH........................? 58.7
CALCULATED REDUCTION FACTOR....................=       16.9254

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       22.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       26.6385
CALCULATED F.D. A..............................=        0.0115
CALCULATED H.C. A..............................=        0.0319
F.D. PEAK OPTICAL DEPTH........................? 45.9
CALCULATED REDUCTION FACTOR....................=       26.8582

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       26.6385
CALCULATED F.D. A..............................=        0.0094
CALCULATED H.C. A..............................=        0.0319
F.D. PEAK OPTICAL DEPTH........................? 38.0
CALCULATED REDUCTION FACTOR....................=       36.6199

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       37.2534
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       26.6385
CALCULATED F.D. A..............................=        0.0068
CALCULATED H.C. A..............................=        0.0319
F.D. PEAK OPTICAL DEPTH........................? 28.4
CALCULATED REDUCTION FACTOR....................=       50.4412

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       57.2533
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       26.6385
CALCULATED F.D. A..............................=        0.0044
CALCULATED H.C. A..............................=        0.0319
F.D. PEAK OPTICAL DEPTH........................? 19.0
CALCULATED REDUCTION FACTOR....................=       62.2319

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       77.2532
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       26.6385
CALCULATED F.D. A..............................=        0.0033
CALCULATED H.C. A..............................=        0.0319
F.D. PEAK OPTICAL DEPTH........................? 14.3
CALCULATED REDUCTION FACTOR....................=       67.7050
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GAS AND LINE...............? NEON, 3-6, 6266
HOLLOW CATHODE (H.C.).......? 350 MA, DOPPLER WIDTH (T = 700 K) & REDUCED PRESSURE W. & SH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6266
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 26.5
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.13
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 21.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.012
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=       17.3760
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       17.5405
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.0384
CALCULATED F.D. A..............................=        0.0147
CALCULATED H.C. A..............................=        0.0314
F.D. PEAK OPTICAL DEPTH........................? 85.9
CALCULATED REDUCTION FACTOR....................=       20.2987

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       22.5404
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.0384
CALCULATED F.D. A..............................=        0.0114
CALCULATED H.C. A..............................=        0.0314
F.D. PEAK OPTICAL DEPTH........................? 67.4
CALCULATED REDUCTION FACTOR....................=       32.4137

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.5403
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.0384
CALCULATED F.D. A..............................=        0.0093
CALCULATED H.C. A..............................=        0.0314
F.D. PEAK OPTICAL DEPTH........................? 55.8
CALCULATED REDUCTION FACTOR....................=       43.2971

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       37.5402
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.0384
CALCULATED F.D. A..............................=        0.0068
CALCULATED H.C. A..............................=        0.0314
F.D. PEAK OPTICAL DEPTH........................? 41.9
CALCULATED REDUCTION FACTOR....................=       56.8708

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       57.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.0384
CALCULATED F.D. A..............................=        0.0045
CALCULATED H.C. A..............................=        0.0314
F.D. PEAK OPTICAL DEPTH........................? 28.1
CALCULATED REDUCTION FACTOR....................=       68.3607

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       77.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.0384
CALCULATED F.D. A..............................=        0.0033
CALCULATED H.C. A..............................=        0.0314
F.D. PEAK OPTICAL DEPTH........................? 21.1
CALCULATED REDUCTION FACTOR....................=       74.3078
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GAS AND LINE................? NEON, 2-4, 6383
HOLLOW CATHODE (H.C.).......? 350 MA, DOPPLER WIDTH (T = 700 K) & REDUCED PRESSURE W. & S
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6383
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 27.0
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.02
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM].................? 22.9
RATIO OF F.D. TO H.C. INTENSITY...............? 0.034
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7004
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.8658
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5383
CALCULATED F.D. A..............................=       0.0145
CALCULATED H.C. A..............................=       0.0308
F.D. PEAK OPTICAL DEPTH.......................? 3.4
CALCULATED REDUCTION FACTOR...................=       2.8788


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.8657
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5383
CALCULATED F.D. A..............................=       0.0113
CALCULATED H.C. A..............................=       0.0308
F.D. PEAK OPTICAL DEPTH.......................? 2.6
CALCULATED REDUCTION FACTOR...................=       3.0698


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.8656
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5383
CALCULATED F.D. A..............................=       0.0093
CALCULATED H.C. A..............................=       0.0308
F.D. PEAK OPTICAL DEPTH.......................? 2.2
CALCULATED REDUCTION FACTOR...................=       3.1796


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.8655
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5383
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0308
F.D. PEAK OPTICAL DEPTH.......................? 1.6
CALCULATED REDUCTION FACTOR...................=       2.8826


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5383
CALCULATED F.D. A..............................=       0.0045
CALCULATED H.C. A..............................=       0.0308
F.D. PEAK OPTICAL DEPTH.......................? 1.1
CALCULATED REDUCTION FACTOR...................=       2.3707


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5383
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0308
F.D. PEAK OPTICAL DEPTH.......................? 0.8
CALCULATED REDUCTION FACTOR...................=       1.9452
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GAS AND LINE...............? NEON, 1-2, 6402
HOLLOW CATHODE (H.C.).......? 350 MA, DOPPLER WIDTH (T = 700 K) & REDUCED PRESSURE W. & SH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]..........................? 6402
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 1
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 27.1
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 1
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.06
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.5
RATIO OF F.D. TO H.C. INTENSITY................? 0.016
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7531
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      18.0272
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.6383
CALCULATED F.D. A..............................=       0.0239
CALCULATED H.C. A..............................=       0.0307
F.D. PEAK OPTICAL DEPTH........................? 253.1
CALCULATED REDUCTION FACTOR....................=      29.8664

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      23.0269
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.6383
CALCULATED F.D. A..............................=       0.0187
CALCULATED H.C. A..............................=       0.0307
F.D. PEAK OPTICAL DEPTH........................? 199.7
CALCULATED REDUCTION FACTOR....................=      39.5194

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      28.0266
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.6383
CALCULATED F.D. A..............................=       0.0153
CALCULATED H.C. A..............................=       0.0307
F.D. PEAK OPTICAL DEPTH........................? 166.0
CALCULATED REDUCTION FACTOR....................=      45.4916

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.0264
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.6383
CALCULATED F.D. A..............................=       0.0112
CALCULATED H.C. A..............................=       0.0307
F.D. PEAK OPTICAL DEPTH........................? 125.2
CALCULATED REDUCTION FACTOR....................=      50.9674

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.0261
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.6383
CALCULATED F.D. A..............................=       0.0074
CALCULATED H.C. A..............................=       0.0307
F.D. PEAK OPTICAL DEPTH........................? 84.5
CALCULATED REDUCTION FACTOR....................=      56.1369

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      78.0260
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.6383
CALCULATED F.D. A..............................=       0.0055
CALCULATED H.C. A..............................=       0.0307
F.D. PEAK OPTICAL DEPTH........................? 63.7
CALCULATED REDUCTION FACTOR....................=      59.2666

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 80
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      98.0259
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.6383
CALCULATED F.D. A..............................=       0.0043
CALCULATED H.C. A..............................=       0.0307
F.D. PEAK OPTICAL DEPTH........................? 51.1
CALCULATED REDUCTION FACTOR....................=      61.2317
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Subset 7

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GAS AND LINE................? NEON, 1-7, 5945
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED H.C. GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]...........................? 5945
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 33
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.22
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.5
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.2
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        16.4858
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        16.8076
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A..............................=         0.0302
CALCULATED H.C. A..............................=         0.0757
F.D. PEAK OPTICAL DEPTH........................? 34.9
CALCULATED REDUCTION FACTOR....................=         6.3605

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        21.8071
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A..............................=         0.0232
CALCULATED H.C. A..............................=         0.0757
F.D. PEAK OPTICAL DEPTH........................? 27.2
CALCULATED REDUCTION FACTOR....................=         9.0884

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        26.8067
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A..............................=         0.0188
CALCULATED H.C. A..............................=         0.0757
F.D. PEAK OPTICAL DEPTH........................? 22.4
CALCULATED REDUCTION FACTOR....................=        12.6896

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        36.8063
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A..............................=         0.0136
CALCULATED H.C. A..............................=         0.0757
F.D. PEAK OPTICAL DEPTH........................? 16.8
CALCULATED REDUCTION FACTOR....................=        21.7509

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        56.8060
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A..............................=         0.0088
CALCULATED H.C. A..............................=         0.0757
F.D. PEAK OPTICAL DEPTH........................? 11.2
CALCULATED REDUCTION FACTOR....................=        37.4611

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        76.8058
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        34.6325
CALCULATED F.D. A..............................=         0.0065
CALCULATED H.C. A..............................=         0.0757
F.D. PEAK OPTICAL DEPTH........................? 8.4
CALCULATED REDUCTION FACTOR....................=        46.3150
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GAS AND LINE................? NEON, 1-5, 6143
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED H.C. GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6143
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 41
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.01
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.0349
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.3038
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      42.6267
CALCULATED F.D. A..............................=       0.0245
CALCULATED H.C. A..............................=       0.0609
F.D. PEAK OPTICAL DEPTH........................? 79.6
CALCULATED REDUCTION FACTOR....................=       6.3652


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.3034
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      42.6267
CALCULATED F.D. A..............................=       0.0189
CALCULATED H.C. A..............................=       0.0609
F.D. PEAK OPTICAL DEPTH........................? 62.2
CALCULATED REDUCTION FACTOR....................=       9.0589


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.3032
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      42.6267
CALCULATED F.D. A..............................=       0.0154
CALCULATED H.C. A..............................=       0.0609
F.D. PEAK OPTICAL DEPTH........................? 51.3
CALCULATED REDUCTION FACTOR....................=      12.7532


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.3029
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      42.6267
CALCULATED F.D. A..............................=       0.0112
CALCULATED H.C. A..............................=       0.0609
F.D. PEAK OPTICAL DEPTH........................? 38.4
CALCULATED REDUCTION FACTOR....................=      22.7563


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.3027
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      42.6267
CALCULATED F.D. A..............................=       0.0073
CALCULATED H.C. A..............................=       0.0609
F.D. PEAK OPTICAL DEPTH........................? 25.8
CALCULATED REDUCTION FACTOR....................=      41.8831


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.3026
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      42.6267
CALCULATED F.D. A..............................=       0.0054
CALCULATED H.C. A..............................=       0.0609
F.D. PEAK OPTICAL DEPTH........................? 19.4
CALCULATED REDUCTION FACTOR....................=      52.9339
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Case 29

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GAS AND LINE...............? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED H.C. GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 38
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=       17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       39.6286
CALCULATED F.D. A..............................=        0.0148
CALCULATED H.C. A..............................=        0.0657
F.D. PEAK OPTICAL DEPTH........................? 58.7
CALCULATED REDUCTION FACTOR....................=        6.0240

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       22.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       39.6286
CALCULATED F.D. A..............................=        0.0115
CALCULATED H.C. A..............................=        0.0657
F.D. PEAK OPTICAL DEPTH........................? 45.9
CALCULATED REDUCTION FACTOR....................=        8.6882

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       27.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       39.6286
CALCULATED F.D. A..............................=        0.0094
CALCULATED H.C. A..............................=        0.0657
F.D. PEAK OPTICAL DEPTH........................? 38.0
CALCULATED REDUCTION FACTOR....................=       12.2744

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       37.2534
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       39.6286
CALCULATED F.D. A..............................=        0.0068
CALCULATED H.C. A..............................=        0.0657
F.D. PEAK OPTICAL DEPTH........................? 28.4
CALCULATED REDUCTION FACTOR....................=       21.5156

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       57.2533
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       39.6286
CALCULATED F.D. A..............................=        0.0044
CALCULATED H.C. A..............................=        0.0657
F.D. PEAK OPTICAL DEPTH........................? 19.0
CALCULATED REDUCTION FACTOR....................=       37.6419

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=        0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=       77.2532
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=       39.6286
CALCULATED F.D. A..............................=        0.0033
CALCULATED H.C. A..............................=        0.0657
F.D. PEAK OPTICAL DEPTH........................? 14.3
CALCULATED REDUCTION FACTOR....................=       46.6985
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GAS AND LINE................? NEON, 3-6, 6266
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED H.C. GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR,
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6266
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 42
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.13
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM].................? 21.9
RATIO OF F.D. TO H.C. INTENSITY...............? 0.012
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.3760
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.5405
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      43.6262
CALCULATED F.D. A.............................=       0.0147
CALCULATED H.C. A.............................=       0.0595
F.D. PEAK OPTICAL DEPTH.......................? 85.9
CALCULATED REDUCTION FACTOR...................=       5.9761


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.5404
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      43.6262
CALCULATED F.D. A.............................=       0.0114
CALCULATED H.C. A.............................=       0.0595
F.D. PEAK OPTICAL DEPTH.......................? 67.4
CALCULATED REDUCTION FACTOR...................=       8.5929


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.5403
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      43.6262
CALCULATED F.D. A.............................=       0.0093
CALCULATED H.C. A.............................=       0.0595
F.D. PEAK OPTICAL DEPTH.......................? 55.8
CALCULATED REDUCTION FACTOR...................=      12.1920


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.5402
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      43.6262
CALCULATED F.D. A.............................=       0.0068
CALCULATED H.C. A.............................=       0.0595
F.D. PEAK OPTICAL DEPTH.......................? 41.9
CALCULATED REDUCTION FACTOR...................=      21.9983


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      43.6262
CALCULATED F.D. A.............................=       0.0045
CALCULATED H.C. A.............................=       0.0595
F.D. PEAK OPTICAL DEPTH.......................? 28.1
CALCULATED REDUCTION FACTOR...................=      40.3590


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      43.6262
CALCULATED F.D. A.............................=       0.0033
CALCULATED H.C. A.............................=       0.0595
F.D. PEAK OPTICAL DEPTH.......................? 21.1
CALCULATED REDUCTION FACTOR...................=      50.4703
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GAS AND LINE...............? NEON, 2-4, 6383
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED H.C. GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6383
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 35
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.02
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.034
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7004
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.8658
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.6308
CALCULATED F.D. A..............................=       0.0145
CALCULATED H.C. A..............................=       0.0714
F.D. PEAK OPTICAL DEPTH........................? 3.4
CALCULATED REDUCTION FACTOR....................=       2.1872

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.8657
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.6308
CALCULATED F.D. A..............................=       0.0113
CALCULATED H.C. A..............................=       0.0714
F.D. PEAK OPTICAL DEPTH........................? 2.6
CALCULATED REDUCTION FACTOR....................=       2.3528

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.8656
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.6308
CALCULATED F.D. A..............................=       0.0093
CALCULATED H.C. A..............................=       0.0714
F.D. PEAK OPTICAL DEPTH........................? 2.2
CALCULATED REDUCTION FACTOR....................=       2.4894

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.8655
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.6308
CALCULATED F.D. A..............................=       0.0068
CALCULATED H.C. A..............................=       0.0714
F.D. PEAK OPTICAL DEPTH........................? 1.6
CALCULATED REDUCTION FACTOR....................=       2.4332

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.6308
CALCULATED F.D. A..............................=       0.0045
CALCULATED H.C. A..............................=       0.0714
F.D. PEAK OPTICAL DEPTH........................? 1.1
CALCULATED REDUCTION FACTOR....................=       2.1831

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.6308
CALCULATED F.D. A..............................=       0.0033
CALCULATED H.C. A..............................=       0.0714
F.D. PEAK OPTICAL DEPTH........................? 0.8
CALCULATED REDUCTION FACTOR....................=       1.8660
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GAS AND LINE...............? NEON, 1-2, 6402
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED H.C. GAUSSIAN WIDTH
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6402
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 3
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 63
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 3
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.06
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM].................? 22.5
RATIO OF F.D. TO H.C. INTENSITY...............? 0.016
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=        17.7531
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        18.0272
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        64.6184
CALCULATED F.D. A..............................=         0.0239
CALCULATED H.C. A..............................=         0.0396
F.D. PEAK OPTICAL DEPTH........................? 253.1
CALCULATED REDUCTION FACTOR....................=         4.8788

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        23.0269
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        64.6184
CALCULATED F.D. A..............................=         0.0187
CALCULATED H.C. A..............................=         0.0396
F.D. PEAK OPTICAL DEPTH........................? 199.7
CALCULATED REDUCTION FACTOR....................=         6.1979

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        28.0266
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        64.6184
CALCULATED F.D. A..............................=         0.0153
CALCULATED H.C. A..............................=         0.0396
F.D. PEAK OPTICAL DEPTH........................? 166.0
CALCULATED REDUCTION FACTOR....................=         8.0592

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        38.0264
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        64.6184
CALCULATED F.D. A..............................=         0.0112
CALCULATED H.C. A..............................=         0.0396
F.D. PEAK OPTICAL DEPTH........................? 125.2
CALCULATED REDUCTION FACTOR....................=        13.7783

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        58.0261
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        64.6184
CALCULATED F.D. A..............................=         0.0074
CALCULATED H.C. A..............................=         0.0396
F.D. PEAK OPTICAL DEPTH........................? 84.5
CALCULATED REDUCTION FACTOR....................=        30.5473

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        78.0260
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        64.6184
CALCULATED F.D. A..............................=         0.0055
CALCULATED H.C. A..............................=         0.0396
F.D. PEAK OPTICAL DEPTH........................? 63.7
CALCULATED REDUCTION FACTOR....................=        41.4440

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 80
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=         0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=        98.0259
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=        64.6184
CALCULATED F.D. A..............................=         0.0043
CALCULATED H.C. A..............................=         0.0396
F.D. PEAK OPTICAL DEPTH........................? 51.1
CALCULATED REDUCTION FACTOR....................=        46.5048
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Subset 8

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GAS AND LINE................? NEON, 1-7, 5945
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 5945
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 6
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 29
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 6
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.22
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.5
ISOTOPE SHIFT [MILLIANGSTROM].................? 20.2
RATIO OF F.D. TO H.C. INTENSITY...............? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      16.4858
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      16.8076
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.3402
CALCULATED F.D. A..............................=       0.0302
CALCULATED H.C. A..............................=       0.1723
F.D. PEAK OPTICAL DEPTH.......................? 34.8
CALCULATED REDUCTION FACTOR...................=       5.2025

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      21.8071
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.3402
CALCULATED F.D. A..............................=       0.0232
CALCULATED H.C. A..............................=       0.1723
F.D. PEAK OPTICAL DEPTH.......................? 27.1
CALCULATED REDUCTION FACTOR...................=       7.2616

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      26.8067
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.3402
CALCULATED F.D. A..............................=       0.0188
CALCULATED H.C. A..............................=       0.1723
F.D. PEAK OPTICAL DEPTH.......................? 22.4
CALCULATED REDUCTION FACTOR...................=       9.8447

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      36.8063
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.3402
CALCULATED F.D. A..............................=       0.0136
CALCULATED H.C. A..............................=       0.1723
F.D. PEAK OPTICAL DEPTH.......................? 16.7
CALCULATED REDUCTION FACTOR...................=      15.6907

