Discussion.

The AUTHOR, in exhibiting some lantern-slides, showed graphically the monthly variation in power-consumption and in the cost of power for the first 8 months' operation of the plant.[1] The Author.

Mr. S. B. DONKIN observed that the Paper was especially interesting because it contained for the first time, so far as he knew, a detailed account of how electricity might be used for heating and other purposes in a big London store. At what price and under what system of charging did the supply company deliver current to the installation ? From curves shown on the screen the charge appeared to be about ½*d.* per unit. Had the Author found that it was better to have an air-heater with a small area at a high temperature or a large area at a lower temperature ; and was it desirable to vary the humidity of the air which was finally discharged by the fans into the building ? Was it possible, for instance, by the control which the Author had indicated, to vary the humidity by allowing some of the spray-water to pass through the heater and still be retained in the air ? He thought that, if the temperature of the elements in the heaters was high, the moisture would be entirely dried out, and the dryness of the atmosphere in the building would be not altogether attractive to the occupants. The foul air was allowed to pass out of the building naturally through any crevices. Was it quite clear, and could it be proved, that any foul air coming up outside the building, say on the windward side, could not get in again through the coolers and fans as it passed over the roof ? Admittedly the Author had arranged for foul air to be recirculated in order to economize ; but Mr. Donkin could not help feeling that, in certain circumstances, it would be desirable to have an ideal system by which only fresh air could be brought in. Had the Author any means of recording the foulness of the air—what he called the smell of it ? An interesting matter was raised by the Author's statement that the cooling-plant took more power than the heating and all the other services put together. He Mr. Donkin.

[1] These data are shown in that portion of *Fig. 9* (p. 34), which extends to Feb. 1929.—SEC. INST. C.E.

Mr. Donkin. presumed—and he would like to be corrected by the Author if he was wrong—that the air heating could be done at about 100 per cent. efficiency, whereas, when the air was cooled, account had to be taken of the low efficiency of the refrigerating-plant. When results over a whole year were available, it would be extremely useful to see how the consumption of power varied as between summer and winter. The ammonia-compressors were mounted on springs with the object of localizing vibration. He wondered why the fan-motors, especially as they were three-phase motors, were not also on springs, so as to prevent them from vibrating the building ; cases were known where vibrations due merely to alternating-current motors had been very bad in large buildings in London. Why had the Author not installed a CO_2 recorder in the control-room to indicate the vitiation of the atmosphere in different parts of the building ? He would be very interested to know the capital cost of the installation.

Mr. Dolby. Mr. E. R. Dolby observed that a large part of his work had to do with the design of heating-installations for large public institutions. In 1908 he had the honour of having a Paper[1] upon the subject read before The Institution. Since that time, nearly 21 years ago, a wonderful evolution had taken place in the art, and the present Paper described probably the first example in the Metropolis of a large building heated entirely by electricity. He congratulated the Author upon his good fortune in having found clients—or possibly he ought to say wealthy patrons—willing to pay for what perhaps he might be allowed to describe without offence as a grandiose experiment. He had read the Paper with some attention, and, on putting it down, he could not resist the feeling that he had been gazing into a shop-window at apparatus built of unusually costly materials and fitted with numerous automatic devices, but bearing no price-label; and that he was diffident about entering the shop, as he felt sure the price would be far beyond his resources. The principal question raised by the Paper was the commercial possibility of heating large buildings in the Metropolis by electricity. He thought that possibility was distinctly remote. He had to examine very frequently the relative costs of electricity for heating, as compared with the older methods, and he had formed the distinct impression that, unless electricity could be purchased at 0·1*d.* per unit, it could not successfully compete with solid or liquid fuel for large installations. One of the most recent examinations of the problem which he had had to make had been in connection with the new William Booth Memorial Training College at Denmark Hill, for the Salvation

[1] Minutes of Proceedings Inst. C.E., vol. clxxiv (1908), p. 91.

