all. The whole onus of drawing the ship was then thrown on to the forward propeller. Hence, there was an abnormal rise in power.

This then was the problem which Mr. Brown, Works Engineer to the Sydney Ferries, Ltd., and two of the Engineering Students from the University set out to investigate. They required some means of determining at any speed precisely how much power was being transmitted by each shaft. Various methods were tried in the workshop first, and they finally decided to work by a simple comparison of the angles of torsion in the two shafts over equal lengths. The basis being a 10ft. length of shaft with a flange at each end; when the engine was stationary, they marked a vertical diameter in each flange, which would be in the same plane when the engine was working, these lines would no longer be in the same plane, but that nearer the engine would lead the other by perhaps 1° or 2°. By a meth od of electrical contacts they were able to measure this angle simultaneously at the two ends on equal and similar lengths of shaft, and thus had a means of directly comparing the powers transmitted.

Before explaining the results he would like to make it clear that this was only an interim report of progress.

They had first of all to see if the angle of torsion was really a measurable effect in the heavily built shaft of the s. s. "Kurraba." Their apparatus was therefore a little on the cheap and rough side and they freely admitted that the results were but indications and involved errors which might sometimes cloak the true result.

Having shown, however, that the angle of torsion was really a measurable effect, two other students, Mr. Swain and Mr. Carter, had taken up the work and were making an apparatus similar to that used by Föttinger for indicating the horsepower of the latest Trans-Atlantic liners, which it was hoped would eliminate these errors, and give an absolute reading of the power transmitted.

In spite of these limitations, however, the curves shown (Plate XI.) were very interesting, and perhaps contained the truth they were seeking if they were able to interpret them correctly.

Mr. R. R. Ferrier desired to thank the President (Mr. Sinclair), and others who had been instrumental in enabling the members of the Association to witness the very instructive and interesting trials on the "Kookooburra," and for the useful data, illustrations, etc., now presented to us in the records of our proceedings.

The steamer was without doubt a credit to those who had been entrusted with her design and completion, and she should prove a welcome addition to the Parramatta River service. The few remarks he wished to make would be particularly confined to the question of mechanical draft and combustion of fuel. The question of forced versus induced draft had been raised, and while many engineers might favour the pressure system, chiefly on the ground that a smaller fan requiring less horse-power could be used with the advantage of dealing with cold air only, against these, that system requires either a closed stokehold or closed furnace and ashpit doors; both methods presented difficulties when in operation and necessitated considerable expenditure, and had it been adopted in the installation under consideration a certain amount of leakage of hot gasses would take place at the smoke box and into the limited engine space, thus causing inconvenience and discomfort to the engineers. The designers would appear to have adopted the right system in this case, and had attained a compact and handy working job.

If it be assumed that under present conditions the coal was being thoroughly consumed, and that the resultant waste gases were of too high a temperature, that state of affairs could be relieved by admitting a regulated supply of cold air near the fan inlet thus decreasing the temperature of the gases, and the reduction in temperature of the hot gases and consequent decrease in volume would compensate for the additional volume of fresh air admitted, thus practically no increase on the duty of the fan would result. When deciding upon the capacity of a fan for either forced or induced draft, it was well to have the fan, if practicable, with a reserve of power; different coals required varied treatment in firing, and N. S. W. coals, owing to the high percentage of volatile carbon, required special care in this respect. According to Mr. Hector Kidd's report, a fairly liberal air supply per lb. of coal, and a fairly high waste gas temperature were figured on when determining the size of the fan in question.

