HEAT TRANSFER IN A HIGH-FREQUENCY ELECTRODELESS PLASMATRON OPERATING IN AIR

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Analysis of the thermal parameters of plasma beams produced by the electrodeless high-frequency plasmatron is still in an initial stage [1].

In this note we report some results of an experimental study of heat transfer in the plasma beam of a high-frequency electrodeless plasmatron operating in air.

The experimental data are compared with those obtained for other gases and sources.

The discharge was produced in a quartz tube with an inside diameter of 55 mm, placed in a four-turn solenoid. The antechamber part of the discharge chamber had a device for the hydrodynamic stabilization of the plasma beam, and for the air-cooling of the inner walls of the discharge cavity. The air-cooling of the outer walls had no effect on the hydrodynamics of the working beam. The flow rate and pressure of the working gas were controlled by double-chamber valves.

The energy source was a commercial high-frequency tube generator (type LGD). Improved oscillatory circuits and high-voltage rectifiers were employed, ensuring continuous input of power into the plasma beam at a rate of 3–40 kW at 6–18 Mc/sec. The power introduced into the plasma was calculated from the measured voltage and current in the anode supply circuit of the generator tube. Losses in the generator elements were allowed for in the usual way. The heat flux was measured by a tubular copper probe 2 mm in diameter [2].

The probe was placed in the plane perpendicular to the beam axis at a distance of 37.5 mm from the edge of the solenoid. The point where the probe intercepted the beam could be displaced in the x direction in the plane in which the probe was located. This was carried out by a positioning device to an accuracy of 0.1 mm.

The heat received by the probe was calculated from the measured consumption and heating of the cooling water. The measurements were carried out at a sufficient number of points to obtain a smooth curve for the amount of heat transferred to the probe as a function of the distance x along the line of displacement.

The heat-flow distribution obtained in this way is axially symmetric relative to the maximum of Q(x) at x = 0. The axial symmetry obtained for the function Q(x) coincides with the beam axis. The existence of the axial symmetry has enabled us to convert the heat flux Q(x) into the radial distribution of the specific heat flux q(r). This transformation has the form

$$Q(x) = 2A \int_r^R \frac{q(r)\, r dr}{\sqrt{r^2 - x^2}}.$$

The function q(r) was determined numerically on a computer [3] using the above equations for 25 points.

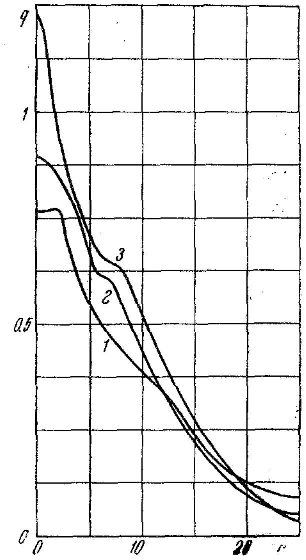
Figure 1 shows the final results: three curves for three different operating conditions of the plasmatron.

These conditions were defined as follows:

Regime		1	2	3	
P	=	16.6	18.25	19.35	[kW]
G	=	1.2	1.065	0.595	[g/sec]

We note that maximum q for curves 2 and 3 was obtained at r = 0.

Curve 1 differs from the other two curves. It has two maxima and a plateau with a small dip at r = 0. Curves 2 and 3 have clearly defined points of inflection which were confirmed by repeated experiments and by an analysis on the Ural computer. A similar point of inflection can be seen on the q(r) curve given in [4].



We note that a small error in the initial data when Q(x) is transformed to q(r) will modify the curves shown in the figures, but the characteristic features of these curves will remain.

The specific heat fluxes for the above three regimes are given below:

	0	5	10	15	20	
$r =$	0	5	10	15	20	[mm]
$q_3 =$	1.43	0.824	0.6	0.312	0.13	[kW/cm²]
$q_2 =$	1.05	0.776	0.518	0.259	0.106	[kW/cm²]
$q_1 =$	0.895	0.654	0.46	0.283	0.136	[kW/cm²]

It is clear from all the curves that the heat flux measured by the probe does not vanish at an axial distance equal to the channel radius. This is connected with the boundary conditions on the walls of the discharge chamber.

Table 3 shows recent results on heat transfer in plasma beams and chemical flames.

The maximum specific heat transfer to cylindrical and plane surfaces is of the same order of magnitude in all cases (other things being equal).

The last row of the table gives the present results.

It is clear from the table below that the high-frequency electrodeless plasmatron deserves further study.

Source of heat	Type of gas	G [g/sec]	max q [kW/cm²]	Reference
Chemical flame	$O_2 + H_2$	9.45	4.1	[2]
Chemical flame	Air + CH_4	0.22	0.13	[2]
Arc plasmatron	Ar	1.18	0.092	[4]
Arc plasmatron	Ar	0.25	1.83	[5]
Arc plasmatron	Air	1	1.69	[6]
High-frequency electrodeless plasmatron	Ar	0.7	0.14	[1]
High-frequency electrodeless plasmatron	Air	0.595	1.43	—

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