Army. That institution was costing £350,000, and it comprised a large number of buildings covering a site of 7 acres. His firm had been asked to report, firstly, whether it was desirable to put down a private electric generating-plant, or to purchase current from public mains; and, secondly, whether electricity should be used for heating and domestic hot-water supply, so as to avoid the necessity of building a central boiler-house and a tall chimney. His clients had been strongly biased in favour of the latter proposal, and an offer had been obtained from the public supply company in the following terms: For lighting, power, and general purposes a standing charge of £8 per kilowatt of maximum demand, with the addition of a running charge of 1·2*d.* per unit; for heating the buildings by means of tubular radiators, a flat rate of 0·6*d.* per unit, except from 4 p.m. to 6 p.m., when the charge would be 1½*d.* per unit; for domestic hot-water service a flat rate of 0·3*d.*, but restricted solely to the period between 11 p.m. and 7 a.m. After very careful calculation his firm had concluded that, firstly, a private electric generating-station could not be advised, and, secondly, electrical heating and domestic hot-water service could not be recommended. The initial capital cost and the running-costs greatly exceeded those of the older systems. The Author had clearly described his reasons for recommending the use of electricity on the premises of Messrs. Bourne and Hollingsworth, and had pointed out that valuable textile fabrics were very much injured by dust; but the damage must be a finite amount. That firm was in competition with large West-End houses in the same trade, and although their business was an exceedingly profitable one, it surely must be necessary to consider the cost of heating and ventilating. He ventured to suggest that the Author's statement was *ex parte*. What was wanted was the views of the owners, after their experience had extended over some time, as to whether the system was adequate and did all they wanted at a reasonable cost. His own experience had pointed to two features as essential—efficiency and simplicity; and perhaps the second had more weight than the first. Automatic apparatus had caused him a great deal of anxiety, and he feared that the life of the engineer in charge of Messrs. Bourne & Hollingsworth's plant was by no means enviable, in view of the number of automatic devices. Could the Author give the capital cost of the installation, and the cost per unit charged by the supply company for the electrical energy used? If he was not at liberty to disclose the capital cost, perhaps he would be able to give the cost per thousand cubic feet. Mr. Dolby.

Mr. C. T. A. HANSSEN remarked that, although the installation described in the Paper might be expensive, it certainly was a very Mr. Hanssen.

Mr. Hanssen. great comfort to the numerous shop-assistants and the thousands of customers. It was impossible to please everybody. His wife had been in the building lately during the prevailing cold weather and her complaint was that it was a little too hot, whereas the assistants told her that they considered it was a little too cold, especially about the floor. Customers, however, appeared to be pleased with the restaurant, where they could sit down in a current of perfectly fresh and perfectly clean air. There was no dust to be seen anywhere. That was a great attraction, and he thought that the high price of the installation would be counteracted by the attraction of additional customers due to the unusual comfort. What appeared to him to be of some importance was the ventilation with warm air, instead of the present craze for ventilation with cold air. Exposing the skin to cold air was a serious disadvantage from the point of view of hygiene, although he understood that medical men approved of it. If people could be persuaded to breathe warmed and cleaned air they would be much healthier. The great predisposing cause for the greater part of human illnesses —he believed even cancer—was exposure to cold air. Chilling the skin neutralized its natural function of assisting to purify the system. An important improvement in the general standard of the health of the community and a reduction of the death-rate would certainly be a consequence of the general introduction of schemes such as the Author had described.

