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**MEDICAL RESEARCH COUNCIL.**

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**REPORTS OF THE  
INDUSTRIAL  
FATIGUE RESEARCH BOARD.**

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**No. 21.—Atmospheric Conditions in  
Cotton Weaving.**

**(Textile Series No. 6.)**

**By S. WYATT, M.Sc.**

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## OFFICES :

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## PREFACE.

The present report, dealing with the atmospheric conditions in weaving sheds, has an important bearing on a question which has long been the subject of controversy in the cotton industry.

For the weaving of certain classes of cotton cloth, moisture (in the form either of steam or of water) is introduced into the air of the sheds, in order to maintain the degree of humidity desirable for successful weaving. This practice, which has always been strongly objected to on the part of the operatives, has for many years been controlled by statutory regulations, the requirements of which have been changed from time to time. The question has always been recognised as a complex one, chiefly because the physiological effects of humidity, temperature, and ventilation on the comfort and health of the operatives, must be considered in conjunction with their physical effects on the yarn in manufacturing. It may be of interest, therefore, to trace briefly the successive stages in legislation from the beginning up to the present time.

The first protest against the artificial humidification of weaving sheds appears to have been made in 1882 by the Parliamentary Committee of the Trade Union Congress, in consequence of which an official inquiry was held by Dr. J. H. Bridges and Mr. E. H. Osborn [1], who arrived at the conclusion that the principal defect in weaving sheds at that time was lack of efficient ventilation and made recommendations for ensuring a sufficient standard.

In 1889, following some local inquiries in Lancashire, an Act\* was passed, in which for the first time the maximum limits of the humidity permissible in the atmosphere for different temperatures were tabulated, and effect was given to the recommendations as to ventilation contained in the Report of 1882 by prescribing for the admission of at least 600 cub. ft. of fresh air per hour for every person employed.

These restrictions, however, failed to satisfy the operatives, and in 1896 the Weavers' Associations again approached the Home Office with a demand for the total abolition of "steaming." A Departmental Committee, under the Chairmanship of Sir Henry Roscoe, was thereupon appointed by the Secretary of State to inquire into the working of the Act of 1889. Their Report [2] made in 1897 contained certain recommendations, most of which were embodied in a Statutory Order of the Secretary of State\*

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\* Cotton Cloth Factories Act, 1889. (52 & 53 Vict. chap. 62).

under powers conferred on him by a special Act.† In this Order the permissible limits of humidity were retained unchanged, but important provisions were introduced relating to temperature and ventilation. Thus, in order to reduce the rise of temperature within the sheds, the white-washing of the roofs of the sheds in summer and the lagging of the steam-pipes were made compulsory, whilst as regards ventilation a chemical standard of purity was introduced for the first time and sufficient means were required to prevent the accumulation of more than nine volumes of carbon dioxide in 10,000 volumes of air.

In 1906, protest from the operative weavers was renewed, a ballot taken showing a large majority in favour of abolition of steaming. Another Departmental Committee was then appointed with Sir Hamilton Freer-Smith, R.N., C.S.I., as Chairman, with more detailed terms of reference as follows :—

- (1) What temperature and humidity are necessary in each case for the manufacture of different classes of cotton fabrics ;
- (2) At what degrees of heat and humidity combined definite bodily discomfort arises, under the conditions of work carried on by the operatives, and what, if any, danger to health is involved by continuous work at those degrees ;
- (3) What means of cooling humid sheds (where necessary) exist, whether combined with the means of humidifying or otherwise, which are both efficient and practicable, having regard to the conditions required for the manufacture of the several classes of goods ;
- (4) What special arrangements, if any, are necessary in order to admit of the proper ventilation of dry weaving sheds without prejudice to the process of manufacture.