Air supply.—23lbs. of air per lb. of coal or about 100% excess was the usual allowance made in practice; this amount was exceeded in many boiler plants working under natural draft, especially on land. Of late, however, owing to the marked trend towards economical combustion of fuels the above figure would be considered high; it was with the adoption of mechanical furnaces and especially mechanical draft that the air supply and draft conditions could be so regulated and gauged with the aid of apparatus for automatically determining the carbon dioxide in the waste gases and the exit temperatures, that many up-to-date plants were working with an air supply very little above the theoretical quantity required which was about 12lbs. for average bituminous coals. A few examples of the bearing of air supply and exit temperatures on efficiencies of boiler plant might be of interest, assuming a coal had a heat value of 13,500 B. T. units per lb. Flue gases with 4% of carbon dioxide and temperatures of 400°F. and 800°F. represented respectively heat losses in the gases alone of 32.4 and 64.8% of the total heat in in the coal, the excess of air being 375%; 8% of carbon dioxide at the same final temperatures represented heat losses of 16.4 and 33.2 respectively, the excess of air being 137%, and 15% of carbon dioxide or about the maximum attainable in practice with bituminous coal, at the same final temperatures represented heat losses of 9.2 and 18.5% respectively, the excess of air being only 27%; the importance of gauging the air supply would thus be readily recognised.

To obtain the best results many factors had to be considered, and each class and composition of coal required special treatment, amount of firegrate, thickness of fires, method of introducing the air supply, draft available and design of furnace must receive due consideration. In practice it was desirable to reduce the air supply as near the theoretical quantity consistent with non-production of carbon monoxide or partially-consumed carbon, with a deficient air supply or an air supply badly applied, a large percentage of carbon monoxide or semi-consumed carbon might be present in the exit gases, and the heating power of the carbon so consumed would not be half that of the same carbon burnt to carbon dioxide. Engineers would readily understand the advantage of reducing the air supply; take the trials of the "Kookooburra" as an example. If 23lbs. of air was used per lb. of coal, 24lbs. of gasses per lb. of coal would require to pass through the boilers and be dealt with by the fan; on the other hand, if it were possible by regulating the supply of air aad draft to reduce it to the theoretical quantity of 12lbs. per lb. of coal, provided that thorough combustion be attained it would result in higher furnace temperatures, better average conductivity through the heating surface of the boilers, and as the averoge speed of the gasses through the boiler would be reduced to one-half most probably, the final gasses would be at a lower temperature than when using the larger quantity of air, and the duty of the fan, would, of course, be materially decreased. There was one more point worthy of attention, namely, the admission of secondary air through the doors above the grate or between the bridge. The New South Wales coals used for steaming purposes were all high in volatiles, as these were given off very rapidly after firing, usually it was necessary to introduce a certain amount of air over the fire, or at the bridge to ensure complete combustion. It was advisable, however, to have such supply under control, the full amount was only necessary for a few minutes after firing, and then should be gradually cut off, so that the air for the combustion of the fixed carbon should be taken entirely through the bars. A fair allowance under ordinary draft conditions, burning bituminous fuels was from 3 to 4 square inches per square foot of firegrate. The boilers of the "Kookooburra" had approximately 54 square inches per boiler through the doors and holes in the furnace front, or about $2\frac{1}{4}$ square inches per square foot of grate. Without analysis of the exit gasses it was difficult to judge on this point, but his opinion was, that under the induced draft the area was excessive, taking into consideration that the air was admitted the whole time, not being controlled in anyway. He would much like to know the results of working with the present area reduced as much as possible, say, to that due to the minimum clearance required between the doors and frames, so that the doors would not jam. The extra resistance thrown on the fan in drawing the whole of the air through the grate would increase the scrubbing tendency on the coal, and would, he believed, result in more perfect combustion.

