The Author. tured to think that an actual room of the sizes mentioned could only be usefully employed for making comparative tests upon small apparatus, which could be placed therein temporarily. He considered that the whole subject should be dealt with upon the basis of the British thermal unit, which formed, in his opinion, a perfectly adequate "standard of comparison" for heating-apparatus such as was described in the Paper, and also for the testing of open stoves such as Dr. Owens had experimented on for the Coal Smoke Abatement Society, if suitable apparatus were used for the purpose. Such a method could be used anywhere, and could be employed without reference to the actual size of the room in which the experiments were carried out. The results obtained should be due to the heating-apparatus, or stove, only, and should not be complicated by a consideration of losses through walls, windows, etc., as such losses would of course differ widely under varying local circumstances. He did not agree with Mr. Hanssen that mechanical power was necessary to ventilate the wards of hospitals properly. Each ward contained only a small number of persons, and the ventilation presented an entirely different problem from that of the ventilation of a crowded theatre or meeting-hall. The Author considered that the methods described in the Paper combined with open windows were adequate for the special buildings described therein.

Correspondence.

Mr. Everard. Mr. J. B. EVERARD desired to draw attention to the "Nuvacuumette" system of heating, which might be described as a steam system almost entirely below atmospheric pressure, and consequently of low temperature, and to submit that it was at least equal, and in some points superior to, the hot-water system favoured by the Author. A brief description of an installation of this system in the new asylum at Narborough, near Leicester, built by Messrs. Everard, Son and Pick, would show the points he wished to raise. The asylum was occupied by about 600 patients with the necessary attendants, but the administrative part provided accommodation for 1,000 patients and officers. A complete electric installation formed part of the plant, being used for driving the laundry, bakery, fans, and other

machinery, in addition to the lighting. Compressed-air plant, princi- Mr. Everard.
pally for ventilation, was also provided. The exhaust steam from the engines forming part of those installations was used for heating. The initial pressure of this exhaust steam, representing the back-pressure put upon the engines, was ½ lb. per square inch above the atmosphere; and it was circulated for heating purposes through the whole length of pipes by vacuum pumps, the vacuum being about 6 inches at the remote part of the installation, and 10 inches at the pumps. Radiators, each under separate control, were attached to the pipes wherever heating was required, and the return from each radiator was carried into the return-pipe, so that there were no steam-traps in the building. The return vapour was passed through calorifiers or "nuconomizers," as they were there termed, for heating the hot-water service, and as condensed water was then sent through Green economizers to the boilers. The hot-water service was circulated by pumps to all parts of the buildings. The temperature of the vapour at the radiators was about 190° F., and that of the hot-water service about 140° F. Live steam was automatically used for either process if found necessary. Mr. Everard submitted the following categorical observations upon the Author's summary of reasons for his preference of water to steam as a heating medium, the reasons being repeated for convenience of reference with Mr. Everard's comments appended to each:—

(1) "The temperature of the radiators is lower, and the dust-particles in the air are not burnt." With the vacuum or vapour system the temperature was practically the same as with hot water.

(2) "The heating is not subject to so much fluctuation." It was believed that there would be less fluctuation with the vapour system, and that the heating would be more under control.

(3) "Steam traps and special automatic valves are needed only at the calorifiers, whereas with steam-heating they are scattered all over the buildings, and need constant attention by the engineering staff." This was not the case with the type of installation described above.

(4) "Condensation pipes are not required in the subways." Some kind of return pipes must be required for the hot water, and these would be much larger than the condensation pipes required in the vapour system.

(5) "The system is much safer for patients, as the temperature of the hot-water radiators and pipes is considerably lower than that of steam radiators." The radiators heated by vapour were maintained at as low a temperature as those heated by hot water.

Mr. Everard. (6) "In most cases the radiators will not want protection." This was a feature of the vapour system also.