The principal recommendations contained in the final report of this Committee [6] may be summarised as follows :—

- (a) The permissible relative humidity is defined in terms of the difference between the dry and wet bulb temperature. Below 70° F. this is limited to two degrees, and above 70° F. to an increased amount on a graduated scale.
- (b) The introduction of humidity is prohibited when the dry bulb temperature is below 50° F. or the wet bulb temperature is above 75° F.

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† Cotton Cloth Factories Act, 1897. (61 & 62 Vict. chap. 58). The Order was subsequently incorporated with slight modifications in the Factory & Workshop Act, 1901. (1 Ed. 7, chap. 22, Sec. 90-96).

- (c) A standard of efficiency is prescribed for the material to be used for the lagging of steam pipes.
- (d) With the object of lessening the quantity of steam introduced into the air, the standard of ventilation is relaxed from 9 volumes of carbon dioxide per 10,000 volumes to 8 volumes in excess of the outside air (roughly equivalent to 12 volumes absolute).

On the submission of this report, the same procedure was adopted as with the earlier Committee. A special Act was passed\*, and under it the recommendations of the Committee were incorporated in a Statutory Order†, which is still operative.

This legislative action, however, like the previous statutes, failed to effect a complete settlement, and in 1914 Sir Hamilton Freer-Smith was engaged, on behalf of the Home Office in further discussions with the employers and operatives until postponement was brought about by the outbreak of war.

An interesting feature in the history of this question is the different aspects from which the factors of humidity, temperature and ventilation have been successively regarded. The earliest report [1], as is natural, is practically silent on the modern physiological views as to the effects of humidity and temperature, and it would appear that the recommendation as to increased ventilation was made solely with a view to replacing vitiated air by fresh, the aspect from which ventilation questions in those days were always regarded. Similarly, in the report [2] of Sir H. Roscoe's Committee, humidity is discussed chiefly from the point of view of deposit of moisture (on the clothing, etc.), and not from its physiological aspect. This is clearly indicated by the schedule of humidity recommended, in which wet-bulb temperatures up to 91° F. are specified, with the implication that work would be possible under those conditions. The report suggests, in short, that atmospheric humidity was regarded as of secondary importance compared with other matters, such as dust, purity of water and ventilation.

At the time when the third inquiry was held, more recent physiological work on the subject was available. Not only was general evidence given before them by Drs. J. S. Haldane, L. Hill, A. E. Boycott and M. S. Pembrey [5<sup>221</sup>], but two important series of observations were made on behalf of the Committee on weavers actually at work. In the former of these [6<sup>15</sup>], which was carried out by Dr. T. M. Legge in co-operation with the Medical Officers of Health of certain Lancashire Boroughs, a large number of mouth

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\* The Factory and Workshop (Cotton Cloth Factories Act, 1911)<sup>2</sup> (1 and 2 Geo. 5, chap. 21).

† Regulations for Cotton Cloth Factories, dated December 21, 1911.

temperatures were taken in weaving sheds, in which the wet-bulb temperature was 75° and over, both before the weaver had begun work and after he had been exposed to shed conditions for some hours. The two series, on being compared, clearly indicated that a rise in mouth temperature occurred in the later observations as compared with the earlier\*. Dr. Legge's conclusion is as follows :—

"The general conclusion I have formed from the detailed study of the observation is that a rise of mouth temperature makes itself distinctly felt when the temperature of the wet bulb exceeds 75° F. ; in other words, that weavers are likely to be working under adverse physiological conditions."

The second inquiry, conducted by Drs. M. S. Pembrey and E. L. Collis [6<sup>24</sup>], was of a more intensive character, and was based on detailed observations of mouth, rectal and skin temperatures, pulse rate, and blood pressure, made on the authors themselves and on certain weavers working under ordinary conditions. The inquiry led them to the following general conclusions :—

"Our observations show that the influence of the warm, moist atmosphere is to diminish the difference between the internal temperature of the body and that of the peripheral parts. The tendency is to establish a more uniform temperature of the body as a whole, and to throw a tax upon the powers of accommodation, which is indicated by the low blood pressure, notwithstanding the rapid rate of the pulse. This is exactly the condition which would explain the discomfort and low state of health of which many of the weavers complain. . . .

