pend on the value for Poisson's ratio. Obviously this is an experimental method which might be used for determining that ratio and also all the other elastic constants of the material.

18. *Strains in the dished ends.*—The strains in the dished ends were measured along two diameters *AA* and *BB*. (See Fig 15.) Fourteen sets of observations were taken, the distance pieces being placed as shown in the right-hand diagram of Fig. 15. The strains are plotted in the left-hand diagram of Fig. 15, those measured radially being marked X, and those measured tangentially being marked Y. It is interesting to note the contra-flexure on the diameter *AA*, this probably being caused by a slight dent in the surface along the latter diameter.

Arrangements are being made to repeat a number of the observations referred to in this section of the paper on a carefully constructed drum of simple design, so as to make the problem of comparing the results obtained with those which would be theoretically expected less complicated.

19. *Acknowledgments.*—In conclusion, the authors desire to thank Mr. Kennedy for making the test welds referred to in the first section of the paper, and also to thank Professor Warren for enabling the tests of the material to be carried out.

Discussion.

Mr. Shirra said that he supposed they were all pretty well familiar with the oxy-acetylene process, which had now attained considerable popularity, even among amateurs. The results put before them by the lecturer were,

on the whole, about what he expected would be the case, and he was interested to know that the percentage of strength of a welded joint was in the region of 75. He would, however, like to ask whether the weld should be hammered during the process, and also if it were necessary to do so afterwards. He thought this question would present itself forcibly to the minds of those who had the privilege of listening to Professor Barraclough's remarks, and that the general concensus of opinion would be that it should not be hammered.

He would also like to remark on the suitability of iron drums for carrying such substances as sulphuric acid and so forth. In the case of welded iron and steam pipes, the Board of Trade required that the weld should be covered, and he thought it was a very important and essential precaution, especially after seeing some of the oxy-acetylene welds to-night. The great advantage of welded drums lies in the fact that the welding made them absolutely tight, and they would readily appreciate the value of this feature in the case of sulphuric acid.

In regard to the strength of the drums, however, he would suggest that it would be easy, by means of ribs, to reinforce the drums on the inside, and then the welding would be rendered more effective.

In connection with the concave ends of the drums acting as a safety valve, he would like to ask why they might not be made in a similar manner to a corrugated disc. There seemed to him to be a great stress on the knuckle. If they converted a concave plate into a convex one, there must be a considerable expansion, and if the ends were made with a series of concentric corrugations the necessary expansion would seem to be practically taken up. It might also be pointed out that if they were

made flat, or corrugated, any pressure occurring upon them would be readily noticeable. Take the tins of salmon which came to this country from America,—they had to be passed through the Customs here—if the flat ends of the salmon tins were found to be convex, due to the pressure of the gas inside, it showed that there was something wrong, and they were destroyed or condemned. He suggested that some such simple appliance could be devised in connection with drums used for the purpose of holding sulphuric acid and other dangerous commodities.

As they were all aware, one of the first experiments made by young chemists was to generate gas from metal filings with dilute sulphuric acid. But the acid must be dilute or the substance became polarised. Of course, the gas did not come from the sulphuric acid, but from the water combined with it, and they knew that commercial sulphuric acid was never absolutely pure, and that, on the contrary, it always contained a fair amount of water. Now, was it not possible that the acid, in this particular case, may have been watered, and that it was this fact which caused the drum, which they now saw before them, to burst? He thought it was a question worthy of very careful investigation; but here again they were faced with the problem as to who would investigate it.

In the "Inspection of Boilers Bill" there was a short clause setting out that an inspector should investigate any trouble with pressure vessels, but sulphuric acid was not mentioned. A great many other things, such as ammonia cylinders, and so on, were to be inspected under the Act. But who were these Inspectors of Boilers? Practical men—workmen. And what did a workman know about the properties or effects of hydrogen?

It seemed to him that a recommendation from such a highly technical authority as the Staff of our University, to the Home Secretary, or the Minister for Home Affairs, or whoever was responsible, suggesting that all these oxy-acetylene welds should be covered, would be well worth while. He thought a riveted strap would be a very useful thing. He might also ask whether mention was made about the stresses on the knuckle, which seemed to him to be a part very liable to fail.

He concluded his remarks by moving that a hearty vote of thanks be accorded to Professor Barraclough for the very valuable and interesting information he had furnished to the Members of this Association.