Mr. Macintyre. Mr. J. A. Macintyre observed that he had read the Paper with pleasure on account of the clear way in which the Author had described the installation, and he congratulated him on the boldness of the design. He agreed that the Author had been very fortunate in getting clients wealthy enough to face the cost. The question of cost, however, was one entirely between the engineer and his client. He thought gas-engineers might have some remarks to make about the difficulty of burning 20,000 cubic feet of gas per hour without risk of explosion. He did not think there need be any risk. During the war he had been partly responsible for two installations having a gas-consumption of about that order. In one case producer-gas from an open-hearth producer had been used, and in the other case town gas. The process had been the melting of picric acid, so that any explosion would have been accompanied by very serious results. However, the pilot jets had been so carefully arranged, the pipes had been so accessible, and everything had been kept so clean, that he was certain there had been no risk. In that case, however, a fully-qualified engineer had been in charge, whereas in such cases as that under consideration semi-skilled attendants were usually preferred. He had recently had an opportunity of investigating the distribution of fumes within a building. At the new Public Offices at Storey's Gate, there was an air-intake at the bottom of a well just below a chimney. A series of tests had been made at the intake, and in no case could it be found that the air there carried appreciably more dust than did the average air in rooms facing the other side of the building. He noticed that ball-bearings had been specified for the fans. He had found ball-bearings noisy, and had had to abandon them for that reason. As he had stated, the question of cost was one for the engineer and the client; but there was a matter in connection with electrical heating in which all engineers were interested. The quantity of coal that must be burned to heat any building through electrical energy was at least three times that required to heat it directly by a boiler. The electric generating-stations serving London had not yet been moved far enough into the country to get rid of the serious effects of sulphur in the flue-gases. With regard to smoke, the boiler required to heat Messrs. Bourne and Hollingsworth's premises would be of such a size that it could economically be arranged to consume the soot as effectively as was done in the boiler of a large power-station. With regard to the sulphur-output, the two boilers would be equal offenders in proportion to the quantity of coal consumed; but, considering the question from the point of view of electrical heating, the big boiler at the station would consume at least three times as much as a boiler heating the premises directly, and therefore three times as much sulphur would be emitted to the air. Electrical heating might be clean for the individual, but it was not clean for the community. There was a belt along Regent's Park, on that side of two power-stations in the vicinity which was the leeward in prevailing winds, in which the leaves dropped earlier than elsewhere. In dry weather sulphur from a dry chimney would go for hundreds of miles. Recent analyses made in connection with building research had indicated that the quantity of sulphur in the air, estimated as SO_3, was not materially different at Watford from what it was in London. To get rid of the surplus heat of the power-stations, however, cooling-towers were required, which were constantly giving off a cloud of water; immediately that water was cool enough to dissolve the SO_2 it brought a fair part of it down in the form of acid. Probably that was what was causing the early fall of leaves in the belt of Regent's Park to which he had referred. Sulphur was causing the decay of the stonework of the Houses of Parliament and other buildings, and he did not think it likely that Mr. Macintyre.

Mr. Macintyre. the lungs of human beings were more resistant than Anston or Portland stone. For the heating of buildings much was to be said for putting down a generator-set in the middle of a large block, warming the buildings by the waste heat, and at the same time supplying current to the public-supply main. Within the last few months he had been interested in the combined warming and electricity- and power-supply to a group of buildings at South Kensington, and the system that would entail the lowest fuel consumption was a mixed-pressure turbine, the low-temperature heat from the turbine being used for warming the buildings, and the surplus current being supplied to the company's mains. The difficulty was that in no group of buildings did the heating and lighting loads exactly coincide, and therefore a machine of that description worked at maximum efficiency for only a very short period; but in nearly all cases, and especially in groups of buildings such as clubs, there was no doubt that the coincidence of the two loads, that was to say the electricity load and the low-temperature heat load, was such as to make the proposition attractive, provided the local electricity supply company would take the current from the generator at times when it was not required in the building, but when warming or cooking was necessary.