"In a weaving shed the machine sets the pace, and the worker must neglect the dictates of his sensations, which are the natural guardians of his health and well-being. He must strive, as far as possible, to accommodate himself to the adverse conditions of heat and moisture. Some workers can respond to the demand better than others, but all must have their powers of accommodation taxed when the temperature of the wet bulb rises much above 70° F. It is not surprising, therefore, that at the end of a day's work many of the weavers complain that they have no energy left, have no great desire for food, and need only drink and rest."

With this evidence before them, the Committee accepted the principle that of all the different factors operating, the most important is the wet-bulb temperature. Not only was their main recommendation concerned with definite limitation of wet-bulb temperature, but with the avowed object of retarding its rise, a relaxed standard of ventilation was put forward, thus reflecting the present views that wet-bulb temperature is of greater physiological importance than change of air.

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\* In an inquiry on similar lines carried out by Legge in certain *linen* weaving sheds, in which the wet-bulb temperatures were higher, the rise in mouth temperature following exposures to shed conditions was found to be still more marked [7<sup>41</sup>].

Such then was the position at the time when the Board was appointed (July, 1918), and amongst the earliest suggestions received by the Board was one from the Home Office calling attention to the need for further investigation into the conditions in weaving sheds in the cotton industry [8<sup>15</sup>]. The Board thereupon decided to pay special attention to this industry, and since their inception investigations have been in progress (under the supervision of Mr. S. Wyatt) into various problems arising in the weaving section. The results of these investigations are only now available, and the present report, which deals with the atmospheric conditions in weaving sheds, is in some sense the logical continuation of the previous inquiries that have been held.

In effect, the report introduces for the first time into the study of this question in cotton weaving, a new and important factor in environment, namely, air *movement*. In recent years, largely through the work of Dr. Leonard Hill, it has gradually become realised that neither the dry nor the wet-bulb thermometer is *per se* an accurate criterion of the physiological effects of environment, but that, in addition to these, the rate of *movement* of the air must be taken into account. For instance, a (wet-bulb) temperature, which will prove insupportable in still air, may be borne without discomfort if the air in contact with the body is kept in a state of movement. An instrument (the kata-thermometer) has been devised by Hill, by which the total cooling effect of the air (depending on the dry and wet bulb temperatures and the air movement) can be measured directly, and the present inquiry is based on a large number of observations which have been made in this way.

The Board desire to direct special attention to certain important points which emerge from this investigation.

In the first place, it appears (so far as conclusions can be drawn from the investigation of sample factories), that in humid cotton weaving sheds the physical conditions of the workers' environment do not reach the standard which ought to exist, and which is, in fact, attained in other, though not in all, industries. The physiological effects of these conditions have already been explored in previous inquiries, the results of which go to show that long continued exposure may produce discomfort, and tend to a low state of health.

Further, in another report dealing with linen weaving [9], some evidence has been recently adduced which suggests that similar environmental conditions when sufficiently pronounced, may react upon the operative in such a way as to impair his productive efficiency. This is shown by the fact that when the wet bulb temperature reaches 73° F., efficiency falls, and since

the high temperature has physically a beneficial effect on the yarn, this can only be ascribed to the bodily discomfort felt and to the fatigue induced by working under such conditions. Similar evidence also has been recently obtained in the case of cotton weaving [10].

