blind-ended tube was not so satisfactory as a tube which could be seen right through, and through which a brush could be passed. He had not yet made any experiments with jet condensers, but was now engaged on such. With regard to Mr. Molé's remarks, the question of the dry air-pump and the pump described in the Paper was one upon which engineers must agree to differ. Mr. Molé was quite right in regard to the Harrogate trials. The Author had put the figures in the Paper for what they were worth, and if p. 213 were referred to it would be seen that the output was only 353 kilowatts, while the full load was 750 kilowatts. As a matter of fact, the circulating-pump was not reduced in speed, and therefore the full quantity of water was passed through. He believed the same results would have been obtained with much less circulating water. The Author.

The PRESIDENT thought some experiments on air-cooled surface condensers, carried out in the same satisfactory and exhaustive manner that Mr. Allen had treated the question of water-cooled surface condensers would be of some interest. Of late years the question had come within the range of practical engineering in connection with motor-cars, and the surface condensing of Sir Hiram Maxim's flying-machine. Cases might arise in a crowded city, in which water was expensive and the cost of land for reservoirs high, where water-cooling would be prohibitive, and where air-cooling might perhaps be desirable. The subject was not new. He remembered inspecting about 54 years ago a small engine in Birmingham, which was fitted with what was then called a "Craddock" air condenser, composed of a number of tubes fitted on a frame which revolved through the air on the top of a building, the exhaust steam from the engine below being led to the top of the building through tubes. It worked satisfactorily, giving a tolerably good vacuum. Other means than rotating the condenser might be employed—such as forced or induced draught—to circulate cold air among the condenser-tubes. The President.

Correspondence.

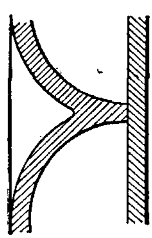
Mr. CHARLES DAY, of Glasgow, considered that the arrangement suggested by the Author for keeping down the temperature of the water entering the air-pump, was unnecessary; moreover, the arrangement was an old one, which had not been found generally advantageous. As the water of condensation fell from tube to tube on its way to the bottom of the condenser, it was generally cooled Mr. Day.

Mr. Day. considerably below the boiling-temperature corresponding with the vacuum attained either in the condenser or in the air-pump, and any further cooling was not only unnecessary but was also disadvantageous, as the water was generally used for boiler-feeding. For a number of years the arrangement had been adopted by The Mirrlees Watson Company, but it was now confined to surface condensers connected with water-distilling plant, where the lowest possible temperature of the discharged water was desired. *Figs. 8–10* showed that with reciprocating engines a vacuum of 25 inches gave more economical working than any less vacuum; but this he believed had been generally recognized for many years, and he thought the Author had stopped short just at the point where data would have been valuable. It was notable that on p. 183 he expressed the opinion that a vacuum of 25 to 26 inches was about the best for small compound engines exhausting into a common main. In expressing this opinion he had gone beyond the range of his experiments, thus proving how much better it would have been had the experiments, instead of ranging from a vacuum of 5 inches to one of 25 inches, ranged from 15 inches to 28 inches or 29 inches. In the Lancashire textile mills, where working-costs had perhaps been more closely watched for a number of years than in any other industry, there was a general opinion that with reciprocating engines a vacuum of about 26 inches gave the best results. With a higher vacuum the gain in steam-consumption at the engine did not sufficiently counterbalance the loss due to lowering the temperature of the hot-well water which was used for boiler-feed, and to the work done in pumping the increased quantity of water. The statement on p. 184 that 2·8 per cent. of the horse-power of the generators was required to drive the condensing-plant, whilst the steam-consumption of the latter was 7·5 per cent., showed that the steam-consumption per horse-power in the condensing-plant engines was nearly 2·7 times that of the main engines, and emphasized the disadvantage of steam-driven as compared with electrically-driven pumps. The figures given on p. 186 regarding water-consumption were interesting and valuable, inasmuch as they formed additional evidence that less water was used when working condensing than when working non-condensing, a point by no means generally appreciated. Such data as the statement that the tube-surface of the condenser should be at the rate of $\frac{1}{9}$ to $\frac{1}{10}$ square foot per pound of steam with circulating water at 65°, and $\frac{1}{8}$ to $\frac{1}{9}$ square foot when the water-temperature was higher than this, were much too general to be satisfactory. Certainly an allowance of $\frac{1}{8}$ square foot per pound of steam was not sufficient if the circulating water entered at a temperature of, say, 85°—a by no means uncommon temperature of water from cooling-towers. With regard to vacuum-efficiency, the Mirrlees Watson Company's experience was that an efficiency of 99·5 per cent. was very commonly reached in testing air-pumps at their works. He thought the condenser designed for a high vacuum (*Fig. 16*) would yield distinctly better results if it were arranged with baffles to secure more effective countercurrent action. He also considered that the particulars given on p. 213, in regard to the condensing-plant at Harrogate, showed that the plant was working very inefficiently. It could hardly be profitable to pump so much water through the surface condenser as to cause the average temperature of the water discharged from the condenser to be 59° F. This Table would have been much more valuable had the quantity of steam condensed per hour been given. Apart from the points criticized in these remarks, the Paper contained much valuable information on a subject of distinct importance, and not only had users of condensing-plants to thank the Author, but other makers of such apparatus must appreciate the frank manner in which he had published so much information. Mr. Day.