(7) "The cost per square foot of operative heating-surface where forced circulation is used is in most cases less than the cost of steam-heating; and not only so, but the total initial cost of forced circulation with hot-water radiators per heat-unit given off, is less than the initial cost of a low-pressure steam-heated system." This assertion could only be substantiated by a careful comparison of cost. It might reasonably be assumed that the mains for circulating hot water through a large building would have to be larger, at least in the return, than those for vapour; and that the pumps for effecting this circulation would have to be much more powerful than those for circulating vapour, when it was considered that a cubic foot of vapour at 10 inches vacuum weighed only 0·0624 lb., against 60 lbs. for water at 190° F.

(8) "The costs of fuel and of maintenance of a forced-circulation hot-water system are less than the costs for a steam-heating system." Again, this could be proved only by a careful comparison of the two systems in actual working, but the figures supplied by the Author in the Appendix, where a comparison was instituted between Camberwell Infirmary (hot water), and Hellingly Asylum (low-pressure steam), appeared to show that, for fuel alone, the cost at Hellingly was about 50 per cent. less per resident than that at Camberwell. Other points in favour of the vapour system were: diminished risk from frost, less risk of injury to the building from leaks in the mains, and more perfect control of the apparatus. The adoption of the system of heating referred to for the Asylum at Narborough had been decided upon after previous satisfactory experience of a similar plant installed by Messrs. Everard, Son and Pick a few years ago at the Leicester General Infirmary.

Mr. Keith. Mr. JAMES KEITH stated that scores of somewhat similar institutions were warmed in something like the same way as those mentioned in the Paper, with this addition, that they were also well ventilated so far as the extraction of vitiated air was concerned. He noticed that, although in three of the schemes provision was made for the admission of fresh air warmed, there was no mention in all the six installations of any special outward ventilation, and there could be very little effective inward ventilation without induction inside the buildings caused by positive extraction towards the outside. The Author indicated that there was some limit to hot-water circulation, and therefore recommended and used steam-pumps for circulating the hot water for heating and supply purposes. Mr.

Keith differed from him entirely on the following grounds: (1) the limit in distance of hot-water circulation, caused by either "heaters" or hot-water boilers of best type, had not yet been reached; (2) there could be no comparison in economy and efficiency between any kind of steam circulation of water for warming purposes, all the balance being in favour of hot-water boiler circulation properly applied. Where assisted circulation might be desirable in the case of dips under the normal level, etc., that was best obtained by the use of specially designed centrifugal pumps worked by electric motors, which could be attached to any of the main circulating-pipes, and (even when not working) did not impede the circulation in the ordinary way. Of course, in special cases it was often advisable to use steam or hot-water heaters or "calorifiers," or even steam injectors, instead of hot-water coke-fired boilers for the circulation of hot water for warming and other purposes. There were also other novel means of accelerating hot-water circulation without the aid of pumps or other outside-driven contrivances: notably, one extremely simple application or arrangement in Mr. Keith's possession with nothing but the hot-water circulation itself to effect the purpose in view: this device enabled a highly increased circulation (and consequently higher temperature on the heating surfaces) to be obtained in a very short time, and by the use of much smaller circulating and branch pipes. This system also, by creating a suction on the main return pipes at the boiler or heater, allowed for the thorough and rapid heating of radiators or pipes below the level of the boiler with equal efficiency. In these circumstances, it appeared to Mr. Keith that there was little novelty—far less, increased efficiency—in the installations described and illustrated by the Author. Mr. Keith.

Mr. E. R. Matthews observed that at the Cardiff Asylum the hot water was pumped into a cistern in the top, and it then flowed through the pipes by gravity. In his opinion the reason for the pumping was because the town water would not supply the cistern at that elevation. But a room could be warmed by a steam-boiler and on the hot-water principle without a pump, 15 feet or 20 feet lower than the boiler. Why use mechanical arrangements when automatic methods would answer? In Mr. Matthews's opinion, the best system of heating was on a simple automatic principle. Any building could be successfully heated and ventilated, and that most economically, upon the hot-water system. If it were a large building it would be necessary to employ steam to heat the water for domestic purposes, but in a smaller building the domestic supply could be Mr. Matthews.

Mr. Matthews. heated by the boiler that heated the rooms by means of a calorifier. His opinion was that the views on heating expressed in the Paper were unsatisfactory from both a theoretical and a practical standpoint.