Mr. Joselin. Mr. E. L. Joselin observed that an alternative scheme, which had not been mentioned, and which perhaps ought to be taken into account in future schemes of this magnitude, was that, instead of the installation of an electrical plant serving a group of buildings as had just been referred to, the waste heat from the condensing-plant at the large power-stations, which represented the bulk of the heat in the coal, should be conducted by underground mains to buildings, for the purpose of warming them. He was not familiar with the building of Messrs. Bourne and Hollingsworth, and so he could not discuss the details, but it was not clear how the large volume of air which was described as being circulated by the fans could possibly find its way out through cracks and crevices, and through the porous materials of the walls of the building. He had made a rough estimate that, if there were no large openings for the escape of the air, on each floor of the building cracks of the average width of $\frac{1}{16}$ inch would have to aggregate miles in length to allow the air to escape. No doubt there was some explanation of that. Had any test been made to determine the actual volume of air being delivered from time to time by the various fans? That of itself would show whether the air was really escaping or not. It was mentioned (p. 8) that a difference of pressure of about 0·01 inch of water or less would be sufficient for the evacuation of the air. Had any accurate data been obtained about the sufficiency of that difference of pressure? In its passage through the building the air must necessarily pick up some dust, and, if it was escaping through small apertures at different places, in course of time there would be a trail of blackish or greyish marks on the decorations of the building. Some triangular openings were mentioned as being provided for the evacuation of foul air from the basement, but he could not trace how they were connected. He would like to know how evacuation was effected, particularly when the fans were not in operation, because a natural circulation seemed to suggest that fans were unnecessary. At what point did the discharge take place of the foul air from the ventilating schemes provided for the kitchens and lavatories? That would have a very important effect upon the intake of fresh air for the main ventilating-system. In the event of high wind outside the building, were the fans capable of maintaining plenum within the building to prevent any infiltration? What was the maximum pressure attainable in the building? Mr. Joselin.

Mr. J. A. Slater remarked that, as the architect of the building under discussion, he was not competent to deal with the intricacies of the technical side of the particular problem involved. He quite understood how some speakers might think that the economics of the installation were somewhat appalling; but it should be realized that the use to which the building was to be put did make a great difference to the economic question. For instance, the institution at Denmark Hill to which Mr. Dolby had referred was altogether different from a commercial house such as Messrs. Bourne and Hollingsworth's. A reputation for having the best ventilated shop in the whole of London, both in the summer, when the shop was cooler than anywhere else, and in the winter, when the air was not stuffy and the heat was pleasant, must be of incalculable value to the business, in view of the number of customers who were attracted to the shop and who purchased goods. That would not apply to an institution such as the training college at Denmark Hill, or to a private house. He did not think that the Author really meant to say that cracks in the building were going to let out the superfluity of air. At present, at least, they did not; nor even in 20 or 30 years would they do so. No doubt the Author would explain how the air did actually get out. Mr. Slater.

Colonel R. E. Crompton remarked that, if, as the last speaker had said, Messrs. Bourne and Hollingsworth found that the arrangements described in the Paper, by giving purer air and greater comfort to their customers, made their premises additionally attractive, then Colonel Crompton.

Colonel Crompton. the costly installation might pay for itself. But the Author had said nothing about the cost of lighting the building; if the lighting was done at the same rate of approximately $\frac{1}{2}d.$ per unit, it was difficult to see how the supply authority could repay itself. The supply-company with which he was associated were making the experiment of supplying certain premises at $\frac{1}{2}d.$ per unit at off-peak hours; but it was then necessary to receive a fair price for the lighting during the peak hours. For this reason, although he was much interested in the experiment, he could not see how it could be made to pay.