Mr. Druitt Halpin considered that the experiments referred to by the Author on p. 173 might lead to erroneous conclusions, if the results were not applied with great care. The total friction through the condenser-tubes was of course made up of the loss of head of the water due to its entry into the tubes, of the friction when passing through the tubes, and of the friction due to its discharge. The frictional loss of head at entry and at discharge in this case was particularly large, as both took place through a sharp-lipped opening, having the disadvantage of two notches disturbing the inflow of the water, which was further impeded by the annular enlargement between the flange of the ferrule and the end of the tube itself. It would be very useful if the Author could see his way to make a few more experiments with tubes of different lengths, so that the retarding effect due to the bad form of the entry and discharge orifices might be separated from the pure tube-friction. For a flow of 10 gallons per minute, equal to a speed of about 700 feet per minute of the water through the tubes, the theoretical head was 2·12 feet, but the Author's diagram showed that this rose to 9·35 feet, or 4·4 times the theoretical requirement; and this loss was increased by the internal horizontal stiffening-ribs in the condenser-cover, which naturally produced most unfavourable eddying motion in the water where its direction of flow was being reversed. The cover at the entrance end had a horizontal dividing plate in the centre Mr. Halpin.

Mr. Halpin. which might be advantageously replaced by a more suitable form, such as that shown in *Fig. 25*, thus reducing useless eddying motion in the water. All savings of this kind were most important, as the steam-consumption of the small engines working the condensing-plant was so high, amounting in the best test to 55·3 lbs. per indicated horse-power-hour, which was nearly three times the amount of steam used by well-designed portable engines, working without the advantages either of condensation or of superheated steam. He considered the arrangement of making the joint of the cover and the tube-plate in one to be most undesirable, as, though it might be necessary to break only one joint, both were virtually broken if the nuts were taken off. The use of separate wet and dry air-pumps, which the Author condemned, was now almost universal, at least on the Continent, when it was necessary to have the highest attainable vacuum. The Author's views respecting the efficiency of condensers must lead to misapprehension, as the efficiency should be given as a percentage of the vacuum obtained and of the barometer-reading. If the Author's views were maintained, no account would be taken of the insufficient reduction of temperature attained by cooling-towers of incorrect design. The Author considered an efficiency of 85 per cent. to be sufficient; but in a plant lately put up by Messrs. Louis Schwarz & Co. an efficiency of 95 per cent. was stated[1] to have been attained. In the comparison of cost given in detail at p. 186 the Author had entirely omitted the cost of land and buildings, which naturally affected the whole case very materially. If buildings without land were taken at 4*d*. per cubic foot, the extra capital outlay would amount to about £600, and would add at least £30 annually to the working-charges, reducing the saving calculated by the Author by about 13 per cent. As to the influence of the velocity of the water through tubes, when the velocity was 600 feet per minute the transfer of heat was 250 to 350 B.Th.U. per hour per square foot of condensing-surface per degree Fahrenheit of difference of temperature; and when the velocity was only 15 feet per hour the transfer was reduced to 25 to 35 B.Th.U. per hour per degree Fahrenheit of difference of temperature.