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      56.8060
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.3402
CALCULATED F.D. A..............................=       0.0088
CALCULATED H.C. A..............................=       0.1723
F.D. PEAK OPTICAL DEPTH.......................? 11.1
CALCULATED REDUCTION FACTOR...................=      25.9207

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.0979
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      76.8058
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      32.3402
CALCULATED F.D. A..............................=       0.0065
CALCULATED H.C. A..............................=       0.1723
F.D. PEAK OPTICAL DEPTH.......................? 8.3
CALCULATED REDUCTION FACTOR...................=      33.4826
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GAS AND LINE...............? NEON, 1-5, 6143
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6143
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 6
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 36
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 6
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.01
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM].................? 22.9
RATIO OF F.D. TO H.C. INTENSITY...............? 0.011
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.0349
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      17.3038
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      39.3141
CALCULATED F.D. A..............................=       0.0245
CALCULATED H.C. A..............................=       0.1388
F.D. PEAK OPTICAL DEPTH.......................? 79.4
CALCULATED REDUCTION FACTOR....................=       5.5443


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      22.3034
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      39.3141
CALCULATED F.D. A..............................=       0.0189
CALCULATED H.C. A..............................=       0.1388
F.D. PEAK OPTICAL DEPTH.......................? 62.1
CALCULATED REDUCTION FACTOR....................=       7.7358


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      27.3032
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      39.3141
CALCULATED F.D. A..............................=       0.0154
CALCULATED H.C. A..............................=       0.1388
F.D. PEAK OPTICAL DEPTH.......................? 51.2
CALCULATED REDUCTION FACTOR....................=      10.5860


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      37.3029
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      39.3141
CALCULATED F.D. A..............................=       0.0112
CALCULATED H.C. A..............................=       0.1388
F.D. PEAK OPTICAL DEPTH.......................? 38.4
CALCULATED REDUCTION FACTOR....................=      17.4704


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      57.3027
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      39.3141
CALCULATED F.D. A..............................=       0.0073
CALCULATED H.C. A..............................=       0.1388
F.D. PEAK OPTICAL DEPTH.......................? 25.8
CALCULATED REDUCTION FACTOR....................=      29.7248


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1003
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      77.3026
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      39.3141
CALCULATED F.D. A..............................=       0.0054
CALCULATED H.C. A..............................=       0.1388
F.D. PEAK OPTICAL DEPTH.......................? 19.4
CALCULATED REDUCTION FACTOR....................=      39.1135
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Case 30

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GAS AND LINE................? NEON, 3-9, 6163
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM].........................? 6163
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 6
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 33
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 6
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.19
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 20.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.013
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=          17.0903
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          17.2537
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          36.3239
CALCULATED F.D. A..............................=           0.0148
CALCULATED H.C. A..............................=           0.1514
F.D. PEAK OPTICAL DEPTH........................? 58.6
CALCULATED REDUCTION FACTOR....................=           5.2298

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          22.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          36.3239
CALCULATED F.D. A..............................=           0.0115
CALCULATED H.C. A..............................=           0.1514
F.D. PEAK OPTICAL DEPTH........................? 45.8
CALCULATED REDUCTION FACTOR....................=           7.4045

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          27.2535
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          36.3239
CALCULATED F.D. A..............................=           0.0094
CALCULATED H.C. A..............................=           0.1514
F.D. PEAK OPTICAL DEPTH........................? 37.9
CALCULATED REDUCTION FACTOR....................=          10.1599

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          37.2534
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          36.3239
CALCULATED F.D. A..............................=           0.0068
CALCULATED H.C. A..............................=           0.1514
F.D. PEAK OPTICAL DEPTH........................? 28.4
CALCULATED REDUCTION FACTOR....................=          16.4808

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          57.2533
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          36.3239
CALCULATED F.D. A..............................=           0.0044
CALCULATED H.C. A..............................=           0.1514
F.D. PEAK OPTICAL DEPTH........................? 19.0
CALCULATED REDUCTION FACTOR....................=          27.1707

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1046
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          77.2532
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          36.3239
CALCULATED F.D. A..............................=           0.0033
CALCULATED H.C. A..............................=           0.1514
F.D. PEAK OPTICAL DEPTH........................? 14.2
CALCULATED REDUCTION FACTOR....................=          35.2158
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GAS AND LINE...............? NEON, 3-6, 6266
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6266
H.C. LORENTZIAN FWHM [MILLIANGSTROM]..........? 6
H.C. GAUSSIAN FWHM [MILLIANGSTROM]............? 37
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 6
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.13
F.D. PRESSURE FWHM [MILLIANGSTROM]............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM].................? 21.9
RATIO OF F.D. TO H.C. INTENSITY...............? 0.012
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=          17.3760
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          17.5405
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          40.3112
CALCULATED F.D. A..............................=           0.0147
CALCULATED H.C. A..............................=           0.1350
F.D. PEAK OPTICAL DEPTH.......................? 85.8
CALCULATED REDUCTION FACTOR...................=           5.2717


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          22.5404
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          40.3112
CALCULATED F.D. A..............................=           0.0114
CALCULATED H.C. A..............................=           0.1350
F.D. PEAK OPTICAL DEPTH.......................? 67.3
CALCULATED REDUCTION FACTOR...................=           7.4308


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          27.5403
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          40.3112
CALCULATED F.D. A..............................=           0.0093
CALCULATED H.C. A..............................=           0.1350
F.D. PEAK OPTICAL DEPTH.......................? 55.7
CALCULATED REDUCTION FACTOR...................=          10.2421


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          37.5402
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          40.3112
CALCULATED F.D. A..............................=           0.0068
CALCULATED H.C. A..............................=           0.1350
F.D. PEAK OPTICAL DEPTH.......................? 41.9
CALCULATED REDUCTION FACTOR...................=          17.0445


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          57.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          40.3112
CALCULATED F.D. A..............................=           0.0045
CALCULATED H.C. A..............................=           0.1350
F.D. PEAK OPTICAL DEPTH.......................? 28.1
CALCULATED REDUCTION FACTOR...................=          28.9424


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=           0.1069
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=          77.5401
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=          40.3112
CALCULATED F.D. A..............................=           0.0033
CALCULATED H.C. A..............................=           0.1350
F.D. PEAK OPTICAL DEPTH.......................? 21.1
CALCULATED REDUCTION FACTOR...................=          37.7617
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GAS AND LINE................? NEON, 2-4, 6383
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]..........................? 6383
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 6
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 31
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 6
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.02
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.2
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.9
RATIO OF F.D. TO H.C. INTENSITY................? 0.034
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=     17.7004
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=      0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=     17.8658
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=     34.3315
CALCULATED F.D. A..............................=      0.0145
CALCULATED H.C. A..............................=      0.1611
F.D. PEAK OPTICAL DEPTH........................? 3.3
CALCULATED REDUCTION FACTOR....................=      2.0694

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=      0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=     22.8657
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=     34.3315
CALCULATED F.D. A..............................=      0.0113
CALCULATED H.C. A..............................=      0.1611
F.D. PEAK OPTICAL DEPTH........................? 2.6
CALCULATED REDUCTION FACTOR....................=      2.2542

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=      0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=     27.8656
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=     34.3315
CALCULATED F.D. A..............................=      0.0093
CALCULATED H.C. A..............................=      0.1611
F.D. PEAK OPTICAL DEPTH........................? 2.2
CALCULATED REDUCTION FACTOR....................=      2.3862

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=      0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=     37.8655
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=     34.3315
CALCULATED F.D. A..............................=      0.0068
CALCULATED H.C. A..............................=      0.1611
F.D. PEAK OPTICAL DEPTH........................? 1.6
CALCULATED REDUCTION FACTOR....................=      2.3475

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=      0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=     57.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=     34.3315
CALCULATED F.D. A..............................=      0.0045
CALCULATED H.C. A..............................=      0.1611
F.D. PEAK OPTICAL DEPTH........................? 1.1
CALCULATED REDUCTION FACTOR....................=      2.1301

ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=      0.1085
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=     77.8654
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=     34.3315
CALCULATED F.D. A..............................=      0.0033
CALCULATED H.C. A..............................=      0.1611
F.D. PEAK OPTICAL DEPTH........................? 0.8
CALCULATED REDUCTION FACTOR....................=      1.8378
```

```
GAS AND LINE................? NEON, 1-2, 6402
HOLLOW CATHODE (H.C.).......? 350 MA, INCREASED PRESSURE WIDTH AND SHIFT
FILTER DISCHARGE (F.D.).....? 2 MA, 2.55 MBAR
MEASURED REDUCTION FACTOR...?
WAVELENGTH [ANGSTROM]........................? 6402
H.C. LORENTZIAN FWHM [MILLIANGSTROM]...........? 6
H.C. GAUSSIAN FWHM [MILLIANGSTROM].............? 55
SHIFT OF H.C. LINE (RED=+) [MILLIANGSTROM].....? 6
TRANS.-PROB.-SUM OF UPPER STATE [1E7*SEC**-1]..? 5.06
F.D. PRESSURE FWHM [MILLIANGSTROM].............? 0.4
ISOTOPE SHIFT [MILLIANGSTROM]..................? 22.5
RATIO OF F.D. TO H.C. INTENSITY................? 0.016
CALCULATED F.D. DOPPLER FWHM [MILLIANGSTROM]...=      17.7531
ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 0
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      18.0272
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.2768
CALCULATED F.D. A..............................=       0.0239
CALCULATED H.C. A..............................=       0.0908
F.D. PEAK OPTICAL DEPTH........................? 252.7
CALCULATED REDUCTION FACTOR....................=       4.9927


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 5
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      23.0269
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.2768
CALCULATED F.D. A..............................=       0.0187
CALCULATED H.C. A..............................=       0.0908
F.D. PEAK OPTICAL DEPTH........................? 199.4
CALCULATED REDUCTION FACTOR....................=       6.3470


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 10
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      28.0266
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.2768
CALCULATED F.D. A..............................=       0.0153
CALCULATED H.C. A..............................=       0.0908
F.D. PEAK OPTICAL DEPTH........................? 165.8
CALCULATED REDUCTION FACTOR....................=       8.2203


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 20
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      38.0264
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.2768
CALCULATED F.D. A..............................=       0.0112
CALCULATED H.C. A..............................=       0.0908
F.D. PEAK OPTICAL DEPTH........................? 125.0
CALCULATED REDUCTION FACTOR....................=      13.4991


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 40
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.0261
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.2768
CALCULATED F.D. A..............................=       0.0074
CALCULATED H.C. A..............................=       0.0908
F.D. PEAK OPTICAL DEPTH........................? 84.5
CALCULATED REDUCTION FACTOR....................=      25.4873


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 60
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      78.0260
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.2768
CALCULATED F.D. A..............................=       0.0055
CALCULATED H.C. A..............................=       0.0908
F.D. PEAK OPTICAL DEPTH........................? 63.7
CALCULATED REDUCTION FACTOR....................=      33.1227


