no means are available for adjusting for this wear without renewing the worn parts as in the case of a cam, it is advisable to investigate the maximum and minimum limits of variation permissible, and then to arrange matters so that when the parts are new they work at or near the higher limits, and as wear takes place the lower limit is approached.

Discussion.

Mr. W. H. Grieve (in proposing a vote of thanks to Mr. Sykes for his interesting paper), said: Mr. Sykes's paper is more or less a statement of facts, as far as I am concerned, and it opens up the big question of policy in machine design—whether in designing machinery, efficiency and long life, or comparative inefficiency and cheapness of manufacture should be the deciding factor in manufacture or selection of machinery.

It is, of course, impossible to have any hard and fast rule to bind all cases, so variable are the requirements and the nature of the work to be done.

The differences of opinion on such an important subject have always been an interesting study to me; these appear to be more or less international, and I think that, when one comes to analyse the question, the reason is obvious. I am referring more particularly to machinery for railway construction and the methods adopted in that important branch of engineering.

The two schools are represented by the British and American systems, and it is most important for us in Australia—I still refer to railway construction—to know how far we should adopt each system. In many ways the conditions in Australia are similar to those appertaining in America and other new countries, and it is of the greatest importance that we should benefit by the experience of other countries, and (if I may be allowed to diverge slightly), it is essential that our Government en-

gineers, while responsible for most of the important engineering undertakings in this country, should be sent regularly to investigate the methods in vogue in other parts of the world. To my idea, the Governments seem to act very miserably in this respect. Very few Ministers appear to realise that the cost of sending their officers on such missions would be miscroscopic in comparison with the benefits derived therefrom. I know of numerous Government engineers, who hold positions of great importance, and who are continually responsible for the expenditure of large amounts of money, who have not as yet been out of Australia, and so cannot possibly benefit to the extent they should by the vast experience of older and more populated countries.

One of the most important Departments in any business is the intelligence department, i.e., a department whose duty it is to ascertain what is going on outside their own business. It is imperative for a State Government, spending the large amounts they do in engineering works, to adopt a similar scheme and so ensure efficiency.

The British school is the natural result of a closely settled country. Referring to railway construction again, few new railways are built in England compared with America and Australia, and machinery which suits the purpose of one may be quite inadequate for the other set of conditions. I think this fact should be remembered when machinery is being selected for special purposes. The benefits to be derived from each type must be weighed in the balance to find if the more expensive machine is worth the additional money compared to the cheaper type.

It appears to me that the trend of Mr. Sykes's paper is with regard to the selection of the most suitable machines for certain work. Although it may be depart-

ing a good deal from the subject matter, a point which appears to me to be of the utmost importance out here is that Government engineers should be in a position, from experience and observation in other countries, to select that machine which is going to be the most valuable to them.

Mr. D. F. J. Harricks (in seconding the motion), said that he was much in the same position as the proposer, in that he had had practically no actual experience with machines that would come under the heading of textile or, to use Mr. Sykes's words, industrial machinery. Mr. Grieve had pointed out that there was quite an important number of people who believed that it was a more economical proposition to install in a new industry machines that might be considered light for the purpose, and consequently cheaper, but, nevertheless, capable of turning out satisfactory work for a number of years, as against more substantial and consequently more expensive machinery. I have been connected almost entirely with an industry that calls largely for heavy machinery, but I have always thought the very important question of the cost of industrial labor has such an influence here in Australia, that a young concern must frequently be forced into the position of having to embark with lighter and consequently cheaper machines than would really be desired if they were free to choose. Whereas, I think you will find that in Australia there is very little real support for flimsy, short-lived machinery, it is, nevertheless, to be borne in mind that many machines are made heavier even than durability requires. The designer who is clever enough to dispose his material to the best advantage is sometimes deprived of his deserts, because he has not wasted material on unimportant parts.

Mr. Sykes, in one passage of his paper, says that "Where there is no liability to bodily injury, the engineer must be prepared to take license with any prin-

ciple involved." Does not Mr. Sykes mean "practice" instead of "principle," for we really cannot take advantageous licence with a principle. We can certainly vary the disposition of the material in a machine so as to possibly reduce the factor of safety, or, we might vary from what is accepted as common practice, but the principle, or theory, involved in the design of structures, cannot really be taken licence with.

Mr. Sykes has very rightly said that English machine makers cannot possibly know Australian conditions as well as the Australians themselves, and in this respect I think it must be admitted that, although improvement in this direction has recently been obvious, English manufacturers have not encouraged their staffs to travel in order to obtain a better understanding of Colonial and Foreign conditions. If, as suggested, it is desirable that we should make more or all of our industrial machinery, the question arises as to whether our technical colleges are devoting sufficient attention to the study of such machinery to suit local conditions.

With regard to gear, the author has said that under certain conditions cut gears are absolutely detrimental, and that he considers that it would be better practice to rely more upon proportions than accuracy of workmanship. Personally, I cannot imagine a condition under which cut gearing is actually detrimental; it is quite obvious, of course, that in many cases the cost of cutting gear is not justified, but even in cases where the gear is cut and clearance is still allowed, the advantage of a parallel face, proving of the metal by cutting and decreasing the risk of brittleness, are distinct advantages. Again, we cannot dispense with accuracy of workmanship even though a gear be cast, for, in the first place, much depends on the making of the pattern, and subsequently the moulding of the teeth. It is, perhaps, only

a matter of a decade or two when it will be a most unusual thing to find cast gearing in use for any class of industrial machinery whatever.