Mr. G. W. F. Findlay said the results of the trials of the s.s. "Kookooburra" were particularly interesting on account of the wide range of speed experimented with, which made it possible to plot out very instructive speed curves, five different speeds being obtained on the trials. The first of these that claimed attention was the indicated horse power curve, Plate XII. This was often assumed to be a parabolic segment, and it would be very nearly so if the only resistance to be overcome were that due to the skin friction of the hull. In reality, however, after a certain speed was reached, depending on the length and shape of the hull, there was an added resistance due to wave making, causing the I.H.P. required to increase very rapidly in proportion to the speed. This resistance did not increase at an even rate, and thus humps would appear on the curve, if as in the present case, there was sufficient range for them to show. The I.H.P. to overcome skin resistance alone might be taken to vary as the speed cubed. The actual curve showed that at $7\frac{1}{2}$ knots the I.H.P. varied as the 2-3rd power of the speed. The explanation of this low rate might be that the curve was just getting over a previous hump, and this would account for the fact that on preparing for the low speed run, there was some difficulty in getting the ship to go slow enough. At $8\frac{1}{2}$ knots the I.H.P. varied as the speed cubed, at $10\frac{1}{2}$ knots as the 5-6th power and at 11 knots as the 6-8th power of the speed. After passing this point the rate decreased again, and at 12 knots it varied only as the 2-8th power of the speed. Starting at $8\frac{1}{2}$ knots he had plotted a curve showing approximately the increase in power due to skin friction, and it showed at a glance the extra power spent in wave making, this being the difference in height of the two curves. A curve of indicated thrust and a curve of I.H.P. per 100 square feet wetted surface had also been added to diagram. The co-efficient of performance $\frac{D^{\frac{2}{3}} S^3}{I.H.P.}$ showed considerable variation, indicating the loss due to wave making by the great drop at high speeds. The drop at low speeds being due to the work done in driving the engines bearing a larger proportion to the total work. It would be noticed that the hump of this curve was situated immediately over the hollow in the I.H.P. curve, and vice versa. In view of the great wave making resistance developed, especially at the bow, it was interesting to look into the design of the hull. The length between perpendiculars was 120ft., which, in a double-ended boat, gave a fore and after body each 60ft. long, so that up to 10 or 11 knots the I.H.P. should not increase much faster than the speed cubed. He had plotted a curve of cross sectional areas (Plate XIII.), showing the longitudinal disposition of the displacement, and compared this with a curve or versed sines for the fore body, and a trochoid for the after body. All these curves were to one scale, and represented the same displacement. The actual curve departed considerably from the C.V.S., being 15 tons fuller at the entrance and 15 tons less in the middle, but was fairly close to the trochoid, so that the bow might be expected to create a worse wave than the stern, which appeared on the trial to be the case. This was also due, no doubt, to the fulness of the water lines at the ends, and to the stream from the bow propeller. A curve which was the mean of the C.V.S and trochoid, was shown in as a compromise for a double-ended boat. This gave a prismatic co-efficient .6 as against .68, and an area of midship section 146 square feet as against 130 square feet. It would thus appear that in designing another vessel, about 12 tons of displacement could be taken from the ends and added to the middle sections, making a total difference of 24 tons. This fining of the lines would also improve the performance by allowing the stream from the forward propeller to get away round the hull quicker, instead of causing an increase of pressure on the bow, and augmenting the wave. A better supply of water would also be allowed to the after propeller. The data and curves from these trials showed the importance of obtaining a good range of speed, as otherwise a fair amount of guess work was involved to approximate to the correct shapes of the curves. In the present case there was ample data to make fairly accurate diagrams.

Mr. F. E. Stowe considered it a source of great gratification that they as an Association were able, not only to have the information on engineering subjects supplied to them, but were also able to participate in its compilation. They were greatly indebted to the President (Mr. Sinclair), for the opportunity they had enjoyed in connection with the "Kookooburra" trials. He understood that Mr. Sinclair had borne all the costs of these experiments and it was not easy for us to thoroughly realise all that this had meant in cost and work, or to fully appreciate the splendid practical loyalty shown to our Association in this matter, for which he was sure all our members were deeply grateful. In any criticism of the papers so ably and fully presented by Messrs. Sinclair and Shirra one was at a loss to find just where any of the information could be supplemented. He had, however, noted with regard to the original propeller something which would indicate that bow propulsion (if such an expression could really be used) could never be a great success. In the "Kookooburra" the area of the projected stream from the bow propeller was roughly 50 square feet, and the amidship immersed section 150 square feet. Since the whole of the projected stream was intercepted by the ships section it followed that one-third of this section at least was operating against a stream of water roughly estimated at 14 knots, with an actual ship speed of 12 knots—this on the assumption that half of the speed was lost in driving the water aft. It would appear therefore that this bow propeller in its action was more than merely a negative evil, and a suggestion would be that this evil might be lessened by the introduction in larger types of vessels by twin screws, provided, of course, that the sponsons could be made fully protective. This would certainly throw the centres of the projecting streams away from the centre of boat section, and so lessen the resistance of motion.

