cent. if the gears themselves are to be self-locking. As, however, there is always some friction in the worm bearings and other parts of the machinery, the efficiency of the gears only may be considerably higher, and the gear still remain self-locking. A point to be remembered, however, is that a worm gear which may be self-locking while at rest may not be so when moving, owing to the fact that the co-efficient of friction with motion is considerably less than when the gearing is at rest.

The considerations which enter into the proper design and manufacture of worm gearings are too extensive to be entered upon now, but those interested will find considerable information on the subject in a book published by the Industrial Press of New York, entitled "Spiral and Worm Gearing."

The author is not in the position of being able to supply any new data affecting the design of gearing generally, but presents these notes in the hope that the modern tendencies in gear design to which attention is drawn may be of sufficient interest to promote discussion.

DISCUSSION.

THE PRESIDENT: We are much indebted to Mr. Snashall for the able manner in which he has delivered his lecture on Gearing. The subject is one of which we have all had some experience, and I hope we will have an interesting discussion.

Mr. SAUNDERS: I have pleasure in moving a vote of thanks to Mr. Snashall for his excellent paper; he seems to have dealt with his subject in such a thorough manner that there seems to be very little room for criticism, but if any member present can show us where Mr. Snashall has erred we shall be glad to hear him.

Mr. McEwin: I have much pleasure in seconding the vote of thanks to Mr. Snashall. I consider the subject matter of the paper has been of great interest both as regards workshop methods as well as the scientific side which has been brought forward. The lecturer has given a good lead, and I hope papers of a similar nature will follow dealing with the application of science to workshop methods. There are plenty of suggestions in Mr. Snashall's paper, which I am sure will give us all a great deal to think about.

There is no special part of the paper to which I wish to direct my remarks, but I think the particulars given by Mr. Snashall respecting worm-gearing were very enlightening. It has been a surprise to me to learn that there is such efficiency in this particular kind of gearing. If worm-gearing were applied to the driving mechanism of the street cars of Sydney it would be a great satisfaction to the citizens on account of lessening the existing noise, which everyone finds so nerve-racking.

Mr. Tourney-Hinde: I have great pleasure in supporting the vote of thanks to Mr. Snashall for the paper rendered this evening. I have spent about a year or more in going over the same ground in connection with some large gear wheels, and I agree with the author in the way he has presented the case for gearing to them, with perhaps one or two possible exceptions: I do not consider that, except in some cases of very high speed, the form of gearing known as worm-gearing carries a much higher efficiency than an ordinary cut steel tooth, provided that the tooth is of the same type as the worm. I might also refer to the difficulty experienced with a set of gears in which the height of the teeth was .7 of the pitch, but when reduced to .4 of the pitch a better running job was obtained, and with far less noise.

I will again express my appreciation of Mr. Snashall's excellent paper.

Mr. FRASER: I have pleasure in supporting the vote of thanks to Mr. Snashall for his paper on a subject which is both interesting and intricate.

With regard to the respective merits of the stub tooth system, where a pressure angle of 20° is adopted, and a gear constructed on the 14½° basis, Mr. Snashall has shown many points in favor of the former, but I think that there is something to be said for the latter also.

By reference to Figures 1 and 2, it will be seen that in the case of the 14½° angle, a greater arc of contact is obtained, and consequently a greater number of teeth are in mesh at one time. This feature should be valuable in tending to reduce noise and backlash, thus making a gear of a given pitch stronger, and, what is of greater importance, more durable. But these advantages are also claimed for the stub tooth system, and it seems to me that in gear design compromises have to be made between varying factors, and in giving too much prominence to one feature, the value of another may be entirely lost. In this country the 14½° angle is popular, as the machine tools used here with their cutters have been standardised, and are largely furnished by makers who adopt this angle. It is therefore a great convenience to follow their lead.

Coming to Lasche's investigations, I understand these are mainly of a theoretical and mathematical order, and I think they have yet to be proven by facts. He says that a variation of .02 of pitch would induce loads 28 times the normal of transmitted load. A steel wheel constructed on this basis would require a factor of safety of 84 to keep within the elastic limit. Many gears have been made by people not well versed in the fine points of design, and these would have been stripped in the first revolution if such a

high factor were necessary. From examples I have come across, factors of 12, 14 and 15 seem common for speeds up to 2,400 feet.

I agree with Mr. Snashall when he says that noise is noticeable at 600 ft. p.m. Many text books say that noise becomes noticeable at 1000 to 1200 ft., but I consider that, with the general run of straight tooth gear, it becomes decidedly objectionable at these speeds.

I am glad Mr. Snashall has made out a good case for worm gear. When large reductions are required, this gear has much to commend it. If well designed, with ample proportions, ball bearings, etc., it is silent, compact, free from vibration, and efficient. Until the electrical engineer can give us a motor of slow speed at moderate cost, and at the same time efficient, the worm gear is here to stay.

A noticeable feature in the slides shown to-night is the prominent position that gearing occupies in relation to the plant generally. Starting with the prime mover and the machine we wish to operate, in the majority of cases, their respective speeds for efficient working compel us to insert an intermediate mechanism or gearing. It is important, then, that this gear should be highly efficient and durable, and Mr. Snashall had recognised this when he placed his note and views before us to-night.

I again wish to add my remarks to those already expressed to Mr. Snashall for his paper on gearing.

THE PRESIDENT: I have only a few remarks to make in connection with Mr. Snashall's paper, but have nevertheless found it very interesting indeed. The improvement in the manufacture of gearing during the last few years is one of the notable developments in mechanical engineering. Perhaps one of the greatest factors in the success of gearing seems to be that the support must be absolutely rigid and substantial. The dimensions of the shafts carry-

ing the gear wheels, and of the bearings carrying the shafts in the illustrations shown to-night, give ample evidence of this particular feature.

The author's remarks with regard to laminated pinions have also interested me very much, and I think that perhaps members might be interested to inspect a special form of spirally built up laminated steel pinion which was brought out a few years ago with the object of providing some degree of resiliency. The pinion on the table has been put to work, but I am unable to say that it has had the best possible treatment to ensure its longevity.

There is ample room for improvement in the design and manufacture of gear pinions, because, although paper, fibre and rawhide give the highest degree of noiselessness, their life is by no means as great as one could desire.

I will now put to the meeting a vote of thanks to the author.

Carried with acclamation.

Mr. SNASHALL: Mr. President, Gentlemen,—I thank you all very much for the way in which you have received my paper. The question of gearing is an interesting one to me, and it has afforded me much pleasure to hear the remarks of the gentlemen who spoke on worm-gearing. As far as our trams are concerned, there is great room for improvement in respect to noise. There are many difficulties in the way of developing worm-gearing; it has been recommended, but I understand from tramway men that there are considerations which interfere largely in the matter.

Mr. Fraser referred to the $14\frac{1}{2}°$ and 20° angle. The reduction at that angle, as is shown by the last diagram, results in more even contact taking place and less wear on the teeth. We find that Lasche says that error in the

teeth results in acceleration. If you take the Lewis formula you will find it entirely different. Reduction in stress is in proportion to the velocity.

Re Mr. Tourney-Hinde's remarks about the disadvantage of double gearing, I must answer that the side pressure on the wheel should not be such as will tend to throw the load on one side or the other, and in pictures you will see that the pinion is locked by the bearings.

Mr. McNamara referred to the involute tooth. The involute tooth has become very popular for the reason that it can be relied upon to give good rolling contact in almost any position on the engaging faces of the teeth.

I do not think there is anything further to be said; I thank you again for the way in which you have received my remarks.