I was quite struck with an incident I saw last year whilst visiting the works of a large textile machinery manufacturer, to find that gearing for every purpose was cut, even though in many cases the clearance, both at the pitch line and at the base of the teeth, was the same as would be allowed in cast gears, for the reason that pieces of cloth were liable to become entangled in parts of the gear. In the early life of gearing we know that many fractures are caused through inequalities of castings.

Mr. Sykes has called attention to the value of "Trial and Error" in the design of machines, and there is no doubt that in many classes of industrial machines, it is practically impossible to determine correctly the stresses that are likely to be thrown upon them, and, although there are many people, even nowadays, who are rather inclined to belittle the necessity under any conditions for "Trial and Error," it is a simple matter for most of us to call to mind instances where experience is not available or has been insufficient to enable us to define the working limits of a device. Of course, in the majority of cases, we are able to prescribe the maximum effort required of a machine, and it is then a simple matter to apply the correct theory and to define the proportions.

Much as we know of the physical properties of materials nowadays, it is in most cases impossible to dispense with an adequate factor of safety, and in this connection it is interesting to notice Mr. Sykes' reference to what he calls "The fusing link in industrial machinery." We know that in almost all devices there are some expensive parts which it would be costly to replace, and if we can insert an unimportant member so much weaker than the rest of the machine that any un-

due stress on the machine would cause the weaker member to break a "fusing" or "breaking link" is an economical arrangement, and even although it may mean an occasional stop, it means an inexpensive instead of an expensive one to repair. Perhaps the most commonly known device of this kind to city dwellers is the fuse in the electric circuit of a tram-car; a weak link in a driving chain is also a very common safeguard.

Would Mr. Sykes be good enough to describe the bearing in which he introduced mild steel against mild steel. The practice, of course, is not altogether unusual, for we know that the coefficient of friction between two surfaces of polished steel is really lower than between any other two metals one can suggest, and one has only to think of the numerous chain drives where steel links, bushes and pins are the usual practice as an example of the steel to steel bearing.

Mr. Sykes has taken for his paper a very broad subject and one which, though difficult to criticise, is, nevertheless, most useful in reminding us of the importance of our local industries, and that we should encourage most heartily the application of engineering science to the design of suitable machinery and labor-saving appliances, in order to offset the exceptionally high cost of labour.

MR. TOURNAY-HINDE said: I have much pleasure in supporting the motion and, also, to some extent, in supporting Mr. Sykes. The difficulties in the position he has striven to expound in the paper he has read to us this evening can probably be only appreciated by persons who have been up against the problem involved in the design and maintenance of certain classes of industrial machinery. If I might be permitted to say so, I think some of the critics this evening have hardly carried in mind

the classes of machinery which Mr. Sykes more particularly describes, and have referred more to the higher classes of machinery amongst which one may classify such apparatus as steam engines, motor cars, turbines, and electrical machinery. It is well known to those who have had experience with certain classes of industrial machinery that, in certain operations, the machine that would appear to most engineers as of the crudest design and roughest manufacture, offers comparatively greater facilities and lower operating cost in the production of the object aimed at; and the machine of apparently finer engineering design, while it may carry out the operation, will not do so as continuously or as cheaply.

I cannot claim extensive experience of textile machinery or of that class of machinery to which Mr. Sykes particularly referred, but I do know from extensive experience in certain kinds of machinery connected with mining and smelting operations, that the heavy, clumsy machine, possessing hardly any appearance of what (for want of a better term) might be called "engineering design," is often far more satisfactory from the owners' point of view. In using the term "engineering design," I do so for want of a better expression. The heavy, clumsy machinery, apparently without appearance of design, is really the result of considerable design gained by the extensive experience of failures of higher class machines. It is, one might say, the result of trial and error.

It often happens that the engineer associated with a manufacturing company is asked to produce a machine to carry out certain operations for the first time, and such information as is available is supplied him. The engineer designs the machine, and from hard, unkind experience often provides for a very much heavier speed of operation, and for heavier stresses, than would seem

reasonable to anyone less experienced with this class of machinery; and, even then, notwithtsanding all his efforts, it frequently happens that when the machine is put into operation the manufacturer finds that to carry out the process economically he has to stress the machine to a greater extent than anticipated, or perhaps run it at a higher speed than was intended, and this often necessitated variations and modifications from the original design which have to be superimposed upon the original structure, making the machine look heavy, clumsy and crude.

With regard to the factor of safety referred to by the author of the paper, one frequently has to take liberties. In certain parts, for instance, the absence of weight is an essential factor—the part consequently has to be made as light as possible, in fact just a little stronger than is actually necessary to stand up to the work. When it fails, as it does occasionally, it is replaced by another similar part, and the ease and quickness with which this replacement can be made is (as stated by Mr. Sykes) one of the essential factors. Often in cases of very large structures, the same reduction of factor of safety might in some instances apply. I can recall, as an illustration, a steel structure about 40 feet in height, carrying the upper floor of a lead smelter. This floor, about once in every 12 or 18 months, was called upon to carry its full load for a period of possibly 24 hours only. During the whole of the rest of the period the load was about one-tenth of its full capacity. In this instance the girders were designed so that they only had a factor of safety of about 2½ to 1 under full load. In cases of this sort it is found very essential to reduce the capital cost to as low a figure as possible—very often it became a question of having to do without the assistance of the additional plant, if it could not be completed within a predeter-