The present Report does not touch on the vexed question that has been so frequently raised but never finally disposed of, namely, whether these conditions, which undoubtedly cause discomfort, are productive of actual ill-health. No conclusive evidence on the subject has ever been obtained, and indeed the lack of any real information relating to it is emphasised by each of the Departmental Committees which have successively dealt with humidity in weaving. The possibility of studying this question by a determination of the actual sickness incidence in humid and dry sheds has already been before the Board, in consultation with the Home Office and the Trade, and at a conference with employers and operatives, held in Manchester in July, 1920, under the Chairmanship of Sir Hamilton Freer-Smith, the action contemplated was unanimously approved by those present. In view of this approval, the Board have made preliminary inquiry into the matter, and have arrived at the conclusion on the advice of the Committee on Industrial Health Statistics that owing to the absence of certain necessary information and to the abnormal conditions prevailing during the war, the use of existing sickness records for this purpose will not be practicable, and that an investigation therefore must be based on records kept in the future. Quite recently, further progress has been made and definite lines of inquiry which seem to offer the most promising prospects are now under consideration. Whilst it appears that actual investigation cannot usefully be started at the present time, the Board hope that when trade conditions again become normal the industry may be disposed to collaborate with them in future work on this subject, for which the expert advice of the Committee on Industrial Health Statistics will be available.

Secondly, the present report suggests two important methods by which improvement in the working conditions can perhaps be brought about. One of these is the use of more suitable clothing on the part of the operatives. Perhaps the most definite feature of the observations on weavers made by Dr. Legge and by Drs. Pembrey and Collis [6] is the consistently higher mouth temperature on the part of women as compared with that of men, and this is ascribed by the authors to the less suitable clothing worn by the former. The great importance of the kind of clothing worn on its bearing on comfort is perhaps not generally realised, and the attention of the industry is accordingly invited to the section in the present report dealing with this subject.

The other method is the introduction of some means for artificially increasing the air movement in the neighbourhood of

the operatives, on the lines of the experiments described on p. 30. The practical adoption of some such method was in fact foreshadowed in 1914 by a Departmental Committee dealing with the kindred process of linen weaving [7]. Referring to Dr. L. Hill's observations with the kata-thermometer, they state :—

“ He urges that in heated atmospheres, whether moist or dry, greater comfort can be secured by the use of appliances which will keep the air in continual motion, even where circumstances render it inexpedient to admit more than a limited amount of fresh air. In our opinion manufacturers might with possible advantage, and at little cost, give efficient trial to Dr. Hill's suggestion. This might be done by small fans placed on the heddle-bars of looms, or by fixing blades in suitable places on the revolving shafting.”

A similar suggestion is contained in the Annual Report of the Chief Inspector of Factories for 1914 (p. 62), from which it even appears that appliances for increasing air movement have already been tried on a practical scale :—

“ Air samples taken when investigating complaints of impure air or of bad ventilation often gave quite satisfactory results upon analysis, and Mr. Crabtree (Burnley) suggests that the cause of complaint is stagnant air, and not excess of carbon dioxide. As a remedy for this he suggests that agitators in the shape of flat boards (about 14 in. wide and 10 in. long) should be fitted to the overhead shafting, so that the air is made to circulate with their revolutions. This plan has been successfully tried in three sheds in this district.”

The Board are advised that the application of this principle is not free from practical difficulties. They understand, for instance, that the actual device described in the report is open to objection on the grounds that it interferes with the free movements of the weavers, and that other appliances suggested (such as the agitators already mentioned) could not be widely adopted without extensive structural alterations. Nevertheless, in view of the suggestive results embodied in this report, the Board think that unless and until it is found possible to dispense with artificial humidification through technical modifications in methods of manufacture (such as sizing), a solution of this question may be found in the control of air-movement. They accordingly hope that textile engineers and all concerned in the industry will bring their practical knowledge to bear on the subject, with the object of devising some means of improving the conditions physiologically without interfering with the process of manufacture, and of ascertaining, through experiments conducted on a larger scale than those described, how far such means are capable of general application.

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- (8) — (1920) : Industrial Fatigue Research Board. First Annual Report. (*H.M. Stationery Office.*)
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## ATMOSPHERIC CONDITIONS IN COTTON WEAVING.