ADDITIONAL F.D. GAUSSIAN FWHM [MILLIANGSTROM]..? 80
CALCULATED F.D. NATURAL FWHM [MILLIANGSTROM]...=       0.1100
CALCULATED F.D. VOIGTIAN FWHM [MILLIANGSTROM]..=      98.0259
CALCULATED H.C. VOIGTIAN FWHM [MILLIANGSTROM]..=      58.2768
CALCULATED F.D. A..............................=       0.0043
CALCULATED H.C. A..............................=       0.0908
F.D. PEAK OPTICAL DEPTH........................? 51.0
CALCULATED REDUCTION FACTOR....................=      38.3965
```

Appendix VIII: Modelling - Spectrum Profile Plots

The plots in this appendix have been produced for the 30 'cases', which are marked in Appendix VII and which should be referred to for information on the corresponding parameters and results. An excerpt of the explanations on the plots which were given in Chapter VII.1 is reproduced here for convenience.

" There are 30 'cases' marked among the computer runs in Appendix VII, which give the data for which synthesized spectrum profile plots have been computed. This appendix contains these plots. The 3-9 line was taken as representative for the group of four 'normal' metastable lines (1-7, 1-5, 3-9, 3-6).

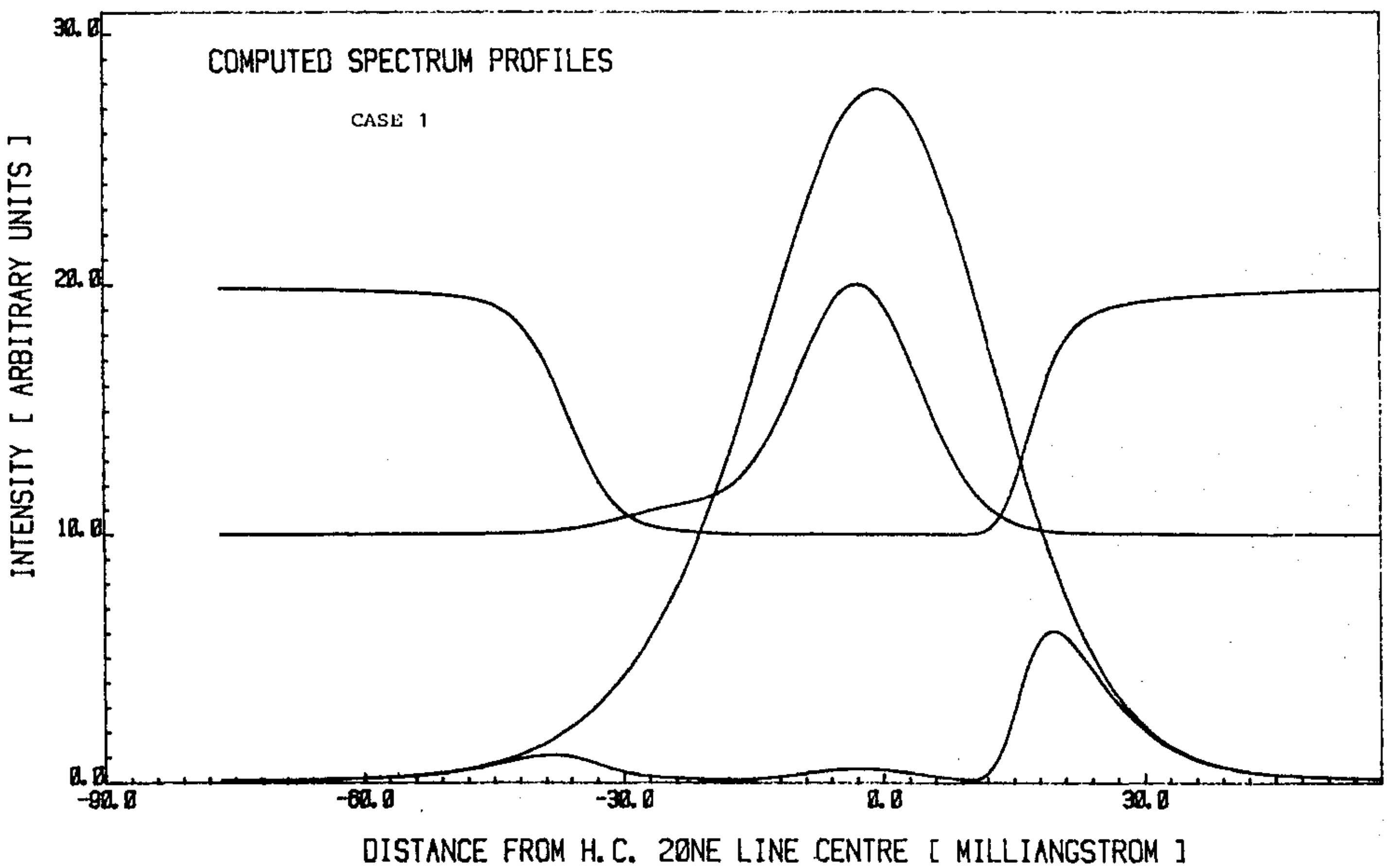
Here some explanations on the plots. 'Case 3' is chosen as an example. The dominant spectral line sitting on the zero-intensity axis is the hollow cathode emission line. If the filter discharge is running, the hollow cathode absorption profile is produced, which is plotted in the same intensity scale. Usually, the two outer parts of the hollow cathode line which 'leak around the edges' of the filter discharge line can be seen as well as the small hump at the centre of the hollow cathode absorption profile, which is due to the filter discharge emission.

