about them. It is a strange thing that it took 20 years before the results of Beauchamp Tower's discovery came to be put in application in a thrust-block. With regard to a bearing, there has always been a tremendous amount of trouble from the friction, and it took over 30 years, from the outset, before that eminently valuable result was put into actual practice. We may suppose from that that there are many principles demonstrated by scientific men in the last 30 years, which, if put into practice in engineering, would almost revolutionize the whole profession.

Mr. Taylor's remarks about the kind of oil to be used with this bearing might apply to almost all lubrications. The thinnest oil which can be used, should be used in the actual contact of metal to metal. The tendency amongst engineers is, I think, to use too thick an oil.

Mr. Shirra seemed rather doubtful about the application of this bearing as a thing really of considerable importance over the old style of thrust-block; but I think most engineers would agree that the saving in space alone would be sufficient warranty for the use of the block.

Mr. Tournay Hinde said: I do not propose to discuss the merits of the Michell thrust bearing, as compared with the well-known thrust block that we have hitherto been used to, but I think it is only fitting for us, as engineers, to express our appreciation in a matter of this kind, that, when the scientific information available was made use of practically, it was made use of by an engineer in Australia.

I had the pleasure about 8 or 9 years ago of meeting Mr. Michell one day in Melbourne, in connection with his centrifugal pumps. I think I am right in saying that a more unassuming, quiet kind of man you would hardly come across. I was very much surprised to learn from our President's remarks that that particular gentleman was the inventor of so epoch-making an invention.

I have simply risen in order to place upon our records our appreciation of the fact that this invention is due to an Australian. At the same time, I desire to thank Mr. Taylor for bringing it before our notice, and before my notice particularly. I have much pleasure in supporting the vote of thanks to Mr. Taylor.

Mr. Holliday said: I should like also to add my thanks to Mr. Taylor for his very interesting and instructive paper, especially as I have been more than interested in the subject since it appeared in "Engineering" some time ago, when it struck me as being the solution of a long felt want.

There are two questions I should like to ask Mr. Taylor. The first is: In a thrust of this description, with the moving parts stationary and, say, a pressure of 400 lbs. per square inch on the bearing surfaces, would it be possible to insert a feeler at the leading edge of the block,

The second question is: Will the oil enter between the surfaces if the parts are assembled dry, or is it necessary to, at all times, have a film of oil between the wearing surfaces?

The President: Gentlemen, there are one or two things I should like to say before asking Mr. Taylor to deal with the various matters that have been brought forward. Several references have been made to the gradual growth of the idea evolved finally in this bearing. I think this particular example shows probably the curious way in which all these things come into ordinary everyday use. One sees that illustrated in any number of cases, and this seems to be a typical one. First of all, a general practice is arrived at, by, more or less, a rule-of-thumb by practising engineers, and very often the practice so arrived at is an extremely good one. I forget what philosopher it was who said that a rule-of-thumb was very good, but it depended very much on the thumb. I think the results arrived at have been because the people concerned have had large experience, very often, with what is already in practice,—with a thing which subsequently can be well justified on scientific grounds, although it may not have been evolved by that method. In the particular case, no doubt, as far as lubrication is concerned, the state of knowledge was very poor up to the time of Beauchamp Tower's experiments, and these experiments (as has been pointed out several times already), were of a very important nature. They were very nearly thoroughly exhaustive of the subject from the experimental side, and they are still quite a mine of information from which one can get many data which one requires in ordinary design work. But Beauchamp Tower himself did not complete the work. One very often finds a huge mass of experimental results, and then those experimental results are very well reported and analysed as far as their statements are concerned. Curves are very well drawn, and you get many novel conclusions from them; but the subject, as a whole, is not co-ordinate with the experimental results, and therefore it requires something still further.

In this case, Osborne Reynolds, who, perhaps, was not a very great engineer, but who was certainly a very great scientist, with a leaning towards the engineering side, a man rather of the type of Rankin, who was able to carry on investigations of such a high scientific character, and making clear what might be difficult to follow to an ordinary person—Osborne Reynolds, who had a tendency towards the side of engineering problems, largely reanalysed the results which Beauchamp Tower arrived at, and has in these really made the final work possible. He explained what were the underlying principles involved in these results, which had been more or less empirically arrived at from experiments of Beauchamp Tower. He put the subject on a really scientific basis. Having got that far, it only required a man with a good engineering knowledge, such as Mr. Michell, and capacity to extend such work as Osborne Reynolds, to embody the thing in a very high-class invention, which we have in the Michell bearing.

Mr. McEwin has referred, during the discussion, to the long time it takes after experiments before it becomes a practical machine that you can purchase. You often find that applies to ordinary cases, such as steamships. I think it is at that stage that, very often, a dead stop comes—you cannot get past the point of the invention. The design is completed, but, to carry it out (especially in a case such as this), where, if it is going to be used at all it requires great assistance. In the case of thrust-bearings for turbine propelled ships, even a single model is going to cost an enormous sum of money; and to actually get on with the invention, so that it can be brought into practical use, requires the assistance of a big wealthy company, before you can go into commercial investigations in order to see how a design can be adapted to larger problems. No doubt Mr. Michell was fortunate in having his work taken up by a large firm, who have always been noted for the sound way in which they develop their industry.

Although it does seem to take a long time between the original inception of the idea and the putting of the finished product on the market, there are a good many steps to be gone through. I think this particular device is a very typical case of the more arduous path that has to be followed before you arrive at what you might call a commercial engineering success.