By S. WYATT, M.Sc., *Investigator to the Board.*

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- No. 12.—Vocational Guidance (a Review of the Literature), by B. Muscio (1921.) 1s. (1s. 1d.)
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- No. 33.—A Study in Vocational Guidance, by F. Gaw, L. Ramsey, M. Smith and W. Spielman, under the general direction of Cyril Burt. (1926.) 4s. (4s. 2d.)
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- No. 55.—A Study of Personal Qualities in Accident Proneness and Proficiency, by E. Farmer and E. G. Chambers. (1929.) 3s. (3s. 2d.)
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- No. 78.—A Borstal Experiment in Vocational Guidance, by Alec Rodger. (1937.) 9d. (11d.)
- References to vocational selection also occur in Report No. 64.*

**(vii). Time and Movement Study, Methods of Work**

- No. 3.—A Study of Improved Methods in an Iron Foundry, by C. S. Myers. (1919.) 2d. (3d.)

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- References to posture, etc., occur also in Reports Nos. 15 and 16.*

#### (ix). Sickness and Absenteeism

- No. 51.—A Study of Absenteeism in a Group of Ten Collieries, by H. M. Vernon and T. Bedford (assisted by C. G. Warner). (1928.) 2s. 6d. (2s. 8d.)
- No. 54.—An Investigation into the Sickness Experience of Printers (with special reference to the Incidence of Tuberculosis), by A. Bradford Hill. (1929.) 4s. 6d. (4s. 8d.)
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- No. 79.—An Investigation into the Sickness Experience of London Transport Workers, with special reference to Digestive Disturbances, by A. Bradford Hill. (1937.) 6d. (7d.)

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NOTE.—Most of the reports in the following list deal exclusively with the industries under which they are placed. In certain instances, however, reports have been prepared on some general subject, but yet make sufficient reference to a particular industry to justify inclusion under the appropriate heading. These reports are distinguished by an \*. Reports which have no application to particular industries are not included in this section.

**A.—MINING INDUSTRY**

- No. 39.—The Relation of Atmospheric Conditions to the Working Capacity and Accident Rates of Miners. 1s. 3d. (1s. 4d.)
- No. 51.—A Study of Absenteeism in a Group of Ten Collieries. 2s. 6d. (2s. 8d.)
- No. 60.—The Atmospheric Conditions in Pithead Baths. 9d. (10d.)
- No. 62.—Two Studies of Absenteeism in Coal Mines. 1s. (1s. 1d.)

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- No. 1.—The Influence of Hours of Work and of Ventilation on Output in Tinplate Manufacture. 6d. (7d.)
- No. 2.—The Output of Women Workers in Relation to Hours of Work in Shell-making. 6d. (7d.)
- No. 3.—A Study of Improved Methods in an Iron Foundry. 2d. (3d.)
- No. 5.—Fatigue and Efficiency in the Iron and Steel Industry. 3s. (3s. 2d.)
- \*No. 6.—The Speed of Adaptation to Altered Hours of Work. 1s. (1s. 1d.)
- No. 15.—Motion Study in Metal Polishing. 2s. (2s. 1d.)

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- No. 7.—Individual Differences in Output in the Cotton Industry. 6d. (7d.)
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- No. 9.—A Study of Output in Silk Weaving during the Winter Months. 2s. 6d. (2s. 8d.)
- No. 17.—An Analysis of the Individual Differences in the Output of Silk-Weavers. 1s. 6d. (1s. 7d.)
- No. 20.—A Study of Efficiency in Fine Linen Weaving. 1s. 6d. (1s. 7d.)
- No. 21.—Atmospheric Conditions in Cotton Weaving. 2s. (2s. 1d.)

