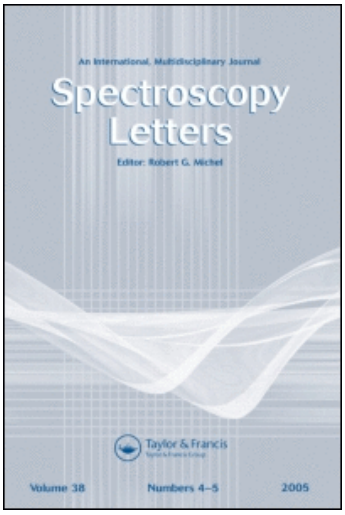

Spectroscopy Letters
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597299

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To cite this Article Senofonte, O. , Caroli, S. and Alimonti, A.(1981) 'A Modified Version of the Grimm's Glow Discharge Lamp for Use as a Demountable Hollow Cathode Emission Source. IV. Further Data on the Behavior of Blackening Curves for Copper', Spectroscopy Letters, 14: 3, 195 — 206
To link to this Article: DOI: 10.1080/00387018108062576
URL: http://dx.doi.org/10.1080/00387018108062576

SPECTROSCOPY LETTERS, 14(3), 195-206 (1981)

A MODIFIED VERSION OF THE GRIMM'S GLOW DISCHARGE LAMP FOR USE AS A DEMOUNTABLE HOLLOW CATHODE EMISSION SOURCE. IV. FURTHER DATA ON THE BEHAVIOR OF BLACKENING CURVES FOR COPPER

Key words: Hollow Cathode, Glow Discharge, Emission Spectroscopy, Copper, Photographic Blackening

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ABSTRACT: The blackening behavior of spectral lines emitted by a hollow cathode in the case of copper was further investigated at closer gas pressure intervals (259, 289, 314, 342, 375, and 416 Pa) and electrode distances (15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0 and 33.0 mm). Results show that a pressure range from 300 to 380 Pa can be considered a transition region in which the electrode distance corresponding to blackening maximum shifts progressively from 20 to 33 mm. These data agree with previous findings on the dependence of photographic blackening of copper spectral lines on electrode distance.

INTRODUCTION

The findings reported in the preceding paper of this series[1] demonstrated the dependence of blackening on discharge parameters. It was established that the behavior of copper hollow cathodes is very different from that of other materials (namely alu-

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minium and graphite). Measurements were carried out at electrode distances of 7.0, 15.0, 20.0, 25.0 and 33.0 for gas pressures of 90, 170, 230, 440, 690 and 1120 Pa. Experimental results showed that the blackening of copper spectral lines reached a maximum at a distance between cathode and anode of ca. 20 mm when the pressure of the argon carrier gas did not exceed a critical value. On the other hand, the distance of 33 mm corresponded to higher blackenings at gas pressure beyond that value. This inversion point was thought to be at ca. 330 Pa.

The purpose of this paper is to explain this unexpected phenomenon better. Other blackening measurements at closer gas pressure intervals are carried out in order to investigate in more detail the behavior of blackening curves for copper in the range of 230 - 440 Pa (hereafter referred to as the "transition region" for the sake of brevity).

EXPERIMENTAL

The structure of the modified RSV glow discharge lamp, the characteristics of the SPV 1m/800 vacuum spectrograph and of the other instrumentation employed, as well as the procedure adopted for performing blackening measurements, have already been reported in detail in the preceding parts of this study[1,2,3]. The discharge parameters selected for investigating the dependence of blackening on anodic distance are given in Table 1.

TABLE 1

Working Conditions Adopted for Investigating the Effect of Anodic Length on Blackening of Copper Spectral Lines Emitted by a Hollow Cathode in the Transition Region

Electrode Distance (mm): 15.0, 17.5, 20.0, 22.5, 25.0, 27.5, 30.0, 33.0
Current Intensity (mA): 100, 150, 200, 250
Argon Gas Pressure (Pa): 259, 289, 314, 342, 375, 416
Spectrograph Entrance Slit: 30 μm
Exposure Time: 30 s

Kodak Spectrum Analysis No. 1 films used for recording the spectra were subjected to the same conditions as reported in Part III of this study[1]. All steps relating to the present blackening measurements were carried out in strict compliance with the procedure previously established. Copper spectral lines used in this study coincide obviously with those chosen in the preceding paper[1]. They are listed in Table 2 together with some argon lines selected to form suitable pairs with the copper lines in order to examine the effect of electrode distance not only on absolute blackening but also on blackening differences.

