DISCUSSION.

Mr. G. Fischer, in opening the discussion, stated that his object in moving the adjournment at the last meeting was to give those members who were thoroughly conversant with the working of the injector an opportunity for carefully studying the paper, and then giving us the benefit of their knowledge, also of affording our younger members an opportunity for framing questions. The author, with his usual modesty, stated that the paper had been specially written for the benefit of young engineers, but he (the speaker) was certain that even those members who could no longer be designated young would agree with him that a more lucid description of the working of the injector had never been published. The invention of the injector dated back as far as the year 1818, when a patent was granted to the Marquis Mannoury d'Ectot, a description of which he (the speaker) had in his possession, and would be very pleased to show to any member interested in the history of this invention. However, the theory of the injector was not then properly understood, as it was considered necessary the steam used must have a greater pressure than the pressure existing in the vessel into which the water was to be forced. Messieurs Bourdon and Pelletan, two French engineers, also undertook the solving of the problem, but without success; and the credit of proving that it was possible to feed a boiler by means of an injector with steam drawn from the same boiler was undoubtedly due to Giffard. At the present time the various types of injectors could be counted by dozens; they had in the past few years been greatly improved, and now little or no trouble was found in working them. He could endorse the remarks made by the author regarding the system of technical education, having had an opportunity of observing its working when acting in conjunction with him as one of the examiners of the Engineering Section of the Technical College a few years ago. In conclusion, he wished to personally thank the author for his instructive paper, and trusted that his efforts would be fully appreciated by those for whom the paper had been specially written, namely, the young engineers.

Professor D. C. Selman, a visitor, stated that although a certain confusion in the treatment of the various subjects dealt with at the Technical College existed in the past, such was not the case at the present time, as it had been decided that the engineering classes should be divided into sections, and an endeavour would be made to avoid what had been termed "a multiplicity of subjects." There would be a distinct course of science training, having a laboratory class devoted to the practical treatment of scientific principles; a drawing class for giving expression to the conception of the designer; and a workshop class for permitting the exemplification of technical skill. He considered the suggestion made by the author regarding the reading of papers before the Association by the young engineers a most valuable one, as it would be a great incentive to work and research, and would tend to bring out ability which would otherwise not be developed.

Mr. Owen Blacket stated that his experience of the working of injectors was considerable, and he recommended that larger sizes than were necessary should be fitted, for the reason that, even if the water before reaching the injector was drawn through a strainer, on being heated by the steam lime was deposited in the nozzles, and the efficiency was thereby constantly diminished, He wished to give an example of the ignorance sometimes exhibited in the fitting of these instruments to boilers. Some years ago he supplied an injector, and also sent a fitter to erect it; calling on his client some short time afterwards, he was informed that the injector worked in a very satisfactory manner, but, on examining the manner in which it had been fitted up, he was surprised at this result, for he found that the steam pipe was connected to water branch and the steam branch to the water supply pipe. On further investigation the cause of its successful working was found to be due to the fact that the water was supplied at a pressure of 50lbs., whereas the working pressure of the boiler was only 40lbs. The author's remarks regarding the Technical College were no doubt correct as regarded the system of working in the past, but not at the present time. When he took charge of this department three years ago he did not attempt too much, for what had originally been a one-year course in applied mechanics he divided into a two-year course, but in the workshops the course adopted was considered correct. On behalf of the Superintendent (Mr. Bridges), he wished to invite any members interested to visit the Technical College and inspect the new workshops and the general working of the institution, after which he had no doubt that they would agree that the course that was now being followed out was the correct one.

