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THE ENERGY BALANCE FOR A HIGH CURRENT ARGON ARC

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Abstract—An experimental investigation of the energy transfers to the anode, to the cathode and to the surroundings by radiation has been made for a direct current free arc in argon, for arc lengths from 0·63 to 2·54 cm and currents from 250 to 1100 A. A split anode arrangement enabled the deduction of the radial distribution of the energy flux and the current density and the maxima of these fluxes are considered in terms of their relation to arc length and to current. The convection heat transfer at the arc centerline is appraised more approximately in terms of a postulated voltage fall at the anode.

NOMENCLATURE

E, electric field;
I, total current;
L, arc length;
Q, total energy transfer;
R, plasma radius;
T, temperature;
V, voltage;
e, electronic charge;
g, Steenbeck column temperature function;
h, heat transfer coefficient;
j, local current density;
k, Boltzmann constant, thermal conductivity;
q, local energy flux;
r, radial coordinate;
u, gas velocity;
x, coordinate in direction of cathode travel.

Greek symbols
α, thermal diffusivity;
μ, dynamic viscosity;
ν, kinematic viscosity;
ρ, gas density;
σ, electrical conductivity;
ϕ, electron work function.

INTRODUCTION

AN INVESTIGATION has been made of a direct current argon arc between a conical cathode and a plane anode to determine as a function of current and of arc length the voltage and the energy transfer to the anode and the distribution of the current density and of the energy flux over the surface of the anode. Such values are important for design and it was the design of a high intensity argon arc for an arc image furnace [1] that prompted this investigation. Argon arcs between 0·63 cm and 2·54 cm in length for currents between 250 and 1100 A have been investigated and the results have been reported [2] in greater detail than is possible in this paper. The range of arc lengths and currents is generally greater than it was for the arcs for which this type of information has previously been presented by Milner *et al.* [3], Nestor [4], Schoeck and Eckert [5], and Olsen [6] who, separately, also provided information on the distributions of temperature and field strength within the arc and on the static pressure at the anode surface, quantities which were not measured in the present investigation.

In free arcs such as those investigated in this work, the electron emission at the cathode takes place over a small region at the tip, and the resultant high current density acts with its

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induced magnetic field to produce a net inward force on the gas immediately below the cathode. The gas pressure increases at the center line as a result of this action, and the gradient in the direction of the anode provides the driving force for the plasma streaming effect observed and explained by Maecker [7]. The high current density and a high electric field in the cathode region are the basis of intensive heating of the entrained gas, and the temperature attains values of the order of 22000°K.

Below the "pinch" the cross section of the plasma stream broadens rapidly so that the luminous gas assumes a bell shape. In this, the column region, there is a rough balance between continued extraction of energy from the field by electrons (carrying 98 per cent of the current) and losses due to radial convection and thermal radiation. The losses exceed the gains to the extent that there is a slow decrease in temperature in the axial direction within the column, to values of the order of 14000°K at the edge of the anode region. Collision cross sections of electrons and ions are so high that thermal equilibrium is assumed to exist within any local region of the column. The electrical field is relatively uniform throughout the column at values near 4 V cm^{-1}.

The anode region is initially marked by a diversion of the plasma stream in a stagnation-like flow; Schoeck [5] estimates this to begin at a distance of 1 mm from the anode. Within this region the electron mean free path increases as the temperature drops until, in a so-called sheath region encompassing the last few electron collisions, with ions and neutral gas particles, the field again increases, the total anode voltage drop being of the order of 1 V. The energy transfer to the anode surface is composed primarily of the electron energy and convective heat transfer. The latter term is controlled by the plasma stream created below the cathode, and is an increasing function of the arc current. The importance of these terms is emphasized by the fact that 70 per cent of the total arc power is transferred to the anode.

SYSTEM

The arc was formed between a 1·27-cm diameter tungsten cathode with a conical tip of 45° half angle and a flat anode formed of two 7·6-cm square tungsten plates,* 3·3-mm thick, each gold brazed into a copper structure which incorporated the cooling water passages and current connections. These two components of the anode were separated by a mica strip 0·125-mm thick to provide electrical isolation and thus form the "D" anode pair as used previously by Nestor, Schoeck and others. This arrangement permits the determination of the electrical current to each half of the anode, and separate cooling water flows and thermocouples provide for the evaluation of the total energy transfer to each half of the anode. Figure 1 shows the configuration of the cathode and the anode, and shows also part of the tank which enclosed the system. The cathode was mounted on a motor-driven traverse unit, with travel normal to the division in the anode through a distance of 5 cm on each side of the division. The tip of the cathode could be set at a variable height above the anode and distances of 0·63, 1·27 and 2·54 cm were used in the experiments.

