DISCUSSION.

Mr. G. A. Julius said he had heard this paper with considerable interest. It was a subject that not a very great deal was known about, but, at the same time, it bore upon a matter which was of considerable importance in practice. Some years ago he had the work of installing a number of electrical cranes built by a Continental firm in which the whole of the gears were worm-driven, and the efficiency of these cranes was so surprising that elaborate tests were made to exactly determine their efficiencies.

Similar results to those that had been outlined by the authors were there found to be the case. Using single-threaded worms and double-ball thrusts, the efficiency was so high as to permit reversibility—that was to say, the application of the load would run the worms backwards even when using single threads. Since then he had carried out a number of experiments, and it might be of interest to mention that at the present time a firm in Sydney was cutting some 15 or 16 worms for electrical cranes, these being wholly "worm-gear" operated, and two of these are now in use, each 42 to 1 ratio and both run backwards, the efficiency being over 50 per cent. Some of these worm sets had been constructed in the way outlined by the authors with the worm underneath, the worm of steel with Hoffman ball thrusts, and carefully cut phosphor bronze worm wheels, and the efficiency obtained was surprising. Certain wheels were now being cut with single-thread worm, with a velocity ratio of 72 to 1, upon which they would be carrying out tests very shortly.

It was obvious to all that the great advantage of worm gear, providing one can get such high efficiency,

was the compactness of the whole appliance, and its extreme suitability where it could be applied, for obtaining considerable reduction in velocity, such as was required in crane work.

He thought the way in which the authors had put the matter before them had made clear that the possibilities in the use of such contrivances were very much greater than had been realised in the past, and that the worm gear, far from being inefficient, was really an appliance from which one could expect efficiencies to run close up to that of well-designed spur gearing, and with one great advantage—that the number of parts is greatly minimised.

He was sure they had all been greatly interested in listening to the data from these tests, and appreciated the thorough way in which they had been carried out. He had much pleasure in proposing a hearty vote of thanks to Messrs. Shaw and McNamara for the extremely valuable paper put before them that evening.

Mr. C. H. Relph said he had great pleasure in seconding the vote of thanks. He considered the authors had given them an excellent paper. Personally, his experience was limited to small motors.

Mr. W. H. German said that he had derived much pleasure in listening to the reading of the paper, and particularly because it had made him realise how a comparatively small matter might form the subject of an interesting and instructive address when carefully dealt with, as this one had been, and, knowing well the difficulty there was in persuading members to submit papers at their meetings, he thought this one was quite an object-lesson to them, for many had seemed to think that, for a paper to be appreciated, it was necessary to

give a long treatise on some scientific and complicated subject, such as is frequently read before the older societies at home.

He thought the authors had intended to explain to members that the gears illustrated and described were made in the Colonial Sugar Refining Co.'s workshops at Pyrmont, and were used in the Refinery there; while it might also be mentioned that the efficiency tests were carried out in the Pyrmont shop in order to show that there was not such a waste of power in this class of drive as was popularly imagined, and for which reason it had come to be somewhat disrespected amongst engineers. The results had been gratifying, and were on lines similar to those being obtained elsewhere with well-designed worm gearing, and which were gradually breaking down the prejudice that had so long existed against this class of reducing gear, which, in any case, was noiseless and compact.

Certainly spur gear, machine cut, might give as high an efficiency as 99 per cent., but it would not be practicable to arrange a 40 to 1 reduction with one pair of spur wheels, so a double pair, at least, would be required, which would bring down the efficiency to pretty nearly that of the best form of worm gearing, and, in any case, would occupy considerable space.

When, some years ago, the Colonial Sugar Refining Co. decided to instal electric power for applying to distant drives (and these were mostly of a slow-running character, such as carrier bands), it was evident that reducing gears must be used. One or two different kinds were imported—viz., the "Baker" and the "Ross"—and these gave more or less satisfactory results; but the time

taken to import them indicated the desirability of manufacture here—hence the worm gear illustrated had been chosen and principally used.

The model showing the method of forming the worm pattern from plaster of Paris, he thought, was an ingenious contrivance; but, of course, it was for producing worms cast in iron, steel, or gun-metal, so was unlike the worms shown in the plans, which are cut from the solid bar of steel. The device, he believed, originated from Mr. Coulson (foreman patternmaker to the C.S.R. Co.), and it was certainly well worth inspection by members.