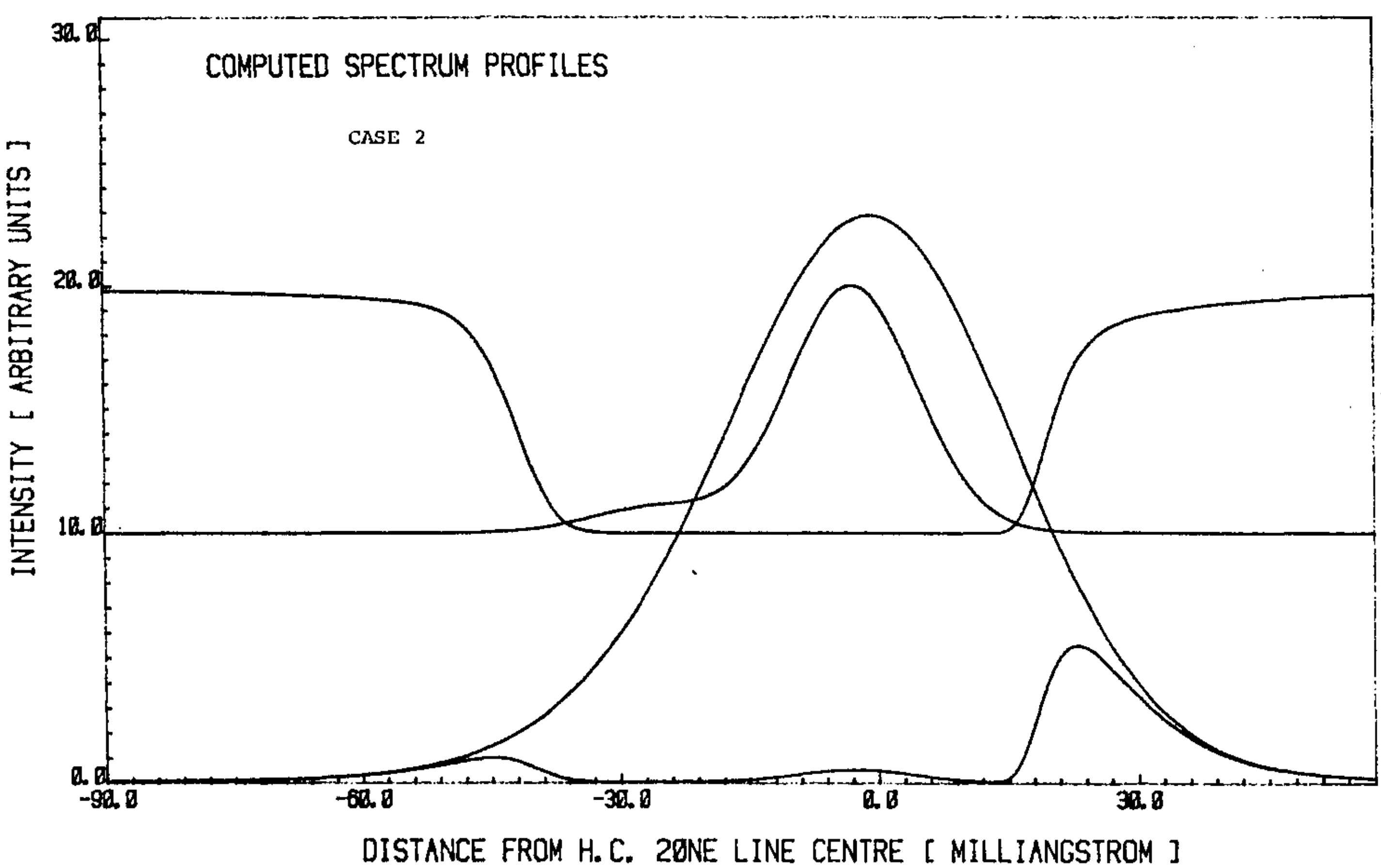
Both the filter discharge line profile and a continuum absorption profile (without filter discharge emission, thus showing the actual equivalent width) have been shifted upwards by 10 intensity units, so that they do not obscure the hollow cathode absorption profile. The last two plots do not have the same intensity scales and both scales are different from those used for the hollow cathode profiles. The intensity-equals-20 line is the full intensity line for both the continuum and the filter discharge spectrum line profiles.

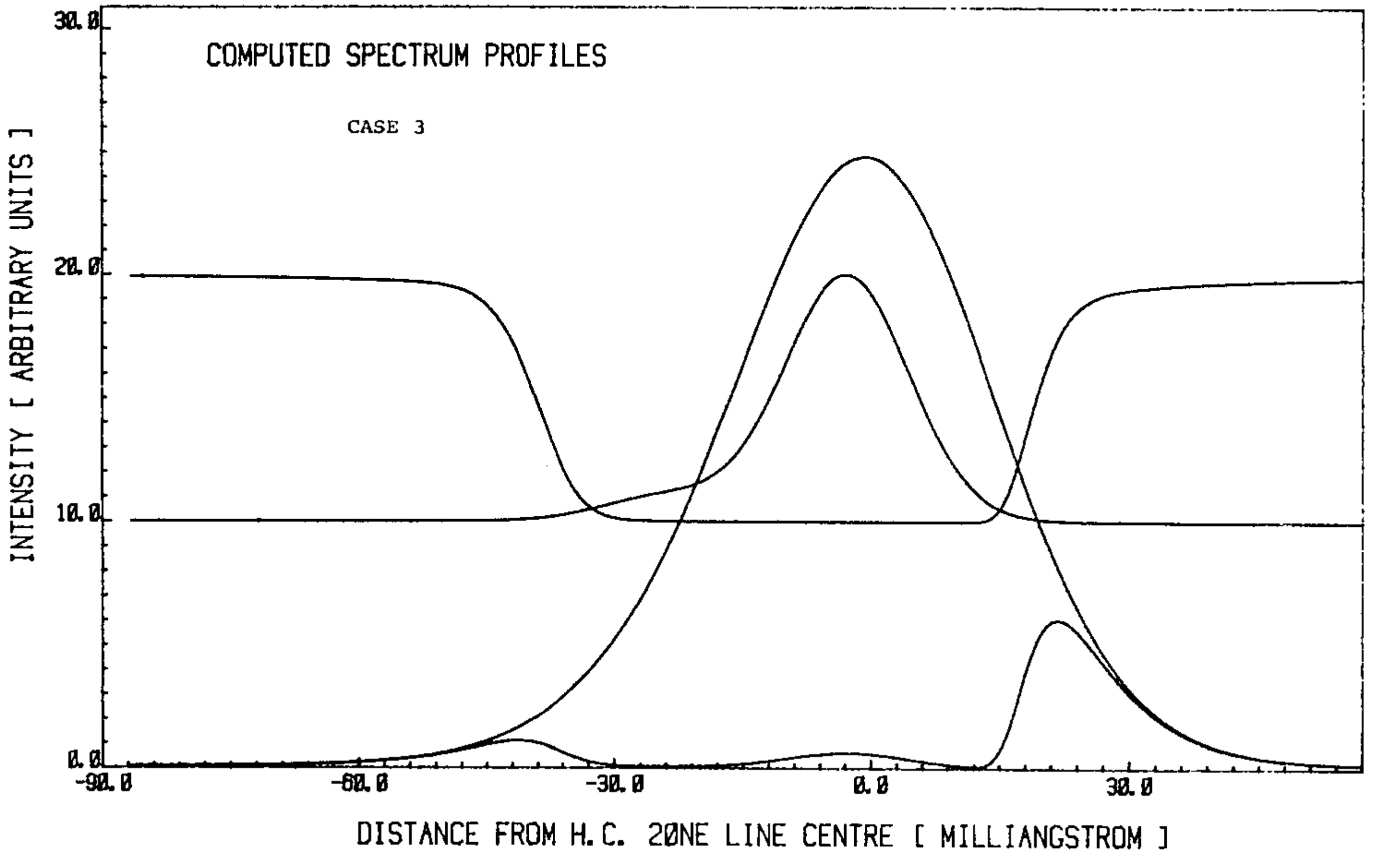
The last two plots have been included for the following reasons:

i) the filter discharge line profile:
- to show the two isotope lines
- to show the hollow cathode Stark shift
- to allow line width comparisons
- to show where the filter discharge line intensity commences to be significantly $\neq 0$.

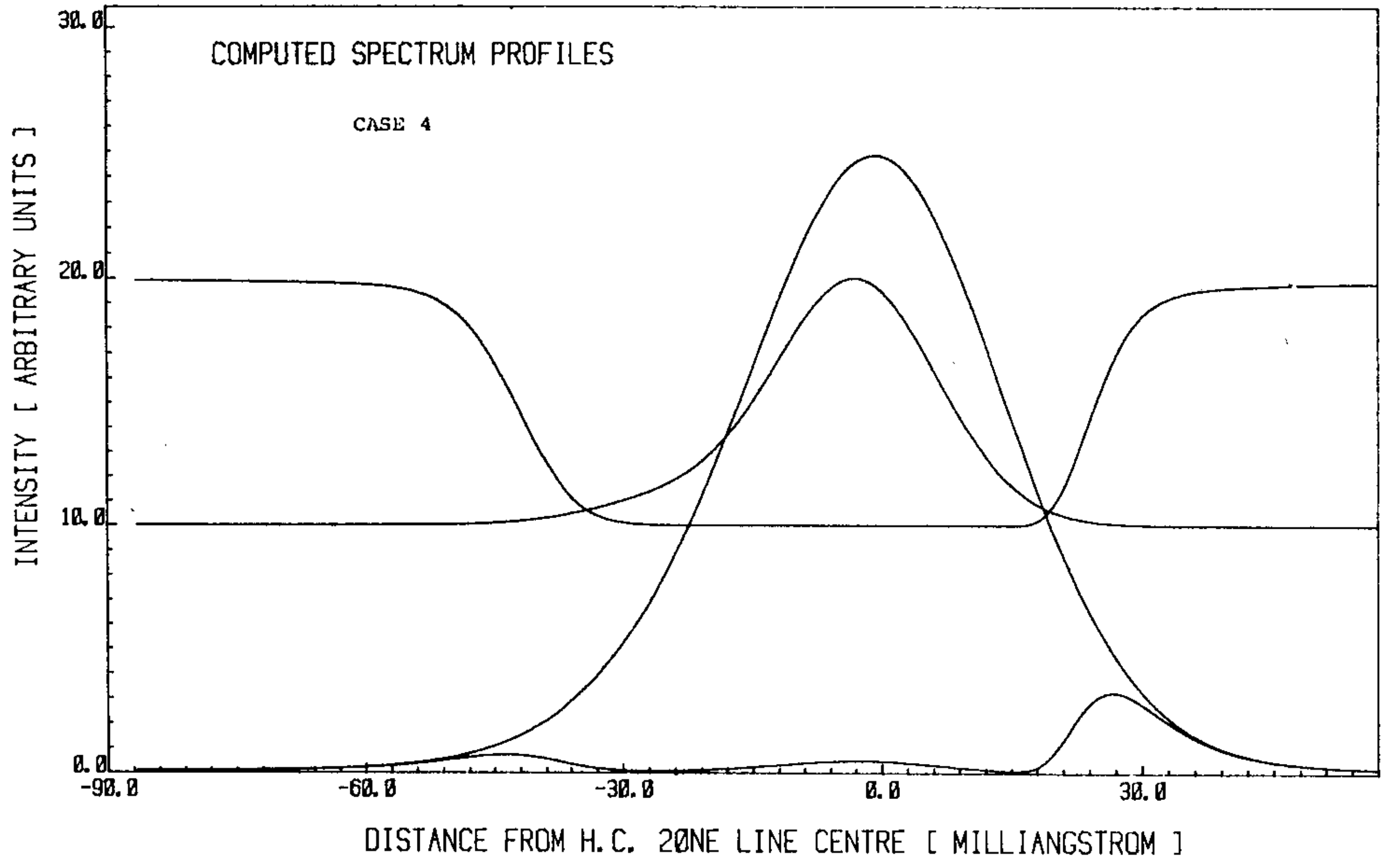
ii) the continuum absorption profile:
- to show how far into the wings the absorption reaches. "


COMPUTED SPECTRUM PROFILES
CASE 1
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

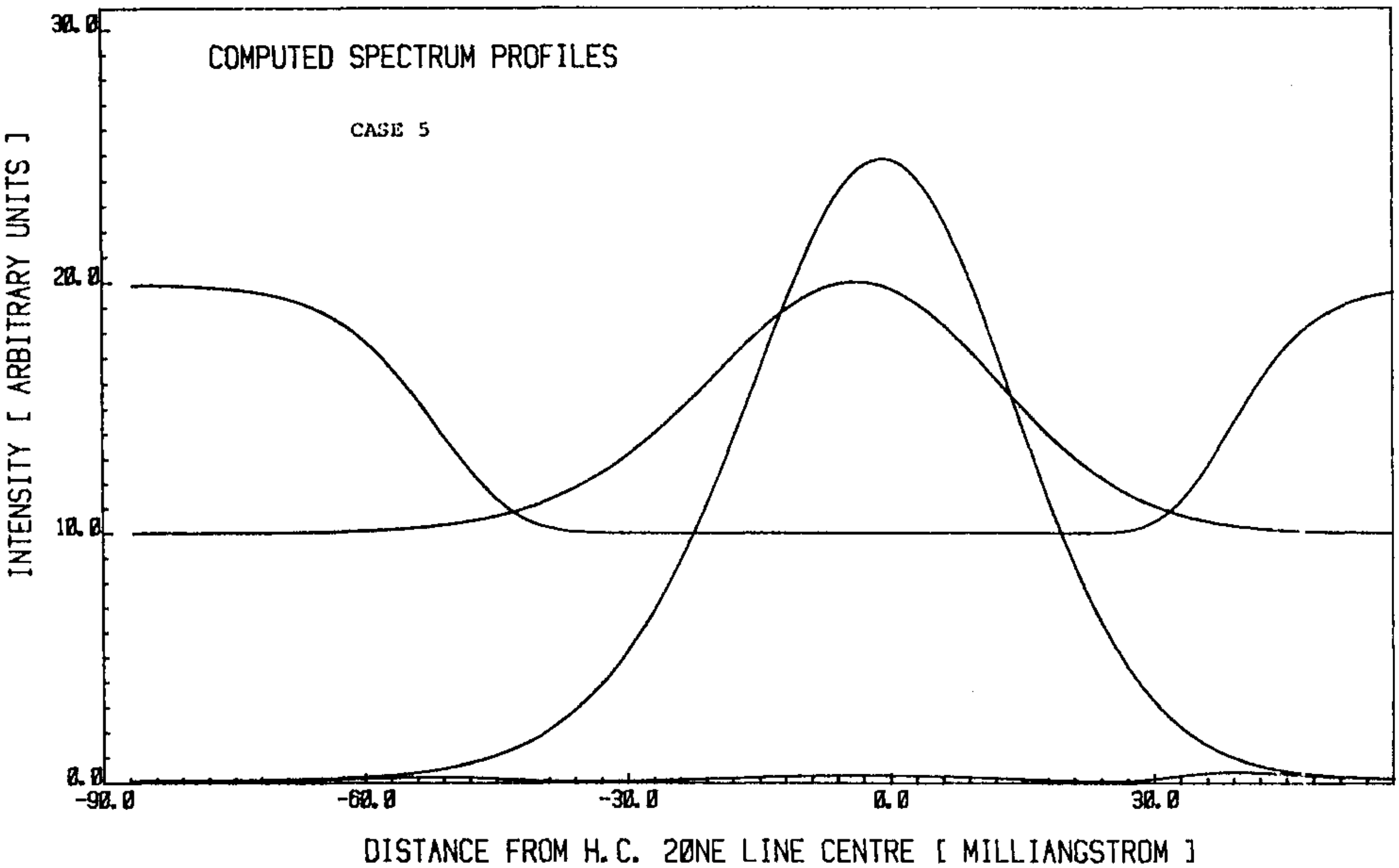

COMPUTED SPECTRUM PROFILES
CASE 2
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]



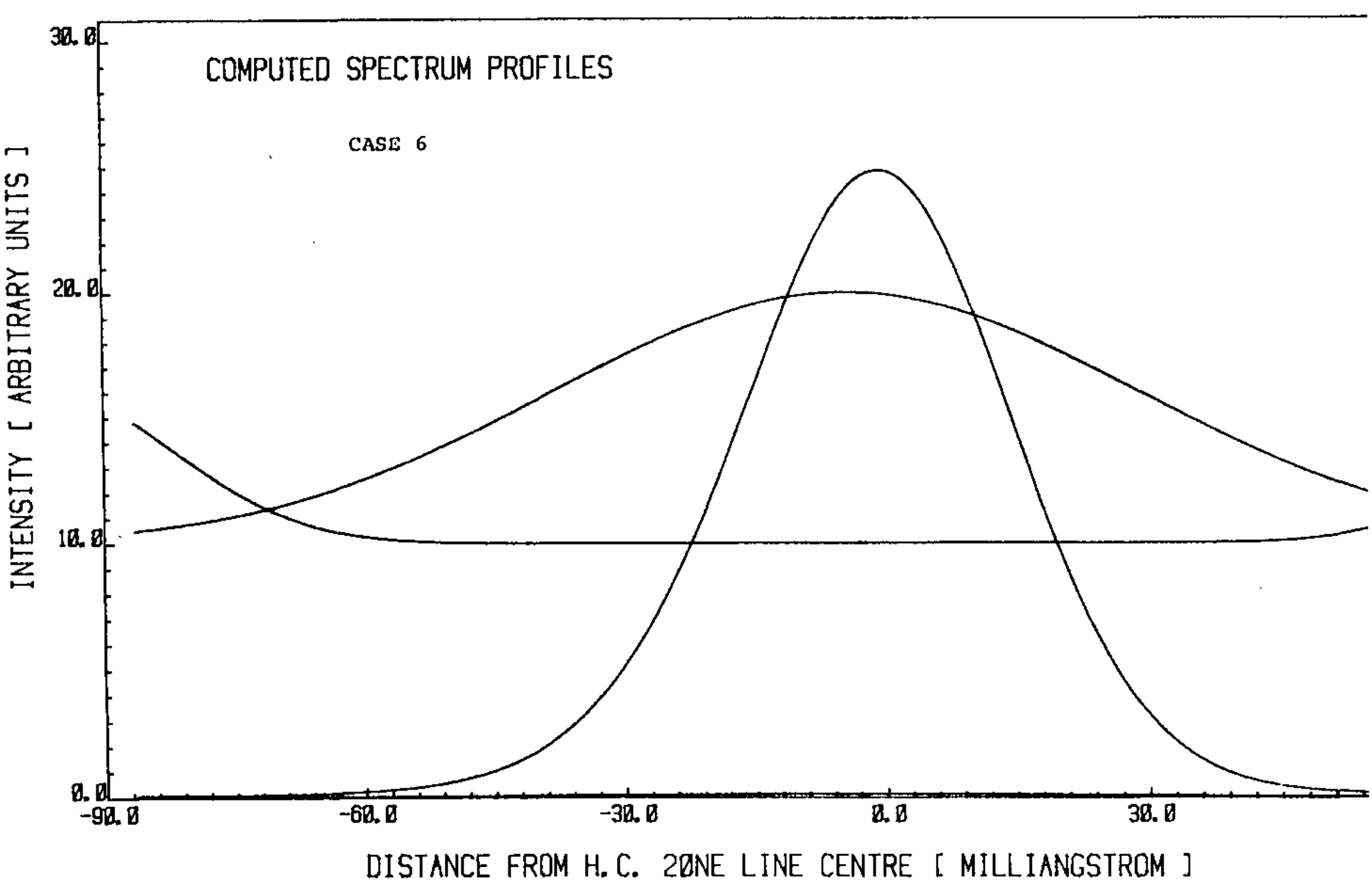
COMPUTED SPECTRUM PROFILES
CASE 3
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]



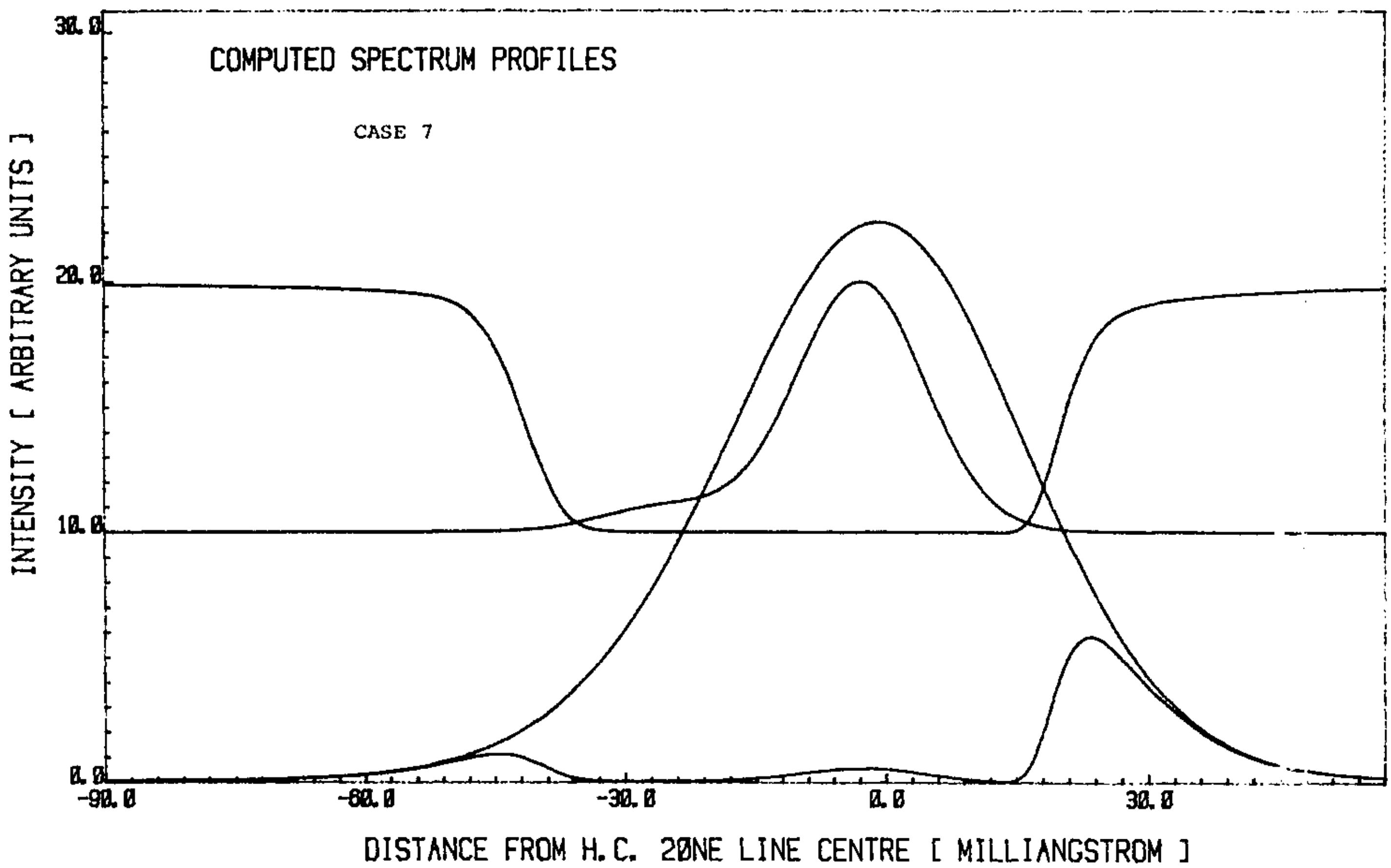