In operation the tank was first evacuated to about 15 μ pressure, then argon was introduced at a rate which during operation would prevent excessive heating of the gas and the tank pressure was maintained at a gage pressure of 2 lb. in^{-2}. The arc was struck by a 17000-V a.c. discharge from a third electrode. Direct current was supplied from constant current solid state rectifiers, with a ripple of less than 0·7 per cent of the load voltage, at currents of about 250, 450, 700, and 1000 A. Total current was determined from voltage measurements across a known resistance in the supply bus bar, and individual currents

* Tungsten was chosen as the anode material because of experience with an arc-image furnace [1] in which a tungsten anode was found to withstand the intense heating at high current, while a copper anode failed. Later analytical considerations based on the energy fluxes measured in the present experiments indicated that copper might have been a satisfactory material.

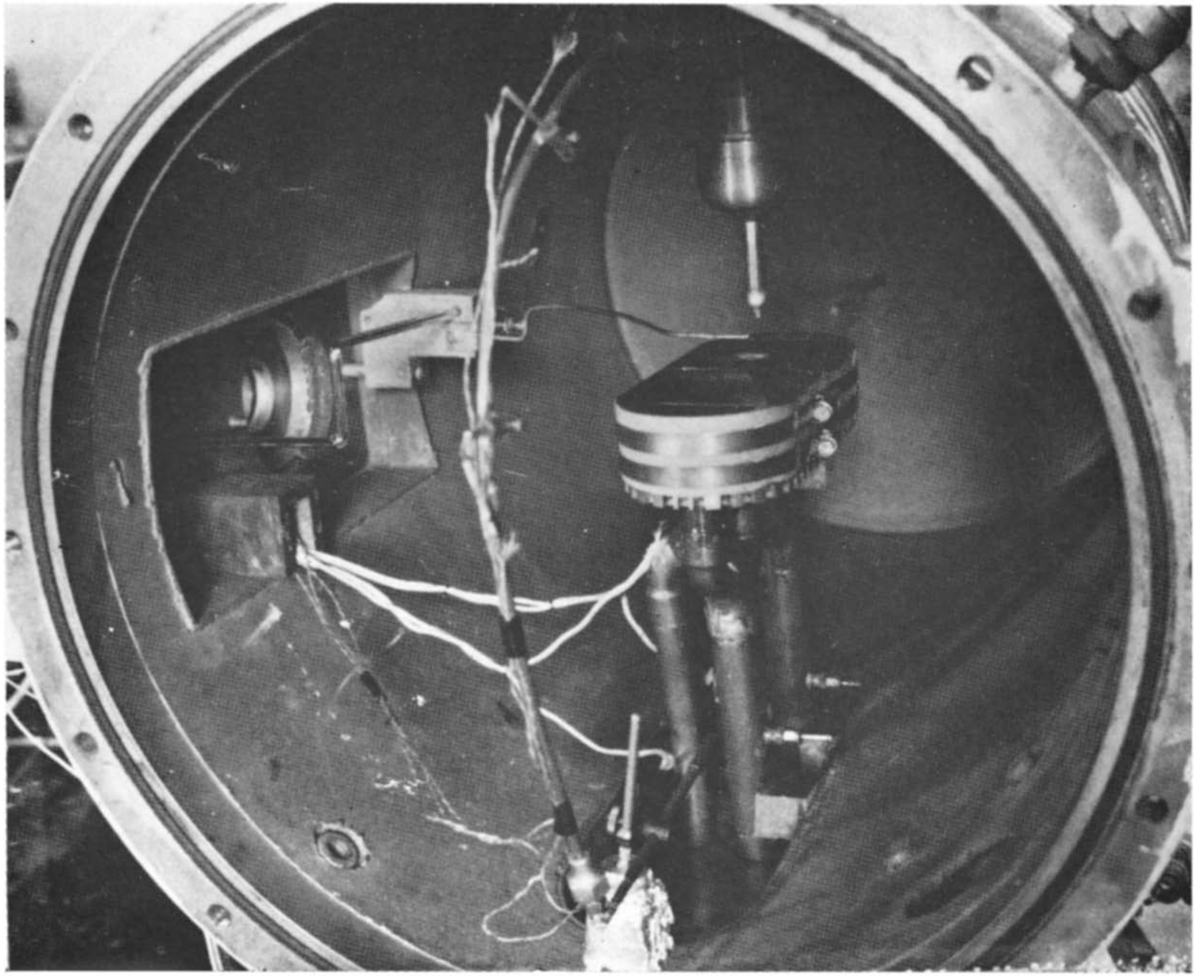

FIG. 1. The arc system.

in each section of the anode by voltage measurement across sections of the anode water inlet pipes, which were the current conductors.

Water temperatures were measured by sheathed Chromel–Alumel differential thermocouples and water rates were deduced from calibrated orifices.