Mr. H. E. Dickinson considered that the paper would commend itself to even the oldest members as there was really so much yet remaining to be explained with regard to the action of the injector. The author's summary of the distinguished names who took part in the discussion on Mr. England's paper, and the variety of views expressed, was quite enough to excite curiosity to inquire into a subject which served as a text for nearly as many explanatory theories as there were speakers, and of which the result was so far inconclusive that it still left matter for discussion. Much good could be derived from a perusal of the old discussion on this subject, if only as a guage of the progress made in scientific research. He might incidentally refer to one striking instance showing that so late as the year 1865, in a company at which Dr. Joule was present, an eminent engineer spoke of the uncertainty of contemporary knowledge with regard to the constitution of steam, "as to whether the caloric surrounded and separated the little particles of water, &c.," indicating that the *material theory of heat* was then currently accepted. The paper under discussion brought us in contact with the laws of the outflow of elastic fluids and the velocity of efflux so lucidly explained by the author as depending on the head due to the height of a column, which was the product of the pressure multiplied by the relative volume. This was correct in theory provided there was no resistance at the outflow. The question of how the outflow was affected by the shape of the orifice of discharge was one which no doubt had a most important bearing on the case, but, as we were not dealing with the question of any variation in the shape of orifice, it might be assumed from a general inspection of the various types of injectors the object of makers had been to employ for the combining nozzles the best form of orifice, viz., the contracted vein as far as possible, which had a co-efficient of discharge of from ·97 to ·99, and might for the purpose of this discussion be regarded as unity. The author referred to certain discrepancies between the theoretical and actual velocity of the outflow as a subject that would well repay the investigation. The theoretical calculations of the amount of steam that would issue from an orifice were based on the supposition that the ratio between the internal and external pressures would only affect the result so far as the velocity was concerned, and, but for experimental research, the work of the steam in so issuing would have continued to be somewhat of a puzzle. Elaborate formulæ were constructed on this theory by Rankine, Zeuner and others; but the credit of showing by actual experiment that the ratio of the external to the internal pressures was an important factor was due to Mr. R. D. Napier. He proved that when the internal pressure was double that of the external pressure, the maximum of efficiency was obtained. Professor Rankine's summary of these experiments is as follows :—

(1) The pressure at the throat of the outlet never falls below that corresponding to the maximum velocity of the outflow, however severe the external pressure may be; and, so far as I know, the merit of originally proposing and applying this principle is due to Mr. R. D. Napier.

And again—

(4) . . . As a rough approximation, the weight of steam discharged through a given area of throat may be taken as nearly equal to one-seventieth of the internal absolute pressure on an equal area, when that pressure is not less than five-thirds of the external absolute pressure. . . .

Mr. Brownlee's more refined experiments referred to by the author distinctly corroborate the earlier ones of Mr. Napier, and show that with dry saturated steam the maximum velocity of efflux is attained when the external absolute pressure is 58 per cent. of the internal absolute pressure. Mr. Napier's explanation of this phenomenon in his own words is as follows :—

My experiments appear to show that if steam flows from a boiler through an orifice into any pressure less than half the total pressure in the boiler, then all, or nearly all, the expansion up to double the specific volume of the steam in the boiler takes place in the direction of the flow, and that all, or nearly all, the further expansion takes place in a lateral direction to that of the flow; in other words, when expanded to about double the volume the ultimate velocity in the direction of the flow is acquired, and that all further expansion simply produces an enlargement of the stream.

Consequently if the maximum velocity never exceeds that due to a difference of pressure of 58 per cent., the weight of the steam will also be at a maximum at that correspondingly fixed point. In applying these conclusions it will be seen that the existence or otherwise of a vacuum has no effect on the weight of steam issuing so long as its gross pressure exceeds 1·6 times the resistance (for the vacuum can only be partial). These results also enable us to see that though according to the gravitation theory the velocity is a constantly decreasing quantity as the pressures increase, yet the weight of steam discharged in a given time increases in practically the same ratio as the pressure, which is very much to the point. If the weight of steam discharged from a boiler under a gross pressure of 50lbs. is 44lbs. per square inch per minute, and with 100lbs. pressure 86lbs., then we can readily ascertain the amount of feed water required to condense that steam and produce a mixture of the temperature at which it enters the boiler.