COMPUTED SPECTRUM PROFILES
CASE 4
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

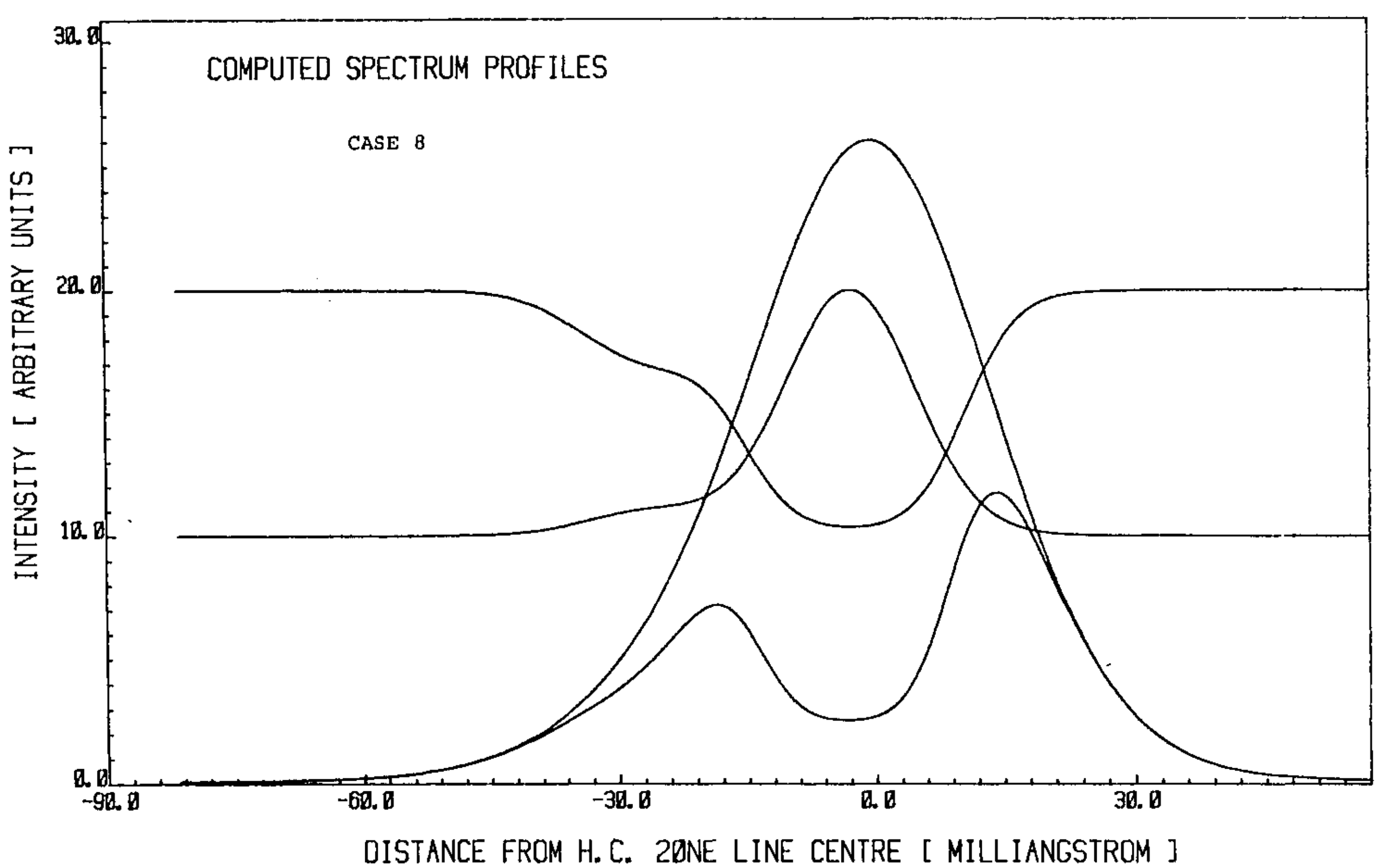


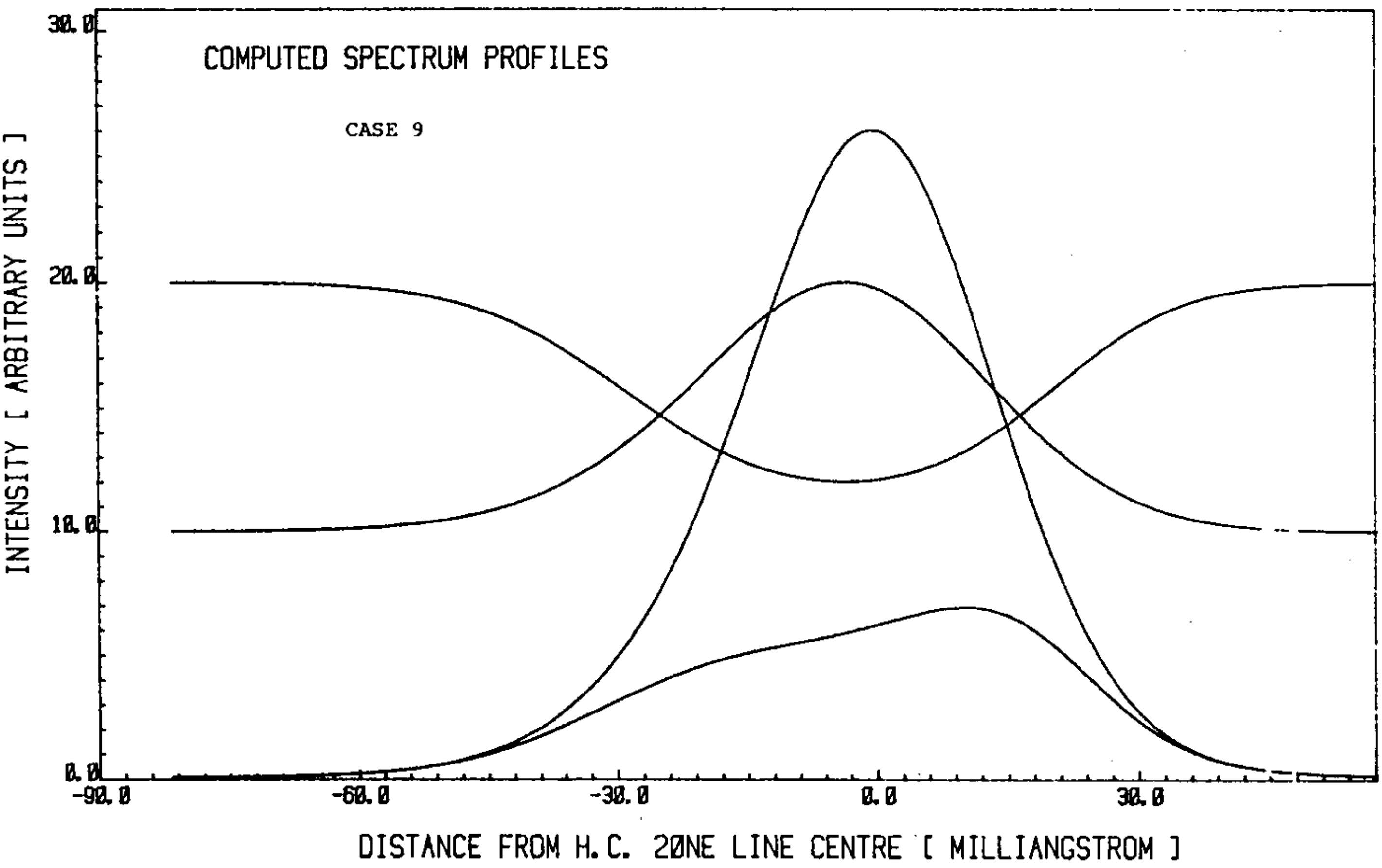
COMPUTED SPECTRUM PROFILES
CASE 5
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

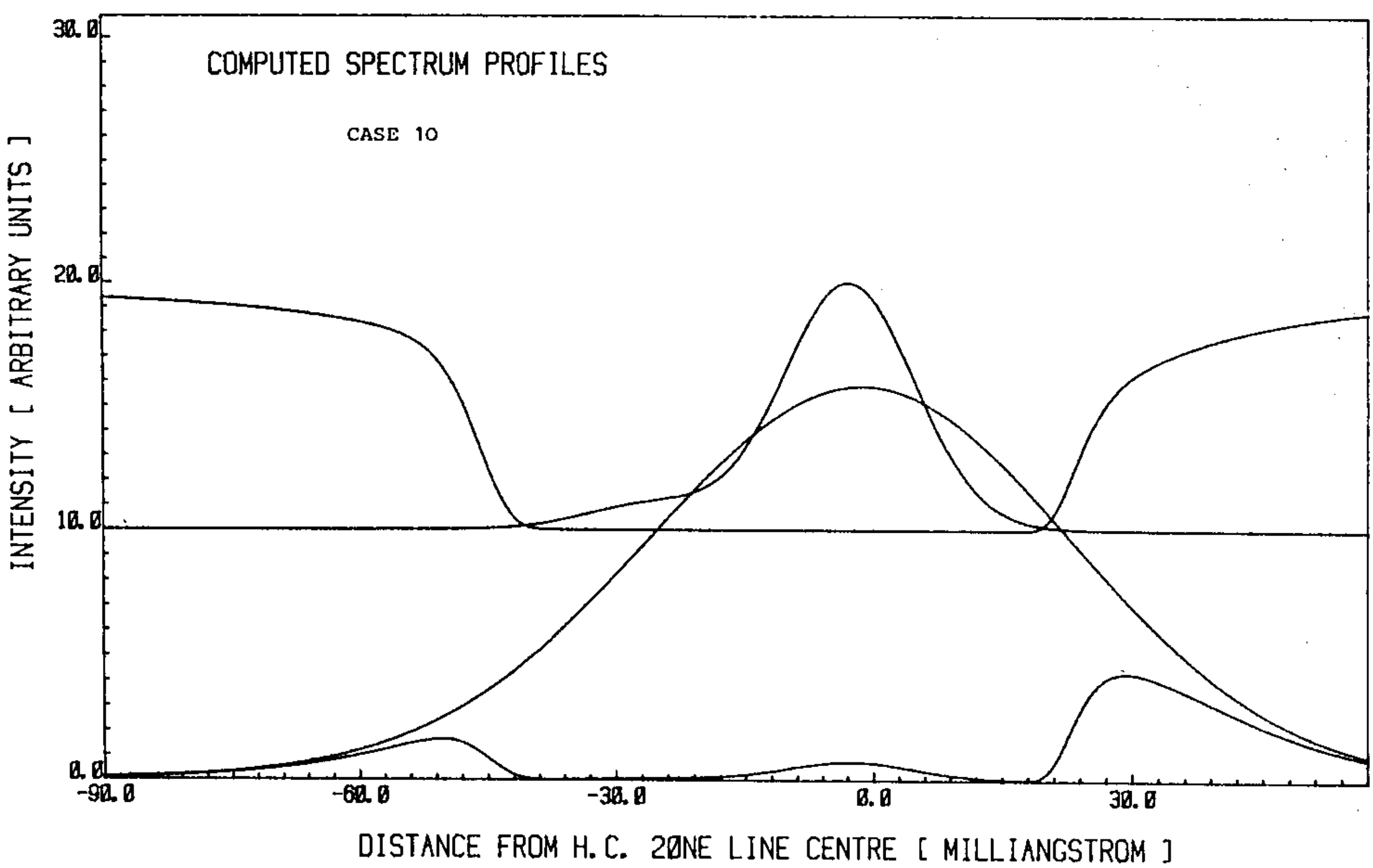


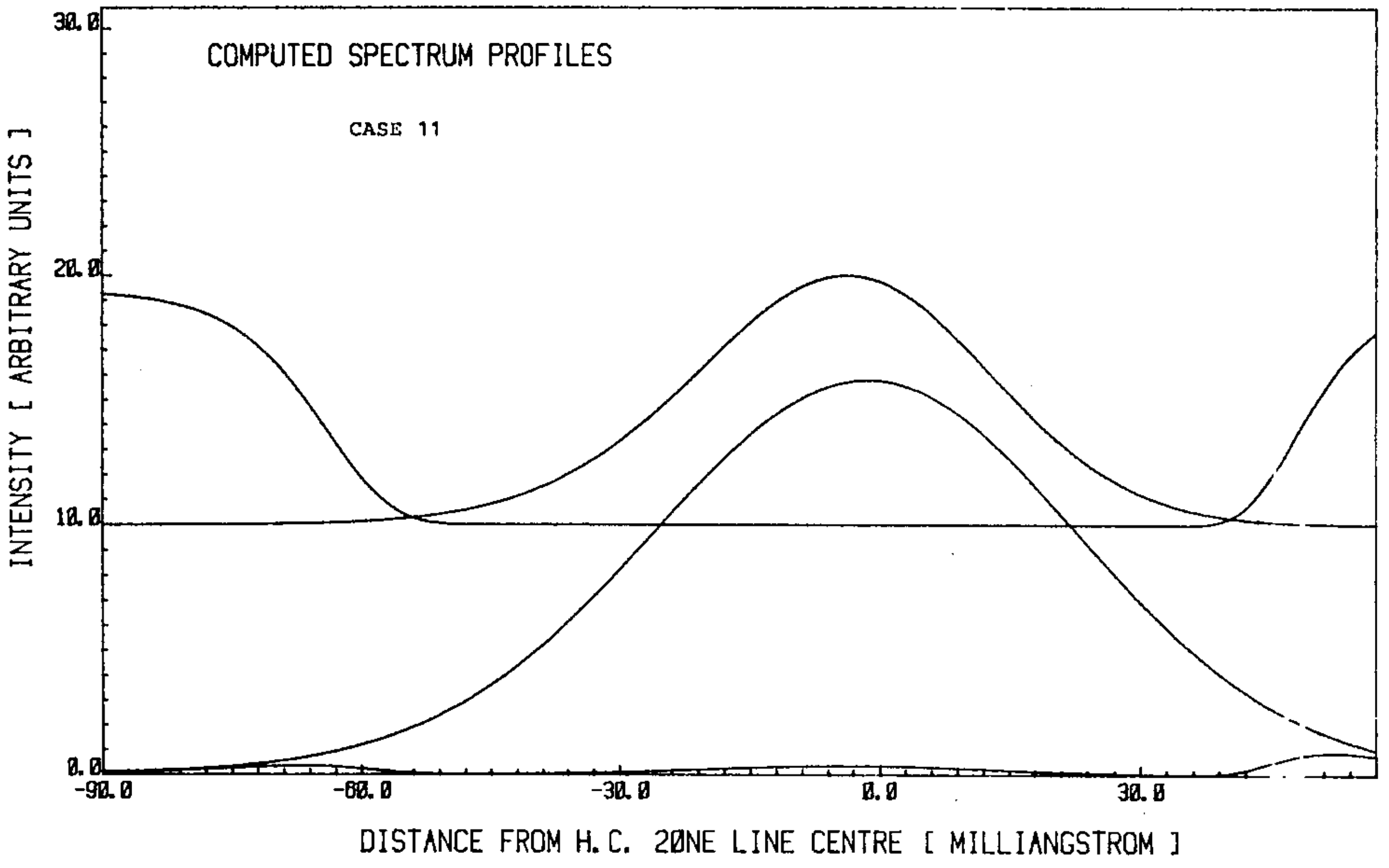
COMPUTED SPECTRUM PROFILES
CASE 6
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

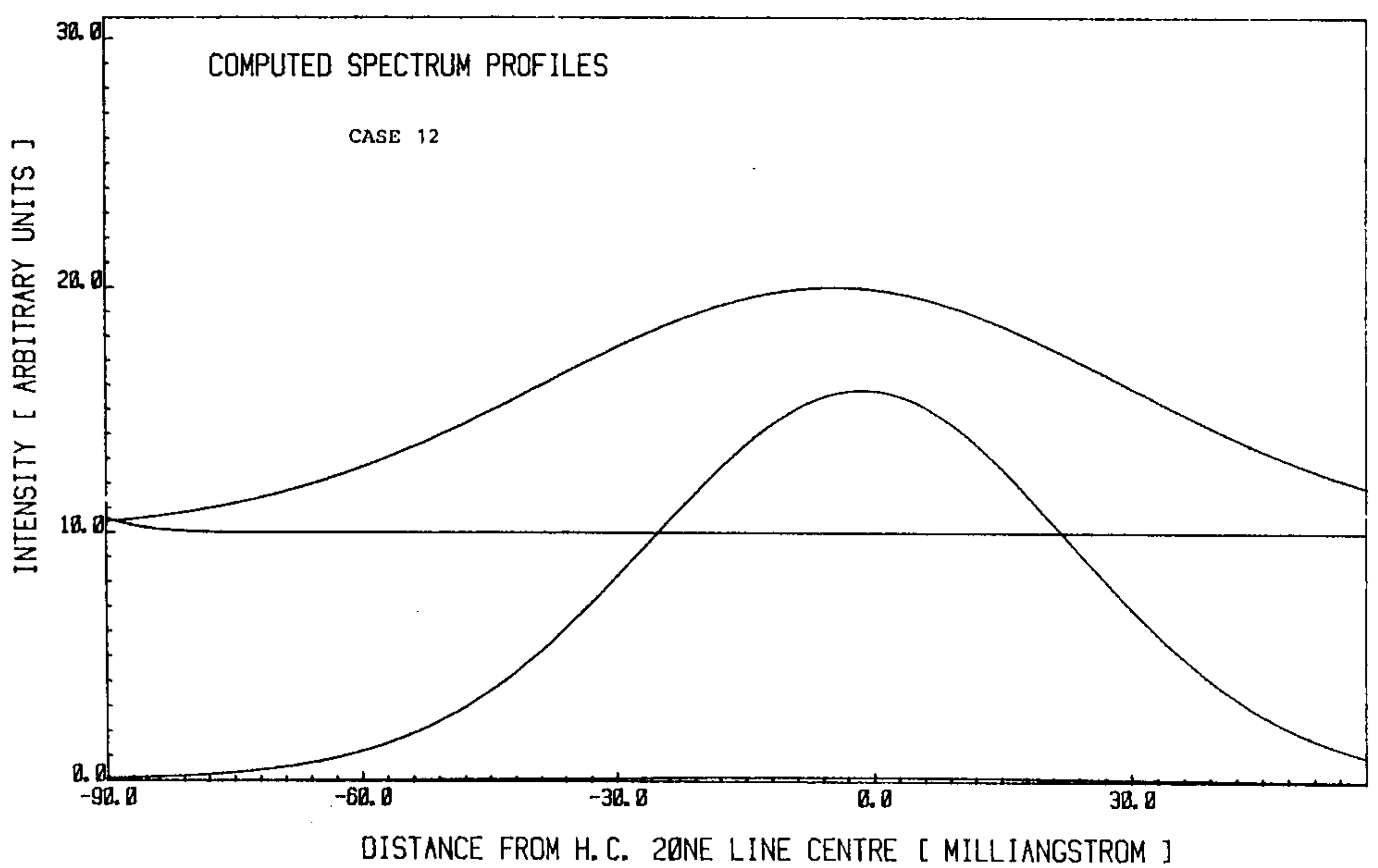

COMPUTED SPECTRUM PROFILES
CASE 7
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

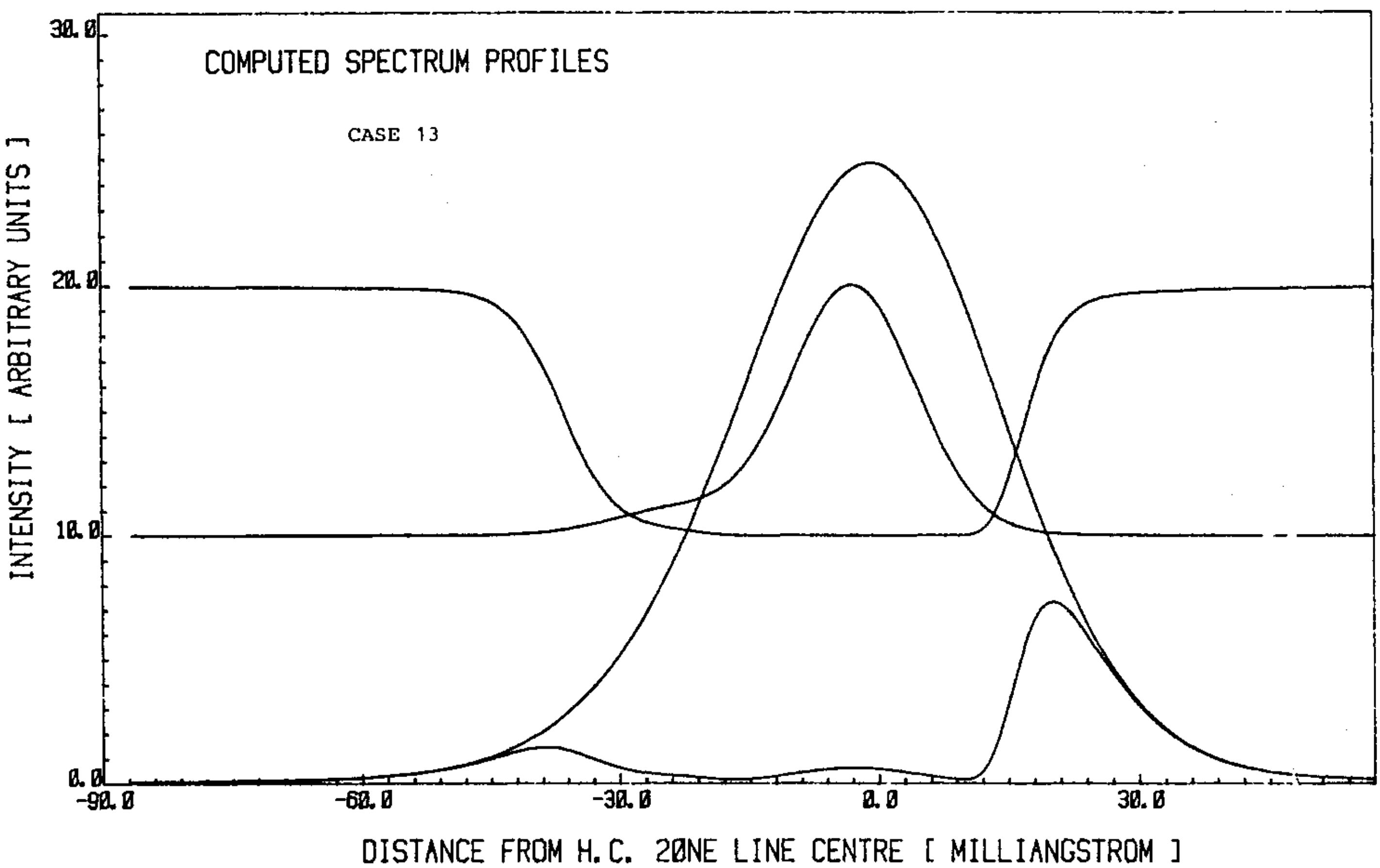

COMPUTED SPECTRUM PROFILES
CASE 8
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

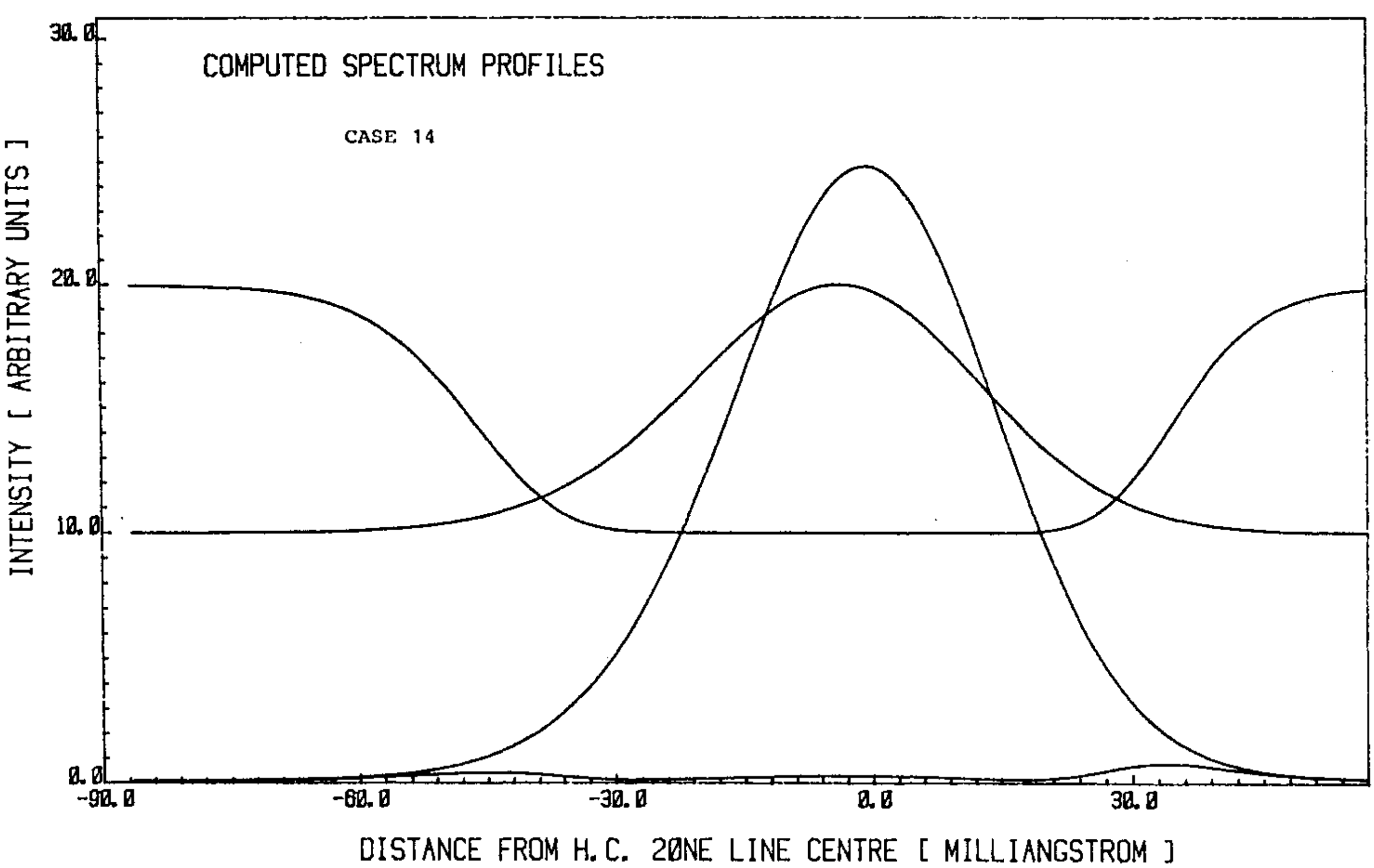

COMPUTED SPECTRUM PROFILES
CASE 9
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
INTENSITY [ARBITRARY UNITS]
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

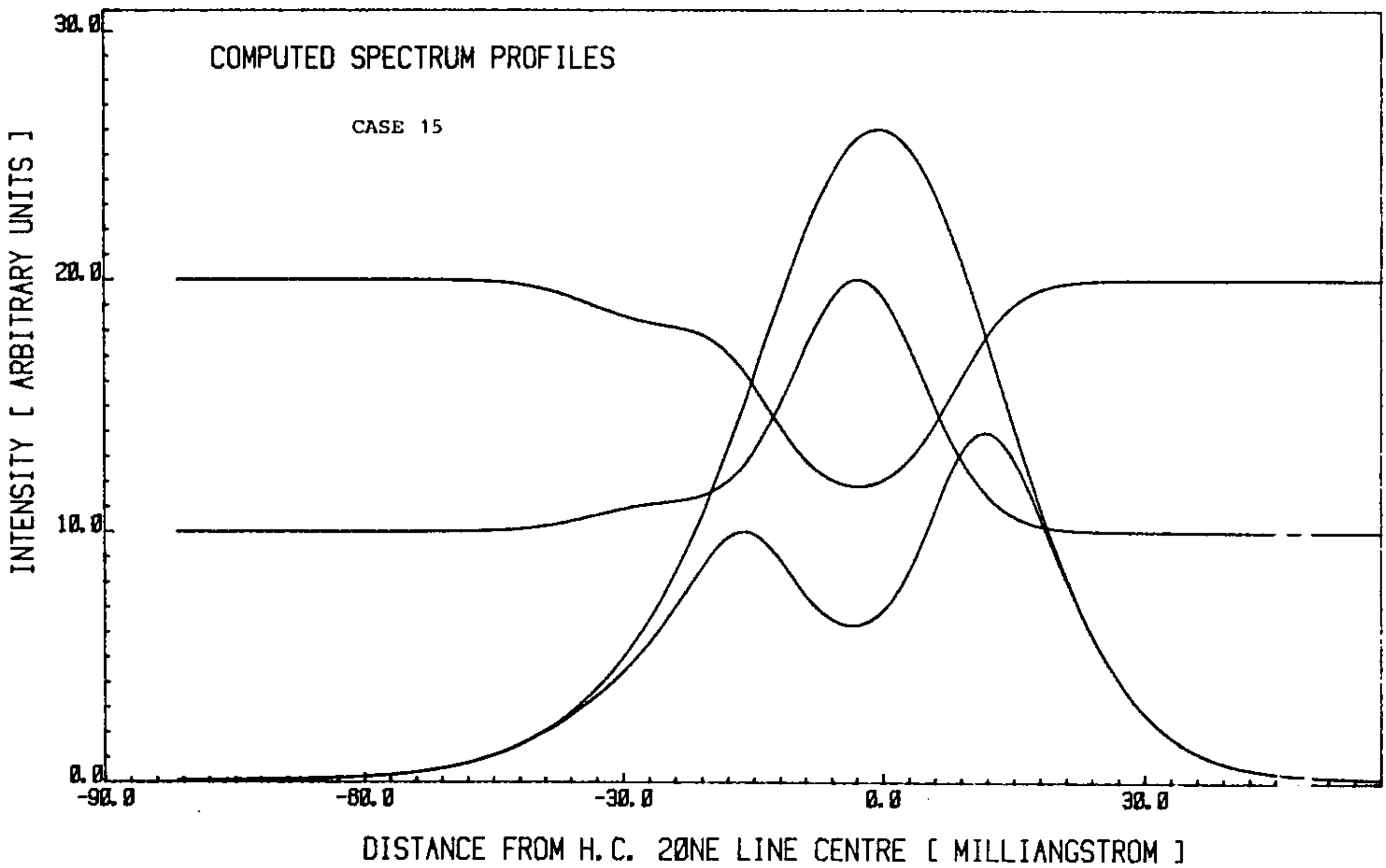

COMPUTED SPECTRUM PROFILES
CASE 10
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
INTENSITY [ARBITRARY UNITS]
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 11
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

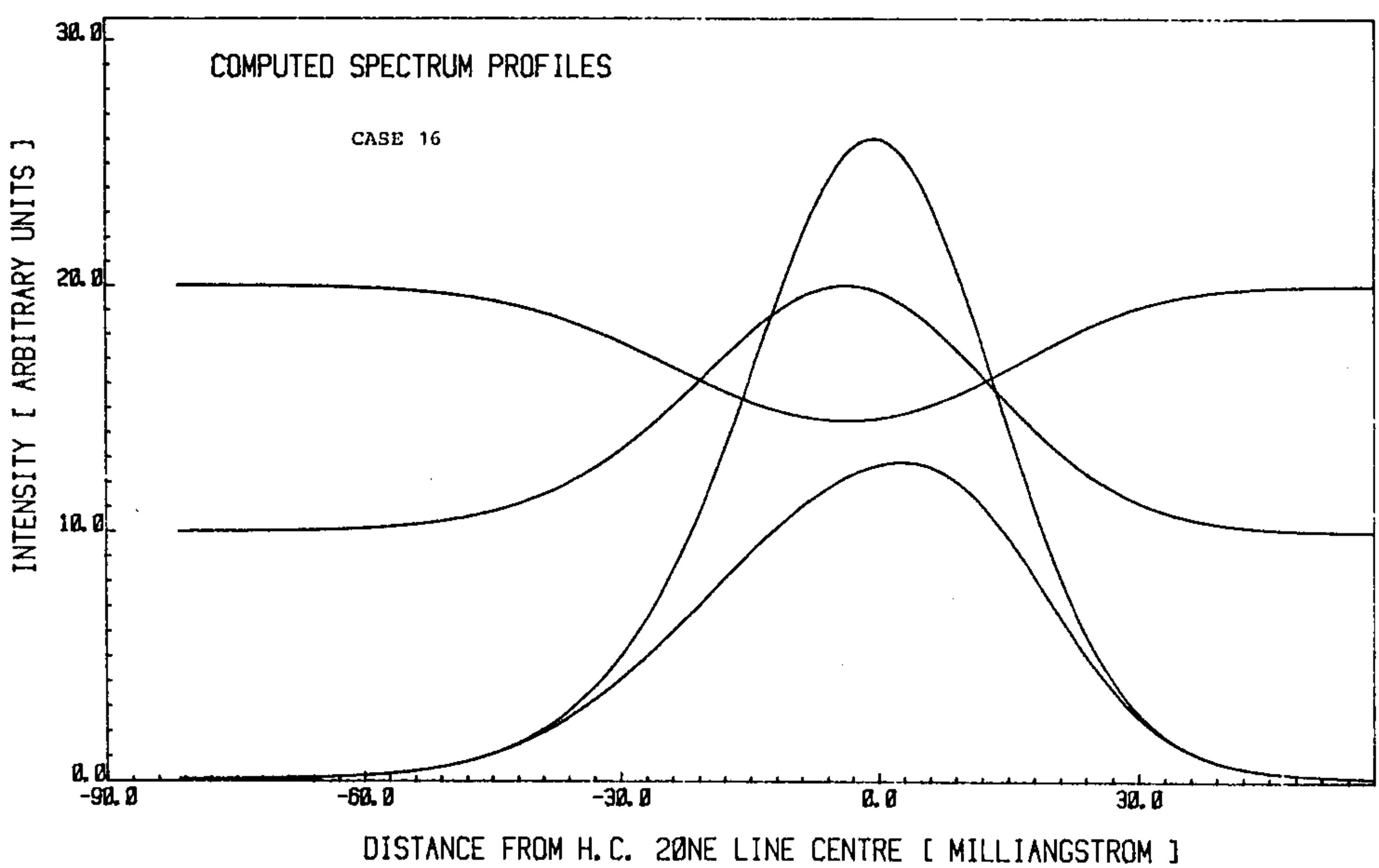

COMPUTED SPECTRUM PROFILES
CASE 12
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 13
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

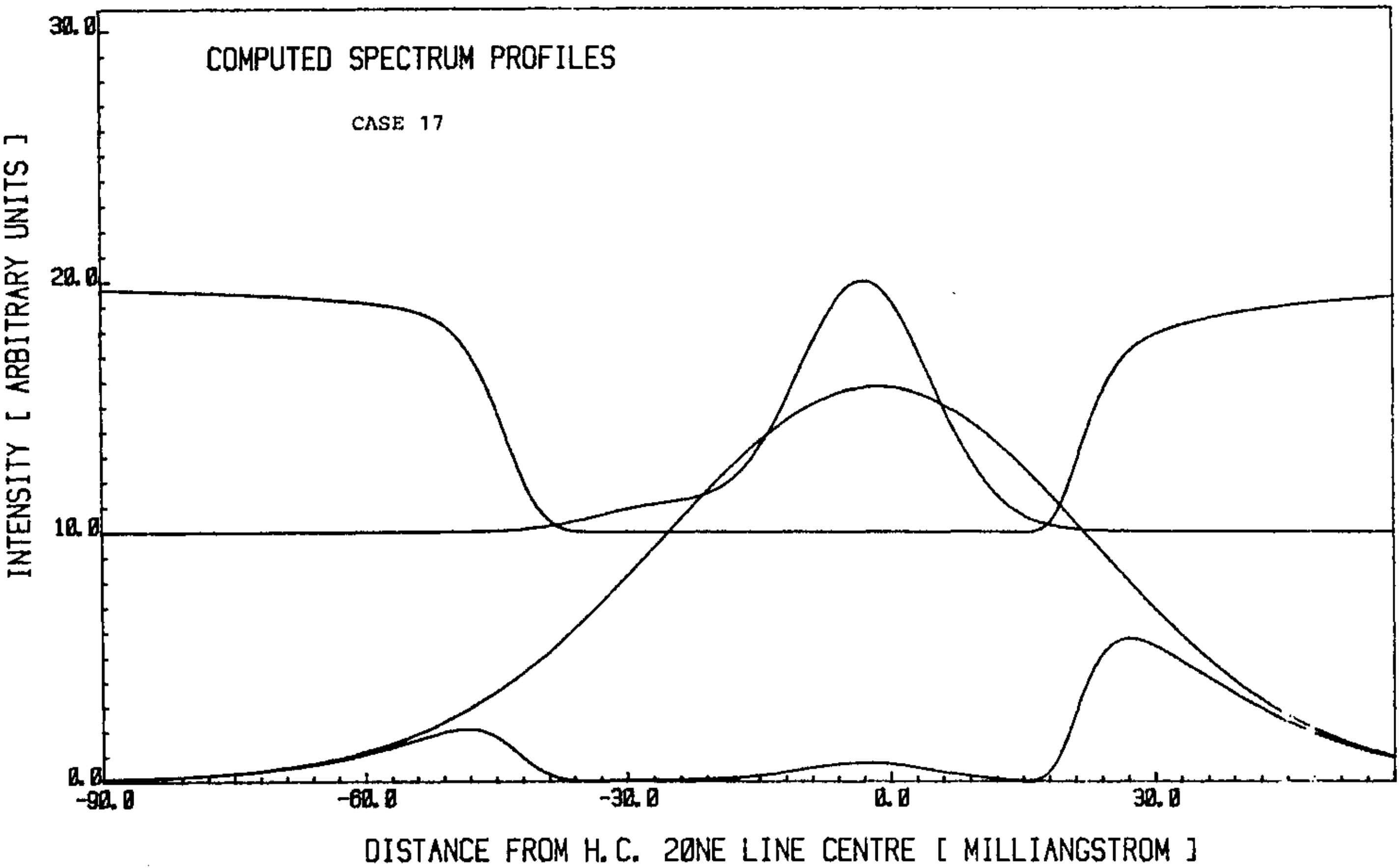

COMPUTED SPECTRUM PROFILES
CASE 14
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

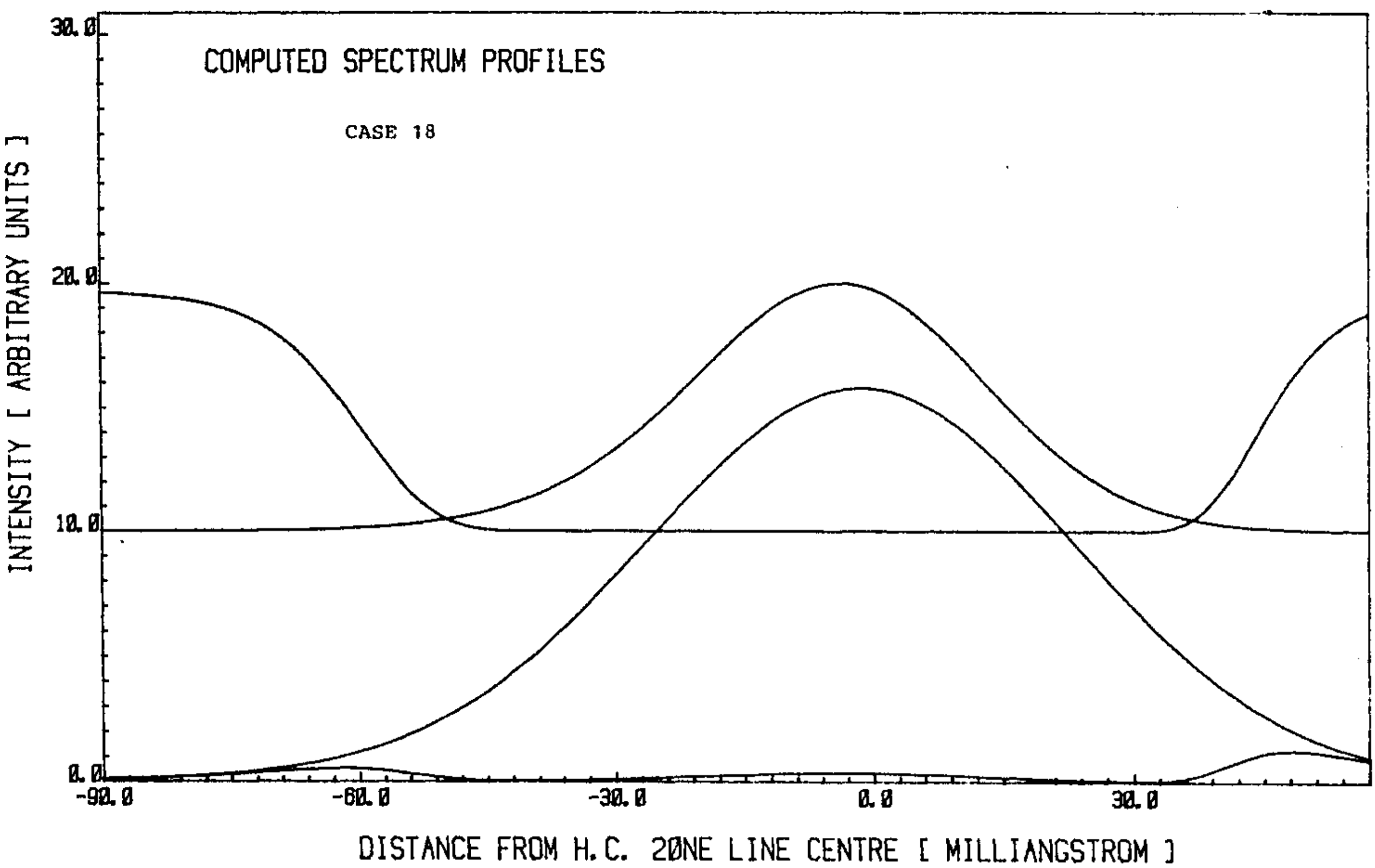


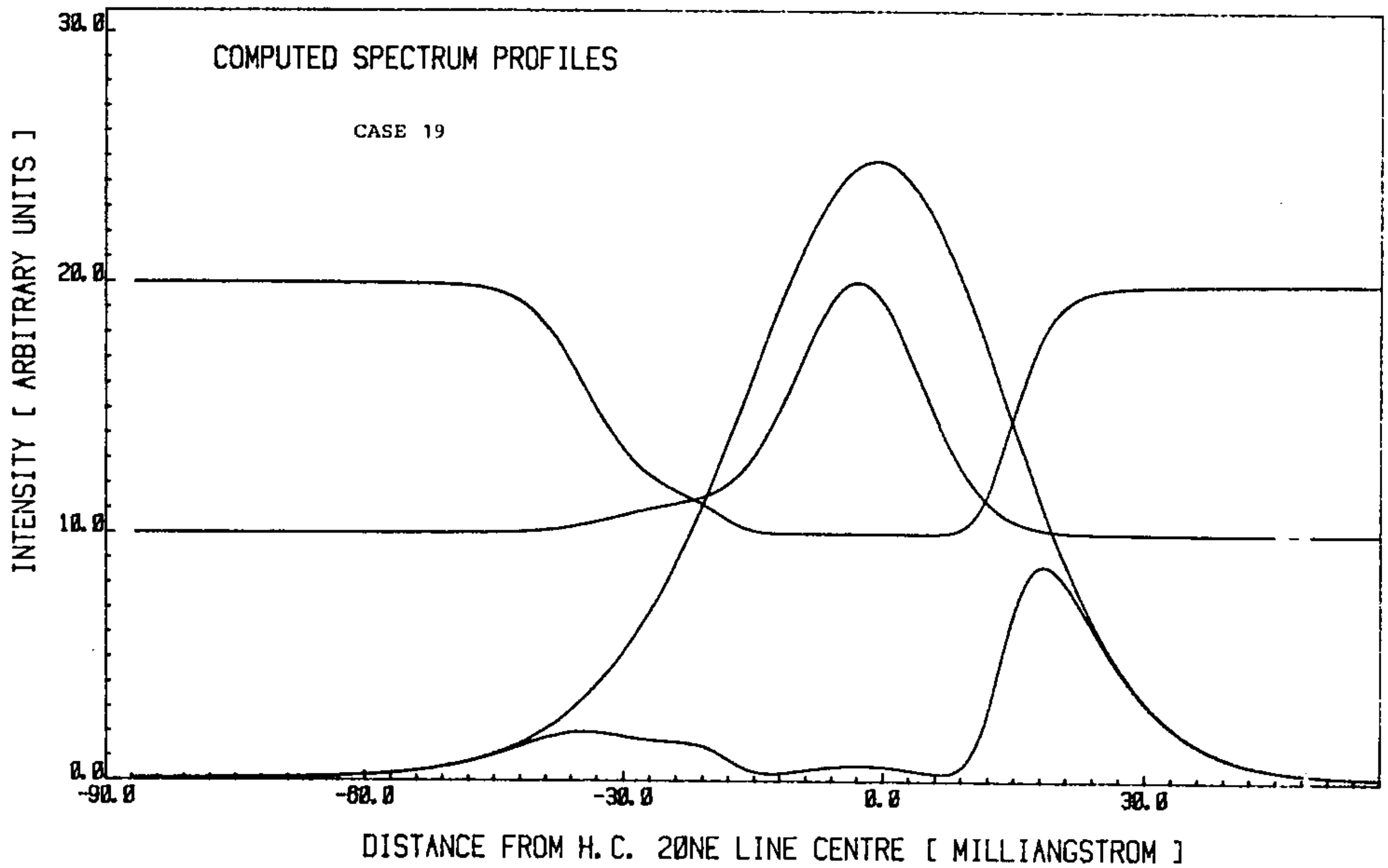