A test at a given arc length and current involved the measurement of voltage, currents to both sections, and the energy transfer to the cooling water streams with the cathode at successive positions 0·05-cm apart, starting at a position where the arc was confined to one anode and continuing to an equal distance on the opposite side. In this operation the arc voltage and the total energy transfer to both halves of the anode were essentially invariable with respect to cathode position.

ARC CHARACTERISTICS

The voltage measurements for the three arc lengths and the four currents were found to be correlated by the expression

$$V = 4{\cdot}3\, I^{0{\cdot}25}\, L^{0{\cdot}30} \qquad I \text{ in A}, \quad L \text{ in cm}. \qquad (1)$$

Figure 2 shows how well this relation fits the present data, as well as other results obtained by Olsen [6], and from the 3·15-cm arc of the arc image furnace [1] with currents from 1000 to 2300 A. The aggregate of points establishes equation (1) for arc lengths from 0·5 to 3·15 cm and for currents from 200 to 2300 A, at pressures near atmospheric. The total power dissipated by the arc is the product of the voltage and the current, which in the present experiment ranged from 4 to 37 kW, and this is given from equation (1) as:

$$VI = 4{\cdot}3 \times 10^{-3}\, I^{1{\cdot}25}\, L^{0{\cdot}30} \text{ kW}. \qquad (2)$$

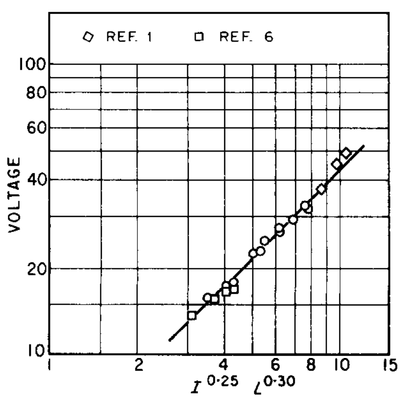

FIG. 2. The correlation for arc voltage.

The total heat transfer to the anode cooling water was found to be correlated in terms of the current and arc length by the relation:

$$Q_A = 3{\cdot}22 \times 10^{-3}\, I^{1{\cdot}25}\, L^{0{\cdot}17} \text{ kW}. \qquad (3)$$

Figure 3 shows how this equation is established by the results for the individual runs and indicates also a reasonable correspondence with the results of Nestor [4] for a 5-mm arc for currents between 100 and 300 A.

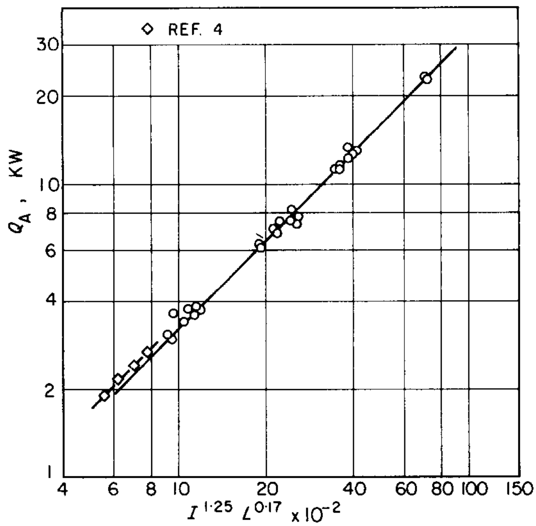

FIG. 3. The correlation for the energy transfer to the anode.

The fraction of the total power dissipation which is transferred to the anode, is, from equations (2) and (3),

$$\frac{Q_A}{VI} = \frac{0{\cdot}75}{L^{0{\cdot}13}}. \qquad (4)$$

This fraction is shown on Fig. 4 in terms of fractions for the individual tests, rather than from the correlation of equation (4); the fraction is independent of arc current. Solid points were obtained from the traverse runs and open points during subsequent tests in which the radiation was measured. This affords a view of the degree of data consistency obtained between measurements separated by a relatively long interval of time.

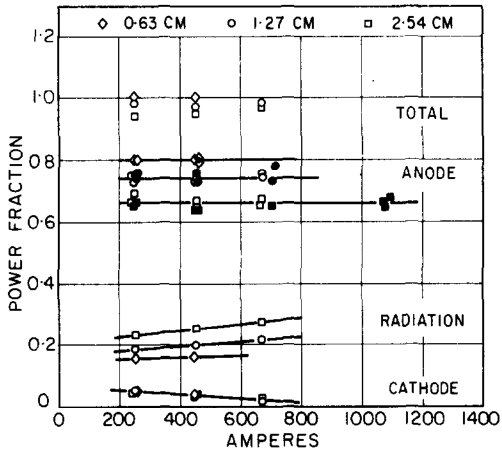

FIG. 4. The energy balance on the arc.