Fig. 25.



Mr. Lasche. Mr. O. Lasche, of Berlin, agreed with the Author that condensing-plants for high vacua, especially those for steam-turbines on account of their importance, still required more thorough study

[1] Zeitschrift des Vereines deutscher Ingenieure, vol. xlix. (1905), p. 252.

than they had received hitherto; and the Paper was a valuable addition to the knowledge on the subject. The Author's results were generally confirmed by Mr. Lasche's experience; but he desired to offer some observations on the use of wet and of dry air-pumps, in regard to which the Author doubted whether, in dividing the wet air-pump in two parts, one for discharging the air and vapour (dry air-pump) and the other for discharging the condensed water (condensed-water pump), the advantages warranted the additional complication. The questions were, whether complications did result from the separation of the air-pump and the condensed-water pump, and what advantages were obtained by such separation. A complication might be seen in the fact that, besides the air-pump, a separate condensed-water pump was necessary; but judging from the illustrations of the Paper, an auxiliary water-pump was also used with the Edwards pump. As stated by the Author, this auxiliary water-pump became absolutely necessary as soon as the pressure-head, against which the pump had to work, surpassed 3 to 4 inches. In order to see what advantages were obtained by the separation, the performance of the two systems must be compared. With the Edwards wet pump condensed water and air were withdrawn at the same place of the condenser and at the same temperature; with the dry (divided) air-pump, however, the condensed water was withdrawn at the warmest place, and the air at the coolest place, of the condenser. The volumetric capacity of the air-pump depended on the temperature of the air, and with the wet air-pump this temperature must be as low as possible. If the temperature was assumed to be the same in both cases, it was evident that the condensed water must be cooled more in the case of the wet air-pump than was necessary with the dry air-pump. In this connection, the following data referred to a plant erected by the Allgemeine Elektricitäts Gesellschaft with dry air-pump and separate condensed-water pump for 11,000 lbs. of steam per hour, a cooling-surface of 6,450 square feet and 40 lbs. of cooling-water per pound of steam:— Mr. Lasche.

	°F.
Cooling-water inlet	51·0
„ „ outlet	75·2
Condensed water discharged	74·0
Air entering the air-pump	64·4

Vacuum, with barometer at 29·8 inches, 28·2 inches.

These data showed that the condensed water was withdrawn at about 10° F. warmer than would have been possible in using a wet air-pump. This cooling of the condensed water

Mr. Lasche. meant on the one hand a loss of heat, and on the other hand a loss of cooling-surface which, as stated by the Author, amounted to about 10 per cent., whence arose necessity for cooling the condensed water below the saturation-temperature. This 10 per cent. was saved by using the dry air-pump. As a less important reason it might be added that the dry air-pump might be lubricated with oil, which was impossible with the wet air-pump. In this way the wear of the piston-rings and cylinders was considerably reduced. Further, the parts made of gun-metal in the Edwards pump might in the dry pump be made of cheaper material, and the pump might be made double-acting. In practical use the foregoing differences in the performance of the two systems would become evident in the answers they afforded to the following three questions:—Which of the two kinds of air-pump required the smaller cooling-surface, and which gave the better vacuum? Which required less energy for working? For which of the two systems was the cost of construction and the cost of working less, taking into consideration the wear?

The Author. The AUTHOR, in reply, stated that Mr. Day's remarks on the Author's arrangement for keeping down the temperature of the water entering the air-pump were not borne out by researches and experiments. If the idea was an old one, it was curious that more attention had not been given to it before, and that it was not until the Author's patent was first published that several engineers claimed its invention. He had designed this apparatus and arrived at the results quite independently, and the trials showed that a higher vacuum was undoubtedly obtained with this arrangement, and that there was a gain if the apparatus was used intelligently. As to the highest vacuum for use with small high-speed reciprocating engines, the Author had met many engineers who firmly believed that a vacuum of 20 to 22 inches was the most satisfactory with the barometer at 30 inches, and a Paper by Professor R. L. Weighton[1] had been quoted latterly in support of these views. The apparently general existence of the impression that a vacuum of 20 to 22 inches was the best was one thing which had made the Author feel the necessity of further research on this subject. Where there were several high-speed engines exhausting into a common main there were many questions to be considered, and in mentioning a vacuum of 25 to 26 inches he had stated values much higher than were usual for such instal-