- No. 23.—Variations in Efficiency in Cotton Weaving. 3s. (3s. 2d.)  
 No. 37.—Fan Ventilation in a Weaving Shed. 1s. 9d. (1s. 10d.)  
 No. 40.—The Effect of Eyestrain on the Output of Linkers in the Hosiery Industry. 1s. (1s. 1d.)  
 No. 48.—Artificial Humidification in the Cotton Weaving Industry. Its Effect upon the Sickness Rates of Weaving Operatives. 2s. 6d. (2s. 8d.)  
 \*No. 49.—On the Relief of Eyestrain amongst Persons Performing very Fine Work. 1s. 3d. (1s. 4d.)  
 No. 59.—Sickness amongst Operatives in Lancashire Cotton Spinning Mills. 1s. 6d. (1s. 8d.)  
 No. 70.—The Performance of Weavers under Varying Conditions of Noise. 6d. (7d.)  
 No. 81.—The Effects of Conditions of Artificial Lighting on the Performance of Worsted Weavers. 9d. (10d.)

#### D.—BOOT AND SHOE INDUSTRY

- No. 10.—Preliminary Notes on the Boot and Shoe Industry. 1s. 6d. (1s. 7d.)  
 No. 11.—Preliminary Notes on Atmospheric Conditions in Boot and Shoe Factories. 3s. (3s. 8d.)

#### E.—POTTERY INDUSTRY

- No. 18.—Two Investigations in Potters' Shops. 2s. 6d. (2s. 8d.)

#### F.—LAUNDRY INDUSTRY

- No. 22.—Some Studies in the Laundry Trade. 2s. 6d. (2s. 8d.)

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 No. 32.—Studies in Repetitive Work with special reference to Rest Pauses. 2s. 6d. (2s. 7d.)  
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- No. 89.—Report on Miners' "Beat Knee," "Beat Hand," and "Beat Elbow." By E. L. Collis and T. L. Llewellyn. (1924.) 1s. 6d. (1s. 7d.)
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- No. 176.—Third Report of the Miners' Nystagmus Committee. (1932.) 9d. (10d.)

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- No. 165.—Studies in Nutrition. An Inquiry into the Diet of Families in Cardiff and Reading. By E. P. Cathcart and A. M. T. Murray, assisted by M. Shanks. (1932.) 6d. (7d.)

*Dust*

- No. 199.—Physical Methods for the Estimation of the Dust Hazards in Industry. By H. L. Green and H. H. Watson. (1935.) 1s. (1s. 2d.)

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- BEDFORD, T.: "Requirements for satisfactory Ventilation and Heating". *Hum. Factor, Lond.*, 1936, 10, 245.
- "Warmth and Comfort." *J. Instn. Heat. and Vent. Engrs.*, 1936, 4, 383.
- "Ventilation and heating in Relation to Comfort." *Industr. Welf.*, 1937, 19, 218, 13.
- "Modern Principles of Ventilation and Heating." *H. K. Lewis & Co., Ltd., London*, 1937.
- CULPIN, MILLAIS: "Psychological Disorders in Industry." *Practitioner* 1936, 137, 324.
- "The Application of Medical Psychology in Industry." *Med. Off.*, March, 1937.

- FARMER, E.: "The Human Factor in Accident Causation." *J. Insur. Inst. Lond.*, 1937, 29, 1.
- LANGDON, J. N.: "A Two-factor Study of Simple Motor Tests with Particular Reference to Practice and Prognosis." *Brit. J. Psychol.*, 1937, 27, 4.
- SMITH, MAY: "Nerves as a Handicap to Efficiency." *Ment. Welf.*, 17, 65.  
 "The Temperamental Factor in Industry." *Engineering*, 1936, 129, 3622.  
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 "Psychology in Industry." *Brit. Med. J.*, 1937, i., 503.
- WESTON, H. C.: "Machine Design and the Welfare of the Operator." *Industr. Welf.*, 1937, 19, 217.  
 "Industrial Lighting." *J. Inst. Production Engrs.*, 1937, 16, 4.

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