Mr. I. T. Haycroft wished to make a few remarks on certain points occurring in the earlier portion of the paper. He quite agreed with the author that scarcely too much time could be devoted in explanation of the fundamental principles of mechanics, and in the statement that, as far as engineers were concerned, the system of technical education followed in this colony too much was attempted and too much ground covered in a given time. But, though this was a fact at present, he did not consider that the system alone was to blame. If matters in another direction were modified, the present system of technical education would be found suitable, with perhaps a few exceptions in certain subjects; the modification which would be found beneficial was that students before joining technical classes should possess sufficient knowledge of elementary subjects necessary for the acquisition of a practical knowledge to the science of engineering. From his experience in this particular branch of tuition, that to expect the average student at the end of eight or nine months of two nights per week to have a complete knowledge of applied mechanics is farcical, due to the fact that when entering the classes the majority of students knew absolutely nothing of elementary mathematics, without a fair knowledge of which it would be foolish to expect a student to become proficient in mechanics. The knowledge of these subjects could be acquired in the Technical College itself, and a rule made to the effect that those students who could not satisfy the teacher at the commencement of a session that they possessed sufficient knowledge to entitle them to enter the class, should be compelled to attend such class where these necessary preparatory subjects where taught, would be found very beneficial. He would not suggest that all students in a mechanical class should attend these preparatory classes, as some acquired the necessary knowledge at superior schools, or otherwise. A good deal of the success in life of a student of the Technical College, or indeed any institution, rested with the student himself as to manner in which he occupied his time out of class hours. Unless students helped themselves by reading up the subjects dealt with by the teacher, and working out the examples given to them in the interim between classes, very little benefit could result from the bare teaching a subject in class. As regarded the investigation of the velocity of efflux of steam and water from the same boiler, it certainly was very lucid and suitable for the capabilities of those for whom the paper was intended, but the statement that the velocity of efflux of steam to that of water was in the proportion of the square root of the height of the column might have been simplified by stating the ratio of the velocity of efflux of steam to that of the water was in the proportion of the square roots of their relative volumes. The relative volumes could be found by any mechanic on reference to the ordinary "Steam Users' Pocket Book," and saved the trouble of calculating the height of the corresponding pressure columns.

Mr. T. W. Seaver considered that Mr. Cruickshank had earned the gratitude of at least the younger members of the Society by his action in drawing attention to an admittedly weak point in connection with technical education, that of trying to cover too much ground in a given time. Each subject, or at least each stage of a subject, should be well grounded into the pupil before his attention was drawn to the following stage; and, so far as he can, he should follow in the steps of the famous Lord St. Leonards, who "resolved when he was beginning to study law to make everything he acquired perfectly his own, and never to go to a second subject till he had entirely mastered the first." Smiles, in his "Self Help," stated that: "The most profitable study is that which is conducted with a definite aim and effect. By thoroughly mastering any given branch of knowledge we render it the more available for use at any moment. Hence it is not enough merely to have books, or to know where to read for information as we want it; practical wisdom for the purposes of life must be carried about with us, and be ready for use at call." A very good example of definite knowledge applied in a clear and definite manner was given in the paper under discussion. The author referred to a discussion which took place upon this subject, at the Institute of Civil Engineers many years ago, and he said that the paper read by Mr. England upon that occasion was founded upon a fallacy, because it was assumed that steam possessed properties which it did not possess. He (the speaker) could not discover that in the paper referred to any such false assumptions were made; an explanation was, however, given as to the composition of the "sheaf," from which most of his distinguished auditors dissented. Mr. England's theory was that the issuing combined stream from the water and steam nozzles did not consist of solid water, but was a mixture of steam and water, and that the "sheaf" was made up of globules of each, the superior velocity of the former dragging forward those of the latter. This might be the "undoubted fallacy" which the author said it was, still Mr. England gave what appeared to be valid reasons for it, as follows:—

1st. It is the view held by most French writers on the subject.