The difference between the total power dissipation and the energy transferred to the anode consists in transfer to the cathode, radiation to the tank walls and in energy remaining in the argon flowing over the edge of the anode. The transfer to the cathode was taken to be the energy evaluated from the cathode cooling water rate and temperature rise; Fig. 4 shows that the transfer to the cathode is a small part of the arc power. Radiation to the tank walls is a larger fraction and this was estimated from the response of three radiation detectors which operated as adiabatic calorimeters. These were copper discs, 6·3 mm in diameter and 1·27-mm thick, with acetylene soot ($\alpha = 0{\cdot}96 \pm 0{\cdot}02$) covering the front surface, the irradiation of which was deduced from the thermal capacity of the discs and the observed rate of temperature rise. These detectors were placed about 35 cm from the arc, in the plane of cathode traverse, at altitudes of 8°, 30°, and 50°, and the irradiation was found to be of the same order for all the detectors. The radiation to the walls of the tank was calculated from the average irradiation of the detectors, and this value, expressed as a fraction of the arc power, is shown in Fig. 4. The increase in the radiated power at the higher currents compensates the decreased transfer to the cathode so that the transfer to the anode, to the cathode and the radiation to the walls add to the fraction that is shown as "sum" on Fig. 4. The remaining fraction, of the order of 5 per cent, contains the errors of the individual measurements but also the energy in the argon leaving the anode surface at the edge of the anode.

DISTRIBUTION OF ENERGY FLUX AND CURRENT DENSITY ON THE ANODE

The split anode system allows a deduction of the flux, q, at a radial distance x from the cathode centerline from the transfer Q, to the half anode beyond the division line, the line being distance, x, from the cathode. Assuming an axially symmetric distribution of the flux and a radial distance R at which the flux is essentially zero the transfer to the half anode is:

$$Q(x) = 2 \int_x^R q(r) \cos^{-1}(x/r) r \, dr. \qquad (5)$$

Equation 5 is a special case of the Volterra integral equation of the first kind, with the solution

$$q(r) = -\frac{1}{\pi} \int_x^R \frac{d^2 Q}{dx^2} \frac{dx}{\sqrt{(x^2 - r^2)}}. \qquad (6)$$

The determination of the flux was made by the numerical scheme given by Nestor and Olsen [8] for the solution of equation (6). As applied, this scheme requires only one differentiation of the observed values of transfer, Q, to the half anode, but the uncertainty implied by the second derivative of experimental data in the integrand of equation 6 remains. As the cathode crosses the anode division dQ/dx is zero by symmetry, and the inversion is exceedingly sensitive to small changes in dQ/dx. Thus the error in the determination of the flux is greatest just where the flux is a maximum. Figures 5–7 show the calculated values of the energy flux and the current density and on the figures both dashed and solid curves are shown for small radial distances to reveal the uncertainty in the results in that region. The dashed lines are the values obtained from the best appraisal of dQ/dx made from the data itself, while the solid lines indicate the values of flux obtained from polynomial approximations for the function dQ/dx in the region near $x = 0$. Since the polynomial approximation provided a monotonic behavior in d^2Q/dx^2 the inversion then provided a monotonic behavior in the flux, $q(r)$. The sensitivity of the inversion is indicated by the fact that a deviation of the order of 0·2 per cent in Q will result in the indication of off-axis peaks in the flux. Since heat transfer errors were larger than 0·2 per cent, and since

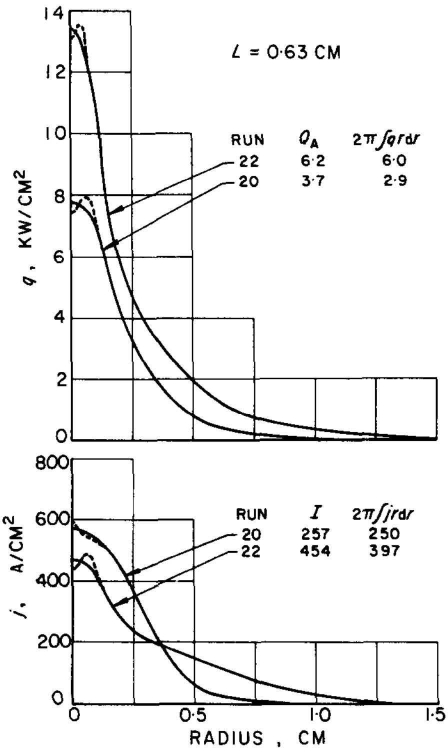

FIG. 5. Radial distributions of energy flux and current density, 0·63-cm arc.