The Author. The AUTHOR, in reply, remarked that Mr. Dolby and others had seemed to suggest that the scheme was a kind of freak, engineered as an experiment at the expense of Messrs. Bourne and Hollingsworth. Anybody who had had any business transactions with that firm would know that they were not to be experimented on. He would not care to have to ask them to pay for anything more than value actually received. After running the apparatus in actual service for almost a year, his clients had expressed entire approval of it as a commercial investment. It had been designed for commercial purposes, and it would have been regarded as a failure if it had not justified itself on commercial grounds. It was gratifying to hear that Mrs. Hanssen had formed such a good opinion of the conditions maintained in the shops. The shop was used almost entirely by ladies. In extremely hot weather the number of customers coming into a shop of that kind usually diminished. Since the apparatus had been introduced there had been no such falling-off. The public used the shop as a refuge from the excessive heat, and that that must lead to purchases was obvious. In winter when there was a dense fog in the street, no fog was found in the building. The determination of the most appropriate means of heating for the special circumstances of that building had been a very interesting problem. As stated in the Paper, the choice had obviously lain between gas and electricity. A large quantity of gas had previously been, and was still, used in the building for various purposes. A good deal of heating was also done by gas in the older portions of the building. A good supply was available from two different sources. The case for gas was, therefore, obvious, and he would have carried out a gas-heated installation with considerable confidence but for the difficulty of dispersing the products of combustion satisfactorily. The essential differences between gas and electrical power for heating purposes had been very carefully weighed and fully discussed with his clients, who themselves had made the decision to adopt electrical power. Those differences might be mentioned, The Author. as they were generally important. The gross cost of gas heat was normally about one-third of that of electrical heat, assuming gas at 10*d*. per therm and electrical energy at 1*d*. per unit. The relative efficiency of use was such that that ratio was generally reduced for net comparison to about 2 or 2½ to 1, depending on the method of use. In the present case the gross cost of electrical heat as quoted by the St. Marylebone Electricity Department was 2·63 times that of gas heat as quoted by the Gas Light and Coke Company, and the net cost, allowing for efficiency, was 1·98 times that of the same quantity of heat actually delivered into the building when derived from gas. Electrical power in that connection might be regarded as nothing but heat, and gas as heat plus products of combustion, which were often troublesome to get rid of. The combustion of gas could be controlled much more finely than could the consumption of electrical energy, as the latter was switched on by a limited number of stages. The accuracy of control, therefore, was in favour of gas, but as against that the time-lag necessary with a gas-heated plant was much longer than with the corresponding electrical plant. The former involved the heating of a large mass of water and iron pipes, whereas the electrical elements employed delivered to the air the full equivalent of the energy used a few seconds after the current was switched on, and that was important where close control was aimed at. There was also the outstanding difference that in the case of electrical power the energy was generated as it was used. Gas, on the other hand, required a large reservoir of energy, of which the great bulk was concentrated in the gasworks, but a considerable quantity of which was in the pipes on the premises where it was to be used. The normal quantity of accumulated energy on the premises might conceivably be greatly and dangerously increased and be let loose by a leakage. Only in that condition did that feature become a possible danger. This fundamental difference produced the result that, while the electric supply company could not provide the large amount of excess power that it was desirable, and even in some cases almost necessary, to have available for emergencies, such as rapid heating-up or extreme weather conditions, the gas company could supply it at any time on demand. There was, therefore, a necessary restriction in consumption of electricity at times of extreme peak load, which perhaps only arose for a few hours or days once or twice a year. That was a considerable disadvantage of electrical power for heating purposes. The consumption of gas, on the contrary, could be increased very greatly to provide for emergencies, without notably adding to either the cost of installation or the difficulties at the supply station. Every kind of energy

The Author. involved a possible source of danger; and it was only where such dangers could be rendered negligible, as far as the public were concerned, that any particular form could be properly recommended for such a duty as this. There was no real danger in the installation in question, on account of the careful wiring, fusing, and earthing. He did not regard the danger introduced by the use of gas as considerable, especially where, as in the scheme mentioned, the only outlet for the gas was on the roof of the building. As gas was now actually used in large quantities in the building in the case under discussion, the use of electrical power instead of gas did not actually obviate any danger there might be from the use of gas. The 20,000 cubic feet of gas per hour given in the Paper included about 5,000 cubic feet at present being used for sundry purposes.