[1] "Some Experiments on Steam-Engine Economy." Proceedings Institution of Mechanical Engineers, 1902, p. 483.

lations in regular work. Various tests he had made tended to confirm his opinions so far as present practice was concerned, but the tests above 25 inches of vacuum were not so extensive as those published in the Paper under Series A, and therefore he did not feel warranted in giving them as proofs. The experience cited by Mr. Day from Lancashire textile mills was in keeping with the Author's observations. The allowance given in the Paper for tube-surface per pound of steam per hour was for conditions such as were described in the experiments. Individual designers frequently increased this allowance unnecessarily; special cases, however, required special attention. Messrs. The Mirrlees Watson Company were to be congratulated upon their ease in obtaining 99·5 per cent. vacuum-efficiency, a result which could be attained only after much care and attention. The Harrogate condensing-plant was mentioned in the Paper as a typical case of a combined steam-turbine and condenser actually at work; time had not allowed of more elaborate tests being made before the Paper was printed. He had already dealt with the question of the quantity of circulating water, in his reply to the discussion. Further tests would be published at some future date, giving full results, including the total steam-consumption. He would draw Mr. Druitt Halpin's attention to the fact that the experimental results recorded in *Fig. 2* applied only to a tube, as stated. The total loss of head in the condenser was measured by the difference in pressure, registered by two sensitive pressure-gauges, placed at the outlet and inlet of the condenser respectively. The head for producing velocity must not be confused with the loss of head due to flow through these tubes. The total head lost in passing through the condenser was the sum of the head lost by friction and the part of the velocity-head which was actually lost. With reference to Mr. Halpin's remarks upon the relation between the rate of convection of heat from a metal surface by means of water, the Author could only refer him to Dr. T. E. Stanton's Paper,[1] wherein the results of a complete experimental investigation were given, together with the theoretical exposition. These experiments showed that the rate of thermal convection was proportional to the velocity, other things being constant. With reference to the joint between tube-plate and cover, numerous collar-studs were used, by which the tube-plate was bolted to the condenser-shell, and the joint was properly made

The Author.

[1] "The Efficiency and Design of Surface Condensers." Minutes of Proceedings Inst. C.E., vol. cxlii. p. 460.

The Author. before the cover was put on. The breaking of the cover-joint could be carried out at any time, without interfering in the least with the soundness of the connection between the tube-plate and the condenser-body. The usefulness of separate wet and dry air-pumps was apparently still a debatable question; the wet air-pump certainly tended to simplify the arrangements; and if the higher vacuum could be obtained and maintained with it, why proceed to more costly and unnecessary complications? In reference to the question of vacuum-efficiency, he believed he had sufficiently stated his case in the Paper, from which no misapprehension could arise. Cooling-towers certainly required attention and must be designed to suit the position in which they were to be placed. Their design, however, was outside the investigation which formed the subject of the Paper. With reference to Mr. Halpin's remarks on the question of the cost of land and buildings, the Author considered that it was unnecessary to complicate the figures by allowance under this head, as a similar allowance would require to be made in the corresponding Table for non-condensing engines, though for practical purposes the capital charges would be the same in the two cases. Referring to Mr. Lasche's remarks, the auxiliary water-pump shown in the Paper was really a force-pump, and could be used to feed the boilers or to distribute water as might be required; and this pump would be equally required for any design of air-pump adopted. With regard to the advantages of being able to lubricate the dry air-pump with oil, one of the great advantages of the combined Edwards air-pump was that no lubrication of the pistons was required. The introduction of cheap metals into the wearing parts of the air-pump was false economy, and the Author was of opinion that at present the answers to the three questions put by Mr. Lasche were in favour of the type of plant described in the Paper. The plant of the Allgemeine Elektricitäts Gesellschaft might be compared with results given on p. 211, where it was shown that approximately the same vacuum was obtained by the combined Edwards air-pump with condensed water discharged at 92·4° F., or 17·6° higher temperature of feed-water. In conclusion, he thanked the correspondents for their friendly criticism. The Paper formed a record of facts, from which each reader could draw his own inferences.