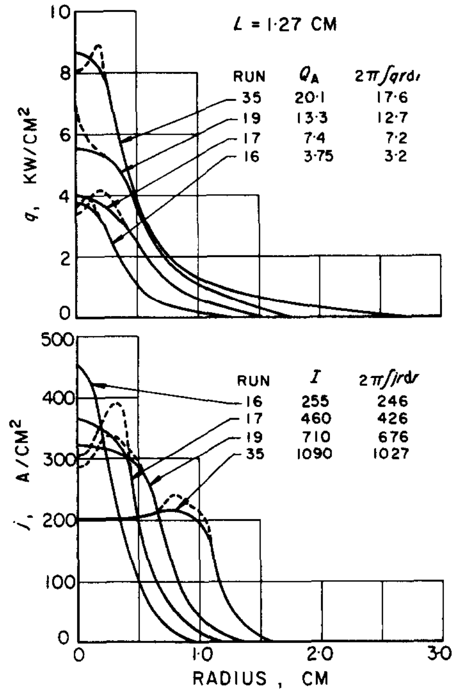

FIG. 6. Radial distributions of energy flux and current density, 1·27-cm arc.

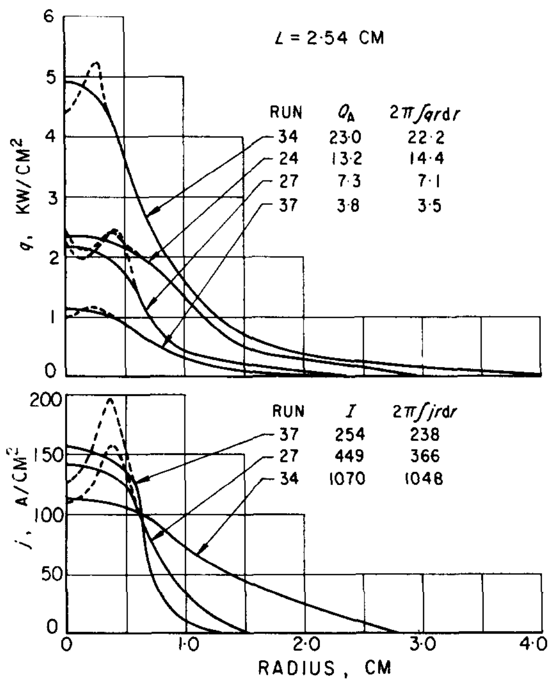

FIG. 7. Radial distributions of energy flux and current density, 2·54-cm arc.

the nature of the system argues against an off-axis maximum in the flux, the solid curves represent the preferred interpretation.

An additional uncertainty was introduced into the deduced radial distribution of the flux by the tendency of the free arc to "blow," that is, become asymmetrical with respect to the cathode centerline. Clearly, any such asymmetry is at variance with the assumption of symmetry in the calculation for the flux and will to some degree invalidate the results of that calculation. Arc symmetry was appraised by visual and photographic observation of the arc and by the symmetry of the experimentally determined transfer, Q, about the point, $x = 0$. Runs exhibiting excessive asymmetry were discarded, and in general these runs involved a combination of low current and large arc length. Asymmetry was most pronounced as the cathode centerline neared the anode division; the cause was never established though one hypothesis is of a non-uniform magnetic field parallel to the anode surface due to the current flow in the surface of the anode.

Figures 5–7 contain, in addition to the distributions of energy and current flux, a tabulation of the measured "total" quantities of energy transfer and current and of the "total" values that are obtained by integration of the values of the flux. The integrated values are always low, due mostly to the uncertainty in the values of the flux at large radial distances. While the flux is low there, the area involved is large.

Figure 5 indicates the highest energy flux experienced, at 454 A, with $q = 13$ kW/cm^2 ($4{\cdot}12 \times 10^7$ Btu/ft^{2}h). This flux probably exceeded the maximum boiling heat flux in the water cooling system and was tolerated only by virtue of lateral conduction from the small area over which this maximum existed. As shown in Fig. 6 for the 1·27-cm arc operating at 1090 A, the maximum flux was only 8·5 kW/cm^2, but the greater area in which a high heat flux occurred caused a burn through the second anode half after the arc had crossed the centerline. Horizontal cracks which had developed in the tungsten on that anode doubtless contributed an increased thermal resistance which led to the failure. Because of the failure, results were obtained for only one half the cathode travel, so that the distribution of the total transfer, Q, was less decisive. The form of the energy flux in Fig. 6 is that which is anticipated, but the current density appears to be too flat in the central region.