Mr. James Kidd said, in reference to the question of the improvement or loss of efficiency after use, he might say that, having a number of gears in use, they found that after from three to six months the efficiency increased by 10 to 15 per cent. The imported reducing gear referred to by Mr. German (that was, the "Baker" and "Ross" makes) gave considerable trouble, and the Baker gear failed when the full load of 10 h.p. was put on, owing, he believed, to being too light in construction; and from the Ross gear they could only obtain h.p. without giving trouble.

One set of gear, as shown on plan, had been running for over six years, and was now in as good order as on the day it was put in. As far as their experience went, having been ten years in use, they found them very satisfactory indeed, and had not had a failure—with the exception of one, in which case it was carrying double the load it was designed for.

Mr. E. F. Boult (visitor) said he had been very much interested in the paper, and would like to ask the authors a question—viz., whether in any of the tests to which they had referred results had been obtained with

gearing that had been running for some months, and, if so, whether they could draw any comparison between such efficiency and that of the ordinary spur gearing in similar conditions.

His (the speaker's) own experience had been limited to motor omnibuses, and in that case they found worm gearing to be unsatisfactory when it came to the matter of upkeep, it being too expensive. Spur gearing had been troublesome enough, and the noises generated by it had led to a lot of friction between the authorities and the operating companies.

When the worm gearing was first put on the market engineers hoped that its use would bring about a better feeling. Several 'buses were re-built with it, but as, with these designs, it was not possible to maintain the direct line, a universal joint had to be resorted to which wore so rapidly that renewals made its further use prohibitive. One type was put on the market in which a direct line was maintained, but the increased cost for worm driving was ½d. per mile, which though not prohibitive prevents the further use of such gearing. That being the case with Road Vehicles he was particularly interested to hear how the efficiency compares after some months running of stationary work.

Mr. James Shirra said he would like to say a few words in expressing the pleasure he had had in listening to the paper. We must remember that worm gearing for the transmission of power is useful in two different respects, it not only imparts motion but may be useful as a self-sustaining non-return gear. To get mechanical efficiency by keeping down frictional losses, it must be reversible; but with a high mechanical "advantage" or "purchase," the friction is so great that the gear is irreversible. This non-reversibility is a

valuable feature in some cases; for instance, worm-gearing is sometimes used for luffing the derrick in cranes, and the friction of worm and tooth is usually enough to prevent the derrick overhauling the gear. Also the turning gear for moving marine engines in port is generally worm-wheel gear; it should hold the engine in any position, but sometimes one gets a surprise when the low pressure piston is descending, by the engine running away and overhauling the worm, which shows we have something yet to learn as to the friction and the lubrication of the gear.

The authors took the co-efficient of friction as .15. He thought it should be.05. A great deal depends on having properly shaped teeth with sufficient bearing of worm on them, so that the oil gets a chance, and is not forced out. His first experience with worm gear was a long time ago, when he was serving his apprenticeship. They constructed a planing machine for hardwood, in which the cutters were on a face-plate made like a fly-wheel, which rotated at a high speed; the feed-table was driven from this cutter spindle through worm-gearing. The worm wheels were very crude, in rough cast iron, and subject to much erosion, but they were not expensive to renew, and the machine worked all right. Mr. German had referred to some recent articles in "Engineering." He might say he had noticed something in a very recent number—July 2, he thought it was—describing a frictionless worm-gear in which the worm and wheel did not come in contact, there being 1-32 inch clearance between the points of the teeth and the outside of the worm. The gear was magnetised by an electric current circulating in a field coil round the axle, and the magnetic flux drew the wheel round without actual contact or friction, the only loss being the

energy in the field coil, which was about 3 per cent. of the power transmitted, so that there was a mechanical efficiency of 97 per cent. The article stated there was no limit to the horse-power transmittable. If this can be made a success it means a revolution in our methods of transmitting power where electric current is available, as it is in so many establishments now. You can do away with all friction and noise by magnetising your gear.

The President then conveyed to Messrs. Shaw and McNamara the thanks of the Association for their paper, which was carried by acclamation.

Mr. Shaw, in reply to the discussion, said that in explanation of the remarks about the co-efficient of friction he thought he had made it clear that the .15 co-efficient was for metal-to-metal surfaces running dry and the .05 co-efficient was for continuously-lubricated metal surfaces.

With regard to the life of the gear he could bear out Mr. Kidd's remarks. The C.S.R. Co. had had similar gear running a number of years, and he thought the principal factor in designing them for a considerable amount of wear was the pressure velocity. If taken at over 200,000, the gear wore rapidly. They had had experience of this with a $1\frac{1}{4}$ horse-power gear doing 2 horse-power duty; it showed signs of erosion within three months, and after working nine months was practically done.