In connection with the engines the tabulated results showed a marked disparity of power at the higher speed, viz.: 177, 278, and 206 for the H.P., I.P., and L.P., respectively; and if this be compared with the Comparative powers of the respective cylinders at the lower speeds the alteration of disposition of power was most marked, which showed that it was impossible to maintain a proper balance of power in triple expansion engines when varying the expansion by means of link motion, or varying the power by wire drawing the steam through the throttle valve, maintaining the link in its normal position.

Mr. Sinclair, in reply, said that he was very glad that the reading of the paper and the report on the tests carried out by the committee had drawn forth such an extended and interesting discussion, although it was to him rather a disappointment that members had not taken up and discussed more of the technical points referred to in the paper, with regard to the actual results, more particularly to the machinery itself. However, those who had spoken had given a great deal of consideration and time to the preparation of what they had said, and he very much appreciated this.

In reply to the points which had been raised, he would say that Mr. Shirra had referred to the mechanical disadvantage of the bow screw, and he (the speaker) considered that there could be no question about this; it was a disadvantage that was well known and when the boat was originally proposed, the whole arrangement of the machinery and the boat itself was known to have this disadvantage but it must not be overlooked that it was not a question of designing or arranging machinery of a better efficiency as compared with a single-ended boat, it was a question of arranging machinery which would suit a boat which must have a propeller at each end, as this was a condition which had to be fulfilled in order to obtain advantages of reliability in steering and handling, these conditions referred to being retained at the loss of a possible mechanical efficiency. Mr. Shirra further pointed out that the steam used by the auxiliaries was very considerable, and if allowed for would improve the consumption and other efficiencies of the main engine. That was, no doubt, correct. In making estimates of consumption, heating and grate surfaces to be provided for, it seemed to the author to be better to adhere to the ratio of consumption per I.H.P. of main engine as a matter of convenience, because it would be almost impossible to estimate with any degree of accuracy the H.P. of the auxiliaries, and after all it was the consumption for the complete machinery with the vessel in going order that was the basis.