The flux distributions of Figs. 5–7 indicate, for any arc length, the expected broadening of the distributions as the current is increased, and the expected reduction in the maximum fluxes as the arc length is increased at a given value of the current. No overall correlation of these effects has been achieved, but as part of a consideration of the effects of arc length and current on the local flux, the maximum values which occur at the centerline can be examined further. Figure 8 shows the value of the energy flux at the centerline as a function of the arc current, to indicate that an approximately linear relation may exist between these quantities for a given arc length. There is considerable scatter in the data, but the present results are supported to some degree for the 0·63-cm arc

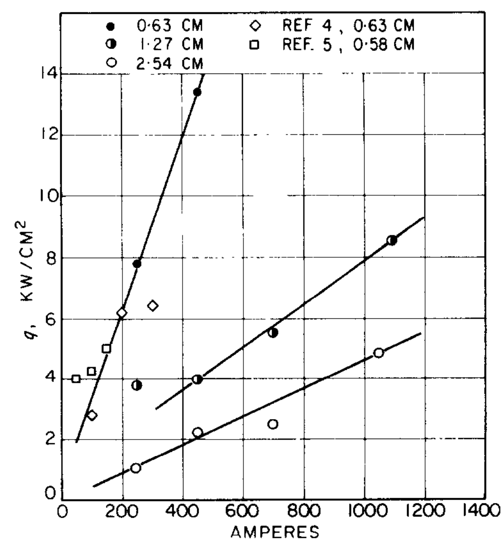

FIG. 8. Energy flux at the centerline.

by the results of Nestor [4] and Schoeck [5]. It is clear that as the current increases, the energy flux continues to increase despite the fact that the centerline current density decreases as the current increases, as is shown in Fig. 9.

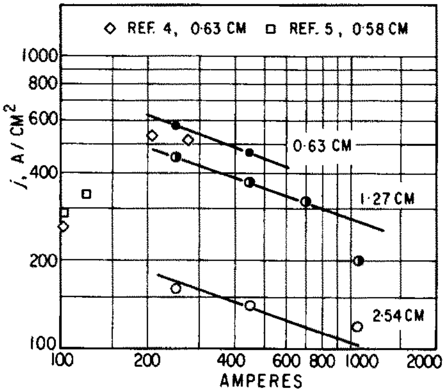

FIG. 9. Current density at the centerline.

There the logarithm of the current density at the centerline is presented as a function of the logarithm of the current because in this representation there is exhibited a power law variation for each of the arc sizes; for the shorter arcs the maximum current density is inversely proportional to the one-third power of the current, while for the 2·54-cm arc, the exponent is but slightly smaller. Only the point for the 1·27-cm arc at 1090 A fails to agree with a power law and it has already been indicated that the nature of the distribution of current density that is shown for this run on Fig. 6 may give too low a value on the centerline.

The power law relation for the maximum current density does not apply for smaller currents; there is apparently a maximum in the centerline current density which was not defined in the range of currents involved in the present experiments. Figure 9 includes the results of Nestor and of Schoeck for arcs of approximately 6 mm at lower currents and these additional results imply the existence for this arc length of a maximum at currents of the order of 200 A.

The power law relation for the maximum current density at the higher current happens to be similar to the relation proposed by Steenbeck [9] for an equilibrium arc column, in which the heat generated in the column is assumed to be transported radially to the surrounding fluid. The radial transport is a function of the temperature of the column and the analysis specifies the field to be the product of a function of the temperature and the reciprocal of the one-third power of the current

$$E = g(T)\, I^{-\frac{1}{3}} \qquad (7)$$

Now $j = \sigma E$ and this relates the current density to the one-third power of the current via a factor which is a function of the temperature. It is an interesting observation that this is the trend of the present results, though the free arc is so much different from the equilibrium arc column of the theory that little deduction can be made from this observation, other than the supportable inference that the temperatures are so high that the electrical conductivity varies little with temperature and so minimizes the influence of temperature in the Steenbeck relation.

CONVECTIVE HEAT TRANSFER

The total energy transfer to the anode, as given by equation (3), and the flux associated with it as shown on Figs. 5–7, are the result of heat transfer by convection and by thermal radiation and an electronic contribution involving electron condensation and electron conduction. These are considered here only in terms of the fluxes at the centerline, for which the energy flux and current density have just been described. The energy flux is written as:

$$q = q_\phi + q_e + q_c + q_r. \qquad (8)$$

The flux, q_ϕ, due to electron condensation, is the product of the current density and the work function. The work function is taken to be 4·6 V, typical for clean tungsten.

The flux, q_e, due to electron conduction, contains as the most important terms the energy of the electrons, and the voltage drop at the anode:

$$q_e = j\left[\tfrac{5}{2}(kT_e/e) + V_A\right]. \qquad (9)$$

Evaluation of this flux requires knowledge of both the plasma temperature, in the region of the anode voltage drop, and the anode voltage drop and both of these must be estimated. Because of the need for this estimate, the ultimate deductions about the convective flux are essentially qualitative, and this is particularly so because available information on the anode voltage drop gives values higher than might be inferred from the present results.