Mr. Watson. Mr. JOHN WATSON, referring to the Author's statements on p. 93, remarked that it was not obvious why, if steam at atmospheric pressure could be used, there should be any back pressure whatever occasioned by using the exhaust steam. The fact was that steam at atmospheric pressure could only be used under the conditions obtained by the atmospheric system, and then the difficulties referred to by the Author vanished. He could not agree with the Author as to the disadvantage of the automatic valves required in the atmospheric system; and in his experience such valves needed but little attention. Again, with regard to leaks, there was no practical difficulty in locating any which would cause trouble. While on the subject of leaks, it might be assumed for the purpose of comparison that during the working of the apparatus a nipple was broken off by expansion. A great advantage possessed by the atmospheric system would then become manifest. No external escape of fluid would occur, but the vacuum gauge would at once indicate the existence of the leak, which would be sought for and rectified without delay. With a hot-water system, on the other hand, such an accident would cause great trouble, and, if it occurred in a ward, probably a panic. It was stated in the Paper that in every system of steam-heating the return of the condensed water necessitated a long length of piping, and it was suggested that there was great deterioration of wrought-iron pipes when used for condensed water. In Mr. Watson's experience such deterioration, if any, was very slight, and he was unaware of any instance of a condense main in an atmospheric system having to be renewed. With regard to the Author's preference for hot-water heating, it seemed obvious that he was comparing what he considered to be the best form of hot-water heating with the worst form of steam-heating. His summarized points Nos. 1, 5 and 6 referred to the same thing, the temperature of the surface, and should therefore be considered together. As compared with a system using steam at a pressure of 10 lbs. per square inch upwards the comparison might be justified, but with the atmospheric system, with an average temperature of less than 212° F., and reducible at will to considerably less than that, it was not so. With regard to the point No. 2, he would ask the Author to explain how and why the heating should be subject to any fluctuation. As to point No. 4, instead of the small

condense main used in the atmospheric steam-apparatus, a return as large as the flow, occupying far more space in the subway, was required for forced circulation of hot water. Points Nos. 7 and 8 referred to initial cost, and cost of maintenance. As regarded the former, it might be asked why an atmospheric steam system should cost more than a forced circulation of hot water when the hot water required (1) 25 per cent. to 30 per cent. more radiating surface, (2) larger pipes both in the subways and for the rising mains, and (3) expensive calorifiers and accessories. In both cases pumps were used, and the only addition to the cost of an atmospheric system to set against the items above mentioned, was that of the automatic valves on radiators and at drip-points. With regard to the cost of working, comparative figures were difficult to obtain. For one atmospheric steam installation, however, which had about 18,000 square feet of radiation, the average coal-consumption was 11 tons per week in summer, and 27 tons per week in winter. That included heating, hot-water supplies, electric lighting, and laundry. The staff consisted of an engineer, a fitter, two drivers, and three stokers. With atmospheric steam the radiators on any floor might be regulated to any extent, without in any way affecting the working of the radiators on the other floors. Further, the costly safeguard of duplicate mains mentioned in the Paper was quite unnecessary with an atmcspheric steam apparatus where there would be no pressure whatever in either steam or condense mains.

Mr. Watson.

Mr. F. G. WOLSTENHOLME was of opinion that the arguments set forth in the Paper in favour of hot-water heating were reasonable, although considerations of equal weight might be urged against that system, such as the following:—The larger diameter of pipes and sizes of radiators required for water heating compared with those required for steam heating. The impeding of circulation through air-locking, which must be met by a liberal provision of self-acting air-cocks. In cases of a sudden rise of temperature, the continued emanation of heat from the hot-water radiators and pipes long after the circulation had been stopped. The considerable pressure on pipes and radiators in high buildings, whether with or without forced circulation, and the consequent risk of damage by flooding through defective joints and pipes. The large capital expenditure required for a double system of pipes, and the necessary three-way valves to connect the systems, so that in the event of the occurrence of defective joints or pipes, either system might be cut off. The summarized reasons Nos. 5 and 6 given by the Author in favour of hot-water heating over steam-heating seemed not to apply under the arrangement described for the East

Mr. Wolstenholme.

Mr. Wolstenholme.

