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An electric arc is formed when a current passes between two conductors through a non-conducting medium like air. Although the phenomenon was discovered during early electrical experiments and utilised widely in lighting by the end of the nineteenth century, its problems were not fully understood. First published in 1902, this book represents one of the first systematic investigations of the electric arc, and the best-known work of suffragist and electrical engineer Hertha Ayrton (1854–1923). It includes a chapter on the history of the discovery, over a hundred illustrations and tables, and Ayrton's explanation of the enduring problem of arc instability. As a result of her research, she went on to patent anti-aircraft lights and new arc-lamp technology. She later became the first female recipient of the Royal Society's Hughes Medal. Remaining relevant to students of electrical engineering and the history of science, this book shares her insights and expertise.

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Hertha Ayrton
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The Electric Arc

Hertha Ayrton

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TO

MADAME BODICHON,

WHOSE CLEAR-SIGHTED ENTHUSIASM FOR THE FREEDOM

AND ENLIGHTENMENT OF WOMEN ENABLED HER TO STRIKE

AWAY SO MANY BARRIERS FROM THEIR PATH ;

WHOSE GREAT INTELLECT, LARGE TOLERANCE AND

NOBLE PRESENCE WERE AN INSPIRATION TO ALL

WHO KNEW HER ;

TO HER

WHOSE FRIENDSHIP CHANGED AND BEAUTIFIED MY

WHOLE LIFE, I DEDICATE THIS BOOK.

THE ELECTRIC ARC.

By HERTHA AYRTON,

MEMBER OF THE INSTITUTION OF ELECTRICAL ENGINEERS.

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PREFACE.

THIS book, which owes its origin to a series of articles published in *The Electrician* in 1895-6, has attained to its present proportions almost with the growth of an organic body. In experimenting on the arc, my aim was not so much to add to the large number of isolated facts that had already been discovered, as to form some idea of the bearing of these upon one another, and thus to arrive at a clear conception of what takes place in each part of the arc and carbons at every moment. The attempt to correlate all the known phenomena, and to bind them together into one consistent whole, led to the deduction of new facts, which, when duly tested by experiment, became parts of the growing body, and, themselves, opened up fresh questions, to be answered in their turn by experiment. Thus the subject grew and developed in what might almost be called a natural way.

From the first it seemed to me that the fact that the resistance of the material in the gap between the carbons must not only depend upon the current, but that it must depend upon it in many apparently contradictory ways, could not but lead to curious complications in the relation between the P.D. and the current—quite apart from any back E.M.F. that the arc might possess. In the attempt to disentangle the various effects on this resistance that a change of current must produce, and to see how far all that was apparently mysterious in the arc might be the natural result of such complexity in the resistance of a portion of the circuit, the theory presented in Chapter XII. gradually evolved itself. This theory, whatever may be its shortcomings, has at least not been hastily built up to fit a few of the more salient characteristics of the arc; it has literally *evolved* itself, during the course of a detailed study, from many points of view, of each separate phenomenon. For although the central idea, that the carbon vapour changed into mist at a short distance from the crater, occurred to me at a very early period of the work, its complete application to the whole series of phenomena, and the full recognition of all that it entailed, followed but slowly, as each part of the subject was considered in turn.

The experiments of other observers have been employed in two ways: (1) In *confirmation* of theory developed from my own experiments, and (2) as the *basis* of theory, for which further tests were devised. The law connecting P.D., current, and length of arc, for instance, was first constructed from my own results, and then was shown to be applicable to those obtained much earlier by Messrs. Edlund, Peukert, Cross and Shepard, and Ayrton. The theory concerning the light, on the other hand, was entirely deduced from the experiments of others. M. Blondel's interesting and systematic researches, the admirable work of Mr. Trotter, and Prof. Ayrton's Chicago Paper were all laid under contribution, and the deductions drawn from them were then tested by new experiments.

In seeking to compare my results with those of other observers, and in searching for accounts of experiments that might furnish material for theory, I have often been struck with the excellent work that has been done by men whose names are quite unfamiliar to us in England. There are admirable Papers on the arc, for instance, by Nebel, Feussner, Luggin, Granquist, and Herzfeld, to which reference is seldom seen in any English publication; while other work, which is in some cases far inferior, is constantly quoted. I have, therefore, given in Chapter II. short abstracts of most of the important Papers on the direct-current arc that appeared up to the end of the nineteenth century, while those referring principally or entirely to the light are discussed in Chapter XI. At the end of Chapter II. is a chronological list of *all* the original communications that I could find when that chapter was written; but the names of a few to which my attention has since been directed, and of some that appeared after the list was made, together with the dates of my own contributions to *The Electrician* and to various societies, are added at the end of the Appendix. The latest paper of all—an extremely interesting one "On the Resistance and Electromotive Forces of the Electric Arc," read by Mr. Duddell before the Royal Society in June last—I should much have liked to discuss in connection with this book, but, as it is not yet published in full, that is unfortunately impossible.

As it seemed better not to wait till the whole book was ready, before publishing the most important of the new results obtained, some part of almost every chapter has been made the subject of a Paper that has been read before one or other of the societies interested in such work. These Papers generally covered but a portion of the ground, however, giving the main experiments and conclusions only, without following them up, or showing how they bore upon one another. In the book these are all connected together, and many new results are set forth which have been developed during the process. At the end of each chapter is a summary of the most important conclusions reached in it, which, it is hoped, may be found useful in making each step perfectly clear before the next is taken.

Besides the light experiments already mentioned, all those on the time-change of P.D. immediately after starting the arc, and after sudden changes of current, originally formed part of Prof. Ayrton's ill-fated Chicago Paper, which, after being read at the Electrical Congress in 1893, was accidentally burnt in the Secretary's office, whilst awaiting publication. These highly important experiments were not only the first of their kind, but, as far as I know, they still remain unique. Most of the figures in the first chapter, all the experiments and curves that relate to cored carbons in the fourth and fifth, and some of those on hissing in the tenth, also belonged to this Chicago Paper, which was as full of suggestion as it was rich in accomplished work.

Although the book is concerned entirely with the arc itself, and does not touch at all upon lamps and their devices, it is hoped that it may appeal to the practical man as well as to the physicist. For not only the cause but the practical bearing of each peculiarity of the arc has been considered; the directions in which improvements may be hoped for have been pointed out, and the conditions requisite to secure the maximum production of light from a given expenditure of power in the generator have been fully discussed.

In conclusion, I have to thank Prof. Blondel, Prof. Fleming and Mr. Trotter for kind permission to use figures from their Papers; Mr. Fithian for taking the beautiful photographs of the Hissing Arc reproduced in Fig. 81; Mr. Mather for much valuable advice and assistance with experiments, and Mr. Maurice Solomon for his suggestive criticism of the MS. and careful revision of the proofs.

HERTHA AYRTON.

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