CAMBRIDGE PHYSICAL SERIES. AIR CURRENTS AND THE LAWS OF VENTILATION: LECTURES ON THE PHYSICS OF THE VENTILATION OF BUILDINGS DELIVERED IN THE UNIVERSITY OF CAMBRIDGE IN THE LENT TERM, 1903

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649440818

Cambridge Physical Series. Air Currents and the Laws of Ventilation: Lectures on the Physics of the Ventilation of Buildings Delivered in the University of Cambridge in the Lent Term, 1903 by W. N. Shaw

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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Trieste

CAMBRIDGE PHYSICAL SERIES.

GENERAL EDITORS:—F. H. NEVILLE, M.A., F.R.S.
AND W. C. D. WHETHAM, M.A., F.R.S.

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CAMBRIDGE UNIVERSITY PRESS WAREHOUSE,
C. F. CLAY, MANAGER.
London: FETTER LANE, E.C.
Glasgow: 50, WELLINGTON STREET.

ALSO
London: H. K. LEWIS, 136, GOWER STREET, W.C.
Leipzig: F. A. BROCKHAUS.
New York: G. P. PUTNAM'S SONS.
Bombay and Calcutta: MACMILLAN AND CO. LTD.

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IN THE LENT TERM, 1903

by

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Cambridge
at the University Press
1907

PREFACE.

AMONG the duties laid upon me by the tenure of a fellowship at my old College from 1900 till 1906 was the delivery each year of a short course of lectures before the University, upon some subject connected with the Physics of the Atmosphere. This little book represents my endeavour to discharge that duty in the year 1903.

For many years I have taken a practical interest in the physical aspects of the general problem of ventilation. When I was a member of the Museums and Lecture Rooms Syndicate, I tried to meet some complaints about the state of the air in the Biological Lecture Room by making use of the furnace draught of the boilers in a neighbouring stoke-hole and communicated an account of the arrangement to the Philosophical Society. The experiment was successful enough from the physical point of view but not from the biological, for the stoker found that, when it was working, the furnace room became uncomfortably warm and any system of ventilation which disregards the comfort of the stoker has serious disadvantages to contend with.

The experiment, however, led to my undertaking the article on "Ventilation and Warming" for Stevenson and Murphy's *Hygiene* and that again to the inspection of the ventilation of Metropolitan Poor Law Schools for the Local Government Board. Since then I have been appealed to for advice as regards ventilation from many directions.

In the course of the preparation of the article for Stevenson and Murphy's *Hygiene*, I came across a small book by M. Murgue, a Belgian engineer, translated by A. L. Steavenson, upon the application of centrifugal ventilating machines to the ventilation of mines. In that book the idea of replacing or representing the pneumatic resistance of a complicated channel by its equivalent thin-plate-orifice is developed and the law of relation of head to flow, which may be regarded as the basis of all ventilation arrangements, is clearly set out. I was struck with the analogy which the relation presented to the distribution of electrical currents in a net-work of conductors and the possibility thus afforded of reducing the problems of ventilation from the chaos of mere qualitative suggestion, by means of diagrams with arrows indicating the paths in which it was desired that air should move, to something like the order of numerical relationship, and I discussed the matter in a short communication to the British Association at Leeds in 1890. Lord Kelvin in commenting upon the paper pointed out the curious reversal of relations, in that the knowledge of electricity, which in his earlier days was illustrated by the more familiar case of pneumatics, should have become so widespread that it could now be appealed to for illustration of the more complicated relations of pneumatics.

I carried the idea of the electrical analogy further by making out of two boxes, communicating with a third in which there was an improvised chimney shaft, a pneumatic analogue of the Wheatstone quadrilateral, which verified the accuracy of the pneumatic laws and their application to the division of air currents in the most conclusive manner. With the assistance of Mr R. S. Cole, a number of most interesting measurements were made with this apparatus. Indeed the use of the apparatus was carried on with complete success, so far as its size would permit. It was only a laboratory model, and our experiments were necessarily confined to small openings or

tubes of about an inch diameter. I feel sure that what is most needed at the present day for the development of an accurate knowledge of the management of pneumatic currents is the carrying out of similiar experiments on the larger and more practical scale appropriate to the Municipal Technical School, instead of on the restricted scale of a Physical Laboratory. The information which could thus be obtained as to the characteristic curves of fans and the effect of divers small variations of condition upon the flow through orifices and tubes would, I feel sure, be at once interesting, instructive and stimulating. It is a matter of great regret that, so far as I know, the real study of pneumatics finds no place in our great technical establishments.

Ventilation, like the weather, is a subject of universal interest and gives rise to the widest differences of opinion. One man's fresh air is another man's draught, and the most difficult part of the ventilation problem is to reconcile the interests of both these classes of persons.

In the practical attempts to solve the problem, too little attention has, I think, been paid to the laws of physics. Hygienic chemists have told us what they consider to be the permissible limit of respirable impurity in air, and various writers have expressed opinions as to what degree the thermometer should mark to keep up healthy conditions; but neither of these important facts suffices to tell us how the supply of air designed to wash away the respirable impurity and maintain the requisite temperature may be expected to fulfil its very difficult task by its journey from an inlet to an outlet.

Take an example: I suppose the greatest social enemy from the ventilation point of view is the individual who sneezes; the person who merely breathes is bad enough, the person who sneezes adds a special difficulty because he distributes a cloud of fine particles which may or may not be deleterious. Imagine

such an enemy in a remote corner of a large room and consider what must be done to wash away the respirable impurity. Some benevolent authority may have decided perhaps that 1000 cubic feet of air per hour is sufficient for the work, because no signs of exceptional discomfort or illness have manifested themselves when that amount of air has been supplied, on the average. So, every second, a quarter of a cubic foot of air is duly provided for our enemy and delivered for him through an opening in the wall, which some say should be high up, others low down. At the same time the quarter cubic foot which was supplied for him some fifteen minutes previously is called for at another opening in another wall, which again some say should be low down and others high up. But how is our enemy with the sneezing cold to be sure of getting his quarter cubic foot, and how shall he be sure of giving it up when he has used it in such a way that it shall reach the proper opening for its removal? As a matter of fact the distribution of the air supply between the occupants of a room is a matter of scrambling between them, with the aid of the convection current which each individual causes; and in the course of the scramble there is much scope for the exercise of various physical laws, that are not much regarded in deciding the general practice of ventilation. Certain it is that, with a single opening in one wall for delivery and a single opening in another for extraction, if every occupant of a school class room does get his fair share and use of the fresh air supply, it is a result that one could not anticipate, and it is well worth consideration from the point of view of experimental physics.

Accordingly, in the middle section of this book I have laid some stress upon the physics of the ventilated space. The conclusion which I draw myself from the consideration of these questions is that the requirements of the physical process indicate a large air supply as a necessity for a solution of the difficult problem of ventilation without draughts. This may