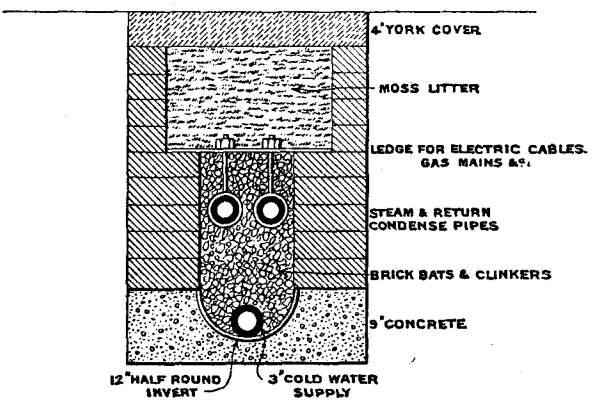
Sussex lunatic-asylum, and although that arrangement was for steam-heating, the methods described would be preferable even in the case of hot-water heating in a building of that character. It frequently occurred that the system was forced in order to meet a sudden fall in temperature, in which case the temperature of the radiators and pipes would be very little lower than if the system was a steam one. The Author's reason No. 7 would have been more convincing had a table of costs, with amounts of operative heating-surface provided, been given for each institution described. His reason No. 8 should surely be rather in favour of exhaust-steam heating, as the saving in fuel would more than balance the extra cost of maintenance. It was not stated in the Paper whether the subway pipes were protected by non-conducting material or not. In the majority of cases described the lengths of subway pipes were considerable, and such protection must materially affect the cost of working. The arrangements in the Royal Victoria Infirmary, Newcastle-on-Tyne, where each block was treated as a separate unit, and each provided with its own calorifier, appeared to be generally preferable to those in the King Edward VII Sanatorium. In single-story blocks the provision of separate calorifiers would be generally found to "surmount the difficulties which arose with the earlier calorifier system when differences of level existed between the different buildings"; and if suitable sizes of calorifiers for the work were selected, no difficulty should be experienced with the circulation. With a system of forced circulation and differences of level in the various buildings, the installation would have to be carried out in a much more substantial manner owing to the pressure on pipes and radiators, than if the system of separate units was employed; and apart from the extra capital expenditure, the increased risk of defective joints and pipes and consequent flooding, was considerable. Also, with the forced system of circulation, the duplication of the mains, as in the King Edward VII Sanatorium, was imperative, entailing large extra expense, whereas, with the unit system, such duplication was unnecessary. With reference to the description of an automatic arrangement for regulating the temperature from hot water radiators, the Author had stated that the valves for steam-heated radiators were so made that they were either fully opened or tightly closed, that being necessary to prevent the accumulation of condensation water in the radiators. In a Paper by Mr. R. P. Bolton on "The High Office-Buildings of New York,"[1] a description was

[1] Minutes of Proceedings Inst. C.E., vol. cxliii.

given of an arrangement for the regulation of the temperature of each individual steam-heated radiator by means of one hand-valve only. Mr. Wolstenholme submitted, as an addition to the information given in the Paper, the following particulars of the system of heating applied to a Fever Hospital at Blackpool, designed and erected by the Borough Engineer. It contained 56 beds, with provision for a future extension of 22 beds. The hospital as originally erected consisted of an administrative block, two ward pavilions, boiler- and disinfecting-houses and mortuary block; while the extensions consisted of additions to the administrative block, one large ward pavilion, isolation block, new boiler-house, laundry and disinfecting-house, and mortuary block. The boiler-house contained one Lancashire boiler, 22 feet long by 7 feet 6 inches

Mr. Wolstenholme.