COMPUTED SPECTRUM PROFILES
CASE 15
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

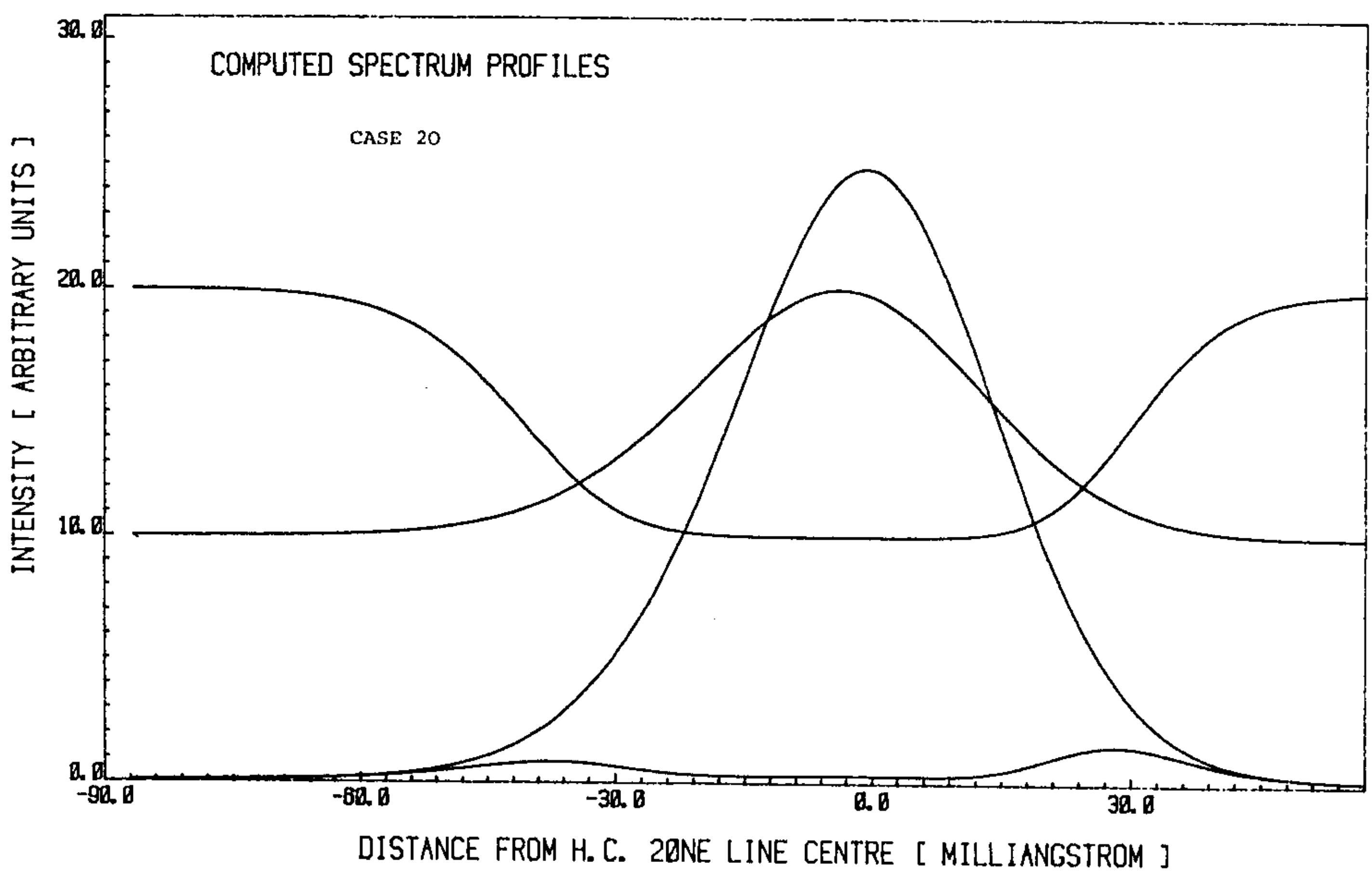


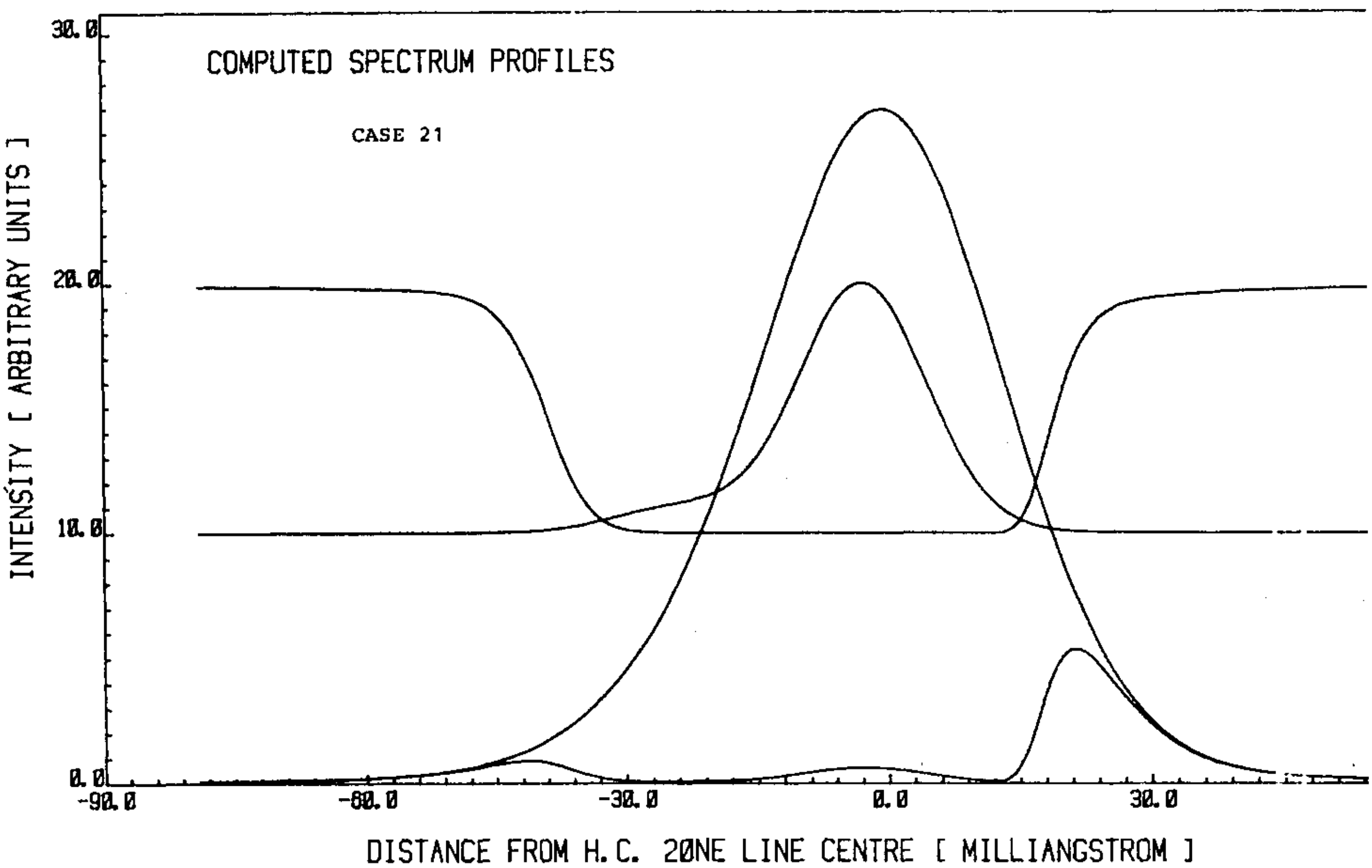
COMPUTED SPECTRUM PROFILES
CASE 16
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 17
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

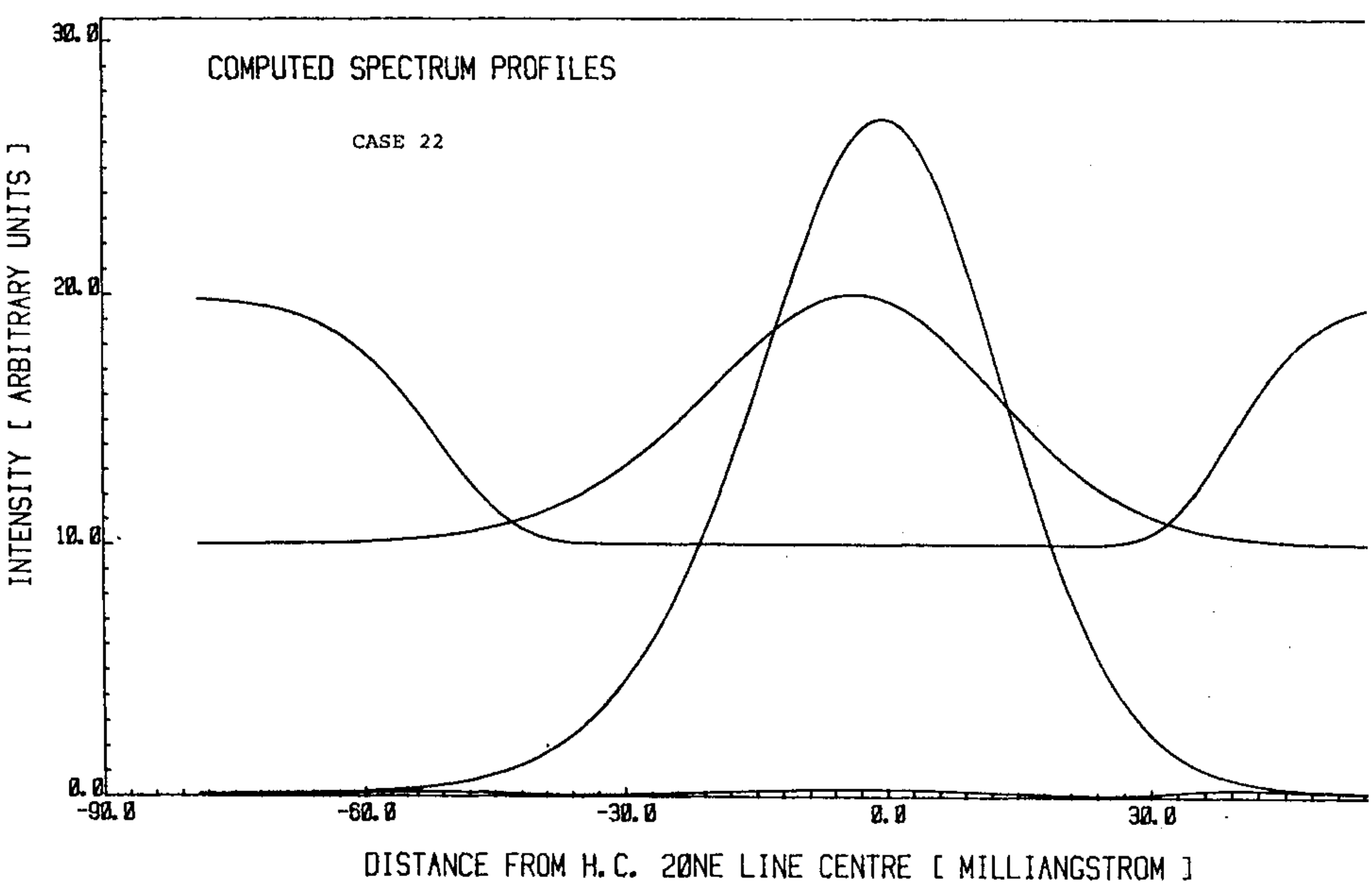

COMPUTED SPECTRUM PROFILES
CASE 18
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 19
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

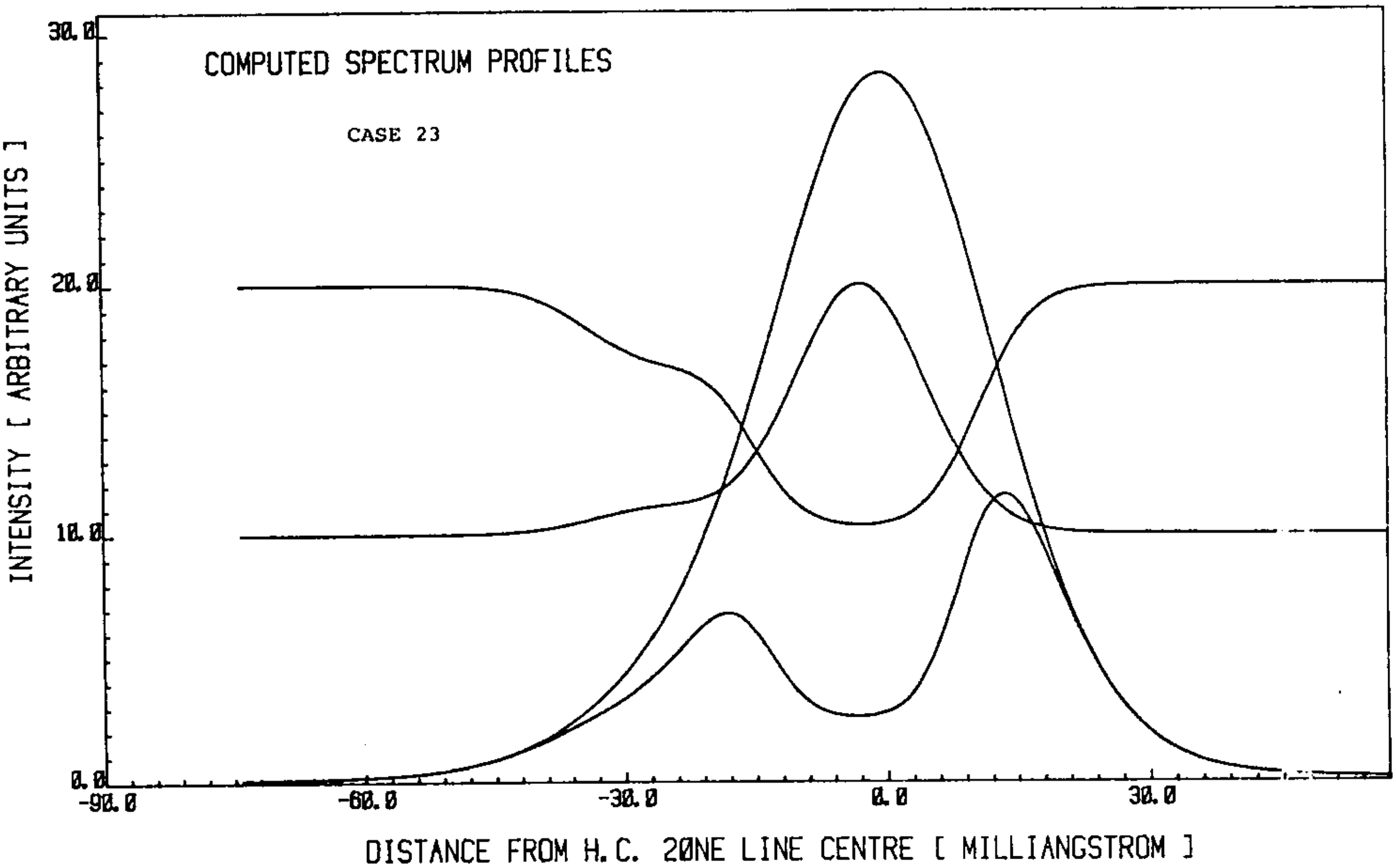

COMPUTED SPECTRUM PROFILES
CASE 20
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

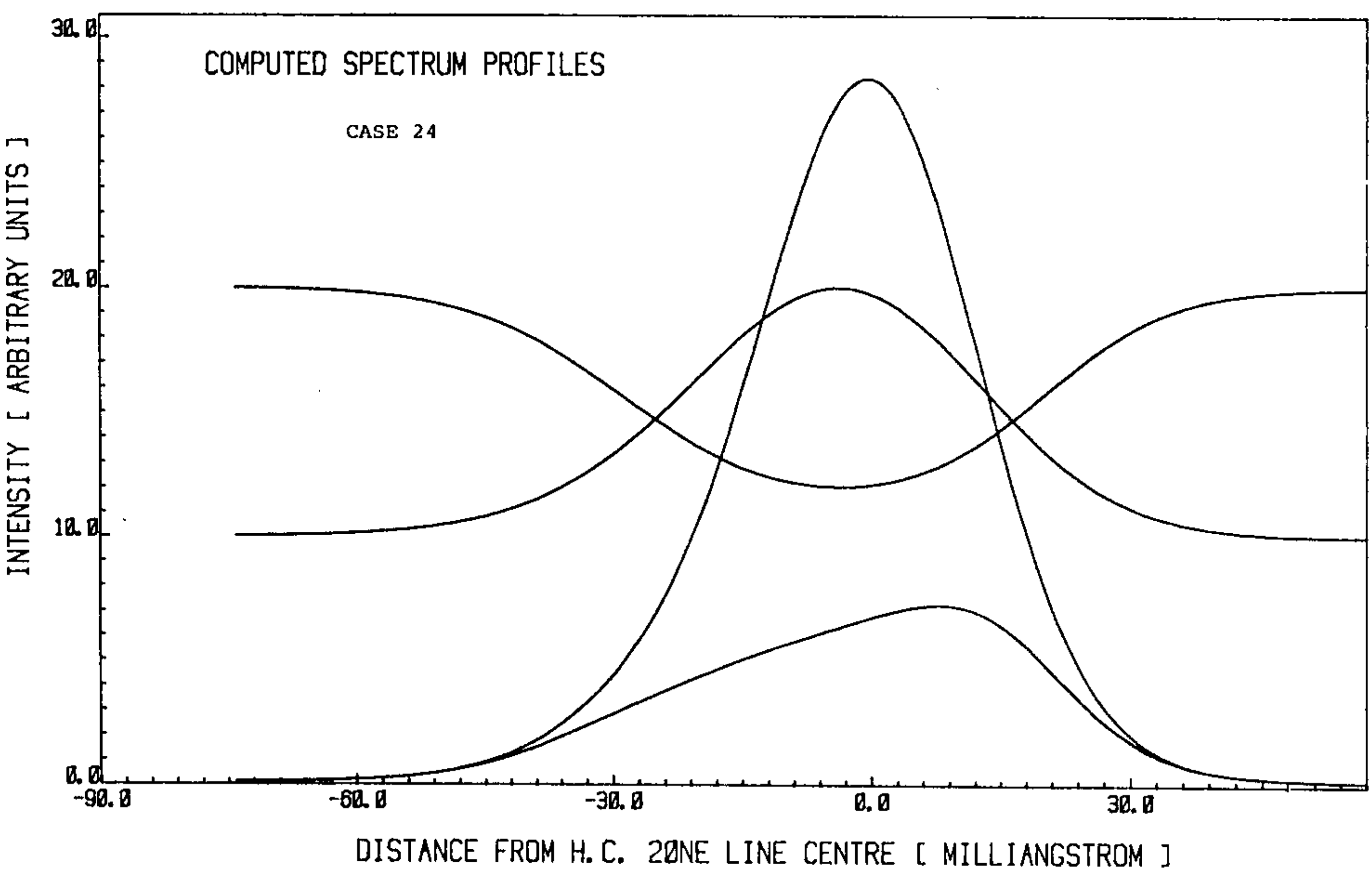


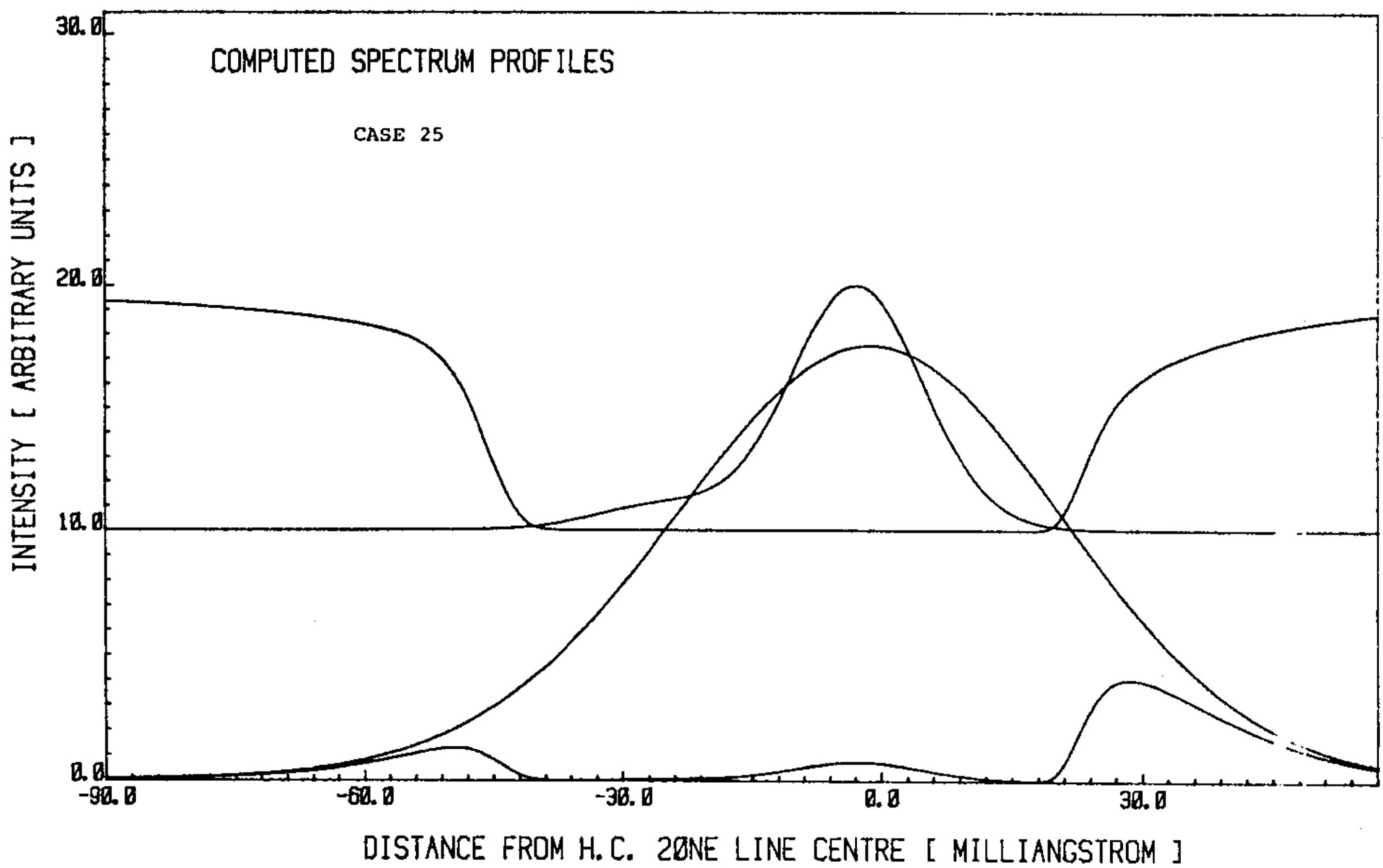
COMPUTED SPECTRUM PROFILES
CASE 21
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

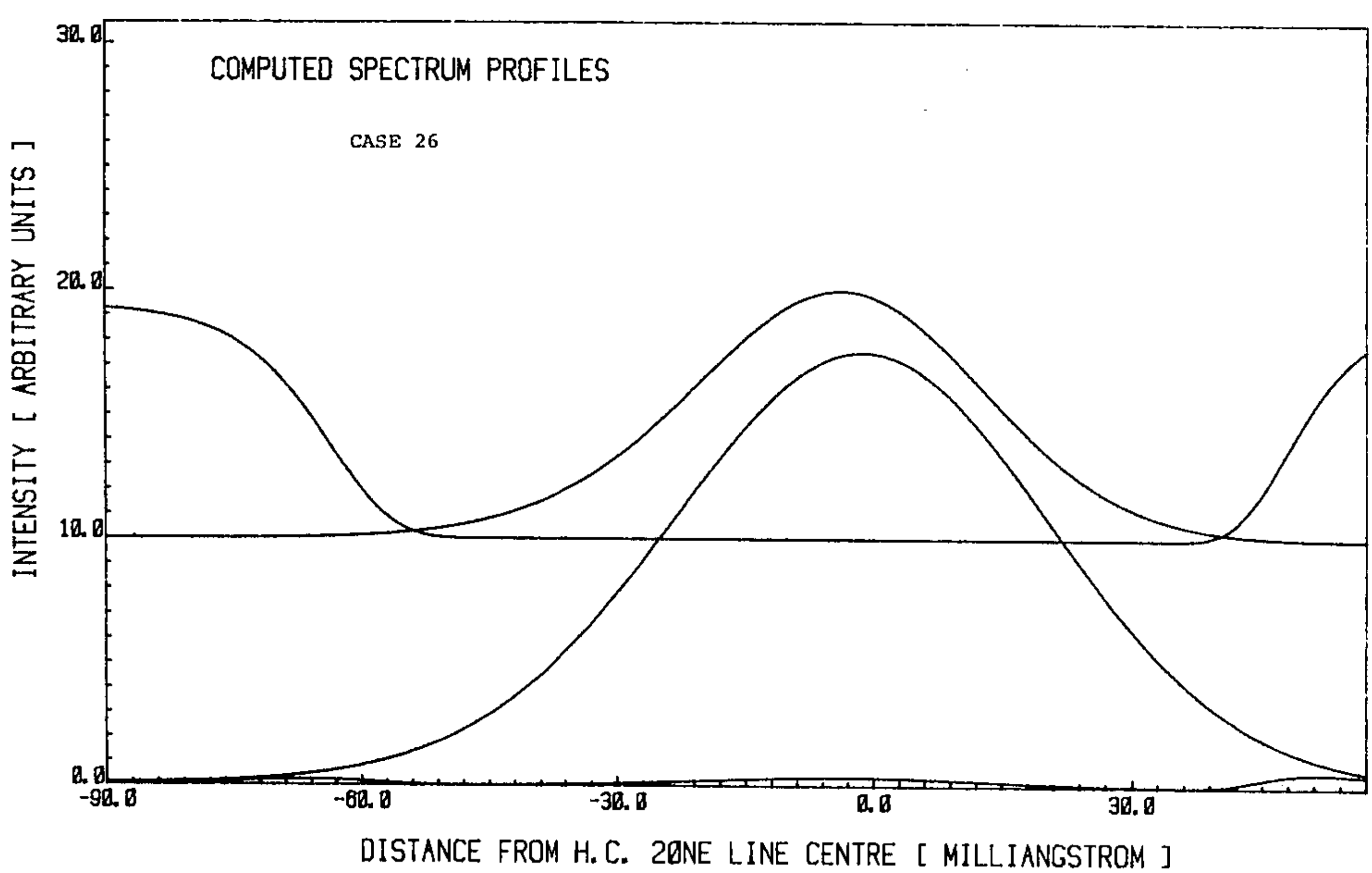


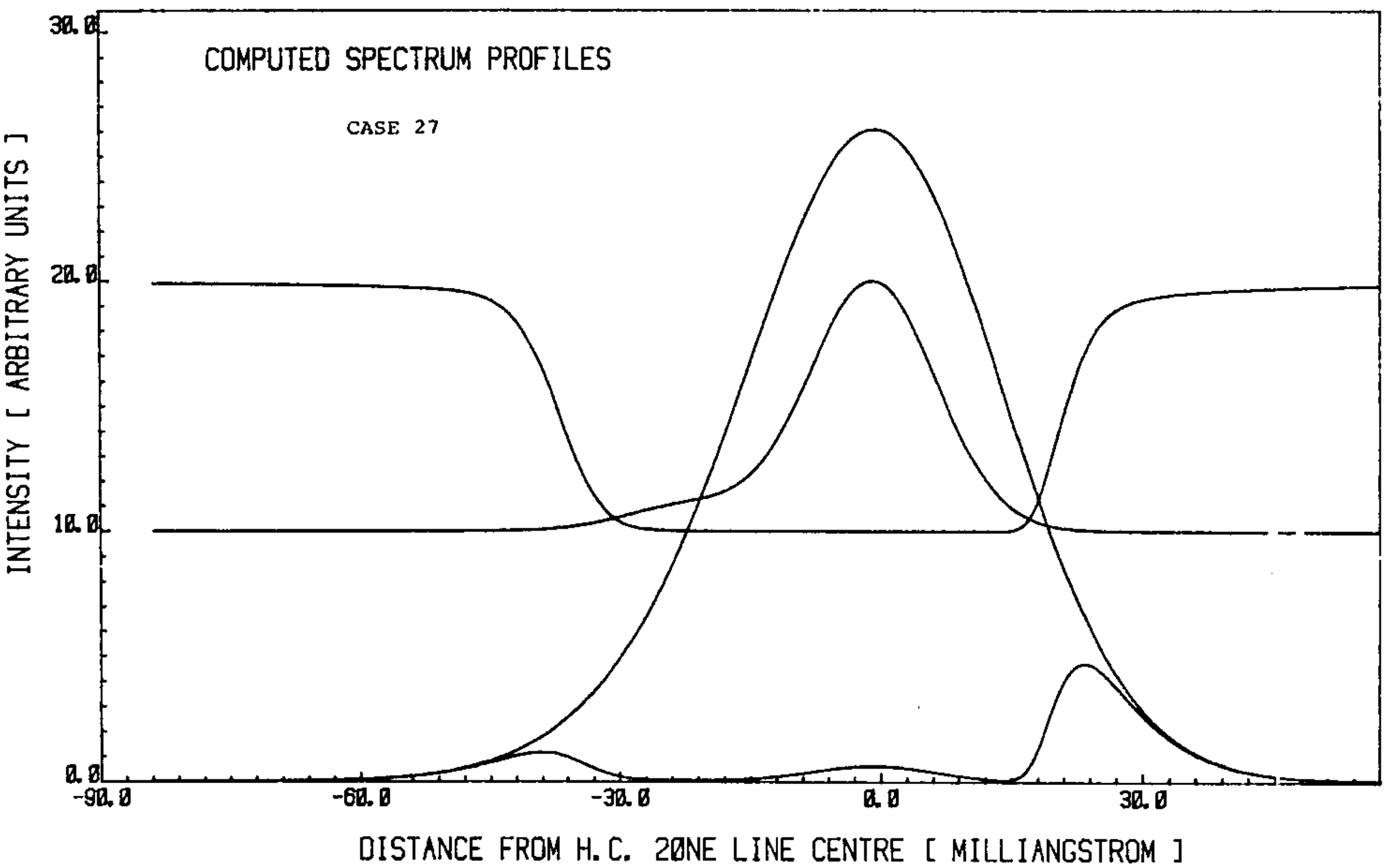
COMPUTED SPECTRUM PROFILES
CASE 22
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

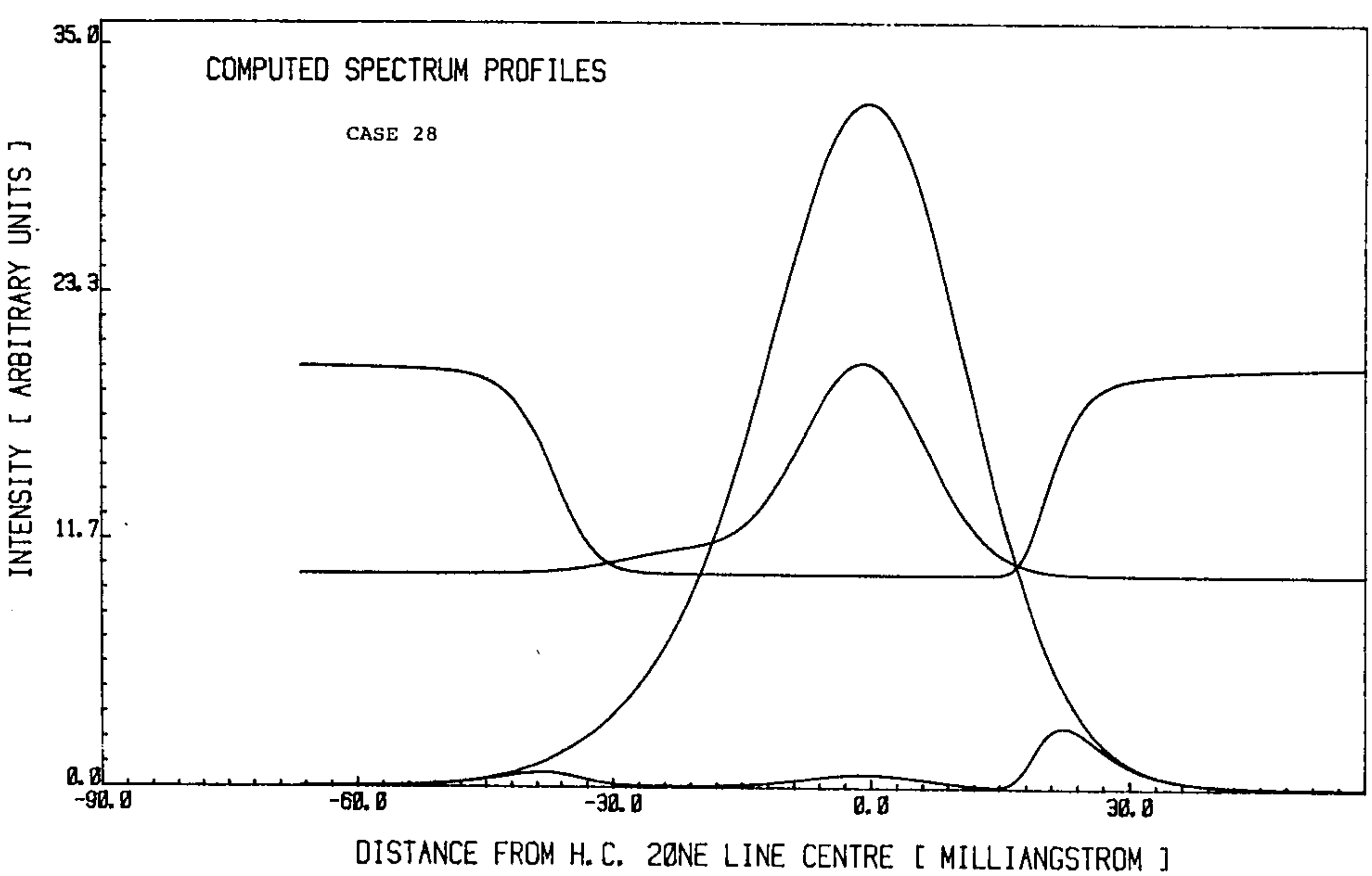

COMPUTED SPECTRUM PROFILES
CASE 23
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

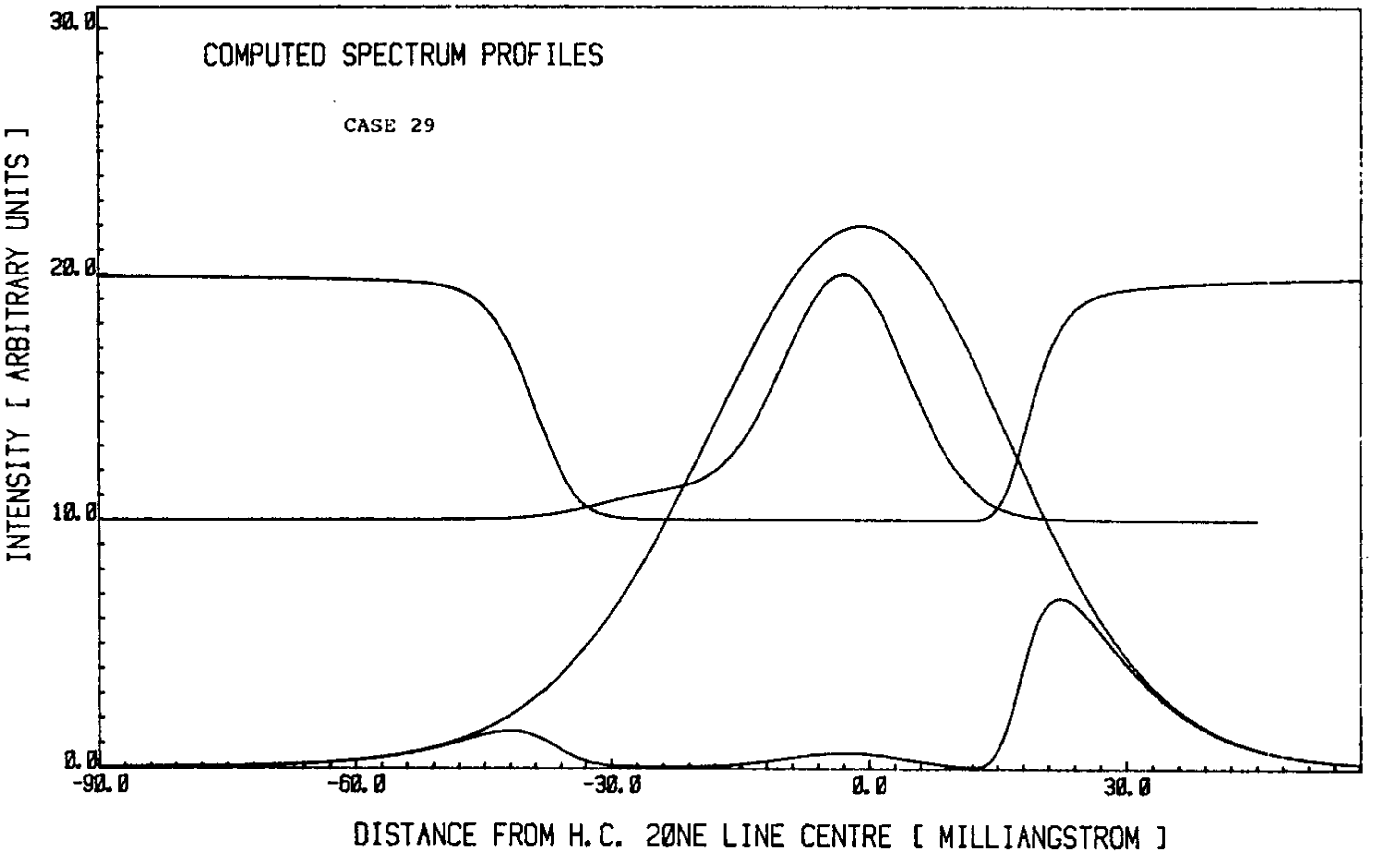

COMPUTED SPECTRUM PROFILES
CASE 24
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

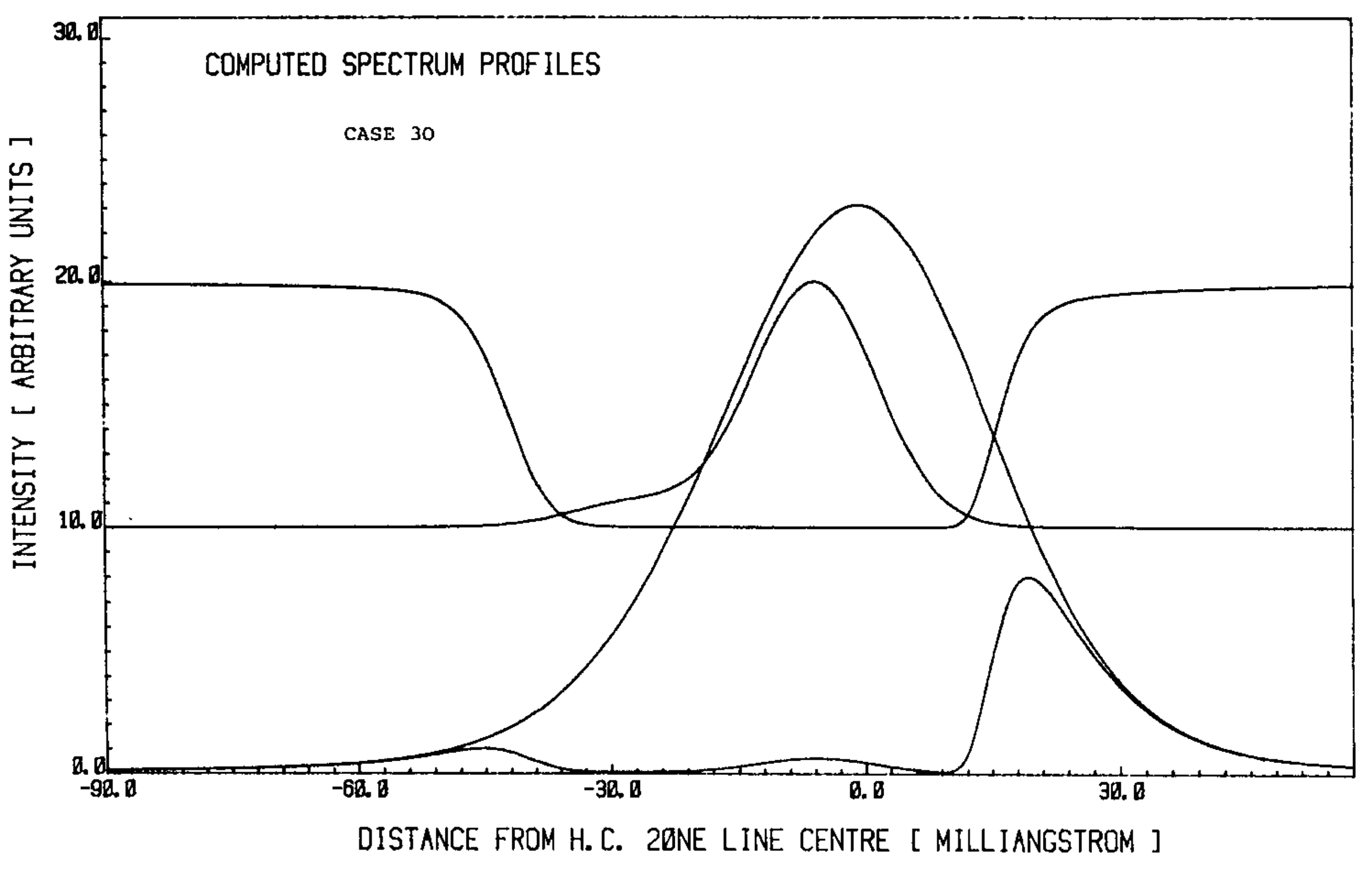

COMPUTED SPECTRUM PROFILES
CASE 25
30.0
20.0
10.0
0.0
INTENSITY [ARBITRARY UNITS]
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 26
30.0
20.0
10.0
0.0
INTENSITY [ARBITRARY UNITS]
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 27
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 28