The electron energy contribution is evaluated on the assumption of a constant electron temperature of 14000°K, giving 3·0 V for the quantity $\frac{5}{2}\, kT_e/e$. Certainly the electron temperature outside the anode sheath should in some degree depend on current and arc length, but the 14000°K estimate is logical in terms of the temperature profiles of Olsen [6], and even substantial changes in this estimate will not resolve the problem associated with the anode voltage drop.

Busz-Peuckert and Finklenburg [10], investigating 10-mm argon arcs at 200-A current, measured anode voltage drops from 4·5 to 8·5 volts, and Schoeck inferred an anode voltage drop of 5·0 V in a 6-mm arc at 150 A. If an anode voltage drop of as much as 5 V is used, then flux due to electron condensation and conduction becomes larger than the measured energy flux for both the lower currents for the 1·27- and 2·54-cm arcs. Even in the recognition that these modes of operation had the least column stability, it is illogical to discount to such an extent the measured energy fluxes, so that there is inferred instead a lower anode voltage drop. One volt is chosen, and then, with the assumed electron temperature the electron contribution to the flux

$$q_\phi + q_e = j[\phi + \tfrac{5}{2}(kT_e/e) + V_A]$$
$$= j(4{\cdot}6 + 3{\cdot}0 + 1) \quad \text{W cm}^{-2}. \qquad (10)$$

Then the heat flux due to radiation and convection is:

$$q_r + q_c = q - 8{\cdot}6 \times 10^{-3} j \quad \text{kW cm}^{-2}. \qquad (11)$$

Table 1 contains this evaluation and it shows that even with the low anode voltage drop of 1 V, the electron contribution produces a flux that exceeds the measured energy flux at the low currents with both the 1·27- and 2·54-cm arcs.

Table 1

L (cm)	I (A)	q (kW cm^{-2})	$(8{\cdot}6 \times 10^{-3})j$ (kW cm^{-2})	$\frac{q_r + q_c}{q}$	q_r (kW cm^{-2})	q_c (kW cm^{-2})
0·63	250	7·80	4·9	0·37	0·21	2·7
	450	13·40	4·05	0·70	0·36	9·0
1·27	250	3·80	3·85	—	0·12	—
	450	4·00	3·15	0·21	0·23	0·6
	700	5·50	2·75	0·50	0·34	2·4
	1090	8·60	1·7	0·80	0·70	6·2
2·54	250	1·10	1·4	—	0·07	—
	450	2·25	1·2	0·47	0·14	0·9
	700	3·00	1·1	0·63	0·24	1·6
	1050	4·90	1·0	0·80	0·42	3·5

The irradiation at the centerline was appraised as the irradiation at the center of the base of a right circular cylinder of isothermal gas, in height equal to that of the arc and in diameter that of the luminous region of the arc at a distance $\frac{1}{3}$ the arc length below the cathode (this diameter, judged from photographs, varied as $I^{0.25}$ $L^{0.36}$, but no such correlation could be found from the photographs for the luminous region in the vicinity of the anode). Negligible self absorption was assumed and the product of the emissive power of the gas and the absorption coefficient was deduced from the radiation measurements previously described, using the volume just defined and accounting for the image of the arc in the anode. The values of the continuous emission coefficient for the gas cannot be calculated without an assumption of the temperature for the evaluation of the total emissive power. If the average temperature is taken as 18000°K, then the emission coefficient for the gas is found to vary from 0.5×10^{-3} to 6×10^{-3} for the range of arc sizes. This is a magnitude estimate only, but it justifies the assumption of negligible self absorption, and the values of q_r obtained from the predicted irradiation and an absorption coefficient of 0·42 for the tungsten surface are contained in Table 1. The absorbed radiant energy, q_r is small compared to the sum $(q_r + q_c)$ and, despite the uncertainty of these calculations, they have but a small influence on the much larger convective contribution, q_c.

Table 1 contains the values of the convective flux, q_c, as deduced from the assumptions that have been indicated. At low currents it is a relatively small fraction of the energy flux but at higher currents it becomes the dominant part of the energy flux because the current density, and hence the electron contribution, decreases as the current increases.