For each spectral line of copper, blackening S was plotted against electrode distance d. Moreover, similar graphs were deduced for blackening differences ΔS obtained by pairing each line of copper with each line of argon.

RESULTS AND DISCUSSION

The patterns shown by the three copper lines are practically identical undependent of wavelength and line origin, and in full agreement with the findings reported previously[1]. The same is valid for the ΔS plots, which show a common general behavior whatever the copper and argon lines paired. For this reason S and ΔS curves are reported only for the copper line at 345.785 nm and the argon line at 345.410 nm, respectively, the graphs for the other two copper lines being characterized by the same pattern. Fig. 1 shows the dependence of S on electrode distance for the above copper line.

TABLE 2

Wavelengths of Spectral lines Chosen for Investigating the Dependence of Blackening on Electrode Distance

Copper λ (nm)	Argon λ (nm)
(I) 345.785	(I) 418.188
(I) 301.084	345.410
(II) 227.625	(II) 228.264

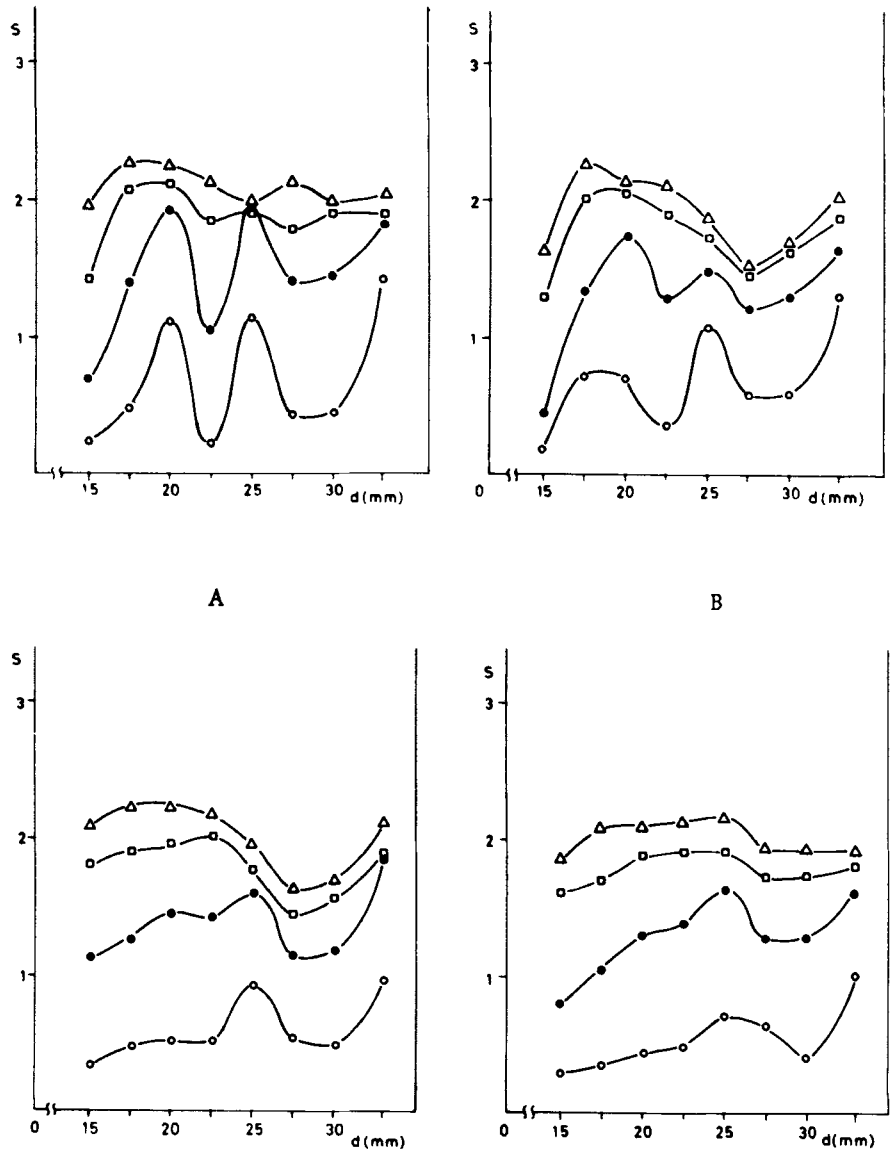

Fig. 1

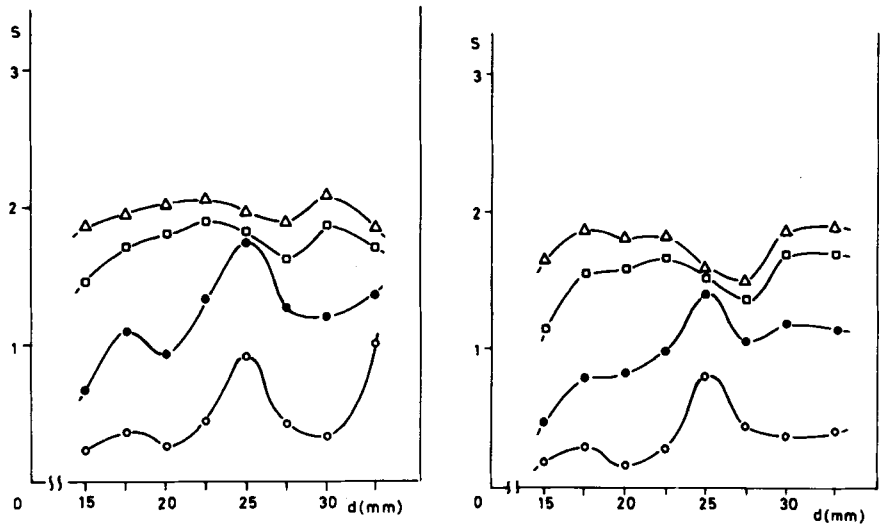

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FIG. 1 - Blackening - Electrode Distance Curves at Varying Current Intensity with Constant Gas Pressure for Spectral Line Cu(I) 345.785 nm. Gas Pressure (Pa): A, 259; B, 289; C, 314; D, 342; E, 375; F, 416. Current Intensity (mA): o = 100; ● = 150; □ = 200; Δ = 250.

An inspection of the graphs given in Fig. 1 allows the following conclusions to be drawn: i) the lower the current intensity the less pronounced the oscillations of blackening with electrode distance; ii) there is a tendency for blackening values pertaining to the longest gap between electrodes (i.e. 33 mm) to progressively increase as carrier gas pressure rises. It must however be outlined that there is a superimposition of two opposite tendencies in the pressure range taken into consideration (259 - 416 Pa).

As shown in Part III[1] of this work, outside the mentioned range, one of the two patterns prevails. Below 230 Pa the maximum of blackening - electrode distance plots occurs at 20 - 30 mm, whereas above 440 Pa the maximum is unambigously shifted to 33 mm.

The data plotted in Fig. 1 can be rearranged to demonstrate the direct dependence of blackening on filler gas pressure, as shown in Fig. 2.