INTENSITY [ARBITRARY UNITS]
35.0
23.3
11.7
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 29
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]


COMPUTED SPECTRUM PROFILES
CASE 30
INTENSITY [ARBITRARY UNITS]
30.0
20.0
10.0
0.0
-90.0
-60.0
-30.0
0.0
30.0
DISTANCE FROM H.C. 20NE LINE CENTRE [MILLIANGSTROM]

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B i b l i o g r a p h y

/1/ Paschen F., Ann. Physik, 50, 901, 1916

/2/ Schueler H., Z. Physik, 59, 149-153, 1930

/3/ Crosswhite H.M., Dieke G.H., Lagagneur C.S., J. Opt. Soc. Am., 45, 4, 270-280, 1955

/4/ Tolansky S., 'High Resolution Spectroscopy', Methmen, 1947

/5/ Crosswhite H.M., J. Research NBS - Atom. Phys. Chem., 79A, 1, 1975

/6/ Brault J.W., 'Solar Fourier Transform Spectroscopy', Kitt Peak National Observatory, Tucson, Arizona, USA

/7/ Ladenburg R., Rev. Mod. Phys., 5, 471, 1933

/8/ Pery-Thorne Anne P., Chamberlain J.E., Proc. Phys. Soc., 82, 133, 1963

/9/ Bridges J.M., Wiese W.L., Phys. Rev. A, 2, 2, 285-293, 1970

/10/ Griem H.R., 'Spectral Line Broadening by Plasmas', Academic Press Inc. (London) Ltd., 196, 1974

/11/ Davies J.T., Vaughan J.M., Astrophys. J., 137, 4, 1302-1305, 1963

/12/ Armstrong B.H., J. Quant. Spect. Rad. Transf., 7, 61-88, 1967

/13/ Landheer B., Durant A.V., J Phys. B, 4, 1, L36-L38, 1971

/14/ Kielkopf J.F., J. Opt. Soc. Am., 63, 8, 987-995, 1973

/15/ Lee Jong-Sen, Astrophys. J., 187, 159-161, 1974

/16/ Mayer-Kuckuk T., 'Atomphysik', Teubner Studienbuecher, 198, 1977

/17/ Keller J.C., J. Phys. B, 6, 1771-1778, 1973

/18/ Odintsov V.I., Opt. Spectrosc., 18, 3, 205-206, 1965