Instead of estimating the anode voltage drop and then deducing the convective heat flux, the inverse can be done and the anode voltage drop deduced from an estimate of the convective heat flux. This was done by Schoeck [5], who measured also the surface pressure distribution on the anode to assist in establishing the convective heat transfer coefficient. It is the lack of such information in the present experiments that obviates the determination of the coefficient and the use of this kind of analysis but it is still of interest to consider the possible magnitude of the coefficient and the convective flux that is indicated. The coefficient can be specified in terms of the Sibulkin [11] formula for an incompressible flow with all properties evaluated at the wall together with a factor involving the density and viscosity at the wall and free stream values.

$$\frac{h}{k} = 0.70\left(\frac{\nu}{\alpha}\right)^{0.4} \sqrt{\left[\frac{1}{\nu}\frac{du_s}{dr}\right]} \left[\frac{(\rho\mu)_s}{(\rho\mu)_w}\right]^{0.4} \qquad (12)$$

To estimate the free stream velocity gradient a velocity of 10^5 cm sec^{-1} in the plasma column is reasonable for a current of 450 A and if it is assumed arbitrarily that for the 0·63-cm arc this velocity is realized at 0·25 cm from the stagnation point, then du_s/dr is specified and, evaluating properties at the temperatures involved, there is obtained a heat transfer coefficient of 240 Btu h^{-1}ft^2. The convective flux is the product of this coefficient and the differences between free stream and surface enthalpies, and because of the high gas-temperatures, the enthalpy of argon at the anode surface temperature makes a negligible contribution to this difference. With this heat transfer coefficient, the convective contribution of 9 kW cm^{-2} obtained with the 450-A arc at 0·63 cm requires a free stream enthalpy of 14000 Btu lb^{-1}, corresponding to a temperature of the order of 15000°K. While this is high, the order of magnitude might be considered to be satisfactory but it is to be noted that because of the strong dependence of the enthalpy of the argon on its temperature, a slight change in the estimated temperature will change radically the convective heat flux. At 14000°K, there is a change of 2800 Btu lb^{-1} in the enthalpy for a change of 1000°K in the temperature and, if the gas temperature was estimated at 12000°K the convective flux as calculated above would be only about 3·3 kW cm^{-2}. In terms of the results contained in Table 1, this would be compatible with a much larger anode voltage drop but, as noted before, while larger anode voltage drops could be considered for the 0·63-cm arc, they are entirely incompatible with the energy fluxes found for the longer arcs.

CONCLUSION

Measurements of the voltage, current, and components of the total energy transfer in argon arcs between a conical tungsten cathode and a tungsten anode have yielded correlations of the voltage and energy transfer to the anode in terms of the current and arc length, and the total power dissipated in the arc has been analyzed in terms of the fractions transferred to the anode and the cathode and radiated to the surroundings.

Radial distributions of the energy flux and current density at the anode have been obtained through analysis of the split anode results. These are of the expected bell-shaped form. The center-line values of the energy flux and the current density have been considered in terms of their relation to current and arc length, but no correlation simple enough to be justified in terms of the limited number of determinations has been achieved.

The maximum energy flux has been analyzed to discern the magnitude of the convective heat flux, under the assumptions of an anode sheath voltage drop of one volt and an average electron temperature of 14000°K. Sufficient experimental information was not available for the evaluation of a heat transfer coefficient, the primary lack being the plasma temperature near the anode surface.

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Résumé—On a étudié expérimentalement les transports d'énergie vers l'anode, la cathode et l'environnement par rayonnement dans le cas d'une arc libre à courant continu dans l'argon pour des longueurs d'arc de 0,63 à 2,54 cm, et des courants allant de 250 à 1100 A. Un système d'anode fendue permettait d'obtenir la distribution radiale de flux d'énergie. La densité de courant et les maxima de ces flux sont examinés en fonction de la longueur de l'arc et du courant. Le transport de chaleur par convection sur l'axe de l'arc est évalué d'une façon plus approchée sous la forme d'une différence de potentiel hypothétique à l'anode.

Zusammenfassung—Eine experimentelle Untersuchung des Energietransportes an die Anode, die Kathode Kathode and die Umgebung durch Strahlung wurde für einen freien Gleichstromlichtbogen in Argon gemacht. Die Bogenlänge betrug von 0,63 bis 2,54 cm, die Ströme von 250 bis 1100 A. Eine Anordnung mit geschlitzter Anode erlaubte die Ableitung der Radialverteilung, des Energieflusses und der Stromdichte;

die Maxima der Flussdichten werden hinsichtlich ihrer Beziehung zu Bogenlänge und Strom betrachtet. Der konvektive Wärmetransport an der Bogenmittellinie wird näherungsweise angeschätzt auf Grund eines angenommenen Spannungsabfalls an der Anode.

Аннотация—Проведено экспериментальное исследование лучистого теплообмена в системе анод-катод-окружаюая среда для свободной дуги постоянного тока в аргоне. Длина дуги составляла от 0,63 до 2,54 см, сила тока от 250 до 1100 А. Специальное устройство анода позволило получить радиальное распределение потока энергии и плотности тока. Максимальные величины этих потоков рассматривались через их отношения к длине дуги и силе тока.

Конвективный теплообмен в центральной части дуги оценивается весьма приближенно через постулированную связь с падением напряжения на аноде.