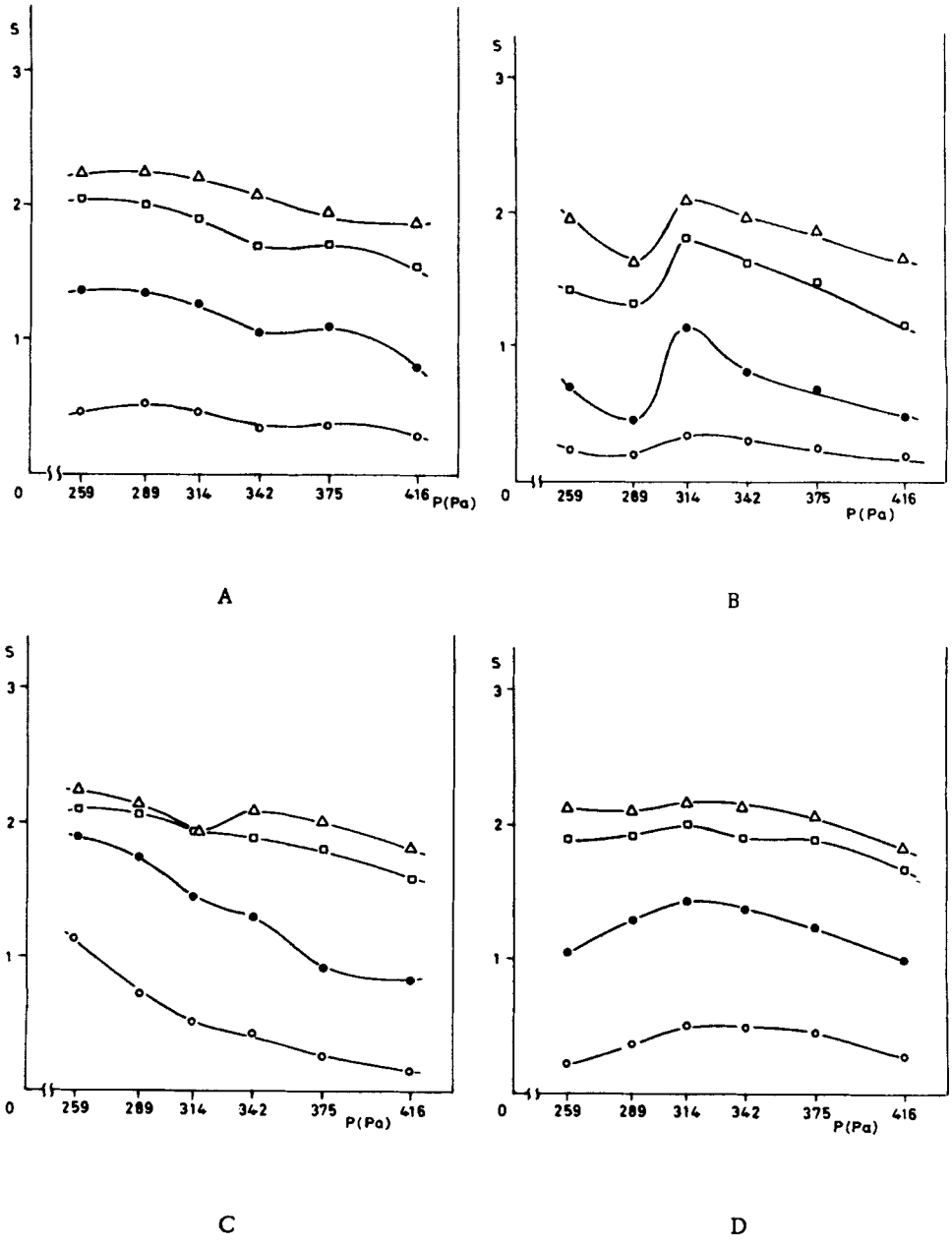

Fig. 2

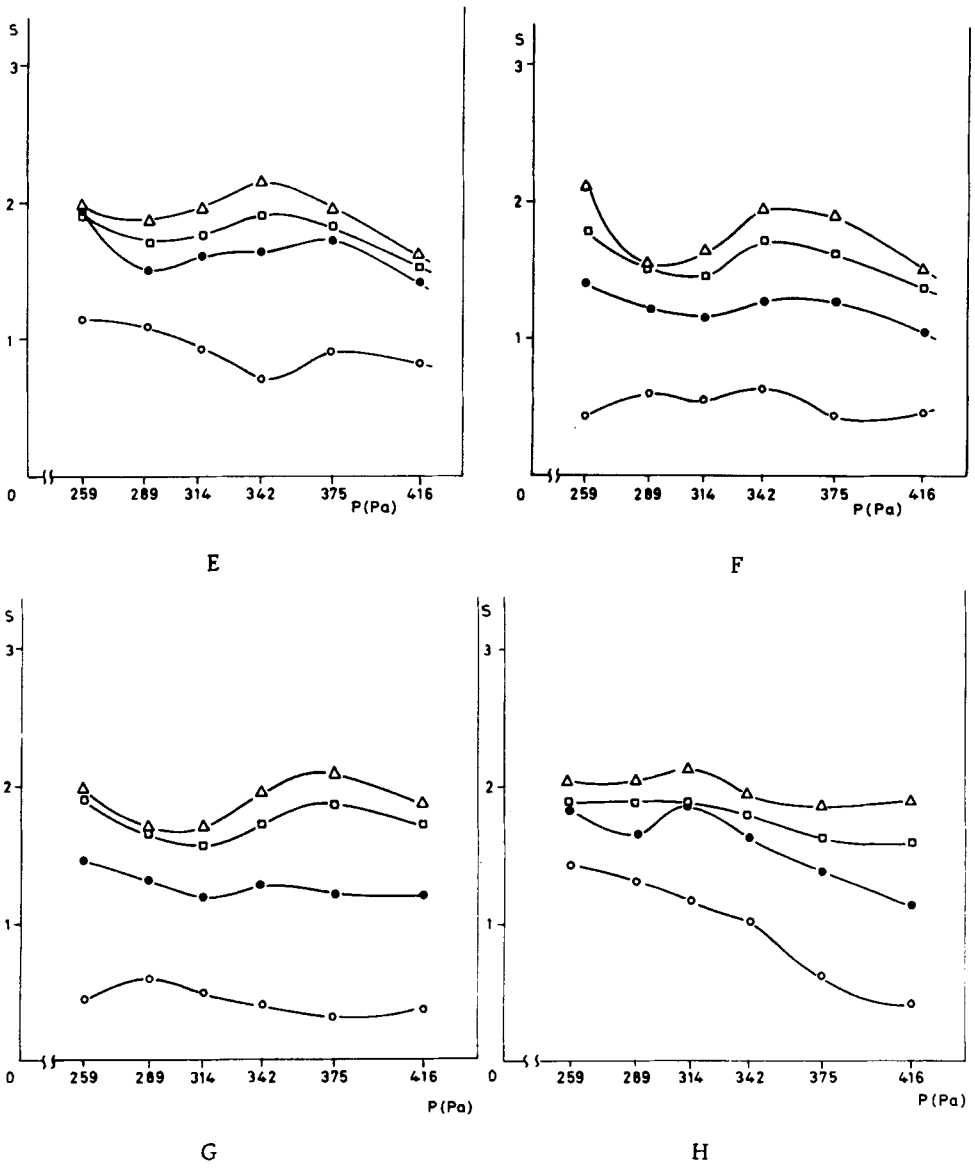

FIG. 2 - Blackening - Gas Pressure Curves at Varying Current Intensity with Constant Electrode Distance for Spectral Line Cu(I) 345.785 nm. Electrode Distance (mm): A, 15.0; B, 17.5; C, 20.0; D, 22.5; E, 25.0; F, 27.5; G, 30.0, H, 33.0. Current Intensity (mA): o = 100; ● = 150; □ = 200; Δ = 250.