Mr. Selfe in his very able and interesting remarks referred to the fact that the diagrams did not show any particulars of the ratio of the work done by the fan to the H.P. of the fan engine. Unfortunately, it would be almost impossible to indicate the fan engine. The author did not think that it would be very satisfactory to drive the fan off the main engine by friction gear, as suggested by Mr. Selfe, no doubt it would be more economical in the use of steam to drive it in that way, but the difficulty would be that when the engines were stopped the fan would be stopped. This would mean that the engineer would require to change the dampers each time the engines were stopped. Reference to the plans submitted showed that while the dampers had been designed to be as simple and convenient as possible, still the operation of changing their position meant the handling of two separate levers, and in a ferry boat, subject to frequent and rapid stops and starts, it was important to reduce the amount of attention required by the engineer to the least possible, in fact, the whole of the arrangements were intended to be as automatic as possible, therefore the adoption of the independent steam driven fan, the engineer being able to control it, as pointed out in the paper, by merely reaching from his position at the starting handles of the main engine to the stop valve of the fan, and either increasing or reducing its speed according to the pressure on his boilers. Both Mr. Selfe and Mr. Shirra referred to the disparity in powers shown between the three cylinders, and Mr. Selfe mentioned that it would have been advisable to have adjustable gear to the cut offs in the cylinders. This could have been done, but it meant some extra weight and the introduction of a complication, which it was considered desirable to avoid. In designing the setting of the valves, what had to be kept in view first, was the necessity of getting 650 I.H.P., this being somewhat more than had so far been obtained from any similar set of engines under similar conditions, neat adjustment of the valves was therefore avoided. Above all, the author considered that the intermediate engine should develop the most power, not only because it had the pumps to drive but because he considered it tended to a more even running engine. Both Mr. Selfe and Mr. Marr referred to the question of induced draft versus forced draft, both apparently indicating that their preference would be for forced draft. The author was not prepared to admit that forced draft had any points in its favour over induced draft. The relative merits were carefully considered for this particular case, and as reference to the plans would show there was not much room at their disposal, it would have been almost impossible to introduce Howden's type of forced draft with the hot-air tubes in the up-take, as the up-take was at one end of the boiler and the furnace at the other. Again, the difficulty of regulating forced draft under frequent stoppages appeared to be greater than the induced draft, so that the system adopted of putting a fan at the base of the funnel with a little engine in the engine room on the starting platform lent itself in every way far more for convenience and adaptability to the conditions to be met than the forced draft would have done. Whether the induced draft as fitted in the "Kookooburra" was more or less economical than the forced draft would have been or not was beside the question, it was certainly more convenient, and had proved so far to huve met the conditions required of it satisfactorily. Mr. Marr referred to the shortness of the retarders. These were made just of the length to allow of them being put in as governed by the length of the stokehold, and as Mr. Shirra pointed out the action of these retarders was really that of a deflector to cause the heated gas to come in contact with the bottom of the tubes as well as the top, it did not appear that it was of vital importance to have the retarders any longer than they were. The suggestion of having some method of turning the retarders or cleaning the tubes without having to withdraw them, had, the author believed, been put in practical use in some of the Colonial Sugar Co.'s mills, each retarder having forged on the end of it a solid rod which projected through the false front of the smoke box immediately inside of the smoke box door. By opening the smoke box door the attendant could apply a handle to these rods and rapidly revolve each one after the other without experiencing any inconvenience, although the boiler was in full use.

He agreed with Mr. Reeks in so far as being pleased to say he had learned a good deal from the trials of the "Kookooburra" and "Northcote," and was sure that investigations of this nature would be of immense interest and usefulness to us all. He thought that Mr. Reeks rather exaggerated the effect of wrong displacement in the "Kookooburra's" hull, when placing it at 60 to 70 tons. He should not judge from observation on the trials that the mean rise of water would be as much as 1ft. 9ins. To him it seemed to be not more than 12ins. This would considerably reduce Mr Reeks' estimate and would be more in line with the estimate which Mr. Findlay made, viz., 24 tons. Again, Mr. Reeks mentioned that using data from other boats $12\frac{1}{4}$ knots should have been obtained on 374 I.H.P. while actually 644 was developed, or that $14\frac{3}{4}$ knots should have been obtained from 644 I.H.P. It would have been more serviceable to us if Mr. Reeks had stated in figures what formula or co-efficient he adopted to arrive at his deduction. He had stated in the paper that 650 I.H.P. was calculated as the power required, this was arrived at by adopting a co-efficient of 151, in the Admiralty formula of $\frac{D2/3 \text{ x } S^3}{151} = 650$. This formula must of course be used as a comparison, not an absolute rule but as a guide there were only available results for a similar type of double-ended boat. He did not think that co-efficients obtained from vessels of a different type could be taken except as a slight assistance. Now in discussion on the "Lady Northcote" trials it was stated that the co-efficient obtained from the "Kurraba," a double ended two propeller vessel was 164 at 12 knots and using this co-efficient it would give only 13·3 knots as the speed to be expected, but the "Kurraba" was a longer boat than the "Kookooburra," therefore, it seemed wise to use a lower co-efficient. Now to get $14\frac{3}{4}$ knots from 644 I.H.P. as suggested by Mr. Reeks, would require a co-efficient of 223, which was a higher co-efficient than he had any knowledge of at this speed for this type of vessel. Referring to the figures given by Mr. Reeks in his paper last year in taking the performance as given of the "Vaucluse" which was stated as having a speed of 14 knots, 400 I.H.P. and a displacement of 178 tons, it gave a co-efficient performance of 181 only, and using 181 for the "Kookooburra" only gave 13·8 knots, so that he was quite at a loss to understand Mr. Reeks' figures. To show that a mean co-efficient obtained from a vessel with a propeller at one end used alternately driving and pushing could not be of any value as a guide for a vessel with a propeller at each end. He would refer to the table of results of the "Lady Northcote," on tables 3 and 4 wth the propeller pulling, the mean speed was 11·3 knots, this gave a co-efficient of performance of 146·2. Now on the D. trials of the "Kookooburra," at a mean speed of 11·144 knots the co-efficient of performance was 145·9, practically the same. This appeared to indicate that the propeller at the forward end in a double-ended boat was really the propeller controlling the ultimate result. As already stated, it was a fixed condition that the "Kookooburra" should have a propeller at each end, a condition which he thoroughly agreed with in a ferry steamer for the sake of surety of handling, even at the cost of increased H.P. At the same time he agreed with those who had spoken that the hull lines might be improved to give a higher speed and co-efficient of efficiency. This condition of a propeller at each end of course required heavier machinery and consequent increased displacement, so that Mr. Reeks' figures of comparison should, he thought, be modified.

