mined sum. It might be said that the factor of safety of 2½ to 1 was sailing too close to the wind and was not good practice, but if care were taken in the manufacture of the girders to see that the material was good, the holes fair, and the rivetting properly done, I think that, with cavil at. At any rate, given certain conditions, it has to be done.

Mr. Sykes has referred to the practice of using breaking pins, or breaking parts, in order to avoid serious injury to more expensive portions of the machine. This, of course, is a well-known practice, and is adopted in many machines; but there are limitations to the immunity from breakage provided by breaking pins. In the case of the ordinary reciprocating jaw breakers for reducing ore, I recollect an instance where I used breaking pins in the pitman for the purpose of preventing fracture of the swing jaw, owing to possible lumps of iron or other hard material in the ore to be crushed, entering the jaws. In this case occasionally the jaw fractured before the breaking pin failed. This is the more curious considering that the jaw had a cross-section of 15 inches by 9 inches of solid cast iron where the break occurred, and the breakage was probably due to the fact that the high speed of the jaw gave it sufficient momentum to carry it on and cause the fracture.

With regard to piece work, it often happens that the operative would object to work piece work on machines unless he can get a long continuous run without stoppages, and in the case of the single machine which produces two or three sizes of one particular article, such, for instance, as a bolt making machine, it is of primary importance that the change from one set of dies to another should be made in as short a time as possible, and also the parts liable to fracture could be rapidly replaced. To do this occasionally involved what appeared, to the

untrained eye, a crudity of design, and is very often more the result of suggestions by the operative than of deliberate design by the engineer. The machine, nevertheless, from the manufacturers' point of view is a satisfactory one, as it enables both himself and the piece work operator to get the largest output possible, and, therefore, the best commercial result.

THE PRESIDENT said: There are two or three points to which I should like to refer before asking Mr. Sykes to reply to the various matters raised. Personally, I do not like the strong opposition set up by the paper and by some points of the discussion between what has been called the engineering side, and the matter of earning money—the financial side—the question whether you should do a particular thing because it is good engineering or something else, because it is good business. Surely it is a fundamental principle of engineering that every engineering problem is a financial problem. I do not know of any class in which that does not hold good. Whenever you come to an engineering problem you are concerned with the finance of it, fitting that to the principles of physical or chemical science. I suppose it is only in the case of things like war that you do not consider the cost—you have to do things not always economically. Not only is an engineering problem a financial one, but what an engineer has to do is to help the man who owns a business, or who is running a concern, in order that he may make as much profit as he can. I do not think it is quite the position to take up between those two sides of the case. That governs also a good many points raised.

With regard to the question of design, and so forth, Mr. Sykes, I think, in some of his remarks, was rather inclined to say that there are occasions when you must abandon theory and take some other thing to guide you.

The only matter about a theory of that kind is that we have not got enough of it. If we knew sufficiently about the subject rightly it would be a great help. The various reasons suggested by Mr. Sykes, and other speakers, seem to me to be guesses—a theory not being elaborate enough. If a man designing a machine for a particular purpose does not design one which will work, that is simply because he does not know enough about the principles of the thing which he is called upon to design. If he adds to his knowledge by studying the results of other people's experience, by which he will be able to make the necessary design, he is what I may call theoretically strengthened on the subject. After all, theory is a grade higher than abstract principles which may end in a line of design, but are certainly not guiding principles. The question of Australian conditions has come in for a good deal of mention in Mr. Sykes's paper, and is, no doubt, extremely interesting for that particular reason. The problem seems, out here, to be more complicated than in countries such as England and America. Take the case which Mr. Sykes instanced of the mill in which he served his time as a lad. It is idle to say that if you are going to put in so many things you are not going to have a big staff to look after them. Under some conditions one may look after a dozen automatic duplicating machines. When you come to work that out under such conditions as are prevailing here, you will come up against the trouble not only of the cost of labor, but you want to cut labor units down as much as possible. By using a specially designed machine you may get over the trouble of the limitation in the amount of labor you are allowed to use. I think it must be admitted, with regard to the problem in Australia, that labour is very expensive, and more costly on a job here than in European countries; the hours of labour are shorter and you also have specially

arbitrary conditions introduced, which are very troublesome. It is an important and great problem for Australia as an industrial country, because in other countries you do not have the same high wages and the same working hours. I do not see any way in which that can be helped, except by the introduction of an extraordinarily efficient class of workmen, that is to say, a class of labour which, if it is going to compete with other countries, must be extraordinarily efficient in view of the class of labour obtainable in other countries.

MR. R. SYKES, in reply, said: Mr. President and Gentlemen—I beg to acknowledge your very kind vote of thanks. I may say I am not disappointed—I expected to raise a discussion and I have succeeded in doing so.

