The charged-particle density found from the Stark broadening of spectral lines in an inhomogeneous plasma source can be attributed with an error of 10-15% to regions of maximum spectral brightness of the line center. If the contour is recorded under conditions such that the spectral brightness of the line center is much greater than that of the wings, the experimental results can be attributed to the central regions of the inhomogeneous source. If, on the other hand, the contour is recorded under conditions such that the spectral brightness of the line center exceeds the measured spectral brightness of the wings only slightly, the experimental results should be applied to the periphery of the inhomogeneous source.

In measuring the density of charged particles on the basis of the broadening of the sodium spectral lines in a dc arc, Kitaeva and Sobolev [1] found important discrepancies in the densities determined from different lines. Since they used spectral lines displaying the quadratic Stark effect, they attributed the discrepancies to deficiencies in the theory of broadening due to the quadratic Stark effect. The theory for the broadening of spectral lines displaying the quadratic Stark effect has now been worked out thoroughly [2], but it still does not explain the experimental discrepancies. We therefore conclude that the discrepancies in the charged-particle densities determined from the broadening of different spectral lines must have a different explanation.

In a study of a dc arc at various pressures [3], these important discrepancies (amounting to a factor of two to three) were observed in the charged-particle densities found from the broadening of spectral lines with various Stark constants. We noted that we found the smallest densities from the broadening of the lines having the maximum Stark constants and the largest densities from the broadening of the lines having the minimum Stark constants. In addition, as the source was made more nearly homogeneous, the densities determined from the different lines approached the same value. We concluded that these density discrepancies had a basis in the physical properties of the source.

It was subsequently shown convincingly [4-6] that the charged-particle density in an inhomogeneous source determined from the broadening of some spectral line should be attributed to the regions of the source in which the spectral brightness of the given line has a maximum at its contour maximum (the center of the line). This was a purely experimental result and was not clearly explained. It was not made clear what errors would result from attributing the densities obtained to regions of the maximum spectral brightness of the line center. Below we take up these questions for the two extreme cases: that in which the contour of the spectral line is recorded under conditions such that the maximum spectral brightness at the center of the line ($I_{\text{cent}}$) exceeds by an order of magnitude or more the minimum brightness which can be reliably measured some distance from the line center ($I_{\text{boun}}$), i.e., at the wings of the line; and that in which the spectral line is recorded under conditions such that this difference is less than an order of magnitude ($I_{\text{cent}}/I_{\text{boun}} < 10$). We used the experimental data of [5] to analyze both cases. The charged-particle density was measured in [5] along the radius of a dc arc (i = 8 A) in the atmosphere on the basis of the lithium lines at 4602.66, 4273.28, and 4132.28 Å, for which the Stark constants differ markedly. Figure 1 shows the distributions of temperature and charged-particle density under these conditions, along with the spectral brightness distribution at the line center, found experimentally in [5], for the 4132 Å lithium line.
Fig. 1. Radial distributions according to the data of [5]: 1) temperature; 2) charged-particle density; 3) spectral brightness of the line center corresponding to the given temperature and density for Li I 4972 Å; 4) the same, for Li I 4132 Å; 5) that found experimentally [5] for Li I 4132 Å.

Fig. 2. 1) Integral contour of the Li I 4972 Å line found by averaging over the line of vision; 2) contour corresponding to the maximum spectral brightness of the line center.

Below we consider the Li I 4972 Å line (a 2P–4S transition) as an example of the first case and the Li I 4132 Å line (2P–5D) as an example of the second case. The greatest spectral brightness at the maximum of the Li I 4132 Å contour is found at the periphery of the discharge. The lithium line at 4972 Å has a low Stark constant, and its spectral density at the maximum of the line contour reaches a maximum at the discharge axis.

In an arc discharge the broadening of the lithium 4972 Å line is due primarily to the quadratic Stark effect and to the Doppler effect. The resultant contour is described by a Voigt integral [6]. We can therefore find the distribution of spectral brightness in the contour of the Li I 4972 Å line along the arc radius through the use of the distributions of temperature and charged-particle density in Fig. 1. Figure 2 shows the contour of the Li I 4972 Å line obtained by integrating over the line of vision at each frequency, compared with the Li I 4972 Å contour in the region of the maximum spectral brightness in the contour; the contours are in good agreement. We can analyze the resultant contour by the procedure described in [6].

The charged-particle density measured from the half-width of the resultant Li I 4972 Å contour differs by only 10% from that found from the half-width of the contour in the region of the maximum spectral brightness of the line contour. The temperature of the radiating lithium atoms differs from the actual temperature by 15%; i.e., it is 3900 K, rather than the 4600 K found experimentally. It follows that if the spectral-line contour is recorded with a ratio I_{cent}/I_{boun} > 10, the plasma properties determined from the average contours of these lines can be assigned with an error of 10–15% to regions of the maximum values of the maximum spectral brightness of the line contour in an inhomogeneous plasma source.

When a line contour is recorded under the condition I_{cent}/I_{boun} < 10, this situation is much more complicated. The lithium line at 4132 Å has a linear Stark effect and displays considerable broadening at large charged-particle densities. In several cases the condition I_{cent}/I_{boun} < 10 may hold. In our case (Fig. 1), this ratio is I_{cent}/I_{boun} ~ 2–3. The broadening of the lithium line at 4132 Å can be calculated on the basis of the theory of the linear Stark effect [7]. We carried out a complete calculation of the spectral-brightness distribution of the Li I 4132 Å line with respect to the wavelength of the contour and with respect to the radius of the arc column, but this calculation did not yield the observed experimental maximum of the spectral brightness of the line center at the periphery of the arc column [5].

The spectral brightness at the center of the Li I 4132 Å line at the arc axis is less than that of the Li I 4972 Å line by more than two orders of magnitude. Photographic plates usually show only an order-of-magnitude range of spectral brightness. For this reason, simultaneous recording of the lithium lines at 4972 and 4132 Å on the same plate is facilitated because the Li I 4132 Å line is radiated efficiently from a