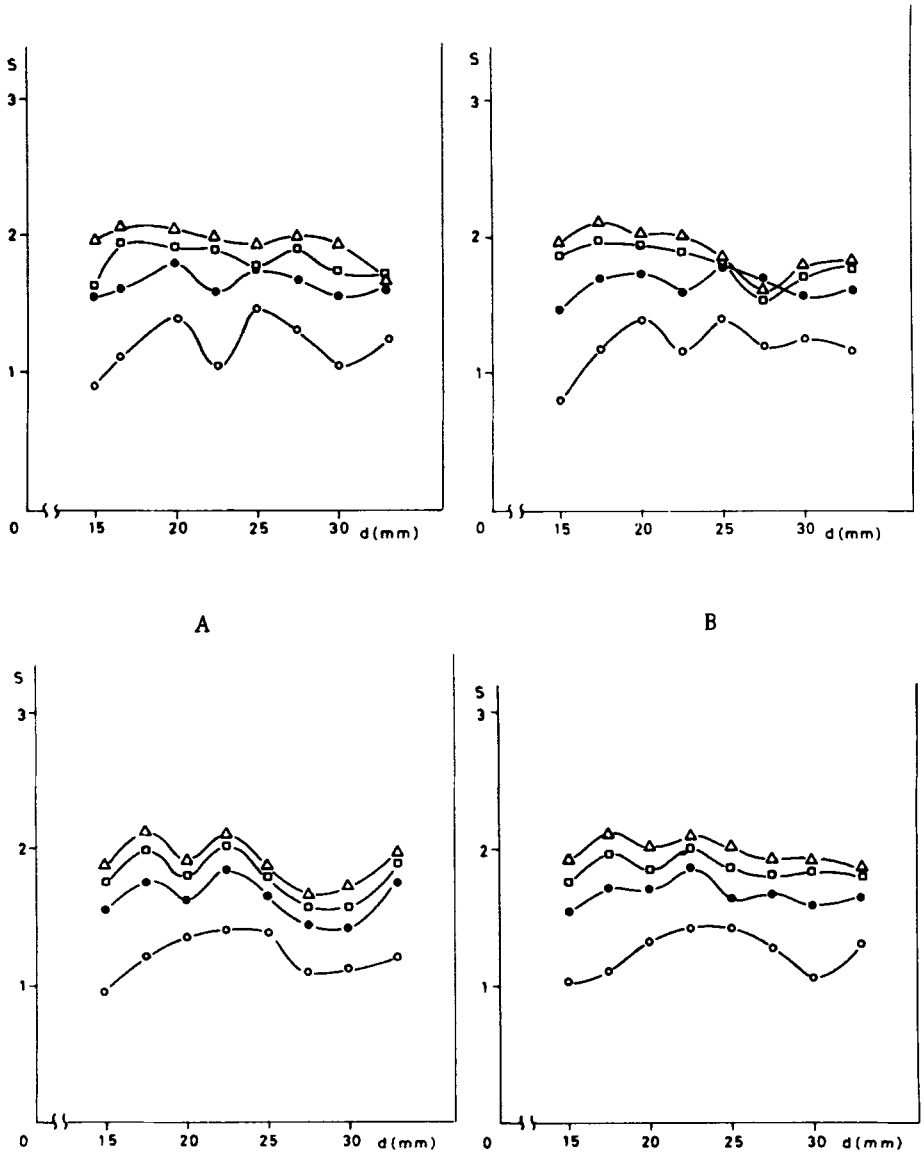

Fig. 3

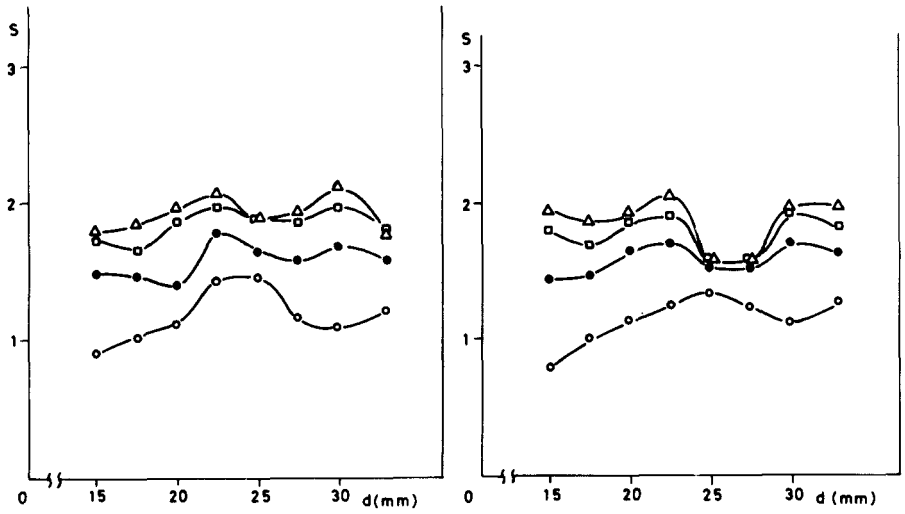

FIG. 3 - Blackening-Electrode Distance Curves at Varying Current Intensity with Constant Gas Pressure for Spectral Line A 345.410 nm. Gas Pressure (Pa): A, 259; B, 289; C, 314; D, 342; E, 375; F, 416. Current Intensity (mA): o = 100; ● = 150; □ = 200; Δ = 250.

On the basis of curves plotted in Fig. 2 it is possible to state that a maximum in emission intensity, reflected by the maximum in blackening, occurs at a pressure of between 300 and 380 Pa. This fact further demonstrates that the noble gas pressure range centered around 340 Pa is effectively a critical interval for the behavior of blackening curves.

On the other hand, the behavior of blackening of argon lines resembles closely that of copper lines (as shown by the graphs plotted in Fig. 3), though the oscillations are in the former case less pronounced.

The combination of the data reported in Figs. 1 and 3, i.e. the plotting of ΔS graphs leads to the curves given in Fig. 4.

By simple comparison of the curves reported in Figs. 1 and 4 it can be easily deduced that their general behavior is fundamentally the same. This fact further supports