Mr. W. Sinclair, in seconding the vote of thanks to the Authors, remarked that he was sure it had afforded every one of them the greatest pleasure to follow Professor Barraclough and Mr. Rorke's very able paper.

He was in Melbourne when, as far as he was aware, oxy-acetylene welding was used for the first time in Australia. It was brought into use by a German gentleman who used it for welding refrigerating coils, and it then appealed to him as being a most astonishing thing. The piping used was about one-eighth of an inch thick; but it was filed off to an angle and welded by the oxy-acetylene process, and then wound round in a coil some six inches in diameter, and it did not matter where the welds happened to be, all of the bends seemed to be maintained in perfect order.

In reference to the Fouché blow-pipes, he might say that another gentleman and himself had spent a great deal of money on oxygen, acetylene, and also on pipes, experimenting with the process, and they came to the conclusion that it required a lot of experience to produce successful results. Just about that time also a book was

published by a German professor named Groth, in which it was stated that no man should be allowed to weld anything which would subsequently be subject to stress or strain until he had acquired some two years' experience watching and helping the work being done. Not long ago he had seen some ventilators, the joints of which had been welded by means of the oxy-acetylene process, and he noticed here and there some hair cracks running up and down the welds. He mentioned this, as his experience had been that the metal in the proximity of the weld became very brittle.

Mr. McEwan said that he had derived much profit from the Authors' paper, and particularly because he had a great deal to do with such drums as were dealt with in the experiments described. The paper had helped to show him how many of the drums he had to do with had failed. In most cases these failures had occurred around the edges of drums enclosed in rings similar to those mentioned by Professor Barraclough.

The drums his company used had not been under much pressure, as they carried oil, but they had been knocked about a great deal. Some of them were dented very considerably through rough handling, and so on, and it had been noticed that most of the faults took place outside the rings and the ends of the drums. A class of drum they had to deal with did not possess separate rolling rings, but a part of the solid metal was bent so as to form these, and they provided numerous failures, more so than any others, and directly the metal became worn the drums failed.

A point not touched upon by the Authors was the effect of oxy-acetylene welding on thick and thin materials respectively. In an article he had read recently it was stated that the thicker material failed more

readily than the thinner, proportionately, of course, to the area of the section. The author of this article maintained that it was usual for failure to take place at some other part of the material than at the weld. Possibly the sections tested by him were without the weld being filed down to the original thickness of the metal.

He would also like to mention that, in his opinion, the whole of Professor Barraclough's remarks showed that there was a very interesting field for research work in the oxy-acetylene process, and the fact that there were so few data on which they could rely was another indication of this, and it was reasonable to assume that there might be a very great opportunity for one of their students to distinguish himself, not only in this Society, but in the Engineering world generally, as the result of researches in this direction. It was an exceedingly great pity that the data on this subject were not more reliable, because there was such a tremendous field of usefulness open for the process. He thought the paper which had been read to them that evening would prove of immense value in leading to some very pronounced results in this connection. He thought they owed a very deep debt of gratitude to the lecturer, and he would like once more to express his very sincere thanks for the privilege which had been afforded him of listening to such an interesting discussion.

Mr. Howarth said he would like to endorse the eulogistic remarks made by the previous speakers. In reference to cast-iron, a material which most Engineers were interested in, he would like to ask if the oxy-acetylene process could be used with advantage in the construction of such things as the columns of steam engines, cylinders, and the like. He made the suggestion because it had occurred to him that if this were practicable it would be of immense importance in the case of breakdowns,

etc. He regretted that the time at his disposal did not permit the Professor to touch upon the subject of cast-iron, and he would like to take this opportunity of expressing a hope that he would find it convenient to do so in the near future. His experience in connection with cast-iron had been that it was a failure in many cases, such as for cylinders, on account of the heat to which such parts were subjected, causing the weld to give out. He would also express the hope that the Authors, in continuing their researches, might touch on the question of brazing cast-iron.

The President, Mr. G. A. Julius, said that he thought the Association was to be congratulated on being the fortunate recipients of such valuable information as that afforded them on this and the last occasion upon which Professor Barraclough had presented a paper to them, and he thought the gentleman who referred to the field now open for research work expressed the opinion of every Member present. Furthermore, he considered it should surely be one of the chief objects of this Association to do all they could to stimulate enquiries in connection with these subjects, and to refer them to the University for fuller investigation. Also, any financial aid within their power they should render that Institution, for there could not be any doubt as to whether they, as members of the Engineering community, would not profit very materially indeed by the adoption of their methods.