/19/ Ladenburg R., Levy S., Z. Physik, 65, 189, 1930

/20/ Hill R.M., J. Quant. Spect. Rad. Transf., 21, 19-22, 1979

/21/ Yamada H.Y., J. Quant. Spect. Rad. Transf., 8, 1463-1473, 1968

/22/ Kostkowski H.J., Bass A.M., J. Opt. Soc. Am., 46, 12, 1060-1064, 1956

/23/ Kusch H.J., Roendigs G., Wendt K., J. Quant. Spect. Rad. Transf., 17, 53-57, 1977

/24/ Schild E., Staatsexamen-Thesis, 'Spektrum des Jod Molekuels', Bonn, 1976

/25/ Moore Charlotte E., 'Atomic Energy Levels', Nat. Stand. Ref. Dat. Ser., NBS (U.S.), 35/V.I, 1971

/26/ Garstang R.H., Blerkom Janet van, J. Opt. Soc. Am., 55, 9, 1054-1057, 1965

/27/ Ladenburg R., Kopfermann H., Z. Physik, 48, 26, 51,1928

/28/ Paschen F., Ann. Phys., 60, 405, 1919

/29/ Paschen F., Ann. Phys., 63, 201, 1920

/30/ Bacher R.F., Goudsmit S., 'Atomic Energy States', McGraw Hill, New York, 1932

/31/ Wiese W.L., Martin G.A., 'Wavelength and Transition Probabilities for atoms and Atomic Ions, Part II, Transition Probabilities', Nat. Stand. Ref. Dat. Ser., NBS (U.S.), 68, 1980

/32/ Chamberlain J.E., DIC-Thesis, 'An Investigation of Transition Probabilities in the Spectra of the Inert Gases', London 1962

/33/ Meissner K.W., Z.Physik, 39, 172, 1926

/34/ Dorgelo H.B., Physica, 5, 90, 1925

/35/ Dorgelo H.B., Phys. Z., 26, 786, 1925

/36/ Thorne Anne P., 'Spectrophysics', Chapman and Hall Ltd., 298, 1974

/37/ Kuhn H.G., Lewis E.L., Proc. Roy. Soc., A 299, 423-433, 1967

/38/ Wiese W.L., Smith M.W., Glennon B.M., 'Atomic Transition Probabilities', Nat. Stand. Ref. Dat. Ser., NBS (U.S.), 4/I, Hydrogen through Neon, 1966