I will attempt to answer a few of the questions which have been asked, but I would sooner have had a little time for reflection before answering them, because the way the questions have been put do not altogether fit in with the case I have tried to present to you. I can only think it is my fault, but it is a very intricate subject—a little bit out of the ordinary.

Mr. Grieve has referred to railway construction. I did not quite catch the first portion of his remarks, but I take it his remarks were in the direction of the lack of facilities in Australia with regard to engineers gaining experience abroad.

MR. W. H. GRIEVE: Government engineers.

MR. R. SYKES: I could scarcely follow the trend of Mr. Grieve's first few sentences,, but, if I may venture to say so with all respect, I think it was more a comment on the paper than any criticism which requires an answer.

With regard to Mr. Harricks's remarks I do not quite remember what he said, but I think they were contrasting light machines with heavy machines. Mr. Harricks

seems to me to contend that, in Australia, owing to financial considerations—the cost of machines—it is advisable to buy light machines, cheap machines, rather than the more substantial heavy ones.

MR. D. F. J. HARRICKS: Not advisable, but the force of circumstances compels it.

MR. R. SYKES: If a man sets out for making a success in manufacturing I do not think he will buy the cheapest machine, but the one from which he can get the best results irrespective of the initial cost. I think that holds good in the case of machines to which I am referring. If there is an unlimited demand, and he is assuming that he could buy a machine at 20 per cent., 30 per cent. or 50 per cent. less, what does it avail him if all the time that the machine is competing against his competitor it is dropping him money? If he has no competition, I can understand the position, but if there is competition, and another man puts in a better machine and produces a better product, my contention is that it would not pay him to buy a cheaper machine. I can quite understand that Mr. Harricks's argument would hold good, but it does not deal quite with the set of conditions to which I am referring. It is no good a manufacturer starting out with insufficient plant. Mr. Harricks has also referred to the passage in my paper where I say that the engineer must be prepared to take licence with any principle involved. What I call licence is one instance practically given of using mild steel against mild steel; but, of course, there are exceptions. If you are going to run a mild steel shaft in a mild steel bearing, that would be sheer madness. The bearings I was referring to were made 10ft. long, and the shaft oscillated about 60 times a minute to and fro. I had some working for 5 years. They showed a little wear, but not more than cast iron. I think it is more a matter for lubrication, consideration being given to the means for allowing the oil to get in between.

Mr. Harricks also wants to know why cut gears are detrimental. In my opinion, cut gears are detrimental for the reason I have stated in my paper, viz., that one of the essential conditions of success for the good running of cut gearing is, of course, the accurate paralleling or angular setting of the axes. I had some cut gears put in a machine 18 months ago. An engineer came up into the room in which they were working. I said, "There are a good lot of cut gears here," and he said, "They are quite good." If there is a bit of wear in the bearings they have to go until an opportunity occurs for taking up the bearings. If a piece of wire or a piece of tin gets in between cast gears, which frequently happens—particularly in the case where you are working with metal—something must go unless the belt slips. If a piece of wire gets in between cut gears it would simply jamb. No doubt practice proves it. I have had to replace cut gears while working wire-working machines where cut gears were an absolute failure. Cast gears can be moulded with extra clearance to get over the difficulty. I noted Mr. Harricks's remarks about chain gear, but I might say that the trouble we have with chain gears is that they are constantly breaking. I had a set of 14 machines running, and made an alteration, introducing gears instead of chains, and we have got over the troubled stages, and considerably increased our output.

I am afraid I have done very poor justice to Mr. Harricks's comments, for the simple reason that they do not, I think, fit in with the class of machine to which I am referring.

With regard to the President's remarks, I think, if I may say so, they tended very much in the same direction as the remarks of Mr. Harricks, only expressed in a different way, and I think my answer to his remarks must be found in my answers to Mr. Harricks. But there was

one question to which the President referred, namely, the question of a good engineering problem being a good financial problem. (No doubt a good engineering problem is a good financial problem.) The President asks why a good engineering problem is not a good financial problem? It is because the theory of engineering is not sufficiently understood—in other words, as the President said, it has not gone far enough. If the matter is threshed out I think it will be found that a good engineering problem entails a good financial problem. Where you find a discrepancy between a good engineering problem and a good financial problem, that discrepancy is due to the theory not being pushed far enough in order to get the facts of the case. Upon perusing the questions asked, I might, perhaps, have put my replies in a clearer way, as there are many points to consider when replying to them all.

I thank you very much for the patient hearing you have given to my replies, but I am afraid I have not answered all the questions as fully as I should perhaps have liked to do, but facts will speak for themselves.