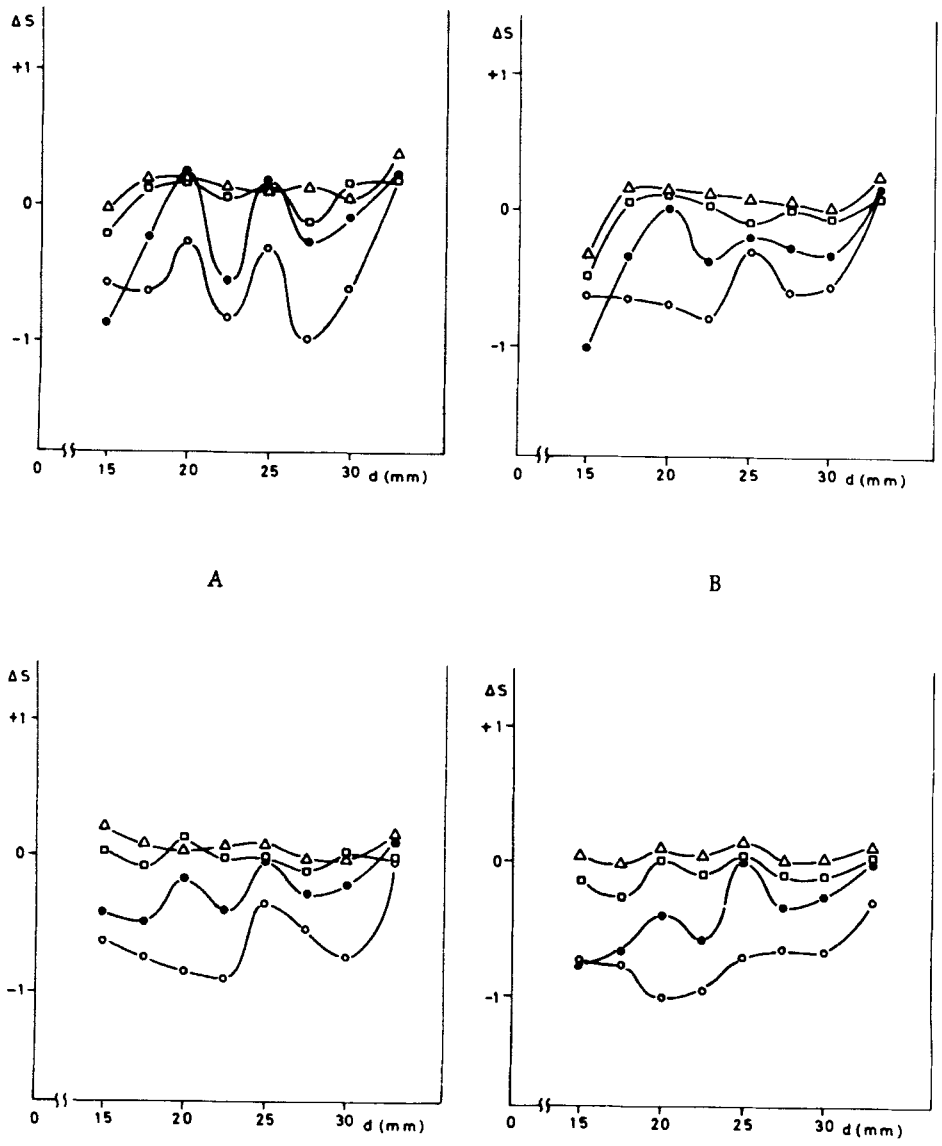

Fig. 4

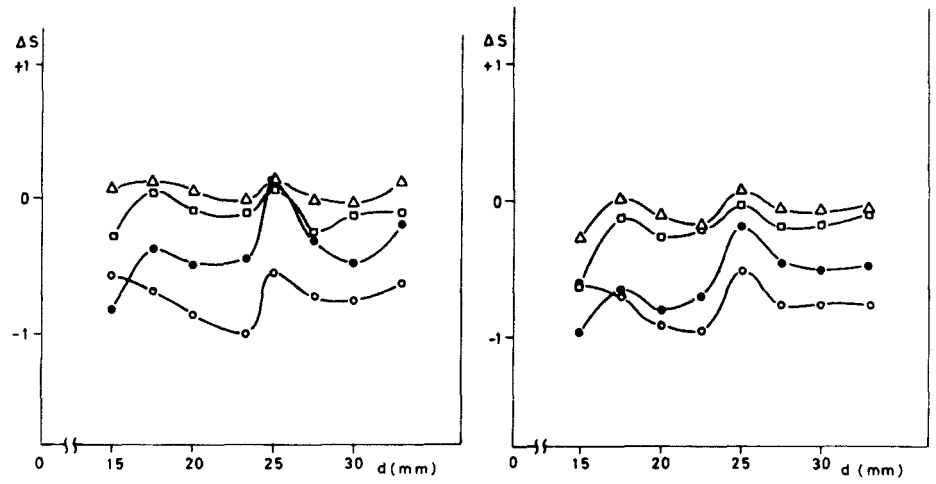

FIG. 4 - Blackening Difference-Electrode Distance Curves at Varying Current Intensity with Constant Gas Pressure for Spectral Line Pair Cu(I) 345.785 – A 345.410 nm. Gas Pressure (Pa): A, 259; B, 289; C, 314; D, 342; E, 375; F, 416. Current Intensity (mA): o = 100; • = 150; □ = 200; Δ = 250.

the assumptions made in previous papers[4,5] that reference lines are superfluous when evaluating spectra emitted by sputtering radiation sources.

CONCLUSIONS

The fact that these latest results are in full agreement with the data discussed in the preceding part of this research[1] would support their validity and their general significance. On the basis of the above findings it can be concluded that at a sufficiently high current intensity (200 - 250 mA) three filler gas pressure ranges can be distinguished, respectively below 240 Pa, between 240 and 430 Pa, and above 430 Pa. In correspondence with each of these gas pressure intervals, blackening curves present in the order maxima at 20 - 23 mm, at both 20 - 23 and 33 mm, and at 33 mm. From a practical point of view, this special behavior of copper hollow cathodes is now entirely evident as far as dependence of blackening on discharge parameters is concerned. It remains still to be clarified how these phenomena are connected with the physical processes occurring

in plasma during discharge. Further studies should be carried out for a definitive correlation of these experimental observations.

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Received: January 14, 1981
Accepted: February 12, 1981