The price originally quoted for power, on which the original calculations had been based, was $\frac{13}{16}d$. per unit less 10 per cent., that was, 4,670 B.Th.U. per penny; while the quotation for gross heat in the form of gas was less than that in the ratio of 100 to 263, or 12,300 B.Th.U. per penny. But the additional advantages offered by the Electricity Department for the supply of the large quantity of power for lighting and other purposes in the building, added to the other great advantages in practical use, had been such as to make the case in favour of electrical energy quite convincing from a financial as well as from a technical standpoint. On account of the large consumption on the premises the price had recently fallen at first to $\frac{11}{16}d$. and later to $\frac{1}{2}d$. per unit. He believed, however, that even at such prices only under rare conditions could electricity be economically used for the generation of heat on a large scale. Those conditions arose where the required control of heating was exacting, the required quality of the heat was high, the business concerned was so profitable and so great that the high cost of the power could be afforded, and the high quality of the result produced an increase in the turnover of the business. It would be a mistake to assume generally, in spite of the unquestionable commercial success of the present installation, that electrical power could be frequently employed with real economy on such a large scale. But electrical power was, without question, a highly efficient and convenient heating-medium when it could be advantageously adopted. It had been suggested by Mr. Dolby that electrical power could not advantageously be adopted for heating unless the price did not exceed 0·1d. per unit. The Author disagreed with that. Electrical heating could very well be generally employed with current at $\frac{1}{4}d$. per unit, and with real economy. He agreed that it was not desirable to consume more of the nation's coal than need be, The Author.

and that the total efficiency of burning coal and producing electricity was about 20 per cent.; whereas with gas 80 per cent. of the total heat could be got into the gas in the mains and could be burnt without fouling the air with sulphur—a very important point. He had prepared a very detailed estimate of the total cost for both gas and electricity before the scheme was accepted. So far as it was possible to tell, that estimate for electricity had been almost exactly borne out by experience up to the present day, and presumably the estimate for gas would also have been, if it had been adopted. The apparatus had been continuously at work since July, 1928. The total cost per annum, including sinking-fund, attendance, rent of apparatus, maintenance, cost of fuel, and so forth, had been estimated as £2,942 for gas and £4,560 for electricity. The actual cost of one complete year's working,[1] including all these items, had proved to be about £4,500, as nearly as it was possible to tell. The cost of the whole plant as far as he had had to deal with it was £23,000; that included all the heating and cooling, and all the fans and the electrical controls. What he had wished to convey in the remark about refrigeration (p. 12) was not that the power required for refrigeration in this scheme was greater than that for heating, but that it took more electrical power to cool a given quantity of air through 1° than to heat the same quantity through the same interval. It was never safe to cool any building more than 10° F. below the outside temperature in hot weather, and that could be done with a smaller expenditure of power than was required ot heat the building through 35° F. Referring to Mr. Joselin's observations, the installation of plant utilizing the waste heat from power-stations, though very attractive, involved so many difficulties that it was almost impracticable in most cases. The heat from the condensing-plant was nearly always at a very low temperature and quite useless for the purpose of heating buildings. Then the cost of the underground mains, and especially of the tunnels to carry them, was high, and unless the station was in the immediate neighbourhood of the place where the heat was to be used the method was generally found to be impossible. He appreciated the fact that heating by electricity was essentially extravagant, because it used high-grade heat for a purpose for which low-grade heat would normally serve. Mr. Macintyre's observation on the undesirability of emitting flue-gases into the air in a crowded district had his hearty

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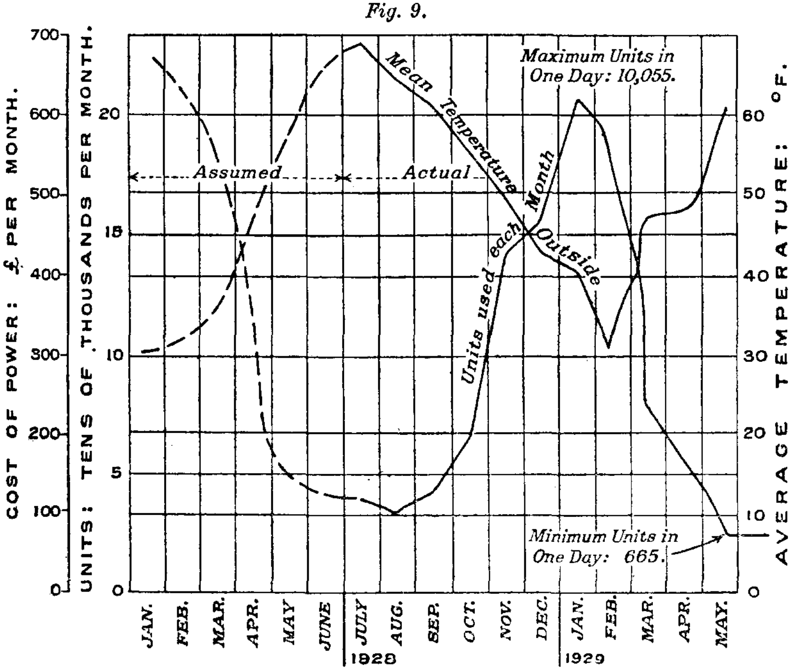
[1] This figure was added at a later date, and the diagram referred to at p. 23 was extended to cover the first year's working, as shown in *Fig. 9* (p. 34).—Sec. Inst. C.E.