Fig. 19.



in diameter, working at a pressure of 60 lbs. per square inch. Provision was made for another similar boiler should it be required. Current for power and lighting were obtained from the Corporation electric station. The boiler supplied steam for the calorifiers, laundry and disinfector. From the boiler a flanged cast-iron steam main 3 inches in diameter was carried in a trench to various points in the grounds, from which branches connected with the various blocks. The trench was utilized to carry also the condensed-water main, the water-supply main, and the electric cables (*Fig. 19*). The branches were of wrought iron, $1\frac{1}{4}$ inch in diameter. The steam mains in the trenches were covered with two coats of asbestos cement, and were afterwards varnished. Horse-shoe expansion joints made of solid drawn copper tubes with strong gun-metal flanges, were fixed at every 100 feet on both the live-

Mr. Wolstenholme. steam and the condensed-water mains. A reducing-valve was placed on the steam main. The calorifiers were of the horizontal type, that for the main ward pavilion having a capacity of 600 gallons per hour, and the others of 300 gallons per hour. The calorifiers were of the Royle pattern with Row indented tubes, and were fitted with automatic bow-string valves to regulate the heat. They were situated in trenches under the floors, the flow and return mains being run in these trenches, and from them the necessary branch pipes were taken to the radiators. The radiators were of the "Ardent" vertical loop pattern, with plain faces, having generally 25 feet of heating-surface. They were fixed in nearly all cases in front of the fresh-air inlets, and were provided with baffle-plates to assist ventilation. Storage calorifiers of various capacities, in addition to the heating calorifiers, were also provided to each block for domestic requirements. The whole of the piping for the hot-water supply was of solid drawn copper, tin lined. The condensed water from the various calorifiers gravitated back to the boiler-house, where it passed into an automatic receiver and feed-pump, and was then fed into the boiler. On the supply side of the receiver, a steam trap was fixed fitted with a check-valve.

The Author. The AUTHOR, in reply, explained that he did not pose as an advocate of any particular system, but that, at the time the Paper was written, the system referred to on p. 92 was, in his opinion, the most economical for the particular purpose specified. Systems might have been devised since, or be discovered shortly, which would prove more economical, and the Author would be one of the first to welcome them. It was difficult to get accurate data based on carefully observed results, which would admit of comparison between the actual cost of heating, say, on the atmospheric system, and on the system of forced circulation of hot water, and one of the chief objects of the Author in writing the Paper would be attained if such a comparison could be effected. The system described by Mr. Everard was evidently that of the Atmospheric Steam-Heating Company. His comparison of this system with hot-water heating called for reply in detail. With reference to the temperature of the radiators, if the vacuum at the air-pump were 10 inches the temperature of the vapour would be about 190° F., and if the vacuum were 6 inches at the radiators, the temperature would be about 200° F., these being the minimum temperatures practically attainable, whereas the temperature with hot-water circulation could be reduced as low as might be thought desirable. The Author did not consider that, with the atmospheric system, the heating would be more under control. Although the fittings

in the atmospheric system were known as "thermostatic valves," they were in reality steam-traps, the distinction being merely one of terms. With a hot-water system, radiators might be fed off the return of the hot-water circulation, but they could not be fed off the condensation-pipe of the atmospheric system. The Author.

In regard to protection of the radiators, in the system described by Mr. Everard steam was said to enter the heating-system at ½ lb. per square inch pressure; its temperature would therefore be about 213° F. The temperature in the flow pipe of a hot-water system would rarely exceed 190° F. The statement at p. 94, in regard to the economy of hot-water heating, where forced circulation was used, was made after careful investigation. One case might be cited where comparison was made of five schemes representing different systems of steam and hot-water heating for a large institution, the requirements specified being the same for all. The actual tenders ranged from £9,699 for forced hot-water circulation, to £11,425 for atmospheric steam-heating, which was the most expensive of all. The cost per square foot of radiating surface was 4*s.* 9½*d.* in the former case and 9*s.* 7¼*d.* in the latter case. In reply to Mr. Everard's last criticism, it should be pointed out that a comparison of the figures quoted for an Asylum where the bulk of the inhabitants were workhouse inmates, where dormitories need not be heated at all in the daytime, and very scantily at night, with the figures given for an institution where the whole of the patients were confined to bed, must give utterly fallacious results. No particulars of radiating surface, cost of fuel, or any other data were given by Mr. Everard in support of his assertions.

With reference to Mr. James Keith's observations, outward ventilation was provided by means of central stoves in the wards, and these stoves were supplied with fresh air from outside, by special flues formed beneath the floors of the wards. At Camberwell Infirmary, there were in addition electric fans at the top of special outlet flues. It was not stated anywhere in the Paper that there was a limit to hot-water circulation, but merely that there was a practical limit imposed by gravity in the particular classes of building alluded to. The choice of the type of pump or other accelerator, and the means for driving it, were obviously matters to be decided in each case after due consideration of the local circumstances.