I will now ask Mr. Taylor to be good enough to reply to the points raised during the course of the discussion.

Mr. Taylor, in reply, said: Mr. President and Gentlemen,—I thank you very much indeed for the kind way in which you have received my paper, which, I think, seems to have aroused quite a lot of interest, while, at the same time, it seems to me it is also going to direct a little attention to Beauchamp Tower's experiments, which have been perhaps a bit neglected in the past.

There is no doubt, as the President has said, that the ingenuity displayed by Mr. Michell in working out this problem has been very marked. I think anybody coming in contact with Mr. Michell personally would agree with the President that he is an extraordinarily able man—a man who sees things twice as quickly as everybody, and four times as quickly as I do myself.

With regard to Mr. Shirra's remarks, as far as I know the thrust-bearings on the "Transylvania" and her sister ship are of the ordinary type, but I do not know definitely —I think it is most probable. There is no reason why an ordinary thrust-bearing should not be made to work all right on such a job, except that its size becomes very large, and you cannot afford to take any risks with a ship of that size. For that reason it is that the thrust-block is ten times as big as it would be in the Michell bearing.

To meet the point Mr. Shirra brought up regarding the large amount of waste material in turning collars on the propellor shaft forging, that was a point brought up, very strangely, on the discussion of Mr. Newbiggen's paper before the Institution of Civil Engineers—in fact, one speaker went so far as to say that if it had not been for the Michell bearing they would not have been able to tackle horse power as large as they have done. No doubt, the amount of waste material, and the amount of time that goes to waste in turning collars out of a big shaft forging is something enormous—to say nothing of the initial extra cost of the forging.

With regard to water cooling, I think the reason why that bearing shown on the screen was provided with a water-cooling arrangement was simply to satisfy people for whom it was designed. I think that they stipulated that a water cooler should be provided; it was put in there to meet their wishes—but they proved it was no use, or, rather, it served no good purpose when used, and they did not use it. The cooling in that case is by means of coils of copper pipe, through which cold water is sent by a circulator, and the oil, after it has passed over the bearing, falls into an oil well in which the cooling coils are situated, and the constant circulation of cold water helps to keep the oil down to the temperature necessary. As the temperature rise, in that particular case, is nothing excessive, they are simply not used. Mr. Shirra says that it is the present day practice to have a tap which drips water on to the shaft as the shaft comes out of the angle bearing, and that takes away any heat generated. I think it is a point in favor of the Michell thrust that that precaution is not necessary. I suppose if the water supply were to fail, or to be shut off, the result would be disastrous, and that would be entirely eliminated with a Michell bearing.

With regard to the chamfering away of the edges of collars in an ordinary block, of course, if you cut the surface of an ordinary thrust block up into a number of patches, you can make an elementary form of a Michell block; but since you do not get the tipping motion you are really making an elementary form of block at the expense of efficiency, and unless you probably allow it to run quite cool the efficiency over-all, from the engine pump, would be nothing like as great as it would be with the Michell bearing. You certainly get the film of oil introduced, and I think the tipping block is altogether far and away superior to chamfering away the edges. In that case, to make it worth the trouble of pumping, the oil grooves in the thrust collars were about an inch and a half wide by the time they had finished with them, so that the pressure on the main surface of the bearings must have gone up pretty considerably. Since the tipping surface was not there, the efficiency must have gone down. I was very much interested in Mr. Grieve's remarks regarding the tests he saw carried out in 1912. I might say that Mr. H. S. Bloom, of the firm of Bloom and Wood, of High Wycombe, England, manufactures a large number of stationary engines with Michell bearings, and tested bearings up to 1200 lbs. per square inch —a momentary test. Again, Mr. Ferranti, in other tests, carried them out to 1000 lbs. per square inch for a long period with no trouble at all, which shows the ingenuity which has been directed towards these thrust bearings. Mr. Ferranti was experimenting with a thrust-block in the Parsons' turbine, apart from marine considerations —he was dealing with large sizes of turbines, and he got out a most elaborate arrangement of springs and levers by which the load between the various collars and thrust-blocks of an ordinary type was distributed; so that if one bearing took more than its load the springs belonging to that particular collar moved through the whole block in one direction and equalized the load on the other. So that it seems to have been a very important problem in the past.

Mr. Reeks' remarks as to the valuable space in steamships are appreciated by all marine engineers.

I was very interested in Mr. Harricks' remarks re centrifugals. I have had a little experience in centrifugals myself. As I mentioned in my paper—the average coefficient of the Michell bearing from start to full speed, is .0078; the ball thrust bearing is .0075—not a great deal of difference—but I think there would be great difficulty in applying the Michell bearings to the suspended bearings of centrifugals.

With regard to the viscosity, of oil, it is, as has been pointed out, a very important point—in fact, the variation of temperature during a test will alter the friction on the Michell bearing when working, from .0048 to well over .0006. It is a very important point to get the proper class of oil at the right temperature.

With regard to the point mentioned by the gentleman who asked about the amount of tilt on the bottom, I think when the bearing is stationary you would not be able to get a wedge in at all, but as soon as the bearing got into motion the block would move very, very slowly—about one part in a thousand.

With regard to oil getting in when the bearing was originally erected, the surface would be certainly smothered in oil when put up, which would be sufficient to get the oil sticky to start with, and the surface of the bearing would always remain greasy. The bearing would not be put up without the oil on the surface, so the surfaces are always oiled.

I think that meets most of the points raised.

I thank you very much for the kind way in which my paper has been received.