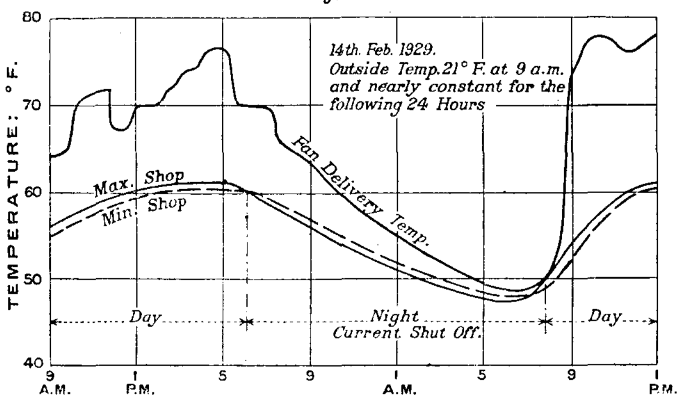
The Author. agreement. There was no reason why any large quantities of noxious gases should be discharged into the atmosphere within 50 miles of a big city. It was never advisable, except in the open country, to equip an institution with its own power-plant. There were instances where a certain economy was possible, but in most cases such a plant was a nuisance as well as a very expensive luxury. The plant described in the Paper had been satisfactory in the recent cold spell; the temperature had been 55° F. in the early morning,

Fig. 9.



and it had risen during the day to 61°, after falling at night to 50°. *Figs. 9* and *10* gave details of the actual experience in the practical working of the plant during some of the coldest weather which had been experienced in recent years. Those diagrams had been obtained in the following way:—Continuous records were taken of the external temperature at a point on the roof near the main inlet air opening. They were averaged daily, and the daily averages were again averaged over the whole month. The value of the monthly mean so calculated was plotted in the middle of the vertical column representing the corresponding month, and curves of average temperatures were drawn through the points so obtained. The total units used for each month were obtained from meter-readings. Those figures The Author. included both heating and refrigeration, not only for the cooling of the building but also for the fur-store in the basement. The costs were calculated at the original rate of $\frac{13}{16}d.$ per unit, less 10 per cent. The total energy actually used in 12 months was about 1,100,000 units; the originally estimated consumption was 1,360,000 for the same period. *Fig. 10* showed an automatically-recorded diagram of temperature for one of the coldest days experienced for several years. The lower two curves crossed one another because the shop whose temperature was indicated by the dotted line had a slightly longer time-lag than the other. There was no difficulty in raising the temperature, even in those extreme conditions, to the calculated standard of 63° F., but the temperature was lower than

Fig. 10.



the standard during the earlier part of the morning, on account of the circumstance already referred to. The temperature could have been raised if an earlier start were made, but this was not desired. The considerable variation in the temperature of the air delivery was due to the operation of the main damper, the delivery temperature rising as the air-delivery was reduced. The delivery-duct was built of insulating materials to avoid loss of heat in the winter and loss of cold in the summer. He could not altogether agree with Mr. Hanssen's opinions on the question of the hygiene of ventilation, as his experience had led him to believe in the hygienic virtues of plenty of fresh cold air. It was very desirable that the contact-area of the heating-elements should be kept as large, and the temperature of the elements consequently as low, as possible. They were much more durable if the temperature was low. The actual temperature