The system adopted at Cardiff differed only from that installed at Camberwell and the King Edward VII Sanatorium in the fact that the circulating pumps delivered the heated water to a storage tank placed at such a level above ground as to afford the necessary head

The Author. required to produce the desired velocity in the mains, after allowance had been made for all frictional and other resistances in the pipes. A constant head was thus obtained, and whether this was preferable to a head variable at will by using the pumps direct on the mains would depend entirely upon local circumstances. The tank with its piping was of course a considerable additional item of expense, and the pumps would be in any case necessary.

The Author did not understand Mr. Matthews's remark as to the town water-supply, as it was not likely that the hot-water tank would be higher than the cold-water tank. He was of course well aware that hot water could be caused to circulate at 15 to 20 feet below the boiler, but that could not be done automatically, if that term be used in its legitimate sense as connoting the circulation of water produced by a difference in weight of two columns of water at different temperatures. Such a circulation could of course be produced by the use of steam as an auxiliary acting in a manner similar to that in a pulsometer: probably it was this to which Mr. Matthews alluded. The energy thus expended, and the initial cost of the necessary plant were in many cases greater than those employed in the use of a mechanical contrivance, such as a centrifugal pump driven in the manner best suited to local circumstances.

In reply to Mr. John Watson, the statements on p. 93 referred solely to cases where no vacuum pump was used on the exhaust main; where such a pump was installed there need of course be no back pressure on the engines. Why the leakage of water in a ward should cause a panic was not clear; a description was given in the Paper of the provision made for emptying each vertical loop without stoppage of the system. The rapid deterioration of wrought-iron pipes by water of condensation from steam traps was a well-known fact, but where a vacuum pump was used on the condense main, this deterioration appeared to be reduced to the minimum. Fluctuation of temperature referred to at p. 94 took place with any steam-heated system, the volume of the heating medium in any radiator being exceedingly small. If a room heated by steam was found too hot, the controlling valves on the radiators would be closed, and in a very short time the radiators would become cold; whereas with a hot-water system the heat in the water contained by the radiators was relatively large, and the fall of temperature comparatively slow. It must be remembered that the Paper referred solely to a small special class of buildings, and whereas in a factory or block of offices closed during the night, it might be highly important to heat the apparatus rapidly in the morning, this was not the case in a hospital where the

temperature of the wards must be kept constant night and day. The Author. It had already been explained that radiators were fed off the return pipe, and the other points referred to by Mr. Watson had also been dealt with. As regarded the cost of working, although Mr. Watson quoted certain figures, he did not state the class of building referred to, the initial cost, or the cost of maintenance, nor was any comparison attempted between the figures given and those obtained from an installation of similar type heated by hot water. With reference to Mr. Wolstenholme's observations, self-acting air-cocks were not found necessary in the systems described, but a certain number of air-pipes were carried high enough to free the apparatus from air. Buildings of the class referred to by the Author were never high. The main circulation loops in the basement were in all cases covered with insulating material.

The description of the fever hospital at Blackpool was interesting, and the arrangement appeared to be identical with that adopted by the Author at the Royal Victoria Infirmary, Newcastle-on-Tyne, except that at Blackpool copper mains were used instead of iron, the former being probably necessitated by the quality of the water-supply.

In view of the very large sums of public money expended on engineering works in buildings of the class described in the Paper, the Author ventured to suggest that some public body, such as the Local Government Board, or one of the Engineering Societies, should investigate the subject dealt with in the Paper, and endeavour to obtain reliable data as to the initial cost and upkeep of the various systems of heating and hot-water supply. The annual financial loss to the community caused by the use of defective and antiquated plant was deplorable, and it seemed impossible for such waste to be stopped except by the action of some public body. The Author desired to thank all the persons who had taken part in the discussion either orally or by correspondence. The evident interest aroused by the Paper led him to hope that it would induce other engineers to furnish similar information.