2nd. The issuing jet is always *milk white,* and not clear as solid water would be.

3rd. It has been found impossible to force water into a boiler by hydraulic pressure, even when such pressure was much in excess of the steam pressure in the boiler.

4th. It is often found necessary to inject more steam than can be condensed, this extra steam being to increase the velocity of the "sheaf."

5th. That although the momentum of a *solid* jet might not be able to lift the foot valve, yet if the jet consisted of alternate layers of steam and water the successive shocks on the valve would compress the layers of steam, thereby storing up energy which might at last be sufficient to open the valve.

The apparently paradoxical fact that steam from a boiler would enter another boiler at a pressure about equal to one-half its own at the same velocity as it would into the air was due to the following reason: That the velocity of weight of the issuing jet varied as the density of the jet, and the density varied as the difference of pressures, so that if W was the weight per unit volume of the gas or steam it varied in a certain power with the density; let this power be c and its value for merely perfect gas is 1·408; it was found from the equation for velocity that when $\frac{p_2}{p_1}$ is indefinitely reduced, that was when p_1 the inside pressure was very much greater than p_2 the outside pressure, that the maximum flow would be 2·413 feet per second x $\sqrt{\frac{T_1}{T_0}}$ where T_0 is the absolute temperature and T_1 that of the steam, from which it would be seen that it varied as the temperature; but the *flow of weight* was obtained by multiplying the velocity of the issuing jet by its density, and this equation is—

$$= A\, p_1 \sqrt{\frac{c\, p_0\, T_0}{(c-1)\, p_0\, T_1}} \cdot \sqrt{\left(1 - \left(\frac{p_2}{p_1}\right)^{\frac{c-1}{c}}\right) \cdot \left(\frac{p_2}{p_1}\right)^{\frac{1}{c}}}$$

where A = area of orifice and d_0 = density corresponding to the absolute temperature. Now in this equation we see that if $\frac{p_2}{p_1} = 1$, that is when there is no difference of pressure outside and inside the boiler, then the velocity = 0, and if $\frac{p_2}{p_1}$ tends to become indefinitely small, that is when the inside pressure is very much larger than the outside, then as $\frac{p_2}{p_1}$ approaches 0 so also will the velocity. Between these values we know there must be some limiting value for $\frac{p_2}{p_1}$ for which the velocity will be a maximum, and this is found to be 0·527, that is to say the maximum velocity of the jet will be when the outside pressure is about half of the inside pressure.

Mr. Cruickshank, in reply, said that some of the remarks in his paper he might possibly have put more plainly, but he was pleased to find that, generally speaking, his effort had given satisfaction. From Professor Selman's remarks, it appeared that that gentleman agreed with him in the statements he (the speaker) had made on the subject of technical education, and he was very glad to hear that some material alterations were under consideration for the Technical College There was no doubt that a tendency existed to endeavour to teach students too much in too short a time. That was where the mistake was made. If a man was an electrical engineer, he was an electrical engineer; if he was a mechanical engineer, then he was a mechanical engineer. Of course he was speaking personally. For himself he found that it took him all his time to "keep himself up" in his particular branch of engineering. If this fact were remembered, it might tend to a saving of time. He would be very sorry if the Professor or Mr. Blacket thought for one moment that he had singled out the Sydney Technical College from any other college, in the remarks he had made. He had merely expressed a personal opinion, which every man had a right to do. He was very glad to find that the very objections he had urged had been attended to and mistakes rectified. He would go further, and say he was sorry he had not taken the precaution to visit the Technical College and so find out for himself what was being done thereat before writing the paper. With regard to "papers for young engineers," he would like to say it was incumbent upon them as a Society to do something in a practical way once or twice in the session—such, for instance, as they had been doing on the present occasion.