The Author. was about 700° F., the resistance of each element being about 8 ohms. The higher the temperature of the heater the worse the effect on the freshness of the heated air. This was probably due to the charring of the ultra-microscopic dust-particles in the air, which were not removed by the washer. Exact regulation of humidity could only be effected by altering the temperature of the washing-water, and subsequently warming the air to the required temperature. That could be done thermostatically so as to maintain any desired dew-point and degree of humidity in the air delivered. Only in special cases was it worth while in England to incur the expense and complication of accurate control of humidity. The human body could deal satisfactorily with wide variations in the quality of the air, and there was no hygienic advantage in keeping it constant—it was rather a disadvantage. The temperature of the elements *per se* would have no effect on the humidity. Any intermixture of what Mr. Donkin had called foul air with fresh air would have no observable deleterious effect. Such intermixture must always take place in all schemes of ventilation. Ventilation was not essentially a process of displacing vitiated air by pushing in fresh air, but a process of continuous dilution of vitiated air with fresh air to such an extent that the degree of vitiation was maintained at a reasonably low level. Perfect ventilation in that sense was only obtainable under the open sky, where the volume of the fresh air was practically infinite. He knew of no instrument that would record the degree of vitiation of the air. The process of analysis required to determine the composition of air so closely as was necessary would be too delicate for automatic recording. He had no figures representing the results of the cooling, except that the general temperature in the building in hot weather was 5 to 10 degrees below the outside temperature. It was difficult to say exactly how the air got out of the building. It was certain that the required quantity of air was forced into the building, because that had been determined at the outlet of the fan. There were numerous possible exits for the air. Whenever a door or a window was opened there was a considerable outward draught. It was also possible to detect the outward passage of air round the metal-cased windows and up or down the various staircases. There were movements of air also between the various shops, up all the numerous lift-shafts into the controller-room on the roof, and from the front, or ventilated portion, to the back, or unventilated portion. A large part of the air escaped through the entrances on the ground floor. In reference to Mr. Slater's observations he certainly had not wished to imply that a possible escape for air was provided by defects in the

The Author.

construction; the fact was that every wall made of ordinary materials, such as plaster and brickwork, and the like, was porous to a certain degree. The air delivered was so clean that there were no traces of staining after 6 months' use. The measurement of the exact value of the interior pressure in a plenum-heated building, though it could be made, was complicated, and it was very indeterminate. Every open window or door made a difference. It might be taken, however, that about 0·01 inch of water-pressure was an approximate figure. The triangular openings spoken of for the evacuation of foul air from the basement arose from the circumstance that a circular finish was given to the angles in the corners of the staircase-well. Those openings were carried to the top of the building and utilized as flues. Natural circulation would not evacuate the large volume of air needed in that case. When the fans were at rest there was a considerable upcast in the ordinary flues, that was, a reverse ventilation in those circumstances. Interchange of air was not desirable when the fans were stopped, because the building was then empty, and in fact all the dampers were closed so as to keep as much of the warm air in the building as possible. The point of discharge of the foul air from the ventilating scheme was at one end of the building, as far away from the inlet openings as could be arranged. It was practically impossible for any considerable amount of that air to be re-introduced into the building. The fan motors were actually mounted on a flexible staging, with a view to reduce vibration. They were insulated on the staging by cork and felt. The mounting was perfectly satisfactory for reducing noise, and in no part of the building could the working of the numerous motors be detected. Up to the present the ball-bearings had not proved to be noisy. Very skilled attention was given, and the engineer-in-charge was the engineer who had been responsible for the wiring. Such a plant could not safely be put into the charge of any unskilled person. There were in all sixty-four electric motors of a total of 300 HP., about 2,200 sets of contactors, and 1,920 heating-elements. The total electrical current calculated on was about 5,700 amperes of alternating current, and 59 amperes of direct current. In reply to Colonel Crompton, the lighting of the building was not one of the Author's responsibilities, and he could not say whether current was being supplied for that purpose at less than its cost.