The diagrams submitted by Mr. Flashman as showing the results that had been obtained from tests on the "Kurraba" of the angle of torsion due to the stress on the propeller shafts, were extremely interesting. It could not however be taken as positive data, at least, until corroborated by the more accurate tests which he, Mr. Flashman, indicated were to be carried out in the near future. The method appeared to be reliable up to a certain extent, it was on exactly the same system as had been used for some time in the case of turbine engines, and only recently a paper had been read before the Institution of Naval

Architects describing some similar apparatus in use on turbine vessels, to determine their indicated H.P. It was almost impossible however to arrive at any conclusion from the results plotted on the diagrams submitted by Mr. Flashman, as there was nothing very much to start from as a basis. The extra torsion indicated at some periods on the forward shaft, as compared to the after shaft, might be due to some other development of power, but it was extremely interesting to note that at the higher speeds the greater variation of torque seemed to be in constant increasing ratio for the forward shaft, if this was corroborated and shown to be constant with all similar vessels, then it opened a wide field for modification in our ideas with regard to the design of our ferry steamers. The results of the further tests would be very welcome.

Mr. Findlay's diagram and remarks with regard to the speed and power curves were very interesting, but did not call for reply.

The author was much indebted to Mr. Ferrier for the particulars which he had given with regard to induced draft. Unfortunately the data at hand and the author's experience with induced draft had not been very extensive, he was therefore not able to reply to all the points raised by Mr. Ferrier, but he was inclined to agree with him that there was too much air supply, all along it was the author's idea to leave the furnaces and grates in their normal condition, that would have been adopted at natural draft with an ordinary funnel, and to add a fan to create an induced draft so as to give the actual condition due to a high funnel, owing to the special condition of having no funnel in this steamer. Generally speaking the special conditions which governed the whole arrangement of the machinery had been somewhat overlooked by all the speakers.

Mr. Stowe pointed out that the area of the projected stream from the bow propeller was roughly 30% of the area of the merged midship section : this was so, but unfortunately it could not be helped, the special conditions of the vessel governed that, and had the propeller been made of a smaller surface and diameter it would have increased the revolutions of the machinery, and this was a point which was fixed as a condition that they were not to exceed 170 revolutions. However, as mentioned in the paper, it was proposed to make a trial with propellers smaller in diameter to see whether they would make any improvement, not so much with regard to the area of the stream of water projected aft, as the prevention of surface disturbance.

ERRATA.

Page 29, sixth line from top of page, "28" should read "25."

Page 36, 20th line from top of page, "15·2" should read "1·52."

Page 41, fifth line from bottom of page, "foot" should read "root."