Another point which interested him greatly was the relative tensile strengths of the welded and unwelded specimens. It seemed to him that there was one factor brought out in the diagrams shown which required a lot of explanation, and that was the extraordinary stress shown on the weld circumferentially, as indicated by the

extensometers. Presumably the stress had been computed by assuming a certain uniform strength in the material under that load, and if any marked change in the material occurred at the point of the weld it seemed to him that it would be easily possible to arrive at an erroneous result, unless some other factor was taken into consideration in connection with the elasticity. He did not know whether this had been taken into account, and he would like to hear something about it.

He was very glad to hear Professor Barraclough draw attention to the necessity for abandoning excessive proof tests. There could be no doubt that drums were excessively proof tested, and, unfortunately, there seemed to be a tendency amongst Engineers to use proof stresses which told them nothing, but merely tended to cripple the drum; and the same remarks applied to cranes, and all manner of materials. Now, however, Engineers seemed to be arriving at a recognition of the fact that to test a chain at half its breaking load for the purpose of learning its capacity at a quarter of its breaking load, told them nothing at all, and only crippled the chain.

Professor Barraclough, in reply, said that he was much obliged for the kind vote of thanks to Mr. Rorke and himself. He was sorry to have no very specific information to give on some of the points brought up on discussion. In reference to Mr. Shirra's comments, he thought that most of the evidence was in favour of the improving of the weld by hammering. Mr. Whittemore, whose work has already been referred to, said in the general conclusions of his paper that "In any case, maximum efficiencies can be obtained only by using every available means to reduce the effects of over-heating. This would require annealing and, if practicable, hammering or rolling." The pieces which the Authors cut

from the welded joint for testing in the testing machine were heated to a dull red heat and then cooled before testing. He thought it was difficult to see any reason why treatment would not improve the weld. As far as the Authors had ascertained from the few published accounts, pretty well everybody seems to agree that annealing would improve the strength of the weld. In regard to Mr. Shirra's remarks about the chief value of the weld being to make a perfectly tight joint, he agreed that the idea of reinforcing the weld was a very good one. No matter how perfectly the welded joint is made, there is no protection against the drums being badly used by being dropped, hammered, and knocked about generally, and, therefore, welds were always liable to severe cross strains, which they were not well suited to resist. The Authors said little about the pressure produced in the drum by the action of the acid, as it was a technical chemical question, and one which did not greatly concern the present enquiry. The only point it was necessary to make quite clear was that, even when the acid was commercially very pure, as was the case in these drums, a heavy pressure could be built up inside the drum if it were left long enough without opening the bung. He agreed with Mr. Shirra that the weak part of the drum was at the knuckle of the dished end, and that was where they nearly all failed. It would be practically impossible to compute the elastic strain in the material constituting the knuckle. He was of opinion that the bulging of the concave dished end did constitute a sort of safety device in the drum, as this bulging usually occurred distinctly below the bursting pressure, and hence the large increase of volume would relieve the pressure inside the drum, and so allow it to be neglected for a much longer period without serious results. Whether that point was in the mind of the designer or

not it was impossible to say. He thought a corrugated end, as suggested by Mr. Shirra, would be probably useful. Mr. McEwan raised an important point in regard to the possibility of the welding affecting the metal just outside the weld, and that this might lead to a fracture. Personally, he thought that with materials like mild steel there was not much risk of that. As far as the Authors' observations went, it did not produce any serious effect on the metal.

No experiments at all had been made on cast-iron, as they had no one in the Mechanical Engineering Laboratory who was skilled at making welds. But if any Member would be good enough to provide them with some cast-iron welds the Authors would be very glad to test them and add the results to the figures already obtained. With regard to the Chairman's remarks as to the use of a coefficient of elasticity in determining the stresses from observed strains, it was, of course, necessary to know this figure with some accuracy. That, however, was not a very difficult matter, and he did not think that any alteration in the material during the process of construction of the drum would greatly affect it. They had determined the coefficient by tests made on pieces of the material cut out of the finished drum. Members would find that this question had been dealt with more fully in the body of the paper, although in actually presenting the matter to the meeting it had possibly not been made sufficiently clear. In conclusion, he would like to say that a very large part of the experimental work described had been done by his colleague, Mr. Rorke, and that much of the credit for any results arrived at was, therefore, due to him, and not to the speaker.